TECHNICAL REPORT

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Measurement of fluid flow by means of pressure-differential devices — Guidelines for the specification of orifice plates, nozzles and Venturi tubes beyond the scope of ISO 5167 series

Mesurage du débit des fluides au moyen d'appareils déprimogènes — Lignes directrices pour la spécification des diaphragmes, des tuyères et des tubes de Venturi non couverts par la série de l'ISO 5167

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Foreword

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This document was prepared by Technical Committee ISO/TC 30, *Measurement of fluid flow in closed conduits*, Subcommittee SC 2, *Pressure differential devices*.

This fourth edition cancels and replaces the third edition (ISO/TR 15377:2018), which has been technically revised.

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.

Measurement of fluid flow by means of pressure-differential devices — Guidelines for the specification of orifice plates, nozzles and Venturi tubes beyond the scope of ISO 5167 series

1 Scope

This document describes the geometry and method of use for conical-entrance orifice plates, quarter-circle orifice plates, eccentric orifice plates and Venturi tubes with 10,5° convergent angles. Information is also given for square-edged orifice plates and nozzles under conditions outside the scope of ISO 5167 series.

NOTE The data on which this document is based are limited in some cases.

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*

3 Terms and definitions

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

4 Symbols

For the purposes of this document, the symbols given in Table 1 apply.

Table 1 — Symbols

Symbols	Represented quantity	Dimensions M: mass L: length T: time	SI unit
a	Orifice plate pressure-tapping hole diameter	L	m
C	Discharge coefficient	dimensionless	
d	Diameter of orifice (or throat) of primary device under working conditions[a]	L	m
d_k	Measured drain hole diameter	L	m

[a] In applications with drain holes, d is calculated from the measured values d_m and d_k [see Formulae (1) and (11)].

NOTE 1 Other symbols used in this document are defined at their place of use.

NOTE 2 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.

Table 1 *(continued)*

Symbols	Represented quantity	Dimensions M: mass L: length T: time	SI unit
d_m	Measured orifice or throat diameter (where the orifice or nozzle has a drain hole)	L	m
D	Upstream internal pipe diameter (or upstream diameter of a classical Venturi tube) under working conditions	L	m
d_{tap}	Diameter of Venturi tube pressure tappings	L	m
e	Thickness of bore	L	m
E, E_1	Thickness of orifice plate	L	m
F_E	Correction factor	dimensionless	
k	Uniform equivalent roughness	L	m
l	Pressure tapping spacing	L	m
L	Relative pressure tapping spacing: $L = l/D$	dimensionless	
p	Static pressure of the fluid	$ML^{-1} T^{-2}$	Pa
q_m	Mass flowrate	MT^{-1}	kg/s
r	Radius of profile	L	m
Ra	Arithmetical mean deviation of the (roughness) profile	L	m
Re	Reynolds number	dimensionless	
Re_D	Pipe Reynolds number	dimensionless	
Re_d	Throat Reynolds number	dimensionless	
Re^*	Throat-tapping Reynolds number (= $d_{tap}\, Re_d/d$)	dimensionless	
β	Diameter ratio, $\beta = \frac{d}{D}$	dimensionless	
Δp	Differential pressure	$ML^{-1} T^{-2}$	Pa
ε	Expansibility (expansion) factor	dimensionless	
θ	Angle between the tappings used and the radius from the centre of the pipe to the centre of the drain hole	dimensionless	°
κ	Isentropic exponent	dimensionless	
λ	Friction factor	dimensionless	
ρ	Mass density of the fluid	ML^{-3}	kg/m^3
τ	Pressure ratio, $\tau = \frac{p_2}{p_1}$	dimensionless	

[a] In applications with drain holes, d is calculated from the measured values d_m and d_k [see Formulae (1) and (11)].

NOTE 1 Other symbols used in this document are defined at their place of use.

NOTE 2 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.

5 Square-edged orifice plates and nozzles: with drain holes, in pipes below 50 mm diameter, and as inlet and outlet devices

5.1 Drain holes through the upstream face of the square-edged orifice plate or nozzle

5.1.1 General

Square-edged orifice plates and nozzles with drain holes are used, installed and manufactured in accordance with the following guidelines.

NOTE 1 The guidelines presented in this document are applicable to both drain holes for liquid in gas and vent holes for gas in liquid.

In a horizontal pipe, a drain hole is positioned at the bottom of the pipe. In a horizontal pipe, a vent hole is positioned at the top of the pipe.

NOTE 2 Use of drain or vent holes can help alleviate the problem of fluid hold-up, but will not resolve measurement errors arising from the presence of two-phase flow.

5.1.2 Square-edged orifice plates

If a drain hole is drilled through the orifice plate, the coefficient values specified in ISO 5167-2 are not used unless the following conditions are observed.

a) The diameter of the drain hole does not exceed 0,1d and no part of the hole lies within a circle, concentric with the orifice, of diameter (D – 0,2d). The outer edge of the drain hole is as close to the pipe wall as practicable. It is very important that neither the upstream nor the downstream pipe obscure the drain hole and that the hole is not so small that it blocks.

b) The drain hole is deburred and the upstream edge is sharp. Spark erosion is a good method of producing the drain hole.

c) Single pressure tappings are orientated so that they are between 90° and 180° to the position of the drain hole. Upstream and downstream pressure tappings are at the same orientation relative to the drain hole.

d) The measured orifice diameter, d_m, is corrected to allow for the additional orifice area represented by the drain hole of measured diameter d_k, as shown in Formula (1):

$$d = \frac{d_m}{\left\{ \left(1-\beta''^4\right) C_1{}^2 \frac{\left[1+a\left(1-\frac{\theta}{180}\right)^n - a\left(1-\frac{\theta*}{180}\right)^n\right]}{\left(1+C_2 \frac{d_k{}^2}{d_m{}^2}\right)^2} + \beta_m{}^4 \right\}^{0,25}} \quad (1)$$

where

$$\beta_m = \frac{d_m}{D} \quad (2)$$

$a, n, \theta', C_2, \beta''$ and C_1 are given in Formulae (3) to (8):

$$a = 0,66\beta_m{}^{4,6} \exp\left(-0,15 \frac{L'_2 d_m}{\beta_m d_k}\right) \quad (3)$$

$$n = -0,45 + 7,3\beta_m{}^{4,6} + 0,117 \frac{d_m}{d_k} \quad (4)$$