INTERNATIONAL STANDARD

ISO 7194

Second edition
2008-07-15

Measurement of fluid flow in closed conduits — Velocity-area methods of flow measurement in swirling or asymmetric flow conditions in circular ducts by means of current-meters or Pitot static tubes

Mesurage de débit des fluides dans les conduites fermées — Mesurage de débit dans les conduites circulaires dans le cas d'un écoulement giratoire ou dissymétrique par exploration du champ des vitesses au moyen de moulinets ou de tubes de Pitot doubles

Reference number
ISO 7194:2008(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 7194 was prepared by Technical Committee ISO/TC 30, *Measurement of fluid flow in closed conduits*, Subcommittee SC 5, *Velocity and mass methods*.

This second edition results from the reinstatement of ISO 7194:1983 which was withdrawn in 2003 and with which it is technically identical.

Introduction

In order to carry out measurements of the flow-rate of single phase fluids in closed pipes by velocity-area methods, using either current-meters or Pitot static tubes, with satisfactory accuracy (e.g. of the order of ± 2 %), it is usually necessary to choose a measuring plane where the velocity distribution approaches that of fully developed flow (see ISO 3354 and ISO 3966).

There are, however, some cases where it is practically impossible to obtain such a flow distribution, but where as good as possible a measurement of the flow-rate is desirable.

Measurement of fluid flow in closed conduits — Velocity-area methods of flow measurement in swirling or asymmetric flow conditions in circular ducts by means of current-meters or Pitot static tubes

1 Scope

This International Standard specifies velocity-area methods for measuring flow in swirling or asymmetric flow conditions in circular ducts by means of current-meters or Pitot static tubes.

It specifies the measurements required, the precautions to be taken, the corrections to apply, and describes the additional uncertainties which are introduced when a measurement in asymmetric or swirling flow has to be made.

Only flows with a negligible radial component are considered, however. Furthermore, it is not possible to make a measurement in accordance with this International Standard if, at any point in the measuring cross-section, the local velocity makes an angle of greater than 40° with the axis of the duct, or where the index of asymmetry Y (defined in Annex F) is greater than 0,15.

This International Standard deals only with instruments for measuring local velocity as defined in ISO 3354 and ISO 3966. If Pitot static tubes are used, this International Standard applies only to flows where the Mach number corresponding to local velocities does not exceed 0,25.

2 Normative references

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

ISO/TR 3313, *Measurement of fluid flow in closed conduits — Guidelines on the effects of flow pulsations on flow-measurement instruments*

ISO 3354:2008, *Measurement of clean water flow in closed conduits — Velocity-area method using current-meters in full conduits and under regular flow conditions*

ISO 3455:2007, *Hydrometry — Calibration of current-meters in straight open tanks*

ISO 3966:2008, *Measurement of fluid flow in closed conduits — Velocity area method using Pitot static tubes*

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

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

3 Symbols

For the purposes of this document, the symbols given in ISO 4006, and the following, apply.

Symbol	Description	Dimension	SI unit
D	Pipe diameter	L	m
d	Diameter of the head of a Pitot static tube Diameter of holes or tubes of a straightener	L	m
E	Uncertainty, as a relative value	—	—
e	Uncertainty, as an absolute value	—[a]	—[a]
k_φ	Directional calibration coefficient	—	—
l	Length of the head of a Pitot static tube	L	m
R	Pipe radius	L	m
r	Measuring circle radius	L	m
U	Mean axial fluid velocity	LT^{-1}	m/s
U_i	Mean velocity along the ith radius	LT^{-1}	m/s
v	Local velocity of the fluid	LT^{-1}	m/s
v_x	Component of the local velocity parallel to the pipe axis	LT^{-1}	m/s
Y	Index of asymmetry of the flow	—	—
y	Distance between the heel of a Pitot static tube and the wall	L	m
y_1	Distance between the nose of a Pitot static tube and the wall	L	m
α	Calibration factor of a Pitot static tube	—	—
Δp	Differential pressure registered by a Pitot static tube	$ML^{-1}\ T^{-2}$	Pa
ε	Expansibility factor	—	—
θ	Angle of the local velocity with the pipe axis	—	rad [b]
ρ	Mass density of the fluid	ML^{-3}	kg/m^3
φ	Angle of the local velocity with the metering device axis	—	rad [b]

[a] The dimensions and units are those of the quantity to which the symbol refers.

[b] Although the radian is the SI unit, for the purposes of this International Standard, angles are expressed in degrees.

4 Principle

This International Standard describes

— methods which minimize the errors in carrying out a traverse in swirling or asymmetric flow;

— corrections which should be applied for certain sources of error;

— methods of determining the increase in uncertainty in the flow-rate measurement when it is not possible to compensate for a particular source of error.

The origins of the errors giving rise to the uncertainties considered in this International Standard are

a) errors in the determination of local velocities, due to the behaviour of the instruments in a disturbed flow;

b) errors in the calculated mean pipe velocity, due to the number and position of the measuring points and the methods of integration used.

Corrections are possible for some of these errors, but, in general, the limiting uncertainty in the flow-rate measurement has to be increased according to the characteristics of the flow.

Although velocity-area integration techniques to measure flow-rate under conditions where there is swirl and/or asymmetry in the flow are described, a measuring section in the pipe where the swirl or asymmetry is as small as possible is preferred.

5 Choice of measuring plane

When the configuration of the pipe and any fittings installed in it is such that any changes of directions of the flow are all in the same plane (e.g. a single bend, a single valve, or two bends in an S-shape), no significant bulk swirl is introduced and the disturbance to the flow results in an essentially asymmetric velocity distribution.

If, however, the pipe configuration is such that the flow changes direction in two or more different planes in rapid succession (e.g. two bends at 90° to each other), a bulk swirl is introduced in addition to the asymmetry which the individual fittings introduce.

Unlike asymmetry, swirl has a big effect on the response of Pitot static tubes and current-meters, and also persists for very much longer distances; whenever possible, therefore, the traverse plane should not be downstream of a swirl-inducing configuration. Care should also be taken to avoid locating the traverse plane downstream of any adjustable fitting for which the geometry may change (e.g. a flow control valve), especially if several different flow-rates have to be measured.

6 Devices for improving flow conditions

6.1 Where asymmetric or swirling flow is to be measured, a device (straightener) for improving flow conditions should be used, if possible. It should be installed as shown in Figure 1.

The lengths L_1, L_2, L_3 shall fulfil the conditions: $L_1 \geqslant 3D$; $L_2 \geqslant 5D$; $L_3 \geqslant 2D$.

These distances should be increased whenever possible, and, where a total straight length of more than $10D$ exists upstream of the traverse plane, it is better to increase the distance between the pipe fitting and the straightener than to increase the distance between the straightener and the traverse plane.

6.2 The choice of straightener is dependent on the nature of the velocity distribution which has to be corrected and on the head loss which can be tolerated. Five types of straightener are described below.

6.2.1 Type A — Zanker straightener (see Figure 2)

The purpose of this device is to eliminate both swirl and asymmetry. It has a head loss of approximately five velocity heads. The various plates should be chosen to provide adequate strength, but should not be unnecessarily thick.

6.2.2 Type B — Sprenkle straightener (see Figure 3)

The Sprenkle straightener consists of three perforated plates in series, and is particularity effective in eliminating asymmetry. It does, however, have a high head loss (about 15 velocity heads) but two plates or even one plate (with head losses of about 10 and five velocity heads, respectively) can be used if such a high head loss is not acceptable. Although they cannot completely eliminate such severe asymmetry as can the three plates, they are often sufficient for disturbances such as a single bend. Perforated plate straighteners have some effect in reducing swirl, but are not designed for this; if, therefore, swirl is the dominant type of irregularity in the velocity distribution, one of the other straighteners should be used.

6.2.3 Type C — Tube bundle straightener (see Figure 4)

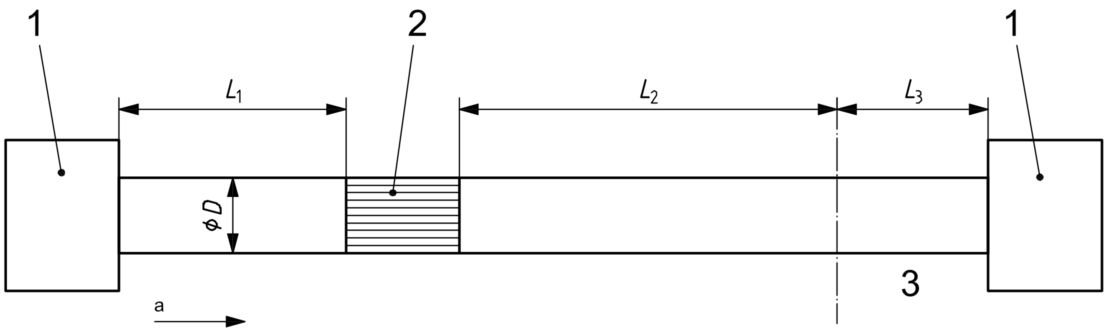
The basic purpose of the tube bundle straightener is to eliminate swirl, but it also has some effect in reducing asymmetry. There shall be a minimum of 19 tubes, with a length of at least 20 times the diameter of the tubes, and each tube shall have a maximum diameter of $D/5$. The head loss of this straightener depends on the size and length of the individual tubes, but is typically about five velocity heads.

6.2.4 Type D — AMCA straightener (see Figure 5)

The AMCA straightener is useful only in eliminating swirl; it does not improve asymmetric velocity distributions. Its dimensions are given in Figure 5, and it has a very low head loss, normally about 0,25 times the velocity head.

6.2.5 Type E — Étoile straightener (see Figure 6)

The étoile straightener is again designed only to eliminate swirl, and is of no assistance with asymmetric velocity distributions. The eight radial vanes should be chosen to provide adequate strength, but should not be unnecessarily thick. This straightener should have a length equal to $2D$. It has a very low head loss, similar to that of the AMCA straightener, but has the advantage that it is much easier to manufacture. In addition, it allows the static pressure to equalize radially as the flow passes through it, unlike the AMCA, tube bundle or Zanker straighteners which can induce significant variation in static pressure across the pipe downstream of them.



Key

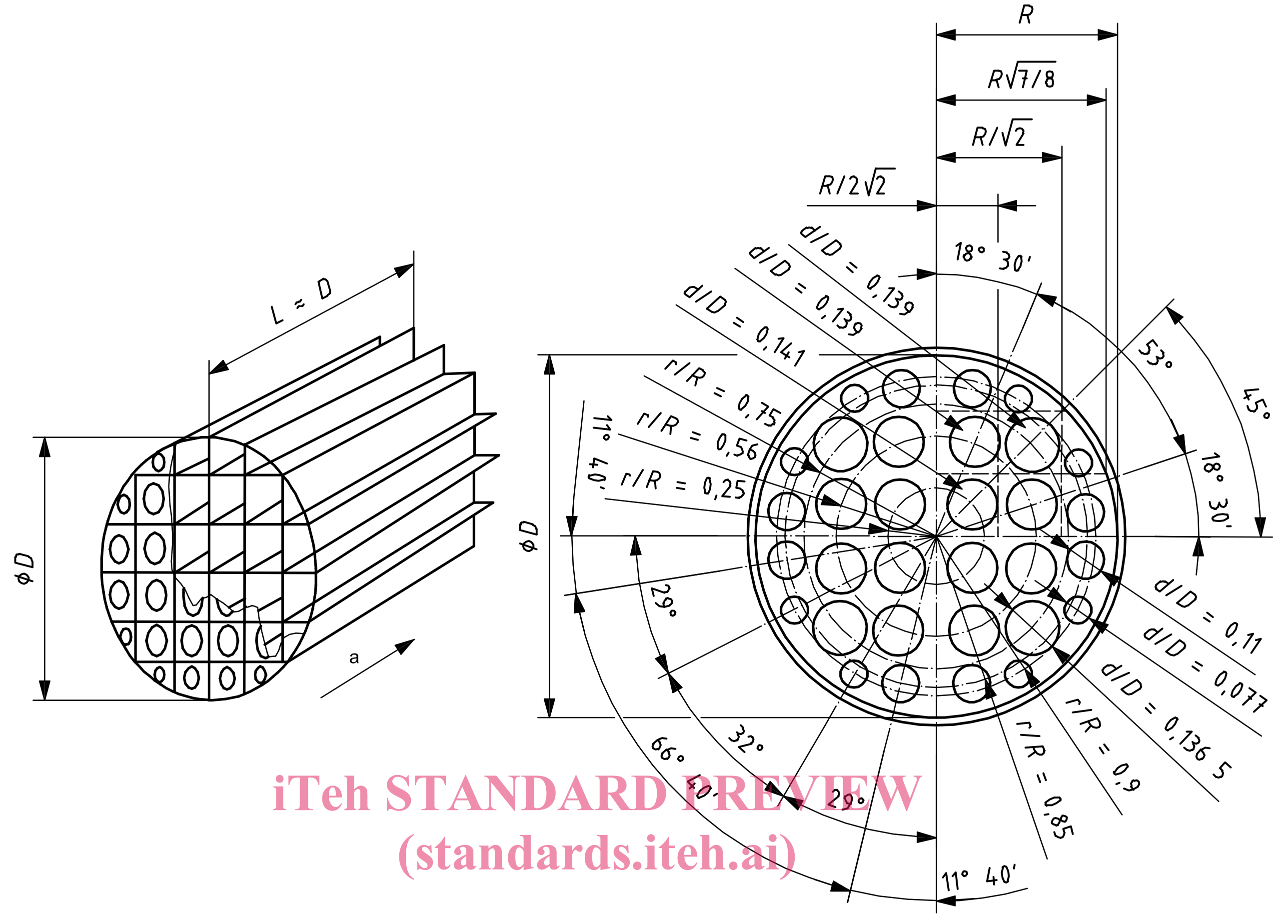
1 any pipe fitting

2 straightener

3 measuring section

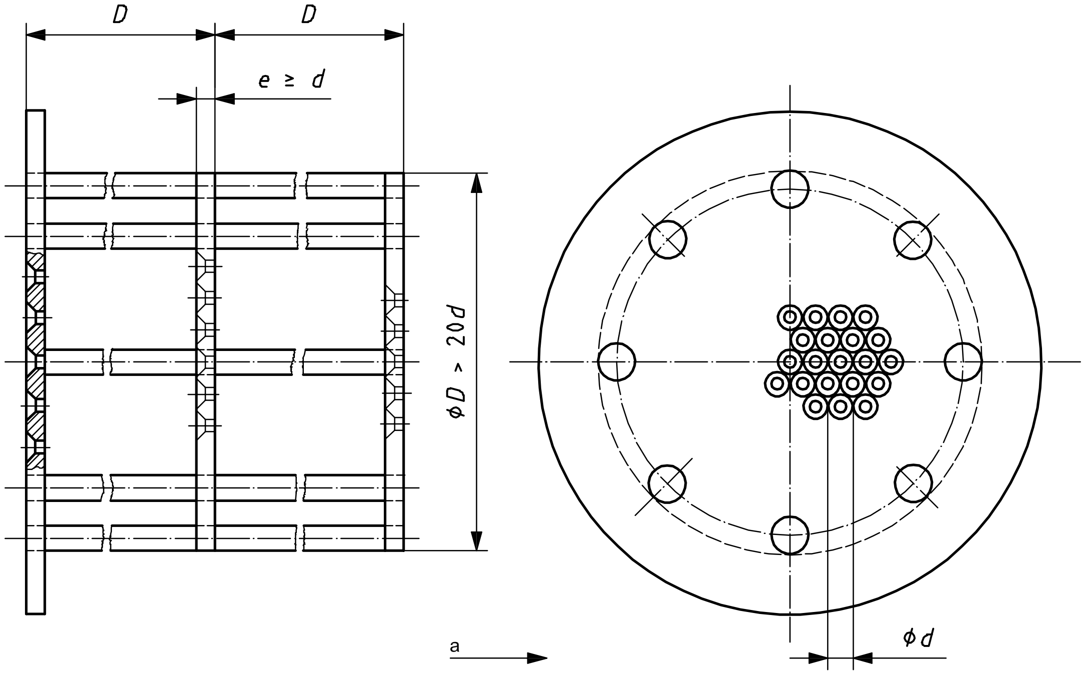
a Flow.

Figure 1 — Installation of straightener



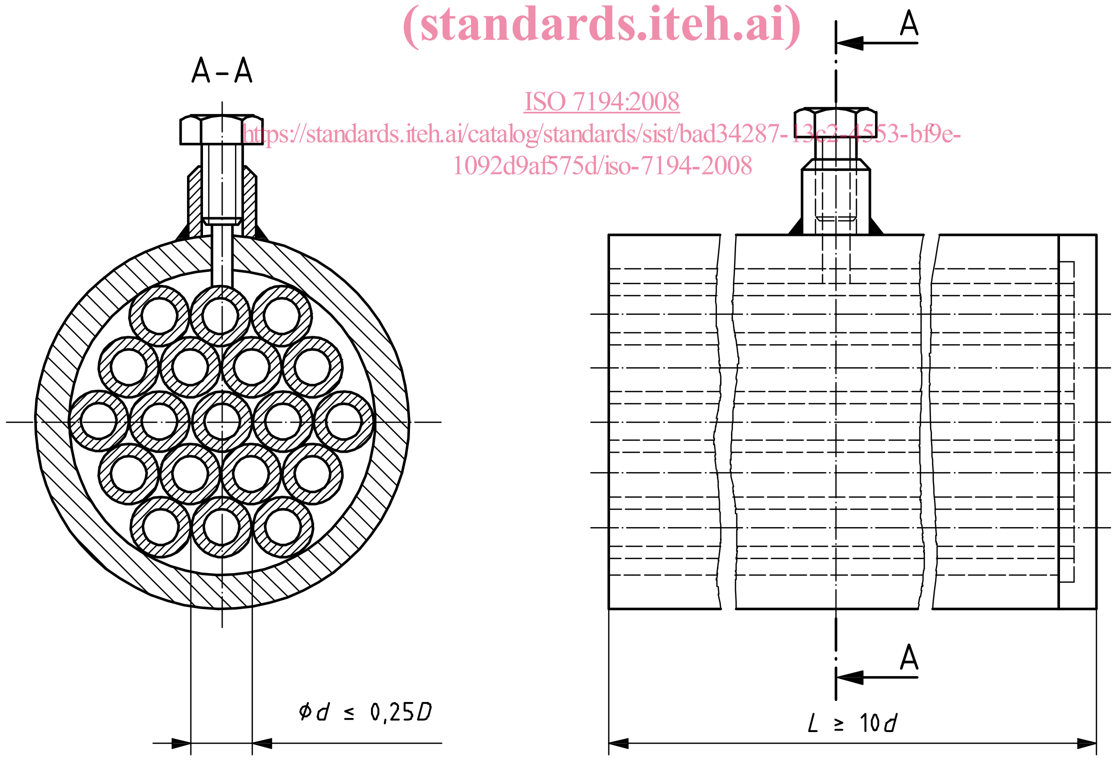
a Flow.

Figure 2 — Type A — Zanker straightener



a Flow direction.

Figure 3 — Type B — Sprenkle straightener (perforated plates)



NOTE In order to decrease the pressure loss, the entrance to the tubes may be bevelled at 45°.

Figure 4 — Type C — Tube bundle straightener