भारतीय मानक
Indian Standard

IS 14615 (Part 2) : 2024
ISO 5167-2 : 2022

पूर्ण भरे बहाव वाली वृत्ताकार अनुप्रस्थ काट की वाहिकाओं में विभेदक दबाव उपकरणों के माध्यम से द्रव प्रवाह मापन

भाग 2 ऑरिफ़िस प्लेट

(पहला पुनरीक्षण)

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

Part 2 Orifice Plates

(First Revision)

ICS 17.120.10

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September 2024 **Price Group 15**

Hydrometry Sectional Committee WRD 01

NATIONAL FOREWORD

This Indian Standard (Part 2) (First Revision) which is identical to ISO 5167-2 : 2022 ‘Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full — Part 2: Orifice plates’ 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 standard was first published in 2018 based on ISO 5167-2 : 2003. This first revision has been undertaken to align it with the latest version of ISO 5167-2 : 2022.

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

Part 1 General principles and requirements
Part 3 Nozzles and venturi nozzles
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.

In this adopted standard, reference to certain International Standards appears 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 : 2022 Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full — Part 1: General principles and requirements	NA	NA

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

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

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.

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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 flow rate of the fluid flowing in the conduit. It also gives necessary information for calculating the flow rate 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 uncalibrated in accordance with this standard within specified limits of pipe size and Reynolds number, or alternatively they can be used across their calibrated range.

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 methodology for bespoke calibration of differential pressure meters.

The devices introduced into the pipe are called primary devices. The term primary device also includes the pressure 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 (see ISO 2186) and tertiary devices will be mentioned only occasionally.

Aspects of safety are not dealt with in 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 2 ORIFICE PLATES

(First Revision)

1 Scope

This document specifies the geometry and method of use (installation and operating conditions) of orifice plates when they are inserted in a conduit running full to determine the flow rate of the fluid flowing in the conduit.

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

This document is applicable to primary devices having an orifice plate used with flange pressure tappings, or with corner pressure tappings, or with D and $D/2$ pressure tappings. Other pressure tappings such as “vena contracta” and pipe tappings are not covered by this document. This document is applicable only to a flow which remains subsonic throughout the measuring section and where the fluid can be considered as single phase. It is not applicable to the measurement of pulsating flow[1]. It does not cover the use of orifice plates in pipe sizes less than 50 mm or more than 1 000 mm, or where the pipe Reynolds numbers are below 5 000.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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

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

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

3 Terms, definitions and symbols

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

ISO and IEC maintain terminology 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 an orifice meter into a pipeline in which a fluid is running full. The presence of the orifice plate causes a static pressure difference between the upstream and downstream sides of the plate. The mass flow rate, q_m, can be determined using 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.

Computation of the mass flow rate, which is an arithmetic process, can be performed by replacing the different terms on the right-hand side of the basic Formula (1) by their numerical values.

Similarly, the value of volume flow rate, q_V, is calculated from Formula (2):

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

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

As will be seen later in this document, the discharge coefficient, C, is dependent on the Reynolds number, *Re*, (see ISO 5167-1:2022, 3.3.2), which is itself dependent on q_m, and has to be obtained by iteration (see ISO 5167-1:2022, Annex A, for guidance regarding the choice of the iteration procedure and initial estimates).

The diameters d and D used in Formula (1) (since D is required to calculate β) 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 orifice plate 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 the 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 Orifice plates

5.1 Description

5.1.1 General

The various types of standard orifice meter designs are similar and therefore only a single description is needed. Each type of standard orifice meter design is characterized by the arrangement of the pressure tappings.

'Orifice plate' can refer just to the plate or to the whole meter; where it is important to be clear that the plate and pipework are meant, 'orifice meter' can be used.

NOTE Limits of use are given in 5.3.1.

The axial plane cross-section of a standard orifice plate is shown in Figure 1.

The letters given in the following text refer to the corresponding references in Figure 1.

5.1.2 General shape

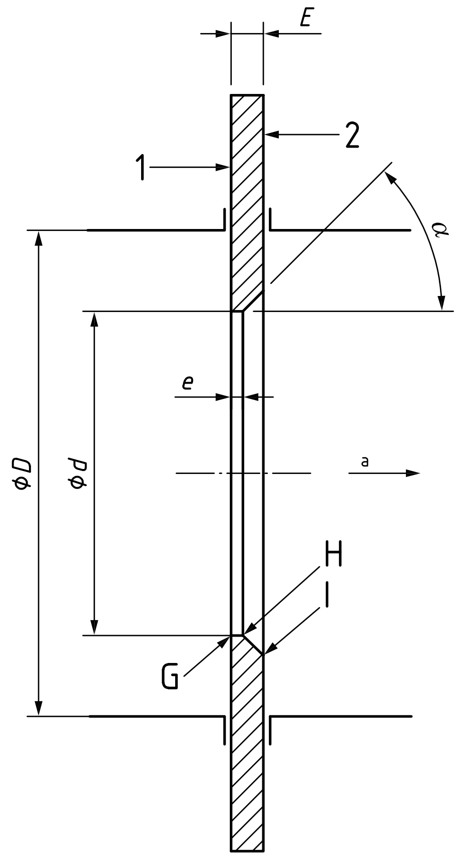
5.1.2.1 The part of the plate inside the pipe shall be circular and concentric with the pipe centreline. The faces of the plate shall always be flat and parallel.

5.1.2.2 Unless otherwise stated, the following requirements apply only to that part of the plate located within the pipe.

5.1.2.3 Care shall be taken in the design of the orifice plate and its installation to ensure that plastic buckling and elastic deformation of the plate, due to the magnitude of the differential pressure or of any other stress, do not cause the slope of the straight line specified in 5.1.3.1 to exceed 1 % under working conditions.

Traditionally, many differential pressure systems had a maximum differential pressure limit of 50 kPa (500 mbar). With modern digital differential pressure instrumentation, a higher maximum differential pressure is possible, provided that the plate material, plate thickness, and method of support are sufficient to prevent bending or buckling.

NOTE Further information is given in ISO/TR 9464:2008, 5.2.5.1.2.3.



Key

1 upstream face A

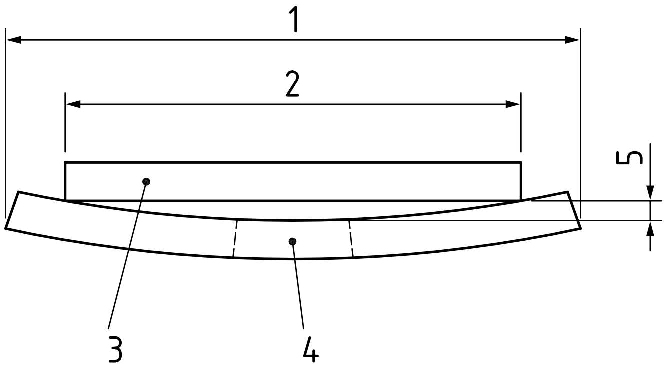
2 downstream face B

[a] Direction of flow.

Figure 1 — Standard orifice plate

5.1.3 Upstream face A

5.1.3.1 The upstream face A of the plate shall be flat when the plate is installed in the pipe with zero differential pressure across it. Provided that it can be shown that the method of mounting does not distort the plate, this flatness may be measured with the plate removed from the pipe. Under these circumstances, the plate may be considered to be flat when the maximum gap between the plate and a straight edge of length D laid across any diameter of the plate (see Figure 2) is less than $0,005(D - d)/2$, i.e. the slope is less than 0,5 % when the orifice plate is examined prior to insertion into the meter line. As can be seen from Figure 2, the critical area is in the vicinity of the orifice bore. The uncertainty requirements for this dimension can be met using feeler gauges.



Key

1	orifice plate outside diameter
2	pipe inside diameter, *D*
3	straight edge
4	orifice
5	departure from flatness (measured at edge of orifice)

Figure 2 — Orifice plate-flatness measurement

5.1.3.2 The upstream face of the orifice plate shall have a roughness criterion $Ra < 10^{-4}d$ within a circle of diameter not less than D and which is concentric with the orifice. In all cases, the roughness of the upstream face of the orifice plate shall not be such that it affects the edge sharpness measurement. If, under working conditions, the plate does not fulfil the specified conditions, it shall be repolished or cleaned to a diameter of at least D.

5.1.3.3 Where possible, it is useful to provide a distinctive mark which is visible even when the orifice plate is installed to show that the upstream face of the orifice plate is correctly installed relative to the direction of flow.

5.1.4 Downstream face B

5.1.4.1 The downstream face B shall be flat and parallel with the upstream face (see also 5.1.5.4).

5.1.4.2 Although it may be convenient to manufacture the orifice plate with the same surface finish on each face, it is unnecessary to provide the same high-quality finish for the downstream face as for the upstream face (see Reference [5]; but also see 5.1.9).

5.1.4.3 The flatness and surface condition of the downstream face may be judged by visual inspection.

5.1.5 Thicknesses *E* and *e*

5.1.5.1 The thickness e of the orifice shall be between $0{,}005D$ and $0{,}02D$ and shall always be less than $0{,}1d$.

5.1.5.2 The difference between the values of e measured at any point on the orifice shall not be greater than $0{,}001D$.

5.1.5.3 The thickness E of the plate shall be between e and $0{,}05D$.

However, when 50 mm ≤ D ≤ 64 mm, a thickness E up to 3,2 mm is acceptable.

It shall also meet the requirements of 5.1.2.3.

5.1.5.4 If $D \geq 200$ mm, the difference between the values of E measured at any point of the plate shall not be greater than $0{,}001D$. If $D < 200$ mm, the difference between the values of E measured at any point of the plate shall not be greater than 0,2 mm.

5.1.6 Angle of bevel, α

5.1.6.1 If the thickness, E, of the plate exceeds the thickness e of the orifice, the plate shall be bevelled on the downstream side. The bevelled surface shall be well finished.

5.1.6.2 The angle of bevel, α, shall be 45° ± 15°.

5.1.7 Edges G, H and I

5.1.7.1 The upstream edge G shall not have wire-edges or burrs.

NOTE A burr is a small sharp piece of metal typically left behind after a manufacturing process. A wire-edge is a burr which extends along a significant part of an edge.

5.1.7.2 The upstream edge G shall be sharp. It is considered so if the edge radius is not greater than $0{,}000\,4d$.

If $d \geq 25$ mm, this requirement can generally be considered as satisfied by visual inspection, by checking that the edge does not reflect a beam of light when viewed with the naked eye.

If $d < 25$ mm, visual inspection is insufficient. Alternatively, a flow calibration can be performed, in accordance with Clause 7.

If there is any doubt as to whether this requirement is met, the edge radius shall be measured.

5.1.7.3 The upstream edge shall be square; it is considered to be so when the angle between the orifice bore and the upstream face of the orifice plate is 90° ± 0,3°. The orifice bore is the region of the orifice plate between edges G and H.

5.1.7.4 The downstream edges H and I are within the separated flow region and hence the requirements for their quality are less stringent than those for edge G. This being the case, small defects (for example, a single nick) are acceptable.

5.1.7.5 Various small non-conformities to the sharp inlet edge G, such as a small nick or partial wear on a small segment of the orifice circumference, do not necessarily produce significant flow prediction biases (see Reference [5]). However, as it is not possible to quantify the effect of all possible non-conformities that may be encountered in service, a plate that is out of specification should be evaluated, and if necessary, changed.

5.1.8 Diameter of orifice, d

5.1.8.1 The diameter d shall in all cases be greater than or equal to 12,5 mm. The diameter ratio, $\beta = d/D$, shall be always greater than or equal to 0,10 and less than or equal to 0,75.

Within these limits, the value of β may be chosen by the user.

5.1.8.2 The value d of the diameter of the orifice shall be taken as the mean of the measurements of at least four diameters at approximately equal angles to each other. Care shall be taken that the edge and bore are not damaged when making these measurements.

5.1.8.3 The orifice shall be cylindrical.

No diameter shall differ by more than 0,05 % from the value of the mean diameter. This requirement is deemed to be satisfied when the difference in the length of any of the measured diameters complies with the said requirement in respect of the mean of the measured diameters. In all cases, the roughness of the orifice bore cylindrical section shall not be such that it affects the edge sharpness measurement.

5.1.9 Bidirectional plates

5.1.9.1 If the orifice plate is intended to be used for measuring reverse flows, the following requirements shall be fulfilled:

a) the plate shall not be bevelled;

b) the two faces shall comply with the specifications for the upstream face given in 5.1.3;

c) the thickness, E, of the plate shall be equal to the thickness e of the orifice specified in 5.1.5; consequently, it may be necessary to limit the differential pressure to prevent plate distortion (see 5.1.2.3);

d) the two edges of the orifice shall comply with the specifications for the upstream edge specified in 5.1.7.

5.1.9.2 Furthermore, for orifice plates with D and $D/2$ tappings (see 5.2), two sets of upstream and downstream pressure tappings shall be provided and used according to the direction of the flow.

5.1.10 Material and manufacture

The plate may be manufactured from any material and in any way, provided that it is and remains in accordance with the foregoing description during the flow measurements.

5.2 Pressure tappings

5.2.1 General

For each orifice plate, at least one upstream pressure tapping and one downstream pressure tapping shall be installed in one or other of the standard locations, i.e. as D and $D/2$, flange or corner tappings.

A single orifice plate may be used with several sets of pressure tappings suitable for different types of standard orifice meters, but to avoid mutual interference, several tappings on the same side of the orifice plate shall be offset by at least 30°.

The location of the pressure tappings characterizes the type of standard orifice meter.

5.2.2 Orifice plate with D and $D/2$ tappings or flange tappings

5.2.2.1 The spacing l of a pressure tapping is the distance between the centreline of the pressure tapping and the plane of a specified face of the orifice plate. When installing the pressure tappings, due account shall be taken of the thickness of the gaskets and/or sealing material.

5.2.2.2 For orifice plates with D and $D/2$ tappings (see Figure 3), the spacing, l_1, of the upstream pressure tapping is nominally equal to D, but may be between $0{,}9D$ and $1{,}1D$ without altering the discharge coefficient.

The spacing, l_2, of the downstream pressure tapping is nominally equal to $0{,}5D$ but may be between the following values without altering the discharge coefficient:

— between $0{,}48D$ and $0{,}52D$ when $\beta \leq 0{,}6$;

— between $0{,}49D$ and $0{,}51D$ when $\beta > 0{,}6$.

Both l_1 and l_2 spacings are measured from the *upstream* face of the orifice plate.

5.2.2.3 For orifice plates with flange tappings (see Figure 3), the spacing l_1 of the upstream pressure tapping is nominally 25,4 mm and is measured from the *upstream* face of the orifice plate.

The spacing $l_2^{'}$ of the downstream pressure tapping is nominally 25,4 mm and is measured from the *downstream* face of the orifice plate.

These upstream and downstream spacings l_1 and $l_2^{'}$ may be within the following ranges without altering the discharge coefficient:

— 25,4 mm ± 0,5 mm when $\beta > 0{,}6$ and $D < 150$ mm;

— 25,4 mm ± 1 mm in all other cases, i.e. $\beta \leq 0{,}6$, or $\beta > 0{,}6$, but 150 mm $\leq D \leq$ 1 000 mm.

5.2.2.4 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.

5.2.2.5 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.

5.2.2.6 Conformity of the pressure tappings with the requirements specified in 5.2.2.4 and 5.2.2.5 may be judged by visual inspection.

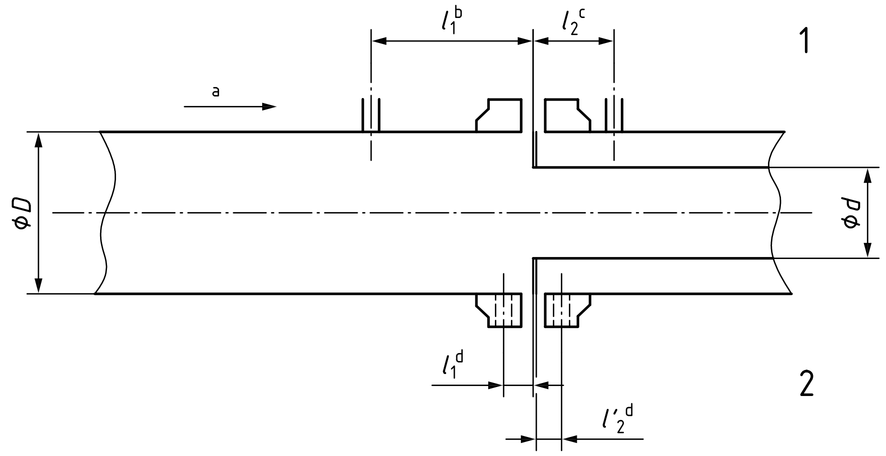
5.2.2.7 The diameter of pressure tappings shall be less than $0{,}13D$ and less than 13 mm.

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.

5.2.2.8 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.

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

5.2.2.10 The axis of the upstream tapping and that of the downstream tapping may be located in different axial planes, but are normally located in the same axial plane.



Key

1 D and $D/2$ pressure tappings

2 flange tappings

[a] Direction of flow.

[b] $l_1 = D \pm 0{,}1D$

[c] $l_2 = 0{,}5D \pm 0{,}02D$ for $\beta \leq 0{,}6$
$0{,}5D \pm 0{,}01D$ for $\beta > 0{,}6$

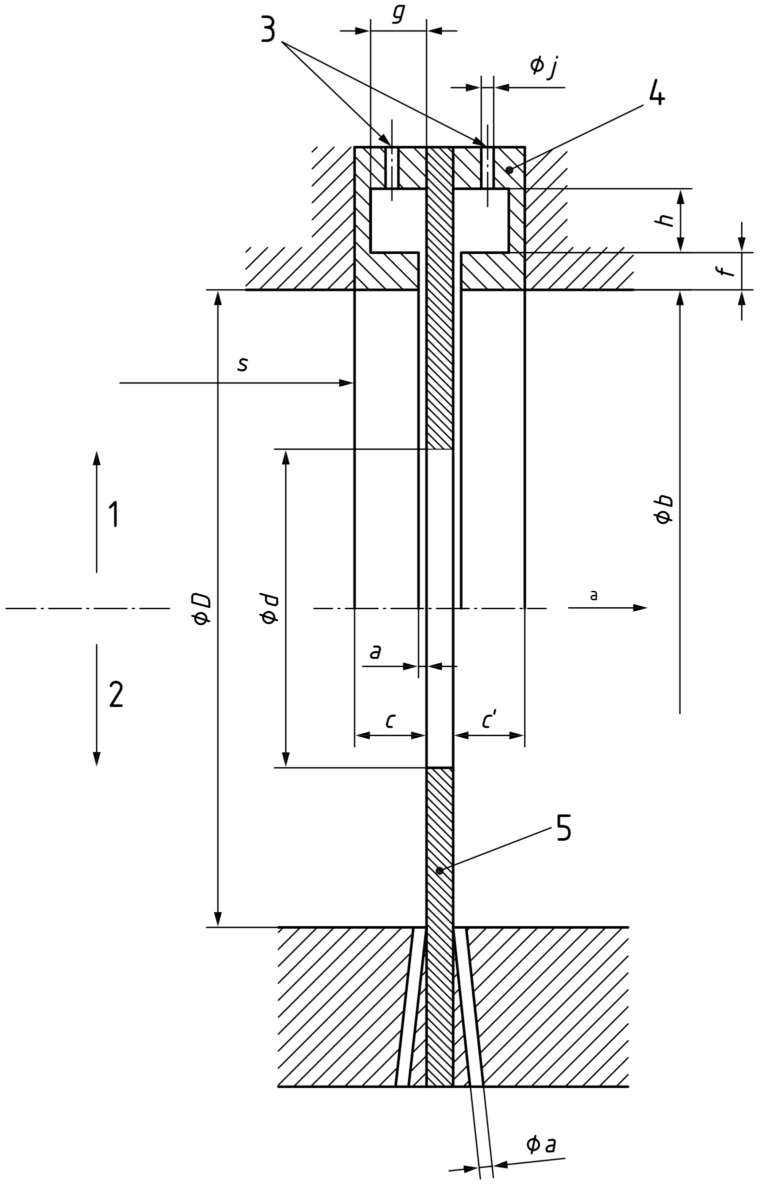
[d] $l_1 = l'_2 = (25{,}4 \pm 0{,}5)$ mm for $\beta > 0{,}6$ and $D < 150$ mm
$(25{,}4 \pm 1)$ mm for $\beta \leq 0{,}6$
$(25{,}4 \pm 1)$ mm for $\beta > 0{,}6$ and $150\ \text{mm} \leq D \leq 1\ 000$ mm

Figure 3 — Spacing of pressure tappings for orifice plates with *D* and *D*/2 tappings or flange tappings

5.2.3 Orifice plate with corner tappings

5.2.3.1 The spacing between the centrelines of the tappings (see Figure 4) and the respective faces of the plate 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 the faces of the plate (see also 5.2.3.5).

5.2.3.2 The pressure tappings may be either single tappings or annular slots. Both types of tappings may be located either in the pipe or in its flanges or in carrier rings as shown in Figure 4.



Key

1	carrier ring with annular slot
2	individual tappings
3	pressure tappings
4	carrier ring
5	orifice plate
a	Direction of flow.

f	thickness of the slot
c	length of the upstream ring
c'	length of the downstream ring
b	diameter of the carrier ring
a	width of annular slot or diameter of single tapping
s	distance from upstream step to carrier ring
g, h	dimensions of the annular chamber
j	chamber tapping diameter

Figure 4 — Corner tappings

5.2.3.3 The diameter a of a single 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 $\beta \leq 0{,}65$: $0{,}005D \leq a \leq 0{,}03D$;

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

If $D < 100$ mm, a value of a up to 2 mm is acceptable for any β.

For any values of β

— for clean fluids: 1 mm $\leq a \leq$ 10 mm;

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

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

NOTE The requirements on size as a fraction of pipe diameter are based on geometrical similarity to the original orifice 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 corner tappings that is in conformity with this document.

5.2.3.4 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.

5.2.3.5 If individual pressure tappings, as shown in Figure 4, are used, the centreline of the tappings shall meet the centreline of the pipe at an angle as near to 90° as possible.

If there are several individual pressure tappings in the same upstream or downstream plane, their centrelines shall form equal angles with each other. The diameters of individual pressure tappings are specified in 5.2.3.3.

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 pipeline.

The upstream and downstream pressure tappings shall have the same diameter.

5.2.3.6 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 condition in Formula (3) shall be met:

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

The lengths c and c' of the upstream and downstream rings (see Figure 4) 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.

5.2.3.7 All surfaces of the ring that are in contact with the measured fluid shall be clean and shall have a well-machined finish. The surface finish shall meet the pipe roughness requirements (see 5.3.1).

5.2.3.8 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 (see 5.2.2.5).

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

5.2.3.10 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.

5.3 Coefficients and corresponding uncertainties of orifice plates

5.3.1 Limits of use

Standard orifice plates shall only be used in accordance with this document under the following conditions.

For orifice plates with corner or with D and $D/2$ pressure tappings:

- $d \geq 12{,}5$ mm;
- 50 mm $\leq D \leq$ 1 000 mm;
- $0{,}1 \leq \beta \leq 0{,}75$;
- $Re_D \geq 5\,000$ for $0{,}1 \leq \beta \leq 0{,}56$;
- $Re_D \geq 16\,000\,\beta^2$ for $\beta > 0{,}56$.

For orifice plates with flange tappings:

- $d \geq 12{,}5$ mm;
- 50 mm $\leq D \leq$ 1 000 mm;
- $0{,}1 \leq \beta \leq 0{,}75$;
- Both $Re_D \geq 5\,000$ and $Re_D \geq 170\,\beta^2 D$ where D is expressed in millimetres.

Table 1 — Maximum value of $10^4 Ra/D$

β	Re_D								
	$\leq 10^4$	3×10^4	10^5	3×10^5	10^6	3×10^6	10^7	3×10^7	10^8
≤0,20	15	15	15	15	15	15	15	15	15
0,30	15	15	15	15	15	15	15	14	13
0,40	15	15	10	7,2	5,2	4,1	3,5	3,1	2,7
0,50	11	7,7	4,9	3,3	2,2	1,6	1,3	1,1	0,9
0,60	5,6	4,0	2,5	1,6	1,0	0,7	0,6	0,5	0,4
≥0,65	4,2	3,0	1,9	1,2	0,8	0,6	0,4	0,3	0,3

The pipe internal roughness shall satisfy the following specification if the uncertainty values in this document are to be met, i.e. the value of the arithmetical mean deviation of the roughness profile, Ra, shall be such that $10^4 Ra/D$ is less than the maximum value given in Table 1 and greater than the minimum value given in Table 2. The discharge coefficient equation (see 5.3.2.1) was determined from a database collected using pipes whose roughness is known; the limits on Ra/D were determined so that the shift in discharge coefficient due to using a pipe of a different roughness should not be so great that the uncertainty value in 5.3.3.1 is no longer met. Information regarding pipe roughness may be found in ISO 5167-1:2022, 7.1.5. The work on which Tables 1 and 2 are based is described in References [6][7] and [8].

Table 2 — Minimum value of $10^4 Ra/D$ (where one is required)

β	Re_D			
	$\leq 3 \times 10^6$	10^7	3×10^7	10^8
≤0,50	0,0	0,0	0,0	0,0
0,60	0,0	0,0	0,003	0,004
≥0,65	0,0	0,013	0,016	0,012

The roughness shall meet requirements given in Tables 1 and 2 for 10D upstream of the orifice plate. The roughness requirements relate to the orifice fitting and the upstream pipework. The downstream roughness is not as critical.

For example, the requirements of this section are satisfied in either of the following cases:

— $1\ \mu\text{m} \leq Ra \leq 6\ \mu\text{m}$, $D \geq 150$ mm, $\beta \leq 0{,}6$ and $Re_D \leq 5 \times 10^7$;

— $1{,}5\ \mu\text{m} \leq Ra \leq 6\ \mu\text{m}$, $D \geq 150$ mm, $\beta > 0{,}6$ and $Re_D \leq 1{,}5 \times 10^7$.

Where D is less than 150 mm, it is necessary to calculate the maximum and minimum values of Ra using Tables 1 and 2.

5.3.2 Coefficients

5.3.2.1 Discharge coefficient, *C*

The discharge coefficient, C, is given by the Reader-Harris/Gallagher (1998) equation[9][10]:

$$C = 0{,}596\ 1 + 0{,}026\ 1\beta^2 - 0{,}216\beta^8 + 0{,}000\ 521\left(\frac{10^6\beta}{Re_D}\right)^{0{,}7} + (0{,}018\ 8 + 0{,}006\ 3A)\beta^{3{,}5}\left(\frac{10^6}{Re_D}\right)^{0{,}3} + \left(0{,}043 + 0{,}080e^{-10L_1} - 0{,}123e^{-7L_1}\right)(1 - 0{,}11A)\frac{\beta^4}{1-\beta^4} - 0{,}031\left(M'_2 - 0{,}8M'^{1{,}1}_2\right)\beta^{1{,}3} \tag{4}$$

Where $D < 71{,}12$ mm (2,8 in), the following term shall be added to Formula (4), with diameter D expressed in millimetres:

$$+0{,}011(0{,}75-\beta)\left(2{,}8-\frac{D}{25{,}4}\right)$$

In these formulae

β (= d/D)	is the diameter ratio, with the diameters d and D expressed in millimetres;
Re_D	is the Reynolds number calculated with respect to D;
L_1 (= l_1/D)	is the quotient of the distance of the upstream tapping from the *upstream* face of the plate and the pipe diameter; and
L'_2 (= l'_2/D)	is the quotient of the distance of the downstream tapping from the *downstream* face of the plate and the pipe diameter (L'_2 denotes the reference of the downstream spacing from the *downstream* face, while L_2 would denote the reference of the downstream spacing from the *upstream* face);

$$M'_2 = \frac{2L'_2}{1-\beta}$$

$$A = \left(\frac{19\ 000\beta}{Re_D}\right)^{0{,}8}$$

The values of L_1 and L'_2 to be used in this formula, when the spacings are in accordance with the requirements of 5.2.2.2, 5.2.2.3 or 5.2.3, are as follows:

— for corner tappings:

$$L_1 = L'_2 = 0$$

— for D and $D/2$ tappings:

$$L_1 = 1$$

$$L'_2 = 0{,}47$$

— for flange tappings:

$$L_1 = L'_2 = \frac{25{,}4}{D}$$

where D is expressed in millimetres.

Formula (4) is only valid for the tapping arrangements specified in 5.2.2 or 5.2.3. In particular, it is not permitted to enter into the equation pairs of values of L_1 and L'_2 which do not match one of the three standardized tapping arrangements.

Formula (4), as well as the uncertainties given in 5.3.3, is only valid when the measurement meets all the limits of use specified in 5.3.1 and the general installation requirements specified in Clause 6 and in ISO 5167-1.

Values of C as a function of β, Re_D and D are given for convenience in Tables A.1 to A.11. These values are not intended for precise interpolation. Extrapolation is not permitted.

5.3.2.2 Expansibility [expansion] factor, ε

For the three types of tapping arrangement, the empirical formula[11] for computing the expansibility [expansion] factor, ε, is as follows:

$$\varepsilon = 1 - \left(0{,}351 + 0{,}256\beta^4 + 0{,}93\beta^8\right)\left[1 - \left(\frac{p_2}{p_1}\right)^{1/\kappa}\right] \tag{5}$$

NOTE p_1 and Δp are usually measured: $p_2 = p_1 - \Delta p$.

Formula (5) is applicable only if $p_2/p_1 \geq 0{,}75$, and only within the range of the limits of use specified in 5.3.1.

Values of the expansibility [expansion] factor as a function of the isentropic exponent, the pressure ratio and the diameter ratio are given for convenience in Table A.12. These values are not intended for precise interpolation. Extrapolation is not permitted.

5.3.3 Uncertainties

5.3.3.1 Uncertainty of discharge coefficient C

For all three types of tappings, 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:

- (0,7 – β) % for $0,1 \leq \beta < 0,2$;
- 0,5 % for $0,2 \leq \beta \leq 0,6$;
- (1,667 β – 0,5) % for $0,6 < \beta \leq 0,75$.

If $D < 71,12$ mm (2,8 in), the following relative expanded uncertainty should be added arithmetically to the above values:

$$+0,9(0,75-\beta)\left(2,8-\frac{D}{25,4}\right)\%$$

If $\beta > 0,5$ and $Re_D < 10\,000$, the following relative expanded uncertainty should be added arithmetically to the above values:

$$+0,5\ \%$$

5.3.3.2 Uncertainty of expansibility [expansion] factor ε

When β, $\Delta p/p_1$ and κ are assumed to be known without error, U'_ε, the relative expanded uncertainty of the value of ε at $k = 2$ (approximately 95 % confidence level), is given by Formula (6):

$$3,5\frac{\Delta p}{\kappa p_1}\% \tag{6}$$

5.4 Pressure loss, $\Delta\varpi$

5.4.1 The pressure loss, $\Delta\varpi$, for the orifice plates described in this document 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 orifice plate, at a section where the influence of the approach impact pressure adjacent to the plate is still negligible (approximately D upstream of the orifice plate), and that measured on the downstream side of the orifice plate, where the static pressure recovery by expansion of the jet may be considered as just completed (approximately $6D$ downstream of the orifice plate). Figure 5 shows the pressure profile through an orifice metering system.

5.4.2 A simpler but less accurate value of $\Delta\varpi/\Delta p$ is

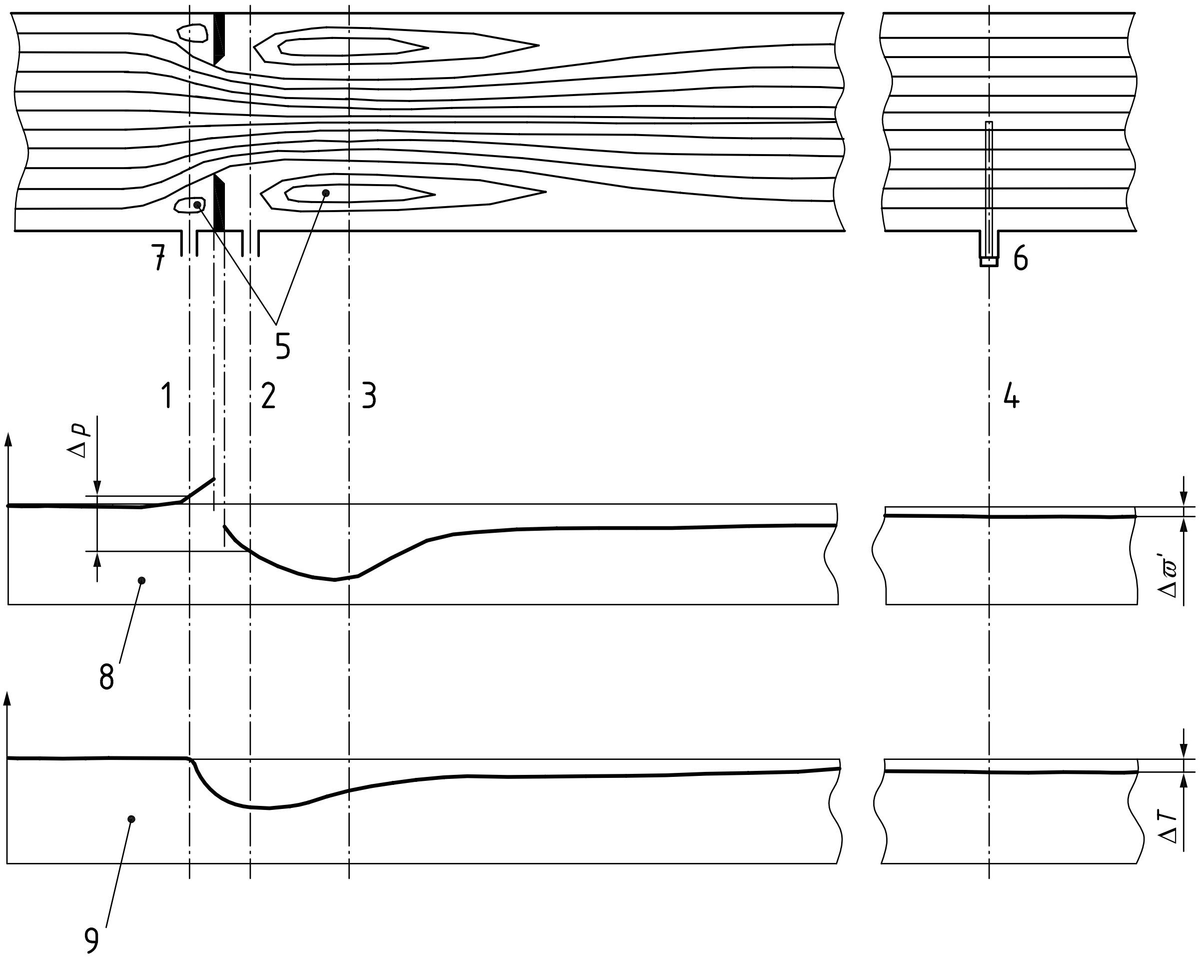
$$\frac{\Delta\varpi}{\Delta p}=1-\beta^{1,9}$$

5.4.3 The pressure loss coefficient, K, for the orifice plate (see Reference [12]) is

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

where K is defined by the following formula:

$$K=\frac{\Delta\varpi}{\frac{1}{2}\rho_1 V^2}$$



Key

1	plane of upstream flange pressure tappings
2	plane of downstream flange pressure tappings
3	plane of “vena contracta” (highest velocities)
4	plane of temperature probe
5	secondary flow regions
6	thermometer pocket or well
7	pressure tappings
8	pressure distribution on the wall
9	mean temperature distribution

Figure 5 — Approximate profiles of flow, pressure and temperature in an orifice metering system

6 Installation requirements

6.1 General

General installation requirements for pressure differential devices are given in ISO 5167-1:2022, Clause 7 and should be followed in conjunction with the additional specific requirements for orifice plates 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 and detailed requirements are given in 6.2. However, a flow conditioner as specified in 6.3

will permit the use of a shorter upstream pipe length; moreover, a flow conditioner shall be installed upstream of the orifice plate where sufficient straight length to achieve the desired level of uncertainty is not available. Downstream of a header the use of a flow conditioner is strongly recommended. Many of the lengths given in 6.2 and all lengths given in 6.3.2 are based on data included in Reference [13]. Additional work which contributed to the lengths in 6.2 is given in References [14] and [15].

6.2 Minimum upstream and downstream straight lengths for installation between various fittings and the orifice plate

6.2.1 The minimum straight lengths of pipe required upstream and downstream of the orifice plate 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.

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 valve shown in Table 3 shall be set fully open during the flow measurement process. It is recommended that control of the flow rate be achieved by valves located downstream of the orifice plate. Isolating valves located upstream of the orifice plate shall be set fully open, and these valves shall be full bore. The valve should be fitted with stops for alignment of the ball 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.

Table 3 — Required straight lengths between orifice plates and fittings without flow conditioners

Values expressed as multiples of internal diameter, D

Diameter ratio β	Upstream (inlet) side of orifice plate																								Downstream (outlet) side of the orifice plate	
	Single 90° bend or two 90° bends in any plane $(S > 30D)$ [a]		Two 90° bends in the same plane: S-configuration $(30D \geq S > 10D)$ [a]		Two 90° bends in the same plane: S-configuration $(10D \geq S)$ [a]		Two 90° bends in perpendicular planes $(30D \geq S \geq 5D)$ [a]		Two 90° bends in perpendicular planes $(5D > S)$ [a, b]		Single 90° tee with or without an extension or Mitre 90° bend		Single 45° bend or Two 45° bends in the same plane: S-configuration $(S \geq 22D)$ [a]		Concentric reducer $2D$ to D over a length of $1{,}5D$ to $3D$		Concentric expander $0{,}5D$ to D over a length of D to $2D$		Full bore ball valve or gate valve fully open		Abrupt symmetrical reduction		Thermometer pocket or well [c] of diameter $\leq 0{,}03D$ [d]		Fittings (columns 2 to 11) and the densitometer pocket	
1	2		3		4		5		6		7		8		9		10		11		12		13		14	
—	A [e]	B [f]	A [e]	B [f]	A [e]	B [f]	A [e]	B [f]	A [e]	B [f]	A [e]	B [f]	A [e]	B [f]	A [e]	B [f]	A [e]	B [f]	A [e]	B [f]	A [e]	B [f]	A [e]	B [f]	A [e]	B [f]
≤ 0,20	6	3	10	[g]	10	[g]	19	18	34	17	3	[g]	7	[g]	5	[g]	6	[g]	12	6	30	15	5	3	4	2
0,40	16	3	10	[g]	10	[g]	44	18	50	25	9	3	30	9	5	[g]	12	8	12	6	30	15	5	3	6	3
0,50	22	9	18	10	22	10	44	18	75	34	19	9	30	18	8	5	20	9	12	6	30	15	5	3	6	3
0,60	42	13	30	18	42	18	44	18	65 [h]	25	29	18	30	18	9	5	26	11	14	7	30	15	5	3	7	3,5
0,67	44	20	44	18	44	20	44	20	60	18	36	18	44	18	12	6	28	14	18	9	30	15	5	3	7	3,5
0,75	44	20	44	18	44	22	44	20	75	18	44	18	44	18	13	8	36	18	24	12	30	15	5	3	8	4

NOTE 1 The minimum straight lengths required are the lengths between various fittings located upstream or downstream of the orifice plate and the orifice plate itself. Straight lengths are measured from the downstream end of the curved portion of the nearest (or only) bend or of the tee or the downstream end of the curved or conical portion of the reducer or the expander.

NOTE 2 Most of the bends on which the lengths in this table are based had a radius of curvature equal to $1{,}5D$.

NOTE 3 The data for configuration 7 came from using an equal tee with the flow from the branch into the run in which the orifice was located, with the other side of the run closed.

[a] S is the separation between the two bends measured from the downstream end of the curved portion of the upstream bend to the upstream end of the curved portion of the downstream bend.

[b] This is not a good upstream installation; a flow conditioner should be used where possible.

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

[d] A thermometer pocket or well of diameter between $0{,}03D$ and $0{,}13D$ may be installed provided that the values in Columns A and B are increased to 20 and 10 respectively. Such an installation is not, however, recommended.

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

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

[g] 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.

[h] $95D$ is recommended for $Re_D > 2 \times 10^6$ if $S < 2D$, see Reference [14].

6.2.8 The values given in Table 3 were determined experimentally with a very long straight length of pipe 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 several fittings of the type covered by Table 3 (treating the combinations of 90° bends already covered by this table as a single fitting) are placed in series upstream of the orifice plate, the following shall be applied:

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

   2) Between fitting 1 and fitting 2 (the next fitting upstream of the orifice plate), there shall be a straight length greater than or equal to half the minimum length given in Table 3 for an orifice plate of diameter ratio 0,67 used with fitting 2 (irrespective of the actual diameter ratio of the orifice plate). If the pipe diameter changes at fitting 1, the pipe diameter between fitting 1 and fitting 2 is used to calculate this minimum length.

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

   3) 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 orifice plate and fitting 1 specified in Table 3; see Figure 6. 6.2.8 b) shall also be satisfied (as it is in Figure 6).

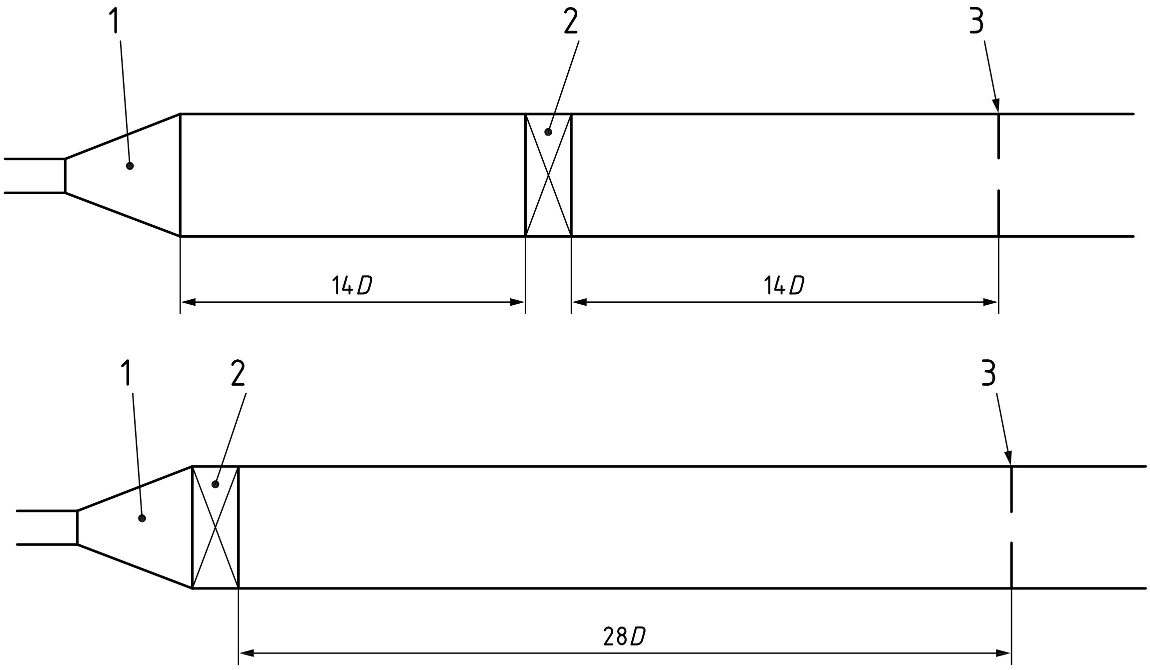
b) Between the orifice plate and any upstream fitting (treating any two consecutive 90° bends as a single fitting), the straight length shall be greater than or equal to the minimum length given in Table 3 appropriate for the specific orifice plate diameter ratio used with that fitting. The pipe diameter upstream of the orifice plate is used to calculate this minimum length.

   The distance between the orifice plate 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 discharge coefficient relative expanded uncertainty. However, this additional uncertainty shall not be added more than once under the provisions of a) and b).

c) It is strongly recommended that a flow conditioner (see ISO 5167-1:2022, 7.4) should be installed downstream of a metering system header (e.g. one whose cross-section area is approximately equal to 1,5 times the cross-sectional area of the operating flow meter tubes) since there will always be distortion of the flow profile and a high probability of swirl.

d) When fitting 2 (or a more distant fitting) is a combination of bends, then in applying Table 3 the separation between the bends is calculated as a multiple of the diameter of the bends themselves.



Key

1 expander

2 full bore ball valve or gate valve fully open

3 orifice plate

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

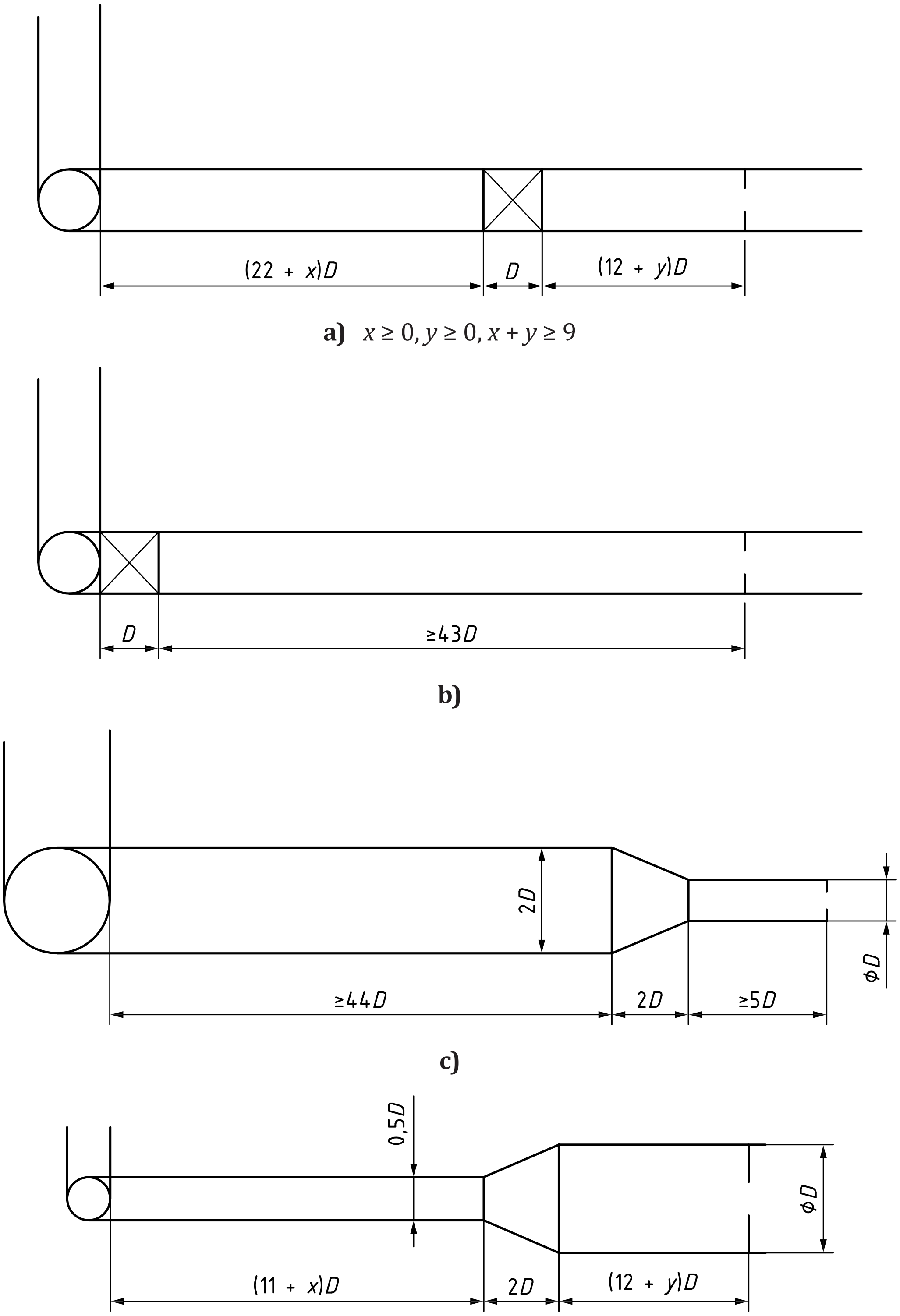
6.2.9 By way of example, three cases of the application of 6.2.8 a) and b) are considered. In each case, fitting 2 is two bends in perpendicular planes (the separation between the bends is 10 times the diameter of the bends) and the orifice plate has diameter ratio 0,4.

6.2.9.1 If fitting 1 is a full bore ball valve fully open [see Figure 7 a)], the distance between the orifice plate and the ball valve shall be at least 12*D* (from Table 3) and that between the valve and the two bends in perpendicular planes shall be at least 22*D* [from 6.2.8 a)]; the distance between the orifice plate and the two bends in perpendicular planes shall be at least 44*D* [from 6.2.8 b)].

If the ball valve has length 1*D*, an additional total length of 9*D* is required, which may be either upstream or downstream of the valve, or partly upstream and partly downstream of it. The instructions in 6.2.8 a) 3) could also be used to move the valve to be adjacent to the two bends in perpendicular planes provided that there is at least 44*D* from the orifice plate to the two bends in perpendicular planes [see Figure 7 b)].

6.2.9.2 If fitting 1 is a reducer from 2*D* to *D* over a length of 2*D* [see Figure 7 c)], the distance between the orifice plate and the reducer shall be at least 5*D* (from Table 3) and that between the reducer and the two bends in perpendicular planes shall be at least 22 × 2*D* [from 6.2.8 a)]; the distance between the orifice plate and the two bends in perpendicular planes shall be at least 44*D* [from 6.2.8 b)]. Therefore, no additional length is required because of 6.2.8 b).

6.2.9.3 If fitting 1 is an expander from 0,5*D* to *D* over a length of 2*D* [see Figure 7 d)], the distance between the orifice plate and the expander shall be at least 12*D* (from Table 3) and that between the expander and the two bends in perpendicular planes shall be at least 22 × 0,5*D* [from 6.2.8 a)]; the distance between the orifice plate and the two bends in perpendicular planes shall be at least 44*D* [from 6.2.8 b)]. Therefore, an additional total length of 19*D* is required which may be either upstream or downstream of the expander, or partly upstream and partly downstream of it.



a) $x \geq 0, y \geq 0, x + y \geq 9$

b)

c)

d) $x \geq 0, y \geq 0, x + y \geq 19$

Figure 7 — Examples of acceptable installations (see 6.2.9)

6.3 Flow conditioners

6.3.1 General

A flow conditioner can be used to reduce upstream straight lengths either through meeting the conformity 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 conformity testing. In either case the test work shall be carried out using orifice plates.

Unpatented flow conditioners which have met the conformity test of ISO 5167-1 are the 19-tube bundle flow straightener (1998) and the Zanker flow conditioner plate. Annex B describes some patented flow conditioners which have met the conformity test.

6.3.2 and 6.3.3 give the situations in which the 19-tube bundle flow straightener (1998) and the Zanker flow conditioner plate can be used upstream of orifice plates: 6.3.2.2 and 6.3.3.2 describe the situations in which the 19-tube bundle flow straightener (1998) and the Zanker flow conditioner plate can be used downstream of any fitting; 6.3.2.3 describes some additional situations in which the 19-tube bundle flow straightener (1998) may be used to reduce the required upstream length.

Annex B describes some flow conditioners which can be used upstream of orifice plates and the requirements for straight lengths associated with them. It is not intended that the inclusion of the flow conditioners described there should limit the use of other flow conditioner designs which have been tested and proved to provide sufficiently small shifts in discharge coefficient.

6.3.2 19-tube bundle flow straightener (1998)

6.3.2.1 Description

6.3.2.1.1 Design

The 19-tube bundle flow straightener (1998) shall consist of 19 tubes arranged in a cylindrical pattern as in Figure 8.

In order to reduce the swirl that can occur between the exterior tubes of the 19-tube bundle flow straightener (1998) and the wall of the pipe, the maximum outside diameter of the flow straightener, D_f, shall satisfy

$$0{,}95D \leq D_\mathrm{f} \leq D$$

The length, L, of the tubes shall be between $2D$ and $3D$, preferably as close to $2D$ as possible.

6.3.2.1.2 Tubing of the 19-tube bundle flow straightener (1998)

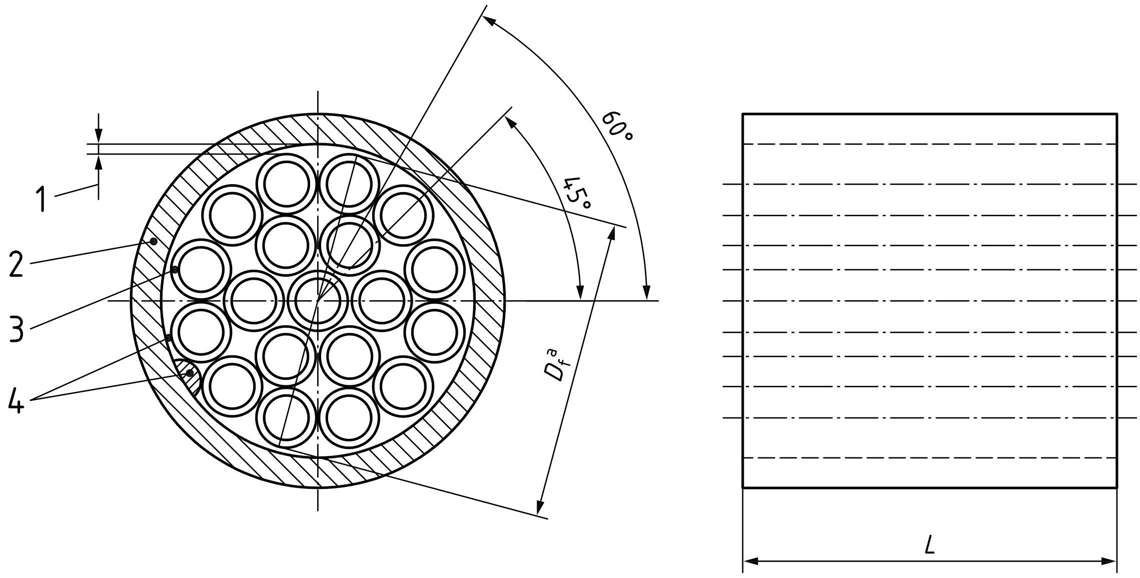
It is necessary for all the tubes in the tube bundle to be of uniform smoothness, outer diameter and wall thickness. The individual tube wall thickness of the 19-tube bundle flow straightener (1998) shall be thin. All tubes shall have an internal chamfer on both ends.

The wall thickness shall be less than $0{,}025D$; this value is based on the wall thickness of the tubes used to collect the data on which this document is based.

6.3.2.1.3 Fabrication of the 19-tube bundle flow straightener (1998)

The 19-tube bundle flow straightener (1998) shall be sturdily fabricated. Individual tubes should be welded together at the points of contact, at least at both ends of the tube bundle. It is important to ensure that the tubes are parallel to each other and to the pipe axis since, if conformity with this requirement is not met, the straightener itself may introduce swirl into the flow. Centring spacers may be provided on the outside of the assembly to assist the installer in centring the device in the pipe;

these may take the form of small lugs or small rods parallel to the pipe axis. After being inserted in the pipe, the tube bundle shall be securely fastened in place. Secure fastening, however, should not distort the tube bundle assembly with respect to symmetry within the pipe.



Key

1	minimized gap
2	pipe wall
3	tube wall thickness
4	centring spacer options (typically four places)
a	D_f is the flow straightener outside diameter.

Figure 8 — 19-tube bundle flow straightener (1998)

6.3.2.1.4 Pressure loss

The pressure loss coefficient, K, for the 19-tube bundle flow straightener (1998) is approximately equal to 0,75, where K is given by the following Formula (8):

$$K = \frac{\Delta p_c}{\frac{1}{2}\rho V^2} \tag{8}$$

where

Δp_c is the pressure loss across the 19-tube bundle flow straightener (1998);

ρ is the density of the fluid in the pipe;

V is the mean axial velocity of the fluid in the pipe.

6.3.2.2 Installation downstream of any fitting

6.3.2.2.1 The 19-tube bundle flow straightener (1998) shown in Figure 8 can be used downstream of any upstream fitting with an orifice plate whose diameter ratio is 0,67 or smaller provided that it meets the manufacturing specification in 6.3.2.1 and is installed in accordance with 6.3.2.2.2.

6.3.2.2.2 The 19-tube bundle flow straightener (1998) shall be installed so that there is at least 30D between the orifice plate and any upstream fitting. The 19-tube bundle flow straightener (1998) shall be installed so that the distance between the downstream end of the 19-tube bundle flow straightener (1998) and the orifice plate is equal to $13D \pm 0{,}25D$.

6.3.2.3 Additional options

6.3.2.3.1 A 19-tube bundle flow straightener (1998) may also be used to reduce the required upstream straight length in situations outside the situation described in 6.3.2.2. The 19-tube bundle flow straightener (1998) shall be as described in 6.3.2.1.

The permitted locations for the 19-tube bundle flow straightener (1998) depend on L_f, the distance from the orifice plate to the nearest upstream fitting, measured to the downstream end of the curved portion of the nearest (or only) bend or of the tee or the downstream end of the curved or conical portion of the reducer or expander.

Table 4 provides the permitted location range and the recommended location for the 19-tube bundle flow straightener (1998) for two ranges of L_f:

— $30D > L_f \geq 18D$, and

— $L_f \geq 30D$.

L_f shall be greater than or equal to $18D$. The locations for the 19-tube bundle flow straightener (1998) are described in Table 4 in terms of the straight lengths between the downstream end of the 19-tube bundle flow straightener (1998) and the orifice plate.

If, for a particular upstream fitting, an orifice plate diameter ratio and a value of L_f, there is no location shown in Table 4 for a 19-tube bundle flow straightener (1998), then an installation with this fitting, β and L_f, is not recommended. In this case, an increase in L_f and/or a reduction in β is necessary.

The length required downstream of the orifice plate shall be as given in Table 3.

An example of the use of Table 4 is given in 6.3.2.4.

6.3.2.3.2 When the straight length between orifice plate and 19-tube bundle flow straightener (1998) is in accordance with the values specified in Columns A of Table 4 and the downstream straight length in accordance with Column 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.

6.3.2.3.3 An additional relative uncertainty of 0,5 % shall be added arithmetically to the relative expanded uncertainty in the discharge coefficient when either:

a) the straight length between orifice plate and 19-tube bundle flow straightener (1998) is not in accordance with the value corresponding to “zero additional uncertainty” shown in Columns A but in accordance with the value corresponding to “0,5 % additional uncertainty” shown in Columns B of Table 4; or

b) the downstream straight length is shorter than the value corresponding to “zero additional uncertainty” shown in Column A but either equal to or greater than the “0,5 % additional uncertainty” value shown in Column B of Table 3 for a given fitting.

6.3.2.3.4 This document cannot be used to predict the value of any additional uncertainty when:

a) the straight length between orifice plate and 19-tube bundle flow straightener (1998) is not in accordance with the value corresponding to “0,5 % additional uncertainty” shown in Columns B of Table 4; or

b) the downstream straight length is shorter than the “0,5 % additional uncertainty” value specified in Column B of Table 3; or

c) both the straight length between orifice plate and 19-tube bundle flow straightener (1998) is not in accordance with the value corresponding to “zero additional uncertainty” shown in Columns A of Table 4 and the downstream straight length is shorter than the “zero additional uncertainty” value specified in Column A of Table 3.

Table 4 — Permitted range of straight lengths between an orifice plate and a 19-tube bundle flow straightener (1998) downstream of fittings located at a distance, L_f, from the orifice plate

Values expressed as multiples of internal diameter, D

Diameter ratio β	Single 90° bend [b]				Two 90° bends [b] in perpendicular planes ($2D \geq S$) [a]				Single 90° tee				Any fitting			
	$30 > L_f \geq 18$		$L_f \geq 30$		$30 > L_f \geq 18$		$L_f \geq 30$		$30 > L_f \geq 18$		$L_f \geq 30$		$30 > L_f \geq 18$		$L_f \geq 30$	
1	2		3		4		5		6		7		8		9	
—	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]
$\leq 0{,}2$	5 to 14,5	1 to n [e]	5 to 25	1 to n [e]	5 to 14,5	1 to n [e]	5 to 25	1 to n [e]	5 to 14,5	1 to n [e]	1 to 25	1 to n [e]	5 to 11	1 to n [e]	5 to 13	1 to n [e]
0,4	5 to 14,5	1 to n [e]	5 to 25	1 to n [e]	5 to 14,5	1 to n [e]	5 to 25	1 to n [e]	5 to 14,5	1 to n [e]	1 to 25	1 to n [e]	5 to 11	1 to n [e]	5 to 13	1 to n [e]
0,5	11,5 to 14,5	3 to n [e]	11,5 to 25	3 to n [e]	9,5 to 14,5	1 to n [e]	9 to 25	1 to n [e]	11 to 13	1 to n [e]	9 to 23	1 to n [e]	[f] [g]	3 to n [e]	11,5 to 14,5	3 to n [e]
0,6	12 to 13	5 to n [e]	12 to 25	5 to n [e]	13,5 to 14,5	6 to n [e]	9 to 25	1 to n [e]	[f] [h]	7 to n [e]	11 to 16	1 to n [e]	[f]	7 to n [e]	12 to 16	6 to n [e]
0,67	13	7 to n [e]	13 to 16,5	7 to n [e]	13 to 14,5	7 to n [e]	10 to 16	5 to n [e]	[f]	8 to n [e]	11 to 13	6 to n [e]	[f]	8 to 10	13	7 to n-1,5 [e]
0,75	14	8 to n [e]	14 to 16,5	8 to n [e]	[f]	9,5 to n [e]	12 to 12,5	8 to n [e]	[f]	9 to n [e]	12 to 14	7 to n [e]	[f]	9,5	[f]	8 to 22
Recommended	13 for $\beta \leq 0{,}67$	13 for $\beta \leq 0{,}75$	14 to 16,5 for $\beta \leq 0{,}75$	14 to 16,5 for $\beta \leq 0{,}75$	13,5 to 14,5 for $\beta \leq 0{,}67$	13,5 to 14,5 for $\beta \leq 0{,}75$	12 to 12,5 for $\beta \leq 0{,}75$	12 to 12,5 for $\beta \leq 0{,}75$	13 for $\beta \leq 0{,}54$	13 for $\beta \leq 0{,}75$	12 to 13 for $\beta \leq 0{,}75$	12 to 13 for $\beta \leq 0{,}75$	9,5 for $\beta \leq 0{,}46$	9,5 for $\beta \leq 0{,}75$	13 for $\beta \leq 0{,}67$	13 for $\beta \leq 0{,}75$

NOTE The straight lengths given in the table are the permitted lengths between the downstream end of a 19-tube bundle flow straightener (1998) (as described in 6.3.2.1) and the orifice plate given that a particular fitting is installed upstream of the 19-tube bundle flow straightener (1998) at a distance L_f from the orifice plate. The distance L_f from the orifice plate is measured to the downstream end of the curved portion of the nearest (or only) bend or of the tee or the downstream end of the curved or conical portion of the reducer or expander. The recommended values give tube bundle locations that are applicable over a specified range of β.

[a] S is the separation between the two bends measured from the downstream end of the curved portion of the upstream bend to the upstream end of the curved portion of the downstream bend.

[b] Bends should have a radius of curvature equal to $1{,}5D$.

[c] Column A for each fitting gives lengths corresponding to “zero additional uncertainty” values (see 6.3.2.3.2).

[d] Column B for each fitting gives lengths corresponding to “0,5 % additional uncertainty” values (see 6.3.2.3.3).

[e] n is the number of diameters such that the upstream end of the 19-tube bundle flow straightener (1998) is situated $1D$ from the downstream end of the curved or conical portion of the nearest fitting. It is desirable that the length between the upstream end of the 19-tube bundle flow straightener (1998) and the downstream end of the curved or conical portion of the nearest fitting should be at least $2{,}5D$, except where this would not give an acceptable value for the distance between the orifice plate and the downstream end of the 19-tube bundle flow straightener (1998).

[f] It is not possible to find an acceptable location for a 19-tube bundle flow straightener (1998) downstream of the particular fitting for all values of L_f to which the column applies.

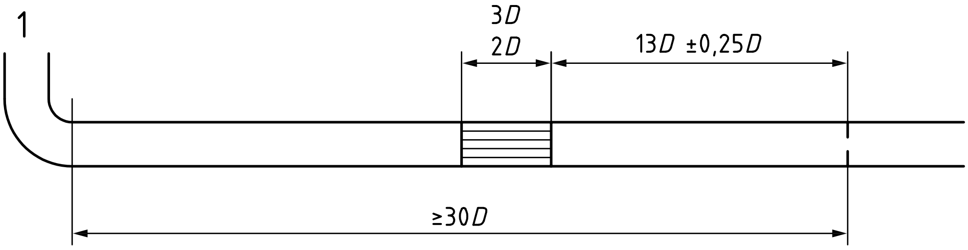
[g] If $\beta = 0{,}46$ a value of 9,5 is possible.

[h] If $\beta = 0{,}54$ a value of 13 is possible.

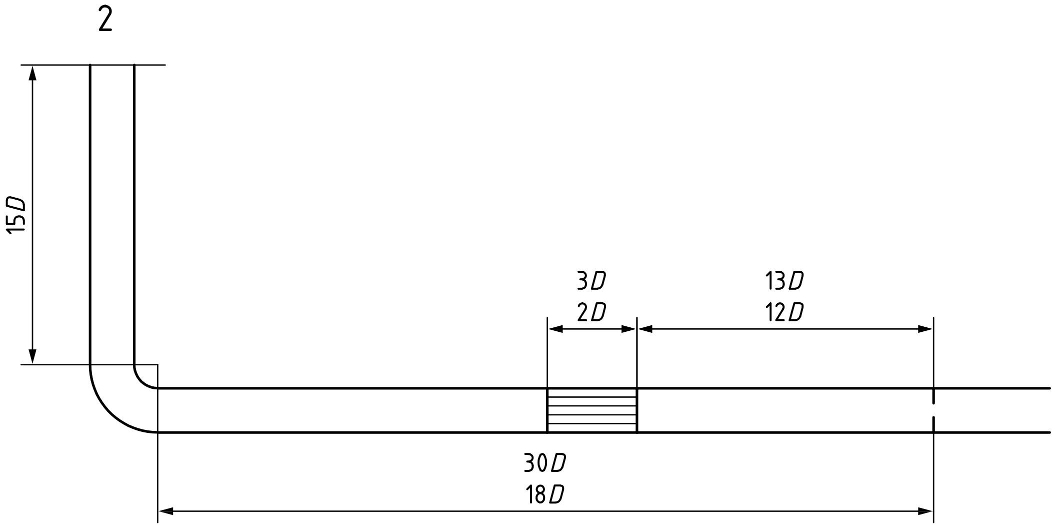
6.3.2.3.5 The values given in Table 4 were determined experimentally with a very long straight length mounted upstream of the fitting in question so that the flow immediately upstream of the fitting was considered as fully developed and swirl-free. Since in practice such conditions are difficult to achieve, there shall be at least 15*D* of straight pipe between the fitting listed in Table 4 and the nearest fitting beyond that one, unless the columns relating to any fitting are used.

6.3.2.4 An example

If it is necessary to install a single bend upstream of an orifice plate of diameter ratio 0,6, there are two options using a 19-tube bundle flow straightener (1998) which will reduce the upstream length in comparison with the 42*D* required (see Table 3) if no flow conditioner is used. Either an installation as in 6.3.2.2.2 is permissible [see Figure 9 a)] which has the advantage that any fitting can be placed at any distance upstream of the single bend or an installation as in Table 4 is permissible [see Figure 9 b)] which gives a shorter straight length required downstream of the bend but a straight length required upstream of the bend. If the upstream straight length from the orifice plate to the bend is greater than or equal to 30*D*, Table 4 can also be used to provide a wider range of tube bundle locations but since these locations will rarely be required in designing installations these options are not shown in Figure 9.



a) Installation using 6.3.2.2.2



b) Installation using Table 4

Key

1 position of any fitting placed at any distance upstream of the single bend

2 position of previous fitting placed before straight length upstream of the single bend

Figure 9 — Examples of installations with a 19-tube bundle flow straightener (1998) downstream of a single bend

6.3.3 The Zanker flow conditioner plate

6.3.3.1 Description

The Zanker flow conditioner plate[16] shown in Figure 10 met the conformity test requirements given in ISO 5167-1:2022, 7.4.1.2 to 7.4.1.6. A Zanker flow conditioner plate which meets the manufacturing specification in 6.3.3.2 and is installed in accordance with 6.3.3.3 will be compliant with this document. It is not patented.

6.3.3.2 Design

The Zanker flow conditioner plate is illustrated in Figure 10 and consists of 32 bored holes arranged in a symmetrical circular pattern. The dimensions of the holes are a function of the pipe inside diameter D and shall be as follows:

a) a ring of 4 central holes of diameter $0{,}141D \pm 0{,}001D$ on a pitch circle diameter of $0{,}25D \pm 0{,}002\,5D$;

b) a ring of 8 holes of diameter $0{,}139D \pm 0{,}001D$ on a pitch circle diameter of $0{,}56D \pm 0{,}005\,6D$;

c) a ring of 4 holes of diameter $0{,}136\,5D \pm 0{,}001D$ on a pitch circle diameter of $0{,}75D \pm 0{,}007\,5D$;

d) a ring of 8 holes of diameter $0{,}110D \pm 0{,}001D$ on a pitch circle diameter of $0{,}85D \pm 0{,}008\,5D$;

e) a ring of 8 holes of diameter $0{,}077D \pm 0{,}001D$ on a pitch circle diameter of $0{,}90D \pm 0{,}009D$.

The tolerance on the diameter of each hole is ±0,1 mm for $D < 100$ mm.

The perforated plate thickness, t_c, is such that $0{,}12D \le t_c \le 0{,}15D$. The flange thickness depends on the application; the outer diameter and flange face surfaces depend on the flange type and application.

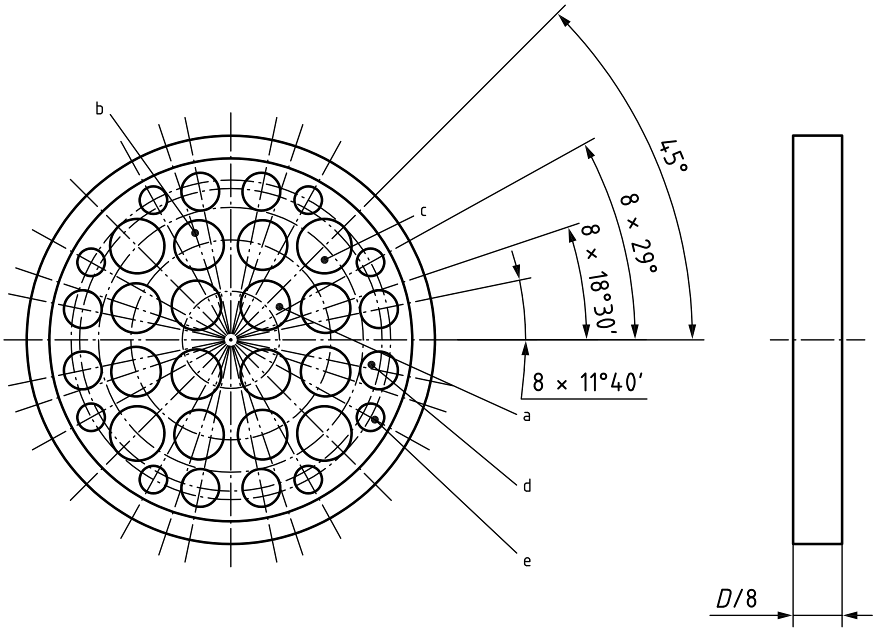


Figure 10 — Drawing of the Zanker flow conditioner plate

The pressure loss coefficient, K, for the Zanker flow conditioner plate is approximately equal to 3, where K is given by the following Formula (9):

$$K = \frac{\Delta p_c}{\frac{1}{2}\rho V^2} \tag{9}$$

where

Δp_c is the pressure loss across the Zanker flow conditioner plate;

ρ is the density of the fluid in the pipe;

V is the mean axial velocity of the fluid in the pipe.

6.3.3.3 Installation

L_f, the distance between the orifice plate and the nearest upstream fitting, shall be at least equal to 17D. The Zanker flow conditioner plate shall be installed so that L_s, the distance between the downstream face of the conditioner plate and the orifice plate, is such that

$$7{,}5D \le L_s \le L_f - 8{,}5D$$

The Zanker flow conditioner plate can be used for $\beta \le 0{,}67$.

The distance to a bend (or bend combination) or a tee is measured to the downstream end of the curved portion of the nearest (or only) bend or of the tee. The distance to a reducer or expander is measured to the downstream end of the curved or conical portion of the reducer or the expander.

The locations in this subclause are acceptable downstream of any fitting. A wider range of locations for the Zanker flow conditioner plate is permissible if the range of upstream fittings is restricted or the overall length between the upstream fitting and the orifice plate is increased or the diameter ratio of the orifice plate is reduced. These locations are not described here.

6.4 Circularity and cylindricality of the pipe

NOTE Guidance is provided in ISO/TR 9464:2008, 5.2.6.4.

6.4.1 The 2D length of the upstream pipe section adjacent to the orifice plate (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 0,5D 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 0,5D, two of the sections being at distance 0D and 0,5D 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 4), this value of 0,5D shall be measured from the upstream edge of the carrier ring.

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

Between 2D and 10D from the orifice plate, 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 10D from the orifice plate (see Reference [17]), 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 % to 6 % of D. On each side of the step, the pipe shall have a diameter between 0,98D and 1,06D. Beyond 10D from the orifice plate, 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.

At a location which is both beyond 10D from the orifice plate and beyond the first location where an expander could be fitted in accordance with Column 10A 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 0,94D and 1,06D. The first location where an expander could be fitted in accordance with Column 10A of Table 3 depends on the diameter ratio of the orifice plate: for example, it is 26D from the orifice plate if $\beta = 0{,}6$.

6.4.4 An additional relative uncertainty of 0,2 % shall be added arithmetically to the relative expanded uncertainty for 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 relationship given by Formula (10):

$$\frac{\Delta D}{D} < 0{,}002\left(\frac{\frac{s}{D}+0{,}4}{0{,}1+2{,}3\beta^4}\right) \qquad (10)$$

and

$$\frac{\Delta D}{D} < 0{,}05$$

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.

6.4.6 No diameter of the downstream straight length, considered along a length of at least 2D from the upstream face of the orifice plate, 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. Mating flanges would require the bores to be matched and the flanges aligned on installation. Dowels or self-centring gaskets could be used.

6.5 Location of orifice plate and carrier rings

6.5.1 The orifice plate shall be placed in the pipe in such a way that the fluid flows from the upstream face towards the downstream face.

All flow shall pass through the orifice bore; no leakage shall be permitted around the periphery of the plate.

6.5.2 The orifice plate shall be perpendicular to the centreline of the pipe to within 1°.

6.5.3 The orifice plate shall be centred in the pipe. The distance e_c between the centreline of the orifice and the centrelines of the pipe on the upstream and downstream sides shall be measured, and for each pressure tapping the components of the distance between the centreline of the orifice and the centreline of the pipe in which it is located in the directions parallel to and perpendicular to the axis of the pressure tapping shall be determined.

$e_{\mathrm{c,l}}$, the component in the direction parallel to the pressure tapping, shall for each pressure tapping be such that

$$e_{\mathrm{c,l}} \leq \frac{0{,}0025D}{0{,}1+2{,}3\beta^4}$$

$e_{\mathrm{c,n}}$, the component in the direction perpendicular to the pressure tapping, shall for each pressure tapping be such that

$$e_{\mathrm{c,n}} \leq \frac{0{,}005D}{0{,}1+2{,}3\beta^4}$$

If, for one or more pressure tappings,

$$\frac{0{,}0025D}{0{,}1+2{,}3\beta^4} < e_{\mathrm{c,l}} \leq \frac{0{,}005D}{0{,}1+2{,}3\beta^4}$$

an additional relative uncertainty of 0,3 % shall be added arithmetically to the relative expanded uncertainty in the discharge coefficient C. This additional uncertainty shall only be added once even if the above inequality holds for several pressure tappings.

In the case where, for any pressure tapping,

$$\text{either } e_{\mathrm{c,l}} \text{ or } e_{\mathrm{c,n}} > \frac{0{,}005D}{0{,}1+2{,}3\beta^4}$$

this document gives no information for predicting any additional uncertainty due to lack of concentricity.

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 orifice plate has been installed in the proper position, it remains so.

It is necessary to allow for the thermal expansion of the orifice plate 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 specified in 5.2.

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

7 Flow calibration of orifice meters

7.1 General

For users of orifice meters of the geometry described in this document that require a lower discharge coefficient uncertainty than that stated in 5.3.3.1, or for users of devices where the geometry differs from that described in this document, the orifice meter shall be calibrated.

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

Where the geometry of the orifice meter differs from that described in this document, the expansibility equation given in Formula (5) shall not be used unless verified. In such a case, the manufacturer of the orifice meter shall provide an appropriate formula for the expansibility (expansion) factor.

Calibrated meters shall only be used within the calibrated Reynolds number range.

NOTE For gas applications (other than those at ambient process conditions), 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 orifice meter shall be calibrated in such a manner as to ensure appropriate traceability for the user of the orifice meter for the intended application.

NOTE For guidance on what might be appropriate, ISO/IEC 17025[4] is applicable.

7.3 Meter installation

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

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

The orientation of the orifice meter is irrelevant.

If the orifice meter 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 orifice meter in its installation.

7.4 Design of the test programme

The orifice meter 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 orifice meter using liquid or gas, or both liquid and gas in separate tests to cover the required Reynolds number range.

The calibration data of an orifice meter are not transferrable to another orifice meter. 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 or ISO/IEC Guide 98-3. 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 orifice meter

The calibration procedure and the calculated uncertainty of the orifice meter 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 — Orifice plate with corner tappings — Discharge coefficient, C, for $D \geq 71{,}12$ mm

Diameter ratio	Discharge coefficient, C, for Re_D equal to											
β	5×10^3	1×10^4	2×10^4	3×10^4	5×10^4	7×10^4	1×10^5	3×10^5	1×10^6	1×10^7	1×10^8	∞
0,10	0,600 6	0,599 0	0,598 0	0,597 6	0,597 2	0,597 0	0,596 9	0,596 6	0,596 5	0,596 4	0,596 4	0,596 4
0,12	0,601 4	0,599 5	0,598 3	0,597 9	0,597 5	0,597 3	0,597 1	0,596 8	0,596 6	0,596 5	0,596 5	0,596 5
0,14	0,602 1	0,600 0	0,598 7	0,598 2	0,597 7	0,597 5	0,597 3	0,596 9	0,596 8	0,596 6	0,596 6	0,596 6
0,16	0,602 8	0,600 5	0,599 1	0,598 5	0,598 0	0,597 8	0,597 6	0,597 1	0,596 9	0,596 8	0,596 8	0,596 8
0,18	0,603 6	0,601 1	0,599 5	0,598 9	0,598 3	0,598 1	0,597 8	0,597 4	0,597 1	0,597 0	0,597 0	0,596 9
0,20	0,604 5	0,601 7	0,600 0	0,599 3	0,598 7	0,598 4	0,598 1	0,597 6	0,597 4	0,597 2	0,597 2	0,597 1
0,22	0,605 3	0,602 3	0,600 5	0,599 8	0,599 1	0,598 7	0,598 5	0,597 9	0,597 6	0,597 4	0,597 4	0,597 4
0,24	0,606 2	0,603 0	0,601 0	0,600 2	0,599 5	0,599 1	0,598 8	0,598 2	0,597 9	0,597 7	0,597 6	0,597 6
0,26	0,607 2	0,603 8	0,601 6	0,600 7	0,599 9	0,599 6	0,599 2	0,598 6	0,598 2	0,598 0	0,597 9	0,597 9
0,28	0,608 3	0,604 6	0,602 2	0,601 3	0,600 4	0,600 0	0,599 7	0,599 0	0,598 6	0,598 3	0,598 2	0,598 1
0,30	0,609 5	0,605 4	0,602 9	0,601 9	0,601 0	0,600 5	0,600 1	0,599 4	0,598 9	0,598 6	0,598 5	0,598 4
0,32	0,610 7	0,606 3	0,603 6	0,602 6	0,601 6	0,601 1	0,600 6	0,599 8	0,599 3	0,599 0	0,598 8	0,598 7
0,34	0,612 0	0,607 3	0,604 4	0,603 3	0,602 2	0,601 7	0,601 2	0,600 3	0,599 8	0,599 3	0,599 2	0,599 1
0,36	0,613 5	0,608 4	0,605 3	0,604 0	0,602 9	0,602 3	0,601 8	0,600 8	0,600 2	0,599 7	0,599 6	0,599 4
0,38	0,615 1	0,609 6	0,606 2	0,604 9	0,603 6	0,603 0	0,602 4	0,601 3	0,600 7	0,600 1	0,599 9	0,599 8
0,40	0,616 8	0,610 9	0,607 2	0,605 8	0,604 4	0,603 7	0,603 1	0,601 9	0,601 2	0,600 6	0,600 3	0, 600 1
0,42	0,618 7	0,612 2	0,608 3	0,606 7	0,605 2	0,604 4	0,603 8	0,602 5	0,601 7	0,601 0	0,600 7	0,600 5
0,44	0,620 7	0,613 7	0,609 4	0,607 7	0,606 1	0,605 2	0,604 5	0,603 1	0,602 2	0,601 4	0,601 1	0,600 8
0,46	0,622 8	0,615 2	0,610 6	0,608 7	0,607 0	0,606 1	0,605 3	0,603 7	0,602 7	0,601 9	0,601 5	0,601 2
0,48	0,625 1	0,616 9	0,611 8	0,609 8	0,607 9	0,606 9	0,606 1	0,604 3	0,603 3	0,602 3	0,601 9	0,601 5
0,50	0,627 6	0,618 6	0,613 1	0,610 9	0,608 8	0,607 8	0,606 9	0,605 0	0,603 8	0,602 7	0,602 2	0,601 8
0,51	0,628 9	0,619 5	0,613 8	0,611 5	0,609 3	0,608 2	0,607 3	0,605 3	0,604 0	0,602 9	0,602 4	0,601 9
0,52	0,630 2	0,620 4	0,614 4	0,612 1	0,609 8	0,608 7	0,607 7	0,605 6	0,604 3	0,603 0	0,602 5	0,602 0
0,53	0,631 6	0,621 3	0,615 1	0,612 6	0,610 3	0,609 1	0,608 0	0,605 9	0,604 5	0,603 2	0,602 6	0,602 1
0,54	0,633 0	0,622 3	0,615 8	0,613 2	0,610 8	0,609 5	0,608 4	0,606 1	0,604 7	0,603 3	0,602 7	0,602 1
0,55	0,634 4	0,623 2	0,616 5	0,613 8	0,611 2	0,609 9	0,608 8	0,606 4	0,604 9	0,603 4	0,602 8	0,602 2
0,56	—	0,624 2	0,617 2	0,614 3	0,611 7	0,610 3	0,609 1	0,606 6	0,605 0	0,603 5	0,602 8	0,602 2
0,57	—	0,625 2	0,617 9	0,614 9	0,612 1	0,610 7	0,609 5	0,606 9	0,605 2	0,603 6	0,602 8	0,602 2
0,58	—	0,626 2	0,618 5	0,615 5	0,612 6	0,611 1	0,609 8	0,607 0	0,605 3	0,603 6	0,602 8	0,602 1
0,59	—	0,627 2	0,619 2	0,616 0	0,613 0	0,611 4	0,610 1	0,607 2	0,605 4	0,603 6	0,602 8	0,602 0
0,60	—	0,628 2	0,619 8	0,616 5	0,613 4	0,611 7	0,610 3	0,607 3	0,605 4	0,603 5	0,602 7	0,601 9
0,61	—	0,629 2	0,620 5	0,617 0	0,613 7	0,612 0	0,610 6	0,607 4	0,605 4	0,603 4	0,602 5	0,601 7
0,62	—	0,630 2	0,621 1	0,617 5	0,614 0	0,612 3	0,610 8	0,607 5	0,605 4	0,603 3	0,602 3	0,601 4
0,63	—	0,631 2	0,621 7	0,617 9	0,614 3	0,612 5	0,610 9	0,607 5	0,605 2	0,603 0	0,602 1	0,601 1
0,64	—	0,632 1	0,622 2	0,618 3	0,614 5	0,612 6	0,611 0	0,607 4	0,605 1	0,602 8	0,601 7	0,600 7

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	5×10^3	1×10^4	2×10^4	3×10^4	5×10^4	7×10^4	1×10^5	3×10^5	1×10^6	1×10^7	1×10^8	∞
0,65	—	0,633 1	0,622 7	0,618 6	0,614 7	0,612 7	0,611 0	0,607 3	0,604 8	0,602 4	0,601 3	0,600 2
0,66	—	0,634 0	0,623 2	0,618 9	0,614 8	0,612 8	0,611 0	0,607 1	0,604 5	0,602 0	0,600 8	0,599 7
0,67	—	0,634 8	0,623 6	0,619 1	0,614 9	0,612 7	0,610 8	0,606 8	0,604 1	0,601 4	0,600 2	0,599 0
0,68	—	0,635 7	0,623 9	0,619 3	0,614 9	0,612 6	0,610 6	0,606 4	0,603 6	0,600 8	0,599 5	0,598 3
0,69	—	0,636 4	0,624 2	0,619 3	0,614 7	0,612 4	0,610 4	0,605 9	0,603 0	0,600 1	0,598 7	0,597 4
0,70	—	0,637 2	0,624 4	0,619 3	0,614 5	0,612 1	0,610 0	0,605 3	0,602 3	0,599 2	0,597 8	0,596 4
0,71	—	0,637 8	0,624 5	0,619 2	0,614 2	0,611 7	0,609 4	0,604 6	0,601 4	0,598 2	0,596 7	0,595 3
0,72	—	0,638 3	0,624 4	0,618 9	0,613 8	0,611 1	0,608 8	0,603 8	0,600 5	0,597 1	0,595 5	0,594 0
0,73	—	0,638 8	0,624 3	0,618 6	0,613 2	0,610 4	0,608 0	0,602 8	0,599 3	0,595 8	0,594 2	0,592 6
0,74	—	0,639 1	0,624 0	0,618 1	0,612 5	0,609 6	0,607 1	0,601 6	0,598 0	0,594 3	0,592 6	0,591 0
0,75	—	0,639 4	0,623 6	0,617 4	0,611 6	0,608 6	0,606 0	0,600 3	0,596 5	0,592 7	0,590 9	0,589 2

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

Table A.2 — Orifice plate with D and $D/2$ tappings — Discharge coefficient, C, for $D \geq 71{,}12$ mm

Diameter ratio	Discharge coefficient, C, for Re_D equal to											
β	5×10^3	1×10^4	2×10^4	3×10^4	5×10^4	7×10^4	1×10^5	3×10^5	1×10^6	1×10^7	1×10^8	∞
0,10	0,600 3	0,598 7	0,597 7	0,597 3	0,596 9	0,596 7	0,596 6	0,596 3	0,596 2	0,596 1	0,596 1	0,596 0
0,12	0,601 0	0,599 1	0,597 9	0,597 5	0,597 1	0,596 9	0,596 7	0,596 4	0,596 2	0,596 1	0,596 1	0,596 1
0,14	0,601 6	0,599 5	0,598 2	0,597 7	0,597 2	0,597 0	0,596 8	0,596 5	0,596 3	0,596 2	0,596 1	0,596 1
0,16	0,602 3	0,600 0	0,598 5	0,598 0	0,597 4	0,597 2	0,597 0	0,596 6	0,596 4	0,596 2	0,596 2	0,596 2
0,18	0,602 9	0,600 4	0,598 9	0,598 2	0,597 7	0,597 4	0,597 1	0,596 7	0,596 5	0,596 3	0,596 3	0,596 3
0,20	0,603 7	0,600 9	0,599 2	0,598 5	0,597 9	0,597 6	0,597 4	0,596 9	0,596 6	0,596 4	0,596 4	0,596 4
0,22	0,604 4	0,601 5	0,599 6	0,598 9	0,598 2	0,597 9	0,597 6	0,597 1	0,596 8	0,596 6	0,596 5	0,596 5
0,24	0,605 3	0,602 1	0,600 1	0,599 3	0,598 5	0,598 2	0,597 9	0,597 3	0,597 0	0,596 7	0,596 7	0,596 6
0,26	0,606 2	0,602 7	0,600 6	0,599 7	0,598 9	0,598 5	0,598 2	0,597 5	0,597 2	0,596 9	0,596 9	0,596 8
0,28	0,607 2	0,603 4	0,601 1	0,600 2	0,599 3	0,598 9	0,598 5	0,597 8	0,597 5	0,597 2	0,597 1	0,597 0
0,30	0,608 2	0,604 2	0,601 7	0,600 7	0,599 8	0,599 3	0,598 9	0,598 2	0,597 8	0,597 4	0,597 3	0,597 3
0,32	0,609 4	0,605 1	0,602 4	0,601 3	0,600 3	0,599 8	0,599 4	0,598 6	0,598 1	0,597 7	0,597 6	0,597 5
0,34	0,610 7	0,606 0	0,603 1	0,602 0	0,600 9	0,600 4	0,599 9	0,599 0	0,598 5	0,598 1	0,597 9	0,597 8
0,36	0,612 1	0,607 1	0,604 0	0,602 7	0,601 6	0,601 0	0,600 5	0,599 5	0,598 9	0,598 4	0,598 3	0,598 1
0,38	0,613 7	0,608 2	0,604 9	0,603 5	0,602 3	0,601 6	0,601 1	0,600 0	0,599 4	0,598 8	0,598 6	0,598 5
0,40	0,615 3	0,609 5	0,605 9	0,604 4	0,603 1	0,602 4	0,601 8	0,600 6	0,599 9	0,599 3	0,599 1	0,598 9
0,42	0,617 2	0,610 9	0,607 0	0,605 4	0,603 9	0,603 2	0,602 5	0,601 2	0,600 5	0,599 8	0,599 5	0,599 3
0,44	0,619 2	0,612 4	0,608 2	0,606 5	0,604 9	0,604 1	0,603 4	0,601 9	0,601 1	0,600 3	0,600 0	0,599 7
0,46	0,621 4	0,614 0	0,609 4	0,607 6	0,605 9	0,605 0	0,604 2	0,602 7	0,601 7	0,600 8	0,600 5	0,600 2
0,48	0,623 8	0,615 7	0,610 8	0,608 8	0,607 0	0,606 0	0,605 2	0,603 5	0,602 4	0,601 4	0,601 0	0,600 6
0,50	0,626 4	0,617 6	0,612 3	0,610 1	0,608 1	0,607 1	0,606 2	0,604 3	0,603 1	0,602 0	0,601 6	0,601 1
0,51	0,627 8	0,618 6	0,613 1	0,610 8	0,608 7	0,607 6	0,606 7	0,604 7	0,603 5	0,602 3	0,601 9	0,601 4
0,52	0,629 2	0,619 7	0,613 9	0,611 5	0,609 3	0,608 2	0,607 2	0,605 2	0,603 9	0,602 7	0,602 1	0,601 6
0,53	0,630 7	0,620 7	0,614 7	0,612 3	0,610 0	0,608 8	0,607 8	0,605 6	0,604 3	0,603 0	0,602 4	0,601 9
0,54	0,632 2	0,621 8	0,615 5	0,613 0	0,610 6	0,609 4	0,608 3	0,606 1	0,604 7	0,603 3	0,602 7	0,602 1
0,55	0,633 7	0,622 9	0,616 4	0,613 8	0,611 3	0,610 0	0,608 9	0,606 5	0,605 0	0,603 6	0,603 0	0,602 4
0,56	—	0,624 1	0,617 3	0,614 5	0,611 9	0,610 6	0,609 5	0,607 0	0,605 4	0,603 9	0,603 2	0,602 6

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	5×10^3	1×10^4	2×10^4	3×10^4	5×10^4	7×10^4	1×10^5	3×10^5	1×10^6	1×10^7	1×10^8	∞
0,57	—	0,625 3	0,618 2	0,615 3	0,612 6	0,611 2	0,610 0	0,607 5	0,605 8	0,604 2	0,603 5	0,602 8
0,58	—	0,626 5	0,619 1	0,616 1	0,613 3	0,611 9	0,610 6	0,607 9	0,606 2	0,604 5	0,603 8	0,603 0
0,59	—	0,627 7	0,620 0	0,616 9	0,614 0	0,612 5	0,611 2	0,608 4	0,606 6	0,604 8	0,604 0	0,603 2
0,60	—	0,629 0	0,621 0	0,617 7	0,614 7	0,613 1	0,611 8	0,608 8	0,607 0	0,605 1	0,604 2	0,603 4
0,61	—	0,630 3	0,621 9	0,618 6	0,615 4	0,613 8	0,612 4	0,609 3	0,607 3	0,605 3	0,604 4	0,603 6
0,62	—	0,631 6	0,622 9	0,619 4	0,616 1	0,614 4	0,612 9	0,609 7	0,607 7	0,605 6	0,604 6	0,603 7
0,63	—	0,632 9	0,623 8	0,620 2	0,616 8	0,615 0	0,613 5	0,610 2	0,608 0	0,605 8	0,604 8	0,603 9
0,64	—	0,634 3	0,624 8	0,621 0	0,617 5	0,615 6	0,614 0	0,610 6	0,608 3	0,606 0	0,605 0	0,603 9
0,65	—	0,635 6	0,625 8	0,621 9	0,618 2	0,616 2	0,614 6	0,610 9	0,608 6	0,606 2	0,605 1	0,604 0
0,66	—	0,637 0	0,626 8	0,622 7	0,618 8	0,616 8	0,615 1	0,611 3	0,608 8	0,606 3	0,605 1	0,604 0
0,67	—	0,638 4	0,627 7	0,623 5	0,619 5	0,617 4	0,615 6	0,611 6	0,609 0	0,606 4	0,605 2	0,604 0
0,68	—	0,639 8	0,628 7	0,624 3	0,620 1	0,617 9	0,616 1	0,612 0	0,609 2	0,606 5	0,605 2	0,603 9
0,69	—	0,641 1	0,629 6	0,625 0	0,620 7	0,618 5	0,616 5	0,612 2	0,609 4	0,606 5	0,605 1	0,603 8
0,70	—	0,642 5	0,630 5	0,625 8	0,621 3	0,618 9	0,616 9	0,612 5	0,609 5	0,606 5	0,605 1	0,603 7
0,71	—	0,643 9	0,631 5	0,626 5	0,621 8	0,619 4	0,617 3	0,612 7	0,609 6	0,606 4	0,604 9	0,603 5
0,72	—	0,645 3	0,632 3	0,627 2	0,622 3	0,619 8	0,617 6	0,612 8	0,609 6	0,606 3	0,604 7	0,603 2
0,73	—	0,646 7	0,633 2	0,627 9	0,622 8	0,620 2	0,617 9	0,612 9	0,609 6	0,606 1	0,604 5	0,602 9
0,74	—	0,648 0	0,634 0	0,628 5	0,623 3	0,620 6	0,618 2	0,613 0	0,609 5	0,605 9	0,604 2	0,602 5
0,75	—	0,649 4	0,634 9	0,629 1	0,623 7	0,620 9	0,618 4	0,613 0	0,609 4	0,605 6	0,603 8	0,602 1
NOTE This table is given for convenience. The values given are not intended for precise interpolation. Extrapolation is not permitted.												

Table A.3 — Orifice plate with flange tappings — Discharge coefficient, C, for D = 50 mm

Diameter ratio	Discharge coefficient, C, for Re_D equal to											
β	5×10^3	1×10^4	2×10^4	3×10^4	5×10^4	7×10^4	1×10^5	3×10^5	1×10^6	1×10^7	1×10^8	∞
0,25	0,610 2	0,606 9	0,604 8	0,604 0	0,603 2	0,602 9	0,602 5	0,601 9	0,601 6	0,601 4	0,601 3	0,601 2
0,26	0,610 6	0,607 1	0,605 0	0,604 1	0,603 3	0,602 9	0,602 6	0,602 0	0,601 6	0,601 4	0,601 3	0,601 2
0,28	0,611 4	0,607 6	0,605 3	0,604 4	0,603 5	0,603 1	0,602 8	0,602 1	0,601 7	0,601 4	0,601 3	0,601 2
0,30	0,612 3	0,608 2	0,605 7	0,604 7	0,603 8	0,603 4	0,603 0	0,602 2	0,601 8	0,601 5	0,601 4	0,601 3
0,32	0,613 2	0,608 9	0,606 2	0,605 2	0,604 2	0,603 7	0,603 2	0,602 4	0,601 9	0,601 6	0,601 4	0,601 3
0,34	0,614 3	0,609 7	0,606 8	0,605 6	0,604 5	0,604 0	0,603 5	0,602 6	0,602 1	0,601 7	0,601 6	0,601 4
0,36	0,615 5	0,610 5	0,607 4	0,606 2	0,605 0	0,604 4	0,603 9	0,602 9	0,602 3	0,601 9	0,601 7	0,601 6
0,38	0,616 9	0,611 5	0,608 1	0,606 8	0,605 5	0,604 9	0,604 3	0,603 2	0,602 6	0,602 1	0,601 9	0,601 7
0,40	0,618 4	0,612 5	0,608 9	0,607 5	0,606 1	0,605 4	0,604 8	0,603 6	0,602 9	0,602 3	0,602 1	0,601 9
0,42	0,620 0	0,613 7	0,609 8	0,608 2	0,606 8	0,606 0	0,605 4	0,604 1	0,603 3	0,602 6	0,602 3	0,602 1
0,44	0,621 9	0,615 0	0,610 8	0,609 1	0,607 5	0,606 7	0,606 0	0,604 5	0,603 7	0,602 9	0,602 6	0,602 3
0,46	0,623 9	0,616 4	0,611 9	0,610 0	0,608 3	0,607 4	0,606 7	0,605 1	0,604 1	0,603 3	0,602 9	0,602 6
0,48	0,626 0	0,618 0	0,613 0	0,611 0	0,609 2	0,608 2	0,607 4	0,605 7	0,604 6	0,603 6	0,603 2	0,602 8
0,50	0,628 4	0,619 6	0,614 3	0,612 1	0,610 1	0,609 1	0,608 2	0,606 3	0,605 1	0,604 0	0,603 6	0,603 1
0,51	0,629 7	0,620 5	0,614 9	0,612 7	0,610 6	0,609 5	0,608 6	0,606 6	0,605 4	0,604 2	0,603 7	0,603 3
0,52	0,631 0	0,621 4	0,615 6	0,613 3	0,611 1	0,610 0	0,609 0	0,606 9	0,605 6	0,604 4	0,603 9	0,603 4
0,53	0,632 4	0,622 4	0,616 3	0,613 9	0,611 6	0,610 5	0,609 4	0,607 3	0,605 9	0,604 6	0,604 1	0,603 5
0,54	0,633 8	0,623 4	0,617 1	0,614 5	0,612 2	0,610 9	0,609 9	0,607 6	0,606 2	0,604 8	0,604 2	0,603 7
0,55	0,635 2	0,624 4	0,617 8	0,615 2	0,612 7	0,611 4	0,610 3	0,608 0	0,606 5	0,605 0	0,604 4	0,603 8
NOTE This table is given for convenience. The values given are not intended for precise interpolation. Extrapolation is not permitted.												

Table A.3 *(continued)*

Diameter ratio	**Discharge coefficient, C, for Re_D equal to**											
β	**5 × 10^3**	**1 × 10^4**	**2 × 10^4**	**3 × 10^4**	**5 × 10^4**	**7 × 10^4**	**1 × 10^5**	**3 × 10^5**	**1 × 10^6**	**1 × 10^7**	**1 × 10^8**	∞
0,56	0,636 7	0,625 4	0,618 6	0,615 9	0,613 3	0,611 9	0,610 8	0,608 3	0,606 7	0,605 2	0,604 5	0,603 9
0,57	0,638 3	0,626 5	0,619 4	0,616 5	0,613 8	0,612 4	0,611 2	0,608 7	0,607 0	0,605 4	0,604 7	0,604 0
0,58	0,639 9	0,627 6	0,620 2	0,617 2	0,614 4	0,613 0	0,611 7	0,609 0	0,607 3	0,605 6	0,604 8	0,604 1
0,59	0,641 6	0,628 7	0,621 0	0,617 9	0,615 0	0,613 5	0,612 2	0,609 3	0,607 5	0,605 8	0,605 0	0,604 2
0,60	0,643 3	0,629 9	0,621 8	0,618 6	0,615 5	0,614 0	0,612 6	0,609 7	0,607 8	0,605 9	0,605 1	0,604 3
0,61	0,645 0	0,631 0	0,622 7	0,619 3	0,616 1	0,614 5	0,613 1	0,610 0	0,608 0	0,606 0	0,605 1	0,604 3
0,62	0,646 8	0,632 2	0,623 5	0,620 0	0,616 7	0,615 0	0,613 5	0,610 3	0,608 2	0,606 2	0,605 2	0,604 3
0,63	0,648 6	0,633 4	0,624 3	0,620 7	0,617 3	0,615 5	0,613 9	0,610 6	0,608 4	0,606 2	0,605 3	0,604 3
0,64	0,650 5	0,634 7	0,625 2	0,621 4	0,617 8	0,616 0	0,614 4	0,610 9	0,608 6	0,606 3	0,605 3	0,604 3
0,65	0,652 4	0,635 9	0,626 0	0,622 1	0,618 4	0,616 4	0,614 8	0,611 1	0,608 8	0,606 4	0,605 3	0,604 2
0,66	0,654 4	0,637 1	0,626 9	0,622 8	0,618 9	0,616 9	0,615 2	0,611 4	0,608 9	0,606 4	0,605 2	0,604 1
0,67	0,656 4	0,638 4	0,627 7	0,623 4	0,619 4	0,617 3	0,615 5	0,611 6	0,609 0	0,606 3	0,605 1	0,603 9
0,68	0,658 4	0,639 6	0,628 5	0,624 1	0,619 9	0,617 7	0,615 8	0,611 7	0,609 0	0,606 2	0,605 0	0,603 7
0,69	0,660 4	0,640 9	0,629 3	0,624 7	0,620 4	0,618 1	0,616 1	0,611 9	0,609 0	0,606 1	0,604 8	0,603 5
0,70	0,662 5	0,642 1	0,630 1	0,625 3	0,620 8	0,618 5	0,616 4	0,612 0	0,609 0	0,606 0	0,604 5	0,603 2
0,71	0,664 6	0,643 4	0,630 9	0,625 9	0,621 2	0,618 8	0,616 6	0,612 0	0,608 9	0,605 7	0,604 3	0,602 8
0,72	0,666 7	0,644 6	0,631 6	0,626 5	0,621 6	0,619 0	0,616 8	0,612 0	0,608 8	0,605 5	0,603 9	0,602 4
0,73	0,668 9	0,645 9	0,632 3	0,627 0	0,621 9	0,619 3	0,617 0	0,612 0	0,608 6	0,605 1	0,603 5	0,601 9
0,74	0,671 0	0,647 1	0,633 0	0,627 5	0,622 2	0,619 5	0,617 1	0,611 9	0,608 4	0,604 7	0,603 0	0,601 4
0,75	0,673 2	0,648 3	0,633 7	0,627 9	0,622 4	0,619 6	0,617 1	0,611 7	0,608 1	0,604 3	0,602 5	0,600 8
NOTE This table is given for convenience. The values given are not intended for precise interpolation. Extrapolation is not permitted.												

Table A.4 — Orifice plate with flange tappings — Discharge coefficient, C, for D = 75 mm

Diameter ratio	**Discharge coefficient, C, for Re_D equal to**											
β	**5 × 10^3**	**1 × 10^4**	**2 × 10^4**	**3 × 10^4**	**5 × 10^4**	**7 × 10^4**	**1 × 10^5**	**3 × 10^5**	**1 × 10^6**	**1 × 10^7**	**1 × 10^8**	∞
0,17	0,602 7	0,600 3	0,598 8	0,598 2	0,597 7	0,597 4	0,597 2	0,596 7	0,596 5	0,596 4	0,596 4	0,596 3
0,18	0,603 1	0,600 5	0,599 0	0,598 4	0,597 8	0,597 5	0,597 3	0,596 8	0,596 6	0,596 4	0,596 4	0,596 4
0,20	0,603 8	0,601 1	0,599 4	0,598 7	0,598 1	0,597 7	0,597 5	0,597 0	0,596 7	0,596 6	0,596 5	0,596 5
0,22	0,604 6	0,601 6	0,599 8	0,599 0	0,598 4	0,598 0	0,597 7	0,597 2	0,596 9	0,596 7	0,596 7	0,596 6
0,24	0,605 4	0,602 2	0,600 2	0,599 4	0,598 7	0,598 3	0,598 0	0,597 4	0,597 1	0,596 9	0,596 9	0,596 8
0,26	0,606 4	0,602 9	0,600 7	0,599 9	0,599 1	0,598 7	0,598 4	0,597 7	0,597 4	0,597 1	0,597 0	0,597 0
0,28	0,607 4	0,603 6	0,601 3	0,600 4	0,599 5	0,599 1	0,598 7	0,598 0	0,597 6	0,597 4	0,597 3	0,597 2
0,30	0,608 4	0,604 4	0,601 9	0,600 9	0,600 0	0,599 5	0,599 1	0,598 4	0,597 9	0,597 6	0,597 5	0,597 4
0,32	0,609 6	0,605 3	0,602 6	0,601 5	0,600 5	0,600 0	0,599 6	0,598 8	0,598 3	0,597 9	0,597 8	0,597 7
0,34	0,610 9	0,606 2	0,603 3	0,602 2	0,601 1	0,600 6	0,600 1	0,599 2	0,598 7	0,598 3	0,598 1	0,598 0
0,36	0,612 3	0,607 3	0,604 2	0,602 9	0,601 7	0,601 2	0,600 7	0,599 7	0,599 1	0,598 6	0,598 4	0,598 3
0,38	0,613 9	0,608 4	0,605 1	0,603 7	0,602 5	0,601 8	0,601 3	0,600 2	0,599 5	0,599 0	0,598 8	0,598 6
0,40	0,615 5	0,609 7	0,606 0	0,604 6	0,603 2	0,602 5	0,602 0	0,600 8	0,600 0	0,599 4	0,599 2	0,599 0
0,42	0,617 4	0,611 0	0,607 1	0,605 5	0,604 1	0,603 3	0,602 7	0,601 4	0,600 6	0,599 9	0,599 6	0,599 4
0,44	0,619 4	0,612 5	0,608 3	0,606 6	0,605 0	0,604 2	0,603 5	0,602 0	0,601 2	0,600 4	0,600 1	0,599 8
0,46	0,621 6	0,614 1	0,609 5	0,607 7	0,605 9	0,605 1	0,604 3	0,602 7	0,601 8	0,600 9	0,600 5	0,600 2
0,48	0,623 9	0,615 8	0,610 8	0,608 9	0,607 0	0,606 0	0,605 2	0,603 5	0,602 4	0,601 4	0,601 0	0,600 6
0,50	0,626 4	0,617 6	0,612 3	0,610 1	0,608 1	0,607 0	0,606 1	0,604 2	0,603 1	0,602 0	0,601 5	0,601 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	**Discharge coefficient, C, for Re_D equal to**											
β	5×10^3	1×10^4	2×10^4	3×10^4	5×10^4	7×10^4	1×10^5	3×10^5	1×10^6	1×10^7	1×10^8	∞
0,51	0,627 8	0,618 6	0,613 0	0,610 7	0,608 6	0,607 5	0,606 6	0,604 6	0,603 4	0,602 2	0,601 7	0,601 3
0,52	0,629 2	0,619 6	0,613 8	0,611 4	0,609 2	0,608 1	0,607 1	0,605 0	0,603 7	0,602 5	0,602 0	0,601 5
0,53	0,630 6	0,620 6	0,614 5	0,612 1	0,609 8	0,608 6	0,607 6	0,605 4	0,604 1	0,602 8	0,602 2	0,601 7
0,54	0,632 1	0,621 6	0,615 3	0,612 8	0,610 4	0,609 2	0,608 1	0,605 8	0,604 4	0,603 0	0,602 4	0,601 9
0,55	0,633 6	0,622 7	0,616 1	0,613 5	0,611 0	0,609 7	0,608 6	0,606 2	0,604 7	0,603 3	0,602 7	0,602 1
0,56	0,635 2	0,623 8	0,617 0	0,614 2	0,611 6	0,610 3	0,609 1	0,606 6	0,605 1	0,603 5	0,602 9	0,602 2
0,57	0,636 8	0,624 9	0,617 8	0,614 9	0,612 2	0,610 8	0,609 6	0,607 0	0,605 4	0,603 8	0,603 1	0,602 4
0,58	0,638 5	0,626 1	0,618 6	0,615 6	0,612 8	0,611 4	0,610 1	0,607 4	0,605 7	0,604 0	0,603 2	0,602 5
0,59	0,640 2	0,627 3	0,619 5	0,616 4	0,613 4	0,611 9	0,610 6	0,607 8	0,606 0	0,604 2	0,603 4	0,602 6
0,60	0,641 9	0,628 4	0,620 3	0,617 1	0,614 0	0,612 5	0,611 1	0,608 2	0,606 3	0,604 4	0,603 5	0,602 7
0,61	0,643 7	0,629 6	0,621 2	0,617 8	0,614 6	0,613 0	0,611 6	0,608 5	0,606 5	0,604 5	0,603 6	0,602 8
0,62	0,645 5	0,630 9	0,622 1	0,618 6	0,615 2	0,613 5	0,612 0	0,608 8	0,606 7	0,604 7	0,603 7	0,602 8
0,63	—	0,632 1	0,622 9	0,619 3	0,615 8	0,614 0	0,612 5	0,609 1	0,606 9	0,604 8	0,603 8	0,602 8
0,64	—	0,633 3	0,623 8	0,620 0	0,616 4	0,614 5	0,612 9	0,609 4	0,607 1	0,604 8	0,603 8	0,602 8
0,65	—	0,634 6	0,624 6	0,620 7	0,616 9	0,615 0	0,613 3	0,609 7	0,607 3	0,604 9	0,603 8	0,602 7
0,66	—	0,635 8	0,625 5	0,621 3	0,617 4	0,615 4	0,613 7	0,609 9	0,607 4	0,604 8	0,603 7	0,602 6
0,67	—	0,637 0	0,626 3	0,622 0	0,617 9	0,615 8	0,614 0	0,610 0	0,607 4	0,604 8	0,603 6	0,602 4
0,68	—	0,638 2	0,627 0	0,622 6	0,618 4	0,616 2	0,614 3	0,610 2	0,607 4	0,604 6	0,603 4	0,602 1
0,69	—	0,639 5	0,627 8	0,623 2	0,618 8	0,616 5	0,614 5	0,610 2	0,607 4	0,604 5	0,603 1	0,601 8
0,70	—	0,640 7	0,628 5	0,623 7	0,619 1	0,616 8	0,614 7	0,610 2	0,607 3	0,604 2	0, 602 8	0,601 4
0,71	—	0,641 8	0,629 2	0,624 2	0,619 4	0,617 0	0,614 8	0,610 2	0,607 1	0,603 9	0,602 4	0,601 0
0,72	—	0,643 0	0,629 8	0,624 6	0,619 7	0,617 1	0,614 9	0,610 1	0,606 8	0,603 5	0,601 9	0,600 4
0,73	—	0,644 1	0,630 4	0,625 0	0,619 9	0,617 2	0,614 9	0,609 9	0,606 5	0,603 0	0,601 4	0,599 8
0,74	—	0,645 1	0,631 0	0,625 3	0,620 0	0,617 3	0,614 9	0,609 6	0,606 1	0,602 5	0,600 8	0,599 1
0,75	—	0,646 2	0,631 4	0,625 6	0,620 1	0,617 2	0,614 7	0,609 3	0,605 6	0,601 8	0,600 0	0,598 3

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

Table A.5 — Orifice plate with flange tappings — Discharge coefficient, C, for D = 100 mm

Diameter ratio	**Discharge coefficient, C, for Re_D equal to**											
β	5×10^3	1×10^4	2×10^4	3×10^4	5×10^4	7×10^4	1×10^5	3×10^5	1×10^6	1×10^7	1×10^8	∞
0,13	0,601 4	0,599 4	0,598 2	0,597 7	0,597 3	0,597 1	0,596 9	0,596 6	0,596 4	0,596 3	0,596 2	0,596 2
0,14	0,601 8	0,599 7	0,598 4	0,597 9	0,597 4	0,597 2	0,597 0	0,596 6	0,596 4	0,596 3	0,596 3	0,596 3
0,16	0,602 5	0,600 1	0,598 7	0,598 1	0,597 6	0,597 4	0,597 2	0,596 8	0,596 5	0,596 4	0,596 4	0,596 4
0,18	0,603 2	0,600 6	0,599 1	0,598 5	0,597 9	0,597 6	0,597 4	0,596 9	0,596 7	0,596 5	0,596 5	0,596 5
0,20	0,603 9	0,601 2	0,599 5	0,598 8	0,598 2	0,597 9	0,597 6	0,597 1	0,596 9	0,596 7	0,596 6	0,596 6
0,22	0,604 7	0,601 7	0,599 9	0,599 2	0,598 5	0,598 1	0,597 9	0,597 3	0,597 0	0,596 9	0,596 8	0,596 8
0,24	0,605 6	0,602 4	0,600 4	0,599 6	0,598 8	0,598 5	0,598 2	0,597 6	0,597 3	0,597 0	0,597 0	0,596 9
0,26	0,606 5	0,603 0	0,600 9	0,600 0	0,599 2	0,598 8	0,598 5	0,597 9	0,597 5	0,597 3	0,597 2	0,597 1
0,28	0,607 5	0,603 8	0,601 4	0,600 5	0,599 7	0,599 2	0,598 9	0,598 2	0,597 8	0,597 5	0,597 4	0,597 4
0,30	0,608 6	0,604 6	0,602 1	0,601 1	0,600 2	0,599 7	0,599 3	0,598 5	0,598 1	0,597 8	0,597 7	0,597 6
0,32	0,609 8	0,605 4	0,602 8	0,601 7	0,600 7	0,600 2	0,599 8	0,598 9	0,598 5	0,598 1	0,598 0	0,597 9
0,34	0,611 1	0,606 4	0,603 5	0,602 4	0,601 3	0,600 7	0,600 3	0,599 4	0,598 8	0,598 4	0,598 3	0,598 2
0,36	0,612 5	0,607 5	0,604 3	0,603 1	0,601 9	0,601 3	0,600 8	0,599 8	0,599 3	0,598 8	0,598 6	0,598 5

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	**Discharge coefficient, C, for Re_D equal to**											
β	**5 × 10^3**	**1 × 10^4**	**2 × 10^4**	**3 × 10^4**	**5 × 10^4**	**7 × 10^4**	**1 × 10^5**	**3 × 10^5**	**1 × 10^6**	**1 × 10^7**	**1 × 10^8**	∞
0,38	0,614 1	0,608 6	0,605 2	0,603 9	0,602 6	0,602 0	0,601 5	0,600 4	0,599 7	0,599 2	0,599 0	0,598 8
0,40	0,615 7	0,609 9	0,606 2	0,604 8	0,603 4	0,602 7	0,602 1	0,600 9	0,600 2	0,599 6	0,599 4	0,599 2
0,42	0,617 6	0,611 2	0,607 3	0,605 7	0,604 2	0,603 5	0,602 9	0,601 5	0,600 8	0,600 1	0,599 8	0,599 6
0,44	0,619 6	0,612 7	0,608 4	0,606 7	0,605 1	0,604 3	0,603 6	0,602 2	0,601 3	0,600 5	0,600 2	0,600 0
0,46	0,621 7	0,614 2	0,609 7	0,607 8	0,606 1	0,605 2	0,604 4	0,602 9	0,601 9	0,601 0	0,600 7	0,600 3
0,48	0,624 1	0,615 9	0,611 0	0,609 0	0,607 1	0,606 1	0,605 3	0,603 6	0,602 5	0,601 5	0,601 1	0,600 7
0,50	0,626 6	0,617 7	0,612 4	0,610 2	0,608 1	0,607 1	0,606 2	0,604 3	0,603 1	0,602 0	0,601 6	0,601 1
0,51	0,627 9	0,618 7	0,613 1	0,610 8	0,608 7	0,607 6	0,606 7	0,604 7	0,603 4	0,602 3	0,601 8	0,601 3
0,52	0,629 3	0,619 7	0,613 8	0,611 5	0,609 2	0,608 1	0,607 1	0,605 1	0,603 8	0,602 5	0,602 0	0,601 5
0,53	0,630 7	0,620 7	0,614 6	0,612 1	0,609 8	0,608 6	0,607 6	0,605 4	0,604 1	0,602 8	0,602 2	0,601 7
0,54	0,632 2	0,621 7	0,615 3	0,612 8	0,610 4	0,609 1	0,608 1	0,605 8	0,604 4	0,603 0	0,602 4	0,601 8
0,55	—	0,622 7	0,616 1	0,613 5	0,610 9	0,609 7	0,608 5	0,606 2	0,604 7	0,603 2	0,602 6	0,602 0
0,56	—	0,623 8	0,616 9	0,614 1	0,611 5	0,610 2	0,609 0	0,606 5	0,605 0	0,603 4	0,602 8	0,602 1
0,57	—	0,624 9	0,617 7	0,614 8	0,612 1	0,610 7	0,609 5	0,606 9	0,605 2	0,603 6	0,602 9	0,602 2
0,58	—	0,626 0	0,618 5	0,615 5	0,612 7	0,611 2	0,610 0	0,607 2	0,605 5	0,603 8	0,603 1	0,602 3
0,59	—	0,627 1	0,619 3	0,616 2	0,613 2	0,611 7	0,610 4	0,607 6	0,605 8	0,604 0	0,603 2	0,602 4
0,60	—	0,628 3	0,620 1	0,616 9	0,613 8	0,612 2	0,610 8	0,607 9	0,606 0	0,604 1	0,603 3	0,602 5
0,61	—	0,629 4	0,620 9	0,617 6	0,614 3	0,612 7	0,611 3	0,608 2	0,606 2	0,604 2	0,603 3	0,602 5
0,62	—	0,630 6	0,621 8	0,618 2	0,614 9	0,613 2	0,611 7	0,608 5	0,606 4	0,604 3	0,603 3	0,602 4
0,63	—	0,631 8	0,622 6	0,618 9	0,615 4	0,613 6	0,612 0	0,608 7	0,606 5	0,604 3	0,603 3	0,602 4
0,64	—	0,632 9	0,623 3	0,619 5	0,615 9	0,614 0	0,612 4	0,608 9	0,606 6	0,604 3	0,603 3	0,602 2
0,65	—	0,634 1	0,624 1	0,620 1	0,616 3	0,614 4	0,612 7	0,609 1	0,606 7	0,604 2	0,603 1	0,602 1
0,66	—	0,635 3	0,624 9	0,620 7	0,616 8	0,614 8	0,613 0	0,609 2	0,606 7	0,604 1	0,603 0	0,601 9
0,67	—	0,636 4	0,625 6	0,621 2	0,617 2	0,615 1	0,613 2	0,609 2	0,606 6	0,604 0	0,602 8	0,601 6
0,68	—	0,637 5	0,626 3	0,621 8	0,617 5	0,615 3	0,613 4	0,609 3	0,606 5	0,603 7	0,602 5	0,601 2
0,69	—	0,638 7	0,626 9	0,622 2	0,617 8	0,615 5	0,613 5	0,609 2	0,606 3	0,603 4	0,602 1	0,600 8
0,70	—	0,639 7	0,627 5	0,622 6	0,618 0	0,615 7	0,613 6	0,609 1	0,606 1	0,603 1	0,601 6	0,600 3
0,71	—	0,640 8	0,628 0	0,623 0	0,618 2	0,615 7	0,613 6	0,608 9	0,605 8	0,602 6	0,601 1	0,599 7
0,72	—	0,641 8	0,628 5	0,623 3	0,618 3	0,615 7	0,613 5	0,608 6	0,605 4	0,602 0	0,600 5	0,599 0
0,73	—	0,642 8	0,629 0	0,623 5	0,618 3	0,615 7	0,613 3	0,608 3	0,604 9	0,601 4	0,599 8	0,598 2
0,74	—	0,643 7	0,629 3	0,623 6	0,618 3	0,615 5	0,613 1	0,607 8	0,604 3	0,600 6	0,598 9	0,597 3
0,75	—	0,644 5	0,629 6	0,623 7	0,618 1	0,615 3	0,612 7	0,607 2	0,603 6	0,599 8	0,598 0	0,596 2
NOTE This table is given for convenience. The values given are not intended for precise interpolation. Extrapolation is not permitted.												

Table A.6 — Orifice plate with flange tappings — Discharge coefficient, C, for D = 150 mm

Diameter ratio	**Discharge coefficient, C, for Re_D equal to**											
β	**5 × 10^3**	**1 × 10^4**	**2 × 10^4**	**3 × 10^4**	**5 × 10^4**	**7 × 10^4**	**1 × 10^5**	**3 × 10^5**	**1 × 10^6**	**1 × 10^7**	**1 × 10^8**	∞
0,10	0,600 5	0,598 8	0,597 8	0,597 4	0,597 1	0,596 9	0,596 7	0,596 5	0,596 3	0,596 2	0,596 2	0,596 2
0,12	0,601 2	0,599 3	0,598 1	0,597 7	0,597 3	0,597 1	0,596 9	0,596 6	0,596 4	0,596 3	0,596 3	0,596 3
0,14	0,601 8	0,599 8	0,598 5	0,598 0	0,597 5	0,597 3	0,597 1	0,596 7	0,596 5	0,596 4	0,596 4	0,596 4
0,16	0,602 5	0,600 2	0,598 8	0,598 2	0,597 7	0,597 5	0,597 3	0,596 9	0,596 6	0,596 5	0,596 5	0,596 5
0,18	0,603 3	0,600 7	0,599 2	0,598 6	0,598 0	0,597 7	0,597 5	0,597 0	0,596 8	0,596 7	0,596 6	0,596 6
0,20	0,604 1	0,601 3	0,599 6	0,598 9	0,598 3	0,598 0	0,597 7	0,597 2	0,597 0	0,596 8	0,596 8	0,596 7
NOTE This table is given for convenience. The values given are not intended for precise interpolation. Extrapolation is not permitted.												

Table A.6 *(continued)*

Diameter ratio	**Discharge coefficient, C, for Re_D equal to**											
β	**5 × 10^3**	**1 × 10^4**	**2 × 10^4**	**3 × 10^4**	**5 × 10^4**	**7 × 10^4**	**1 × 10^5**	**3 × 10^5**	**1 × 10^6**	**1 × 10^7**	**1 × 10^8**	∞
0,22	0,604 9	0,601 9	0,600 0	0,599 3	0,598 6	0,598 3	0,598 0	0,597 5	0,597 2	0,597 0	0,596 9	0,596 9
0,24	0,605 7	0,602 5	0,600 5	0,599 7	0,599 0	0,598 6	0,598 3	0,597 7	0,597 4	0,597 2	0,597 1	0,597 1
0,26	0,606 7	0,603 2	0,601 1	0,600 2	0,599 4	0,599 0	0,598 7	0,598 0	0,597 7	0,597 4	0,597 4	0,597 3
0,28	0,607 7	0,603 9	0,601 6	0,600 7	0,599 8	0,599 4	0,599 1	0,598 4	0,598 0	0,597 7	0,597 6	0,597 5
0,30	0,608 8	0,604 8	0,602 3	0,601 3	0,600 3	0,599 9	0,599 5	0,598 7	0,598 3	0,598 0	0,597 9	0,597 8
0,32	0,610 0	0,605 6	0,603 0	0,601 9	0,600 9	0,600 4	0,600 0	0,599 1	0,598 7	0,598 3	0,598 2	0,598 1
0,34	0,611 3	0,606 6	0,603 7	0,602 6	0,601 5	0,600 9	0,600 5	0,599 6	0,599 0	0,598 6	0,598 5	0,598 4
0,36	0,612 7	0,607 7	0,604 5	0,603 3	0,602 1	0,601 5	0,601 0	0,600 0	0,599 5	0,599 0	0,598 8	0,598 7
0,38	0,614 3	0,608 8	0,605 4	0,604 1	0,602 8	0,602 2	0,601 7	0,600 6	0,599 9	0,599 4	0,599 2	0,599 0
0,40	0,616 0	0,610 1	0,606 4	0,605 0	0,603 6	0,602 9	0,602 3	0,601 1	0,600 4	0,599 8	0,599 6	0,599 4
0,42	0,617 8	0,611 4	0,607 5	0,605 9	0,604 4	0,603 7	0,603 0	0,601 7	0,600 9	0,600 2	0,600 0	0,599 7
0,44	0,619 8	0,612 8	0,608 6	0,606 9	0,605 3	0,604 5	0,603 8	0,602 3	0,601 5	0,600 7	0,600 4	0,600 1
0,46	—	0,614 4	0,609 8	0,607 9	0,606 2	0,605 3	0,604 6	0,603 0	0,602 0	0,601 1	0,600 8	0,600 5
0,48	—	0,616 0	0,611 1	0,609 1	0,607 2	0,606 2	0,605 4	0,603 6	0,602 6	0,601 6	0,601 2	0,600 8
0,50	—	0,617 8	0,612 4	0,610 2	0,608 2	0,607 1	0,606 2	0,604 3	0,603 1	0,602 1	0,601 6	0,601 2
0,51	—	0,618 7	0,613 1	0,610 8	0,608 7	0,607 6	0,606 7	0,604 7	0,603 4	0,602 3	0,601 8	0,601 3
0,52	—	0,619 7	0,613 8	0,611 4	0,609 2	0,608 1	0,607 1	0,605 0	0,603 7	0,602 5	0,602 0	0,601 5
0,53	—	0,620 6	0,614 5	0,612 1	0,609 7	0,608 6	0,607 5	0,605 4	0,604 0	0,602 7	0,602 1	0,601 6
0,54	—	0,621 6	0,615 3	0,612 7	0,610 3	0,609 0	0,608 0	0,605 7	0,604 2	0,602 9	0,602 3	0,601 7
0,55	—	0,622 6	0,616 0	0,613 3	0,610 8	0,609 5	0,608 4	0,606 0	0,604 5	0,603 1	0,602 4	0,601 8
0,56	—	0,623 7	0,616 7	0,614 0	0,611 3	0,610 0	0,608 8	0,606 3	0,604 7	0,603 2	0,602 5	0,601 9
0,57	—	0,624 7	0,617 5	0,614 6	0,611 9	0,610 5	0,609 2	0,606 6	0,605 0	0,603 4	0,602 6	0,602 0
0,58	—	0,625 8	0,618 2	0,615 2	0,612 4	0,610 9	0,609 6	0,606 9	0,605 2	0,603 5	0,602 7	0,602 0
0,59	—	0,626 9	0,619 0	0,615 9	0,612 9	0,611 4	0,610 0	0,607 2	0,605 4	0,603 6	0,602 8	0,602 0
0,60	—	0,628 0	0,619 8	0,616 5	0,613 4	0,611 8	0,610 4	0,607 4	0,605 5	0,603 6	0,602 8	0,602 0
0,61	—	0,629 0	0,620 5	0,617 1	0,613 8	0,612 2	0,610 7	0,607 6	0,605 6	0,603 7	0,602 8	0,601 9
0,62	—	0,630 1	0,621 2	0,617 7	0,614 3	0,612 6	0,611 1	0,607 8	0,605 7	0,603 6	0,602 7	0,601 8
0,63	—	—	0,621 9	0,618 2	0,614 7	0,612 9	0,611 4	0,608 0	0,605 8	0,603 6	0,602 6	0,601 6
0,64	—	—	0,622 6	0,618 8	0,615 1	0,613 2	0,611 6	0,608 1	0,605 8	0,603 5	0,602 4	0,601 4
0,65	—	—	0,623 3	0,619 3	0,615 5	0,613 5	0,611 8	0,608 1	0,605 7	0,603 3	0,602 2	0,601 1
0,66	—	—	0,623 9	0,619 7	0,615 8	0,613 8	0,612 0	0,608 1	0,605 6	0,603 1	0,601 9	0,600 8
0,67	—	—	0,624 5	0,620 2	0,616 0	0,613 9	0,612 1	0,608 1	0,605 4	0,602 8	0,601 6	0,600 4
0,68	—	—	0,625 1	0,620 5	0,616 2	0,614 0	0,612 1	0,607 9	0,605 2	0,602 4	0,601 1	0,599 9
0,69	—	—	0,625 6	0,620 9	0,616 4	0,614 1	0,612 1	0,607 7	0,604 9	0,601 9	0,600 6	0,599 3
0,70	—	—	0,626 0	0,621 1	0,616 5	0,614 1	0,612 0	0,607 4	0,604 4	0,601 4	0,600 0	0,598 6
0,71	—	—	0,626 4	0,621 3	0,616 5	0,614 0	0,611 8	0,607 1	0,603 9	0,600 7	0,599 3	0,597 8
0,72	—	—	0,626 7	0,621 4	0,616 4	0,613 8	0,611 5	0,606 6	0,603 3	0,600 0	0,598 4	0,596 9
0,73	—	—	0,626 9	0,621 4	0,616 2	0,613 5	0,611 1	0,606 0	0,602 6	0,599 1	0,597 5	0,595 9
0,74	—	—	0,627 1	0,621 3	0,615 9	0,613 1	0,610 6	0,605 3	0,601 7	0,598 1	0,596 4	0,594 7
0,75	—	—	0,627 1	0,621 1	0,615 4	0,612 5	0,610 0	0,604 4	0,600 7	0,596 9	0,595 1	0,593 4
NOTE	This table is given for convenience. The values given are not intended for precise interpolation. Extrapolation is not permitted.											

Table A.7 — Orifice plate with flange tappings — Discharge coefficient, *C*, for *D* = 200 mm

Diameter ratio	Discharge coefficient, *C*, for Re_D equal to											
β	**5 × 10³**	**1 × 10⁴**	**2 × 10⁴**	**3 × 10⁴**	**5 × 10⁴**	**7 × 10⁴**	**1 × 10⁵**	**3 × 10⁵**	**1 × 10⁶**	**1 × 10⁷**	**1 × 10⁸**	∞
0,10	0,600 5	0,598 9	0,597 9	0,597 5	0,597 1	0,596 9	0,596 8	0,596 5	0,596 3	0,596 3	0,596 2	0,596 2
0,12	0,601 2	0,599 3	0,598 2	0,597 7	0,597 3	0,597 1	0,596 9	0,596 6	0,596 4	0,596 3	0,596 3	0,596 3
0,14	0,601 9	0,599 8	0,598 5	0,598 0	0,597 5	0,597 3	0,597 1	0,596 7	0,596 6	0,596 4	0,596 4	0,596 4
0,16	0,602 6	0,600 3	0,598 9	0,598 3	0,597 8	0,597 5	0,597 3	0,596 9	0,596 7	0,596 6	0,596 5	0,596 5
0,18	0,603 3	0,600 8	0,599 3	0,598 6	0,598 1	0,597 8	0,597 5	0,597 1	0,596 9	0,596 7	0,596 7	0,596 7
0,20	0,604 1	0,601 4	0,599 7	0,599 0	0,598 4	0,598 1	0,597 8	0,597 3	0,597 1	0,596 9	0,596 8	0,596 8
0,22	0,605 0	0,602 0	0,600 1	0,599 4	0,598 7	0,598 4	0,598 1	0,597 6	0,597 3	0,597 1	0,597 0	0,597 0
0,24	0,605 8	0,602 6	0,600 6	0,599 8	0,599 1	0,598 7	0,598 4	0,597 8	0,597 5	0,597 3	0,597 2	0,597 2
0,26	0,606 8	0,603 3	0,601 1	0,600 3	0,599 5	0,599 1	0,598 8	0,598 1	0,597 8	0,597 5	0,597 5	0,597 4
0,28	0,607 8	0,604 1	0,601 7	0,600 8	0,600 0	0,599 5	0,599 2	0,598 5	0,598 1	0,597 8	0,597 7	0,597 6
0,30	0,608 9	0,604 9	0,602 4	0,601 4	0,600 5	0,600 0	0,599 6	0,598 8	0,598 4	0,598 1	0,598 0	0,597 9
0,32	0,610 1	0,605 8	0,603 1	0,602 0	0,601 0	0,600 5	0,600 1	0,599 2	0,598 8	0,598 4	0,598 3	0,598 2
0,34	0,611 4	0,606 7	0,603 8	0,602 7	0,601 6	0,601 1	0,600 6	0,599 7	0,599 2	0,598 7	0,598 6	0,598 5
0,36	0,612 8	0,607 8	0,604 7	0,603 4	0,602 2	0,601 7	0,601 2	0,600 2	0,599 6	0,599 1	0,598 9	0,598 8
0,38	0,614 4	0,608 9	0,605 6	0,604 2	0,602 9	0,602 3	0,601 8	0,600 7	0,600 0	0,599 5	0,599 3	0,599 1
0,40	—	0,610 2	0,606 5	0,605 1	0,603 7	0,603 0	0,602 4	0,601 2	0,600 5	0,599 9	0,599 7	0,599 5
0,42	—	0,611 5	0,607 6	0,606 0	0,604 5	0,603 8	0,603 1	0,601 8	0,601 0	0,600 3	0,600 1	0,599 8
0,44	—	0,612 9	0,608 7	0,607 0	0,605 4	0,604 5	0,603 8	0,602 4	0,601 5	0,600 8	0,600 4	0,600 2
0,46	—	0,614 5	0,609 9	0,608 0	0,606 3	0,605 4	0,604 6	0,603 0	0,602 1	0,601 2	0,600 8	0,600 5
0,48	—	0,616 1	0,611 1	0,609 1	0,607 2	0,606 2	0,605 4	0,603 7	0,602 6	0,601 6	0,601 2	0,600 9
0,50	—	0,617 9	0,612 4	0,610 2	0,608 2	0,607 1	0,606 2	0,604 3	0,603 2	0,602 1	0,601 6	0,601 2
0,51	—	0,618 8	0,613 1	0,610 8	0,608 7	0,607 6	0,606 7	0,604 7	0,603 4	0,602 3	0,601 8	0,601 3
0,52	—	0,619 7	0,613 8	0,611 4	0,609 2	0,608 1	0,607 1	0,605 0	0,603 7	0,602 5	0,601 9	0,601 4
0,53	—	0,620 6	0,614 5	0,612 0	0,609 7	0,608 5	0,607 5	0,605 3	0,603 9	0,602 6	0,602 1	0,601 5
0,54	—	0,621 6	0,615 2	0,612 6	0,610 2	0,609 0	0,607 9	0,605 6	0,604 2	0,602 8	0,602 2	0,601 6
0,55	—	—	0,615 9	0,613 2	0,610 7	0,609 4	0,608 3	0,605 9	0,604 4	0,603 0	0,602 3	0,601 7
0,56	—	—	0,616 6	0,613 8	0,611 2	0,609 9	0,608 7	0,606 2	0,604 6	0,603 1	0,602 4	0,601 8
0,57	—	—	0,617 4	0,614 5	0,611 7	0,610 3	0,609 1	0,606 5	0,604 8	0,603 2	0,602 5	0,601 8
0,58	—	—	0,618 1	0,615 1	0,612 2	0,610 7	0,609 4	0,606 7	0,605 0	0,603 3	0,602 5	0,601 8
0,59	—	—	0,618 8	0,615 6	0,612 7	0,611 1	0,609 8	0,607 0	0,605 1	0,603 3	0,602 5	0,601 8
0,60	—	—	0,619 5	0,616 2	0,613 1	0,611 5	0,610 1	0,607 2	0,605 2	0,603 4	0,602 5	0,601 7
0,61	—	—	0,620 2	0,616 8	0,613 5	0,611 9	0,610 4	0,607 3	0,605 3	0,603 3	0,602 4	0,601 6
0,62	—	—	0,620 9	0,617 3	0,613 9	0,612 2	0,610 7	0,607 5	0,605 3	0,603 3	0,602 3	0,601 4
0,63	—	—	0,621 6	0,617 8	0,614 3	0,612 5	0,610 9	0,607 6	0,605 3	0,603 2	0,602 2	0,601 2
0,64	—	—	0,622 2	0,618 3	0,614 7	0,612 8	0,611 1	0,607 6	0,605 3	0,603 0	0,601 9	0,600 9
0,65	—	—	0,622 8	0,618 8	0,615 0	0,613 0	0,611 3	0,607 6	0,605 2	0,602 8	0,601 6	0,600 6
0,66	—	—	0,623 4	0,619 2	0,615 2	0,613 2	0,611 4	0,607 5	0,605 0	0,602 5	0,601 3	0,600 2
0,67	—	—	0,623 9	0,619 5	0,615 4	0,613 3	0,611 4	0,607 4	0,604 7	0,602 1	0,600 9	0,599 7
0,68	—	—	0,624 4	0,619 8	0,615 5	0,613 3	0,611 4	0,607 2	0,604 4	0,601 6	0,600 3	0,599 1
0,69	—	—	0,624 8	0,620 1	0,615 6	0,613 3	0,611 2	0,606 9	0,604 0	0,601 1	0,599 7	0,598 4
0,70	—	—	0,625 2	0,620 2	0,615 5	0,613 1	0,611 0	0,606 5	0,603 5	0,600 4	0,599 0	0,597 6
0,71	—	—	0,625 5	0,620 3	0,615 4	0,612 9	0,610 7	0,606 0	0,602 8	0,599 6	0,598 2	0,596 7
0,72	—	—	0,625 7	0,620 3	0,615 2	0,612 6	0,610 3	0,605 4	0,602 1	0,598 8	0,597 2	0,595 7
0,73	—	—	0,625 8	0,620 2	0,614 9	0,612 2	0,609 8	0,604 7	0,601 2	0,597 7	0,596 1	0,594 5
0,74	—	—	0,625 8	0,619 9	0,614 5	0,611 6	0,609 2	0,603 8	0,600 2	0,596 6	0,594 9	0,593 2

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

Table A.7 *(continued)*

Diameter ratio	Discharge coefficient, C, for Re_D equal to											
β	5×10^3	1×10^4	2×10^4	3×10^4	5×10^4	7×10^4	1×10^5	3×10^5	1×10^6	1×10^7	1×10^8	∞
0,75	—	—	0,625 6	0,619 6	0,613 9	0,611 0	0,608 4	0,602 8	0,599 1	0,595 3	0,593 5	0,591 7

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

Table A.8 — Orifice plate with flange tappings — Discharge coefficient, C, for D = 250 mm

Diameter ratio	Discharge coefficient, C, for Re_D equal to											
β	5×10^3	1×10^4	2×10^4	3×10^4	5×10^4	7×10^4	1×10^5	3×10^5	1×10^6	1×10^7	1×10^8	∞
0,10	0,600 5	0,598 9	0,597 9	0,597 5	0,597 1	0,596 9	0,596 8	0,596 5	0,596 4	0,596 3	0,596 3	0,596 3
0,12	0,601 2	0,599 4	0,598 2	0,597 7	0,597 3	0,597 1	0,597 0	0,596 6	0,596 5	0,596 4	0,596 3	0,596 3
0,14	0,601 9	0,599 8	0,598 5	0,598 0	0,597 6	0,597 3	0,597 1	0,596 8	0,596 6	0,596 5	0,596 5	0,596 4
0,16	0,602 6	0,600 3	0,598 9	0,598 3	0,597 8	0,597 6	0,597 4	0,596 9	0,596 7	0,596 6	0,596 6	0,596 6
0,18	0,603 4	0,600 9	0,599 3	0,598 7	0,598 1	0,597 8	0,597 6	0,597 1	0,596 9	0,596 8	0,596 7	0,596 7
0,20	0,604 2	0,601 4	0,599 7	0,599 0	0,598 4	0,598 1	0,597 9	0,597 4	0,597 1	0,596 9	0,596 9	0,596 9
0,22	0,605 0	0,602 0	0,600 2	0,599 4	0,598 8	0,598 4	0,598 1	0,597 6	0,597 3	0,597 1	0,597 1	0,597 1
0,24	0,605 9	0,602 7	0,600 7	0,599 9	0,599 1	0,598 8	0,598 5	0,597 9	0,597 6	0,597 4	0,597 3	0,597 3
0,26	0,606 8	0,603 4	0,601 2	0,600 4	0,599 6	0,599 2	0,598 8	0,598 2	0,597 8	0,597 6	0,597 5	0,597 5
0,28	0,607 9	0,604 1	0,601 8	0,600 9	0,600 0	0,599 6	0,599 2	0,598 5	0,598 1	0,597 9	0,597 8	0,597 7
0,30	0,609 0	0,604 9	0,602 5	0,601 5	0,600 5	0,600 1	0,599 7	0,598 9	0,598 5	0,598 2	0,598 1	0,598 0
0,32	0,610 2	0,605 8	0,603 2	0,602 1	0,601 1	0,600 6	0,600 2	0,599 3	0,598 8	0,598 5	0,598 4	0,598 3
0,34	0,611 5	0,606 8	0,603 9	0,602 8	0,601 7	0,601 1	0,600 7	0,599 8	0,599 2	0,598 8	0,598 7	0,598 6
0,36	—	0,607 9	0,604 7	0,603 5	0,602 3	0,601 7	0,601 2	0,600 2	0,599 7	0,599 2	0,599 0	0,598 9
0,38	—	0,609 0	0,605 6	0,604 3	0,603 0	0,602 4	0,601 8	0,600 7	0,600 1	0,599 6	0,599 4	0,599 2
0,40	—	0,610 2	0,606 6	0,605 1	0,603 8	0,603 1	0,602 5	0,601 3	0,600 6	0,600 0	0,599 7	0,599 5
0,42	—	0,611 6	0,607 6	0,606 1	0,604 6	0,603 8	0,603 2	0,601 9	0,601 1	0,600 4	0,600 1	0,599 9
0,44	—	0,613 0	0,608 7	0,607 0	0,605 4	0,604 6	0,603 9	0,602 5	0,601 6	0,600 8	0,600 5	0,600 2
0,46	—	0,614 5	0,609 9	0,608 1	0,606 3	0,605 4	0,604 7	0,603 1	0,602 1	0,601 2	0,600 9	0,600 6
0,48	—	0,616 2	0,611 2	0,609 1	0,607 2	0,606 3	0,605 5	0,603 7	0,602 6	0,601 7	0,601 3	0,600 9
0,50	—	—	0,612 5	0,610 3	0,608 2	0,607 2	0,606 3	0,604 4	0,603 2	0,602 1	0,601 6	0,601 2
0,51	—	—	0,613 1	0,610 8	0,608 7	0,607 6	0,606 7	0,604 7	0,603 4	0,602 3	0,601 8	0,601 3
0,52	—	—	0,613 8	0,611 4	0,609 2	0,608 1	0,607 1	0,605 0	0,603 7	0,602 4	0,601 9	0,601 4
0,53	—	—	0,614 5	0,612 0	0,609 7	0,608 5	0,607 5	0,605 3	0,603 9	0,602 6	0,602 1	0,601 5
0,54	—	—	0,615 2	0,612 6	0,610 2	0,608 9	0,607 9	0,605 6	0,604 1	0,602 8	0,602 2	0,601 6
0,55	—	—	0,615 9	0,613 2	0,610 7	0,609 4	0,608 3	0,605 9	0,604 4	0,602 9	0,602 3	0,601 7
0,56	—	—	0,616 6	0,613 8	0,611 2	0,609 8	0,608 6	0,606 1	0,604 5	0,603 0	0,602 3	0,601 7
0,57	—	—	0,617 3	0,614 4	0,611 6	0,610 2	0,609 0	0,606 4	0,604 7	0,603 1	0,602 4	0,601 7
0,58	—	—	0,618 0	0,615 0	0,612 1	0,610 6	0,609 3	0,606 6	0,604 9	0,603 2	0,602 4	0,601 7
0,59	—	—	0,618 7	0,615 5	0,612 5	0,611 0	0,609 7	0,606 8	0,605 0	0,603 2	0,602 4	0,601 6
0,60	—	—	0,619 4	0,616 1	0,613 0	0,611 4	0,610 0	0,607 0	0,605 1	0,603 2	0,602 3	0,601 5
0,61	—	—	0,620 1	0,616 6	0,613 4	0,611 7	0,610 3	0,607 1	0,605 1	0,603 1	0,602 3	0,601 4
0,62	—	—	0,620 7	0,617 1	0,613 8	0,612 0	0,610 5	0,607 2	0,605 1	0,603 1	0,602 1	0,601 2
0,63	—	—	0,621 4	0,617 6	0,614 1	0,612 3	0,610 7	0,607 3	0,605 1	0,602 9	0,601 9	0,601 0
0,64	—	—	0,622 0	0,618 1	0,614 4	0,612 5	0,610 9	0,607 3	0,605 0	0,602 7	0,601 7	0,600 6
0,65	—	—	0,622 6	0,618 5	0,614 7	0,612 7	0,611 0	0,607 3	0,604 8	0,602 4	0,601 3	0,600 3
0,66	—	—	0,623 1	0,618 9	0,614 9	0,612 8	0,611 0	0,607 2	0,604 6	0,602 1	0,600 9	0,599 8

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

Table A.8 *(continued)*

Diameter ratio	Discharge coefficient, C, for Re_D equal to											
β	5×10^3	1×10^4	2×10^4	3×10^4	5×10^4	7×10^4	1×10^5	3×10^5	1×10^6	1×10^7	1×10^8	∞
0,67	—	—	0,623 6	0,619 2	0,615 0	0,612 9	0,611 0	0,607 0	0,604 3	0,601 7	0,600 4	0,599 3
0,68	—	—	0,624 0	0,619 4	0,615 1	0,612 9	0,610 9	0,606 7	0,603 9	0,601 2	0,599 9	0,598 6
0,69	—	—	—	0,619 6	0,615 1	0,612 8	0,610 7	0,606 4	0,603 5	0,600 5	0,599 2	0,597 9
0,70	—	—	—	0,619 7	0,615 0	0,612 6	0,610 5	0,605 9	0,602 9	0,599 8	0,598 4	0,597 0
0,71	—	—	—	0,619 7	0,614 8	0,612 3	0,610 1	0,605 4	0,602 2	0,599 0	0,597 5	0,596 1
0,72	—	—	—	0,619 6	0,614 5	0,611 9	0,609 6	0,604 7	0,601 4	0,598 0	0,596 5	0,595 0
0,73	—	—	—	0,619 4	0,614 1	0,611 4	0,609 0	0,603 9	0,600 4	0,596 9	0,595 3	0,593 7
0,74	—	—	—	0,619 1	0,613 6	0,610 8	0,608 3	0,602 9	0,599 4	0,595 7	0,594 0	0,592 3
0,75	—	—	—	0,618 7	0,613 0	0,610 0	0,607 4	0,601 8	0,598 1	0,594 3	0,592 5	0,590 8

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

Table A.9 — Orifice plate with flange tappings — Discharge coefficient, *C*, for *D* = 375 mm

Diameter ratio	Discharge coefficient, C, for Re_D equal to											
β	5×10^3	1×10^4	2×10^4	3×10^4	5×10^4	7×10^4	1×10^5	3×10^5	1×10^6	1×10^7	1×10^8	∞
0,10	0,600 6	0,598 9	0,597 9	0,597 5	0,597 1	0,597 0	0,596 8	0,596 5	0,596 4	0,596 3	0,596 3	0,596 3
0,12	0,601 3	0,599 4	0,598 2	0,597 8	0,597 4	0,597 2	0,597 0	0,596 7	0,596 5	0,596 4	0,596 4	0,596 4
0,14	0,602 0	0,599 9	0,598 6	0,598 1	0,597 6	0,597 4	0,597 2	0,596 8	0,596 6	0,596 5	0,596 5	0,596 5
0,16	0,602 7	0,600 4	0,599 0	0,598 4	0,597 9	0,597 6	0,597 4	0,597 0	0,596 8	0,596 7	0,596 6	0,596 6
0,18	0,603 5	0,600 9	0,599 4	0,598 7	0,598 2	0,597 9	0,597 7	0,597 2	0,597 0	0,596 8	0,596 8	0,596 8
0,20	0,604 2	0,601 5	0,599 8	0,599 1	0,598 5	0,598 2	0,597 9	0,597 4	0,597 2	0,597 0	0,597 0	0,596 9
0,22	0,605 1	0,602 1	0,600 3	0,599 5	0,598 8	0,598 5	0,598 2	0,597 7	0,597 4	0,597 2	0,597 2	0,597 1
0,24	0,606 0	0,602 8	0,600 8	0,600 0	0,599 2	0,598 9	0,598 6	0,598 0	0,597 7	0,597 4	0,597 4	0,597 3
0,26	0,606 9	0,603 5	0,601 3	0,600 5	0,599 7	0,599 3	0,598 9	0,598 3	0,597 9	0,597 7	0,597 6	0,597 6
0,28	0,608 0	0,604 2	0,601 9	0,601 0	0,600 1	0,599 7	0,599 3	0,598 6	0,598 3	0,598 0	0,597 9	0,597 8
0,30	—	0,605 1	0,602 6	0,601 6	0,600 6	0,600 2	0,599 8	0,599 0	0,598 6	0,598 3	0,598 2	0,598 1
0,32	—	0,606 0	0,603 3	0,602 2	0,601 2	0,600 7	0,600 3	0,599 4	0,599 0	0,598 6	0,598 5	0,598 4
0,34	—	0,606 9	0,604 0	0,602 9	0,601 8	0,601 3	0,600 8	0,599 9	0,599 4	0,598 9	0,598 8	0,598 7
0,36	—	0,608 0	0,604 9	0,603 6	0,602 4	0,601 9	0,601 4	0,600 4	0,599 8	0,599 3	0,599 1	0,599 0
0,38	—	0,609 1	0,605 8	0,604 4	0,603 1	0,602 5	0,602 0	0,600 9	0,600 2	0,599 7	0,599 5	0,599 3
0,40	—	—	0,606 7	0,605 3	0,603 9	0,603 2	0,602 6	0,601 4	0,600 7	0,600 1	0,599 9	0,599 7
0,42	—	—	0,607 8	0,606 2	0,604 7	0,603 9	0,603 3	0,602 0	0,601 2	0,600 5	0,600 2	0,600 0
0,44	—	—	0,608 9	0,607 1	0,605 5	0,604 7	0,604 0	0,602 6	0,601 7	0,600 9	0,600 6	0,600 3
0,46	—	—	0,610 0	0,608 2	0,606 4	0,605 5	0,604 8	0,603 2	0,602 2	0,601 3	0,601 0	0,600 7
0,48	—	—	0,611 3	0,609 2	0,607 3	0,606 4	0,605 5	0,603 8	0,602 7	0,601 8	0,601 3	0,601 0
0,50	—	—	0,612 5	0,610 3	0,608 3	0,607 2	0,606 3	0,604 4	0,603 2	0,602 1	0,601 7	0,601 2
0,51	—	—	0,613 2	0,610 9	0,608 8	0,607 7	0,606 7	0,604 7	0,603 5	0,602 3	0,601 8	0,601 4
0,52	—	—	0,613 9	0,611 5	0,609 2	0,608 1	0,607 1	0,605 0	0,603 7	0,602 5	0,601 9	0,601 5
0,53	—	—	0,614 5	0,612 1	0,609 7	0,608 5	0,607 5	0,605 3	0,603 9	0,602 6	0,602 1	0,601 5
0,54	—	—	0,615 2	0,612 6	0,610 2	0,609 0	0,607 9	0,605 6	0,604 1	0,602 8	0,602 2	0,601 6
0,55	—	—	0,615 9	0,613 2	0,610 7	0,609 4	0,608 2	0,605 8	0,604 3	0,602 9	0,602 2	0,601 7
0,56	—	—	0,616 6	0,613 8	0,611 1	0,609 8	0,608 6	0,606 1	0,604 5	0,603 0	0,602 3	0,601 7
0,57	—	—	—	0,614 4	0,611 6	0,610 2	0,608 9	0,606 3	0,604 7	0,603 0	0,602 3	0,601 7
0,58	—	—	—	0,614 9	0,612 0	0,610 6	0,609 3	0,606 5	0,604 8	0,603 1	0,602 3	0,601 6

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

Table A.9 *(continued)*

Diameter ratio	**Discharge coefficient, C, for Re_D equal to**											
β	**5 × 10³**	**1 × 10⁴**	**2 × 10⁴**	**3 × 10⁴**	**5 × 10⁴**	**7 × 10⁴**	**1 × 10⁵**	**3 × 10⁵**	**1 × 10⁶**	**1 × 10⁷**	**1 × 10⁸**	∞
0,59	—	—	—	0,615 5	0,612 4	0,610 9	0,609 6	0,606 7	0,604 9	0,603 1	0,602 3	0,601 5
0,60	—	—	—	0,616 0	0,612 8	0,611 2	0,609 8	0,606 9	0,604 9	0,603 0	0,602 2	0,601 4
0,61	—	—	—	0,616 5	0,613 2	0,611 6	0,610 1	0,607 0	0,605 0	0,603 0	0,602 1	0,601 2
0,62	—	—	—	0,617 0	0,613 6	0,611 8	0,610 3	0,607 0	0,604 9	0,602 8	0,601 9	0,601 0
0,63	—	—	—	0,617 4	0,613 9	0,612 1	0,610 5	0,607 1	0,604 8	0,602 6	0,601 7	0,600 7
0,64	—	—	—	0,617 8	0,614 1	0,612 2	0,610 6	0,607 0	0,604 7	0,602 4	0,601 4	0,600 3
0,65	—	—	—	0,618 2	0,614 3	0,612 4	0,610 6	0,606 9	0,604 5	0,602 1	0,601 0	0,599 9
0,66	—	—	—	0,618 5	0,614 5	0,612 4	0,610 6	0,606 8	0,604 2	0,601 7	0,600 5	0,599 4
0,67	—	—	—	0,618 8	0,614 6	0,612 4	0,610 6	0,606 5	0,603 9	0,601 2	0,600 0	0,598 8
0,68	—	—	—	0,619 0	0,614 6	0,612 4	0,610 4	0,606 2	0,603 4	0,600 6	0,599 3	0,598 1
0,69	—	—	—	—	0,614 5	0,612 2	0,610 2	0,605 8	0,602 9	0,600 0	0,598 6	0,597 3
0,70	—	—	—	—	0,614 4	0,612 0	0,609 8	0,605 3	0,602 2	0,599 2	0,597 7	0,596 4
0,71	—	—	—	—	0,614 1	0,611 6	0,609 4	0,604 6	0,601 5	0,598 2	0,596 8	0,595 3
0,72	—	—	—	—	0,613 8	0,611 1	0,608 8	0,603 9	0,600 6	0,597 2	0,595 6	0,594 1
0,73	—	—	—	—	0,613 3	0,610 5	0,608 1	0,602 9	0,599 5	0,596 0	0,594 4	0,592 8
0,74	—	—	—	—	0,612 6	0,609 8	0,607 3	0,601 9	0,598 3	0,594 6	0,592 9	0,591 3
0,75	—	—	—	—	0,611 9	0,608 9	0,606 3	0,600 7	0,596 9	0,593 1	0,591 3	0,589 6

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

Table A.10 — Orifice plate with flange tappings — Discharge coefficient, C, for D = 760 mm

Diameter ratio	**Discharge coefficient, C, for Re_D equal to**											
β	**5 × 10³**	**1 × 10⁴**	**2 × 10⁴**	**3 × 10⁴**	**5 × 10⁴**	**7 × 10⁴**	**1 × 10⁵**	**3 × 10⁵**	**1 × 10⁶**	**1 × 10⁷**	**1 × 10⁸**	∞
0,10	0,600 6	0,599 0	0,597 9	0,597 5	0,597 2	0,597 0	0,596 9	0,596 6	0,596 4	0,596 3	0,596 3	0,596 3
0,12	0,601 3	0,599 4	0,598 3	0,597 8	0,597 4	0,597 2	0,597 0	0,596 7	0,596 5	0,596 4	0,596 4	0,596 4
0,14	0,602 0	0,599 9	0,598 6	0,598 1	0,597 7	0,597 4	0,597 2	0,596 9	0,596 7	0,596 6	0,596 6	0,596 5
0,16	0,602 8	0,600 5	0,599 0	0,598 5	0,597 9	0,597 7	0,597 5	0,597 1	0,596 9	0,596 7	0,596 7	0,596 7
0,18	0,603 5	0,601 0	0,599 4	0,598 8	0,598 2	0,598 0	0,597 7	0,597 3	0,597 0	0,596 9	0,596 9	0,596 8
0,20	—	0,601 6	0,599 9	0,599 2	0,598 6	0,598 3	0,598 0	0,597 5	0,597 3	0,597 1	0,597 1	0,597 0
0,22	—	0,602 2	0,600 4	0,599 6	0,598 9	0,598 6	0,598 3	0,597 8	0,597 5	0,597 3	0,597 3	0,597 2
0,24	—	0,602 9	0,600 9	0,600 1	0,599 3	0,599 0	0,598 7	0,598 1	0,597 8	0,597 6	0,597 5	0,597 5
0,26	—	0,603 6	0,601 4	0,600 6	0,599 8	0,599 4	0,599 1	0,598 4	0,598 1	0,597 8	0,597 7	0,597 7
0,28	—	—	0,602 0	0,601 1	0,600 3	0,599 8	0,599 5	0,598 8	0,598 4	0,598 1	0,598 0	0,598 0
0,30	—	—	0,602 7	0,601 7	0,600 8	0,600 3	0,599 9	0,599 2	0,598 7	0,598 4	0,598 3	0,598 2
0,32	—	—	0,603 4	0,602 3	0,601 3	0,600 8	0,600 4	0,599 6	0,599 1	0,598 7	0,598 6	0,598 5
0,34	—	—	0,604 2	0,603 0	0,602 0	0,601 4	0,601 0	0,600 0	0,599 5	0,599 1	0,599 0	0,598 8
0,36	—	—	0,605 0	0,603 8	0,602 6	0,602 0	0,601 5	0,600 5	0,599 9	0,599 5	0,599 3	0,599 2
0,38	—	—	0,605 9	0,604 6	0,603 3	0,602 7	0,602 1	0,601 0	0,600 4	0,599 9	0,599 7	0,599 5
0,40	—	—	—	0,605 4	0,604 1	0,603 4	0,602 8	0,601 6	0,600 9	0,600 3	0,600 0	0,599 8
0,42	—	—	—	0,606 4	0,604 9	0,604 1	0,603 5	0,602 2	0,601 4	0,600 7	0,600 4	0,600 2
0,44	—	—	—	0,607 3	0,605 7	0,604 9	0,604 2	0,602 7	0,601 9	0,601 1	0,600 8	0,600 5
0,46	—	—	—	0,608 4	0,606 6	0,605 7	0,604 9	0,603 4	0,602 4	0,601 5	0,601 2	0,600 8
0,48	—	—	—	0,609 4	0,607 5	0,606 5	0,605 7	0,604 0	0,602 9	0,601 9	0,601 5	0,601 1
0,50	—	—	—	—	0,608 4	0,607 4	0,606 5	0,604 6	0,603 4	0,602 3	0,601 8	0,601 4

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

Table A.10 *(continued)*

Diameter ratio	Discharge coefficient, C, for Re_D equal to											
β	5×10^3	1×10^4	2×10^4	3×10^4	5×10^4	7×10^4	1×10^5	3×10^5	1×10^6	1×10^7	1×10^8	∞
0,51	—	—	—	—	0,608 9	0,607 8	0,606 9	0,604 9	0,603 6	0,602 5	0,602 0	0,601 5
0,52	—	—	—	—	0,609 4	0,608 2	0,607 3	0,605 2	0,603 9	0,602 6	0,602 1	0,601 6
0,53	—	—	—	—	0,609 9	0,608 7	0,607 6	0,605 4	0,604 1	0,602 8	0,602 2	0,601 7
0,54	—	—	—	—	0,610 3	0,609 1	0,608 0	0,605 7	0,604 3	0,602 9	0,602 3	0,601 7
0,55	—	—	—	—	0,610 8	0,609 5	0,608 4	0,606 0	0,604 4	0,603 0	0,602 4	0,601 8
0,56	—	—	—	—	0,611 2	0,609 9	0,608 7	0,606 2	0,604 6	0,603 1	0,602 4	0,601 8
0,57	—	—	—	—	0,611 7	0,610 3	0,609 0	0,606 4	0,604 7	0,603 1	0,602 4	0,601 7
0,58	—	—	—	—	0,612 1	0,610 6	0,609 3	0,606 6	0,604 8	0,603 1	0,602 4	0,601 7
0,59	—	—	—	—	0,612 5	0,611 0	0,609 6	0,606 8	0,604 9	0,603 1	0,602 3	0,601 6
0,60	—	—	—	—	0,612 9	0,611 3	0,609 9	0,606 9	0,605 0	0,603 1	0,602 2	0,601 4
0,61	—	—	—	—	0,613 2	0,611 6	0,610 1	0,607 0	0,605 0	0,603 0	0,602 1	0,601 2
0,62	—	—	—	—	0,613 6	0,611 8	0,610 3	0,607 0	0,604 9	0,602 8	0,601 9	0,601 0
0,63	—	—	—	—	—	0,612 0	0,610 4	0,607 0	0,604 8	0,602 6	0,601 6	0,600 6
0,64	—	—	—	—	—	0,612 2	0,610 5	0,606 9	0,604 6	0,602 3	0,601 3	0,600 3
0,65	—	—	—	—	—	0,612 3	0,610 5	0,606 8	0,604 4	0,602 0	0,600 9	0,599 8
0,66	—	—	—	—	—	0,612 3	0,610 5	0,606 6	0,604 1	0,601 5	0,600 4	0,599 2
0,67	—	—	—	—	—	0,612 3	0,610 4	0,606 3	0,603 7	0,601 0	0,599 8	0,598 6
0,68	—	—	—	—	—	0,612 2	0,610 2	0,606 0	0,603 2	0,600 4	0,599 1	0,597 9
0,69	—	—	—	—	—	0,611 9	0,609 9	0,605 5	0,602 6	0,599 6	0,598 3	0,597 0
0,70	—	—	—	—	—	0,611 6	0,609 5	0,604 9	0,601 9	0,598 8	0,597 4	0,596 0
0,71	—	—	—	—	—	0,611 2	0,609 0	0,604 2	0,601 0	0,597 8	0,596 3	0,594 9
0,72	—	—	—	—	—	0,610 7	0,608 4	0,603 4	0,600 1	0,596 7	0,595 1	0,593 6
0,73	—	—	—	—	—	0,610 0	0,607 6	0,602 4	0,598 9	0,595 4	0,593 8	0,592 2
0,74	—	—	—	—	—	—	0,606 7	0,601 2	0,597 6	0,594 0	0,592 3	0,590 6
0,75	—	—	—	—	—	—	0,605 6	0,599 9	0,596 2	0,592 3	0,590 6	0,588 8

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

Table A.11 — Orifice plate with flange tappings — Discharge coefficient, C, for D = 1 000 mm

Diameter ratio	Discharge coefficient, C, for Re_D equal to											
β	5×10^3	1×10^4	2×10^4	3×10^4	5×10^4	7×10^4	1×10^5	3×10^5	1×10^6	1×10^7	1×10^8	∞
0,10	0,600 6	0,599 0	0,598 0	0,597 6	0,597 2	0,597 0	0,596 9	0,596 6	0,596 4	0,596 3	0,596 3	0,596 3
0,12	0,601 3	0,599 4	0,598 3	0,597 8	0,597 4	0,597 2	0,597 0	0,596 7	0,596 6	0,596 5	0,596 4	0,596 4
0,14	0,602 0	0,599 9	0,598 7	0,598 1	0,597 7	0,597 4	0,597 3	0,596 9	0,596 7	0,596 6	0,596 6	0,596 6
0,16	0,602 8	0,600 5	0,599 0	0,598 5	0,598 0	0,597 7	0,597 5	0,597 1	0,596 9	0,596 7	0,596 7	0,596 7
0,18	—	0,601 0	0,599 5	0,598 8	0,598 3	0,598 0	0,597 7	0,597 3	0,597 1	0,596 9	0,596 9	0,596 9
0,20	—	0,601 6	0,599 9	0,599 2	0,598 6	0,598 3	0,598 0	0,597 5	0,597 3	0,597 1	0,597 1	0,597 1
0,22	—	0,602 2	0,600 4	0,599 6	0,599 0	0,598 6	0,598 4	0,597 8	0,597 5	0,597 3	0,597 3	0,597 3
0,24	—	0,602 9	0,600 9	0,600 1	0,599 4	0,599 0	0,598 7	0,598 1	0,597 8	0,597 6	0,597 5	0,597 5
0,26	—	—	0,601 5	0,600 6	0,599 8	0,599 4	0,599 1	0,598 4	0,598 1	0,597 9	0,597 8	0,597 7
0,28	—	—	0,602 1	0,601 2	0,600 3	0,599 9	0,599 5	0,598 8	0,598 4	0,598 1	0,598 1	0,598 0
0,30	—	—	0,602 7	0,601 7	0,600 8	0,600 4	0,600 0	0,599 2	0,598 8	0,598 5	0,598 3	0,598 3
0,32	—	—	0,603 5	0,602 4	0,601 4	0,600 9	0,600 5	0,599 6	0,599 2	0,598 8	0,598 7	0,598 6
0,34	—	—	0,604 3	0,603 1	0,602 0	0,601 5	0,601 0	0,600 1	0,599 6	0,599 1	0,599 0	0,598 9

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

Table A.11 *(continued)*

Diameter ratio	**Discharge coefficient, C, for Re_D equal to**											
β	**5×10^3**	**1×10^4**	**2×10^4**	**3×10^4**	**5×10^4**	**7×10^4**	**1×10^5**	**3×10^5**	**1×10^6**	**1×10^7**	**1×10^8**	∞
0,36	—	—	—	0,603 8	0,602 7	0,602 1	0,601 6	0,600 6	0,600 0	0,599 5	0,599 4	0,599 2
0,38	—	—	—	0,604 6	0,603 4	0,602 7	0,602 2	0,601 1	0,600 5	0,599 9	0,599 7	0,599 5
0,40	—	—	—	0,605 5	0,604 1	0,603 4	0,602 8	0,601 6	0,600 9	0,600 3	0,600 1	0,599 9
0,42	—	—	—	0,606 4	0,604 9	0,604 2	0,603 5	0,602 2	0,601 4	0,600 7	0,600 5	0,600 2
0,44	—	—	—	—	0,605 8	0,605 0	0,604 3	0,602 8	0,601 9	0,601 2	0,600 9	0,600 6
0,46	—	—	—	—	0,606 7	0,605 8	0,605 0	0,603 4	0,602 4	0,601 6	0,601 2	0,600 9
0,48	—	—	—	—	0,607 6	0,606 6	0,605 8	0,604 0	0,603 0	0,602 0	0,601 6	0,601 2
0,50	—	—	—	—	0,608 5	0,607 5	0,606 5	0,604 6	0,603 5	0,602 4	0,601 9	0,601 5
0,51	—	—	—	—	0,609 0	0,607 9	0,606 9	0,604 9	0,603 7	0,602 5	0,602 0	0,601 6
0,52	—	—	—	—	0,609 5	0,608 3	0,607 3	0,605 2	0,603 9	0,602 7	0,602 2	0,601 7
0,53	—	—	—	—	0,609 9	0,608 7	0,607 7	0,605 5	0,604 1	0,602 8	0,602 3	0,601 7
0,54	—	—	—	—	0,610 4	0,609 1	0,608 1	0,605 8	0,604 3	0,603 0	0,602 4	0,601 8
0,55	—	—	—	—	—	0,609 6	0,608 4	0,606 0	0,604 5	0,603 1	0,602 4	0,601 8
0,56	—	—	—	—	—	0,609 9	0,608 8	0,606 3	0,604 7	0,603 1	0,602 5	0,601 8
0,57	—	—	—	—	—	0,610 3	0,609 1	0,606 5	0,604 8	0,603 2	0,602 5	0,601 8
0,58	—	—	—	—	—	0,610 7	0,609 4	0,606 7	0,604 9	0,603 2	0,602 4	0,601 7
0,59	—	—	—	—	—	0,611 0	0,609 7	0,606 8	0,605 0	0,603 2	0,602 4	0,601 6
0,60	—	—	—	—	—	0,611 3	0,609 9	0,606 9	0,605 0	0,603 1	0,602 3	0,601 5
0,61	—	—	—	—	—	0,611 6	0,610 2	0,607 0	0,605 0	0,603 0	0,602 1	0,601 3
0,62	—	—	—	—	—	0,611 9	0,610 3	0,607 1	0,604 9	0,602 9	0,601 9	0,601 0
0,63	—	—	—	—	—	0,612 1	0,610 5	0,607 0	0,604 8	0,602 6	0,601 6	0,600 7
0,64	—	—	—	—	—	0,612 2	0,610 6	0,607 0	0,604 7	0,602 3	0,601 3	0,600 3
0,65	—	—	—	—	—	—	0,610 6	0,606 8	0,604 4	0,602 0	0,600 9	0,599 8
0,66	—	—	—	—	—	—	0,610 5	0,606 6	0,604 1	0,601 6	0,600 4	0,599 3
0,67	—	—	—	—	—	—	0,610 4	0,606 3	0,603 7	0,601 0	0,599 8	0,598 6
0,68	—	—	—	—	—	—	0,610 2	0,606 0	0,603 2	0,600 4	0,599 1	0,597 9
0,69	—	—	—	—	—	—	0,609 9	0,605 5	0,602 6	0,599 7	0,598 3	0,597 0
0,70	—	—	—	—	—	—	0,609 5	0,604 9	0,601 9	0,598 8	0,597 4	0,596 0
0,71	—	—	—	—	—	—	0,609 0	0,604 2	0,601 0	0,597 8	0,596 3	0,594 9
0,72	—	—	—	—	—	—	0,608 4	0,603 3	0,600 0	0,596 7	0,595 1	0,593 6
0,73	—	—	—	—	—	—	0,607 6	0,602 4	0,598 9	0,595 4	0,593 8	0,592 2
0,74	—	—	—	—	—	—	0,606 6	0,601 2	0,597 6	0,593 9	0,592 2	0,590 6
0,75	—	—	—	—	—	—	0,605 5	0,599 9	0,596 1	0,592 3	0,590 5	0,588 7

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

Table A.12 — Orifice plates — Expansibility [expansion] factor, ε

Diameter ratio		**Expansibility [expansion] factor, ε, for p_2/p_1 equal to**							
β	β^4	**0,98**	**0,96**	**0,94**	**0,92**	**0,90**	**0,85**	**0,80**	**0,75**
for $\kappa = 1{,}2$									
0,100 0	0,000 1	0,994 1	0,988 3	0,982 4	0,976 4	0,970 5	0,955 5	0,940 4	0,925 2
0,562 3	0,100 0	0,993 6	0,987 1	0,980 6	0,974 1	0,967 6	0,951 1	0,934 5	0,917 7
0,668 7	0,200 0	0,992 7	0,985 3	0,977 9	0,970 5	0,963 1	0,944 3	0,925 4	0,906 3
0,740 1	0,300 0	0,991 5	0,982 9	0,974 3	0,965 7	0,957 0	0,935 2	0,913 2	0,891 0
0,750 0	0,316 4	0,991 2	0,982 4	0,973 6	0,964 8	0,955 9	0,933 5	0,910 9	0,888 1

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

Table A.12 *(continued)*

Diameter ratio		Expansibility [expansion] factor, ε, for p_2/p_1 equal to							
β	β^4	**0,98**	**0,96**	**0,94**	**0,92**	**0,90**	**0,85**	**0,80**	**0,75**
for κ = 1,3									
0,100 0	0,000 1	0,994 6	0,989 1	0,983 7	0,978 2	0,972 7	0,958 7	0,944 6	0,930 3
0,562 3	0,100 0	0,994 0	0,988 1	0,982 1	0,976 0	0,970 0	0,954 7	0,939 1	0,923 4
0,668 7	0,200 0	0,993 2	0,986 4	0,979 6	0,972 7	0,965 8	0,948 4	0,930 7	0,912 8
0,740 1	0,300 0	0,992 1	0,984 2	0,976 2	0,968 2	0,960 2	0,939 9	0,919 3	0,898 5
0,750 0	0,316 4	0,991 9	0,983 8	0,975 6	0,967 4	0,959 1	0,938 3	0,917 2	0,895 8
for κ = 1,4									
0,100 0	0,000 1	0,995 0	0,989 9	0,984 8	0,979 7	0,974 6	0,961 5	0,948 3	0,934 8
0,562 3	0,100 0	0,994 5	0,988 9	0,983 3	0,977 7	0,972 0	0,957 7	0,943 1	0,928 3
0,668 7	0,200 0	0,993 7	0,987 4	0,981 0	0,974 6	0,968 1	0,951 8	0,935 3	0,918 4
0,740 1	0,300 0	0,992 7	0,985 3	0,977 9	0,970 4	0,962 9	0,943 9	0,924 6	0,905 0
0,750 0	0,316 4	0,992 5	0,984 9	0,977 3	0,969 6	0,961 9	0,942 4	0,922 6	0,902 5
for κ= 1,66									
0,100 0	0,000 1	0,995 8	0,991 5	0,987 2	0,982 8	0,978 4	0,967 3	0,955 8	0,944 1
0,562 3	0,100 0	0,995 3	0,990 6	0,985 9	0,981 1	0,976 3	0,964 0	0,951 5	0,938 6
0,668 7	0,200 0	0,994 7	0,989 3	0,983 9	0,978 5	0,973 0	0,959 0	0,944 7	0,930 1
0,740 1	0,300 0	0,993 8	0,987 6	0,981 3	0,974 9	0,968 5	0,952 3	0,935 7	0,918 6
0,750 0	0,316 4	0,993 6	0,987 2	0,980 8	0,974 3	0,967 7	0,951 0	0,934 0	0,916 4

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

Annex B
(informative)

Flow conditioners

B.1 General

This annex describes some patented flow conditioners which can be used upstream of orifice plates and the requirements for straight lengths associated with them. It describes the Gallagher flow conditioner and NOVA's design of K-Lab perforated plate flow conditioner. It gives the situations in which the flow conditioners have passed the conformity test and can be used downstream of any upstream fitting. It is not intended that the inclusion of the flow conditioners described here should limit the use of other flow conditioner designs which have been tested and proved to provide sufficiently small shifts in discharge coefficient. These flow conditioners, available commercially, are given as examples of devices which have passed the conformity test. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of these products.

B.2 Gallagher flow conditioner — Conformity testing

B.2.1 The Gallagher flow conditioner shown in Figure B.1 meets the conformity test given in of ISO 5167-1:2022, 7.4.1.2 to 7.4.1.7 (significant part of conformity test results can be found in References [13] and [18]) and can be used downstream of any fitting provided that it meets the required manufacturing specification (which shall be obtained from the patent holder) and is installed in accordance with B.2.3.

B.2.2 The Gallagher flow conditioner is covered by an existing patent. It consists of an anti-swirl device, a settling chamber and lastly a profile device as shown in Figure B.1 a).

The pressure loss coefficient, K, for the Gallagher flow conditioner depends on the manufacturing specification of the conditioner; it is approximately equal to 2, where K is given by the following formula:

$$K = \frac{\Delta p_c}{\frac{1}{2}\rho V^2}$$

where

Δp_c is the pressure loss across the Gallagher flow conditioner;

ρ is the density of the fluid in the pipe;

V is the mean axial velocity of the fluid in the pipe.

B.2.3 L_f, the distance between the orifice plate and the nearest upstream fitting, is at least equal to $17D$. The Gallagher flow conditioner is installed so that L_s, the distance between the downstream end of the Gallagher flow conditioner and the orifice plate, is such that

$$5D \le L_s \le L_f - 8D$$

In this location, the Gallagher flow conditioner can be used for $\beta \le 0{,}67$.

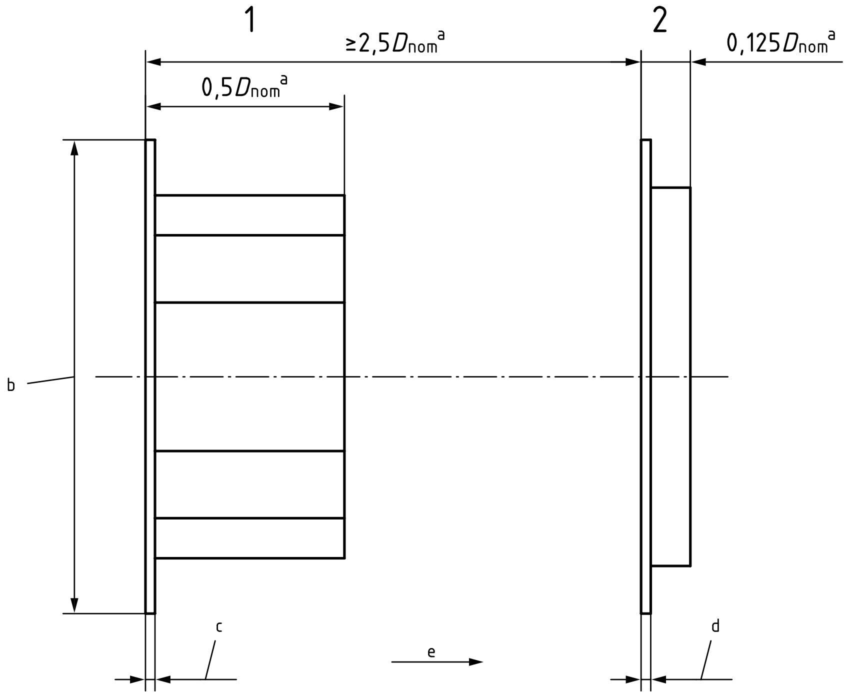
If 0,67 < $\beta \leq 0{,}75$, the location of the Gallagher flow conditioner is more restricted, and L_s is equal to

$$7D \pm D$$

In this location, the Gallagher flow conditioner has satisfied ISO 5167-1:2022, 7.4.1.7 for $\beta = 0{,}75$.

The distance to a bend (or bend combination) or a tee is measured to the downstream end of the curved portion of the nearest (or only) bend or of the tee. The distance to a reducer or expander is measured to the downstream end of the curved or conical portion of the reducer or expander.

The locations given in this subclause are acceptable downstream of any fitting. A wider range of locations for the Gallagher flow conditioner is permissible if the range of upstream fittings is restricted or the overall length between the upstream fitting and the orifice plate is increased or the diameter ratio of the orifice plate is reduced. These locations are not described here.



Key

1 anti-swirl device

2 profile device

[a] D_{nom} is the nominal pipe diameter.

[b] Length equal to diameter of raised face.

[c] 3,2 mm for D_{nom} = 50 mm to 75 mm tube style
6,4 mm for D_{nom} = 100 mm to 450 mm tube style
12,7 mm for D_{nom} = 500 mm to 600 mm tube style
12,7 mm for D_{nom} = 50 mm to 300 mm vane style
17,1 mm for D_{nom} = 350 mm to 600 mm vane style.

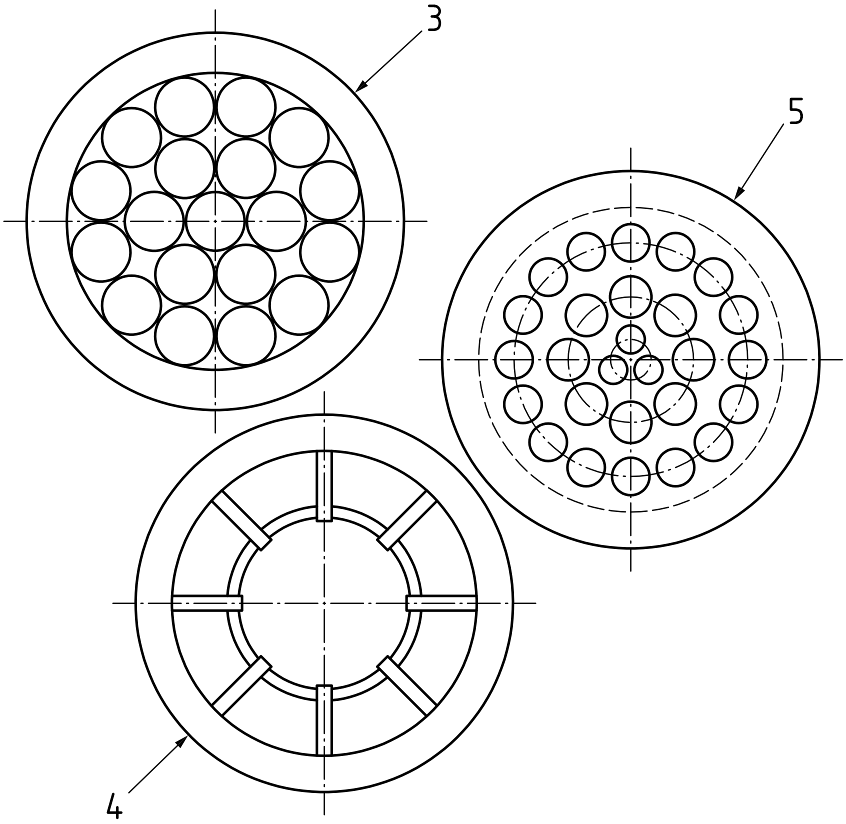
[d] 3,2 mm for D_{nom} = 50 mm to 75 mm

6,4 mm for D_{nom} = 100 mm to 450 mm

12,7 mm for D_{nom} = 500 mm to 600 mm.

[e] Direction of flow.

a) Typical arrangement



Key

3 anti-swirl device — tube style option: 19-tube uniform concentric bundle (it may be pin-mounted)

4 anti-swirl device — vane style option: 8 vanes of length 0,125D to 0,25D, concentric with the pipe (the device may be placed at the entrance to the meter run)

5 profile device: 3-8-16 pattern (see Note)

NOTE The 3-8-16 pattern for a profile device is:

— 3 holes on pitch circle diameter 0,15D to 0,155D; their diameter is such that the sum of their areas is 3 % to 5 % of the pipe area;

— 8 holes on pitch circle diameter 0,44D to 0,48D; their diameter is such that the sum of their areas is 19 % to 21 % of the pipe area;

— 16 holes on pitch circle diameter 0,81D to 0,85D; their diameter is such that the sum of their areas is 25 % to 29 % of the pipe area.

b) Typical components (face views)

Figure B.1 — Gallagher flow conditioner

B.3 NOVA's design of K-Lab perforated plate flow conditioner — Conformity testing

B.3.1 NOVA's design of K-Lab perforated plate flow conditioner, known as the K-Lab NOVA flow conditioner, shown in Figure B.2 meets the conformity test given in ISO 5167-1:2022, 7.4.1.2 to 7.4.1.6 (compliance test results can be found in References [13], [19] and [20]) and can be used downstream of any fitting provided that it meets the manufacturing specification in B.3.2 and B.3.3 and is installed in accordance with B.3.4.

B.3.2 The K-Lab NOVA flow conditioner consists of a plate with 25 bored holes arranged in a symmetrical circular pattern as shown in Figure B.2. The dimensions of the holes are a function of the pipe inside diameter, D, and depend on the pipe Reynolds number. The hole locations for $Re_D \geq 10^5$ are given in B.3.3.

The perforated plate thickness, t_c, is such that $0{,}125D \leq t_c \leq 0{,}15D$. The flange thickness depends on the application; the outer diameter and flange face surface depend on the flange type and the application.

The pressure loss coefficient, K, for the K-Lab NOVA flow conditioner is approximately equal to 2, where K is given by the following formula:

$$K = \frac{\Delta p_\mathrm{c}}{\frac{1}{2}\rho V^2}$$

where

Δp_c is the pressure loss across the K-Lab NOVA flow conditioner;

ρ is the density of the fluid in the pipe;

V is the mean axial velocity of the fluid in the pipe.

B.3.3 Hole locations

B.3.3.1 Provided that $Re_D \geq 8 \times 10^5$, there are

- a central hole of diameter $0{,}186\ 29D \pm 0{,}000\ 77D$,
- a ring of 8 holes of diameter $0{,}163D \pm 0{,}000\ 77D$ on a pitch circle diameter of $0{,}5D$ ± 0,5 mm, and
- a ring of 16 holes of diameter $0{,}120\ 3D \pm 0{,}000\ 77D$ on a pitch circle diameter of $0{,}85D$ ± 0,5 mm.

B.3.3.2 Provided that $8 \times 10^5 > Re_D \geq 10^5$, there are

- a central hole of diameter $0{,}226\ 64D \pm 0{,}000\ 77D$,
- a ring of 8 holes of diameter $0{,}163\ 09D \pm 0{,}000\ 77D$ on a pitch circle diameter of $0{,}5D$ ± 0,5 mm, and
- a ring of 16 holes of diameter $0{,}124\ 22D \pm 0{,}000\ 77D$ on a pitch circle diameter of $0{,}85D$ ± 0,5 mm.

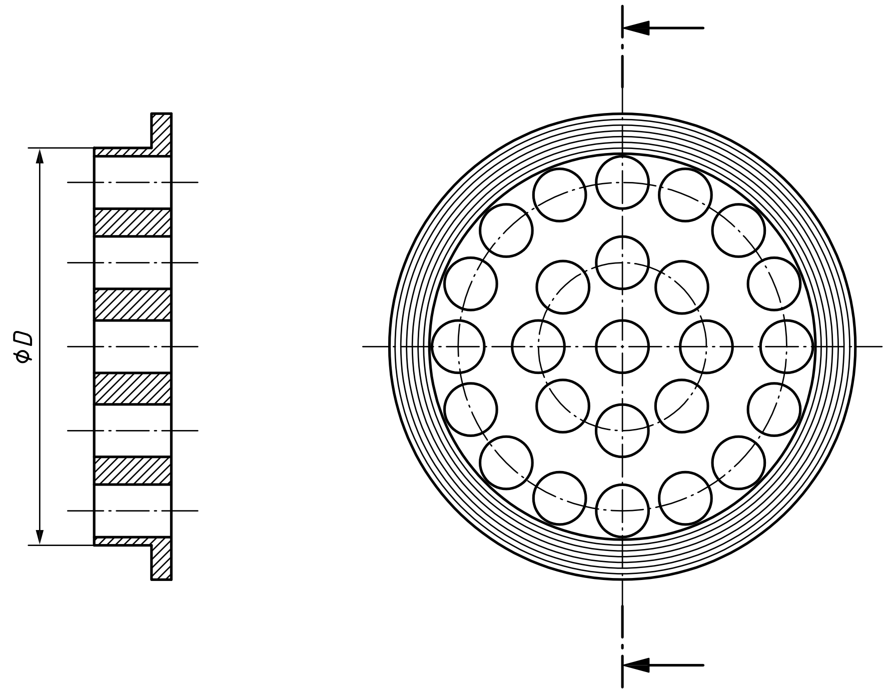


Figure B.2 — The K-Lab NOVA flow conditioner

B.3.4 L_f, the distance between the orifice plate and the nearest upstream fitting, is at least equal to 17*D*. The K-Lab NOVA flow conditioner is installed so that L_s, the distance between the downstream end of the K-Lab NOVA flow conditioner and the orifice plate, is such that

$$8{,}5D \le L_s \le L_f - 7{,}5D$$

The K-Lab NOVA flow conditioner can be used for $\beta \le 0{,}67$.

The distance to a bend (or bend combination) or a tee is measured to the downstream end of the curved portion of the nearest (or only) bend or of the tee. The distance to a reducer or expander is measured to the downstream end of the curved or conical portion of the reducer or the expander.

The locations given in this subclause are acceptable downstream of any fitting. A wider range of locations for the K-Lab NOVA flow conditioner is permissible if the range of upstream fittings is restricted or the overall length between the upstream fitting and the orifice plate is increased or the diameter ratio of the orifice plate is reduced. These locations are not described here.

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