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Measurement of gas flow in closed conduits — Turbine meters

Mesure de débit de gaz dans les conduites fermées — Compteurs à turbine

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Contents

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Annexes

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.

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.

International Standard ISO 9951 was prepared by Technical Committee ISO/TC 30, *Measurement of fluid flow in closed conduits*, Sub-Committee SC 10, *Turbine meters*.

Annexes A, B, C, D and E of this International Standard are for information only.

Measurement of gas flow in closed conduits — Turbine meters

1 Scope

This International Standard specifies dimensions, ranges, construction, performance, calibration and output characteristics of turbine meters for gas flow measurement.

It also deals with installation conditions, leakage testing and pressure testing and provides a series of informative annexes A to E including recommendations for use, field checks and perturbations of the fluid flowing.

In many countries, some or all of the items covered by this International Standard are subject to mandatory regulations imposed by the laws of these countries. In cases where conflict exists between such mandatory regulations and this International Standard, the former shall prevail.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 3:1973, *Preferred numbers — Series of preferred numbers.*

ISO 4006:1991, *Measurement of fluid flow in closed conduits — Vocabulary and symbols.*

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.*

ISO 5168:1978, *Measurement of fluid flow — Estimation of uncertainty of a flow-rate measurement.*

ISO 5208:1993, *Industrial valves — Pressure testing of valves.*

ISO 6708:1980, *Pipe components — Definition of nominal size.*

IEC 79:—, *Electrical apparatus for explosive gas atmospheres.*

OIML R 6:1989, *General provisions for gas meters.*

OIML R 32:1989, *Rotary piston gas meters and turbine gas meters.*

VIM:1984, *International vocabulary of basic and general terms in metrology* (BIPM, IEC, ISO, OIML).

3 Definitions and symbols

3.1 Definitions

For the purposes of this International Standard, the definitions given in ISO 4006 and the International vocabulary of basic and general terms in metrology apply. The following definitions are given only for terms used in some special sense or for terms whose meaning it seems useful to recall.

3.1.1 flowrate: Actual volume of flow per unit of time.

3.1.2 working range: Range of flowrates of gas limited by the maximum flowrate q_{max} and the minimum flowrate q_{min}, for which the meter error lies within specified limits (sometimes also called "rangeability").

3.1.3 metering pressure: Gas pressure in a meter to which the indicated volume of gas is related.

3.1.4 average velocity: Volume flowrate per unit of cross-sectional area.

3.1.5 shell: Pressure-containing structure of the meter.

3.1.6 metering conditions: Conditions, at the point of measurement, of the gas whose volume is to be measured (for example gas temperature and pressure).

3.1.7 base conditions: Conditions to which the measured volume of the gas is converted (for example base temperature and base pressure).

3.1.8 specified conditions: Conditions of the gas at which performance specifications of the meter are given.

NOTE 1 Metering and base conditions relate only to the volume of the gas to be measured or indicated, and should not be confused with "rated operating conditions" or "reference conditions" (VIM 5.05 and 5.07), which refer to influence quantities (VIM 2.10).

3.2 Symbols and subscripts

The symbols and subscripts used in this International Standard are given in table 1.

Table 1 — Symbols and subscripts

Symbol	Quantity	Dimensions1)	SI unit
c	Pressure loss coefficient depending on meter type	L^{-4}	m^{-4}
d	Relative density of the gas ($d_{air} = 1$)	Dimensionless	—
D	Inside diameter meter outlet/inlet	L	m
D_1	Inside diameter pipe	L	m
DN	Nominal size meter outlet/inlet	Dimensionless	—
DN_1	Nominal size pipe	Dimensionless	—
H	Height of strut	L	m
L	Length of the strut	L	m
m	Mass	M	kg
M	Molar mass	M	kg/mol
N	Number of moles of gas		mol
p	Absolute pressure	$ML^{-1} T^{-2}$	Pa
p_m	Metering pressure	$ML^{-1} T^{-2}$	Pa
q	Flowrate	$L^3 T^{-1}$	m^3/s
R	Molar gas constant	$ML^2 T^{-2} \Theta^{-1}$	J/(mol·K)
S	Chord distance between adjacent struts measured at the tip	L	m
t	Time	T	s
T	Absolute temperature of the gas	Θ	K
V	Volume	L^3	m^3
Z	Compressibility factor (deviation from ideal gas laws)	Dimensionless	—
ρ	Density of the gas	ML^{-3}	kg/m^3
ψ	Working range q_{max}/q_{min}	Dimensionless	—
	Subscripts		
b	Base conditions for volume or rate calculations		
m	Metering conditions of the gas		
s	Specified conditions for volume or rate		

1) M = mass; L = length; T = time; Θ = temperature.

4 Principle of the method of measurement

The turbine meter is a fluid measuring device in which the dynamic forces of the flowing fluid cause the turbine wheel to rotate with a speed approximately proportional to the rate of volume flow. The number of revolutions of the turbine wheel is the basis for the indication of the volume passed through the meter.

5 Flowrates

The maximum and minimum flowrates shall be specified for the gas densities for which the meter will operate within the specifications of meter performance defined in clause 8. The maximum flowrate in cubic metres per hour (m^3/h) of the meter should preferably be a number in the set R5 of preferred numbers specified in ISO 3 (the value 63 has been rounded to 65). The unit of cubic metres per hour (m^3/h) is preferred.

6 Meter construction

6.1 General

Meters shall be designed and manufacturing tolerances shall be set to allow interchangeability of meters of the same size and type.

6.2 Materials

The meter body and the internal mechanism shall be manufactured of materials suited for the service conditions and resistant to attack by the fluid which the meter is to handle. Exterior surfaces of the meter shall be protected as necessary against corrosion.

6.3 Shell

The meter shell and all other parts comprising the fluid-containing structure of the meter shall be constructed of sound materials and designed to handle the pressures and temperatures for which they are rated.

6.4 Connections and maximum flowrates

The inlet and outlet connections of the meter shall conform to recognized standards.

The preferred nominal sizes (DN) and corresponding maximum flowrates (q_{max}) are given in table 2.

Table 2 — Maximum flowrates and nominal sizes

Maximum flowrates, q_{max} m^3/h	Nominal size DN
40	50
65	50
100	50
160	80
250	80
400	100
650	150
1 000	150
1 600	200
2 500	250
4 000	300
6 500	400
10 000	500
16 000	600
25 000	750
40 000	1 000

6.5 Length

The length of the meter between the ends of its inlet and outlet connections shall be less than or equal to $5D$.

6.6 Pressure tappings

6.6.1 Metering-pressure tappings

At least one metering-pressure tapping shall be provided on the meter, to enable measurement (indirectly if necessary) of the static pressure at the turbine wheel of the meter at metering conditions. The connection of this pressure tapping shall be marked "p_m". If more than one "p_m" tapping is provided, the difference in pressure readings shall not exceed 100 Pa at maximum flowrate with an air density of 1,2 kg/m^3.

6.6.2 Other pressure tappings

A meter may be equipped with other pressure tappings in addition to the "p_m" tapping. These may serve to determine the pressure drop over a part of the meter or for other purposes. The other pressure tappings shall be marked "p".

6.6.3 Dimensions

6.6.3.1 Circular tappings shall conform to the requirement given in ISO 5167-1 except that they shall have a minimum bore diameter of 3 mm and a maximum bore diameter of 12 mm, and the length of the bore shall be a minimum of one bore diameter.

6.6.3.2 Slit-shaped tappings shall have a minimum dimension of 2 mm and a maximum dimension of 10 mm in the direction of flow, and a minimum cross-sectional area of 10 mm^2.

6.6.4 Sealing

Any pressure test point or tapping connection on the meter shall be provided with a suitable means of closure, e.g. a plug, and shall be capable of being sealed against unauthorized interference.

6.7 Flow direction

The direction of flow or the inlet of the meter shall be clearly and permanently marked.

6.8 Meter having a removable meter mechanism

6.8.1 The construction of a meter with a removable meter mechanism shall be such that the performance characteristics of the meter as defined in 8.1 are maintained after interchange of the mechanism and/or after repeated mounting and dismounting of the same mechanism.

6.8.2 The design and method of replacement of a removable mechanism shall ensure that the construction of the meter as specified in this clause is maintained.

6.8.3 Each removable meter mechanism shall have a unique serial number marked on it.

6.8.4 Each removable meter mechanism shall be capable of being sealed against unauthorized interference.

6.9 Overloading

The meter shall be designed to be capable of occasionally running 20 % above the maximum flowrate, within the range of pressure and temperature for which it is rated, for a time period of 30 min without damage or without influence on the error curve of the meter.

6.10 Marking

The badge of the meter shall be marked with at least the following information:

a) manufacturer's name or mark;

b) serial number;

c) maximum flowrate, q_{max}, in actual volume units;

d) maximum allowable operating pressure;

e) minimum flowrate, q_{min}, at 1,2 kg/m^3 fluid density.

7 Pressure testing

7.1 General

7.1.1 The pressure testing shall be based on the shell test for industrial valves as specified in ISO 5208.

7.1.2 Meters shall not be painted or otherwise coated with materials capable of sealing against leakage before leakage tests are completed. Chemical corrosion protection treatments and internal linings are permitted. If pressure tests in the presence of a representative of the purchaser are specified, painted meters from stock may be retested without removal of paint.

7.1.3 Test equipment shall not subject the meter to externally applied stress which may affect the results of the tests.

7.2 Test fluid

7.2.1 At the discretion of the testing facility the tests can be carried out with water, kerosine, or any other suitable liquid having a viscosity not greater than that of water or with gas (air or any other suitable gas).

7.2.2 When testing with a liquid, the meter shall be thoroughly purged of any air which it contains.

7.3 Strength test of the pressure-containing parts

7.3.1 The test shall be performed at a minimum internal pressure of 1,5 times the maximum allowable operating pressure at 20 °C (nominal).

7.3.2 The test shall be performed by applying pressure inside the pressure-retaining walls of the assembled meter with the connections closed.

7.3.3 Visually detectable leakage through the pressure-retaining walls is not acceptable.

The test duration shall not be less than that specified in table 3.

Table 3 — Strength test duration

Nominal size, DN	Minimum test duration s
DN = 50	15
50 < DN ⩽ 200	60
DN > 200	180

7.4 Meter leakage test

The assembled meter shall be pneumatically tested for external leakage at a minimum internal pressure of 1,1 times the maximum allowable operating pressure. The pressure shall be increased slowly up to the test pressure and shall be maintained there for a minimum of 1 min. During this period no fluid shall escape from the meter. If a leakage test is run after a hydrostatic test, a water seal could develop, therefore the meter should be dried before assembling the mechanism and carrying out the leak test. After the test, the pressure shall be released at a rate not greater than that used for pressurization.

8 Performance characteristics

See also annex B.

8.1 Error

The relative error, E, in percent, is defined as the ratio of the difference between the indicated value V_{ind} and the conventional true value V_{true} of the volume of the test medium which has passed through the gas meter, to this latter value:

$$E = \frac{V_{ind} - V_{true}}{V_{true}}$$

All meters shall have a maximum permissible error of ± 1 % over the designated flow range. When q_{min} is less than 0,2 q_{max}, the maximum permissible error between q_{min} and 0,2 q_{max} is ± 2 %.

A meter is considered to satisfy this requirement if it is met at the flowrates specified in 8.2.1.

The density range for which the relative errors are within these allowances shall be specified.

For the calculation of errors, see also ISO 5168.

8.2 Calibration

An individual calibration of each meter shall be made. The results of this calibration shall be available on request, together with a statement of conditions under which the calibration took place.

8.2.1 Calibration data

The calibration data provided shall include:

a) the error at q_{min} and all the following flowrates that are above q_{min}:

0,1; 0,25; 0,4; 0,7 of q_{max} and q_{max};

b) the name and location of the calibration facility;

c) the method of calibration (bell prover, sonic nozzles, other meters, etc.);

d) the estimated uncertainty of the method;

e) the nature and conditions (pressure and temperature) of the test gas;

f) the position of the meter (horizontal, vertical flow upwards, vertical flow downwards).

8.2.2 Calibration conditions

The calibration is preferably carried out at conditions as close as possible to operating conditions.

8.2.3 Calibration facility

The facility at which the calibration is carried out shall be traceable to the primary standards of mass, length, time and temperature.

8.2.4 Installation conditions at calibration

The performance of the meter shall not be influenced by the installation conditions of the test facility.

8.3 Meter position

The position in which the meter is mounted to achieve the specified performance shall be stated. The following positions shall be considered: horizontal; vertical flow upwards, or vertical flow downwards. If a mechanical output and/or mechanical counter is used, the different possible positions of these devices shall be taken into consideration when specifying the meter position.

8.4 Temperature range

The fluid and ambient temperature ranges over which the meter is designed to perform within standard performance specification shall be stated.

8.5 Pressure loss

Pressure loss data for the meter shall be provided (see annex B). Apart from the pressure loss across the meter, the pressure loss in adjacent pipework and flow conditioners necessary to satisfy the requirements for performance limits shall be taken into account.

8.6 Installation conditions

The conditions for the installation of the meter shall be specified in order that the relative meter error does not differ by more than one third of the maximum permissible error specified in 8.1 from the meter error obtained with an undisturbed upstream flow condition. Consideration shall be given to such items as the straight lengths of pipe upstream and/or downstream of the meter, and/or the type and location of a flow conditioner if required (see annex E).

8.7 Mechanically driven external equipment

If an output shaft is provided which drives instrumentation other than the normal mechanical counter, loading of this shaft will retard the meter. This effect is largest for small flowrates and low gas densities. Therefore, the meter specifications shall state the maximum torque which may be applied by the output shaft and the effect of this torque on the meter performance for different densities, as well as the range of flowrates for which this statement is valid.

9 Output and readout

9.1 General

The output of the meter consists of an electrical or mechanical counter totalling the throughput of the meter. An electrical pulse rate signal or a rotating shaft may be used to represent the flowrate through the meter.

9.2 Counters

9.2.1 Counter capacity

The number of digits in a counter shall be sufficient to indicate, to within one unit of the last digit, a throughput volume corresponding to at least 2 000 hours of operation at the maximum flowrate.

9.2.2 Units

The counter shall indicate the throughput of the meter in SI units or units directly derived from SI units. On the counter the units used shall be clearly and unambiguously stated.

9.2.3 Numbers

The height of the numerals of the counter shall be a minimum of 4 mm. The change of numerals shall be such that the advance of one figure at any point of the counter must be completed while the figure of the next lower range describes the last tenth of its course.

9.2.4 Construction

Counters shall be of good design and reliable construction. When mounted on the turbine meter they are required to operate reliably and remain legible over the entire temperature range (see 8.4).

9.2.5 Smallest division of the counter

When the only output of the meter is a mechanical counter, the readout shall enable the meter to be calibrated with the required accuracy at the minimum flowrate in a reasonably short time. The smallest division of the least significant digit of the counter or test element should therefore be smaller than the minimum hourly flowrate divided by 400.

9.3 Flowrate output

The flowrate output of the meter, whether it is in the form of a pulse rate or the rotational speed of a shaft, shall be in a known ratio to the rate of change in the counter.

9.4 Mechanical output

Provision shall be made for covering and sealing the free ends on any extra output shafts, when they are not being used. The value per revolution of an output shaft, expressed as 1 rev $\triangleq$ ... m^3 (see OIML R6), and the direction of rotation shall be marked on the shaft or on an adjacent point on the meter.

9.5 Voltage-free contact

If a voltage-free contact is provided, its operation shall represent a volume being a decimal submultiple of, equal to, or a decimal multiple of the volume indicated per revolution of the driven part of the counter. The value of the pulse shall be clearly indicated on the meter.

9.6 Electrical pulse output

The number of pulses per cubic metre indicated by the counter shall be stated on the meter. The number of pulses representing a cubic metre (the meter factor) on meters without mechanical indexes shall be defined for the flowrates given in 8.2.1.

9.7 Electrical safety

Meters equipped with electrical or electronic equipment shall satisfy IEC 79 if intended for use with combustible gas or in a hazardous atmosphere.

Annex A
(informative)

Recommendations for use

A.1 General

Turbine meters should be operated within the specified flow range and operating conditions to achieve the desired accuracy and normal lifetime. Premature wear and damage may be caused by turbine wheel overspeed and the presence of debris in the pipeline. Key considerations for successful operation are appropriate meter size for the intended flow, correct installation, and proper operation and maintenance procedures.

A.2 Start-up recommendation for new lines

Before starting up a meter installation, particularly on new lines or lines that have been repaired, the line should first be cleaned to remove any collection of welding beads, rust accumulation and other pipeline debris. The meter mechanism should be removed during all hydrostatic testing and such line cleaning operations to prevent serious damage to the meter measuring element.

A.3 Strainers or filters

A.3.1 Foreign substances in a pipeline can seriously damage turbine meters. Strainers are recommended when the presence of damaging foreign material in the gas stream can be anticipated. Strainers should be sized so that at maximum flow there is a minimum pressure drop and installed so that there is no undue flow distortion (see annex E).

A.3.2 A greater degree of meter protection can be achieved through the use of a dry-type or separator-type filter installed upstream of the meter inlet piping.

A.3.3 It is recommended that the pressure differential across a filter be monitored to ensure that the filter remains in good condition and that flow distortion is prevented.

A.4 Overrange protection

Turbine meters can generally withstand a gradual overranging without suffering internal damage other than accelerated wear. However, extreme gas velocity encountered during pressurizing, venting or purging can cause severe damage to the meter due to the resulting sudden turbine wheel overspeed.

A.4.1 As with all meters, turbine meters should be pressurized and started up slowly. Shock loading by opening valves quickly will usually result in turbine wheel damage. In high pressure applications, the installation of a small bypass line around the upstream meter-isolating valve can be utilized to safely pressurize the meter to its operating pressure.

A.4.2 In installations where adequate pressure is available, either a critical flow orifice or a sonic Venturi nozzle may be installed to help protect the meter turbine wheel from overspeeding. The restriction should be installed in the piping downstream of the meter and should be sized to limit the meter loading to approximately 20 % above its q_{max}. Generally, a critical flow orifice will result in a 50 % pressure loss and a sonic Venturi nozzle will result in a 5 % to 20 % pressure loss.

A.5 Bypass

If interruption of the gas supply cannot be tolerated, a bypass should be installed so that the meter can be maintained.

A.6 Frequency of maintenance and inspection

Turbine meter accuracy, in addition to depending on sound design and installation procedures, is dependent on good maintenance practice and adequate frequency of inspection. Basically, the time between meter inspections is dependent on the gas conditions. Meters used in dirty gas applications will require more frequent attention than those used with clean gas, and inspection periods should reflect this aspect.

A.7 Other installation considerations

In addition to the above-mentionned items, it is also necessary to take the following installation practices into consideration, as the lack of attention to any one item could result in serious measurement errors.

a) The meter and meter piping should be installed so as to minimize strain on the meter due to pipeline stresses.