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Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full - Part 2: Orifice plates (ISO 5167-2:2003)

Mesure de débit des fluides au moyen d'appareils déprimogènes insérés dans des conduites en charge de section circulaire - Partie 2: Diaphragmes (ISO 5167-2:2003)

Durchflussmessung von Fluiden mit Drosselgeräten in voll durchströmten Leitungen mit Kreisquerschnitt - Teil 2: Blenden (ISO 5167-2:2003)

This European Standard was approved by CEN on 20 February 2003.

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This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Management Centre has the same status as the official versions.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
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Foreword

This document (EN ISO 5167-2:2003) has been prepared by Technical Committee ISO/TC 30 "Measurement of fluid flow in closed conduits" in collaboration with CMC.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by September 2003, and conflicting national standards shall be withdrawn at the latest by September 2003.

This document, together with EN ISO 5167-1:2003, EN ISO 5167-3:2003 and EN ISO 5167-4:2003, supersedes EN ISO 5167-1:1995.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom.

Endorsement notice

The text of ISO 5167-2:2003 has been approved by CEN as EN ISO 5167-2:2003 without any modifications.

NOTE Normative references to International Standards are listed in Annex ZA (normative).

Annex ZA
(normative)

Normative references to international publications
with their relevant European publications

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

NOTE Where an International Publication has been modified by common modifications, indicated by (mod.), the relevant EN/HD applies.

Publication	Year	Title	EN	Year
ISO 4006	1991	Measurement of fluid flow in closed conduits - Vocabulary and symbols	EN 24006	1993
ISO 5167-1	1991	Measurement of fluid flow by means of pressure differential devices - Part 1: Orifice plates, nozzles and Venturi tubes inserted in circular cross-section conduits running full	EN ISO 5167-1	1995

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

Part 2:
Orifice plates

1 Scope

This part of ISO 5167 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 flowrate of the fluid flowing in the conduit.

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

This part of ISO 5167 is applicable to 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 have been used with orifice plates but are not covered by this part of ISO 5167. This part of ISO 5167 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. It does not cover the use of orifice plates in pipe sizes less than 50 mm or more than 1 000 mm, or for pipe Reynolds numbers below 5 000.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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

3 Terms, definitions and symbols

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

4 Principles of the method of measurement and computation

The principle of the method of measurement is based on the installation of an orifice plate 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 flowrate, q_m, can be determined using Equation (1):

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

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

Computation of the mass flowrate, which is a purely arithmetic process, can be performed by replacing the different terms on the right hand side of the basic Equation (1) by their numerical values.

Similarly, the value of volume flowrate, q_V, is calculated from:

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

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

As will be seen later in this part of ISO 5167, the coefficient of discharge, C, is dependent on the Reynolds number, Re, which is itself dependent on q_m, and has to be obtained by iteration (see Annex A of ISO 5167-1:2003 for guidance regarding the choice of the iteration procedure and initial estimates).

The diameters d and D mentioned in the formula 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

NOTE 1   The various types of standard orifice meters are similar and therefore only a single description is needed. Each type of standard orifice meter is characterized by the arrangement of the pressure tappings.

NOTE 2   Limits of use are given in 5.3.1.

5.1 Description

5.1.1 General

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 defined in 5.1.3.1 to exceed 1 % under working conditions.

NOTE   Further information is given in 8.1.1.3 of ISO/TR 9464:1998.
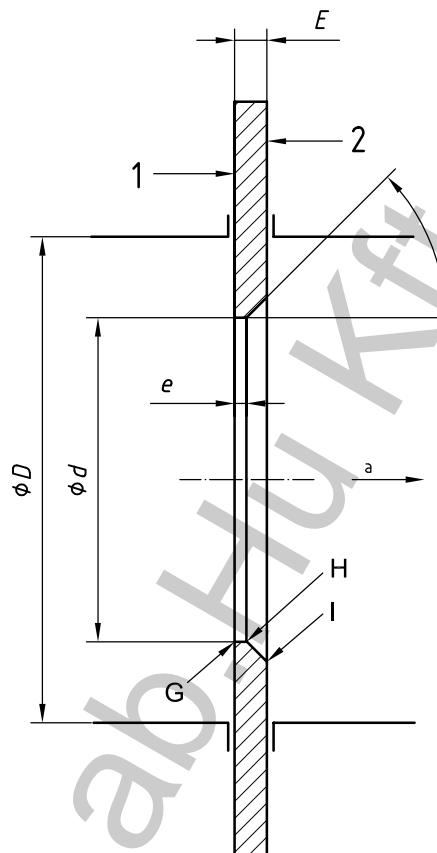
Key

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.
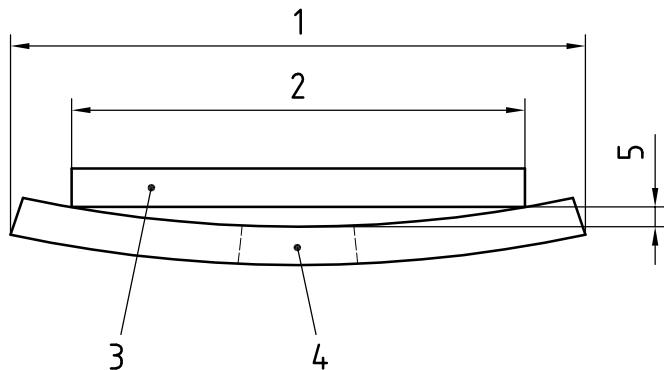
Key

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 [1]; 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 $0,02D$.

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 $\leqslant D \leqslant$ 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 $D \geqslant$ 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.

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 $d \geqslant 25$ 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 not sufficient.

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.

5.1.8 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 taps 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 $\beta \leqslant 0,6$;

— 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:

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

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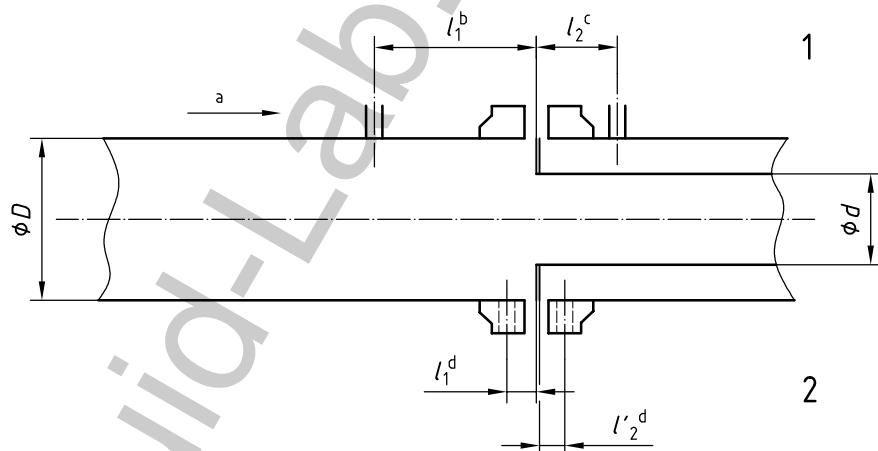
Key

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 $\beta \leqslant 0,6$
$0,5D \pm 0,01D$ 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 $\beta \leqslant 0,6$
$(25,4 \pm 1)$ mm for $\beta > 0,6$ and 150 mm $\leqslant D \leqslant 1\,000$ 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 (see Figure 4)

5.2.3.1 The spacing between the centrelines of the tappings 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 its flanges or in carrier rings as shown in Figure 4.
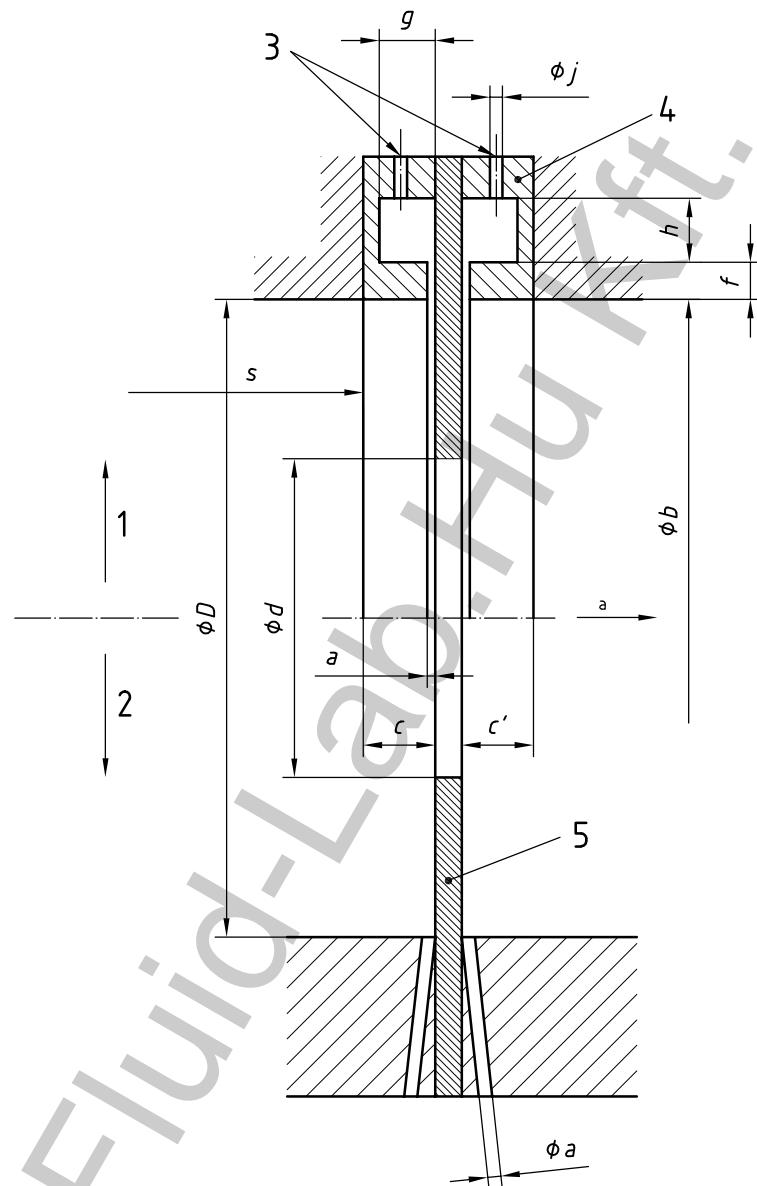
Key

1	carrier ring with annular slot	f =	thickness of the slot
2	individual tappings	c =	length of upstream ring
3	pressure tappings	c' =	length of the downstream ring
4	carrier ring	b =	diameter of the carrier ring
5	orifice plate	a =	width of annular slot or diameter of single tapping
		s =	distance from upstream step to carrier ring
[a]	Direction of flow.	g, h =	dimensions of the annular chamber
		$\varnothing j$ =	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 $\beta \leqslant 0{,}65$: $0{,}005D \leqslant a \leqslant 0{,}03D$;

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

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 $\leqslant a \leqslant$ 10 mm;

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

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

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 following condition 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 part of ISO 5167 under the following conditions.

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

— $d \geqslant 12{,}5$ mm;

— 50 mm $\leqslant D \leqslant 1\,000$ mm;

— $0{,}1 \leqslant \beta \leqslant 0{,}75$;

— $Re_D \geqslant 5\,000$ for $0{,}1 \leqslant \beta \leqslant 0{,}56$;

— $Re_D \geqslant 16\,000\,\beta^2$ for $\beta > 0{,}56$.

For orifice plates with flange tappings:

— $d \geqslant 12{,}5$ mm;

— 50 mm $\leqslant D \leqslant 1\,000$ mm;

— $0{,}1 \leqslant \beta \leqslant 0{,}75$.

Both $Re_D \geqslant 5\,000$ and $Re_D \geqslant 170\beta^2 D$

where D is expressed in millimetres.

The pipe internal roughness shall satisfy the following specification if the uncertainty values in this part of ISO 5167 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 7.1.5 of ISO 5167-1:2003. The work on which Tables 1 and 2 are based is described in the references [2] to [4] in the Bibliography.

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

β	Re_D								
	$\leqslant 10^4$	3×10^4	10^5	3×10^5	10^6	3×10^6	10^7	3×10^7	10^8
$\leqslant 0{,}20$	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
$\geqslant 0{,}65$	4,2	3,0	1,9	1,2	0,8	0,6	0,4	0,3	0,3

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

β	Re_D			
	$\leqslant 3 \times 10^6$	10^7	3×10^7	10^8
$\leqslant 0{,}50$	0,0	0,0	0,0	0,0
0,60	0,0	0,0	0,003	0,004
$\geqslant 0{,}65$	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 µm $\leqslant Ra \leqslant$ 6 µm, $D \geqslant$ 150 mm, $\beta \leqslant$ 0,6 and $Re_D \leqslant 5 \times 10^7$;

— 1,5 µm $\leqslant Ra \leqslant$ 6 µm, $D \geqslant$ 150 mm, $\beta >$ 0,6 and $Re_D \leqslant 1,5 \times 10^7$.

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[5]:

$$C = 0{,}596\,1 + 0{,}026\,1\beta^2 - 0{,}216\beta^8 + 0{,}000\,521\left(\frac{10^6 \beta}{Re_D}\right)^{0{,}7} + (0{,}018\,8 + 0{,}006\,3A)\beta^{3{,}5}\left(\frac{10^6}{Re_D}\right)^{0{,}3}$$

$$+ (0{,}043 + 0{,}080e^{-10L_1} - 0{,}123e^{-7L_1})(1 - 0{,}11A)\frac{\beta^4}{1-\beta^4} - 0{,}031(M'_2 - 0{,}8M'^{1{,}1}_2)\beta^{1{,}3} \tag{4}$$

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

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

In these equations

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 equation, 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.

The Reader-Harris/Gallagher (1998) equation, Equation (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.

Equation (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[6] for computing the expansibility [expansion] factor, ε, is as follows:

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

Equation (5) is applicable only within the range of the limits of use specified in 5.3.1.

Test results for the determination of ε are only known for air, steam and natural gas. However, there is no known objection to using Equation (5) for other gases and vapours of which the isentropic exponent is known.

Nonetheless, Equation (5) is applicable only if $p_2/p_1 \geqslant 0,75$.

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, the relative uncertainty of the value of C is equal to:

— $(0,7 - \beta)$ %   for $0,1 \leqslant \beta < 0,2$;

— $0,5$ %   for $0,2 \leqslant \beta \leqslant 0,6$;

— $(1,667\beta - 0,5)$ %   for $0,6 < \beta \leqslant 0,75$.

If $D < 71,12$ mm (2,8 in), the following relative 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 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, the relative uncertainty of the value of ε is equal to

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

5.4   Pressure loss, $\Delta\varpi$

5.4.1   The pressure loss, $\Delta\varpi$, for the orifice plates described in this part of ISO 5167 is approximately related to the differential pressure Δp by Equation (7)

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

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   Another approximate 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 is (see Reference [7])

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

where K is defined by the following equation:

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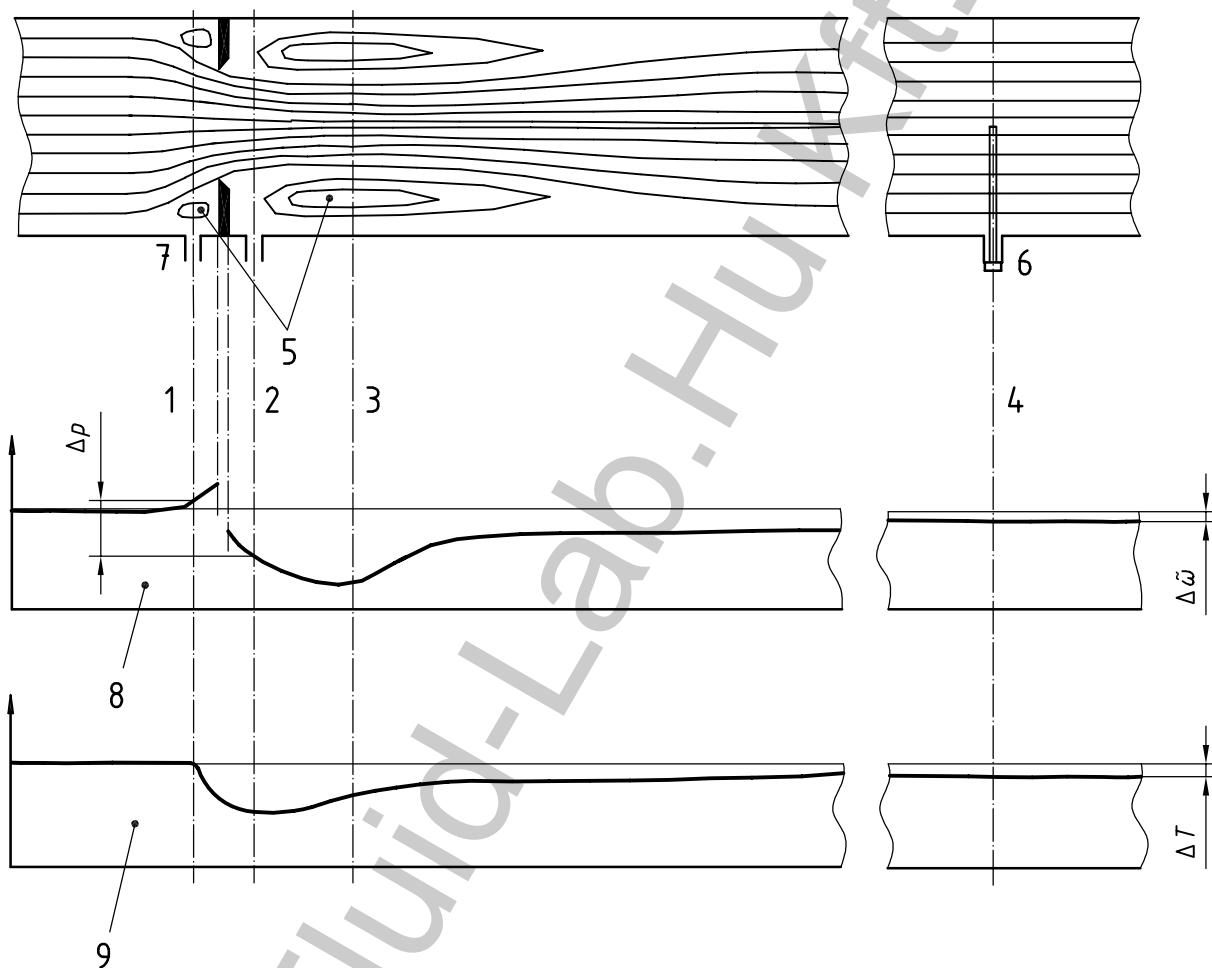
Key

1   plane of upstream pressure tappings
2   plane of downstream 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 Clause 7 of ISO 5167-1:— 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 7.3 of ISO 5167-1:—. The requirements for use of a flow conditioner are given in 7.4 of ISO 5167-1:—. 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 [8] of the Bibliography. Additional work which contributed to the lengths in 6.2 is given in References [9] and [10].

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 uncertainty of 0,5 % shall be added arithmetically to the uncertainty in the discharge coefficient.

6.2.5   This part of ISO 5167 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 flowrate 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

	Upstream (inlet) side of orifice plate																						Down-stream (outlet) side of the orifice plate	
Diameter ratio β	Single 90° bend / Two 90° bends in any plane ($S > 30D$) [a]		Two 90° bends in the same plane: S-configuration ($30D \geqslant S > 10D$) [a]		Two 90° bends in the same plane: S-configuration ($10D \geqslant S$) [a]		Two 90° bends in perpendicular planes ($30D \geqslant S > 5D$) [a]		Two 90° bends in perpendicular planes ($5D > S$) [a],[b]		Single 90° tee with or without an extension / Mitre 90° bend		Single 45° bend / Two 45° bends in the same plane: S-configuration ($S \geqslant 2D$) [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 $\leqslant 0,03D$ [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]
$\leqslant 0,20$	6	3	10	9 [g]	10	9 [g]	19	18	34	17	3	9 [g]	7	9 [g]	5	9 [g]	6	9 [g]	12	6	30	15	5	3	4	2
0,40	16	3	10	9 [g]	10	9 [g]	44	18	50	25	9	3	30	9	5	9 [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 shall be 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 $1,5D$.

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 required for $Re_D > 2 \times 10^6$ if $S < 2D$.

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 these tables as a single fitting, are placed in series upstream of the orifice plate the following shall be applied.

   1) Between the fitting immediately upstream of the orifice plate, fitting 1, and the orifice plate itself there shall be a straight length at least equal to the minimum length given in Table 3 appropriate for the specific orifice plate diameter ratio in conjunction with fitting 1.

   2) In addition, between fitting 1 and the next fitting further from the orifice plate (fitting 2), a straight length at least equal to half the product of the diameter of the pipe between fitting 1 and fitting 2 and the number of diameters given in Table 3 for an orifice plate of diameter ratio 0,67 used in conjunction with fitting 2 shall be included between fittings 1 and 2 irrespective of the actual β for the orifice plate used. If either of the minimum straight lengths is selected from Column B (i.e. prior to taking the half value from fitting 1 to 2 of Table 3, a 0,5 % additional uncertainty shall be added arithmetically to the discharge coefficient uncertainty.

   3) If the upstream metering section has a full bore valve (as in Table 3) preceded by another fitting, e.g. an expander, then the valve can be installed at the outlet of the 2nd fitting from the orifice plate. The required length between the valve and the 2nd fitting according to 2) should be added to the length between the orifice plate and the 1st fitting specified in Table 3; see Figure 6. It should be noted that 6.2.8 b) shall also be satisfied (as it is in Figure 6).

b) In addition to the rule in a) any fitting, treating any two consecutive 90° bends as a single fitting, shall be located at a distance from the orifice plate at least as great as the distance given by the product of the pipe diameter at the orifice and the number of diameters required between that fitting and an orifice plate of the same diameter ratio in Table 3, regardless of the number of fittings between that fitting and the orifice plate. 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 uncertainty shall be added arithmetically to the discharge coefficient uncertainty, but 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 7.4 of ISO 5167-1:2003) 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 the second (or more distant) fitting from the orifice 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.
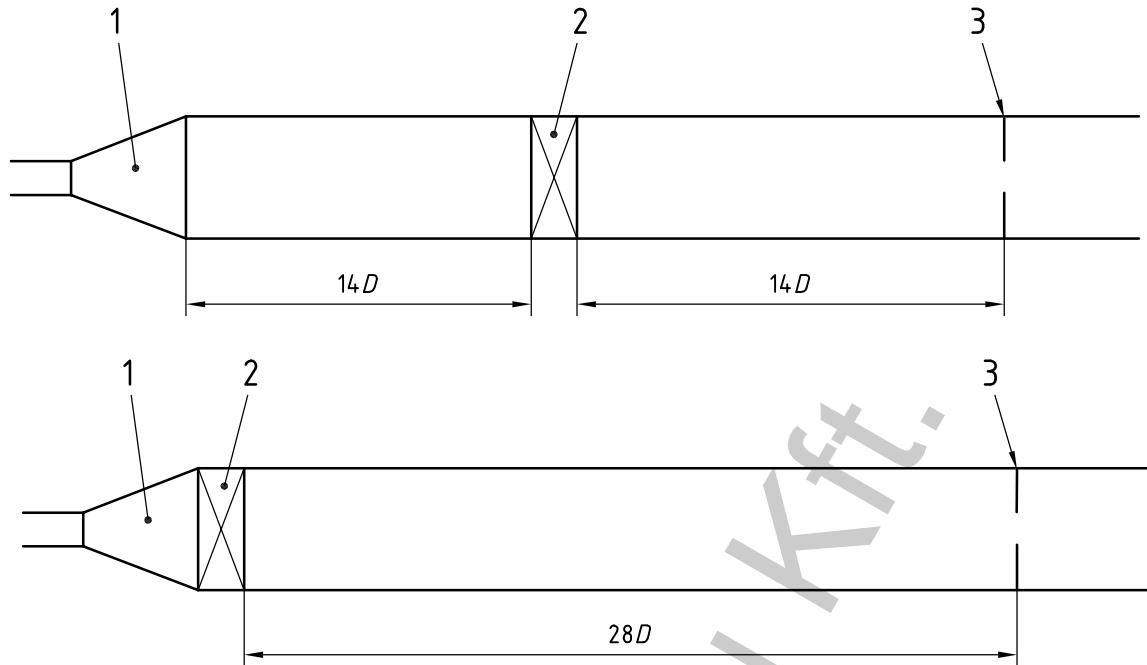
Key

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, the second fitting from the orifice plate 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 the first fitting is a full bore ball valve fully open [see Figure 7 a)], the distance between the valve and the orifice plate shall be at least $12D$ (from Table 3) and that between the two bends in perpendicular planes and the valve shall be at least $22D$ [from 6.2.8 a)]; the distance between the two bends in perpendicular planes and the orifice plate shall be at least $44D$ [from 6.2.8 b)]. If the valve has length $1D$ an additional total length of $9D$ is required which may be either upstream or downstream of the valve or partly upstream and partly downstream of it. 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 $44D$ from the two bends in perpendicular planes to the orifice plate [see Figure 7 b)].

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

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

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

b)

c)

d) $x \geqslant 0, y \geqslant 0, x + y \geqslant 19$
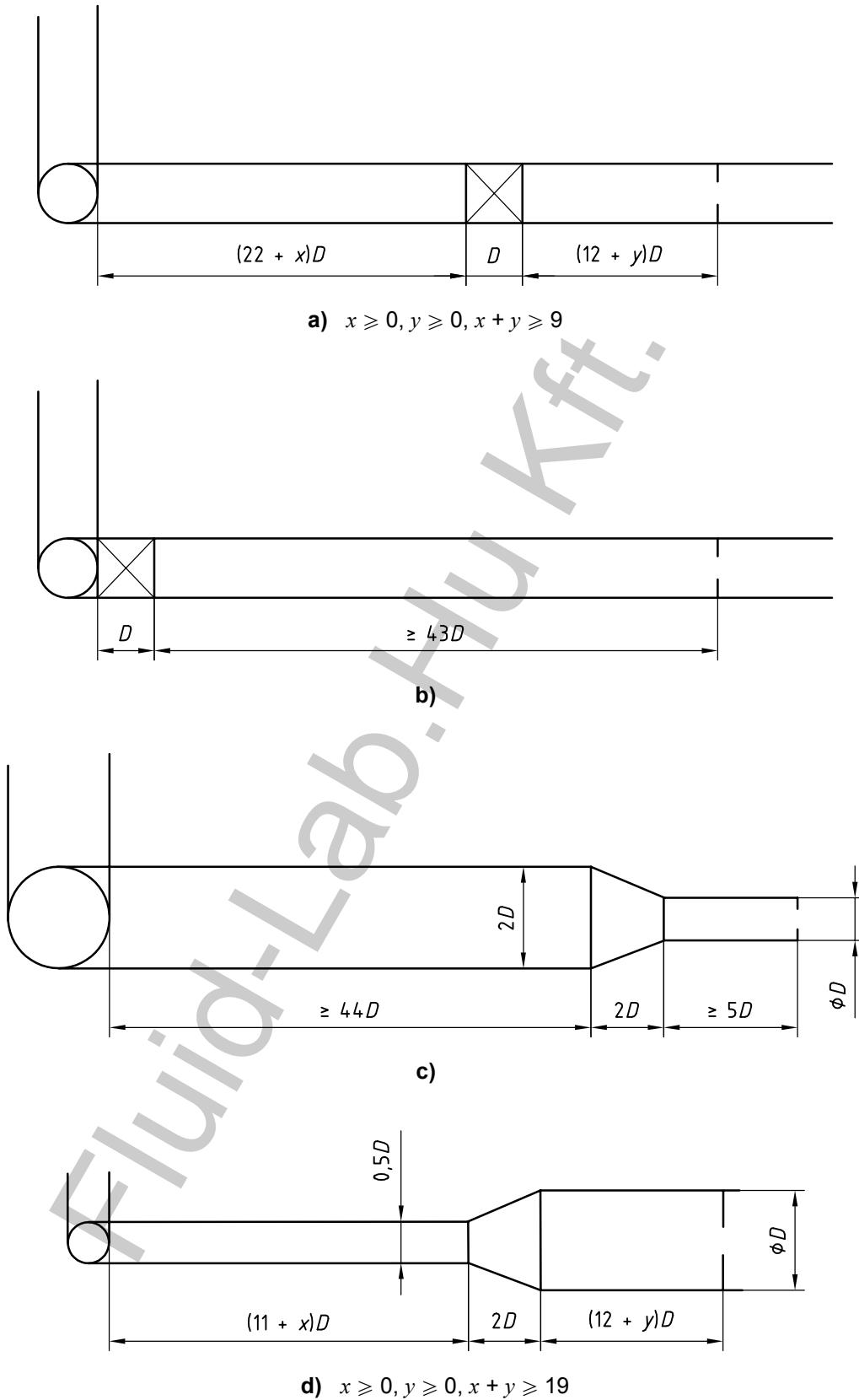
Figure 7 — Examples of acceptable installations (see 6.2.9)

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6.3 Flow conditioners

6.3.1 General

A flow conditioner can be used to reduce upstream straight lengths either through meeting the compliance test given in 7.4.1 of ISO 5167-1:2003, in which case it can be used downstream of any upstream fitting, or through meeting the requirements of 7.4.2 of ISO 5167-1:2003, which gives additional possibilities outside compliance testing. In either case the test work shall be carried out using orifice plates.

Unpatented flow conditioners which have met the compliance 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 compliance 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

$$0,95D \leqslant D_f \leqslant D$$

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 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 part of ISO 5167 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 compliance 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.
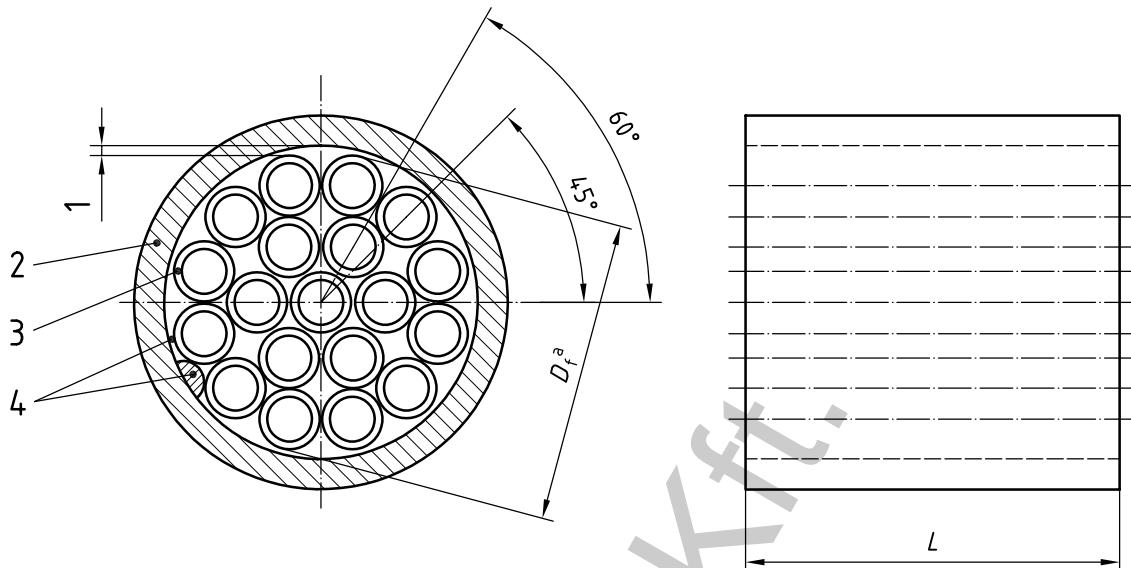
Key

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 equation:

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

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 13$D \pm 0,25D$.

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:

— $30D > L_f \geqslant 18D$, and

— $L_f \geqslant 30D$.

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 uncertainty of 0,5 % shall be added arithmetically to the 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 part of ISO 5167 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 ≥ 18		L_f ≥ 30		30 > L_f ≥ 18		L_f ≥ 30		30 > L_f ≥ 18		L_f ≥ 30		30 > L_f ≥ 18		L_f ≥ 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]
≤ 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 β ≤ 0,67	13 for β ≤ 0,75	14 to 16,5 for β ≤ 0,75	14 to 16,5 for β ≤ 0,75	13,5 to 14,5 for β ≤ 0,67	13,5 to 14,5 for β ≤ 0,75	12 to 12,5 for β ≤ 0,75	12 to 12,5 for β ≤ 0,75	13 for β ≤ 0,54	13 for β ≤ 0,75	12 to 13 for β ≤ 0,75	12 to 13 for β ≤ 0,75	9,5 for β ≤ 0,46	9,5 for β ≤ 0,75	13 for β ≤ 0,67	13 for β ≤ 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 6.3.2.2).

d   Column B for each fitting gives lengths corresponding to "0,5 % additional uncertainty" values (see 6.3.2.3).

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 β = 0,46 a value of 9,5 is possible.

h   If β = 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 15D 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 42D 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 30D, 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.
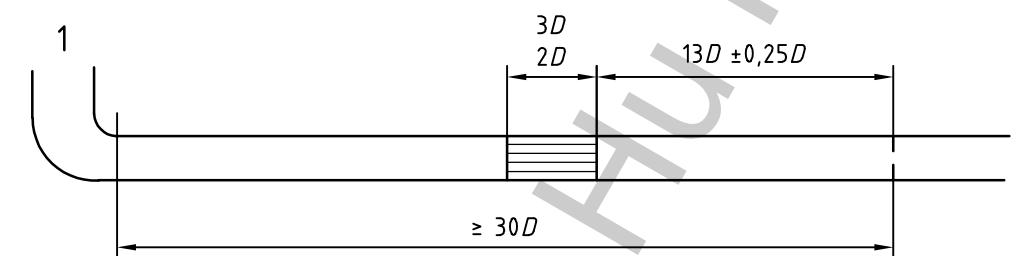
a)   **Installation using 6.3.2.2.2**
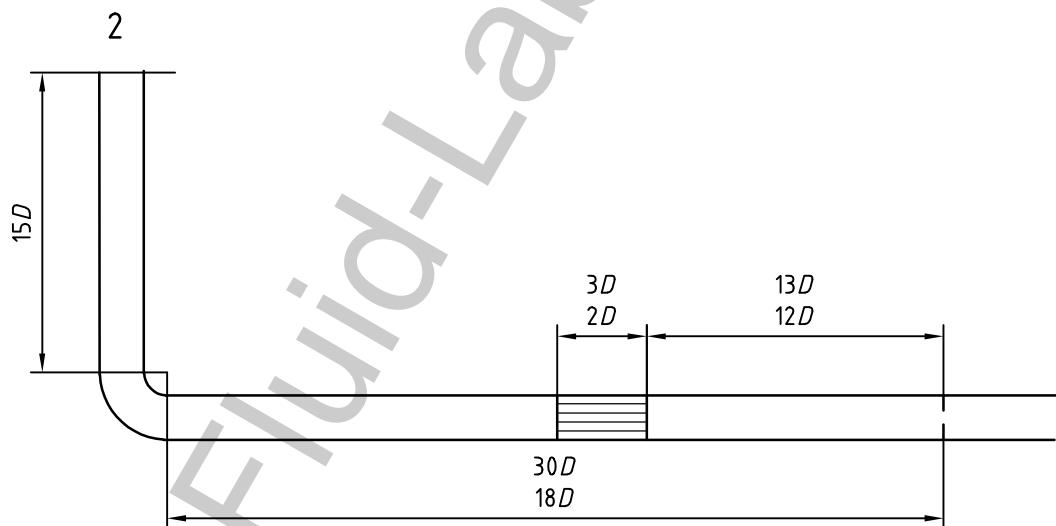
b)   **Installation using Table 4**

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 described here is a development of the Zanker conditioner described in C.3.2.5 of ISO 5167-1:2003 The Zanker flow conditioner plate has the same distribution of holes in a plate but does not have the egg-box honeycomb attached to the plate; instead the plate thickness has been increased to $D/8$. It is not patented.

The Zanker flow conditioner plate[11] shown in Figure 10 met the compliance test requirements given in 7.4.1.2 to 7.4.1.6 of ISO 5167-1:2003 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 part of ISO 5167.

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 $\pm 0,1$ mm for $D < 100$ mm.

The perforated plate thickness, t_c, is such that $0,12D \leqslant t_c \leqslant 0,15D$. The flange thickness depends on the application; the outer diameter and flange face surfaces depend on the flange type and application.
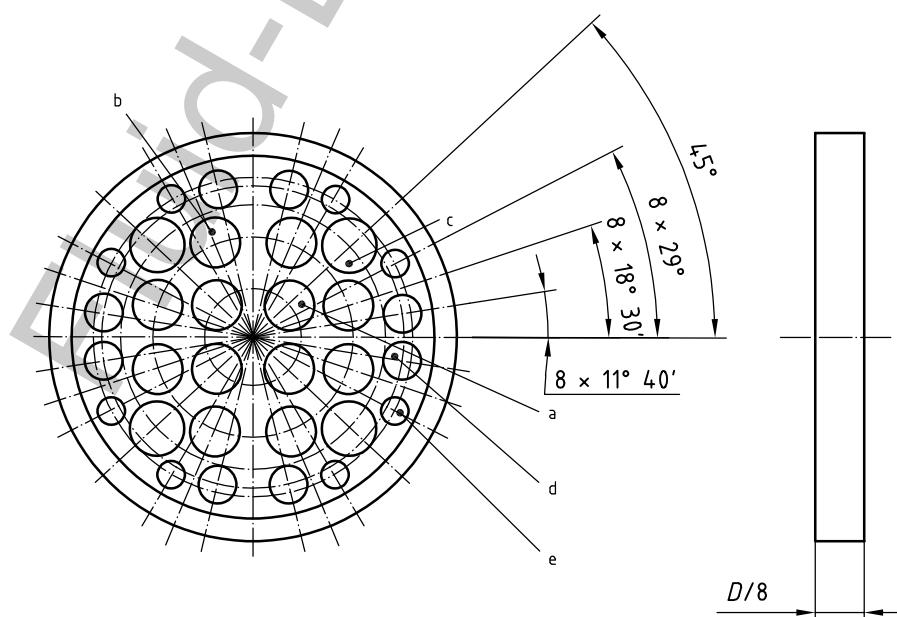
Figure 10 — Drawing of the Zanker flow conditioner plate

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

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

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

$$7,5D \leqslant L_s \leqslant L_f - 8,5D$$

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

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

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 [12] in the Bibliography), 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 β = 0,6.

6.4.4   An additional uncertainty of 0,2 % shall be added arithmetically to the 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:

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

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 part of ISO 5167.

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.

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_{cl}, the component in the direction parallel to the pressure tapping, shall for each pressure tapping be such that

$$e_{cl} \leqslant \frac{0,002\,5D}{0,1+2,3\beta^4}$$

e_{cn}, the component in the direction perpendicular to the pressure tapping, shall for each pressure tapping be such that

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

If, for one or more pressure tappings,

$$\frac{0,002\,5D}{0,1+2,3\beta^4} < e_{cl} \leqslant \frac{0,005D}{0,1+2,3\beta^4}$$

an additional uncertainty of 0,3 % shall be added arithmetically to the uncertainty on 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,

$$\text{either } e_{cl} \text{ or } e_{cn} > \frac{0,005D}{0,1+2,3\beta^4}$$

this part of ISO 5167 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, when holding the orifice plate between flanges, to allow for its free thermal expansion and to avoid buckling and distortion.

6.6.2   Gaskets or sealing rings shall be made and inserted in such a way that they do not protrude at any point inside the pipe or across the pressure tappings or slots when corner tappings are used. They shall be as thin as possible, with due consideration taken in maintaining the relationship as defined in 5.2.

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

Annex A
(informative)

Tables of discharge coefficients and expansibility [expansion] factors

Table A.1 — Orifice plate with corner tappings — Discharge coefficient, C, for $D \geqslant 71{,}12$ mm

Diameter ratio β	Discharge coefficient, C, for Re_D equal to											
	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 7	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
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 $D \geqslant 71,12$ mm

Diam-eter 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
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 β	Discharge coefficient, C, for Re_D equal to											
	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
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

Diam-eter ratio β	Discharge coefficient, *C*, for Re_D equal to											
	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
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

Diam-eter ratio β	Discharge coefficient, *C*, for Re_D equal to											
	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
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

Diam-eter 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
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 β	Discharge coefficient, C, for Re_D equal to											
	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 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 9	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
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

Diam-eter ratio β	Discharge coefficient, C, for Re_D equal to											
	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	0,5964	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	0,5965	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	0,5966	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	0,5967	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	0,5969	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	0,5971	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	0,5973	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	0,5976	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	0,5978	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	0,5981	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	0,5985	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	0,5988	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	0,5992	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	0,5997	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	0,6001	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	0,6006	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	0,6011	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	0,6016	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	0,6021	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	0,6026	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	0,6032	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	0,6034	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	0,6037	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	0,6039	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	0,6041	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	0,6044	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	0,6045	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	0,6047	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	0,6049	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	0,6050	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	0,6051	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	0,6051	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	0,6051	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	0,6051	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	0,6050	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	0,6048	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	0,6046	0,602 1	0,600 9	0,599 8
0,67	—	—	0,623 6	0,619 2	0,615 0	0,612 9	0,611 0	0,607 0	0,6043	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	0,6039	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	0,6035	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	0,6029	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	0,6022	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	0,6014	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	0,6004	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	0,5994	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	0,5981	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

Diam-eter 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
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

Diam-eter 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	0,597 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
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 β	Discharge coefficient, C, for Re_D equal to											
	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
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
for $\kappa = 1,3$									
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 $\kappa = 1,4$									
0,100 0	0,000 1	0,995 0	0,988 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 $\kappa = 1,66$									
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 compliance 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 compliance test. This information is given for the convenience of users of this part of ISO 5167 and does not constitute an endorsement by ISO of these products.

B.2 Gallagher flow conditioner — Compliance testing

B.2.1   The Gallagher flow conditioner shown in Figure B.1 meets the compliance test given in 7.4.1.2 to 7.4.1.7 of ISO 5167-1:2003 (significant part of compliance test results can be found in References [8] and [13]) 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 equation:

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

where Δp_c is the pressure loss across the Gallagher flow conditioner and 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

$$5D \leqslant L_\mathrm{s} \leqslant L_\mathrm{f} - 8D$$

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

If $0{,}67 < \beta \leqslant 0{,}75$, 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 7.4.1.7 of ISO 5167-1:2003 for β = 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.
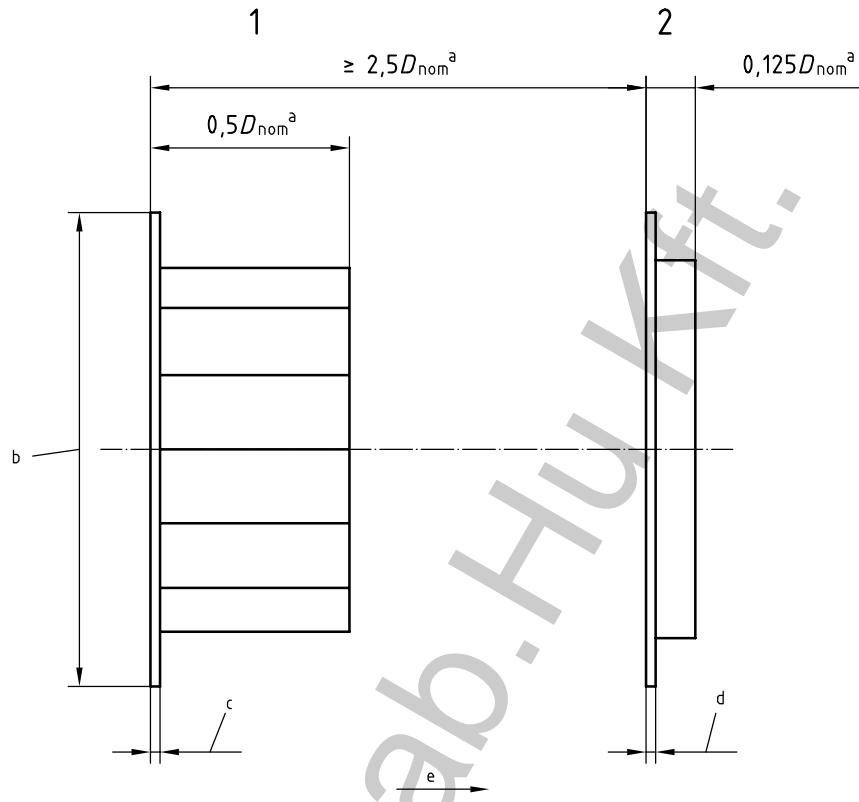

a) Typical arrangement

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.
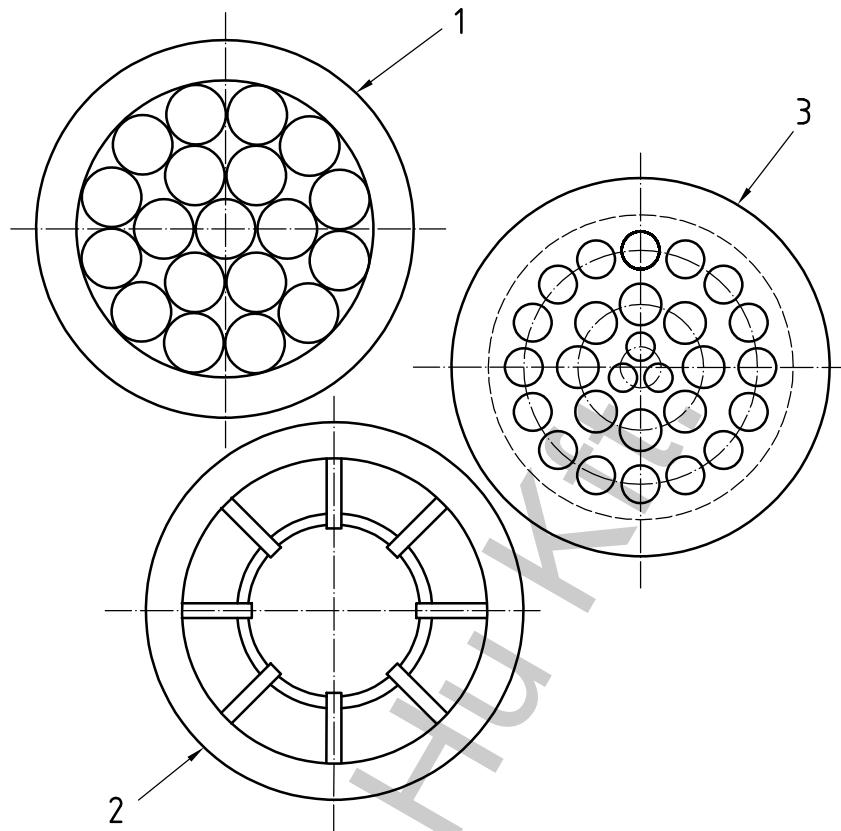
b) Typical components (face views)

Key

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

2 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)

3 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.

Figure B.1 — Gallagher flow conditioner

B.3 NOVA's design of K-Lab perforated plate flow conditioner — Compliance 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 compliance test given in 7.4.1.2 to 7.4.1.6 of ISO 5167-1:2003 (compliance test results can be found in References [8], [14] and [15] of the Bibliography) 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 $Re_D \geqslant 10^5$ are given in B.3.3.

The perforated plate thickness, t_c, is such that $0,125D \leqslant t_c \leqslant 0,15D$. 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 equation:

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

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 $Re_D \geqslant 8 \times 10^5$, 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 $0,5D \pm 0,5$ mm, and

— a ring of 16 holes of diameter $0,120\,3D \pm 0,000\,77D$ on a pitch circle diameter of $0,85D \pm 0,5$ mm.

B.3.3.2   Provided that $8 \times 10^5 > Re_D \geqslant 10^5$, 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 $0,5D \pm 0,5$ mm, and

— a ring of 16 holes of diameter $0,124\,22D \pm 0,000\,77D$ on a pitch circle diameter of $0,85D \pm 0,5$ mm.
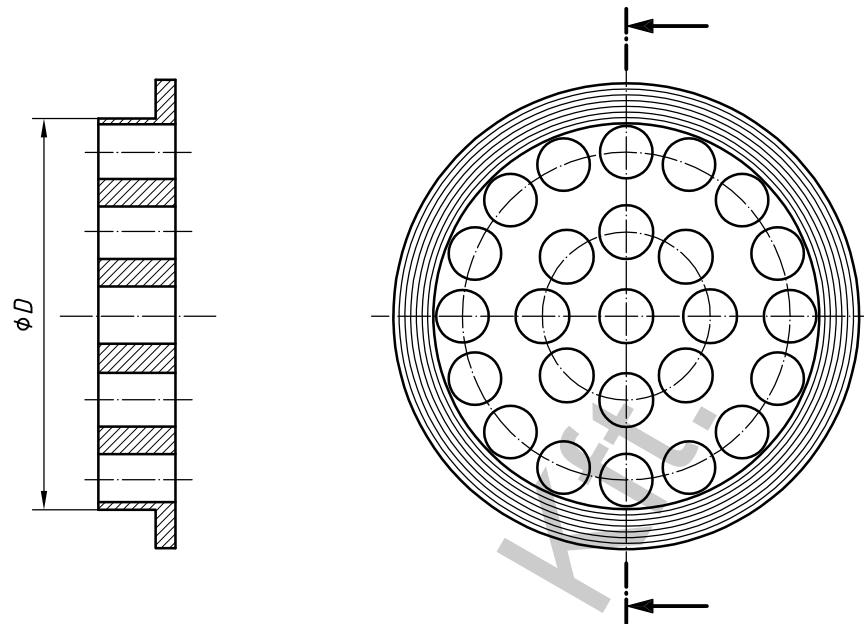
Figure B.2 — The K-Lab NOVA flow conditioner

B.3.4 L_f, the distance between the orifice plate and the nearest upstream fitting, is at least equal to $17D$. 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

$$8,5D \leqslant L_s \leqslant L_f - 7,5D$$

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

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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