INTERNATIONAL STANDARD

# ISO 5167-2

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

## Part 2:
## Orifice plates

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

*Partie 2: Diaphragmes*



Reference number
ISO 5167-2:2022(E)

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# Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.



ISO 5167-2 was prepared by Technical Committee ISO/TC 30, *Measurement of fluid flow in closed conduits*, Subcommittee SC 2, *Pressure differential devices*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/SS F05, *Measuring instruments*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition of ISO 5167-2 cancels and replaces the first edition (ISO 5167-2:2003), which has been technically revised.

The main changes are as follows:

— a revised maximum orifice edge thickness is given for $\beta < 0,2$;

— a correction has been made to the required spacing between two 45° bends for which the straight length upstream of an orifice plate is stated;

— a clearer specification has been given for the tee for which the straight length upstream of an orifice plate is stated;

— flow calibration of orifice plates is included;

— there is improved wording of the rules for spacing of multiple fittings but no change in actual requirements.

A list of all parts in the ISO 5167 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

# Introduction

ISO 5167, consisting of six parts, covers the geometry and method of use (installation and operating conditions) of orifice plates, nozzles, Venturi tubes, cone meters and wedge meters when they are inserted in a conduit running full to determine the flow rate of the fluid flowing in the conduit. It also gives necessary information for calculating the flow rate and its associated uncertainty.

ISO 5167 (all parts) is applicable only to pressure differential devices in which the flow remains subsonic throughout the measuring section and where the fluid can be considered as single-phase, but is not applicable to the measurement of pulsating flow. Furthermore, each of these devices can only be used uncalibrated in accordance with this standard within specified limits of pipe size and Reynolds number, or alternatively they can be used across their calibrated range.

ISO 5167 (all parts) deals with devices for which direct calibration experiments have been made, sufficient in number, spread and quality to enable coherent systems of application to be based on their results and coefficients to be given with certain predictable limits of uncertainty. ISO 5167 also provides methodology for bespoke calibration of differential pressure meters.

The devices introduced into the pipe are called primary devices. The term primary device also includes the pressure tappings. All other instruments or devices required to facilitate the instrument readings are known as secondary devices, and the flow computer that receives these readings and performs the algorithms is known as a tertiary device. ISO 5167 (all parts) covers primary devices; secondary devices (see ISO 2186) and tertiary devices will be mentioned only occasionally.

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

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

## Part 2:
## Orifice plates

## 1 Scope

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

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

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



## 2 Normative references

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

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

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

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

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

## 3 Terms, definitions and symbols

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

## 4 Principles of the method of measurement and computation

The principle of the method of measurement is based on the installation of an orifice meter into a pipeline in which a fluid is running full. The presence of the orifice plate causes a static pressure difference between the upstream and downstream sides of the plate. The mass flow rate, $q_m$, can be determined using Formula (1):

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

The uncertainty limits can be calculated using the procedure given in ISO 5167-1:2022, Clause 8.

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

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

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

where $\rho$ is the fluid density at the temperature and pressure for which the volume is stated.

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



The diameters $d$ and $D$ used in Formula (1) (since $D$ is required to calculate $\beta$) are the values of the diameters at working conditions. Measurements taken at any other conditions should be corrected for any possible expansion or contraction of the orifice plate and the pipe due to the values of the temperature and pressure of the fluid during the measurement.

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

## 5 Orifice plates

### 5.1 Description

#### 5.1.1 General

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

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

NOTE Limits of use are given in 5.3.1.

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

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

#### 5.1.2 General shape

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

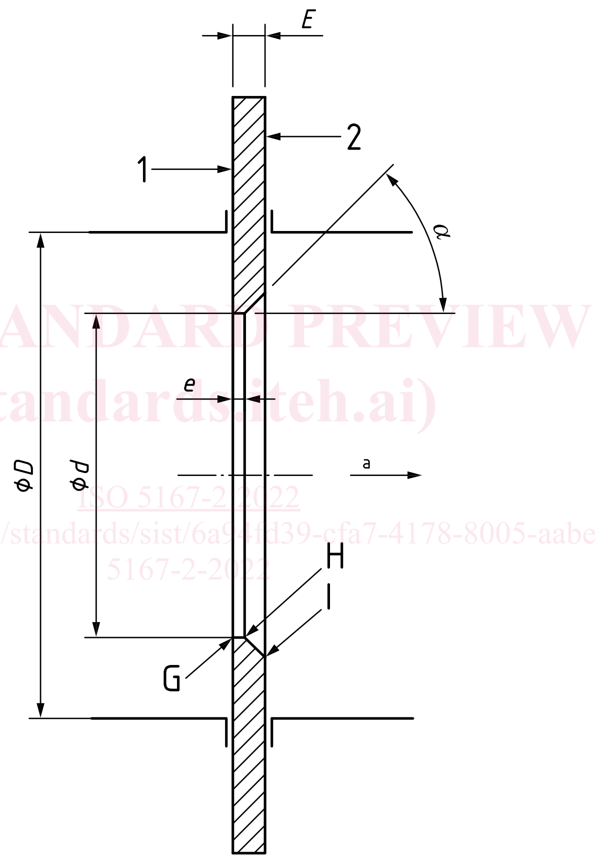
 

**5.1.2.2** Unless otherwise stated, the following requirements apply only to that part of the plate located within the pipe.

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

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

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






**Key**

1 upstream face A

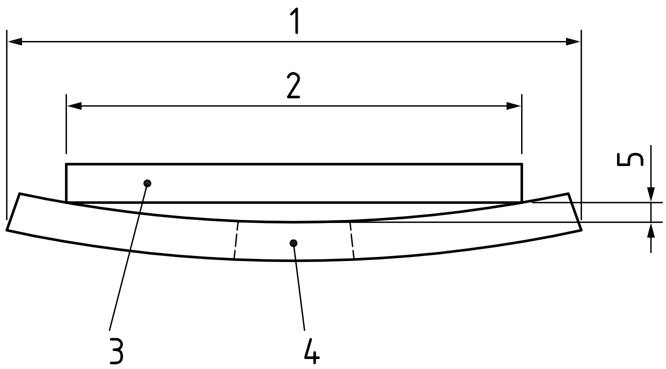
2 downstream face B

a Direction of flow.

**Figure 1 — Standard orifice plate**

### 5.1.3 Upstream face A

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




**Key**

1 orifice plate outside diameter

2 pipe inside diameter, *D*

3 straight edge

4 orifice

5 departure from flatness (measured at edge of orifice)

**Figure 2 — Orifice plate-flatness measurement**

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

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

### 5.1.4 Downstream face B

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

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

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

### 5.1.5 Thicknesses *E* and *e*

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

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

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

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

It shall also meet the requirements of 5.1.2.3.

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

### 5.1.6 Angle of bevel, $\alpha$

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

**5.1.6.2** The angle of bevel, $\alpha$, shall be 45° ± 15°.

### 5.1.7 Edges G, H and I

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

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



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

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

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

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

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

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

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

### 5.1.8 Diameter of orifice, $d$

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

Within these limits, the value of $\beta$ may be chosen by the user.

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

**5.1.8.3** The orifice shall be cylindrical.

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

### 5.1.9 Bidirectional plates

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

a) the plate shall not be bevelled;

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

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

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



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



### 5.1.10 Material and manufacture

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

## 5.2 Pressure tappings

### 5.2.1 General

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

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

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

### 5.2.2 Orifice plate with *D* and *D*/2 tappings or flange tappings

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

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

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

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

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

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

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

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

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

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

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



**5.2.2.4** The centreline of the tapping shall meet the pipe centreline at an angle as near to 90° as possible, but in every case within 3° of the perpendicular.

**5.2.2.5** At the point of break-through, the hole shall be circular. The edges shall be flush with the internal surface of the pipe wall and as sharp as possible. To ensure the elimination of all burrs or wire edges at the inner edge, rounding is permitted but shall be kept as small as possible and, where it can be measured, its radius shall be less than one-tenth of the pressure tapping diameter. No irregularity shall appear inside the connecting hole, on the edges of the hole drilled in the pipe wall or on the pipe wall close to the pressure tapping.

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

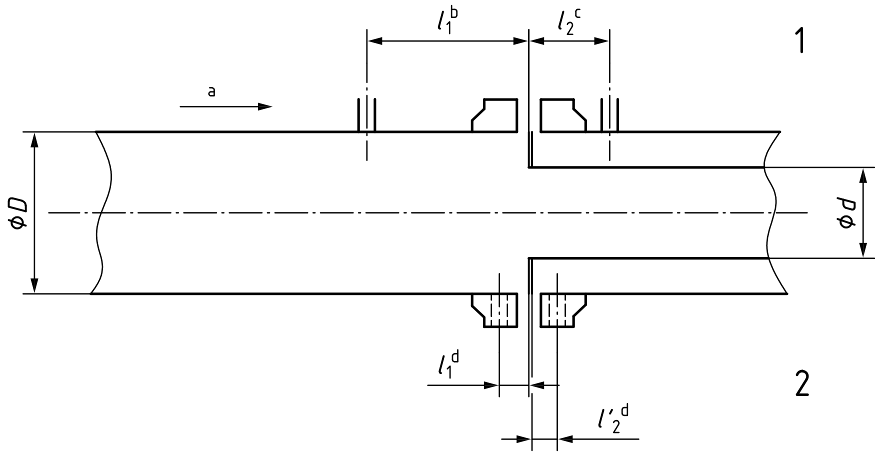
**5.2.2.7** The diameter of pressure tappings shall be less than $0{,}13D$ and less than 13 mm.

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

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

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

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




**Key**

1 $D$ and $D/2$ pressure tappings

2 flange tappings

a Direction of flow.

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

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

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

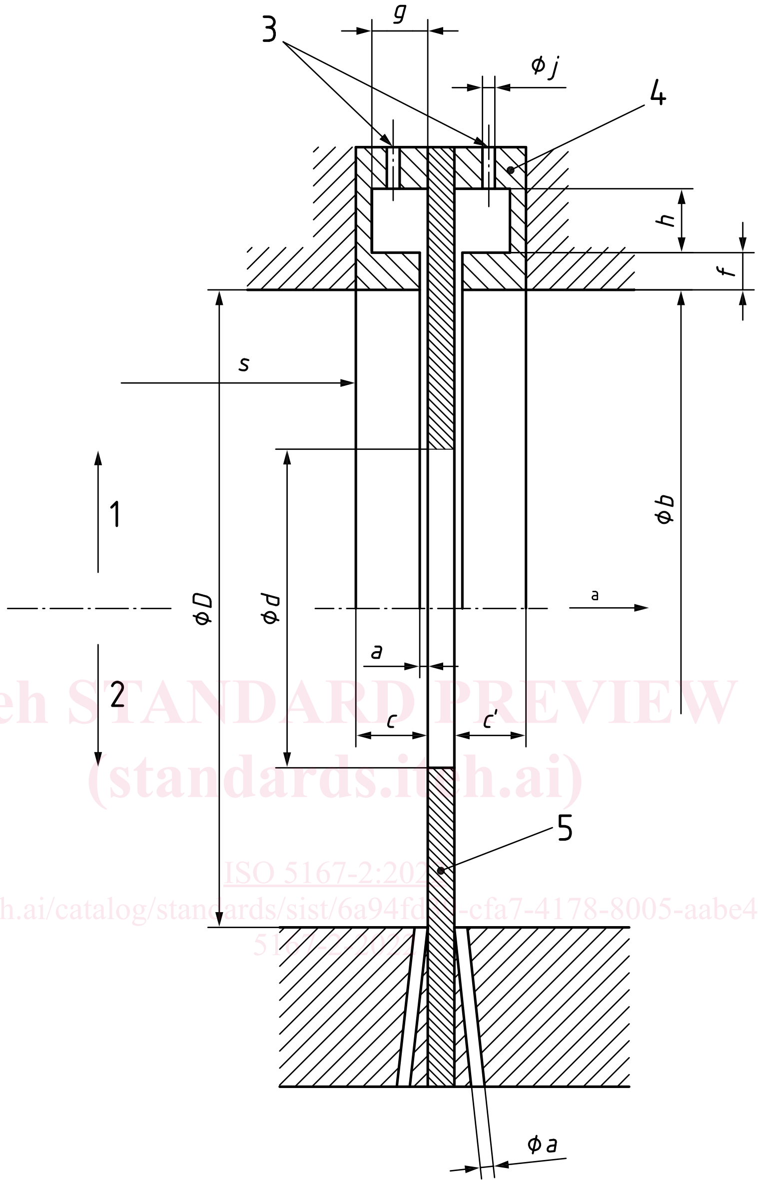


**Figure 3 — Spacing of pressure tappings for orifice plates with *D* and *D*/2 tappings or flange tappings**

### 5.2.3 Orifice plate with corner tappings

**5.2.3.1** The spacing between the centrelines of the tappings (see Figure 4) and the respective faces of the plate is equal to half the diameter or to half the width of the tappings themselves, so that the tapping holes break through the wall flush with the faces of the plate (see also 5.2.3.5).

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





**Key**

1 carrier ring with annular slot
2 individual tappings
3 pressure tappings
4 carrier ring
5 orifice plate

a Direction of flow.

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

**Figure 4 — Corner tappings**