International Standard ISO 5167

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION•МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ•ORGANISATION INTERNATIONALE DE NORMALISATION

Measurement of fluid flow by means of orifice plates, nozzles and venturi tubes inserted in circular cross-section conduits running full

Mesure de débit des fluides au moyen de diaphragmes, tuyères et tubes de Venturi insérés dans des conduites en charge de section circulaire

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FOREWORD

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO member bodies). The work of developing International Standards is carried out through ISO technical committees. Every member body interested in a subject for which a technical committee has been set up has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 5167 was developed by Technical Committee ISO/TC 30 has been set up in order to resolve the differences between the two documents.

It has been approved by the member bodies of the following countries :

Australia
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Finland
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Turkey
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The member body of the following country expressed disapproval of the document on technical grounds :

USA

This International Standard cancels and replaces ISO Recommendations R 541-1967 and R 781-1968, of which it constitutes a technical revision.

During the development of this International Standard, it was found that it was in conflict with a document on the same subject being prepared by ISO/TC 28/SC 5 *"Measurement of light hydrocarbon fluids"*. A liaison group ISO/TC 28/SC 5 — ISO/TC 30 has been set up in order to resolve the differences between the two documents.

The completion in the future of the work of this liaison group may therefore lead to the revision of this International Standard.

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Annexes

Measurement of fluid flow by means of orifice plates, nozzles and venturi tubes inserted in circular cross-section conduits running full

1 SCOPE AND FIELD OF APPLICATION

This International Standard specifies the geometry and method of use (installation and operating conditions) of orifice plates, nozzles and venturi tubes when they are inserted in a conduit running full, to determine the rate of the fluid flowing in the conduit. It also gives necessary information for calculating the flow-rate and its associated uncertainty.

This International Standard applies only to pressure difference devices in which the flow remains subsonic throughout the measuring section, is steady or varies only slowly with time and the fluid is single-phased. In addition, each of these devices can only be used within limits which are specified, for example of pipe size and Reynolds number. Thus this International Standard cannot be used for pipe sizes less than 50 mm or more than 1 200 mm or for pipe Reynolds numbers below 3150.

It deals with devices for which direct calibration experiments have been made, sufficient in number and quantity to enable coherent systems of application to be based on their results and coefficients to be given with certain predictable limits of uncertainty.

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

The different primary devices dealt with in this International Standard are as follows :

- orifice plates, which can be used with the various following arrangements of pressure tappings :
  - corner pressure tappings,
  - D and $D/2$ pressure tappings,[2]
  - flange pressure tappings,
- nozzles :
  - ISA 1932 nozzle[3],
  - long radius nozzle,

  which differ in shape and/or in the position of the pressure tappings,
- venturi tubes :
  - classical venturi tube[4],
  - venturi-nozzle,

  which differ in shape and/or in the position of pressure tappings.

2 SYMBOLS AND DEFINITIONS

The vocabulary and symbols used in this International Standard are defined in ISO 4006, *Measurement of fluid flow in closed conduits — Vocabulary and symbols.*

Table 1 reproduces the symbols which are used in this International Standard.

The definitions in the following clauses are given only for terms used in some special sense or for terms the meaning of which it seems useful to emphasize.

1) See ISO 2186, *Fluid flow in closed conduits — Connections for pressure signal transmission between primary and secondary devices.*

2) Orifice plates with *vena contracta* pressure tappings are not considered in this International Standard.

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

4) In the U.S.A. the classical venturi tube is sometimes called Herschel venturi tube.

2.1 Symbols

TABLE 1 – Symbols

Symbols	Represented quantity	Dimensions M : mass L : length T : time Θ : temperature	SI Unit
C	Coefficient of discharge, $C = \frac{\alpha}{E}$	dimensionless	
d	Diameter of orifice or throat of primary device at operating conditions	L	m
D	Upstream internal pipediameter (or upstream diameter of a classical venturi tube) at operating conditions	L	m
e	Relative uncertainty	dimensionless	
E	Velocity of approach factor, $E = (1 - \beta^4)^{-1/2}$	dimensionless	
k	Uniform equivalent roughness (see 7.3.2.1)	L	m
l	Pressure tapping spacing	L	m
L	Relative pressure tapping spacing, $L = \frac{l}{D}$	dimensionless	
p	Static pressure of the fluid	$ML^{-1}T^{-2}$	Pa
q_m	Mass rate of flow	MT^{-1}	kg/s
q_v	Volume rate of flow	L^3T^{-1}	m^3/s
R	Radius	L	m
R_a	Arithmetical mean deviation from the mean line of the profile (see ISO/R 468)	L	m
Re	Reynolds number	dimensionless	
Re_D Re_d	Reynolds number referred to D or d	dimensionless	
t	Temperature of the fluid	Θ	°C
U	Mean axial velocity of the fluid in the pipe	LT^{-1}	m/s
X	Acoustic ratio, $X = \frac{\Delta p}{p_1 \kappa}$	dimensionless	
α	Flow coefficient	dimensionless	
β	Diameter ratio, $\beta = \frac{d}{D}$	dimensionless	
γ	Specific heat capacities ratio[1)]	dimensionless	
Δp	Differential pressure	$ML^{-1}T^{-2}$	Pa
$\Delta\bar{\omega}$	Pressure loss	$ML^{-1}T^{-2}$	Pa
ϵ	Expansibility (expansion) factor	dimensionless	
κ	Isentropic exponent[1)]	dimensionless	
μ	Dynamic viscosity of the fluid	$ML^{-1}T^{-1}$	Pa.s
ν	Kinematic viscosity of the fluid, $\nu = \frac{\mu}{\rho}$	L^2T^{-1}	m^2/s
ξ	Relative pressure loss	dimensionless	
ρ	Mass density of the fluid	ML^{-3}	kg/m^3
τ	Pressure ratio, $\tau = \frac{p_2}{p_1}$	dimensionless	
φ	Total angle of the divergent	dimensionless	radian

1) Ratio of the specific heat capacity at constant pressure to the specific heat capacity at constant volume. For ideal gases, the ratio of the specific heat capacities and the isentropic exponent have the same values (see 2.4.3). These values depend on the nature of the gas.

NOTE – Subscript 1 refers to the cross-section at the plane of the upstream pressure tapping.
Subscript 2 refers to the cross-section at the plane of the downstream pressure tapping.

2.2 Pressure measurement : Definitions

2.2.1 wall pressure tapping : Hole drilled in the wall of a pipe, the inside edge of which is flush with the inside surface of the pipe.

The hole is usually circular but in certain cases may be an annular slot.

2.2.2 static pressure of a fluid flowing through a straight pipe-line : Pressure which can be measured by connecting a pressure gauge to a wall pressure tapping. Only the value of the absolute static pressure is used in this International Standard.

2.2.3 differential pressure : Difference between the static pressure measured by wall tappings, one of which is on the upstream side and the other on the downstream side of a primary device (or in the throat for a venturi tube) inserted in a straight pipe through which flow occurs, when any difference in height between the upstream and downstream tappings has been taken into account.

The term "differential pressure" is used only if the pressure tappings are in the positions specified by this International Standard for each standard primary device.

2.2.4 pressure ratio : the absolute static pressure at the downstream pressure tapping, divided by that at the upstream pressure tapping.

2.3 Primary devices : Definitions

2.3.1 orifice or throat : Opening of minimum cross-sectional area in a primary device.

Standard primary device orifices are circular and coaxial with the pipe-line.

2.3.2 orifice plate : Thin plate in which a circular aperture has been machined.

Standard orifice plates are described as "thin plate" and "with sharp square edge", because the thickness of the plate is small compared with the diameter of the measuring section and because the upstream edge of the orifice is sharp and square.

2.3.3 nozzle : Device which consists of a convergent inlet connected to a cylindrical portion generally called the "throat".

2.3.4 venturi tube : Device which consists of a convergent inlet connected to a cylindrical part called the "throat" and an expanding section called the "divergent" which is conical.

If the convergent part is a standardized ISA 1932 nozzle, the device is called a "venturi-nozzle". If the convergent part is conical, the device is called a "classical venturi tube".

2.3.5 diameter ratio of a primary device in a given pipe : The diameter of the orifice (or throat) of the primary device divided by the internal diameter of the measuring pipe upstream of the primary device.

However, when the primary device has a cylindrical section upstream, equivalent in diameter to that of the pipe (as in the case of the classical venturi tube), the diameter ratio is the quotient of the throat diameter divided by the diameter of this cylindrical section at the plane of the upstream pressure tappings.

2.4 Flow : Definitions

2.4.1 rate of flow of fluid passing through a primary device : Mass or volume of fluid passing through the orifice or throat per unit time; in all cases it is necessary to state explicitly whether the mass rate of flow, expressed in mass per time unit, or the volume rate of flow, expressed in volume per time unit, is being used.

2.4.2 Reynolds number

The Reynolds number used in this International Standard is referred to :

— either the upstream condition of the fluid and the upstream diameter of the pipe, i.e.

$$Re_D = \frac{U_1 D}{\nu_1}$$

— or the orifice or throat diameter of the primary device, i.e.

$$Re_d = Re_D \times \beta^{-1}$$

2.4.3 isentropic exponent

The isentropic exponent κ appears in the different formulae for the expansibility (expansion) factor ϵ either directly or in the ratio X. The isentropic exponent varies with the nature of the gas and with its temperature and pressure.

There are many gases and vapours for which no values for κ have been published so far. In such a case, for the purpose of this International Standard, the ratio of the specific heat capacities of ideal gases may be used in place of the isentropic exponent for the computation of the rate of flow.

2.4.4 acoustic ratio : The differential pressure ratio divided by the isentropic exponent (compressible fluid).

2.4.5 velocity of approach factor

It is equal to :

$$E = (1 - \beta^4)^{-1/2} = \frac{D^2}{\sqrt{D^4 - d^4}}$$

2.4.6 flow and discharge coefficients

Calibration of standard primary devices by means of nominally incompressible fluids (liquids) shows that α, called the flow coefficient, a pure number defined by the following relation, is dependent only on the Reynolds number for a given primary device in a given installation.

$$\alpha = \frac{q_m}{\frac{\pi}{4} d^2 \sqrt{2 \Delta p \times \rho_1}}$$

The numerical value of α is the same for different installations, whenever such installations are geometrically similar and the flows are characterized by the identical Reynolds number.

The ratio $C = \frac{\alpha}{E}$ is called the "discharge coefficient".

The equations for the numerical values of α and of C given in this International Standard were based on data determined experimentally.

2.4.7 expansibility (expansion) factor

Calibration of a given primary device by means of a compressible fluid (gas), shows that the ratio :

$$\frac{q_m}{\frac{\pi}{4} d^2 \sqrt{2 \Delta p \times \rho_1}}$$

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

The method adopted for representing these variations consists in multiplying the flow coefficient α of the considered primary device as determined by direct calibration effected by means of liquids for the same value of Reynolds number, by the "expansibility", a so-called (expansion) factor defined by the relation :

$$\epsilon = \frac{q_m}{\alpha \frac{\pi}{4} d^2 \sqrt{2 \Delta p \times \rho_1}}$$

ϵ is equal to unity when the fluid is incompressible and less than unity when the fluid is compressible.

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

The numerical values of ϵ given in this International Standard have been based on data determined experimentally.

2.4.8 roughness criterion

The roughness criterion R_a used in this standard is that given in ISO/R 468 and equals the arithmetic mean deviation from the mean line of the profile being measured. The mean line is such that the sum of the squares of the distances between the effective surface and the mean line is a minimum. In practice R_a can be measured with standard equipment for machined surfaces but can only be estimated for the rougher surfaces of pipes.

For pipes, the equivalent roughness is used. This height k can be determined experimentally (see 7.3.1) or taken from tables (see table 6).

3 PRINCIPLE OF THE METHOD OF MEASUREMENT AND COMPUTATION

3.1 Principle of the method of measurement

The principle of the method of measurement is based on the introduction of a primary device (such as an orifice plate, a nozzle or a venturi tube) into a pipe-line through which a fluid is running full. The introduction of the primary device creates a static pressure difference between the upstream side and the throat or downstream side of the device. The rate of flow can be determined from the measured value of this pressure difference and from a knowledge of the flowing fluid as well as the circumstances under which the device is being used, assuming the device is geometrically similar to one on which calibration has been made and that the conditions of use are the same, i.e. that it is in accordance with this International Standard.

This can be done since the mass rate of flow is related to the pressure differential within the uncertainty stated in this International Standard, by the following formulae :

$$q_m = \alpha \epsilon \frac{\pi}{4} d^2 \sqrt{2 \Delta p \times \rho_1} \qquad \ldots (1)$$

or

$$q_m = CE \epsilon \frac{\pi}{4} d^2 \sqrt{2 \Delta p \times \rho_1} \qquad \ldots (2)$$

Similarly, the value of the volume rate of flow, can be calculated since :

$$q_v = \frac{q_m}{\rho} \qquad \ldots (3)$$

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

3.2 Method of determination of the diameter ratio of the selected standard primary device

In practice, when one has to determine the diameter of a primary element to be installed in a given pipe line in order to perform a flow measurement, α or CE used in the basic formulae (1) or (2) are, in general, not known. Hence the following shall be selected *a priori* :

- the type of primary device to be used,
- a rate of flow and the corresponding value of the differential pressure.

The related values of q_m and Δp shall then be inserted in the basic formulae rewritten in the form below :

$$\alpha \beta^2 = \frac{4\, q_m}{\epsilon\, \pi\, D^2 \sqrt{2\, \Delta p \times \rho_1}}$$

and the diameter ratio of the selected primary device can be determined by successive approximations.

3.3 Computation of rate of flow

Computation of the rate of flow is effected by replacing the different terms on the right-hand side of the basic formulae (1) or (2) by their numerical values.

The computation itself involves no difficulty other than of an arithmetical nature and merely calls for the following comments :

a) α may be dependent on Re, which is itself dependent on q_m. In such cases the final value of α, and hence of q_m, is to be obtained by iteration from an initial chosen value of α (or Re). Generally it may be convenient to adopt the value of α at a Reynolds number of 10^6 as the starting point.

b) Δp represents the differential pressure, as defined under 2.2.3.

c) Attention is called to the fact that d and D mentioned in the formulae, are the values of the diameters at operating conditions and hence measurements taken at ambient conditions must be corrected for any possible expansion or contraction of the primary device and the pipe due to the values of fluid temperature and pressure during the measurement.

d) For the purpose of the measurement, it is necessary to know the mass density and the viscosity of the fluid under the conditions of the measurement.

3.4 Determination of mass density

The mass density of the fluid is required to be known at the plane of the upstream pressure tapping; it can either be measured directly or calculated from the knowledge of static pressure, temperature and characteristics of the fluid at this plane.

3.4.1 The static pressure of the fluid shall be measured in the plane of the upstream pressure tapping, by means of an individual pipe-wall pressure tapping (as described in 7.2.1) or by means of a carrier ring tappings (as described in 7.2.4).

3.4.1.1 This static pressure tapping shall preferably be separate from the tapping provided for measuring the upstream component of the differential pressure, unless the intention is to measure upstream and downstream pressures separately.

It is however permissible to link simultaneously one upstream pressure tapping with a differential pressure measuring device and a static pressure measuring device, provided it is verified that this double connection does not lead to any distortion of the differential pressure measurement.

3.4.1.2 The static pressure value to be used in subsequent computations is that existing at the level of the centre of the upstream measured cross-section, which may differ from the pressure measured at the wall.

3.4.2 Although the temperature of the fluid from which the density and viscosity are calculated is that measured in the upstream pressure tappings plane, the temperature of the fluid shall preferably be measured downstream of the primary device, and the thermometer well or pocket shall take up as little space as possible. The distance between it and the primary device shall be at least equal to 5 D if the pocket is located downstream, and in accordance with the last two lines of table 3 if the pocket is located upstream.

If the measured fluid is a gas, its upstream temperature may be calculated from the temperature measured on the downstream side when assuming an isentropic expansion through the primary device.

3.4.3 Any method of determining the density, static pressure and the temperature of the fluid is acceptable if it enables reliable values of the pressure, the temperature, the viscosity and the mass density of the fluid at the upstream tapping plane to be obtained without disturbing the flow measurement in any way.

3.4.4 The temperature of the primary device and that of the fluid upstream of the primary device are assumed to be the same (see 6.1.9).

4 SELECTION OF THE PRIMARY DEVICE

Table 2 gives some indications to enable the selection of the type of primary device to be made to meet the required characteristics.

TABLE 2 – **Selection criteria of the type of primary device**

Characteristics to be considered	Consideration for selection
Pipe diameter Diameter ratio Reynolds number	For each primary device, there exist limiting values of the internal pipe diameter, the diameter ratio β and the flow Reynolds number. If the chosen value of the differential pressure and flow-rate are such that the value of β for an orifice plate exceeds the permissible limit, it may be possible to use a nozzle since it results in a lower β value for the same conditions.
Pressure loss	For the same pressure difference, pressure losses are 4 to 6 times lower for classical venturi tubes and venturi nozzles than for orifice plates and nozzles.
Straight lengths to be provided upstream and downstream	Classical venturi tubes require smaller pipe straight lengths than orifice plates, nozzles and venturi nozzles.
Overall dimensions	The required distance between flanges to mount the device into the pipe is significant for classical venturi tubes and venturi nozzles.
Type of fluid	With abrasive or corrosive fluids, the coefficients of orifice plates may change steadily with time as the square edge becomes rounded; surface deposits on nozzles and venturi tubes have an immediate effect on the flow coefficient but thereafter there is a probability that the change with time will be less.
Accuracy	The uncertainties on the flow-rate coefficient are defined for each primary device.
Cost and manufacture	Orifice plates are cheaper and simpler to manufacture than any other primary device.

5 GENERAL REQUIREMENTS FOR THE MEASUREMENTS

It is necessary to ensure that all the following requirements, some of which are explained in detail in the following sections, are completely fulfilled during the period of measurement.

5.1 Primary device

5.1.1 The primary device shall be manufactured, installed and used in accordance with this International Standard.

When the manufacturing characteristics and conditions of use of the primary devices are outside the limits given in this International Standard, it is necessary to calibrate the primary device separately under the actual conditions of use.

5.1.2 The condition of the primary device shall be checked after each measurement or after each series of measurements or at intervals close enough to each other so that the conformity with this International Standard is maintained.

Attention is drawn to the fact that even apparently neutral fluids may form deposits or encrustations on primary devices. Variations or changes in the discharge coefficient which may occur over a period of time may lead to values outside the uncertainties given in this International Standard.

5.1.3 The primary device shall be manufactured from material the coefficient of expansion of which is known, except if the user decides that the variations of dimensions due to temperature changes may be properly neglected, according to the temperature of the measured fluid.

5.2 Type of fluid

5.2.1 The fluid may be either compressible (gas) or considered as incompressible (liquid).

5.2.2 The fluid shall be physically and thermally homogeneous and of single phase. Colloidal solutions with a high degree of dispersion (such as milk), and those only, are considered to behave as a single phase fluid.

5.2.3 To carry out the measurement, it is necessary to know the density and viscosity of the fluid under the conditions of measurement (see 3.3 d).

5.3 Flow conditions

5.3.1 The rate of flow shall be constant or, in practice, vary only slightly and slowly with time. This International Standard does not provide for the measurement of pulsating flow.[1)]

5.3.2 The flow of fluid through the primary device shall not cause any change of phase. To determine whether there is a change of phase, the computation of flow shall be carried out on the assumption that the expansion is isentropic if the fluid is a gas, or isothermal if the fluid is a liquid.

5.3.3 If the fluid is gas, the pressure ratio as defined in 2.2.4 shall be equal to or greater than 0,75.

6 INSTALLATION REQUIREMENTS

6.1 General

6.1.1 The measuring process applies only to fluids flowing through a pipe-line of circular cross-section.

6.1.2 The pipe shall run full at the measuring section.

6.1.3 The primary device shall be installed in the pipe-line at a position such that the flow conditions immediately upstream sufficiently approach those of a fully developed profile and are free from swirl (see 6.4). Such conditions may be expected to exist if the installation conforms to requirements given in clause 6.

6.1.4 The primary device shall be fitted between two sections of straight cylindrical pipe of constant cross-sectional area, in which there is no obstruction or branch connection (whether or not there is flow into or out of such connections during measurement) other than those specified in this International Standard.

The pipe is considered straight when it appears so by mere visual inspection. The required minimum straight lengths of pipe, which conform to the description above, vary according to the nature of the fittings, the type of primary device and the diameter ratio. They are indicated in tables 3 and 4.

6.1.5 The value for the pipe diameter *D* to be used in the computation of the diameter ratio shall be the mean of the internal diameter over a length of 0,5 *D* upstream of the upstream pressure tapping. This internal mean diameter shall be the arithmetic mean of measurements at four diameters at least, distributed in each of at least three cross-sections themselves distributed over a length of 0,5 *D*, two of these sections being at distances 0 *D* and 0,5 *D* from the upstream tapping. If then is a carrier ring (figure 4 a) this value of 0,5 *D* is to be taken from the upstream edge of the carrier ring.

6.1.6 The pipe bore shall be circular over the entire minimum length of straight pipe required. The cross-section is taken to be circular if it appears so by mere visual inspection. The circularity of the outside of the pipe may be taken as a guide, except in the immediate vicinity of the primary device where special requirements shall apply according to the type of primary device used (see 6.5.1 and 6.6.1).

6.1.7 The internal diameter *D* of the measuring pipe shall comply with the values given for each type of primary device.

6.1.8 The inside surface of the measuring pipe shall be clean, free from pitting and deposit and not encrusted for at least a length of 10 *D* upstream and 4 *D* downstream of the primary device.

6.1.9 The measuring section and the pipe flanges shall be lagged over at least the whole length of the required straight runs. It is, however, unnecessary to lag the pipe when the temperature of the fluid, between the inlet of the minimum straight length of the upstream pipe and the outlet of the straight length of the downstream pipe, does not exceed any limiting value selected by the user as being sufficient for the accuracy of flow measurement which he requires.

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

6.2.1 The minimum straight lengths are given in tables 3 and 4.

6.2.2 The straight lengths given in tables 3 and 4 are minimum values, and straight lengths longer than those indicated are always recommended. For research work especially at least double the upstream values given in tables 3 and 4 are recommended for "zero additional uncertainty".

6.2.3 When the straight lengths comply with the requirements of tables 3 and 4 and when they are longer than or equal to the values given for "zero additional uncertainty"[2)], there is no need to add any additional deviation to the flow coefficient uncertainty to take account of the effect of such installation conditions.

1) This is the subject of Technical Report 3313 *"Measurement of pulsating fluid flow by means of orifice plates, nozzles or venturi tubes, in particular in the case of sinusoidal or square wave intermittent periodic type fluctuation"*.

2) Unbracketed values in tables 3 and 4.

6.2.4 When the upstream OR downstream straight lengths are shorter than the "zero additional uncertainty" values[1]) and equal to or greater than the "± 0,5 % additional uncertainty" values[2]), as given in tables 3 and 4, an additional deviation of ± 0,5 % shall be added arithmetically to the uncertainty on the flow coefficient.

6.2.5 If the straight lengths are shorter than "the ± 0,5 % additional uncertainty" values[2]) given in tables 3 and 4, this International Standard gives no information by which to predict the value of any further uncertainty to be taken into account; this is also the case when the upstream AND downstream straight lengths are simultaneously shorter than the "zero additional uncertainty" values[1]).

6.2.6 The valves mentioned in tables 3 and 4 shall be fully open. It is recommended that control be effected by valves located downstream of the primary device. Isolating valves located upstream shall be preferably of the "gate" type and shall be fully open.

6.2.7 After a single change of direction (bend or tee), it is recommended that the tappings (if pairs of single tappings) be installed in such a way that their axis will be perpendicular to the plane of the bend or tee.

TABLE 3 — **Required straight lengths for orifice plates, nozzles and venturi nozzles**

Minimum straight lengths required between various fittings located upstream or downstream of the primary device and the primary device itself.

The unbracketed values are "zero additional uncertainty" values (see 6.2.3).

The bracketed values are "± 0,5 % additional uncertainty" values (see 6.2.4).

All straight lengths are expressed as multiples of the diameter *D*. They shall be measured from the upstream face of the primary device.

β	**On upstream (inlet) side of the primary device**							**On downstream (outlet) side**
	Single 90° bend or tee (flow from one branch only)	Two or more 90° bends in the same plane	Two or more 90° bends in different planes	Reducer (2 *D* to *D* over a length of 1,5 *D* to 3 *D*)	Expander (0,5 *D* to *D* over a length of 1 *D* to 2 *D*)	Globe valve fully open	Gate valve fully open	All fittings included in this table
⩽ 0,20	10 (6)	14 (7)	34 (17)	5	16 (8)	18 (9)	12 (6)	4 (2)
0,25	10 (6)	14 (7)	34 (17)	5	16 (8)	18 (9)	12 (6)	4 (2)
0,30	10 (6)	16 (8)	34 (17)	5	16 (8)	18 (9)	12 (6)	5 (2,5)
0,35	12 (6)	16 (8)	36 (18)	5	16 (8)	18 (9)	12 (6)	5 (2,5)
0,40	14 (7)	18 (9)	36 (18)	5	16 (8)	20 (10)	12 (6)	6 (3)
0,45	14 (7)	18 (9)	38 (19)	5	17 (9)	20 (10)	12 (6)	6 (3)
0,50	14 (7)	20 (10)	40 (20)	6 (5)	18 (9)	22 (11)	12 (6)	6 (3)
0,55	16 (8)	22 (11)	44 (22)	8 (5)	20 (10)	24 (12)	14 (7)	6 (3)
0,60	18 (9)	26 (13)	48 (24)	9 (5)	22 (11)	26 (13)	14 (7)	7 (3,5)
0,65	22 (11)	32 (16)	54 (27)	11 (6)	25 (13)	28 (14)	16 (8)	7 (3,5)
0,70	28 (14)	36 (18)	62 (31)	14 (7)	30 (15)	32 (16)	20 (10)	7 (3,5)
0,75	36 (18)	42 (21)	70 (35)	22 (11)	38 (19)	36 (18)	24 (12)	8 (4)
0,80	46 (23)	50 (25)	80 (40)	30 (15)	54 (27)	44 (22)	30 (15)	8 (4)

	Fittings	**Minimum upstream (inlet) straight length required**
For all β values	Abrupt symmetrical reduction having a diameter ratio ⩾ 0,5	30 (15)
	Thermometer pocket or well of diameter ⩽ 0,03 *D* Thermometer pocket or well of diameter between 0,03 *D* and 0,13 *D*	5 (3) 20 (10)

1) Unbracketed values in tables 3 and 4.

2) Bracketed values in tables 3 and 4.

TABLE 4 — **Required straight lengths for classical venturi tubes**

Minimum straight lengths required between various fittings located upstream of the classical venturi tube and the classical venturi tube itself.

The values without brackets are values for a "zero additional uncertainty" (see 6.2.3).

The values between brackets are values for an "additional uncertainty of ± 0,5 %" (see 6.2.4).

All straight lengths are expressed as multiples of diameter *D*. They shall be measured from the pressure tapping plane upstream of the classical venturi tube. The pipe roughness, at least over the length indicated in table 4 shall not exceed that of a smooth, commercially available pipe-line (approximately $k/D \leqslant 10^{-3}$).

Downstream straight lengths. Fittings or other disturbances (as indicated in table 4) situated at least four throat diameters downstream of the throat pressure tapping plane do not affect the accuracy of the measurement.

Diameter ratio	Single 90° short radius bend[1]	Two or more 90° bends in the same plane[1]	Two or more 90° bends in different planes[1] [2]	Reducer 3 *D* to *D* over a length of 3,5 *D*	Expander 0,75 *D* to *D* over a length of *D*	Gate valve fully open
0,30	0,5[3]	1,5 (0,5)	(0,5)	0,5[3]	1,5 (0,5)	1,5 (0,5)
0,35	0,5[3]	1,5 (0,5)	(0,5)	1,5 (0,5)	1,5 (0,5)	2,5 (0,5)
0,40	0,5[3]	1,5 (0,5)	(0,5)	2,5 (0,5)	1,5 (0,5)	2,5 (1,5)
0,45	1,0 (0,5)	1,5 (0,5)	(0,5)	4,5 (0,5)	2,5 (1,0)	3,5 (1,5)
0,50	1,5 (0,5)	2,5 (1,5)	(8,5)	5,5 (0,5)	2,5 (1,5)	3,5 (1,5)
0,55	2,5 (0,5)	2,5 (1,5)	(12,5)	6,5 (0,5)	3,5 (1,5)	4,5 (2,5)
0,60	3,0 (1,0)	3,5 (2,5)	(17,5)	8,5 (0,5)	3,5 (1,5)	4,5 (2,5)
0,65	4,0 (1,5)	4,5 (2,5)	(23,5)	9,5 (1,5)	4,5 (2,5)	4,5 (2,5)
0,70	4,0 (2,0)	4,5 (2,5)	(27,5)	10,5 (2,5)	5,5 (3,5)	5,5 (3,5)
0,75	4,5 (3,0)	4,5 (3,5)	(29,5)	11,5 (3,5)	6,5 (4,5)	5,5 (3,5)

1) The radius of curvature of the bend shall be equal to or greater than the pipe diameter.

2) As the effect of these fittings may still be present after 40 *D*, no unbracketed values can be given in the table.

3) Since no fitting can be placed closer than 0,5 *D* to the upstream pressure tapping in the venturi tube, the "zero additional uncertainty" value is the only one applicable in this distance.

NOTE — The reasons for which the minimum straight lengths required for classical venturi tubes are less than those defined in table 3 for orifice plates, nozzles and venturi nozzles, include the following :

a) they are derived from different experimental results and different correlation approaches;

b) the convergent portion of the classical venturi tube is designed to obtain a more uniform "velocity profile" at the throat of the device. Tests have shown that with identical diameter ratios, the minimum straight lengths upstream of the classical venturi tube may be less than those required for orifice plates, nozzles and venturi nozzles.

6.2.8 The values given in tables 3 and 4 were obtained experimentally with a very long straight length upstream of the particular fitting in question and so it could be assumed that the flow upstream the disturbance was close enough to a fully developed and swirl-free flow. Usually, such conditions are not available and the following remarks may be used as a guide for normal installation practice.

a) If the primary device is installed in a pipe leading from an upstream open space or large vessel, either directly or through any fitting, the total length of pipe between the open space and the primary device shall never be less than 30 *D*[4]. If any fitting is installed, then the straight lengths given in tables 3 and 4 shall also apply between this fitting and the primary device.

b) If several fittings other than 90° bends[5] are placed in series upstream from the primary device, the following rule shall be applied : between the closest fitting (1) to the primary device and the primary device itself, there shall be a minimum straight length such as is indicated for the fitting (1) in question and the actual values of β in tables 3 and 4. But, in addition, between this fitting (1) and the preceding one (2), there shall be a straight length equal to one half of the value given in the tables 3 and 4 for fitting (2) applicable to a primary device of diameter ratio $\beta = 0,7$, whatever the actual value of β may be. This requirement does not apply when the fitting (2) is an abrupt symmetrical reduction, which case is covered by paragraph a) above.

If one of the minimum straight lengths so adopted is a bracketed one, a ± 0,5 % additional uncertainty shall be added to the flow coefficient uncertainty.

4) In the absence of experimental data, it has seemed wise to adopt for the classical venturi tubes, the conditions required for orifice plates and nozzles.

5) In the case of several 90° bends, refer to tables 3 and 4 which can be applied whatever the length between two consecutive bends.

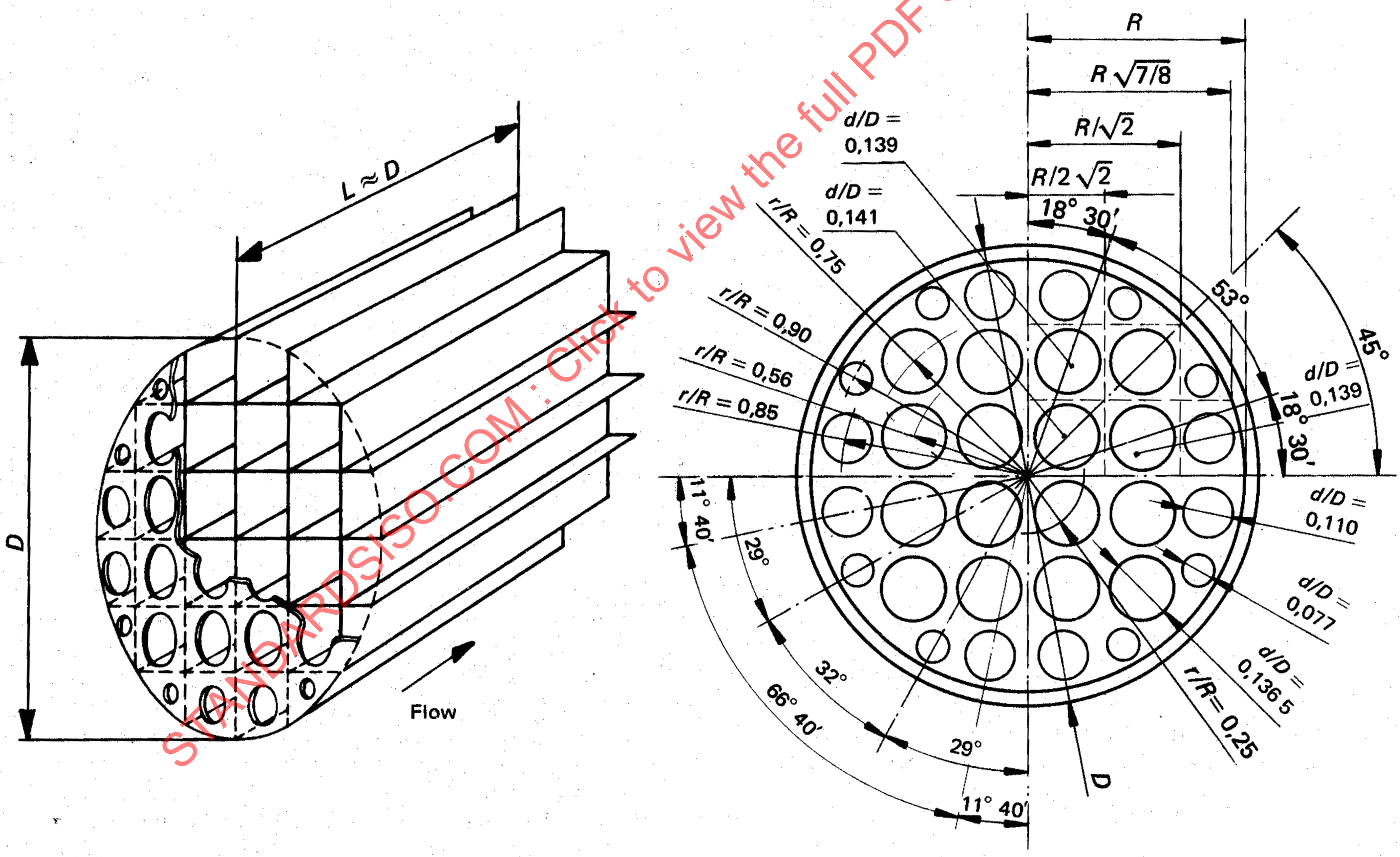
6.3 Straightening devices

The use of flow straightening devices of the types described in 6.3.2 and figure 1 is recommended to permit the installation of primary devices downstream of fittings not included in table 3 or table 4. When a large area ratio primary device is to be used the inclusion of such devices sometimes permits the use of shorter installation lengths upstream of the primary device than are given in table 3.

When installed as described in 6.3.1, the use of a flow straightener does not introduce any additional uncertainty to the flow coefficient uncertainty.

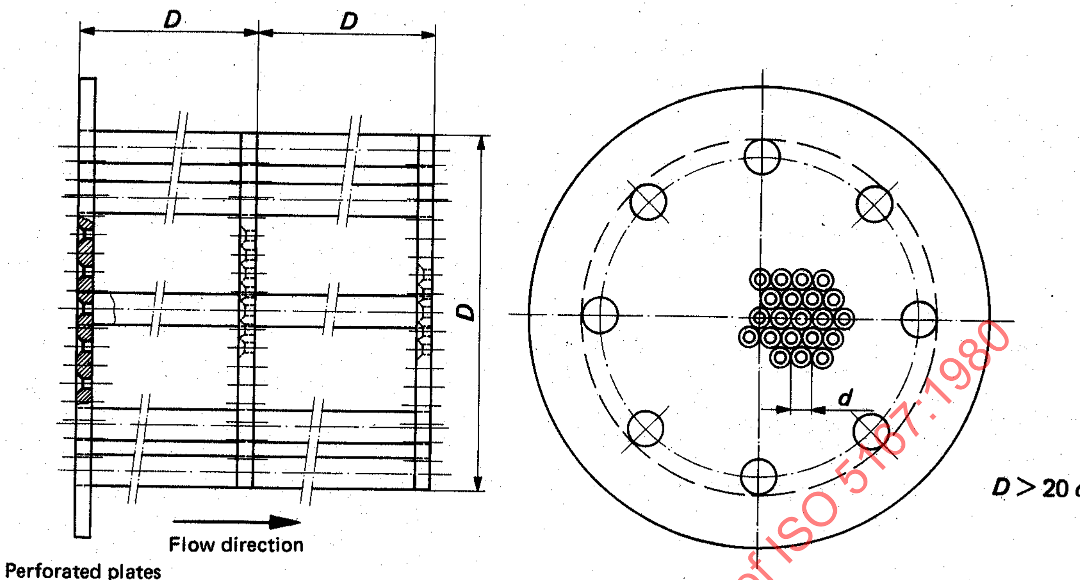
6.3.1 *Installation*

Any flow straightener used shall be installed in the straight length between the primary device and the upstream disturbance or fitting closest to the primary device. Unless the conditions stated in the first paragraph of 6.4 have been met, the straight length between this fitting and the straightener itself shall be equal to at least 20 D, and the straight length between the straightener and the primary device shall be equal to at least 22 D. Straighteners are only fully effective if their installation is such that the minimum of gaps are left around the resistive elements of the device, therefore permitting no by-pass flows which would prevent their proper functioning.

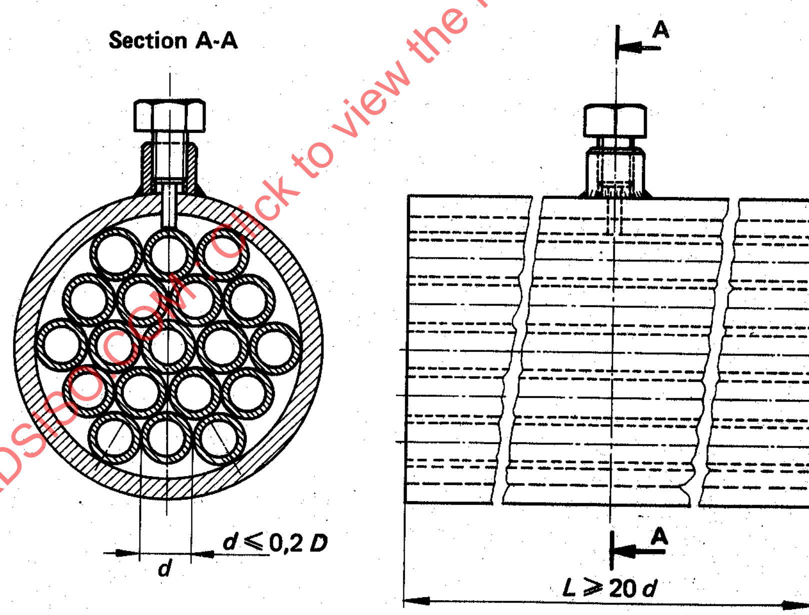


Type A : "Zanker" straightener

FIGURE 1 — Straighteners



Type B : "Sprenkle" straightener



Type C : Tube bundle straightener

NOTE — In order to decrease the pressure loss the entrance of the holes may be bevelled at 45°.

FIGURE 1 — **Straighteners** *(end)*

6.3.2 *Types of straightening devices*

The three standardised types of straighteners, A, B and C are shown in figure 1. It should be noted that these devices create a pressure loss which in the case of type A is approximately 5 $(1/2\,\rho U^2)$, in the case of type B is approximately 15 $(1/2\,\rho U^2)$, and in the case of type C is approximately 5 $(1/2\,\rho U^2)$.

6.3.2.1 TYPE A : ZANKER STRAIGHTENER

This straightener consists of a perforated plate with holes of certain specified sizes followed by a number of channels (one for each hole) formed by the intersection of a number of plates. The important dimensions are given in figure 1.

The various plates should be chosen to provide adequate strength, but they should not be unnecessarily thick.

6.3.2.2 TYPE B : SPRENKLE STRAIGHTENER

This straightener consists of three perforated plates in series with a length equal to one pipe diameter between successive plates. The perforations should preferably be chamfered on the upstream side, and the total area of the holes in each plate should be greater than 40 % of the cross sectional area of the pipe. The ratio of plate thickness to hole diameter shall be at least 1,0 and the diameter of the holes shall be less than 1/20 of the pipe diameter.

The three plates shall be held together by bars or studs, which shall be located around the periphery of the pipe bore, and which shall be of as small a diameter as possible, consistent with providing the required strength.

6.3.2.3 TYPE C : TUBE BUNDLE STRAIGHTENER

This type of straightener consist of a number of parallel tubes fixed together and held rigidly in the pipe. It is important in this case to ensure that the various tubes are parallel with each other and with the pipe axis since, if this requirement is not complied with, the straightener itself might introduce disturbances into the flow.

There shall be at least 19 tubes. Their length shall be more or equal to 20 *d*. The tubes shall be joined together and the bundle tangent to the pipe.

6.4 General requirement for flow conditions at the primary device

If the prescribed installation conditions given in tables 3 and 4 or in 6.3 cannot be met this International Standard still remains valid if it can be demonstrated that the flow conditions immediately upstream of the primary device conform to 6.1.3.

Swirl free conditions can be taken to exist when the swirl angle over the pipe is less than 2°.

Acceptable velocity profile conditions can be presumed to prevail when at each point across the pipe cross-section the ratio of the local axial velocity to the maximum axial velocity at the cross-section agrees to within ± 5 % with that which would be achieved in swirl-free flow at the same radial position at a cross-section located at the end of a very long straight length (over 100 *D*) of similar pipe.

6.5 Additional specific installation requirements for orifice plates, nozzles and venturi nozzles

6.5.1 *Circularity of the pipe*

In the immediate vicinity of the primary device the following requirements shall apply :

6.5.1.1 The length of the upstream pipe section adjacent to the primary device (or to the carrier ring if there is one) shall be at least 2 *D* and cylindrical. The pipe is said to be cylindrical when no diameter in any plane differs by more than 0,3 % from the value of *D* obtained as a mean value of all measurements in 6.1.5.

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

No additional uncertainty in the discharge coefficient is involved provided that the step between any two sections does not exceed the requirement for cylindricality of 0,3 % as defined in 6.5.1.1.

6.5.1.3 If the step *h* between any two sections exceeds the limits given in 6.5.1.2, but complies with the following relationships :

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

and

$$\frac{h}{D} \leqslant 0{,}05$$

where *s* is the distance of the step from the upstream pressure tapping or carrier ring respectively, then an additional uncertainty of ± 0,2 % shall be added arithmetically to the uncertainty for the flow coefficient.

6.5.1.4 If the step is greater than any one of the limits given in the equation above, the installation is not in accordance with this International Standard.

6.5.1.5 No diameter of the downstream straight length, considered along a length of at least 2 *D* from the upstream face of the primary device, shall differ from the mean diameter of the upstream straight length by more than ± 3 %. This can be judged by the check of a single diameter of the downstream straight length.

6.5.2 *Drain holes and vent holes*

The pipe may be provided with the necessary drain holes for the removal of solid deposits and fluids other than the measured fluid and also of vent holes. There shall be no flow through these drain holes and vent holes however while flow measurement is in progress.

The drain holes and vent holes should not be located near to the primary device, unless it is unavoidable to do so. In such a case, the diameter of these drain holes shall be smaller than 0,08 D and their location such that the distance, measured on a straight line, from one of these holes to a pressure tapping of the primary device placed on the same side of this primary device, is always greater than 0,5 D. Furthermore, the centre-line of the drain hole or vent hole shall be situated in an axial sector of the pipe which does not include any pressure tapping.

6.5.3 *Location of primary device and rings*

6.5.3.1 The primary device shall be placed in the pipe in such a way that the fluid flows from the upstream face towards the downstream face (see the arrow "flow direction" on the figures.

6.5.3.2 The primary device shall be perpendicular to the centre-line of the pipe to within ± 1°.

6.5.3.3 The primary device shall be centred in the pipe or, if applicable, in the carrier rings. The distance e_x between the centre-line of the orifice and the centre-lines of the pipe on the upstream and downstream sides shall be less than or equal to :

$$\frac{0{,}000\,5\,D}{0{,}1 + 2{,}3\,\beta^4}$$

If $\frac{0{,}000\,5\,D}{0{,}1 + 2{,}3\,\beta^4} < e_x \leqslant \frac{0{,}005\,D}{0{,}1 + 2{,}3\,\beta^4}$, an additional error of ± 0,3 % shall be added arithmetically to the uncertainty on the flow coefficient α. In the case where $e_x > \frac{0{,}005\,D}{0{,}1 + 2{,}3\,\beta^4}$ this International Standard gives no information by which to predict the value of any further uncertainty to be taken into account.

6.5.3.4 When carrier rings are used, they shall be so centred that at no point do they protrude into the pipe.

6.5.4 *Fixing and gaskets*

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

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

6.5.4.2 Gaskets, if used, shall be made and inserted in such a way that they do not protrude at any point inside the pipe or across the pressure hole or slot when corner tappings are used. They shall be as thin as possible and in any case shall not be thicker than 0,03 D.

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

6.6 Additional specific installation requirements for classical venturi tubes

6.6.1 *Circularity of the pipe*

In the immediate vicinity of the classical venturi tube the following requirements shall apply :

6.6.1.1 Over an upstream length of at least 2 D measured from the upstream end of the entrance cylinder of the venturi tube, the pipe shall be cylindrical.

6.6.1.2 The mean diameter of the pipe, D, where it joins the classical venturi tube shall be within ± 1 % of the classical venturi tube entrance cylinder diameter. Moreover, no single diameter of this inlet pipe section shall differ from the mean of the measured diameters by more than ± 2 % for a distance of two pipe diameters preceding the classical venturi tube.

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

6.6.2 *Roughness of the upstream pipe*

The upstream pipe shall have a roughness of $k/D \leqslant 10^{-3}$ on a length at least equal to 2 D measured upstream from the classical venturi tube.

6.6.3 *Alignment of the classical venturi tube*

The offset or distance between the centre-lines of the upstream pipe and of the venturi tube as measured in the connecting plane of the upstream pipe and piece of pipe A, (see 9.1.2), shall be less than 0,005 D. The angular alignment uncertainty of the venturi tube centre-line with respect to the upstream pipe centre-line shall be less than 1°. Finally the sum of the offset and half the diameter deviation (see 6.1.5) shall be less than 0,007 5 D.

6.6.4 *Drain holes and vent holes*

The pipe may be provided with the drain holes necessary for the removal of solid deposits and fluids other than the measured fluid and also with vent holes. There shall be no flow however through these drain holes or vent holes while flow measurement is in progress.

7 ORIFICE PLATES

The various types of standard orifice plates are similar and therefore need only the one description. Each type of standard orifice plate is characterized by the arrangement of pressure tappings.

No orifice plate can be used according to this standard unless it conforms with the following description under flowing conditions.

7.1 Description

The axial plane cross-section of the plate is shown in figure 2.

The letters shown in figure 2 are for reference purposes in the following text.

7.1.1 *General shape*

7.1.1.1 The part of the plate inside the pipe shall be circular and concentric with the pipe centre-line. The faces of this plate shall always be flat and parallel.

7.1.1.2 Unless otherwise stated, the following descriptions apply only to that part of the plate intended to be located within the pipe.

7.1.1.3 Care shall be taken in the design of the orifice plate to ensure that the plastic buckling and elastic deformation of the plate, due to the strength of the differential pressure or of any other stress does not cause the flatness limit given below to be exceeded.

7.1.2 *Upstream face* A

7.1.2.1 The upstream face of the plate A shall be flat. It is considered as such when the slope of a straight line connecting any two points of its surface in relation to a plane perpendicular to the centre-line is less than 1 %, ignoring the inevitable local defects of the surface which are invisible to the naked eye.

7.1.2.2 The upstream face of the orifice plate shall have a roughness criterion $R_a \leqslant 10^{-4}\, d$ within a circle whose diameter is not less than 1,5 d and which is concentric with the orifice.

7.1.2.3 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.

7.1.3 *Downstream face* B

7.1.3.1 The downstream face shall be flat and parallel with the upstream face.

7.1.3.2 It is unnecessary to provide the same quality of surface finish for the downstream face as for the upstream face.

7.1.3.3 The flatness and surface condition of the downstream face can be judged by mere visual inspection.

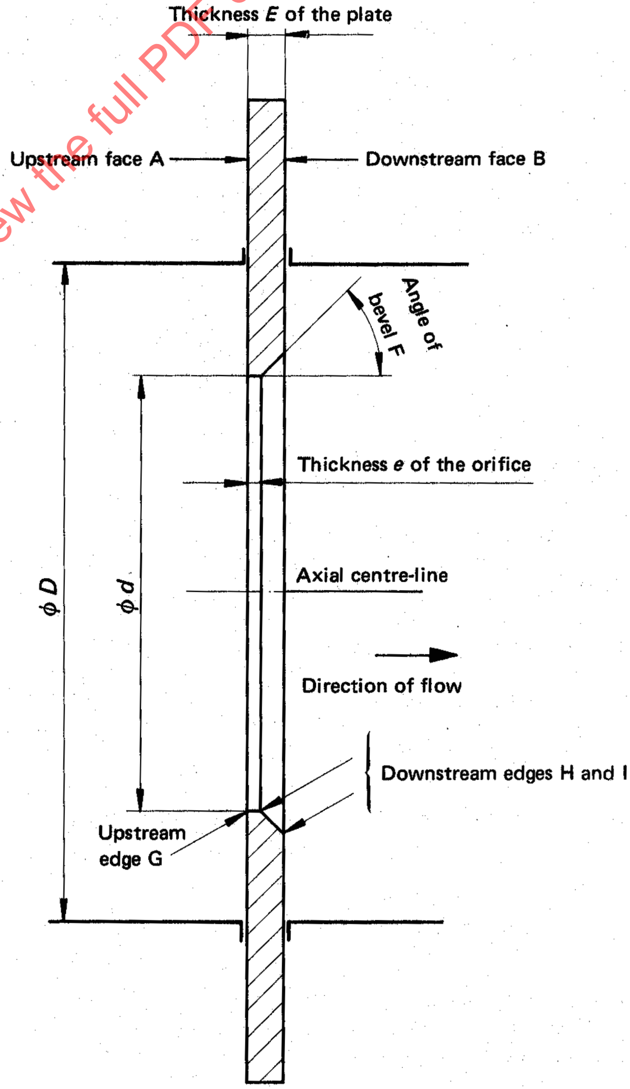


FIGURE 2 — **Standard orifice plate**

7.1.4 *Thickness E and e*

7.1.4.1 The thickness e of the orifice shall be between 0,005 D and 0,02 D.

7.1.4.2 The values of e measured at any point on the orifice shall not differ among themselves by more than 0,001 D.

7.1.4.3 The thickness E of the plate shall be between e and 0,05 D.

7.1.4.4 The values of E measured at any point of the plate shall not differ among themselves by more than 0,001 D.

7.1.5 *Angle of bevel* F

7.1.5.1 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.

7.1.5.2 The angle of bevel F shall be between 30 and 45°.

7.1.6 *Edges* G, H *and* I

7.1.6.1 The upstream edge G and the downstream edges H and I shall have neither wire-edges, nor burrs, nor, in general, any peculiarities visible to the naked eye.

7.1.6.2 The upstream edge G shall be sharp. It is considered so if the edge radius is not greater than 0,000 4 d.

If $d \geqslant 125$ mm this condition may generally be considered as satisfied by mere visual inspection, checking that the edge does not seem to reflect a beam of light when viewed with a naked eye.

If $d < 125$ mm visual inspection is not sufficient but this condition may generally be considered as satisfied when the upstream face of the orifice plate is finished by a very fine radial cut from the centre outwards (see 7.1.9.2).

However if there is any doubt as to whether this condition is satisfied, the edge radius must be actually measured.

7.1.7 *Diameter of orifice d*

7.1.7.1 The diameter d shall be in any case equal to or greater than 12,5 mm. The ratio $\beta = d/D$ is always equal to or greater than 0,20 or 0,23 and less than or equal to 0,75 or 0,80 according to the type of orifice plate used.

Within these limits, the value of β is chosen by the user and represents a parameter for defining an orifice plate of a given type.

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

7.1.7.3 The orifice shall be cylindrical and perpendicular to the upstream face.

No diameter shall differ by more than 0,05 % from the value of the mean diameter. This requirement is 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.

Attention is called to the fact that it is possible to check circularity of an orifice bore within the accuracy required without it being necessary to measure the mean diameter of the orifice bore itself.

7.1.8 *Symmetrical plates*

7.1.8.1 If the orifice plate is intended to be used for measuring reverse flows,

- the plate shall not be bevelled;
- the two faces shall be in accordance with the description of the upstream face as in 7.1.2;
- the thickness E of the plate shall be equal to the thickness e of the orifice as described in 7.1.4;
- the two edges of the orifice shall be in accordance with the description of the upstream edge as in 7.1.6.

7.1.8.2 Furthermore (see 7.2), for orifice plates with D and $D/2$ tappings, two sets of upstream and downstream pressure taps should be arranged and used alternatively.

7.1.9 *Material and manufacture*

7.1.9.1 The plate can be manufactured of any material and in any way, provided it is and remains in accordance with the foregoing description during the flow measurements.

In particular, the plate shall be clean when the measurements are made.

7.1.9.2 The machining required to obtain a plate conforming to the description of this International Standard calls for the use of machine tools of good quality and in good condition.

7.2 Pressure tappings

At least one upstream pressure tapping and one downstream pressure tapping shall be provided for each primary device, installed in one or other of the recommended standard positions.

A single plate can be used with several sets of pressure tappings suitable for different types of standard orifice plates, but to avoid mutual interference, several tappings on the one side of the orifice plate shall not be in the same axial plane.

7.2.1 *Shape and diameters of pressure tappings, other than corner tappings (for corner tappings see 7.2.4)*

7.2.1.1 The centre-line of the tapping shall meet the pipe centre-line and be at right angles to it.

7.2.1.2 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, a minimum rounding shall be permitted but shall be kept as small as possible and where it can be measured its radius shall be less than 1/10th 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.

7.2.1.3 Conformity of the pressure tappings with the two foregoing descriptions can be judged by mere visual inspection.

7.2.1.4 The diameters of pressure tappings shall be less than 0,08 D and preferably less than 12 mm. No restriction is placed on the minimum diameter which is determined in practice by the likelihood of accidental blockage and satisfactory dynamic performance. The upstream and downstream pressure tappings shall have the same diameter.

7.2.1.5 The pressure tappings shall be cylindrical over a length at least 2,5 times the diameter of the tapping, measured from the inner wall of the pipe-line.

7.2.2 *Angular position of pressure tappings, other than corner tappings*

7.2.2.1 The centre-lines of the pressure tappings may be located in any axial plane of the pipe-line subject to the comment made in 6.2.7.

7.2.2.2 The axis of the upstream tapping and that of the downstream tapping may be located in different axial planes (see also 6.2.7).

7.2.2.3 However, attention is drawn to the fact that, in all cases, the readings of differential pressure obtained by these pressure tappings shall be in accordance with the definition of 2.2.3.

7.2.3 *Spacing of pressure tappings*

7.2.3.1 The spacing l of a pressure tapping is the distance between the centre-line of the pressure tapping and the plane of one specified face of the orifice plate. When installing the pressure tappings, due account must be taken of the thickness of the gaskets and/or sealing material, if such gaskets or material are to be used.

7.2.3.2 The spacing of the pressure tapping characterizes the type of standard orifice plate.

7.2.3.3 The spacing of corner tappings is described under 7.2.4.

7.2.3.4 ORIFICE PLATE 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 0,9 D and 1,1 D without modification of the flow coefficient.

The spacing l_2 of the downstream pressure tapping is nominally equal to 0,5 D, but may be between following values without modification of the flow coefficient :

between 0,48 D and 0,52 D when $\beta \leqslant 0{,}6$

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

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

7.2.3.5 ORIFICE PLATE WITH FLANGE TAPPINGS (see figure 3)

The spacing l_1 of the upstream pressure tapping is nominally of 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 of 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 between the following values without modification of the flow coefficient :

between 25,4 ± 0,5 mm when, simultaneously, $\beta > 0{,}6$ and 58 mm $< D <$ 150 mm

between 25,4 ± 1 mm in the other cases, that is $\beta \leqslant 0{,}6$

or $\beta > 0{,}6$ but 50 mm $\leqslant D \leqslant$ 58 mm

or $\beta > 0{,}6$ but 150 mm $\leqslant D \leqslant$ 760 mm

7.2.4 *Corner tappings*

7.2.4.1 The spacing between the centre-lines 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 7.2.4.5).

7.2.4.2 The pressure tappings may be either single tappings or annular slots, as shown in figure 4, to which the letters below refer. Both types of tappings can be located either in the pipe or its flanges or in carrier rings as shown in the figures.

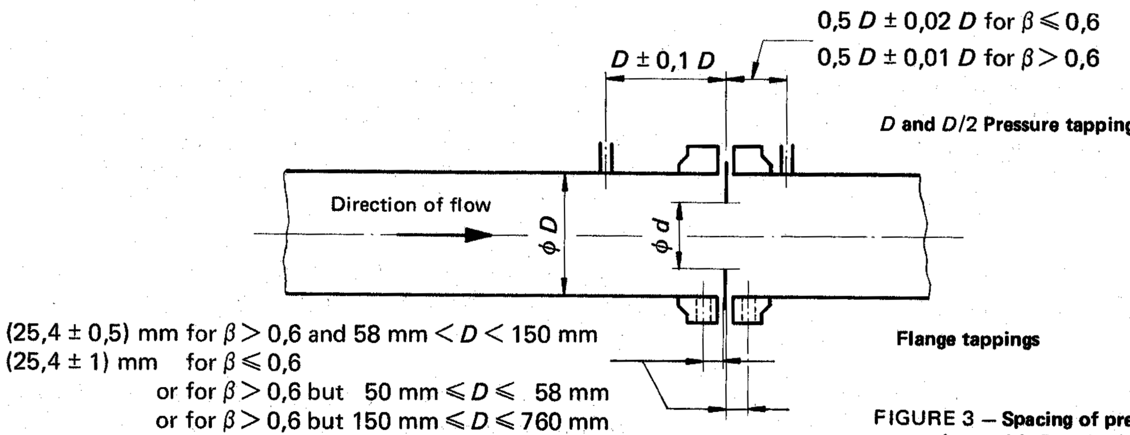


FIGURE 3 — **Spacing of pressure tappings for orifice plates with D and $D/2$ or flange tappings**

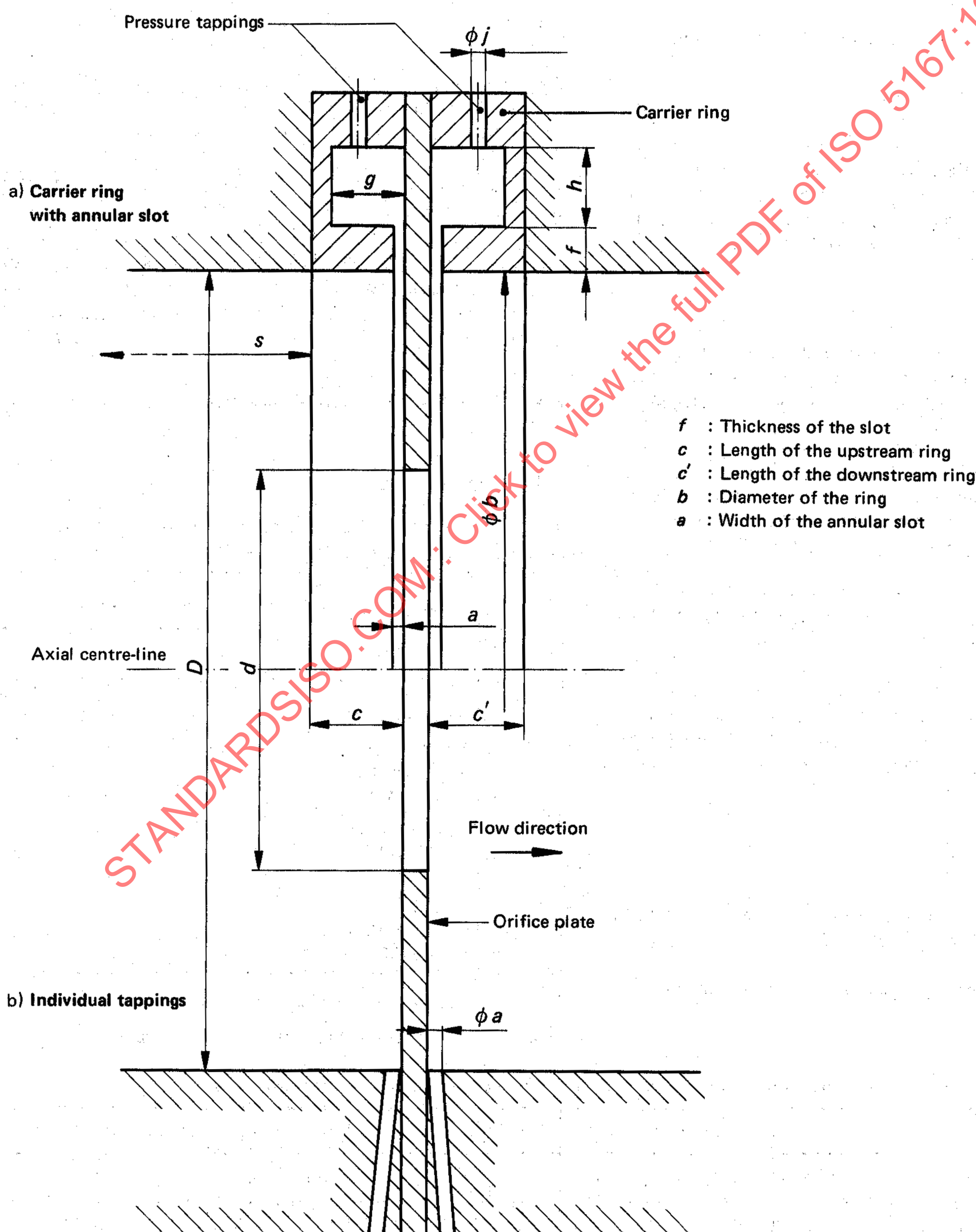


FIGURE 4 — **Corner tappings**

7.2.4.3 The diameter a of single tappings or the width a of annular slots are given below. The minimum diameter is determined in practice by the likelihood of accidental blockage and satisfactory performance.

Clean fluids and steam

For $\beta \leqslant 0{,}65$: $0{,}005\,D \leqslant a \leqslant 0{,}03\,D$

For $\beta > 0{,}65$: $0{,}01\,D \leqslant a \leqslant 0{,}02\,D$

For any values of β

For clean fluids : $1\text{ mm} \leqslant a \leqslant 10\text{ mm}$

For steam with annular chambers : $1\text{ mm} \leqslant a \leqslant 10\text{ mm}$

For steam and for liquefied gases with single tappings : $4\text{ mm} \leqslant a \leqslant 10\text{ mm}$

7.2.4.4 The annular slots usually break through the pipe over the entire perimeter, with no break in continuity. If not, each 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 each is at least 12 mm².

7.2.4.5 If individual pressure tappings, as shown in figure 4 b), are used, the centre-line of the tappings shall cross the centre-line of the pipe at as near a right angle (90°) as possible.

If there are several individual pressure tappings for the same upstream or downstream axial plane, their centre-lines shall form equal angles with each other. The diameters of individual pressure tappings are given in 7.2.4.3.

The pressure tappings shall be cylindrical over a length at least 2,5 times the diameter of the tappings, measured from the inner wall of the pipe-line.

7.2.4.6 The inner diameter b of the carrier rings must be equal to or greater than the diameter D of the pipe to ensure that they do not protrude into the pipe. The following relation must be fulfilled :

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

The lengths c and c' of the upstream and downstream rings (figure 4) shall not be greater than $0{,}5\,D$.

Moreover, the value of b shall be within the following limits :

$D \leqslant b \leqslant 1{,}04\,D$

The length f 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 $g \times h$ shall be greater than or equal to half the total area of the opening connecting this chamber to the inside of the pipe.

7.2.4.7 All surfaces of the ring which can be in contact with the measured fluid shall be clean and have a good machine finish.

7.2.4.8 The pressure tappings connecting the annular chambers to the secondary devices are pipe-wall tappings, circular at the point of breakthrough and with diameters j between 4 and 10 mm. (See 7.2.1.2.)

7.2.4.9 The upstream and downstream carrier rings are not necessarily symmetrical in relation to each other, but they shall both conform with the foregoing specifications.

7.2.4.10 The diameter of the pipe to be used for the calculation of the diameter ratio, and hence the flow-rate, is to be measured as defined in 6.1.5, the carrier ring being regarded as part of the primary device. This also applies to the length requirement given in 6.5.1.3 so that the length s is to be taken from the upstream edge of the recess formed by the carrier ring.

7.3 Coefficients and corresponding uncertainties of orifice plates

7.3.1 *Limits of use*

These types of orifice plates shall only be used in accordance with this International Standards when :

	Corner taps	Flange taps	D and $D/2$ taps
d (mm)	$\geqslant 12{,}5$	$\geqslant 12{,}5$	$\geqslant 12{,}5$
D (mm)	$50 \leqslant D \leqslant 1\,000$	$50 \leqslant D \leqslant 760$	$50 \leqslant D \leqslant 760$
β	$0{,}23 \leqslant \beta \leqslant 0{,}80$	$0{,}2 \leqslant \beta \leqslant 0{,}75$	$0{,}2 \leqslant \beta \leqslant 0{,}75$
Re_D	$5\,000 \leqslant Re_D \leqslant 10^8$ for $0{,}23 \leqslant \beta \leqslant 0{,}45$ $10\,000 \leqslant Re_D \leqslant 10^8$ for $0{,}45 < \beta \leqslant 0{,}77$ $20\,000 \leqslant Re_D \leqslant 10^8$ for $0{,}77 < \beta \leqslant 0{,}80$	$\geqslant 1\,260\,\beta^2 D$ 1) $\leqslant 10^8$	$\geqslant 1\,260\,\beta^2 D$ 1) $\leqslant 10^8$

1) Where D is expressed in millimetres.

In addition, roughness shall conform to the values in table 5.

TABLE 5 — **Upper limits of relative roughness of the upstream pipe-line for orifice plates**

β		$\leqslant 0{,}3$	0,32	0,34	0,36	0,38	0,4	0,45	0,5	0,6	0,7	0,8
Corner taps	$10^4\,k/D$	25	18,1	12,9	10,0	8,3	7,1	5,6	4,9	4,2	4,0	3,9
Flange taps and D and $D/2$ taps	$10^4\,k/D$	25	18,1	12,9	10	10	10	10	10	10	10	10

The value of k, uniform equivalent roughness, expressed in length units, depends on several factors such as height, distribution, angularity and other geometric aspects of the roughness elements at the pipe wall.

A full scale pressure loss test of a sample length of the particular pipe should be carried out to determine the value of k satisfactorily.

However, approximate values of k for different materials can be obtained from the various tables given in reference literature, and table 6 gives values of k for a variety of materials, as derived from the Colebrook formula.

Most of the experiments on which the values of C given in the present International Standard are based, were carried out in pipes with a relative roughness $k/D \leqslant 3{,}8 \times 10^{-4}$ as regards corner tappings, or $k/D \leqslant 10 \times 10^{-4}$ as regards D and $D/2$ or flange tappings.

Pipes with higher relative roughness may be used if the roughness for at least 10 D upstream of the orifice plate is within the limits given in table 5.

7.3.2 *Coefficients*

7.3.2.1 Discharge coefficient

The discharge coefficient C is given by the Stolz equation :

$$C = 0{,}595\,9 + 0{,}031\,2\,\beta^{2{,}1} - 0{,}184\,0\,\beta^{8} + 0{,}002\,9\,\beta^{2{,}5}\left[\frac{10^6}{Re_D}\right]^{0{,}75} + 0{,}090\,0\,L_1\,\beta^4\,(1-\beta^4)^{-1} - 0{,}033\,7\,L'_2\,\beta^3$$

NOTE — When $L_1 \geqslant \dfrac{0{,}039\,0}{0{,}090\,0}$ ($= 0{,}433\,3$), use 0,039 0 for coefficient of $\beta^4\,(1-\beta^4)^{-1}$.

COMMENTS

In this equation :

C is the discharge coefficient;

β is the diameter ratio, $\beta = d/D$;

Re_D is the pipe Reynolds number;

$L_1 = l_1/D$ is the quotient of the distance of upstream tapping from the UPSTREAM face of the plate, divided by the pipe diameter;

$L'_2 = l'_2/D$ is the quotient of the distance of downstream tapping from the DOWNSTREAM face of the plate, divided by the pipe diameter. (The notation L'_2 denotes the reference of the downstream spacing from the DOWNSTREAM face, while L_2 would denote a reference of the downstream spacing from the UPSTREAM face.)

The values of L_1 and L'_2 to be entered in the equation, when the spacings are in accordance with the conditions of clauses 7.2.4 or 7.2.3.4 or 7.2.3.5 are as follows :

— for corner tappings :

$L_1 = L'_2 = 0$

— for D and $D/2$ tappings :

$L_1 = 1$

$L'_2 = 0{,}47$

(since L_1 is always $> 0{,}433\,3\ldots$ one will always use 0,039 0 for coefficient of $\beta^4\,(1-\beta^4)^{-1}$)

— for flange tappings

$L_1 = L'_2 = 25{,}4/D$ (D in millimetres)

TABLE 6 — Examples of values of the pipe wall roughness k

Material	Condition	k, mm
brass, copper, aluminium, plastics, glass	smooth, without sediments	< 0,03
steel	new, seamless cold drawn	< 0,03
	new, seamless hot drawn new, seamless rolled new, welded longitudinally	0,05 to 0,10
	new, welded spirally	0,10
	slightly rusted	0,10 to 0,20
	rusty	0,20 to 0,30
	encrusted	0,50 to 2
	with heavy incrustations	> 2
	bituminized, new	0,03 to 0,05
	bituminized, normal	0,10 to 0,20
	galvanized	0,13
cast iron	new	0,25
	rusty	1,0 to 1,5
	encrusted	> 1,5
	bituminized, new	0,03 to 0,05
asbestos cement	insulated and not insulated, new	< 0,03
	not insulated, normal	0,05

(in pipe lines with $D \leqslant 58{,}62$ mm, $L_1 \geqslant 0{,}433\,3 \ldots$ and one will then use 0,039 0 for the coefficient of $\beta^4 (1-\beta^4)^{-1}$)

Moreover :

This formula is to be used only for the tappings arrangements defined in sub-clauses 7.2.3.4 or 7.2.3.5 or 7.2.4. 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 tappings arrangements.

This formula is valid and so are the uncertainties as given hereunder, when the measurement matches all the limits stated in 7.3.1, and the general installation conditions as stated in clause 6.

7.3.2.2 EXPANSIBILITY (EXPANSION) FACTOR

For the three tappings arrangements, the empirical formula for computing the expansibility (expansion) factor is as follows :

$$\epsilon = 1 - (0{,}41 + 0{,}35\,\beta^4)\,\frac{\Delta p}{\kappa p_1}$$

This formula is applicable only within the range of the limits of use given in 7.3.1.

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

However, the formula is applicable only if $\frac{p_2}{p_1} \geqslant 0{,}75$.

7.3.3 *Uncertainties*

7.3.3.1 UNCERTAINTY OF DISCHARGE COEFFICIENT

When β, D, Re_D and k/D are assumed to be known without error, the percentage uncertainty of the value of C is equal to :

	Corner taps	Flange taps	D and $D/2$ taps
$\beta \leqslant 0{,}6$	0,6 %	0,6 %	0,6 %
$0{,}6 \leqslant \beta < 0{,}8$	β %	–	–
$0{,}6 \leqslant \beta \leqslant 0{,}75$	–	β %	β %

7.3.3.2 UNCERTAINTY OF EXPANSIBILITY (EXPANSION FACTOR)

When β, $\frac{\Delta p}{p_1}$ and κ are assumed to be known without error, the percentage uncertainty of the value of ϵ is equal to :

$\pm 4 \frac{\Delta p}{p_1}$ % when $\beta \leqslant 0{,}75$

$\pm 8 \frac{\Delta p}{p_1}$ % when $0{,}75 < \beta \leqslant 0{,}8$ (corner taps only)

7.3.3.3 Tables 10 to 29 which show the values of C and α as functions of β, Re_D and D are given for convenience. They are not intended for precise interpolation. Extrapolation is not permitted.

7.4 Pressure loss $\Delta\overline{\omega}$

The pressure loss, $\Delta\overline{\omega}$, for the orifice plates described in this International Standard is approximately related to the differential pressure Δp by the equation,

$$\Delta\overline{\omega} \approx \frac{1 - \alpha\beta^2}{1 + \alpha\beta^2}\,\Delta p$$

This pressure loss is the difference in static pressure between a wall pressure measured on the upstream side of the primary device where the influence of the approach impact pressure adjacent to the plate becomes negligible and that measured on the downstream side of the device where the static pressure recovery by expansion of the jet may be considered as just completed.

8 NOZZLES

There are two types of standard nozzles :

– ISA 1932 nozzles, and

– long radius nozzle,

which are different and are described separately.

8.1 ISA 1932 nozzle

Figure 5 shows the section of an ISA 1932 nozzle at a plane passing through the centre-line of the throat.

The letters in the following text are those shown on figure 5.

8.1.1 *General shape*

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

8.1.2 *Nozzle profile*

8.1.2.1 The profile of the nozzle may be characterized by describing :

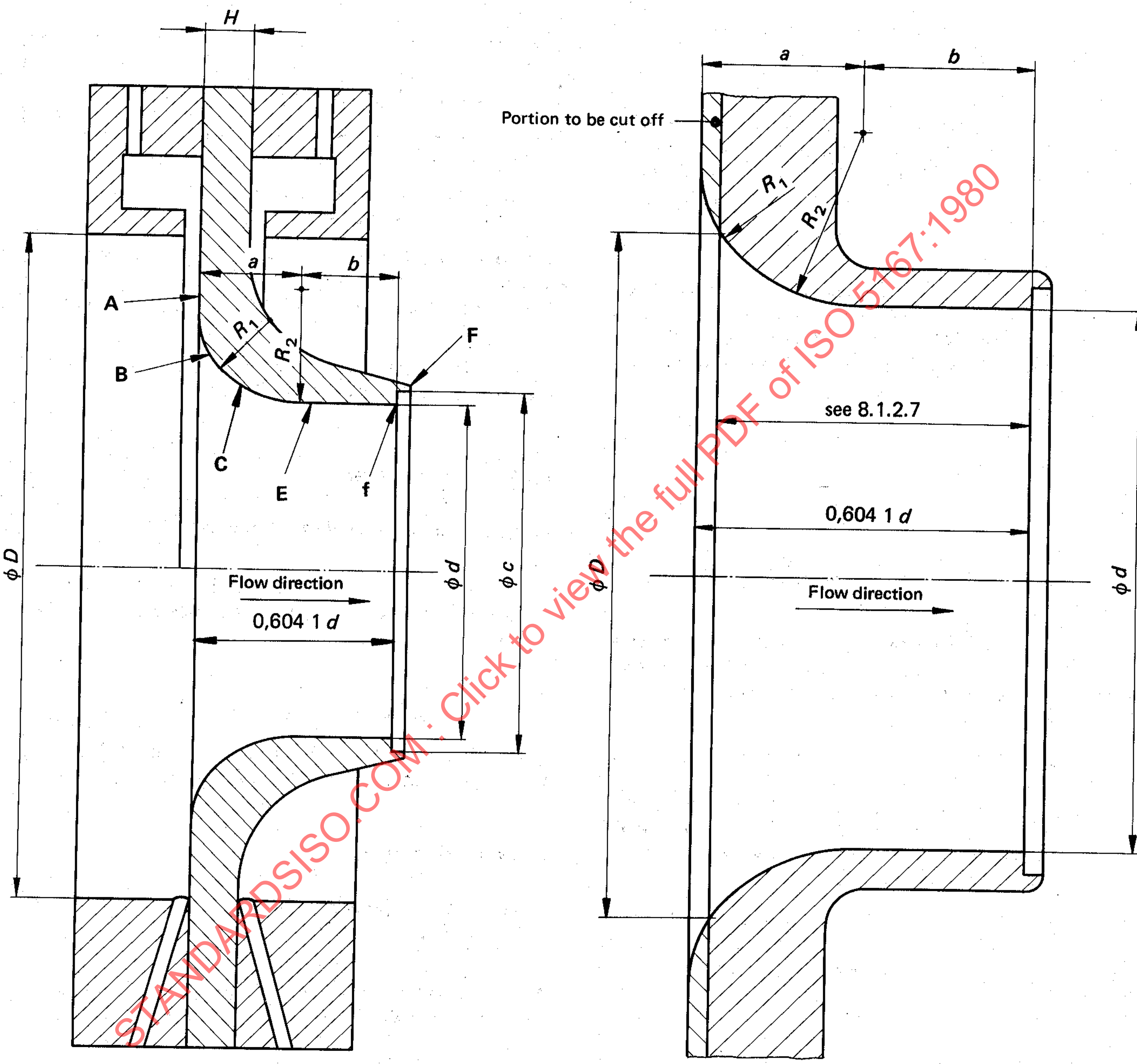
– a flat inlet part A, perpendicular to the centre-line,

– a convergent section defined by two arcs of circumference, B and C,

– a cylindrical throat E,

– a recess F which is required only if damage to the edge f is feared.

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



a) $d < \frac{2}{3} D$

b) $d > \frac{2}{3} D$

FIGURE 5 — ISA 1932 nozzle

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

When d is more than $2\ D/3$, the upstream face of the nozzle does not include a flat inlet part within the pipe. In this case, the nozzle is manufactured as if D is greater than $3\,d/2$ and the inlet flat part is then faced off so that the smallest diameter of this flat part is just equal to D (see figure 5 b), and 8.1.2.7).

8.1.2.3 The arc of circumference B is tangential to the flat inlet part A, when $d < 2\ D/3$ while its radius R_1 is equal to $0{,}2\ d \pm 10\ \%$ for $\beta < 0{,}5$; to $0{,}2\ d \pm 3\ \%$ for $\beta \geqslant 0{,}5$ and its centre is at $0{,}2\ d$ from the inlet plane and at $0{,}75\ d$ from the axial centre-line.

8.1.2.4 The arc of circumference C is tangential to the arc of circumference B and to the throat E. Its radius R_2 is equal to $d/3 \pm 10\ \%$ for $\beta < 0{,}5$ and to $d/3 \pm 3\ \%$ for $\beta \geqslant 0{,}5$. Its centre is at $d/2 + d/3 = 5\ d/6$ from the axial centre-line and at

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

from the flat inlet part A.

8.1.2.5 The throat E has a diameter d and a length $b = 0{,}3\,d$.

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

The throat shall be cylindrical. Any diameter of any cross-section shall not differ by more than 0,05 % from the value of the mean diameter. This requirement is considered as satisfied when the deviations in the length of any of the measured diameters comply with the said requirement in respect of deviation from the mean.

Attention is called to the fact that it is possible to check the circularity of the nozzle bore within the accuracy required without it being necessary to measure the mean diameter of nozzle bore itself.

8.1.2.6 The recess F has a diameter c equal to at least $1{,}06\,d$ and a length equal to or less than $0{,}03\,d$. The ratio of the height $\frac{c-d}{2}$ of the recess to its axial length shall not be greater than 1,2.

The outlet edge f shall be sharp.

8.1.2.7 The total length of the nozzle, excluding the recess F is $0{,}604\ 1\ d$ when d is less than $2\ D/3$ and is shorter, due to the inlet profile, if d is more than $2\ D/3$.

The values below summarize the total length of the nozzle, excluding the recess, as a function of β.

TABLE 7

Values of β	Total length of the nozzle, excluding the recess
$0{,}32 \leqslant \beta \leqslant \frac{2}{3}$	$0{,}604\ 1\ d$
$\frac{2}{3} < \beta \leqslant 0{,}8$	$\left[0{,}404\ 1 + \left(\frac{0{,}75}{\beta} - \frac{0{,}25}{\beta^2} - 0{,}522\ 5\right)^{\frac{1}{2}}\right] d$

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

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

8.1.2.9 The surface of the upstream face and the throat shall have a roughness criterion $R_a \leqslant 10^{-4}\ d$.

8.1.3 *Downstream face*

8.1.3.1 The thickness H shall not exceed $0{,}1\ D$.

8.1.3.2 Apart from the above condition, the profile and the surface finish of the downstream face are not specified (see 8.1.1).

8.1.4 *Material and manufacture*

The equivalent details given in 7.1.9.1 and 7.1.9.2, apply, to the manufacture of the ISA 1932 nozzle.

8.1.5 *Pressure tappings*

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

8.1.5.2 The upstream corner tappings shall comply with the requirements in 7.2.4.

8.1.5.3 The downstream pressure tappings may be corner tappings or located further downstream but in all cases the distance between the centre of the tapping and the upstream of the nozzle must be

$\leqslant 0{,}15\ D$ for $\beta \leqslant 0{,}67$

and

$\leqslant 0{,}2\ D$ for $\beta > 0{,}67$

8.1.5.4 The diameter of the downstream tappings shall be in accordance with 7.2.1.4. Corner tappings as described in 7.2.4 may also be used.

8.1.6 *Coefficients of ISA 1932 nozzles*

8.1.6.1 Limits of use

This type of nozzle shall only be used in accordance with this International Standard when :

$50 \text{ mm} \leqslant D \leqslant 500 \text{ mm}$

$0,3 \leqslant \beta \leqslant 0,8$

and Re_D is within following limits :

for $0,30 \leqslant \beta < 0,44$ $\quad 70\,000 \leqslant Re_D \leqslant 10^7$

for $0,44 \leqslant \beta \leqslant 0,80$ $\quad 20\,000 \leqslant Re_D \leqslant 10^7$

8.1.6.2 Discharge coefficient

The discharge coefficient C is given by the following formula :

$$C = 0,990\,0 - 0,226\,2\,\beta^{4,1} + \left[0,000\,215 - 0,001\,125\,\beta + 0,002\,490\,\beta^{4,7}\right]\left[\frac{10^6}{Re_D}\right]^{1,15}$$

Tables 30 and 31 which show the corresponding values of C or α as a function of β and Re_D are given for convenience. They are not intended for precise interpolation; extrapolation is not permitted.

Most of the experiments on which the above values of C are based were carried out in pipes with a relative roughness $k/D \leqslant 3,8 \times 10^{-4}$. Pipes with higher relative roughness may be used if the roughness of at least $10\,D$ upstream of the nozzle is within the limits given in table 8 (see 7.3.1 for estimation of k/D).

8.1.6.3 Expansibility (expansion) factor

The expansibility (expansion) factor, ϵ, is calculated by means of the following formula :

$$\epsilon = \left[\left(\frac{\kappa\,\tau^{\frac{2}{\kappa}}}{\kappa - 1}\right)\left(\frac{1-\beta^4}{1-\beta^4\,\tau^{\frac{2}{\kappa}}}\right)\left(\frac{1-\tau^{\frac{\kappa-1}{\kappa}}}{1-\tau}\right)\right]^{\frac{1}{2}}$$

This formula is applicable only for values of β, D and Re_D as stated in 8.1.6.1. Test results for determination of ϵ are known for air, steam and natural gas only. However, there is no known objection to using the same formula for other gases and vapours the isentropic exponent of which is known.

However, the formula is applicable only if $\dfrac{p_2}{p_1} \geqslant 0,75$.

Table 34 which shows the corresponding values of the expansibility factor for a range of isentropic exponents, pressure ratios and area ratio values is given for convenience. It is not intended for precise interpolation; extrapolation is not permitted.

8.1.7 *Uncertainties*

8.1.7.1 Uncertainty of discharge coefficient *C*

The relative uncertainty on the value of C, disregarding the uncertainties on β, D, Re_D and assuming that k/D is within the prescribed limits, is equal to :

0,8 % for $\beta \leqslant 0,6$

$(2\,\beta - 0,4)$% for $\beta > 0,6$

8.1.7.2 Uncertainty of expansibility (expansion) factor ϵ

The percentage uncertainty of ϵ is equal to $2\,\dfrac{\Delta p}{p_1}$ %.

8.1.8 *Pressure loss* $\Delta\bar{\omega}$

Clause 7.4 also applies to the pressure loss of ISA 1932 nozzles.

8.2 Long radius nozzles

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

- high-ratio nozzles ($0,25 \leqslant \beta \leqslant 0,8$), and
- low-ratio nozzles ($0,20 \leqslant \beta \leqslant 0,5$).

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

Figure 6, page 24, shows the geometric shapes of long-radius nozzles by taking planes passing through the throat centre-lines.

The reference letters used in the text are shown on the figure.

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

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

8.2.1 *Profile of high-ratio nozzle*

8.2.1.1 The inner face can be characterized by :

- a convergent section A;
- a cylindrical throat B;
- and a plain end C.

TABLE 8 – **Upper limits of relative roughness for ISA 1932 nozzles**

β	$\leqslant 0,35$	0,36	0,38	0,40	0,42	0,44	0,46	0,48	0,50	0,60	0,70	0,77	0,80
$10^4\,k/D$	25	18,6	13,5	10,6	8,7	7,5	6,7	6,1	5,6	4,5	4,0	3,9	3,9

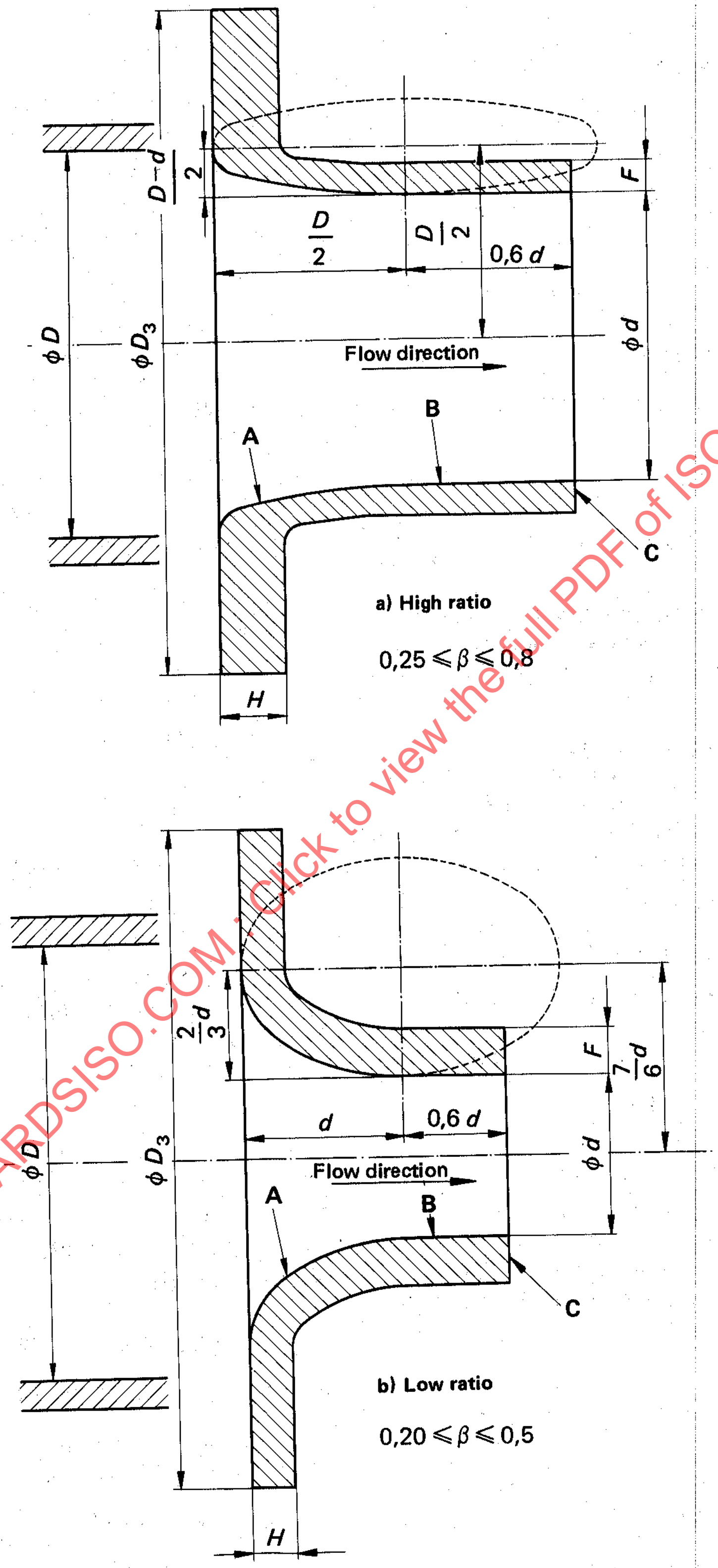


FIGURE 6 — **Long-radius nozzles**

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

The centre of the ellipse is $D/2$ for the axial centre-line.

The major centre-line of the ellipse is parallel to the axial centre-line. The value of half the major centre-line is $D/2$. The value of half the minor is $(D-d)/2$.

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

8.2.1.3 The throat B has a diameter d and a length 0,6 d.

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

The throat shall be cylindrical. Any diameter of any cross-section shall not differ by more than 0,05 % from the value of the mean diameter. Measurement at a sufficient number of cross-sections shall be made to determine that in no circumstances is the throat divergent in the direction of flow; it may be slightly convergent within the stated uncertainty. The section nearest the outlet is particularly important in this respect. This requirement is considered as satisfied when the deviations in the length of any of the measured diameters comply with the said requirement in respect of its deviation from the mean.

Attention is called to the fact that it is possible to check circularity of the throat within the accuracy required without measuring the diameter of the throat itself.

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

8.2.1.5 The thickness H shall be greater than or equal to 3 mm and less than or equal to 0,15 D. The thickness F of the throat shall be between 3 and 13 mm.

8.2.1.6 The surface of the inner face shall have a roughness criterion $R_a \leqslant 10^{-4}\,d$.

8.2.1.7 The shape of the downstream (outside) face is not specified but shall comply with 8.2.1.4 and 8.2.1.5 and the last sentence before 8.2.1.

8.2.2 *Shape of low-ratio nozzle*

8.2.2.1 The requirements given in 8.2.1 for the high-ratio nozzle apply to the low-ratio nozzle with the exception of the shape of the ellipse itself, which is given in 8.2.2.2 below.

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

8.2.3 *Material and manufacture*

The equivalent requirements given in 7.1.9.1 and 7.1.9.2 apply, to the manufacture of long-radius nozzles.

8.2.4 *Pressure tappings*

8.2.4.1 The pressure tappings shall comply with the description in 7.2.1 and 7.2.2.

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

The centre-line of the downstream tapping shall be at $0,50\,D \pm 0,01\,D$ from the inlet face of the nozzle with the exception that it shall not in any case be further downstream than the nozzle outlet.

8.2.4.3 The upstream and downstream pressure tappings break through the inside wall of the pipe.

8.2.5 *Coefficients of long-radius nozzles*

8.2.5.1 LIMITS OF USE

The long radius nozzles shall only be used in accordance with this International Standard when :

$50\text{ mm} \leqslant D \leqslant 630\text{ mm}$

$0,2 \leqslant \beta \leqslant 0,8$

$10^4 \leqslant Re_D \leqslant 10^7$

$k/D \leqslant 10 \times 10^{-4}$ (see 8.1.6.2 and 7.3.1)

8.2.5.2 DISCHARGE COEFFICIENT

The discharge coefficients are the same for both types of the long-radius nozzles when the tappings are in accordance with 8.2.4.

The discharge coefficient C is given by the following formula, when referring to the upstream pipe Re_D :

$$C = 0,996\,5 - 0,006\,53\,\beta^{0,5}\left[\frac{10^6}{Re_D}\right]^{0,5}$$

When referring to Reynolds number at the throat Re_d, it becomes

$$C = 0,996\,5 - 0,006\,53\left[\frac{10^6}{Re_d}\right]^{0,5}$$

and, in this case, C is independent of the ratio β.

Tables 32 and 33, which show the corresponding values of C or α as a function of β, Re_D and Re_d are given for convenience. They are not intended for precise interpolation; extrapolation is not permitted.

8.2.5.3 EXPANSIBILITY (EXPANSION) FACTOR ϵ

The indications given in clause 8.1.6.3 also apply to the expansibility factor for long radius nozzles, but within the limits of use of clause 8.2.5.1.

8.2.6 *Uncertainties*

8.2.6.1 UNCERTAINTY OF DISCHARGE COEFFICIENT C

When β and Re_d are assumed to be known without error, the percentage uncertainty of the value of C is ± 2,0 % for all values of β between 0,2 and 0,8.

8.2.6.2 UNCERTAINTY OF EXPANSIBILITY (EXPANSION) FACTOR ϵ

The relative uncertainty on ϵ is equal to $2 \Delta p/p_1$ % .

8.2.7 *Pressure loss* $\Delta\overline{\omega}$

Clause 7.4 also applies to the pressure loss of long radius nozzles.

9 VENTURI TUBES

There are two different types of venturi tubes :

- classical venturi tube,
- venturi nozzle.

They are described in 9.1. and 9.2.

9.1 Classical venturi tubes

9.1.1 *Field of application*

The range of use of the classical venturi tubes dealt with in this International Standard depends on the way they are manufactured.

Three types of standard classical venturi tubes are identified by the method of manufacturing the internal surface of the entrance cone and the profile at the intersection of the entrance cone and the throat. These three methods of manufacture are described in 9.1.1.1 to 9.1.1.3 and have somewhat different characteristics.

9.1.1.1 CLASSICAL VENTURI TUBE WITH A ROUGH CAST CONVERGENT

This is a classical venturi tube made by casting in a sand mould or by other methods which leave a finish on the surface of the convergent part similar to that of the sand casting. The throat is machined and the junctions between the cylinders and cones are rounded.

These classical venturi tubes may be used in pipes in the range of diameters between 100 mm and 800 mm and in the range of diameter ratios β between 0,3 and 0,75 inclusive.

9.1.1.2 CLASSICAL VENTURI TUBE WITH A MACHINED CONVERGENT

This is defined as a classical venturi tube cast or fabricated as above but in which the convergent part is machined, as are the throat and entrance cylinder. The junctions between the cylinders and cones may or may not be rounded.

These classical venturi tubes may be used in pipes in the range of diameters between 50 mm and 250 mm and in the range of diameter ratios β between 0,4 and 0,75 inclusive.

9.1.1.3 CLASSICAL VENTURI TUBE WITH A ROUGH WELDED SHEET-IRON CONVERGENT

This classical venturi tube is normally fabricated by welding. For the larger sizes it is not machined in any way, but in the smaller sizes, has the throat machined.

These classical venturi tubes may be used in pipes in the range of diameters between 200 mm and 1 200 mm and in the range of diameter ratios β between 0,4 and 0,7 inclusive.

9.1.2 *Geometric profile*

Figure 7, page 27, shows a section passing through the centre-line of the throat of a classical venturi tube. The letters are for reference purposes.

The classical venturi tube is made up of an entrance cylinder (A) connected to a conical convergent (B), a cylindrical throat (C) and a conical divergent (E). The internal surface of the device is a surface of revolution and concentric with the pipe centre-line. The convergent and the cylindrical throat are considered as coaxial by mere visual inspection.

9.1.2.1 The entrance cylinder (A) shall have a diameter D which shall not differ from the pipe inside diameter by more than 0,01 D.

The minimum cylinder length, measured from the plane containing the intersection of cone frustum (B) with cylinder (A), may vary as a result of the manufacturing process (see 9.1.2.7, 9.1.2.8, 9.1.2.9). It is however recommended that it shall be equal to D.

The entrance cylinder diameter D shall be measured in the plane of the upstream pressure tappings. The number of measurements shall at least be equal to that of the pressure tappings (with a minimum of four).

The diameters shall be measured near each pair of pressure tappings, and also between these pairs. The mean value of all these measurements shall be taken as the value of D in the calculations.

Diameters shall also be measured in planes other than the plane of the pressure tappings.

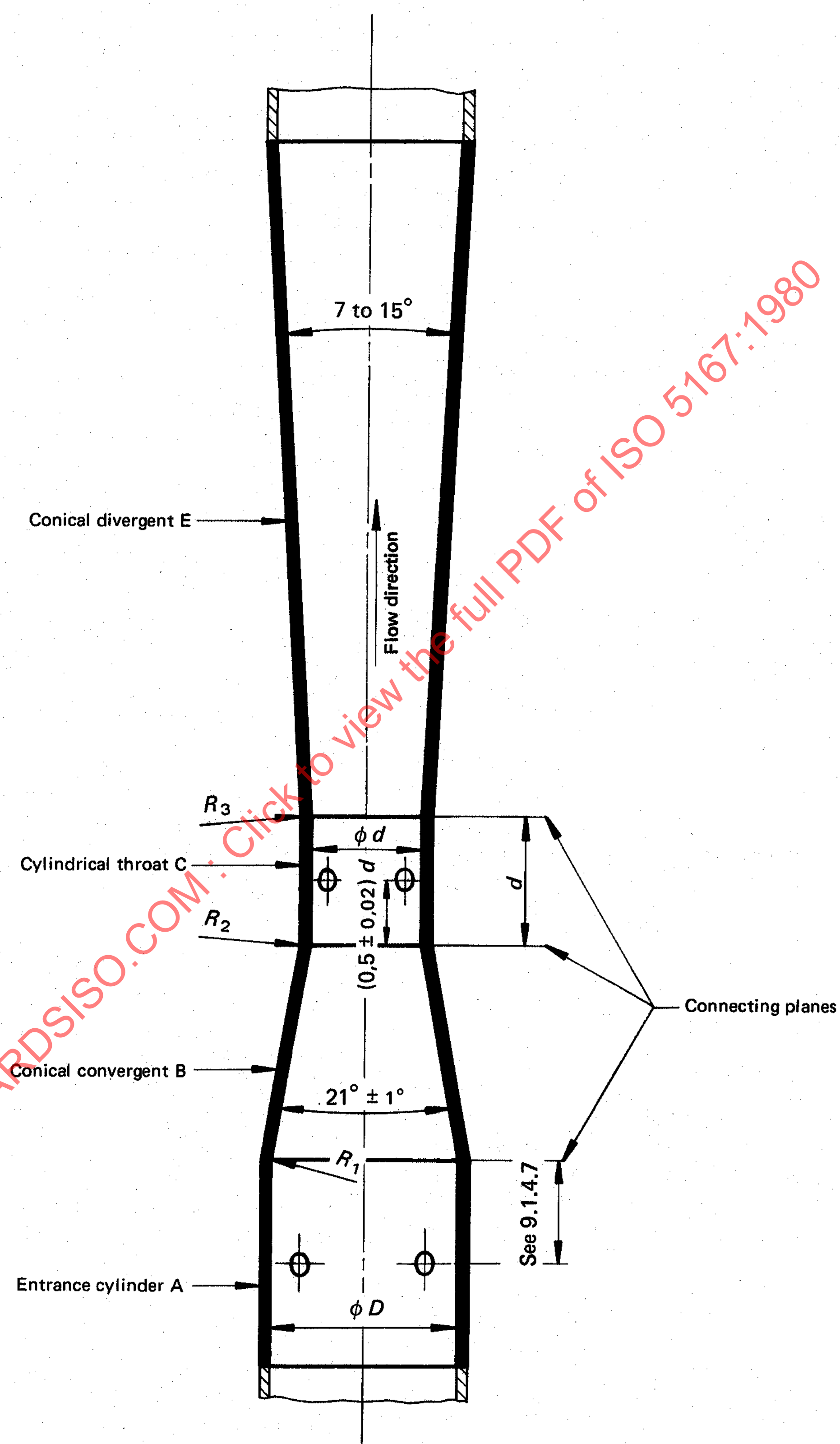


FIGURE 7 — **Geometric profile of the classical venturi tube**

No diameter along the entrance cylinder shall differ by more than 0,4 % from the value of the mean diameter. This requirement is 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.

Attention is called to the fact that it is possible to check the circularity of the cylindrical portion and the pipe bore within the accuracy required without measuring the mean diameter of the cylindrical portion and the pipe bore themselves.

9.1.2.2 The convergent section (B) shall be conical and shall have an included angle of 21 ± 1° for any type of classical venturi tube. It is limited upstream by the plane containing the intersection of the cone frustum (B) with the entrance cylinder (A) (or their prolongations) and downstream by the plane containing the intersection of the cone frustum (B) with the throat (C) (or their prolongations).

The overall length of the convergent (B) measured parallel to the axis of revolution of the venturi tube is therefore approximately equal to 2,7 $(D - d)$.

The convergent section (B) is blended to the entrance cylinder (A) by a curvature of radius R_1, the value of which depends on the type of classical venturi tube.

The profile of the convergent section shall be checked by means of a template. The deviation between the template and the conical section of the convergent shall not exceed, in any place, 0,4 % of D.

The internal surface of the conical section of the convergent is taken as being a surface of revolution when two diameters situated in the same plane perpendicular to the axis of revolution do not differ from the value of mean diameter by more than 0,4 %.

It shall be checked in the same way that the joining curvature with a radius R_1 is a surface of revolution.

9.1.2.3 The throat (C) shall be cylindrical with a diameter d. It is limited upstream by the plane containing the intersection of the cone frustum (B) with the throat (C) (or their prolongations) and downstream by the plane containing the intersection of the throat (C) with the cone frustum (E) (or their prolongations). The length of the throat (C), i.e. the distance between those two planes, shall be equal to d whatever the type of the classical venturi tube.

The throat (C) is connected to the convergent (B) by a curvature of radius R_2 and to the divergent (E) by a curvature of radius R_3. The values of R_2 and R_3 depend on the type of classical venturi tube.

The diameter d shall be measured very carefully in the plane of the throat pressure tappings. The number of measurements shall at least be equal to that of the pressure tappings (with a minimum of four). The diameters shall be measured near each pair of pressure tappings and also between these pairs. The mean value of all these measurements shall be taken as the value of d in the calculations.

Diameters shall also be measured in planes other than the plane of the pressure tappings.

No diameter along the throat shall differ by more than 0,1 % of the value of the mean diameter. This requirement is 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.

Attention is called to the fact that it is possible to check the circularity of the throat bore within the accuracy required without measuring the mean diameter of the throat bore itself.

The classical venturi tube shall be machined or be of equivalent smoothness over the whole of its length to the roughness level given in 9.1.2.6.

It shall be checked that the joining curvatures into the throat with radii R_2 and R_3 are surfaces of revolution as described in 9.1.2.2. This requirement is satisfied when two diameters, situated in the same plane perpendicular to the axis of revolution, do not differ from the value of the mean diameter by more than 0,1 %.

The values of the radii of curvature R_2 and R_3 shall be checked by means of a template.

The deviation between the template and the classical venturi tube shall evolve in a regular way for each curvature so that the single maximum deviation that is measured occurs at approximately mid-way along the template profile. The value of this maximum deviation shall not exceed 0,02 d.

9.2.1.4 The divergent section (E) shall be conical and can have an included angle lying between 7 and 15°; it is however recommended that an angle between 7 and 8° be chosen. Its smallest diameter shall not be less than the throat diameter.

9.1.2.5 A classical venturi tube is called "truncated" when the outlet diameter of the divergent is less than the diameter D and "not truncated" when the outlet diameter is equal to diameter D. The divergent portion can be truncated down by about 35 % of its length without greatly modifying the pressure loss in the device.

9.1.2.6 The roughness criterion R_a of the throat and that of the adjacent curvature shall be less than 10^{-5} d (see 5.1.2). The divergent is roughcast. Its internal surface shall be clean and smooth. The roughness of other parts of the classical venturi tube depends on the type considered.

9.1.2.7 CHARACTERISTICS OF THE PROFILE OF THE CLASSICAL VENTURI TUBE WITH A ROUGH-CAST CONVERGENT

The minimum length of the entrance cylinder (A) shall be equal to the smaller of the two quantities : 1 D and 0,25 D + 250 mm (see 9.1.2.1).

Its internal surface may be left rough-cast provided it is smooth, free from cracks, fissures, depressions, irregularities and impurities (with a roughness criterion R_a less than 10^{-4} D), i.e. of the same surface finish as the convergent section B.

The radius of curvature R_1 shall be equal to 1,375 D (+ 20 %).

The internal surface of the convergent B can be sand-cast and rough-cast. It shall be smooth, free from cracks, fissures, depression, irregularities and impurities.

The roughness criterion R_a for this surface shall be less than 10^{-4} D.

The radius of curvature R_2 shall be equal to 3,625 d (+ 0,125 d).

The length of the cylindrical part of the throat shall be not less than $d/3$. In addition, the length of the cylindrical part lying between the end of the joining curvature R_2 and the plane of the pressure tappings as well as the length of the cylindrical part between the plane of the throat pressure tappings and the beginning of the joining curvature R_3 shall be not less than $d/6$ (see also 9.1.2.3 for the throat length).

The radius of curvature R_3 shall lie between 5 and 15 d. Its value shall increase as the divergent angle decreases. A value close to 10 d is recommended.

9.1.2.8 CHARACTERISTICS OF THE PROFILE OF THE CLASSICAL VENTURI TUBE WITH A MACHINED CONVERGENT

The minimum length of cylinder (A) shall be equal to D.

The radius of curvature R_1 shall be less than 0,25 D and preferably equal to zero.

The radius of curvature R_2 shall be less than 0,25 d and preferably equal to zero.

The length of the throat cylindrical part lying between the end of the curvature R_2 and the plane of the throat pressure tappings shall be not less than 0,25 d.

The length of the throat cylindrical part lying between the end of the curvature R_3 and the plane of the throat pressure tappings shall be not less than 0,3 d.

The radius of curvature R_3 shall be less than 0,25 d and preferably equal to zero.

The entrance cylinder and the convergent section shall have a surface finish equal to that of the throat (see 9.1.2.6).

9.1.2.9 CHARACTERISTICS OF THE PROFILE OF THE CLASSICAL VENTURI TUBE WITH A ROUGH WELDED SHEET-IRON CONVERGENT

The minimum length of entrance cylinder (A) shall be equal to D.

There shall be no joining curvature between entrance cylinder (A) and convergent section (B) other than that resulting from the welding.

There shall be no joining curvature between convergent section (B) and throat (C) other than that resulting from the welding.

There shall be no joining curvature between the throat and the divergent section.

The internal surface of the entrance cylinder (A) and the convergent section (B) shall be clean and free from encrustation and welding deposits. It may be galvanized. Its roughness criterion R_a shall be about 5×10^{-4} D.

The internal welded seams shall be flush with the surrounding surfaces and shall not be in the vicinity of any pressure tapping.

9.1.3 *Material and manufacture*

9.1.3.1 The classical venturi tube may be manufactured of any material, provided it is in accordance with the foregoing description and will remain so during use.

9.1.3.2 It is also recommended that the convergent section (B) and the throat (C) be joined as one part. It is recommended that in the case of a classical venturi tube with a machined convergent, the throat and the convergent shall be manufactured from one piece of material. If however they are made in two separate parts they shall be assembled before the internal surface is finally machined.

9.1.3.3 Particular care shall be given to the centring of the divergent section (E) on the throat. Thus there shall be no step in diameters between the two parts.

This can be established by touch before the classical venturi tube is installed, but after the divergent section has been assembled with the throat section.

9.1.3.4 When a lining is added in the throat, it shall be machined after being assembled.

9.1.4 *Pressure tappings*

9.1.4.1 The upstream and throat pressure tappings shall be made in the form of separate pipe wall pressure tappings interconnected by annular chambers.

9.1.4.2 The diameter of these tappings shall lie between 4 mm and 10 mm and moreover shall never be greater than 0,1 D for the upstream tappings and 0,13 d for the throat pressure tappings.

It is recommended that pressure tappings as small as compatible with the fluid shall be used (for example, its viscosity and cleaness).

9.1.4.3 At least four pressure tappings shall be provided for the upstream and throat pressure measurements. The centre-lines of the pressure tappings shall form equal angles with each other and shall be contained in a plane perpendicular to the centre-line of the classical venturi tube.

9.1.4.4 At the point of break-through, the hole of the pressure tapping shall be circular. The edges shall be flush with the pipe wall, free from burrs and generally have no peculiarities. If joining curvatures are required the radius shall not exceed one-tenth of the diameter of the pressure tapping.

9.1.4.5 The pressure tappings shall be cylindrical over a length at least 2,5 times the diameter of the tapping, measured from the inner wall of the pipe-line.

9.1.4.6 Conformity of the pressure tappings with the two foregoing requirements can be assessed by mere visual inspection.

9.1.4.7 The spacing of a pressure tapping is the distance, measured on a straight line parallel to the centre-line of the classical venturi tube, between the centre-line of the pressure tapping and the reference planes defined below.

For the classical venturi tube with a rough-cast convergent, the spacing between the upstream pressure tappings situated on the entrance cylinder and the intersection plane between the prolongation of convergent section (B) and entrance cylinder (A) shall be :

$0,5\,D \pm 0,25\,D$ for D between 100 mm and 150 mm,

and

$0,5\,D\,^{\;0}_{-0,25}\,D$ for D between 150 mm and 800 mm.

For the classical venturi tubes with a machined convergent and for that with a rough welded sheet-iron convergent, the spacing between the upstream pressure tappings and the intersection plane of entrance cylinder (A) and convergent (B) (or their prolongations) shall be :

$0,5\,D \pm 0,05\,D$

For all types of classical venturi tube, the spacing between the throat pressure tappings and the intersection plane of convergent section (B) and throat (C) (or their prolongations) shall be :

$0,5\,d \pm 0,02\,d$

9.1.4.8 The area of the free cross-section of the annular chamber of the pressure tappings shall be equal to or more than half the total area of the tapping holes connecting the chamber to the pipe.

It is recommended however that the chamber section given above shall be doubled when the classical venturi tube is used with a minimum upstream straight length from a fitting causing non-symmetrical flows.

9.1.5 *Discharge coefficient C*

9.1.5.1 LIMITS OF USE

Whatever may be the type of the classical venturi tube, a simultaneous use of extreme values for D, β and Re_D must be avoided as otherwise the uncertainties given in 9.1.7 are likely to be increased.

The effects of Re_D, k/D and β or C are not yet sufficiently known for it to be possible to give reliable values of C outside the limits defined for each type of classical venturi tube (see however for guidance annex B).

9.1.5.2 DISCHARGE COEFFICIENT OF THE CLASSICAL VENTURI TUBE WITH A ROUGH-CAST CONVERGENT

Classical venturi tubes with a rough-cast convergent can only be used in accordance with this International Standard when :

$$100 \text{ mm} \leqslant D \leqslant 800 \text{ mm}$$

$$0,3 \leqslant \beta \leqslant 0,75$$

$$2 \times 10^5 \leqslant Re_D \leqslant 2 \times 10^6$$

Under these conditions the value of the discharge coefficient C is :

$$C = 0,984$$

9.1.5.3 DISCHARGE COEFFICIENT OF THE CLASSICAL VENTURI TUBE WITH A MACHINED CONVERGENT

Classical venturi tubes with a machined convergent can only be used in accordance with this International Standard when :

$$50 \text{ mm} \leqslant D \leqslant 250 \text{ mm}$$

$$0,4 \leqslant \beta \leqslant 0,75$$

$$2 \times 10^5 \leqslant Re_D \leqslant 1 \times 10^6$$

Under these conditions the value of the discharge coefficient C is :

$$C = 0,995$$

9.1.5.4 DISCHARGE COEFFICIENT OF THE CLASSICAL VENTURI TUBE WITH A ROUGH WELDED SHEET-IRON CONVERGENT

Classical venturi tubes with a rough welded sheet-iron convergent can only be used in accordance with this International Standard when :

$$200 \text{ mm} \leqslant D \leqslant 1\,200 \text{ mm}$$

$$0,4 \leqslant \beta \leqslant 0,7$$

$$2 \times 10^5 \leqslant Re_D \leqslant 2 \times 10^6$$

Under these conditions the value of the discharge coefficient C is :

$$C = 0,985$$

9.1.6 *Expansibility (expansion) factor ε*

The indications given in 8.1.6.3 also apply to the expansibility factor for the different types of classical venturi tubes, but within the limits of use of clauses 9.1.5.2 or 9.1.5.3 or 9.1.5.4.

9.1.7 *Uncertainty of the discharge coefficient C*

9.1.7.1 CLASSICAL VENTURI TUBE WITH A ROUGH-CAST CONVERGENT

The percentage uncertainty of the discharge coefficient as given in 9.1.5.2 is equal to 0,7 %[1)].

9.1.7.2 CLASSICAL VENTURI TUBE WITH A MACHINED CONVERGENT

The percentage uncertainty of the discharge coefficient as given in 9.1.5.3 is equal to 1 %[1)].

9.1.7.3 CLASSICAL VENTURI TUBE WITH A ROUGH WELDED SHEET-IRON CONVERGENT

The percentage uncertainty of the discharge coefficient as given in 9.1.5.4 is equal to 1,5 %[1)].

9.1.8 *Uncertainty of the expansibility (expansion) factor ε*

The percentage uncertainty of ϵ is equal to $(4 + 100\,\beta^8)\dfrac{\Delta p}{p_1}\,\%$.

9.1.9 *Pressure loss*

9.1.9.1 DEFINITION OF THE PRESSURE LOSS (see figure 8)

The pressure loss caused by the venturi tube may be determined by pressure measurement made prior and subsequent to the installation of the venturi tube in a pipe through which there is a given flow.

If $\Delta p'$ is the difference in pressure, measured prior to the installation of the venturi tube, between two pressure tappings one of which is situated at least 1 D upstream of the flanges where the venturi tube shall be inserted and the other is 6 D downstream of the same flanges, and if $\Delta p''$ is the difference in pressure measure between the same pressure tappings after installation of the venturi tube between these flanges, then the pressure loss caused by the venturi tube is given by $\Delta p'' - \Delta p'$.

9.1.9.2 VALUE OF THE PRESSURE LOSS

The value $\xi = \dfrac{\Delta p'' - \Delta p'}{\Delta p}$ of the pressure loss related to the differential pressure Δp depends in particular on :

– the diameter ratio $\left(\xi = \dfrac{\Delta p'' - \Delta p'}{\Delta p}\right.$ decreases when β increases$\Big)$;

– the Reynolds number $\left(\xi = \dfrac{\Delta p'' - \Delta p'}{\Delta p}\right.$ decreases when Re_D increases$\Big)$;

– the manufacturing characteristics of the venturi tube angle of the divergent, manufacturing of the convergent, surface finish of the different parts, etc. (ξ increases when φ and k/D increases);

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

For guidance, the percentage value of the pressure loss can be accepted as being generally between 5 and 20 %.

Annex C gives, for guidance only, some information on the effect of these different factors on the values the pressure loss ξ is likely to have for classical venturi tubes.

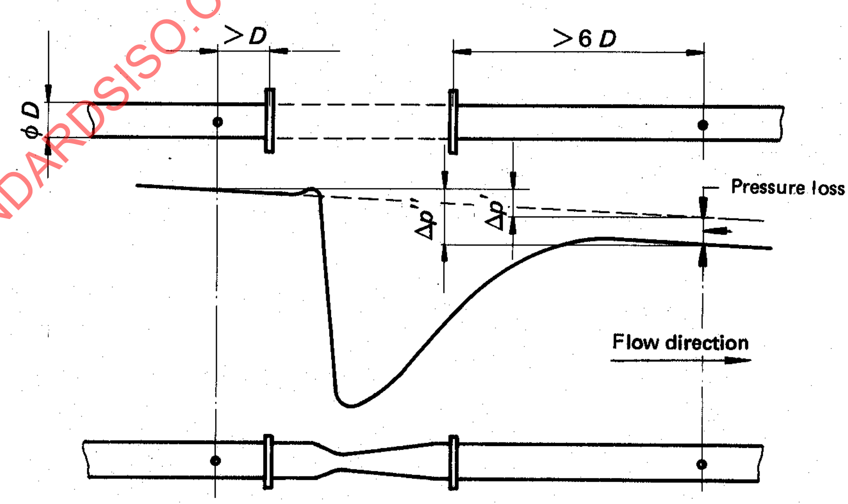


FIGURE 8 — **Pressure loss across classical venturi tube**

1) The differences between the uncertainties show on the one hand the number of results available for each type of classical venturi tube and on the other hand the more or less precise definition of the geometric profile.

9.2 Venturi nozzles

9.2.1 *Geometric profile*

The profile of the venturi nozzle (see figure 9) is axisymmetric. Its consists of a convergent portion, with a rounded profile, a cylindrical throat and a divergent.

9.2.1.1 The upstream face is identical with an ISA 1932 nozzle as defined in figure 5.

The descriptions in 8.1.2.2, 8.1.2.3 and 8.1.2.4 apply equally to venturi nozzles.

9.2.1.2 The throat (see figure 9) consists of a part (E) of length 0,3 d which is the same as for ISA 1932 nozzles (figure 5) and a part (E′) of a length 0,4 d to 0,45 d.

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

The throat shall be cylindrical. Any diameter of any cross-section shall not differ by more than 0,05 % from the value of the mean diameter. This requirement is considered as satisfied when the deviations in the length of any of the measured diameters comply with the said requirement in respect of deviation from the mean.

Attention is called to the fact that it is possible to check circularity of the throat within the accuracy required without measuring the mean diameter of the throat itself.

9.2.1.3 The divergent section (see figure 9) shall be connected with part (E′) of the throat without a rounded part, but any burrs shall be removed.

The included angle of the divergent section, φ, shall be $\leqslant 30°$.

The length L of the divergent section has practically no influence on the flow coefficient α. The included angle of the divergent section, and hence the length, does influence, however, the pressure loss.

9.2.1.4 The venturi nozzle may be truncated in the same way as the classical venturi tube (see 9.1.2.5).

9.2.1.5 The internal surfaces of the venturi nozzles shall have a roughness criterion $R_a \leqslant 10^{-4}\,d$ (see 5.1.2).

9.2.2 *Material and manufacture*

9.2.2.1 The venturi nozzle may be manufactured of any material provided it is in accordance with the foregoing description in 9.2.1 and will remain so during use. In particular, the venturi nozzle shall be clean when the measurements are made.

9.2.2.2 The venturi nozzle is usually made of metal, and shall be erosion and corrosion proof against the fluid with which it is to be used.

9.2.3 *Pressure tappings*

9.2.3.1 ANGULAR POSITION OF PRESSURE TAPPINGS

The centre-lines of the pressure tappings may be located in any axial sector of the pipe. Attention is drawn to 7.2.1.

9.2.3.2 UPSTREAM PRESSURE TAPPINGS

The upstream pressure tappings shall be corner tappings identical with those of an ISA 1932 nozzle, as defined in this International Standard in 7.2.4 (see also figures 9 and 10.)

9.2.3.3 THROAT PRESSURE TAPPINGS

Throat pressure tappings shall be single pressure tappings leading into an annular chamber. Annular slots or interrupted slots shall not be used.

There shall be at least four single pressure tappings; their centre-lines shall make equal angles one to another, and lie in the plane perpendicular to the centre-line of the venturi nozzle, which is the imaginary border between the parts (E) and (E′) of the cylindrical throat.

The tappings shall always be large enough to ensure that clogging by dirt plugs or gas bubbles is prevented.

The diameter δ of the single tappings in the throat of venturi nozzles shall be less than or equal to 0,04 d and moreover be between 2 and 10 mm.

9.2.4 *Coefficients*

9.2.4.1 LIMITS OF USE

Venturi nozzles shall only be used in accordance with this International Standard when :

$$65\ \text{mm} \leqslant D \leqslant 500\ \text{mm}$$

$$d \geqslant 50\ \text{mm}$$

$$0{,}316 \leqslant \beta \leqslant 0{,}775$$

$$1{,}5 \times 10^5 \leqslant Re_D \leqslant 2 \times 10^6$$

9.2.4.2 FLOW COEFFICIENT AND DISCHARGE COEFFICIENT

The discharge coefficient C is given by the formula :

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

Table 35 which shows the corresponding values of C and α as a function of β, is given for convenience. It is not intended for precise interpolation; extrapolation is not permitted.

NOTE — Within the above limits of 9.2.4.1, C is independent of Reynolds number and of the diameter.

Most of the experiments on which the above values of C are based were carried out in pipes with a relative roughness

$k/D \leqslant 3{,}8 \times 10^{-4}$. Pipes with higher relative roughness may be used if the roughness of at least 10 D upstream of the primary device is within the limits of table 9 (see 7.3.1 for estimation of k/D).

9.2.4.3 Expansibility (expansion) factor ϵ

The indications given in 8.1.6.3 also apply to the expansibility factor for venturi nozzles, but within the limits of use of 9.2.4.1.

9.2.5 *Uncertainties*

9.2.5.1 Uncertainties of flow coefficient α

Within the limits of 9.2.4.1, and when β is assumed to be known without error, the percentage uncertainty of the value of α, within the limits of the Reynolds numbers shown in 9.2.4.1, is given by the formula :

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

9.2.5.2 Uncertainty of expansibility (expansion) factor ϵ

The percentage uncertainty of ϵ is equal to $(4 + 100\,\beta^8)\,\dfrac{\Delta p}{p_1}\,\%$.

9.2.6 *Pressure loss*

The indications given in 9.1.9 also apply to venturi nozzles when the divergent angle is not greater than 15°.

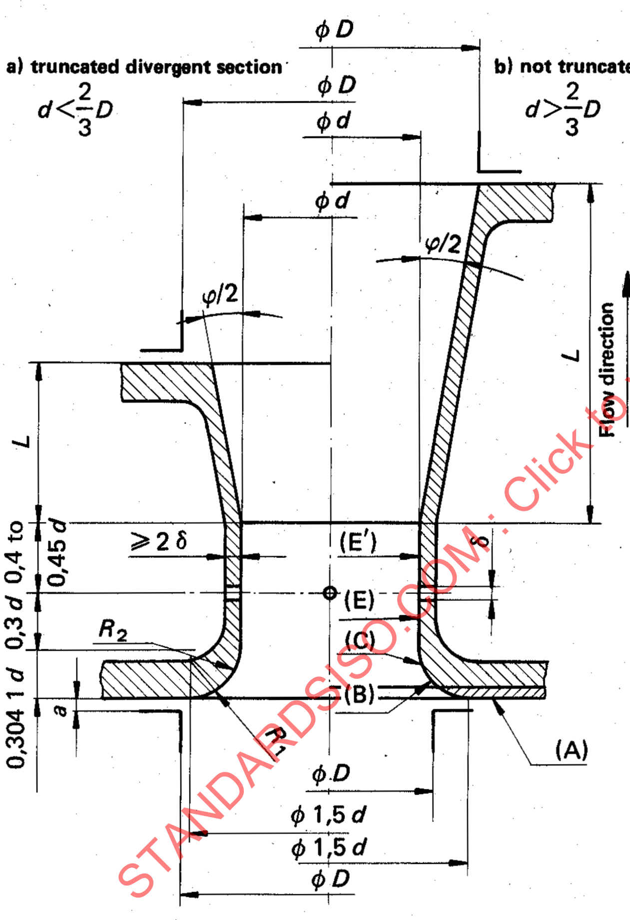


FIGURE 9 – **Venturi nozzle**

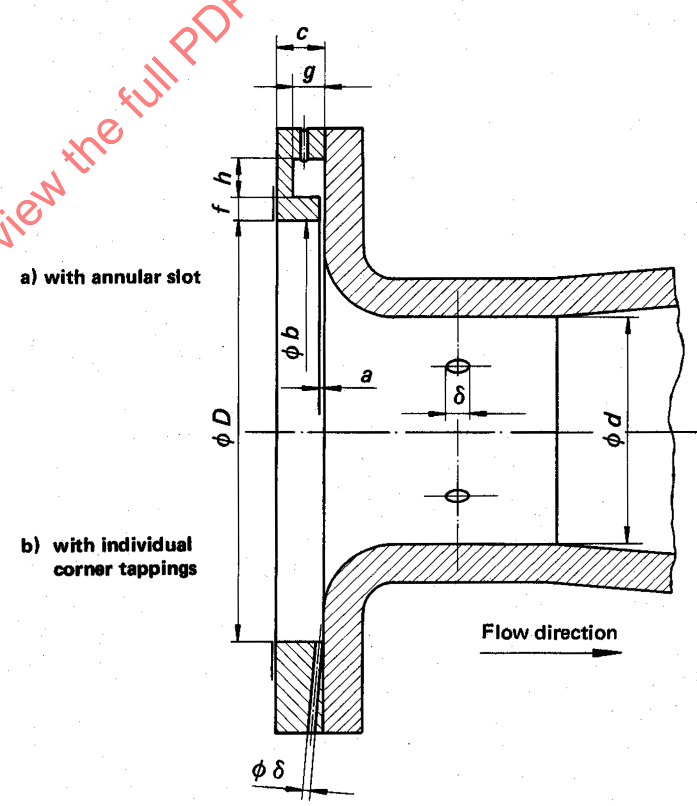


FIGURE 10 – **Carrier ring**

TABLE 9 – **Upper limits of relative roughness for venturi nozzles**

β	⩽ 0,35	0,36	0,38	0,40	0,42	0,44	0,46	0,48	0,50	0,60	0,70	0,775
$10^4\,k/D$	25	18,6	13,5	10,6	8,7	7,5	6,7	6,1	5,6	4,5	4,0	3,9

10 UNCERTAINTIES ON THE MEASUREMENT OF FLOW-RATE

Reference shall be made to ISO 5168, *Calculation of the uncertainty of a measurement of flow-rate,* which gives useful general information on this subject.

10.1 Definition of uncertainty

10.1.1 For the purpose of this International Standard the uncertainty is defined as a range of values within which the true value of the measurement is estimated to lie at the 95 % probability.

In some cases, the confidence level which can be attached to this range of values will be greater than 95 %, but this will be so only where the value of a quantity used in the calculation of flow-rate is known with a confidence level in excess of 95 %; in such a case, reference shall be made to ISO 5168.

10.1.2 The uncertainty on the measurement of the flow-rate shall be calculated and given under this name whenever a measurement is claimed to be in conformity with this International Standard.

10.1.3 The uncertainty can be expressed in absolute or relative terms and the result of the flow measurement can then be given in any one of the following forms :

rate of flow $= q \pm \delta q$

or rate of flow $= q\,(1 \pm e)$

or rate of flow $= q$ within $(100\,e)$ %

where the uncertainty δq shall have the same dimensions as q while $e = \frac{\delta q}{q}$ and is non-dimensional.

10.1.4 The uncertainty of the flow measurement so defined is equivalent to twice the standard deviation of statistical terminology. Like the latter, it is obtained by combining the partial uncertainties on the individual quantities which are used in the calculation of the flow-rate, assuming then to be small, numerous and independent of each other. Although for one single measuring device and for coefficients used in one test, some of these uncertainties may in reality be the result of systematic errors (of which only an estimation of their maximum absolute amount is known) their combination is permitted as if they were random errors having a distribution conforming to the Laplace-Gauss normal law.

10.1.5 For convenience a distinction is made between the uncertainties linked to measurements made by the user and those linked to quantities specified in this International Standard. The latter uncertainties are on the flow coefficient and the expansibility factor and indicate the amount of the variation which the user has to tolerate since he has no control over their size. They occur because small variations in geometry are allowed and because the investigations on which the values have been based could not be made in "ideal" conditions.

10.2 Practical computation of the uncertainty

10.2.1 The basic formula of computation of the mass rate of flow q_m is :

$$q_m = \alpha\,\epsilon\,\frac{\pi}{4}\,d^2\sqrt{2\,\Delta p \times \rho_1}$$

In fact, the various quantities which appear on the right-hand side of this formula are not independent, so that it is not correct to compute the uncertainty of q_m directly from the uncertainties of these quantities.

For example, α is a function of d, D, κ, u_1, ν_1

ϵ is a function of $d, D, \Delta p, \rho_1, \kappa$

10.2.1.1 However, it is sufficient, for most practical purposes, to assume that the uncertainties of ϵ, Δp, and ρ_1 are independent of each other and are also independent of the uncertainties of α and d.

10.2.1.2 A practical working formula for δq_m may then be derived, which takes account of the interdependence of α, d and D which enters into the calculation as a consequence of the dependence of α on β. It shall be noted that α may also be dependent on the pipe diameter D, as well as on the Reynolds number Re_D. However, the deviations of α due to these influences are of a second order and are included in the uncertainty on α.

Similarly, the deviations of ϵ which are due to uncertainties in the value of β, the pressure ratio and the isentropic exponent are also of a second order and are included in the uncertainty on ϵ.

10.2.1.3 The uncertainties which shall be included in a practical working formula for δq_m are therefore those of the quantities $\alpha, \epsilon, d, D, \Delta p$ and ρ_1.

10.2.2 The practical working formula for the uncertainty, δq_m, of the mass rate of flow is as follows :

$$\frac{\delta q_m}{q_m} = \left[\left(\frac{\delta\alpha}{\alpha}\right)^2 + \left(\frac{\delta\epsilon}{\epsilon}\right)^2 + 4\left(\frac{\beta^4}{\alpha}\right)^2\left(\frac{\delta D}{D}\right)^2 + 4\left(1+\frac{\beta^4}{\alpha}\right)^2\left(\frac{\delta d}{d}\right)^2 + \frac{1}{4}\left(\frac{\delta\Delta p}{\Delta p}\right)^2 + \frac{1}{4}\left(\frac{\delta\rho_1}{\rho_1}\right)^2\right]^{\frac{1}{2}}$$

In the formula above some of the uncertainties, like those on the flow and expansibility coefficients, are given in this International Standard (see 10.2.2.1 and 10.2.2.2) while others have to be determined by the user (see 10.2.2.3 and 10.2.2.4).

10.2.2.1 In the formula above, the values of $\frac{\delta\alpha}{\alpha}$ or of $\frac{\delta C}{C}$ and of $\frac{\delta\epsilon}{\epsilon}$ shall be taken from the appropriate clauses of this International Standard.

10.2.2.2 When the straight lengths are such that an additional uncertainty of ± 0,5 % is to be considered, this additional uncertainty shall be added according to 6.2.4 and not quadratically with the other uncertainties in the formula given in 10.2.2. Other additional uncertainties (6.5.1.3 and 6.5.3.3) must be added in the same way.

10.2.2.3 In the formula above the maximum values of $\delta D/D$ and of $\delta d/d$, which can be derived from the specifications given in section 6, and in 7.1.7, 8.1.2.5, 8.2.1.3, 9.1.2.3 and 9.2.1.2, can be adopted or alternatively the smaller actual values can be computed by the user. (The maximum values for $\delta D/D$ may be taken as ± 0,4 % while the maximum value for $\delta d/d$ may be taken as ± 0,07 %).

10.2.2.4 The values of $\delta \Delta p/\Delta p$ and $\delta \rho_1/\rho_1$ shall be determined by the user because this International Standard does not specify in detail the method of measurement of the quantities Δp and ρ_1.

ANNEX A

TABLES OF DISCHARGE AND FLOW COEFFICIENTS

TABLE 10 – **Orifice plate with corner tappings; discharge coefficient *C***

β \ Re_D	5×10^3	10^4	2×10^4	3×10^4	5×10^4	7×10^4	10^5	3×10^5	10^6	10^7
0,23	0,601 2	0,599 7	0,598 7	0,598 3	0,598 0	0,597 9	0,597 7	0,597 5	0,597 4	0,597 3
0,24	0,601 8	0,600 0	0,599 0	0,598 6	0,598 2	0,598 1	0,597 9	0,597 7	0,597 5	0,597 5
0,26	0,603 1	0,600 9	0,599 6	0,599 1	0,598 7	0,598 5	0,598 3	0,598 0	0,597 8	0,597 8
0,28	0,604 4	0,601 9	0,600 3	0,599 7	0,599 2	0,598 9	0,598 7	0,598 3	0,598 2	0,598 1
0,30	0,606 0	0,602 9	0,601 1	0,600 4	0,599 7	0,599 4	0,599 2	0,598 7	0,598 3	0,598 4
0,32	0,607 7	0,604 0	0,601 9	0,601 1	0,600 3	0,600 0	0,599 7	0,599 1	0,598 9	0,598 8
0,34	0,609 5	0,605 3	0,602 8	0,601 8	0,601 0	0,600 5	0,600 2	0,599 6	0,599 3	0,599 1
0,36	0,611 5	0,606 6	0,603 7	0,602 6	0,601 6	0,601 2	0,600 8	0,600 1	0,599 7	0,599 5
0,38	0,613 6	0,608 1	0,604 8	0,603 5	0,602 4	0,601 8	0,601 4	0,600 5	0,600 2	0,600 0
0,40	0,615 9	0,609 6	0,605 9	0,604 4	0,603 1	0,602 5	0,602 0	0,601 1	0,600 6	0,600 4
0,42	0,618 4	0,611 3	0,607 0	0,605 4	0,603 9	0,603 2	0,602 6	0,601 6	0,601 1	0,600 8
0,44	0,621 0	0,613 0	0,608 2	0,606 4	0,604 7	0,603 9	0,603 3	0,602 1	0,601 6	0,601 3
0,46	0,623 8	0,614 8	0,609 5	0,607 4	0,605 6	0,604 7	0,604 0	0,602 7	0,602 1	0,601 7
0,48	***	0,616 7	0,610 8	0,608 5	0,606 4	0,605 5	0,604 7	0,603 2	0,602 5	0,602 1
0,50	***	0,618 7	0,612 1	0,609 6	0,607 3	0,606 2	0,605 3	0,603 7	0,603 0	0,602 6
0,52	***	0,620 7	0,613 5	0,610 7	0,608 2	0,607 0	0,606 0	0,604 2	0,603 4	0,602 9
0,54	***	0,622 8	0,614 8	0,611 7	0,609 0	0,607 7	0,606 6	0,604 7	0,603 7	0,603 2
0,56	***	0,624 9	0,616 2	0,612 8	0,609 8	0,608 4	0,607 2	0,605 0	0,604 0	0,603 5
0,58	***	0,627 0	0,617 5	0,613 8	0,610 5	0,608 9	0,607 7	0,605 3	0,604 2	0,603 6
0,60	***	0,629 1	0,618 7	0,614 7	0,611 1	0,609 4	0,608 0	0,605 5	0,604 3	0,603 6
0,62	***	0,631 1	0,619 8	0,615 5	0,611 6	0,609 8	0,608 3	0,605 5	0,604 2	0,603 5
0,64	***	0,633 0	0,620 8	0,616 1	0,611 9	0,609 9	0,608 3	0,605 3	0,603 9	0,603 1
0,65	***	0,633 9	0,621 2	0,616 4	0,612 0	0,609 9	0,608 2	0,605 1	0,603 7	0,602 8
0,66	***	0,634 8	0,621 6	0,616 5	0,612 0	0,609 9	0,608 1	0,604 8	0,603 3	0,602 5
0,67	***	0,635 6	0,621 9	0,616 7	0,612 0	0,609 7	0,607 9	0,604 5	0,602 9	0,602 1
0,68	***	0,636 3	0,622 2	0,616 7	0,611 8	0,609 5	0,607 6	0,604 1	0,602 5	0,601 6
0,69	***	0,637 0	0,622 3	0,616 7	0,611 6	0,609 2	0,607 2	0,603 6	0,601 9	0,601 0
0,70	***	0,637 6	0,622 4	0,616 5	0,611 3	0,608 8	0,606 7	0,603 0	0,601 2	0,600 3
0,71	***	0,638 2	0,622 4	0,616 3	0,610 9	0,608 3	0,606 1	0,602 3	0,600 4	0,599 4
0,72	***	0,638 6	0,622 2	0,616 0	0,610 3	0,607 6	0,605 4	0,601 4	0,599 5	0,598 5
0,73	***	0,638 9	0,622 0	0,615 5	0,609 7	0,606 9	0,604 6	0,600 4	0,598 5	0,597 4
0,74	***	0,639 1	0,621 6	0,614 9	0,608 9	0,606 0	0,603 6	0,599 3	0,597 3	0,596 2
0,75	***	0,639 2	0,621 1	0,614 1	0,607 9	0,604 9	0,602 5	0,598 0	0,595 9	0,594 8
0,76	***	0,639 1	0,620 4	0,613 2	0,606 8	0,603 7	0,601 2	0,596 6	0,594 4	0,593 2
0,77	***	0,638 9	0,619 6	0,612 1	0,605 5	0,602 3	0,599 7	0,594 9	0,592 7	0,591 5
0,78	***	***	0,618 5	0,610 8	0,603 9	0,600 7	0,598 0	0,593 1	0,590 8	0,589 5
0,79	***	***	0,617 3	0,609 3	0,602 2	0,598 8	0,596 0	0,591 0	0,588 6	0,587 3
0,80	***	***	0,615 8	0,607 6	0,600 3	0,596 8	0,593 9	0,588 7	0,586 2	0,584 9

NOTE – This table is given for convenience. It is not intended for precise interpolation.

TABLE 11 — **Orifice plate with corner tappings; flow coefficient** α

β \ Re_D	5×10^3	10^4	2×10^4	3×10^4	5×10^4	7×10^4	10^5	3×10^5	10^6	10^7
0,23	0,602 1	0,600 5	0,599 5	0,599 2	0,598 9	0,598 7	0,598 6	0,598 3	0,598 2	0,598 2
0,24	0,602 8	0,601 0	0,600 0	0,599 6	0,599 2	0,599 1	0,598 9	0,598 7	0,598 5	0,598 5
0,26	0,604 4	0,602 3	0,601 0	0,600 5	0,600 1	0,599 8	0,599 7	0,599 4	0,599 2	0,599 1
0,28	0,606 3	0,603 7	0,602 2	0,601 6	0,601 0	0,600 8	0,600 6	0,600 2	0,600 0	0,599 9
0,30	0,608 4	0,605 4	0,603 5	0,602 8	0,602 2	0,601 9	0,601 6	0,601 2	0,601 0	0,600 8
0,32	0,610 9	0,607 2	0,605 1	0,604 2	0,603 5	0,603 1	0,602 8	0,602 3	0,602 1	0,601 9
0,34	0,613 6	0,609 4	0,606 8	0,605 9	0,605 0	0,604 6	0,604 3	0,603 6	0,603 3	0,603 2
0,36	0,616 7	0,611 8	0,608 9	0,607 8	0,606 7	0,606 3	0,605 9	0,605 2	0,604 8	0,604 6
0,38	0,620 1	0,614 5	0,611 2	0,609 9	0,608 7	0,608 2	0,607 7	0,606 9	0,606 5	0,606 3
0,40	0,624 0	0,617 6	0,613 8	0,612 3	0,611 0	0,610 4	0,609 8	0,608 9	0,608 5	0,608 2
0,42	0,628 3	0,621 0	0,616 7	0,615 0	0,613 5	0,612 8	0,612 2	0,611 2	0,610 7	0,610 4
0,44	0,633 0	0,624 8	0,619 9	0,618 1	0,616 4	0,615 6	0,614 9	0,613 7	0,613 2	0,612 8
0,46	0,638 2	0,629 0	0,623 6	0,621 5	0,619 6	0,618 7	0,618 0	0,616 6	0,616 0	0,615 7
0,48	***	0,633 8	0,627 7	0,625 3	0,623 2	0,622 2	0,621 4	0,619 9	0,619 2	0,618 8
0,50	***	0,639 0	0,632 2	0,629 6	0,627 2	0,626 1	0,625 2	0,623 5	0,622 7	0,622 3
0,52	***	0,644 7	0,637 2	0,634 3	0,631 7	0,630 5	0,629 4	0,627 6	0,626 7	0,626 2
0,54	***	0,651 1	0,642 7	0,639 5	0,636 7	0,635 3	0,634 2	0,632 1	0,631 2	0,630 6
0,56	***	0,658 1	0,648 9	0,645 3	0,642 2	0,640 7	0,639 4	0,637 2	0,636 1	0,635 5
0,58	***	0,665 8	0,655 7	0,651 8	0,648 3	0,646 6	0,645 3	0,642 8	0,641 6	0,641 0
0,60	***	0,674 3	0,663 2	0,658 9	0,655 0	0,653 2	0,651 7	0,649 0	0,647 7	0,647 0
0,62	***	0,683 6	0,671 4	0,666 7	0,662 5	0,660 5	0,658 9	0,655 9	0,654 5	0,653 7
0,64	***	0,693 9	0,680 5	0,675 4	0,670 8	0,668 6	0,666 8	0,663 5	0,662 0	0,661 1
0,65	***	0,699 4	0,685 4	0,680 0	0,675 2	0,672 9	0,671 1	0,667 6	0,666 0	0,665 1
0,66	***	0,705 2	0,690 6	0,684 9	0,679 9	0,677 5	0,675 5	0,671 9	0,670 3	0,669 3
0,67	***	0,711 3	0,696 0	0,690 1	0,684 8	0,682 3	0,680 3	0,676 5	0,674 8	0,673 8
0,68	***	0,717 7	0,701 7	0,695 5	0,690 0	0,687 4	0,685 2	0,681 3	0,679 5	0,678 5
0,69	***	0,724 4	0,707 7	0,701 2	0,695 5	0,692 7	0,690 5	0,686 4	0,684 5	0,683 4
0,70	***	0,731 5	0,714 0	0,707 3	0,701 2	0,698 4	0,696 0	0,691 7	0,689 7	0,688 6
0,71	***	0,738 9	0,720 6	0,713 6	0,707 3	0,704 3	0,701 8	0,697 3	0,695 2	0,694 1
0,72	***	0,746 8	0,727 7	0,720 3	0,713 7	0,710 6	0,708 0	0,703 3	0,701 1	0,699 9
0,73	***	0,755 1	0,735 1	0,727 4	0,720 5	0,717 2	0,714 5	0,709 6	0,707 3	0,706 0
0,74	***	0,763 8	0,742 9	0,734 9	0,727 6	0,724 2	0,721 4	0,716 2	0,713 8	0,712 5
0,75	***	0,773 1	0,751 2	0,742 8	0,735 2	0,731 6	0,728 7	0,723 3	0,720 8	0,719 4
0,76	***	0,782 9	0,760 0	0,751 2	0,743 3	0,739 5	0,736 4	0,730 8	0,728 2	0,726 7
0,77	***	0,793 4	0,769 4	0,760 1	0,751 9	0,747 9	0,744 7	0,738 8	0,736 0	0,734 5
0,78	***	***	0,779 3	0,769 7	0,761 0	0,756 8	0,753 5	0,747 3	0,744 4	0,742 8
0,79	***	***	0,790 0	0,779 8	0,770 7	0,766 4	0,762 9	0,756 4	0,753 3	0,751 6
0,80	***	***	0,801 4	0,790 7	0,781 2	0,776 6	0,772 9	0,766 1	0,762 9	0,761 2

NOTE — This table is given for convenience. It is not intended for precise interpolation.

TABLE 12 — **Orifice plate with *D* and *D*/2 tappings; discharge coefficient *C***

β \ Re_D	5×10^3	10^4	2×10^4	3×10^4	5×10^4	7×10^4	10^5	3×10^5	10^6	10^7
0,20	0,599 7	0,598 5	0,597 9	0,597 6	0,597 4	0,597 3	0,597 2	0,597 0	0,596 9	0,596 9
0,22	0,600 6	0,599 2	0,598 4	0,598 0	0,597 7	0,597 6	0,597 5	0,597 3	0,597 2	0,597 1
0,24	0,601 7	0,600 0	0,598 9	0,598 5	0,598 1	0,598 0	0,597 8	0,597 6	0,597 4	0,597 4
0,26	0,603 0	0,600 8	0,599 5	0,599 0	0,598 6	0,598 4	0,598 2	0,597 9	0,597 7	0,597 7
0,28	0,604 3	0,601 7	0,600 2	0,599 6	0,599 1	0,598 8	0,598 6	0,593 2	0,598 1	0,598 0
0,30	***	0,602 8	0,601 0	0,600 3	0,599 6	0,599 3	0,599 1	0,598 6	0,598 4	0,598 3
0,32	***	0,603 9	0,601 8	0,601 0	0,600 2	0,599 9	0,599 6	0,599 0	0,598 8	0,598 7
0,34	***	0,605 2	0,602 7	0,601 7	0,600 9	0,600 4	0,600 1	0,599 5	0,599 2	0,599 0
0,36	***	0,606 6	0,603 7	0,602 6	0,601 6	0,601 1	0,600 7	0,600 0	0,599 7	0,599 5
0,38	***	0,608 0	0,604 7	0,603 5	0,602 3	0,601 8	0,601 3	0,600 5	0,600 1	0,599 9
0,40	***	0,609 6	0,605 9	0,604 4	0,603 1	0,602 5	0,602 0	0,601 1	0,600 6	0,600 4
0,42	***	***	0,607 1	0,605 4	0,604 0	0,603 3	0,602 7	0,601 7	0,601 2	0,600 9
0,44	***	***	0,608 4	0,606 5	0,604 9	0,604 1	0,603 5	0,602 3	0,601 7	0,601 4
0,46	***	***	0,609 8	0,607 7	0,605 9	0,605 0	0,604 3	0,603 0	0,602 3	0,602 0
0,48	***	***	0,611 2	0,608 9	0,606 9	0,605 9	0,605 1	0,603 6	0,603 0	0,602 6
0,50	***	***	0,612 7	0,610 2	0,607 9	0,606 8	0,606 0	0,604 3	0,603 6	0,603 2
0,52	***	***	0,614 3	0,611 5	0,609 0	0,607 8	0,606 8	0,605 1	0,604 2	0,603 8
0,54	***	***	0,615 9	0,612 9	0,610 1	0,608 8	0,607 7	0,605 8	0,604 9	0,604 4
0,56	***	***	0,617 6	0,614 3	0,611 3	0,609 8	0,608 7	0,606 5	0,605 5	0,604 9
0,58	***	***	***	0,615 7	0,612 4	0,610 8	0,609 5	0,607 2	0,606 1	0,605 5
0,60	***	***	***	0,617 1	0,613 5	0,611 8	0,610 4	0,607 9	0,606 7	0,606 0
0,62	***	***	***	0,618 5	0,614 6	0,612 8	0,611 2	0,603 5	0,607 2	0,606 5
0,64	***	***	***	0,619 8	0,615 6	0,613 6	0,612 0	0,609 0	0,607 6	0,606 8
0,66	***	***	***	0,621 1	0,616 6	0,614 4	0,612 7	0,609 4	0,607 9	0,607 1
0,68	***	***	***	0,622 3	0,617 5	0,615 1	0,613 2	0,609 7	0,608 1	0,607 2
0,70	***	***	***	***	0,618 2	0,615 7	0,613 6	0,609 9	0,608 1	0,607 1
0,71	***	***	***	***	0,618 5	0,615 9	0,613 8	0,609 9	0,608 1	0,607 1
0,72	***	***	***	***	0,618 7	0,616 1	0,613 9	0,609 8	0,608 0	0,606 9
0,73	***	***	***	***	0,619 0	0,616 2	0,613 9	0,609 7	0,607 8	0,606 7
0,74	***	***	***	***	0,619 1	0,616 3	0,613 9	0,609 6	0,607 6	0,606 5
0,75	***	***	***	***	0,619 3	0,616 3	0,613 8	0,609 4	0,607 3	0,606 2

NOTE — This table is given for convenience. It is not intended for precise interpolation.

TABLE 13 – **Orifice plate with *D* and *D*/2 tappings; flow coefficient α**

β \ Re_D	5×10^3	10^4	2×10^4	3×10^4	5×10^4	7×10^4	10^5	3×10^5	10^6	10^7
0,20	0,600 1	0,599 0	0,598 4	0,598 1	0,597 9	0,597 8	0,597 7	0,597 5	0,597 4	0,597 4
0,22	0,601 3	0,599 9	0,599 1	0,598 7	0,598 4	0,598 3	0,598 2	0,598 0	0,597 9	0,597 8
0,24	0,602 7	0,601 0	0,599 9	0,599 5	0,599 1	0,599 0	0,598 8	0,598 6	0,598 4	0,598 4
0,26	0,604 3	0,602 2	0,600 9	0,600 4	0,600 0	0,599 7	0,599 6	0,599 3	0,599 1	0,599 0
0,28	0,606 2	0,603 6	0,602 1	0,601 5	0,600 9	0,600 7	0,600 5	0,600 1	0,599 9	0,599 8
0,30	***	0,605 2	0,603 4	0,602 7	0,602 1	0,601 8	0,601 5	0,601 1	0,600 8	0,600 7
0,32	***	0,607 1	0,605 0	0,604 1	0,603 4	0,603 0	0,602 7	0,602 2	0,602 0	0,601 8
0,34	***	0,609 3	0,606 8	0,605 8	0,604 9	0,604 5	0,604 2	0,603 5	0,603 3	0,603 1
0,36	***	0,611 7	0,608 8	0,607 7	0,606 7	0,606 2	0,605 8	0,605 1	0,604 8	0,604 6
0,38	***	0,614 5	0,611 1	0,609 8	0,608 7	0,608 1	0,607 7	0,606 9	0,606 5	0,606 3
0,40	***	0,617 6	0,613 8	0,612 3	0,611 0	0,610 4	0,609 9	0,608 9	0,608 5	0,608 2
0,42	***	***	0,616 8	0,615 1	0,613 6	0,612 9	0,612 3	0,611 3	0,610 8	0,610 5
0,44	***	***	0,620 1	0,618 2	0,616 6	0,615 8	0,615 1	0,613 9	0,613 4	0,613 0
0,46	***	***	0,623 9	0,621 8	0,619 9	0,619 0	0,618 3	0,616 9	0,616 3	0,615 9
0,48	***	***	0,628 1	0,625 8	0,623 7	0,622 6	0,621 8	0,620 3	0,619 6	0,619 2
0,50	***	***	0,632 8	0,630 2	0,627 9	0,626 7	0,625 8	0,624 2	0,623 4	0,623 0
0,52	***	***	0,638 1	0,635 2	0,632 6	0,631 3	0,630 3	0,628 5	0,627 6	0,627 1
0,54	***	***	0,643 9	0,640 7	0,637 9	0,636 5	0,635 4	0,633 3	0,632 4	0,631 8
0,56	***	***	0,650 4	0,646 9	0,643 7	0,642 2	0,641 0	0,638 7	0,637 7	0,637 1
0,58	***	***	***	0,653 8	0,650 3	0,648 6	0,647 3	0,644 8	0,643 6	0,643 0
0,60	***	***	***	0,661 4	0,657 6	0,655 8	0,654 3	0,651 5	0,650 3	0,649 6
0,62	***	***	***	0,670 0	0,665 8	0,663 8	0,662 1	0,659 1	0,657 7	0,656 9
0,64	***	***	***	0,679 4	0,674 8	0,672 7	0,670 9	0,667 6	0,666 0	0,665 2
0,66	***	***	***	0,690 0	0,685 0	0,682 6	0,680 6	0,677 0	0,675 4	0,674 4
0,68	***	***	***	0,701 9	0,696 4	0,693 7	0,691 6	0,687 7	0,685 8	0,684 8
0,70	***	***	***	***	0,709 1	0,706 3	0,703 9	0,699 6	0,697 6	0,696 5
0,71	***	***	***	***	0,716 1	0,713 1	0,710 7	0,706 2	0,704 1	0,702 9
0,72	***	***	***	***	0,723 6	0,720 4	0,717 8	0,713 1	0,710 9	0,709 7
0,73	***	***	***	***	0,731 5	0,728 2	0,725 5	0,720 6	0,718 3	0,717 0
0,74	***	***	***	***	0,739 9	0,736 5	0,733 7	0,728 5	0,726 1	0,724 8
0,75	***	***	***	***	0,749 0	0,745 4	0,742 4	0,737 0	0,734 5	0,733 1

NOTE – This table is given for convenience. It is not intended for precise interpolation.

TABLE 14 – **Orifice plate with flange tappings; discharge coefficient *C***
$D = 50$ mm

Re_D / β	5×10^3	10^4	2×10^4	3×10^4	5×10^4	7×10^4	10^5	3×10^5	10^6	10^7
0,25	0,602 3	0,600 3	0,599 2	0,598 7	0,598 3	0,598 1	0,598 0	0,597 7	0,597 6	0,597 5
0,26	0,602 9	0,600 8	0,599 5	0,599 0	0,598 6	0,598 4	0,598 2	0,597 9	0,597 7	0,597 6
0,28	0,604 3	0,601 7	0,600 2	0,599 6	0,599 0	0,598 8	0,598 6	0,598 2	0,598 0	0,597 9
0,30	***	0,602 8	0,600 9	0,600 2	0,599 6	0,599 3	0,599 0	0,598 6	0,598 4	0,598 3
0,32	***	0,603 9	0,601 7	0,600 9	0,600 2	0,599 8	0,599 5	0,599 0	0,598 8	0,598 6
0,34	***	0,605 1	0,602 6	0,601 7	0,600 8	0,600 4	0,600 1	0,599 4	0,599 2	0,599 0
0,36	***	0,606 5	0,603 8	0,602 5	0,601 5	0,601 0	0,600 6	0,599 9	0,599 6	0,599 4
0,38	***	0,608 0	0,604 7	0,603 4	0,602 2	0,601 7	0,601 3	0,600 4	0,600 1	0,599 8
0,40	***	***	0,605 8	0,604 3	0,603 0	0,602 4	0,601 9	0,601 0	0,600 6	0,600 3
0,42	***	***	0,607 0	0,605 4	0,603 9	0,603 2	0,602 6	0,601 6	0,601 1	0,600 8
0,44	***	***	0,608 3	0,606 4	0,604 8	0,604 0	0,603 4	0,602 2	0,601 6	0,601 3
0,46	***	***	0,609 6	0,607 6	0,605 7	0,604 9	0,604 1	0,602 8	0,602 2	0,601 9
0,48	***	***	0,611 1	0,608 8	0,606 7	0,605 8	0,605 0	0,603 5	0,602 8	0,602 4
0,50	***	***	0,612 6	0,610 0	0,607 8	0,606 7	0,605 8	0,604 2	0,603 4	0,603 0
0,52	***	***	0,614 1	0,611 3	0,608 8	0,607 6	0,606 7	0,604 9	0,604 1	0,603 6
0,54	***	***	0,615 7	0,612 7	0,609 9	0,608 6	0,607 5	0,605 6	0,604 7	0,604 2
0,56	***	***	0,617 4	0,614 0	0,611 0	0,609 6	0,608 4	0,606 3	0,605 3	0,604 7
0,58	***	***	***	0,615 4	0,612 1	0,610 6	0,609 3	0,607 0	0,605 9	0,605 3
0,60	***	***	***	0,616 8	0,613 2	0,611 5	0,610 1	0,607 6	0,606 4	0,605 7
0,62	***	***	***	0,618 2	0,614 3	0,612 4	0,610 9	0,608 2	0,606 9	0,606 2
0,64	***	***	***	0,619 5	0,615 3	0,613 3	0,611 7	0,608 7	0,607 3	0,606 5
0,65	***	***	***	0,620 1	0,615 8	0,613 7	0,612 0	0,608 9	0,607 4	0,606 6
0,66	***	***	***	0,620 8	0,616 2	0,614 1	0,612 3	0,609 1	0,607 6	0,606 7
0,67	***	***	***	0,621 4	0,616 7	0,614 4	0,612 6	0,609 2	0,607 6	0,606 8
0,68	***	***	***	0,621 9	0,617 1	0,614 7	0,612 8	0,609 3	0,607 7	0,606 8
0,69	***	***	***	0,622 5	0,617 4	0,615 0	0,613 0	0,609 4	0,607 7	0,606 8
0,70	***	***	***	***	0,617 7	0,615 2	0,613 2	0,609 4	0,607 7	0,606 7
0,71	***	***	***	***	0,618 0	0,615 4	0,613 3	0,609 4	0,607 6	0,606 6
0,72	***	***	***	***	0,618 3	0,615 6	0,613 4	0,609 4	0,607 5	0,606 4
0,73	***	***	***	***	0,618 5	0,615 7	0,613 4	0,609 2	0,607 3	0,606 2
0,74	***	***	***	***	0,618 6	0,615 7	0,613 4	0,609 1	0,607 1	0,605 9
0,75	***	***	***	***	0,618 7	0,615 7	0,613 3	0,608 8	0,606 8	0,605 6

NOTE – This table is given for convenience. It is not intended for precise interpolation.

TABLE 15 – **Orifice plate with flange tappings; flow coefficient** α
$D = 50$ mm

β \ Re_D	5×10^3	10^4	2×10^4	3×10^4	5×10^4	7×10^4	10^5	3×10^5	10^6	10^7
0,25	0,603 5	0,601 5	0,600 4	0,599 9	0,599 5	0,599 3	0,599 2	0,598 9	0,598 7	0,598 7
0,26	0,604 3	0,602 2	0,600 9	0,600 4	0,599 9	0,599 7	0,599 6	0,599 2	0,599 1	0,599 0
0,28	0,606 2	0,603 6	0,602 0	0,601 4	0,600 9	0,600 6	0,600 4	0,600 1	0,599 9	0,599 8
0,30	***	0,605 2	0,603 4	0,602 7	0,602 0	0,601 7	0,601 5	0,601 0	0,600 8	0,600 7
0,32	***	0,607 1	0,604 9	0,604 1	0,603 3	0,603 0	0,602 7	0,602 2	0,601 9	0,601 8
0,34	***	0,609 2	0,606 7	0,605 7	0,604 9	0,604 4	0,604 1	0,603 5	0,603 2	0,603 0
0,36	***	0,611 7	0,608 7	0,607 6	0,606 6	0,606 1	0,605 7	0,605 0	0,604 7	0,604 5
0,38	***	0,614 4	0,611 1	0,609 8	0,608 6	0,608 1	0,607 6	0,606 8	0,606 4	0,606 2
0,40	***	***	0,613 7	0,612 2	0,610 9	0,610 3	0,609 8	0,608 8	0,608 4	0,608 2
0,42	***	***	0,616 7	0,615 0	0,613 5	0,612 8	0,612 2	0,611 2	0,610 7	0,610 4
0,44	***	***	0,620 0	0,618 1	0,616 5	0,615 7	0,615 0	0,613 8	0,613 2	0,612 9
0,46	***	***	0,623 8	0,621 7	0,619 8	0,618 9	0,618 1	0,616 8	0,616 2	0,615 8
0,48	***	***	0,628 0	0,625 6	0,623 5	0,622 5	0,621 7	0,620 2	0,619 5	0,619 1
0,50	***	***	0,632 6	0,630 0	0,627 7	0,626 6	0,625 7	0,624 0	0,623 2	0,622 8
0,52	***	***	0,637 9	0,635 0	0,632 4	0,631 2	0,630 1	0,628 3	0,627 4	0,626 9
0,54	***	***	0,643 7	0,640 5	0,637 6	0,636 3	0,635 2	0,633 1	0,632 1	0,631 6
0,56	***	***	0,650 2	0,646 7	0,643 5	0,642 0	0,640 8	0,638 5	0,637 4	0,636 8
0,58	***	***	***	0,653 5	0,650 0	0,648 4	0,647 0	0,644 5	0,643 4	0,642 7
0,60	***	***	***	0,661 1	0,657 3	0,655 5	0,654 0	0,651 3	0,650 0	0,649 3
0,62	***	***	***	0,669 6	0,665 4	0,663 4	0,661 8	0,658 8	0,657 4	0,656 6
0,64	***	***	***	0,679 1	0,674 5	0,672 3	0,670 5	0,667 2	0,665 7	0,664 8
0,65	***	***	***	0,684 2	0,679 4	0,677 1	0,675 2	0,671 8	0,670 2	0,669 3
0,66	***	***	***	0,689 6	0,684 6	0,682 2	0,680 2	0,676 6	0,675 0	0,674 0
0,67	***	***	***	0,695 4	0,690 1	0,687 6	0,685 5	0,681 8	0,680 0	0,679 0
0,68	***	***	***	0,701 4	0,695 9	0,693 3	0,691 1	0,687 2	0,685 4	0,684 3
0,69	***	***	***	0,707 9	0,702 1	0,699 3	0,697 1	0,693 0	0,691 1	0,690 0
0,70	***	***	***	***	0,708 6	0,705 8	0,703 4	0,699 1	0,697 1	0,696 0
0,71	***	***	***	***	0,715 6	0,712 6	0,710 1	0,705 6	0,703 5	0,702 4
0,72	***	***	***	***	0,723 0	0,719 9	0,717 3	0,712 6	0,710 4	0,709 2
0,73	***	***	***	***	0,730 9	0,727 6	0,724 9	0,720 0	0,717 7	0,716 4
0,74	***	***	***	***	0,739 3	0,735 9	0,733 1	0,727 9	0,725 5	0,724 2
0,75	***	***	***	***	0,748 3	0,744 7	0,741 8	0,736 4	0,733 9	0,732 5

NOTE – This table is given for convenience. It is not intended for precise interpolation.

TABLE 16 – **Orifice plate with flange tappings; discharge coefficient *C***
$D = 75$ mm

β \ Re_D	5×10^3	10^4	2×10^4	3×10^4	5×10^4	7×10^4	10^5	3×10^5	10^6	10^7
0,20	0,599 7	0,598 6	0,597 9	0,597 6	0,597 4	0,597 3	0,597 2	0,597 0	0,597 0	0,596 9
0,22	0,600 6	0,599 2	0,598 4	0,598 1	0,597 8	0,597 6	0,597 5	0,597 3	0,597 2	0,597 2
0,24	***	0,600 0	0,598 9	0,598 5	0,598 2	0,598 0	0,597 9	0,597 6	0,597 5	0,597 4
0,26	***	0,600 8	0,599 6	0,599 1	0,598 6	0,598 4	0,598 2	0,597 9	0,597 8	0,597 7
0,28	***	0,601 8	0,600 2	0,599 7	0,599 1	0,598 9	0,598 7	0,598 3	0,598 1	0,598 0
0,30	***	0,602 8	0,601 0	0,600 3	0,599 7	0,599 4	0,599 1	0,598 7	0,598 5	0,598 3
0,32	***	0,604 0	0,601 8	0,601 0	0,600 3	0,599 9	0,599 6	0,599 1	0,598 8	0,598 7
0,34	***	***	0,602 7	0,601 8	0,600 9	0,600 5	0,600 2	0,599 6	0,599 3	0,599 1
0,36	***	***	0,603 7	0,602 6	0,601 6	0,601 1	0,600 8	0,600 0	0,599 7	0,599 5
0,38	***	***	0,604 8	0,603 5	0,602 4	0,601 8	0,601 4	0,600 6	0,600 2	0,600 0
0,40	***	***	0,605 9	0,604 5	0,603 2	0,602 6	0,602 1	0,601 1	0,600 7	0,600 5
0,42	***	***	0,607 1	0,605 5	0,604 0	0,603 3	0,602 8	0,601 7	0,601 2	0,601 0
0,44	***	***	0,608 4	0,606 6	0,604 9	0,604 2	0,603 5	0,602 3	0,601 8	0,601 5
0,46	***	***	0,609 8	0,607 7	0,605 9	0,605 0	0,604 3	0,603 0	0,602 4	0,602 0
0,48	***	***	***	0,608 9	0,606 9	0,605 9	0,605 1	0,603 6	0,603 0	0,602 6
0,50	***	***	***	0,610 2	0,607 9	0,606 8	0,605 9	0,604 3	0,603 6	0,603 2
0,52	***	***	***	0,611 5	0,609 0	0,607 8	0,606 8	0,605 0	0,604 2	0,603 7
0,54	***	***	***	0,612 8	0,610 0	0,608 7	0,607 7	0,605 7	0,604 8	0,604 3
0,56	***	***	***	0,614 1	0,611 1	0,609 7	0,608 5	0,606 4	0,605 4	0,604 8
0,58	***	***	***	***	0,612 2	0,610 6	0,609 3	0,607 0	0,605 9	0,605 3
0,60	***	***	***	***	0,613 2	0,611 5	0,610 1	0,607 6	0,606 4	0,605 7
0,62	***	***	***	***	0,614 2	0,612 3	0,610 8	0,608 0	0,606 8	0,606 0
0,64	***	***	***	***	0,615 1	0,613 1	0,611 4	0,608 4	0,607 0	0,606 3
0,65	***	***	***	***	0,615 5	0,613 4	0,611 7	0,608 6	0,607 1	0,606 3
0,66	***	***	***	***	0,615 9	0,613 7	0,611 9	0,608 7	0,607 2	0,606 4
0,67	***	***	***	***	0,616 2	0,614 0	0,612 1	0,608 8	0,607 2	0,606 3
0,68	***	***	***	***	0,616 5	0,614 2	0,612 3	0,608 8	0,607 2	0,606 3
0,69	***	***	***	***	0,616 8	0,614 4	0,612 4	0,608 8	0,607 1	0,606 1
0,70	***	***	***	***	0,617 0	0,614 5	0,612 4	0,608 7	0,606 9	0,606 0
0,71	***	***	***	***	0,617 2	0,614 6	0,612 4	0,608 6	0,606 7	0,605 7
0,72	***	***	***	***	0,617 3	0,614 6	0,612 4	0,608 4	0,606 5	0,605 4
0,73	***	***	***	***	***	0,614 5	0,612 2	0,608 1	0,606 1	0,605 1
0,74	***	***	***	***	***	0,614 4	0,612 0	0,607 7	0,605 7	0,604 6
0,75	***	***	***	***	***	0,614 2	0,611 8	0,607 3	0,605 2	0,604 1

NOTE – This table is given for convenience. It is not intended for precise interpolation.

TABLE 17 — **Orifice plate with flange tappings; flow coefficient α**
D = 75 mm

β \ Re_D	5×10^3	10^4	2×10^4	3×10^4	5×10^4	7×10^4	10^5	3×10^5	10^6	10^7
0,20	0,600 2	0,599 0	0,598 4	0,598 1	0,597 9	0,597 8	0,597 7	0,597 5	0,597 4	0,597 4
0,22	0,601 4	0,599 9	0,599 1	0,598 8	0,598 5	0,598 3	0,598 2	0,598 0	0,597 9	0,597 9
0,24	***	0,601 0	0,599 9	0,599 5	0,599 2	0,599 0	0,598 9	0,598 6	0,598 5	0,598 4
0,26	***	0,602 2	0,600 9	0,600 4	0,600 0	0,599 8	0,599 6	0,599 3	0,599 1	0,599 1
0,28	***	0,603 6	0,602 1	0,601 5	0,601 0	0,600 7	0,600 5	0,600 1	0,600 0	0,599 9
0,30	***	0,605 3	0,603 5	0,602 7	0,602 1	0,601 8	0,601 6	0,601 1	0,600 9	0,600 8
0,32	***	0,607 2	0,605 0	0,604 2	0,603 4	0,603 1	0,602 8	0,602 3	0,602 0	0,601 9
0,34	***	***	0,606 8	0,605 8	0,605 0	0,604 6	0,604 2	0,603 6	0,603 3	0,603 1
0,36	***	***	0,608 9	0,607 7	0,606 7	0,606 3	0,605 9	0,605 1	0,604 8	0,604 6
0,38	***	***	0,611 2	0,609 9	0,608 8	0,608 2	0,607 8	0,606 9	0,606 5	0,606 3
0,40	***	***	0,613 8	0,612 4	0,611 1	0,610 4	0,609 9	0,609 0	0,608 5	0,608 3
0,42	***	***	0,616 8	0,615 1	0,613 7	0,612 9	0,612 4	0,611 3	0,610 8	0,610 5
0,44	***	***	0,620 2	0,618 3	0,616 6	0,615 8	0,615 2	0,614 0	0,613 4	0,613 1
0,46	***	***	0,623 9	0,621 8	0,619 9	0,619 0	0,618 3	0,617 0	0,616 3	0,616 0
0,48	***	***	***	0,625 8	0,623 7	0,622 7	0,621 8	0,620 3	0,619 6	0,619 3
0,50	***	***	***	0,630 2	0,627 8	0,626 7	0,625 8	0,624 1	0,623 4	0,622 9
0,52	***	***	***	0,635 1	0,632 5	0,631 3	0,630 3	0,628 4	0,627 6	0,627 1
0,54	***	***	***	0,640 6	0,637 8	0,636 4	0,635 3	0,633 2	0,632 3	0,631 7
0,56	***	***	***	0,646 7	0,643 6	0,642 1	0,640 8	0,638 6	0,637 5	0,636 9
0,58	***	***	***	***	0,650 1	0,648 4	0,647 0	0,644 5	0,643 4	0,642 7
0,60	***	***	***	***	0,657 3	0,655 4	0,653 9	0,651 2	0,649 9	0,649 2
0,62	***	***	***	***	0,665 3	0,663 3	0,661 7	0,658 7	0,657 3	0,656 5
0,64	***	***	***	***	0,674 2	0,672 0	0,670 2	0,667 0	0,665 4	0,664 6
0,65	***	***	***	***	0,679 1	0,676 8	0,674 9	0,671 5	0,669 9	0,669 0
0,66	***	***	***	***	0,684 2	0,681 8	0,679 8	0,676 2	0,674 6	0,673 6
0,67	***	***	***	***	0,689 6	0,687 1	0,685 0	0,681 3	0,679 5	0,678 5
0,68	***	***	***	***	0,695 3	0,692 7	0,690 5	0,686 6	0,684 8	0,683 8
0,69	***	***	***	***	0,701 4	0,698 6	0,696 4	0,692 3	0,690 4	0,689 3
0,70	***	***	***	***	0,707 8	0,704 9	0,702 6	0,698 3	0,696 3	0,695 1
0,71	***	***	***	***	0,714 6	0,711 6	0,709 1	0,704 6	0,702 5	0,701 4
0,72	***	***	***	***	0,721 8	0,718 7	0,716 1	0,711 4	0,709 2	0,708 0
0,73	***	***	***	***	***	0,726 2	0,723 5	0,718 6	0,716 3	0,715 0
0,74	***	***	***	***	***	0,734 3	0,731 5	0,726 3	0,723 9	0,722 6
0,75	***	***	***	***	***	0,742 9	0,739 9	0,734 5	0,732 0	0,730 6

NOTE — This table is given for convenience. It is not intended for precise interpolation.

TABLE 18 — **Orifice plate with flange tappings; discharge coefficient *C***
$D = 100$ mm

Re_D / β	10^4	2×10^4	3×10^4	5×10^4	7×10^4	10^5	3×10^5	10^6	10^7
0,20	0,598 6	0,597 9	0,597 6	0,597 4	0,597 3	0,597 2	0,597 1	0,597 0	0,596 9
0,22	0,599 2	0,598 4	0,598 1	0,597 8	0,597 6	0,597 5	0,597 3	0,597 2	0,597 2
0,24	0,600 0	0,599 0	0,598 5	0,598 2	0,598 0	0,597 9	0,597 6	0,597 5	0,597 4
0,26	0,600 9	0,599 6	0,599 1	0,598 6	0,598 4	0,598 3	0,597 9	0,597 8	0,597 7
0,28	0,601 8	0,600 3	0,599 7	0,599 1	0,598 9	0,598 7	0,598 3	0,598 1	0,598 0
0,30	***	0,601 0	0,600 3	0,599 7	0,599 4	0,599 1	0,598 7	0,598 5	0,598 4
0,32	***	0,601 9	0,601 0	0,600 3	0,599 9	0,599 6	0,599 1	0,598 9	0,598 7
0,34	***	0,602 8	0,601 8	0,600 9	0,600 5	0,600 2	0,599 6	0,599 3	0,599 1
0,36	***	0,603 7	0,602 6	0,601 6	0,601 1	0,600 8	0,600 0	0,599 7	0,599 5
0,38	***	0,604 8	0,603 5	0,602 4	0,601 8	0,601 4	0,600 6	0,600 2	0,600 0
0,40	***	***	0,604 5	0,603 2	0,602 5	0,602 0	0,601 1	0,600 7	0,600 4
0,42	***	***	0,605 5	0,604 0	0,603 3	0,602 7	0,601 7	0,601 2	0,600 9
0,44	***	***	0,606 5	0,604 9	0,604 1	0,603 5	0,602 3	0,601 7	0,601 4
0,46	***	***	0,607 7	0,605 8	0,604 9	0,604 2	0,602 9	0,602 3	0,602 0
0,48	***	***	0,608 8	0,606 8	0,605 8	0,605 0	0,603 5	0,602 9	0,602 5
0,50	***	***	***	0,607 8	0,606 7	0,605 8	0,604 2	0,603 4	0,603 0
0,52	***	***	***	0,608 8	0,607 6	0,606 6	0,604 8	0,604 0	0,603 5
0,54	***	***	***	0,609 8	0,608 5	0,607 4	0,605 4	0,604 5	0,604 0
0,56	***	***	***	0,610 8	0,609 3	0,608 2	0,606 0	0,605 0	0,604 5
0,58	***	***	***	0,611 8	0,610 2	0,608 9	0,606 6	0,605 5	0,604 9
0,60	***	***	***	0,612 7	0,611 0	0,609 6	0,607 0	0,605 8	0,605 2
0,62	***	***	***	0,613 5	0,611 7	0,610 2	0,607 4	0,606 1	0,605 4
0,64	***	***	***	***	0,612 3	0,610 7	0,607 7	0,606 3	0,605 5
0,65	***	***	***	***	0,612 5	0,610 8	0,607 7	0,606 3	0,605 5
0,66	***	***	***	***	0,612 7	0,611 0	0,607 7	0,606 2	0,605 4
0,67	***	***	***	***	0,612 9	0,611 1	0,607 7	0,606 1	0,605 3
0,68	***	***	***	***	0,613 0	0,611 1	0,607 6	0,606 0	0,605 1
0,69	***	***	***	***	0,613 1	0,611 1	0,607 5	0,605 8	0,604 9
0,70	***	***	***	***	0,613 1	0,611 0	0,607 3	0,605 5	0,604 5
0,71	***	***	***	***	0,613 0	0,610 9	0,607 0	0,605 2	0,604 2
0,72	***	***	***	***	0,612 8	0,610 6	0,606 6	0,604 7	0,603 7
0,73	***	***	***	***	0,612 6	0,610 3	0,606 2	0,604 2	0,603 1
0,74	***	***	***	***	0,612 3	0,609 9	0,605 6	0,603 6	0,602 5
0,75	***	***	***	***	***	0,609 4	0,605 0	0,602 9	0,601 8

NOTE — This table is given for convenience. It is not intended for precise interpolation.

TABLE 19 — **Orifice plate with flange tappings; flow coefficient** α
D = 100 mm

β \ Re_D	10^4	2×10^4	3×10^4	5×10^4	7×10^4	10^5	3×10^5	10^6	10^7
0,20	0,599 1	0,598 4	0,598 1	0,597 9	0,597 8	0,597 7	0,597 5	0,597 5	0,597 4
0,22	0,599 9	0,599 1	0,598 8	0,598 5	0,598 3	0,598 2	0,598 0	0,597 9	0,597 9
0,24	0,601 0	0,599 9	0,599 5	0,599 2	0,599 0	0,598 9	0,598 6	0,598 5	0,598 4
0,26	0,602 2	0,600 9	0,600 5	0,600 0	0,599 8	0,599 6	0,599 3	0,599 2	0,599 1
0,28	0,603 7	0,602 1	0,601 5	0,601 0	0,600 7	0,600 5	0,600 1	0,600 0	0,599 9
0,30	***	0,603 5	0,602 8	0,602 1	0,601 8	0,601 6	0,601 1	0,600 9	0,600 8
0,32	***	0,605 0	0,604 2	0,603 5	0,603 1	0,602 8	0,602 3	0,602 0	0,601 9
0,34	***	0,606 8	0,605 9	0,605 0	0,604 6	0,604 2	0,603 6	0,603 3	0,603 2
0,36	***	0,608 9	0,607 7	0,606 7	0,606 3	0,605 9	0,605 1	0,604 8	0,604 6
0,38	***	0,611 2	0,609 9	0,608 7	0,608 2	0,607 7	0,606 9	0,606 5	0,606 3
0,40	***	***	0,612 3	0,611 0	0,610 4	0,609 9	0,609 0	0,608 5	0,608 3
0,42	***	***	0,615 1	0,613 6	0,612 9	0,612 3	0,611 3	0,610 8	0,610 5
0,44	***	***	0,618 2	0,616 6	0,615 8	0,615 1	0,613 9	0,613 3	0,613 0
0,46	***	***	0,621 7	0,619 8	0,619 0	0,618 2	0,616 9	0,616 2	0,615 9
0,48	***	***	0,625 7	0,623 6	0,622 5	0,621 7	0,620 2	0,619 5	0,619 1
0,50	***	***	***	0,627 7	0,626 6	0,625 7	0,624 0	0,623 2	0,622 8
0,52	***	***	***	0,632 3	0,631 1	0,630 1	0,628 2	0,627 4	0,626 9
0,54	***	***	***	0,637 5	0,636 1	0,635 0	0,632 9	0,632 0	0,631 5
0,56	***	***	***	0,643 2	0,641 7	0,640 5	0,638 2	0,637 2	0,636 6
0,58	***	***	***	0,649 6	0,648 0	0,646 6	0,644 1	0,642 9	0,642 3
0,60	***	***	***	0,656 7	0,654 9	0,653 4	0,650 7	0,649 4	0,648 7
0,62	***	***	***	0,664 6	0,662 6	0,661 0	0,658 0	0,656 6	0,655 8
0,64	***	***	***	***	0,671 2	0,669 4	0,666 1	0,664 6	0,663 7
0,65	***	***	***	***	0,675 8	0,673 9	0,670 5	0,668 9	0,668 0
0,66	***	***	***	***	0,680 7	0,678 8	0,675 2	0,673 5	0,672 5
0,67	***	***	***	***	0,685 9	0,683 8	0,680 1	0,678 3	0,677 4
0,68	***	***	***	***	0,691 4	0,689 2	0,685 3	0,683 5	0,682 4
0,69	***	***	***	***	0,697 2	0,694 9	0,690 8	0,688 9	0,687 8
0,70	***	***	***	***	0,703 3	0,700 9	0,696 6	0,694 6	0,693 5
0,71	***	***	***	***	0,709 8	0,707 3	0,702 8	0,700 7	0,699 5
0,72	***	***	***	***	0,716 7	0,714 1	0,709 4	0,707 2	0,706 0
0,73	***	***	***	***	0,724 0	0,721 3	0,716 4	0,714 1	0,712 8
0,74	***	***	***	***	0,731 8	0,728 9	0,723 8	0,721 4	0,720 1
0,75	***	***	***	***	***	0,737 1	0,731 7	0,729 2	0,727 8

NOTE — This table is given for convenience. It is not intended for precise interpolation.

TABLE 20 – **Orifice plate with flange tappings; discharge coefficient** C
D = 150 mm

β \ Re_D	10^4	2×10^4	3×10^4	5×10^4	7×10^4	10^5	3×10^5	10^6	10^7
0,20	0,598 6	0,597 9	0,597 7	0,597 4	0,597 3	0,597 2	0,597 1	0,597 0	0,596 9
0,22	0,599 3	0,598 4	0,598 1	0,597 8	0,597 7	0,597 5	0,597 3	0,597 2	0,597 2
0,24	***	0,599 0	0,598 6	0,598 2	0,598 0	0,597 9	0,597 6	0,597 5	0,597 4
0,26	***	0,599 6	0,599 1	0,598 7	0,598 4	0,598 3	0,598 0	0,597 8	0,597 7
0,28	***	0,600 3	0,599 7	0,599 2	0,598 9	0,598 7	0,598 3	0,598 1	0,598 0
0,30	***	0,601 0	0,600 3	0,599 7	0,599 4	0,599 2	0,598 7	0,598 5	0,598 4
0,32	***	0,601 9	0,601 0	0,600 3	0,599 9	0,599 6	0,599 1	0,598 9	0,598 7
0,34	***	***	0,601 8	0,600 9	0,600 5	0,600 2	0,599 6	0,599 3	0,599 1
0,36	***	***	0,602 6	0,601 6	0,601 2	0,600 8	0,600 0	0,599 7	0,599 5
0,38	***	***	0,603 5	0,602 4	0,601 8	0,601 4	0,600 6	0,600 2	0,600 0
0,40	***	***	***	0,603 1	0,602 5	0,602 0	0,601 1	0,600 7	0,600 4
0,42	***	***	***	0,604 0	0,603 3	0,602 7	0,601 7	0,601 2	0,600 9
0,44	***	***	***	0,604 8	0,604 0	0,603 4	0,602 2	0,601 7	0,601 4
0,46	***	***	***	0,605 7	0,604 9	0,604 1	0,602 8	0,602 2	0,601 9
0,48	***	***	***	0,606 7	0,605 7	0,604 9	0,603 4	0,602 7	0,602 4
0,50	***	***	***	0,607 6	0,606 5	0,605 6	0,604 0	0,603 3	0,602 9
0,52	***	***	***	***	0,607 4	0,606 4	0,604 6	0,603 8	0,603 3
0,54	***	***	***	***	0,608 2	0,607 1	0,605 2	0,604 3	0,603 8
0,56	***	***	***	***	0,609 0	0,607 8	0,605 7	0,604 7	0,604 1
0,58	***	***	***	***	0,609 8	0,608 5	0,606 1	0,605 1	0,604 4
0,60	***	***	***	***	0,610 5	0,609 1	0,606 5	0,605 3	0,604 7
0,62	***	***	***	***	***	0,609 5	0,606 8	0,605 5	0,604 8
0,64	***	***	***	***	***	0,609 9	0,606 9	0,605 5	0,604 7
0,65	***	***	***	***	***	0,610 0	0,606 8	0,605 4	0,604 6
0,66	***	***	***	***	***	0,610 0	0,606 8	0,605 3	0,604 4
0,67	***	***	***	***	***	0,610 0	0,606 6	0,605 1	0,604 2
0,68	***	***	***	***	***	0,609 9	0,606 4	0,604 8	0,603 9
0,69	***	***	***	***	***	0,609 8	0,606 2	0,604 5	0,603 6
0,70	***	***	***	***	***	0,609 6	0,605 8	0,604 1	0,603 1
0,71	***	***	***	***	***	0,609 3	0,605 4	0,603 6	0,602 6
0,72	***	***	***	***	***	0,608 9	0,604 9	0,603 0	0,602 0
0,73	***	***	***	***	***	***	0,604 3	0,602 3	0,601 2
0,74	***	***	***	***	***	***	0,603 5	0,601 5	0,600 4
0,75	***	***	***	***	***	***	0,602 7	0,600 6	0,599 4

NOTE – This table is given for convenience. It is not intended for precise interpolation.

TABLE 21 – **Orifice plate with flange tappings; flow coefficient** α
D = 150 mm

β \ Re_D	10^4	2×10^4	3×10^4	5×10^4	7×10^4	10^5	3×10^5	10^6	10^7
0,20	0,599 1	0,598 4	0,598 1	0,597 9	0,597 8	0,597 7	0,597 5	0,597 5	0,597 4
0,22	0,600 0	0,599 1	0,598 8	0,598 5	0,598 4	0,598 2	0,598 0	0,597 9	0,597 9
0,24	***	0,600 0	0,599 6	0,599 2	0,599 0	0,598 9	0,598 6	0,598 5	0,598 4
0,26	***	0,601 0	0,600 5	0,600 0	0,599 8	0,599 6	0,599 3	0,599 2	0,599 1
0,28	***	0,602 1	0,601 5	0,601 0	0,600 7	0,600 5	0,600 2	0,600 0	0,599 9
0,30	***	0,603 5	0,602 8	0,602 1	0,601 8	0,601 6	0,601 1	0,600 9	0,600 8
0,32	***	0,605 0	0,604 2	0,603 5	0,603 1	0,602 8	0,602 3	0,602 0	0,601 9
0,34	***	***	0,605 9	0,605 0	0,604 6	0,604 2	0,603 6	0,603 3	0,603 2
0,36	***	***	0,607 7	0,606 7	0,606 3	0,605 9	0,605 2	0,604 8	0,604 6
0,38	***	***	0,609 9	0,608 7	0,608 2	0,607 7	0,606 9	0,606 5	0,606 3
0,40	***	***	***	0,611 0	0,610 4	0,609 9	0,608 9	0,608 5	0,608 3
0,42	***	***	***	0,613 6	0,612 9	0,612 3	0,611 2	0,610 7	0,610 5
0,44	***	***	***	0,616 5	0,615 7	0,615 0	0,613 8	0,613 3	0,613 0
0,46	***	***	***	0,619 8	0,618 9	0,618 1	0,616 8	0,616 2	0,615 8
0,48	***	***	***	0,623 4	0,622 4	0,621 6	0,620 1	0,619 4	0,619 0
0,50	***	***	***	0,627 5	0,626 4	0,625 5	0,623 8	0,623 1	0,622 6
0,52	***	***	***	***	0,630 9	0,629 9	0,628 0	0,627 1	0,626 7
0,54	***	***	***	***	0,635 8	0,634 7	0,632 7	0,631 7	0,631 2
0,56	***	***	***	***	0,641 4	0,640 1	0,637 9	0,636 8	0,636 2
0,58	***	***	***	***	0,647 5	0,646 2	0,643 7	0,642 5	0,641 9
0,60	***	***	***	***	0,654 3	0,652 8	0,650 1	0,648 8	0,648 1
0,62	***	***	***	***	***	0,660 3	0,657 3	0,655 9	0,655 1
0,64	***	***	***	***	***	0,668 5	0,665 2	0,663 7	0,662 8
0,65	***	***	***	***	***	0,673 0	0,669 5	0,667 9	0,667 0
0,66	***	***	***	***	***	0,677 7	0,674 1	0,672 4	0,671 5
0,67	***	***	***	***	***	0,682 7	0,678 9	0,677 1	0,676 2
0,68	***	***	***	***	***	0,687 9	0,684 0	0,682 1	0,681 1
0,69	***	***	***	***	***	0,693 4	0,689 3	0,687 4	0,686 3
0,70	***	***	***	***	***	0,699 3	0,695 0	0,693 0	0,691 9
0,71	***	***	***	***	***	0,705 5	0,701 0	0,698 9	0,697 7
0,72	***	***	***	***	***	0,712 1	0,707 3	0,705 2	0,703 9
0,73	***	***	***	***	***	***	0,714 1	0,711 8	0,710 5
0,74	***	***	***	***	***	***	0,721 3	0,718 9	0,717 5
0,75	***	***	***	***	***	***	0,728 9	0,726 4	0,725 0

NOTE – This table is given for convenience. It is not intended for precise interpolation.

TABLE 22 – **Orifice plate with flange tappings; discharge coefficient *C***
D = 200 mm

β \ Re_D	2×10^4	3×10^4	5×10^4	7×10^4	10^5	3×10^5	10^6	10^7
0,20	0,597 9	0,597 7	0,597 4	0,597 3	0,597 2	0,597 1	0,597 0	0,597 0
0,22	0,598 4	0,598 1	0,597 8	0,597 7	0,597 5	0,597 3	0,597 2	0,597 2
0,24	0,599 0	0,598 6	0,598 2	0,598 0	0,597 9	0,597 6	0,597 5	0,597 4
0,26	0,599 6	0,599 1	0,598 7	0,598 5	0,598 3	0,598 0	0,597 8	0,597 7
0,28	0,600 3	0,599 7	0,599 2	0,598 9	0,598 7	0,598 3	0,598 1	0,598 0
0,30	***	0,600 3	0,599 7	0,599 4	0,599 2	0,598 7	0,598 5	0,598 4
0,32	***	0,601 0	0,600 3	0,599 9	0,599 7	0,599 1	0,598 9	0,598 7
0,34	***	0,601 8	0,600 9	0,600 5	0,600 2	0,599 6	0,599 3	0,599 1
0,36	***	***	0,601 6	0,601 2	0,600 8	0,600 1	0,599 7	0,599 5
0,38	***	***	0,602 4	0,601 8	0,601 4	0,600 6	0,600 2	0,600 0
0,40	***	***	0,603 1	0,602 5	0,602 0	0,601 1	0,600 7	0,600 4
0,42	***	***	0,604 0	0,603 3	0,602 7	0,601 6	0,601 1	0,600 9
0,44	***	***	0,604 8	0,604 0	0,603 4	0,602 2	0,601 7	0,601 4
0,46	***	***	***	0,604 8	0,604 1	0,602 8	0,602 2	0,601 8
0,48	***	***	***	0,605 6	0,604 8	0,603 4	0,602 7	0,602 3
0,50	***	***	***	0,606 5	0,605 6	0,604 0	0,603 2	0,602 8
0,52	***	***	***	0,607 3	0,606 3	0,604 5	0,603 7	0,603 2
0,54	***	***	***	***	0,607 0	0,605 0	0,604 1	0,603 6
0,56	***	***	***	***	0,607 7	0,605 5	0,604 5	0,604 0
0,58	***	***	***	***	0,608 3	0,605 9	0,604 8	0,604 2
0,60	***	***	***	***	0,608 8	0,606 3	0,605 1	0,604 4
0,62	***	***	***	***	0,609 2	0,606 4	0,605 2	0,604 4
0,64	***	***	***	***	***	0,606 5	0,605 1	0,604 3
0,65	***	***	***	***	***	0,606 4	0,605 0	0,604 1
0,66	***	***	***	***	***	0,606 3	0,604 8	0,603 9
0,67	***	***	***	***	***	0,606 1	0,604 5	0,603 7
0,68	***	***	***	***	***	0,605 9	0,604 2	0,603 3
0,69	***	***	***	***	***	0,605 5	0,603 9	0,602 9
0,70	***	***	***	***	***	0,605 1	0,603 4	0,602 4
0,71	***	***	***	***	***	0,604 6	0,602 8	0,601 8
0,72	***	***	***	***	***	0,604 0	0,602 1	0,601 1
0,73	***	***	***	***	***	0,603 3	0,601 4	0,600 3
0,74	***	***	***	***	***	0,602 5	0,600 5	0,599 3
0,75	***	***	***	***	***	0,601 5	0,599 4	0,598 3

NOTE – This table is given for convenience. It is not intended for precise interpolation.

TABLE 23 – **Orifice plate with flange tappings; flow coefficient** α
D = 200 mm

Re_D / β	2×10^4	3×10^4	5×10^4	7×10^4	10^5	3×10^5	10^6	10^7
0,20	0,598 4	0,598 1	0,597 9	0,597 8	0,597 7	0,597 6	0,597 5	0,597 4
0,22	0,599 1	0,598 8	0,598 5	0,598 4	0,598 2	0,598 0	0,597 9	0,597 9
0,24	0,600 0	0,599 6	0,599 2	0,599 0	0,598 9	0,598 6	0,598 5	0,598 4
0,26	0,601 0	0,600 5	0,600 0	0,599 8	0,599 7	0,599 3	0,599 2	0,599 1
0,28	0,602 1	0,601 5	0,601 0	0,600 8	0,600 5	0,600 2	0,600 0	0,599 9
0,30	***	0,602 8	0,602 2	0,601 8	0,601 6	0,601 1	0,600 9	0,600 8
0,32	***	0,604 2	0,603 5	0,603 1	0,602 8	0,602 3	0,602 0	0,601 9
0,34	***	0,605 9	0,605 0	0,604 6	0,604 2	0,603 6	0,603 3	0,603 2
0,36	***	***	0,606 7	0,606 3	0,605 9	0,605 2	0,604 8	0,604 6
0,38	***	***	0,608 7	0,608 2	0,607 7	0,606 9	0,606 5	0,606 3
0,40	***	***	0,611 0	0,610 4	0,609 9	0,608 9	0,608 5	0,608 2
0,42	***	***	0,613 6	0,612 9	0,612 3	0,611 2	0,610 7	0,610 4
0,44	***	***	0,616 5	0,615 7	0,615 0	0,613 8	0,613 3	0,612 9
0,46	***	***	***	0,618 8	0,618 1	0,616 8	0,616 1	0,615 8
0,48	***	***	***	0,622 4	0,621 6	0,620 1	0,619 4	0,619 0
0,50	***	***	***	0,626 3	0,625 4	0,623 8	0,623 0	0,622 5
0,52	***	***	***	0,630 8	0,629 8	0,627 9	0,627 0	0,626 6
0,54	***	***	***	***	0,634 6	0,632 5	0,631 6	0,631 0
0,56	***	***	***	***	0,640 0	0,637 7	0,636 6	0,636 1
0,58	***	***	***	***	0,645 9	0,643 4	0,642 3	0,641 6
0,60	***	***	***	***	0,652 6	0,649 8	0,648 6	0,647 8
0,62	***	***	***	***	0,659 9	0,656 9	0,655 5	0,654 7
0,64	***	***	***	***	***	0,664 8	0,663 3	0,662 4
0,65	***	***	***	***	***	0,669 1	0,667 5	0,666 6
0,66	***	***	***	***	***	0,673 6	0,671 9	0,670 9
0,67	***	***	***	***	***	0,678 3	0,676 5	0,675 6
0,68	***	***	***	***	***	0,683 3	0,681 5	0,680 4
0,69	***	***	***	***	***	0,688 6	0,686 7	0,685 6
0,70	***	***	***	***	***	0,694 2	0,692 2	0,691 0
0,71	***	***	***	***	***	0,700 1	0,698 0	0,696 8
0,72	***	***	***	***	***	0,706 3	0,704 1	0,702 9
0,73	***	***	***	***	***	0,713 0	0,710 7	0,709 4
0,74	***	***	***	***	***	0,720 0	0,717 6	0,716 3
0,75	***	***	***	***	***	0,727 5	0,725 0	0,723 6

NOTE – This table is given for convenience. It is not intended for precise interpolation.

TABLE 24 – Orifice plate with flange tappings; discharge coefficient *C*
D = 250 mm

β \ Re_D	2×10^4	3×10^4	5×10^4	7×10^4	10^5	3×10^5	10^6	10^7
0,20	0,597 9	0,597 7	0,597 4	0,597 3	0,597 2	0,597 1	0,597 0	0,597 0
0,22	0,598 4	0,598 1	0,597 8	0,597 7	0,597 6	0,597 3	0,597 2	0,597 2
0,24	0,599 0	0,598 6	0,598 2	0,598 0	0,597 9	0,597 6	0,597 5	0,597 5
0,26	***	0,599 1	0,598 7	0,598 5	0,598 3	0,598 0	0,597 8	0,597 7
0,28	***	0,599 7	0,599 2	0,598 9	0,598 7	0,598 3	0,598 1	0,598 0
0,30	***	0,600 3	0,599 7	0,599 4	0,599 2	0,598 7	0,598 5	0,598 4
0,32	***	***	0,600 3	0,599 9	0,599 7	0,599 1	0,598 9	0,598 7
0,34	***	***	0,600 9	0,600 5	0,600 2	0,599 6	0,599 3	0,599 1
0,36	***	***	0,601 6	0,601 2	0,600 8	0,600 1	0,599 7	0,599 5
0,38	***	***	0,602 4	0,601 8	0,601 4	0,600 6	0,600 2	0,600 0
0,40	***	***	***	0,602 5	0,602 0	0,601 1	0,600 6	0,600 4
0,42	***	***	***	0,603 2	0,602 7	0,601 6	0,601 1	0,600 9
0,44	***	***	***	0,604 0	0,603 4	0,602 2	0,601 6	0,601 3
0,46	***	***	***	0,604 8	0,604 1	0,602 8	0,602 2	0,601 8
0,48	***	***	***	***	0,604 8	0,603 3	0,602 7	0,602 3
0,50	***	***	***	***	0,605 5	0,603 9	0,603 2	0,602 7
0,52	***	***	***	***	0,606 2	0,604 5	0,603 6	0,603 2
0,54	***	***	***	***	0,606 9	0,605 0	0,604 1	0,603 5
0,56	***	***	***	***	0,607 6	0,605 4	0,604 4	0,603 9
0,58	***	***	***	***	***	0,605 8	0,604 7	0,604 1
0,60	***	***	***	***	***	0,606 1	0,604 9	0,604 2
0,62	***	***	***	***	***	0,606 3	0,605 0	0,604 2
0,64	***	***	***	***	***	0,606 2	0,604 8	0,604 1
0,65	***	***	***	***	***	0,606 1	0,604 7	0,603 9
0,66	***	***	***	***	***	0,606 0	0,604 5	0,603 7
0,67	***	***	***	***	***	0,605 8	0,604 2	0,603 4
0,68	***	***	***	***	***	0,605 5	0,603 9	0,603 0
0,69	***	***	***	***	***	0,605 1	0,603 5	0,602 5
0,70	***	***	***	***	***	0,604 7	0,602 9	0,602 0
0,71	***	***	***	***	***	0,604 1	0,602 3	0,601 3
0,72	***	***	***	***	***	0,603 5	0,601 6	0,600 6
0,73	***	***	***	***	***	0,602 7	0,600 8	0,599 7
0,74	***	***	***	***	***	0,601 8	0,599 8	0,598 7
0,75	***	***	***	***	***	0,600 8	0,598 7	0,597 6

NOTE – This table is given for convenience. It is not intended for precise interpolation.

TABLE 25 — **Orifice plate with flange tappings; flow coefficient** α
D = 250 mm

β \ Re_D	2×10^4	3×10^4	5×10^4	7×10^4	10^5	3×10^5	10^6	10^7
0,20	0,598 4	0,598 1	0,597 9	0,597 8	0,597 7	0,597 6	0,597 5	0,597 4
0,22	0,599 1	0,598 8	0,598 5	0,598 4	0,598 3	0,598 0	0,597 9	0,597 9
0,24	0,600 0	0,599 6	0,599 2	0,599 0	0,598 9	0,598 6	0,598 5	0,598 4
0,26	***	0,600 5	0,600 0	0,599 8	0,599 7	0,599 3	0,599 2	0,599 1
0,28	***	0,601 5	0,601 0	0,600 8	0,600 6	0,600 2	0,600 0	0,599 9
0,30	***	0,602 8	0,602 2	0,601 9	0,601 6	0,601 2	0,600 9	0,600 8
0,32	***	***	0,603 5	0,603 1	0,602 8	0,602 3	0,602 0	0,601 9
0,34	***	***	0,605 0	0,604 6	0,604 2	0,603 6	0,603 3	0,603 2
0,36	***	***	0,606 7	0,606 3	0,605 9	0,605 2	0,604 8	0,604 6
0,38	***	***	0,608 7	0,608 2	0,607 7	0,606 9	0,606 5	0,606 3
0,40	***	***	***	0,610 4	0,609 9	0,608 9	0,608 5	0,608 2
0,42	***	***	***	0,612 9	0,612 3	0,611 2	0,610 7	0,610 4
0,44	***	***	***	0,615 7	0,615 0	0,613 8	0,613 2	0,612 9
0,46	***	***	***	0,618 8	0,618 1	0,616 7	0,616 1	0,615 8
0,48	***	***	***	***	0,621 5	0,620 0	0,619 3	0,618 9
0,50	***	***	***	***	0,625 4	0,623 7	0,622 9	0,622 5
0,52	***	***	***	***	0,629 7	0,627 8	0,627 0	0,626 5
0,54	***	***	***	***	0,634 5	0,632 5	0,631 5	0,631 0
0,56	***	***	***	***	0,639 9	0,637 6	0,636 5	0,636 0
0,58	***	***	***	***	***	0,643 3	0,642 1	0,641 5
0,60	***	***	***	***	***	0,649 7	0,648 4	0,647 7
0,62	***	***	***	***	***	0,656 7	0,655 3	0,654 5
0,64	***	***	***	***	***	0,664 5	0,663 0	0,662 2
0,65	***	***	***	***	***	0,668 8	0,667 2	0,666 3
0,66	***	***	***	***	***	0,673 2	0,671 6	0,670 6
0,67	***	***	***	***	***	0,677 9	0,676 2	0,675 2
0,68	***	***	***	***	***	0,682 9	0,681 1	0,680 0
0,69	***	***	***	***	***	0,688 1	0,686 2	0,685 2
0,70	***	***	***	***	***	0,693 7	0,691 7	0,690 6
0,71	***	***	***	***	***	0,699 5	0,697 4	0,696 3
0,72	***	***	***	***	***	0,705 7	0,703 5	0,702 3
0,73	***	***	***	***	***	0,712 3	0,710 0	0,708 7
0,74	***	***	***	***	***	0,719 3	0,716 9	0,715 5
0,75	***	***	***	***	***	0,726 7	0,724 2	0,722 8

NOTE — This table is given for convenience. It is not intended for precise interpolation.

TABLE 26 — **Orifice plate with flange tappings; discharge coefficient** *C*
$D = 375$ mm

β \ Re_D	2×10^4	3×10^4	5×10^4	7×10^4	10^5	3×10^5	10^6	10^7
0,20	0,597 9	0,597 7	0,597 4	0,597 3	0,597 2	0,597 1	0,597 0	0,597 0
0,22	***	0,598 1	0,597 8	0,597 7	0,597 6	0,597 3	0,597 3	0,597 2
0,24	***	0,598 6	0,598 2	0,598 0	0,597 9	0,597 6	0,597 5	0,597 5
0,26	***	***	0,598 7	0,598 5	0,598 3	0,598 0	0,597 8	0,597 7
0,28	***	***	0,599 2	0,598 9	0,598 7	0,598 3	0,598 2	0,598 1
0,30	***	***	0,599 7	0,599 4	0,599 2	0,598 7	0,598 5	0,598 4
0,32	***	***	0,600 3	0,600 0	0,599 7	0,599 1	0,598 9	0,598 8
0,34	***	***	***	0,600 5	0,600 2	0,599 6	0,599 3	0,599 1
0,36	***	***	***	0,601 2	0,600 8	0,600 1	0,599 7	0,599 5
0,38	***	***	***	0,601 8	0,601 4	0,600 6	0,600 2	0,600 0
0,40	***	***	***	***	0,602 0	0,601 1	0,600 6	0,600 4
0,42	***	***	***	***	0,602 7	0,601 6	0,601 1	0,600 9
0,44	***	***	***	***	0,603 3	0,602 2	0,601 6	0,601 3
0,46	***	***	***	***	0,604 0	0,602 7	0,602 1	0,601 8
0,48	***	***	***	***	***	0,603 3	0,602 6	0,602 2
0,50	***	***	***	***	***	0,603 8	0,603 1	0,602 7
0,52	***	***	***	***	***	0,604 4	0,603 5	0,603 1
0,54	***	***	***	***	***	0,604 9	0,604 0	0,603 4
0,56	***	***	***	***	***	0,605 3	0,604 3	0,603 7
0,58	***	***	***	***	***	0,605 6	0,604 6	0,603 9
0,60	***	***	***	***	***	0,605 9	0,604 7	0,604 0
0,62	***	***	***	***	***	0,606 0	0,604 7	0,604 0
0,64	***	***	***	***	***	0,605 9	0,604 5	0,603 7
0,65	***	***	***	***	***	0,605 8	0,604 3	0,603 5
0,66	***	***	***	***	***	0,605 6	0,604 1	0,603 3
0,67	***	***	***	***	***	0,605 4	0,603 8	0,602 9
0,68	***	***	***	***	***	0,605 0	0,603 4	0,602 5
0,69	***	***	***	***	***	0,604 6	0,602 9	0,602 0
0,70	***	***	***	***	***	0,604 1	0,602 4	0,601 4
0,71	***	***	***	***	***	0,603 5	0,601 7	0,600 7
0,72	***	***	***	***	***	0,602 8	0,600 9	0,599 9
0,73	***	***	***	***	***	0,602 0	0,600 0	0,598 9
0,74	***	***	***	***	***	0,601 0	0,599 0	0,597 9
0,75	***	***	***	***	***	0,599 9	0,597 8	0,596 6

NOTE — This table is given for convenience. It is not intended for precise interpolation.