

Measurement of fluid flow by means of pressure-differential devices — Guidelines to the effect of departure from the specifications and operating conditions given in ISO 5167-1

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National foreword

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, the ISO/TR title page, pages ii to iv, pages 1 to 30 and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

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TECHNICAL REPORT

ISO/TR 12767

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Measurement of fluid flow by means of pressure-differential devices — Guidelines to the effect of departure from the specifications and operating conditions given in ISO 5167-1

*Mesurage du débit des fluides au moyen d'appareils déprimogènes —
Lignes directrices relatives aux effets de divergence par rapport aux
spécifications et conditions de fonctionnement données dans l'ISO 5167-1*



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Descriptors: Fluid flow, pipe flow, flow measurement, diaphragms (mechanics), nozzles, form specifications, generalities.

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 main task of technical committees is to prepare International Standards. In exceptional circumstances a technical committee may propose the publication of a Technical Report of one of the following types:

- type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;
- type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;
- type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard (“state of the art”, for example).

Technical Reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

ISO/TR 12767, which is a Technical Report of type 3, was prepared by Technical Committee ISO/TC 30, *Measurement of fluid flow in closed conduits*, Subcommittee SC 2, *Pressure-differential devices*.

Annex A of this Technical Report is for information only.

Introduction

ISO 5167-1 is an International Standard for flowrate measurement using a differential-pressure device. Adherence to that standard will result in flowrate measurements the uncertainty of which will lie within specified limits. If, however, a flowmetering installation departs, for whatever reason, from the conditions specified in ISO 5167-1, the specified limits of uncertainty may not be achieved. Many metering installations exist where these conditions either have not been or cannot be met. In these circumstances it is usually not possible to evaluate the precise effect of any such deviations. However, a considerable amount of data exists which can be used to give a general indication of the effect of non-conformity to ISO 5167-1, and it is presented in this Technical Report as a guideline to users of flow-metering equipment.

1 Scope

This Technical Report provides guidance to assist in estimating the flowrate when using pressure-differential devices constructed or operated outside the scope of ISO 5167-1.

It should not be inferred that additional tolerances or corrections can necessarily compensate for the effects of deviating from ISO 5167-1. The information is given, in the first place, to indicate the degree of care necessary in the manufacture, installation and maintenance of pressure-differential devices by describing some of the effects of non-conformity to the requirements; and in the second place, to permit those users who may not be able to comply fully with the requirements to assess, however roughly, the magnitude and direction of the resulting error in flowrate.

Each variation dealt with is treated as though it were the only one present. Where more than one is known to exist, there may be unpredictable interactions and care has to be taken when combining the assessment of these errors. If there is a significant number of errors, means of eliminating some of them must be considered. The variations included in this Technical Report are by no means complete and relate largely to examples with orifice plates. There are, no doubt, many similar examples of installations not conforming to ISO 5167-1 for which no comparable data have been published. Such additional information from users, manufacturers and any others may be taken into account in future revisions of this Technical Report.

2 Reference

ISO 5167-1:1991, *Measurement of fluid flow by means of pressure-differential devices — Part 1: Orifice plates, nozzles and Venturi tubes inserted in circular cross-section conduits running full*.

3 Symbols and definitions

3.1 Symbols

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

3.2 Definitions

For the purposes of this Technical Report, the definitions given in ISO 5167-1 and the following definitions apply.

3.2.1

square edge

angular relationship between the orifice bore of the flow measurement device and the upstream face, when the angle between them is $90^\circ \pm 0,3^\circ$

3.2.2

sharpness

radius of the edge between the orifice bore of the flow measurement device and the upstream face

NOTE The upstream edge of the orifice bore is considered to be sharp when its radius is not greater than $0,0004 d$, where d is the diameter of the orifice bore.

Table 1 — Symbols

Symbol	Represented quantity	Dimensions M: mass L: length T: time	SI units
c	Percentage change in discharge coefficient $\left(\equiv 100 \frac{\Delta C}{C} \right)$	dimensionless	
C	Discharge coefficient	dimensionless	
C_c	Contraction coefficient	dimensionless	
d	Diameter of orifice or throat of primary device at operating conditions	L	m
D	Upstream internal pipe diameter at operating conditions	L	m
D_1	Carrier ring diameter	L	m
D_2	Orifice plate support diameter	L	m
e	Relative uncertainty	dimensionless	
E	Orifice plate thickness	L	m
E_e	Thickness of orifice	L	m
k	Uniform equivalent roughness	L	m
L_1	Distance of upstream pressure tapping from upstream face of plate divided by pipe bore (D)	dimensionless	
L'_2	Distance of downstream pressure tapping from downstream face of plate divided by pipe bore (D)	dimensionless	
q_m	Mass rate of flow	MT^{-1}	kg/s
r	Orifice plate edge radius	L	m
Re_D	Reynolds number based on upstream pipe diameter	dimensionless	
Re_d	Reynolds number based on throat bore of device	dimensionless	
$S_{L,1}$	Distance from upstream fitting to straightener	L	m
$S_{L,2}$	Distance from straightener to primary device	L	m
$S_{L,3}$	Distance from primary device to downstream fitting	L	m
u	Local axial velocity	LT^{-1}	m/s
u_{CL}	Centreline axial velocity	LT^{-1}	m/s
U	Mean axial velocity	LT^{-1}	m/s
Y	Modulus of elasticity of orifice plate material	$ML^{-1}T^{-2}$	Pa
β	Diameter ratio, $\beta = d/D$	dimensionless	
Δp	Differential pressure	$ML^{-1}T^{-2}$	Pa
Δp_y	Differential pressure required to reach orifice plate yield stress	$ML^{-1}T^{-2}$	Pa
ε_1	Expansibility (expansion) factor at the upstream pressure tapping	dimensionless	
λ	Friction factor	dimensionless	
ρ	Fluid density	ML^{-3}	kg/m ³
ρ_1	Fluid density at the upstream pressure tapping	ML^{-3}	kg/m ³
σ_y	Yield stress of orifice plate material	$ML^{-1}T^{-2}$	Pa

4 Effect of errors on flowrate calculations

4.1 General

In this Technical Report the effects of deviations from the conditions specified in ISO 5167-1 are described in terms of changes in the discharge coefficient of the meter. The discharge coefficient of a pressure-differential device (C) is given by the following equation:

$$C = \frac{4 q_m \sqrt{(1 - \beta^4)}}{\varepsilon_1 \pi d^2 \sqrt{(2 \Delta p \rho_1)}} \quad (1)$$

The sharp edge of an orifice plate ensures separation of the flow and consequently contraction of the fluid stream to the vena contracta. Defining the contraction coefficient, C_c , as

$$\frac{\text{flow area}}{\text{geometric area}},$$

the orifice produces $C_c \cong 0,6$, which mainly accounts for the discharge coefficient, $C \cong 0,6$.

The effect of change in the discharge coefficient is illustrated by the following example.

Consider an orifice plate with an unduly rounded edge. The result of this will be to reduce the separation and increase C_c , leading in turn to reduced velocities at the vena contracta. The observed differential pressure will therefore decrease. From the equation above, it can be seen that the discharge coefficient would therefore increase. Alternatively, as C_c increases so does C . If no correction is made for this change in C , the meter will under-read (register).

It can therefore be concluded that:

- a) an effect which causes an increase in discharge coefficient will result in an under-reading of flow if the coefficient is not corrected;
- and conversely,
- b) an effect which causes a decrease in discharge coefficient will result in an over-reading of flow if the coefficient is not corrected.

4.2 Quantifiable effects

When the user is aware of such effects and they can be quantified, the appropriate discharge coefficient can be used and the correct flowrate calculated. However, the precise quantification of these effects is difficult and so any flowrate calculated in such a manner should be considered to have an increased uncertainty.

Except where otherwise stated, an additional uncertainty factor, equivalent to 100 % of the discharge coefficient correction, should be added arithmetically to that of the discharge coefficient when estimating the overall uncertainty of the flowrate measurement.

5 Effects of deviations in construction

5.1 Orifice plate edge sharpness

Orifice plates that do not have the specified sharpness of the inlet edge (edge radius $r \leq 0,0004 d$ in accordance with 8.1.6.2 of ISO 5167-1:1991), will have progressively increasing discharge coefficients as the edge radius increases. Tests have shown that the effect on the discharge coefficient, C , is to increase it by 0,5 % for r/d of 0,001, and by about 5 % for r/d of 0,01. This is an approximately linear relationship (see Figure 1 and Hobbs and Humphreys[1]). These values apply particularly to Re_d values above 300 000 and for β values below 0,7, but they can be used as a general guide for other values.

Measurement techniques for edge radius are available, but in general it is better to improve the edge sharpness to the required value rather than attempt to measure it and make appropriate corrections.

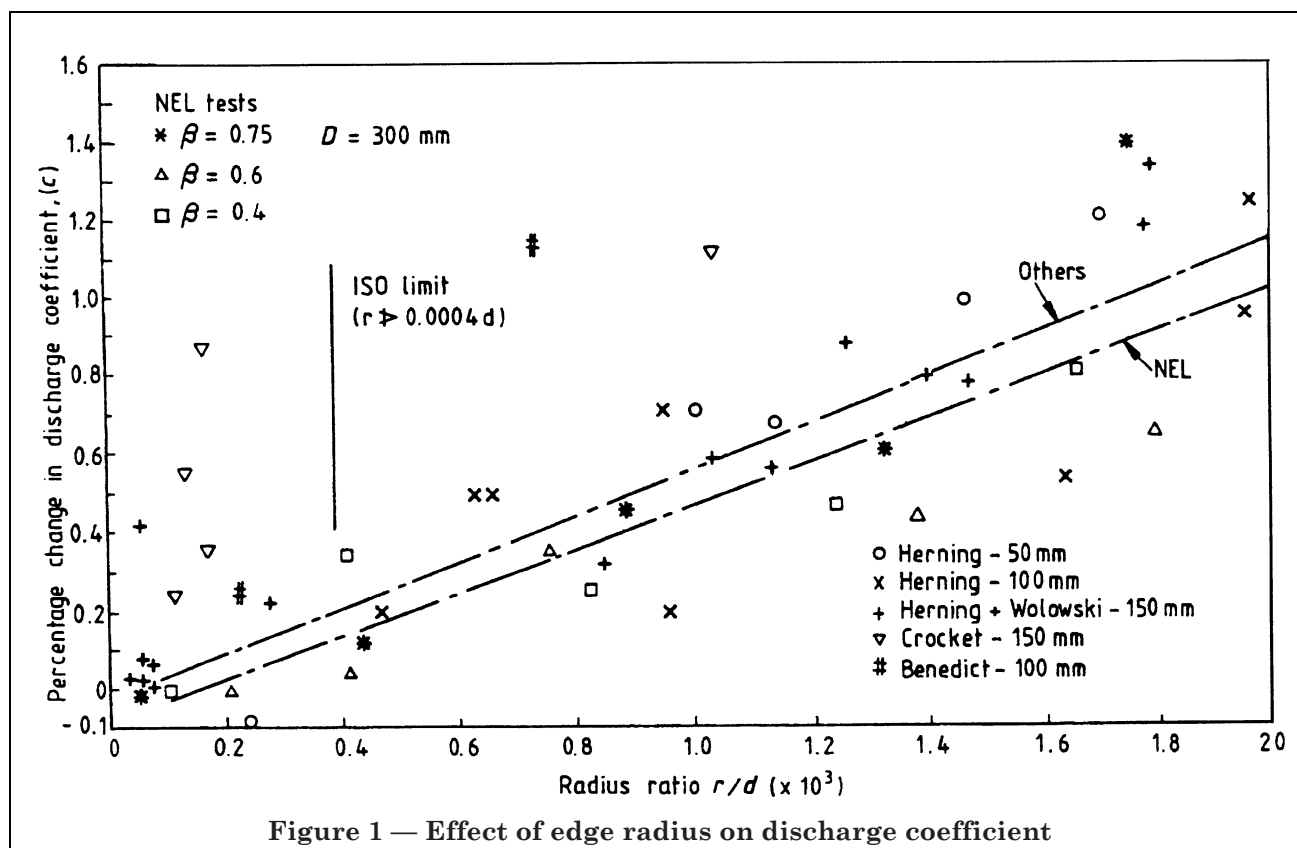


Figure 1 — Effect of edge radius on discharge coefficient

5.2 Thickness of orifice edge

For orifice plates, the increase in discharge coefficient due to the excessive thickness of the orifice edge (see 8.1.4 of ISO 5167-1:1991) can be appreciable. With a straight-bore orifice plate in a 150 mm pipe, the changes in discharge coefficient shown in Figure 2 were obtained (see Husain and Teyssandier [2]).

5.3 Condition of upstream and downstream faces of orifice plate

The upstream face should be flat and smooth. Excessive roughness leads to an increase in the discharge coefficient. Tests have indicated that a surface roughness of $0.0003 d$ will cause an increase in discharge coefficient of the order of 0.1 %. Since the requirement for edge sharpness is $r \leq 0.0004 d$, an increase in plate roughness will make it difficult to define or confirm that the sharp edge requirement has been met.

Local damage to the upstream face or edge of an orifice plate does not adversely affect the discharge coefficient provided that the damage is kept as far away from the pressure tapping as possible (see Hobbs and Humphreys [1]). The discharge coefficient is much less sensitive to the surface condition of the downstream face of the plate (Hobbs and Humphreys [1]).

Large scale lack of flatness, e.g. "dishing", leads to flow measurement errors. A "dishing" of 1 % in the direction of flow will cause an under-reading, i.e. an increase in C , of about 0.2 % for $\beta = 0.2$ and about 0.1 % for $\beta = 0.7$. Distortion against the direction of flow also causes errors which could be either positive or negative depending on the amount of distortion.