TECHNICAL REPORT

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Guidelines for the use of ISO 5167-1:1991

Guide pour l'emploi de l'ISO 5167-1:1991

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Contents

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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 main task of technical committees is to prepare International Standards, but 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 Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.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 9464, 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, *Differential pressure methods.*

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Guidelines for the use of ISO 5167-1:1991

Section 1 - Guidance relating to specific clauses in ISO 5167-1:1991

1 Introduction

The objective of this Technical Report is to assist users of ISO 5167-1:1991. For convenience of use, it is divided into two Sections, as

Section 1 - Makes reference to specific clauses and subclauses in ISO 5167-1:1991, and provides guidance on details and interpretation of the requirements specified in ISO 5167-1:1991. The clause numbers in this Section have been arranged to be the same as the corresponding clause numbers in ISO 5167-1:1991.

Section 2 - Gives further information of a general nature, relevant to the application of ISO 5167-1:1991, but does not refer to specific clauses in ISO 5167-1:1991.

In Section 1, cross-reference is simplified by using the same clause and subclause numbering as in ISO 5167-1. To avoid confusing figures and tables of this Technical Report with those of the reference standard ISO 5167-1, references to the latter are made within square brackets, i.e. [...].

Some clauses of ISO 5167-1 are not commented upon and the corresponding clause numbers are therefore omitted from this Technical Report, except when it has been thought to be useful to keep a continuous numbering of paragraphs.

All quantities and constants quoted in this Technical Report are expressed in SI units.

1.1 ISO 5167-1

ISO 5167-1 is an International Standard for flow measurement based on the differential pressure generated by a constriction introduced into a circular conduit [ISO 5167-1, 5.1]. It presents a set of rules and requirements based on theory and experimental work undertaken in the field of flow measurement. Neither ISO 5167-1 nor this Technical Report give the detailed theoretical background and reference should be made to any general textbook on fluid flow.

With the application of the rules and requirements set out in ISO 5167-1, it is practicable to achieve flow measurement within an uncertainty of approximately 1 per cent on the calculated rate of flow.

For more detailed description of the scope, reference should be made to [ISO 5167-1, clause 1].

1.2 Selection of the primary device

The constraints applicable to each of the primary devices need to be given proper consideration before determining the most suitable type for a particular application. Clause 4 of this Technical Report gives guidance. A final decision should not be made unless it is clear that, for a particular application, the appropriate requirements of the clauses and subclauses of ISO 5167-1 listed in column 1 of table 1 of this Technical Report can be fulfilled.

These paragraphs will also form the basis for preliminary design. [ISO 5167-1, Clauses 3 and 4] give definitions and symbols.

1.3 Detail design

The information necessary for detailed design, manufacture and final check is specified in the clauses and paragraphs of ISO 5167-1 listed in column 2 of table 1.

1.4 Computation

Operation of a measuring system, once installed, requires several computations to establish the resultant flow-rate. Some results of these calculations will be fixed with installation dimensions and will only need to be computed once. Other calculations will need to be repeated for every flow measurement point. The equations to be used are given in the clauses and sub-clauses of ISO 5167-1 listed in column 3 of table 1.

1.5 Secondary instrumentation

Secondary instrumentation is not covered by ISO 5167-1 but Section 2 of this Technical Report makes reference to ISO 2186, which will be required.

2 Normative references

No comments on this clause.

3 Definitions

3.1 Pressure measurement

No comments on this clause

3.2 Primary devices

No comments on this clause

3.3 Flow

No comments on this clause

4 Symbols and subscripts

For explanation of the symbols and definitions, reference is made to [ISO 5167-1, clause 4.1] which is based on ISO 4006.

5 Principle of measurement and computation : Examples

5.1 Principle of the method of measurement

No specific comments on this clause, but note that throughout this guide, ρ_2 and ε_2 may be used as alternatives to ρ_1 and ε_1 .

5.2 Determination of the diameter ratio

Refer to annex A.

5.3 Determination of the rate of flow

Refer to annex A.

5.4 Determination of the density

For more details on density measurement, see Part 2.

For more details on density computation, see 6.2.

5.4.1 No specific comments on this clause.

Table 1 : Reference clauses in ISO 5167-1

	1. Selection	2. Design	3. Computation
General	1, 2, 5.1	3.3.6	3.3, 5.1, 5.3, 11
Fluid and flow conditions	6.2, 6.3	5.4	5.4.3
Primary device	6.1	3.2, 6.1.3	
Pipe work	7.1	7.1 and 7.5 or 7.6	7.5.1.2
Minimum straight lengths	7.2 or 7.4	7.2	
Orifice plates	8.3.1, 8.4	8.1, 8.2	8.3.2, 8.3.3
ISA 1932 nozzles	9.1.6.1, 9.1.8	9.1.2 to 9.1.5	9.1.6.2, 9.1.6.3, 9.1.7
Long radius nozzles	9.2.5.1, 9.2.7	9.2.1 to 9.2.4	9.2.5.2, 9.2.5.3, 9.2.6
Classical Venturi tubes	10.1.1, 10.1.5, 10.1.9.2	10.1.2 to 10.1.4	10.1.5 to 10.1.8
Venturi nozzles	10.2.4.1, 10.2.6	10.2.1 to 10.2.3	10.2.4.2, 10.2.4.3, 10.2.5.1, 10.2.5.2

5.4.2 Temperature measurement

Within the limits of application of the international standard [ISO 5167-1, 5.4.2] it may be assumed that the downstream and the upstream temperatures of the fluid are the same. For very accurate measurements it is advisable that the actual temperature at the upstream plane is measured under flowing conditions using a temporarily installed temperature probe.

If the fluid being measured is a gas and high accuracy is required and there is a large pressure loss between the upstream pressure tapping and the location of the temperature measuring device downstream of the primary device, then it is necessary to calculate the upstream temperature from the temperature measured downstream. Experimental work has shown that an isenthalpic expansion is a reasonable approximation for orifice plates. Further work is required to check its correctness for other primary devices. To perform the calculation, the pressure loss $\Delta\omega$ should be calculated from ISO 5167-1, 8.4, 9.1.8, 9.2.8, 10.1.9.2, or 10.2.6, The corresponding temperature drop from the upstream tapping to the downstream temperature measurement location, ΔT, can be evaluated given the rate of change of T with respect to p at constant enthalpy:

$$\Delta T = \left.\frac{\partial T}{\partial p}\right|_H \Delta\omega$$

$$= \frac{R_g T^2}{p c_p} \left.\frac{\partial Z}{\partial T}\right|_p \Delta\omega$$

where T is the absolute temperature, R_g is the universal gas constant, c_p is the heat capacity at constant pressure and Z is the compressibility factor.

In the 1980 edition of ISO 5167-1 it was stated that if the measured fluid is a gas an isentropic expansion should be assumed through the primary device. This is now known to be incorrect. The complete process includes both isentropic and isenthalpic expansions between upstream of the primary device and the location at which the static pressure recovery is completed.

REFERENCE : "Performance Equations for Compressible Flow Through Orifices and Other Δp Devices : A Thermodynamic Approach", AIChe Journal, March 1986, Vol. 32, No 3.

5.4.3 No specific comments on this clause.

5.4.4 Temperature of primary device

This assumption is made when correcting the primary device dimensions for temperature changes when very accurate flow measurement is required.

6 General requirements for measurements

6.1 Material and manufacture

Table 2 whilst not exhaustive, lists materials most commonly used for orifice plate manufacture.

Table 2 : Commonly used steels for orifice plate manufacture

	AISI	BS970	AFNOR	DIN
Stainless steels	304 316	304-S15 316-S16	Z6CN18-09 Z6CND17-11	1,430 1 1,440 1
High elastic limit stainless steel	420	420-S37	Z30C13	

Table 3 gives the mean linear expansion coefficient, elasticity modulii and yield stresses for the materials of table 2 according to their AISI designation.

Table 3 : Characteristics of commonly used steels

AISI designation	10^{-6} Mean Linear Expansion Coefficient between 0 and 100°C in K^{-1}	10^{9} Elasticity Modulus in Pa	10^{6} Yield Stresses in Pa
304	17	193	215
316	16	193	230
420	10	200	494

NOTE : the figures given in table 3 vary with both temperature and the treatment process of the steel. For precise calculations it is recommended that the data are obtained from the manufacturer.

6.1.1 No specific comments on this clause.

6.1.2 No specific comments on this clause.

6.1.3 When the primary device under operating conditions is at a different temperature from the one at which the diameter "d" was determined (this temperature is referred to as the reference or calibration temperature) the expansion or contraction of the primary device shall be taken into account in the computation of diameter ratio and flowrate using the following equation, assuming there is no restraint due to the mounting :

$$d = d_0 \left[1 + \lambda_d (T - T_0)\right] \quad (1)$$

where d : primary device diameter in flowing conditions ;

d_0 : primary device diameter at reference temperature ;

λ_d : mean linear expansion coefficient of the primary device material ;

T : primary device temperature in flowing conditions ;

T_0 : reference or calibration temperature.

Where automatic temperature correction is not required in the flow computer, the uncertainty for "d" included in the overall uncertainty calculations should be increased to allow for the change in "d" due to temperature variation (see ISO 5167-1, 11.2.2.3). An initial calculation may show that this additional uncertainty is small enough to be considered negligible.

6.2 Nature of the fluid

6.2.1 No specific comments on this clause.

6.2.2 Universal gas constant

The value indicated for the universal gas constant

6.2.3 Ascertaining density and viscosity of the flowing fluid

Annex B lists references for physical properties whilst annex C gives specific information for natural gases. They provide data relating to the dependence of density and viscosity on temperature and pressure.

For gases, several methods can be used to calculate density from pressure and temperature :

(a) by using tables, or equations of density versus pressure and temperature.

(b) when the molar mass M of the fluid is known, by first computing the compressibility factor Z_1, in flowing conditions, and then the density using the equation :

$$\rho_1 = \frac{p_1 M}{R T_1 Z_1} \qquad (2)$$

where R is the universal gas constant (= 8,314 50 $J.mol^{-1}.K^{-1}$)

(c) when the density at standard conditions, ρ_R is known (from calculation or measurement) for given conditions of pressure and temperature, p_R and T_R, by first computing the compressibility factors Z_1 and Z_R and then using the equation :

$$\rho_1 = \rho_R \frac{p_1 T_R Z_R}{p_R T_1 Z_1} \qquad (3)$$

For complex mixtures such as natural gas, the two latter methods are generally the only practicable ones. Annex C gives a list of the main existing methods of computation of the compressibility factor Z for a number of gas mixtures.

6.3 Flow conditions

6.3.1 No specific comments on this clause.

6.3.2 If there is a likelihood of such a change of phase, a way of overcoming the problem is to increase the diameter ratio, so that the differential pressure is reduced.

7 Installation requirements

7.0 Inspection equipment

The following list of inspection equipment is not exhaustive, but provides a basis for inspection control.

- calipers (thickness, diameters) ;
- internal micrometer (diameters) ;
- micrometer (thickness) ;
- gauge block, feeler gauge (relative position, absolute standard for checking micrometers) ;
- protractor (angles) ;
- profile measuring apparatus (edge) ;
- straight edge rule (flatness) ;
- three point bore gauge (internal diameter).

Only instruments which may be calibrated to primary standards should be used if optimum accuracy is required.

7.1 Pipe sections adjacent to the primary device

For additional requirements for orifice plates, nozzles and Venturi nozzles, refer to [ISO 5167-1, 7.5]. For classical Venturi tubes, refer to [ISO 5167-1, 7.6].

For pipe roughness criteria, refer to the following paragraphs of [ISO 5167-1 : 8.3.1, 9.1.6.1, 10.2.4.1].

7.1.1 No specific comments on this clause.

7.1.2 No specific comments on this clause.

7.1.3 No specific comments on this clause.

7.1.4 No specific comments on this clause.

7.1.5 Internal diameter of the measuring pipe

The value of "D", corrected for thermal expansion (see below), is that used for the computation of the diameter ratio β. This value of "D" is also used as the basis for establishing the circularity of the pipe over a length of at least 2 D upstream and downstream of the primary device (see 7.5.1).

The distance to the measurement station is expressed in terms of "D", which is not known before taking measurements at prescribed stations. For the purpose of establishing the position of these stations, it is permissible to take "D" as equal to the nominal bore of the pipe.

Figure 1 gives an example for orifice meters where diameters are measured in only three different cross-sections :

- A_1, B_1, C_1 for orifice plates with corner tappings.
- A_2, B_2, C_2 for orifice plates with flange tappings.
- A_3, B_3, C_3 for orifice plates with D and D/2 tappings.

In any case, individual diameters should be measured with an accuracy of at least 0,1 per cent, as the overall tolerance is 0,3 per cent (see 7.5.1).

When the measuring pipe under flowing conditions is at a significantly different temperature from the one at which diameter D_0 was determined (this temperature, referred to as the reference or calibration temperature) the expansion or contraction of the pipe shall be taken into account in the computation of diameter ratio and flow-rate, using the following equation:

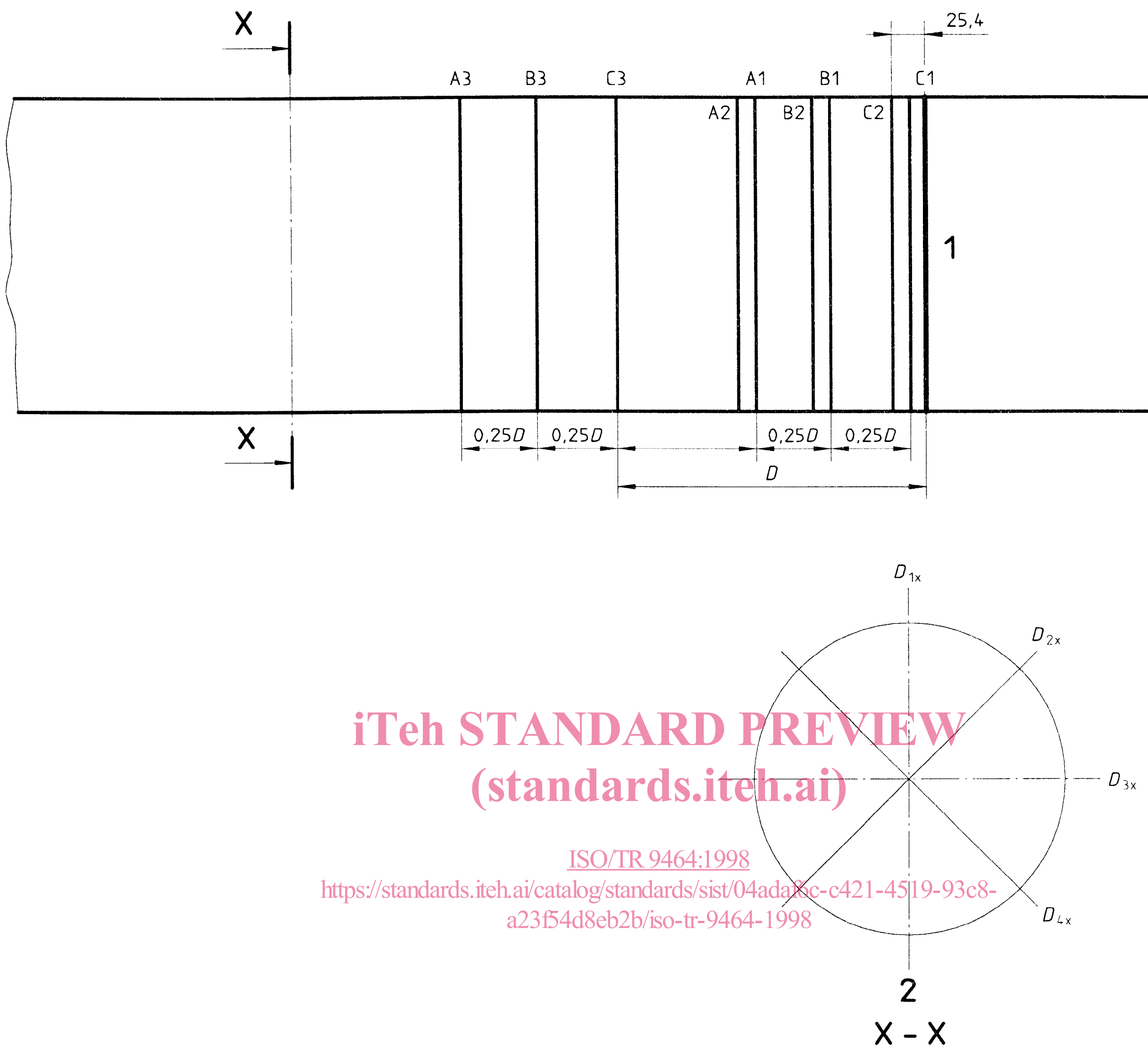
$$D = D_0 \left[1 + \lambda_D (T - T_0)\right] \quad (4)$$

where :

D : diameter of the pipe in flowing conditions ;
D_0 : diameter of the pipe at reference temperature ;
λ_D : mean linear expansion coefficient of the pipe material ;
T : pipe temperature in flowing conditions ;
T_0 : reference or calibration temperature.

The value for λ_D should be obtained from the manufacturer of the measuring pipe.

Dimensions in millimetres



1. Plate upstream face
2. Cross section X

Internal diameter D to be used in flowrate computation :

$$D = \frac{1}{12}\left[\sum_{i=1}^{4} D_{iA_n} + \sum_{i=1}^{4} D_{iB_n} + \sum_{i=1}^{4} D_{iC_n}\right]$$

n = 1 for corner tappings
n = 2 for flange tappings
n = 3 for D and D/2 tappings

Figure 1 : Measurement of internal diameter D

Where automatic temperature correction is not required in the flow computer the uncertainty for "D" included in the overall uncertainty should be increased to allow for the change in "D" due to temperature variation (see 11.2.2.3). An initial calculation may show that this additional uncertainty is small enough to be considered negligible.

7.1.6 No specific comments on this clause.

7.1.7 No specific comments on this clause.

7.1.8 The requirements in [7.1.8] where drain or vent holes are located near to the primary device are illustrated in Figure2. It should be realised that the flowing fluid may cause deposition, corrosion or erosion of the inner wall of the pipe. The installation may therefore not comply with the requirements of ISO 5167-1. Users should consider internal inspection of the pipe at intervals appropriate to the conditions of application.

7.1.9 This clause is intended to ensure a reliable measurement of temperature. Although the flowing temperature is not a quantity directly involved in the equation for calculating flow-rate, it is an important parameter since it may be used to calculate "d" and "D" plus critical process parameters under flowing conditions.

7.2 Straight lengths

7.2.1 When designing a metering pipe installation it is recommended that the required minimum straight lengths are determined by the maximum diameter ratio that is expected in the life of the installation.

For diameter ratios not covered by [ISO 5167-1, table 1 or 2] but inside the limits of the standard, it is reasonable practice to interpolate linearly between the nearest table values of the closest diameter ratio and to round up to the next integer number for [table 1] and to the next half number for [table 2].

If an orifice meter is designed to measure the flowrate in either direction, the minimum straight lengths of pipe on both sides of the orifice plate shall comply with the minimum requirements for upstreamstraight lengths as specified in [ISO 5167-1, 7.2 and Tables 1 and 2].

7.2.2 No specific comments on this clause.

7.2.3 No specific comments on this clause.

7.2.4 No specific comments on this clause.

7.2.5 No specific comments on this clause.

7.2.6 No specific comments on this clause.

7.2.7 No specific comments on this clause.