IS 15676 (2006): Flow measurement of natural gas by turbine meter [PGD 26: Weights and Measures]

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Indian Standard

FLOW MEASUREMENT OF NATURAL GAS BY TURBINE METERS

ICS 75.160.30; 75.180.30

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FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Weights and Measures Sectional Committee had been approved by the Production and General Engineering Division Council.

This standard is taken for measuring the gas consumption at bulk supplier as well as the users' end when the gas is supplied through the pipelines. In order to meet the requirement of bulk supplier and consumer, the Bureau of Indian Standards, has formulated the above standard for accuracy of metering system and regulation of gas at different delivery point to fulfill the consumer satisfaction. This standard deals with installation conditions, leakage, testing and pressure testing and provides a series of information as well as recommendation for use, field checks and perturbations of the fluid flow.

In preparing this standard considerable amount of assistance has been taken from the following publications:

ISO 9951 : 1993 Measurement of gas flow in closed conduits — Turbine meters

AGA 7 American gas authority report for turbine meters

Annexes A, B, C, D and E are for information only.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

FLOW MEASUREMENT OF NATURAL GAS BY TURBINE METERS

1 SCOPE

This standard specifies the requirements of dimensions, ranges, construction, performance, calibration and output characteristics of turbine meters for gas flow measurement for custody transfer.

It also specifies 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.

This standard does not cover the equipment used in the determinations of the pressures, temperatures, densities and other variable that must be known for the accurate determination of measured gas quantities.

In cases where conflict exists between mandatory regulations and this standard, the former shall prevail.

2 REFERENCES

The following standards contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

Standard No.	Title
IS 1076 (Part 1) : 1985	Preferred numbers : Part 1 Series of preferred numbers (*second revision*)
IS 2148 : 2004	Electrical apparatus for explosive gas atmospheres — Flameproof enclosures "d" (*third revision*)
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 minning 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

3 DEFINITIONS

3.1 For the purpose of this standard, following 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 *Designated Flow Range* — Flow between $0.2\ q_{Max}$ to q_{Min}.

3.1.4 *Metering Pressure* — Gas pressure in a meter to which the indicated volume of gas is related.

3.1.5 *Average Velocity* — Volume flowrate per unit of cross-sectional area.

3.1.6 *Shell* — Pressure-containing structure of the meter.

3.1.7 *Metering Conditions* — Conditions, at the point of measurement, of the gas whose volume is to be measured, for example, gas temperature and pressure.

3.1.8 *Base Conditions* — Conditions to which the measured volume of the gas is converted (for example, base temperature and base pressure).

3.1.9 *Specified Conditions* — Conditions of the gas at which performance specifications of the meter are given.

> NOTE — 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).

4 SYMBOLS AND SUBSCRIPTS

See Table 1.

5 PRINCIPLE OF THE METHOD OF MEASUREMENT

A turbine meter is a fluid flow 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.

Table 1 Symbols and Subscripts

(Clause 4)

Symbol	Quantity	Dimensions	SI Unit
(1)	(2)	(3)	(4)
Symbol			
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 pipe 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 or 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	Dimensionless	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	$ML^2T^{-2}O^{-1}$	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	O	K
V	Volume	L^3	m^3
Z	Compressibility factor (deviation from ideal gas laws)	Dimensionless	—
p	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		

A second turbine wheel may be included in the mechanism, designed to rotate at a significantly slower speed than the first due to the difference in blade angles of the two rotors. A change in rotational speed between the two rotors for a given fluid velocity will indicate a shift in calibration conditions, for example, a change in bearing friction, flow pulsations or a change in flow profile.

Schematics of axial-flow gas turbine meters are shown in Fig. 1. Gas entering the meter increases in velocity through the annular passage formed by the nose cone and the interior wall of the body. The movement of gas over the angled rotor blades imparts a force to the rotor, causing it to revolve. The ideal rotational speed is directly proportional to the flowrate. The actual rotational speed is a function of the passageway size and shape, and the rotor design. It is also dependent upon the load, that is, imposed due to internal mechanical friction, fluid drag, external loading, and the gas density.

6 FLOW METER

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 3. The maximum flowrate in cubic metres per hour (m^3/h) of the meter shall preferably be a number of the preferred series [*see* IS 1076 (Part 1)]. The unit of cubic metres per hour (m^3/h) is preferred.

7 METER CONSTRUCTION

7.1 General

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

7.2 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.

7.3 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.

7.4 Connections and Maximum Flowrates

The inlet and outlet connections of the meter shall conform to recognized standards (*see* Table 2).
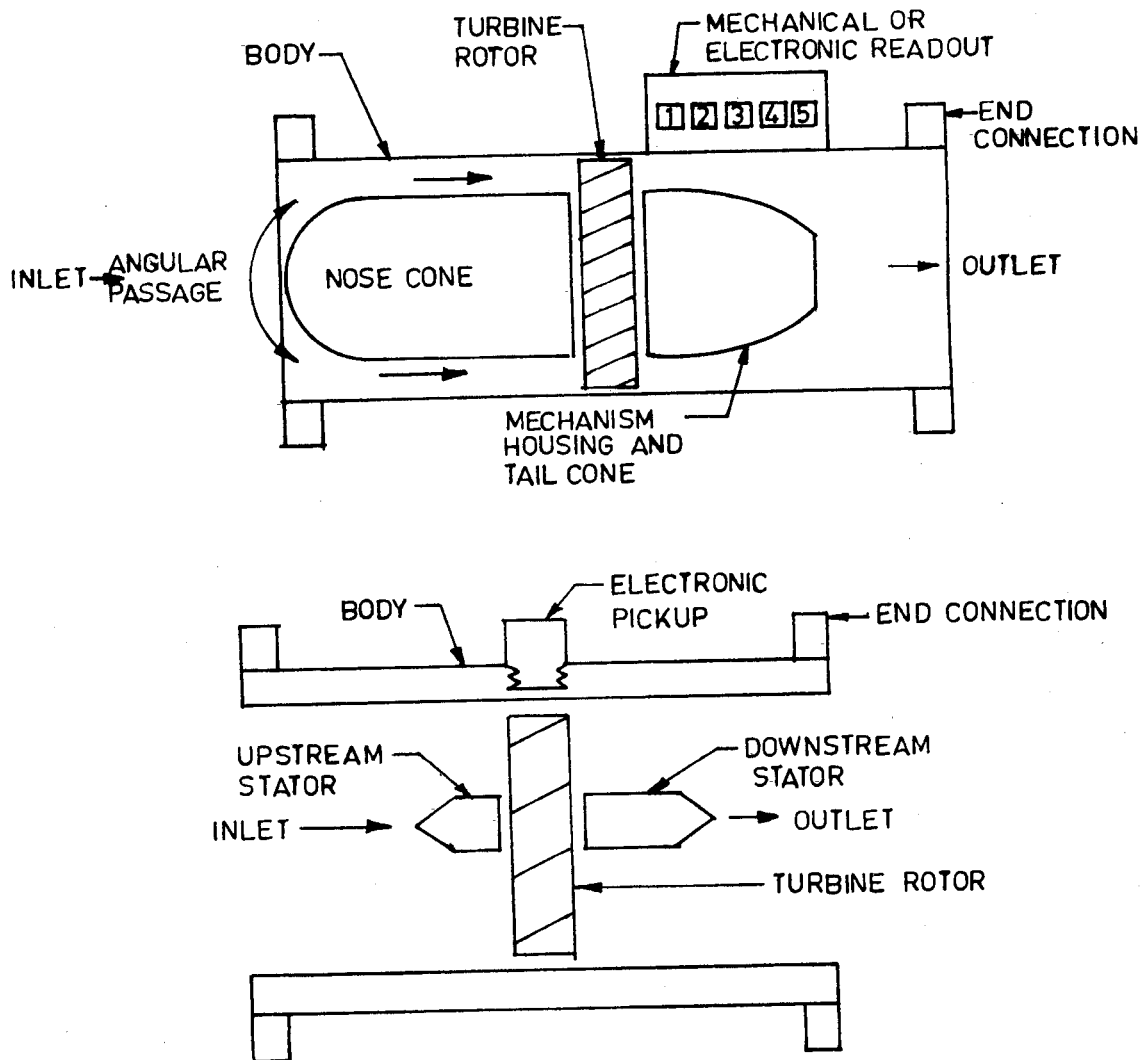
Fig. 1 Schematic Drawings of Axial Flow Gas Turbine Meters

Table 2 Preferred Nominal Sizes (*DN*) and Corresponding Maximum
Flowrates at Metering Conditions (q_{Max})
(*Clause* 7.4)

SI No.	Maximum Flowrates at Metering Conditions m^3/h	Nominal Size, *DN* mm
(1)	(2)	(3)
i)	40	50
ii)	65	50
iii)	100	50
iv)	160	80
v)	250	80
vi)	400	100
vii)	650	150
viii)	1 000	150
ix)	1 600	200
x)	2 500	250
xi)	4 000	300
xii)	6 500	400
xiii)	10 000	500
xiv)	16 000	600
xv)	25 000	750
xvi)	40 000	1 000

NOTE — Meter sizes are designated by G 16, G 40, etc, according to OIML R-32.

7.5 Length

The length of the meter between the ends of its inlet and outlet connections shall be less than or equal to 5 D of meter sizes greater than 25 mm.

7.6 Pressure Tappings

7.6.1 *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.

7.6.2 *Other Pressure Tappings*

A meter shall be equipped with other pressure tappings in addition to the 'p_m' tapping. These serve to determine the pressure drop over a meter tappings shall be marked 'p_m'.

7.6.3 *Dimensions*

7.6.3.1 Circular tappings shall conform to the requirement given in ISO 5167-1 except that they shall have 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.

7.6.3.2 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.

7.6.4 *Sealing*

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

7.7 Flow Direction

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

7.8 Meter Having a Removable Meter Mechanism

7.8.1 The construction of a meter with a removable meter mechanism shall be such that the performance characteristics of the meter as defined in 3.1 are maintained after interchange of the mechanism and/or after repeated mounting and dismounting of the same mechanism.

7.8.2 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.

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

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

7.9 Overloading

The meter shall be designed to be capable of occasionally running 20 percent 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.

8 PRESSURE TESTING

8.1 General

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

8.1.2 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.

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

8.2 Test Fluid

8.2.1 The test may be carried out with water, kerosene, or any other suitable liquid having a viscosity not greater than that of water or with gas (air or any other suitable gas).

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

8.3 Strength Test of the Pressure-Containing Parts

8.3.1 The test shall be performed at a minimum internal pressure of 1.5 times the maximum allowable operating pressure at ambient temperature.

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

8.3.3 There shall be no 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
(*Clause* 8.3.3)

Sl No.	Nominal Size, *DN*	Minimum Test Duration *S*
(1)	(2)	(3)
i)	*DN* = 50	15
ii)	50 < *DN* ≤ 200	60
iii)	*DN* > 200	180

8.4 Meter Leakage Test

The assembled meter shall be pneumatically tested for external leakage at 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 shall 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.

9 PERFORMANCE CHARACTERISTICS

See also Annex C.

9.1 Error

The relative error, *E*, in percent, is defined as the ratio of the difference between the indicated value V_{ind} 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 percent over the designated flow range. Between q_{Min} to 0.2 q_{Max}, the permissible error shall be ±2 percent.

A meter is considered to satisfy this requirement, if it is met at the flowrates.

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

For the calculation or errors, *see* ISO 5168.

9.2 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.

9.2.1 *Calibration Data*

The calibration data provided shall include:

a) 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) name and location of the calibration facility;

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

d) estimated uncertainty of the method;

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

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

9.2.2 *Calibration Conditions*

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

9.2.3 *Calibration Facility*

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

9.2.4 *Installation Conditions at Calibration*

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

9.2.5 Meter shall conforms to accuracy of ±1 percent over a specified flow range for any operating density. Turbine meters are capable of ±0.25 percent accuracy over a specified flow range if they are individually calibrated against an acceptable standard at the particular density at which they will be operated. Therefore, the most accurate turbine meter performance is obtained when each meter is calibrated under density conditions approaching the meter's actual operating density. If meter calibration at operating density is impractical, it is necessary to rely on the manufacturer's prediction of the calibration shift to be expected between the calibrating and operating densities.

9.2.6 *Determination of Calibration Factor*

It is a general practice, and most convenient, to use a fixed meter calibration factor over the whole range of flowrates. This will be a calibration factor 'K' (pulses per unit volume) for an electrical output. For mechanical output meters, the factor is set by choosing change gears that make each meter output shaft revolution represent a definite volume, for example, 0.085 or 0.85 m^3 at flowing conditions.

9.3 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.

9.4 Temperature Range

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

9.5 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 pipe work and flow conditioners necessary to satisfy the requirements for performance limits shall be taken into account.

9.6 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 **9.1** 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 conditions if required (*see* Annex E).

9.7 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.

10 OUTPUT AND READOUT

10.1 General

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

10.2 Counters

10.2.1 *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 h of operation at the maximum flowrate.

10.2.2 *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.

10.2.3 *Numbers*

The height of the numerals of the counter shall be minimum 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.

10.2.4 *Construction*

Counters shall be of good design and reliable construction. When mounted on the turbine meter they shall operate reliably and remain legible over the entire temperature range.

10.2.5 *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.

10.3 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.

10.4 Mechanical Output

Provision shall be made for covering and sealing the free ends on any extra output shafts, where provided and when they are not being used. The revolution of an output shaft and the direction of rotation shall be marked on the shaft or on an adjacent point on the meter.

10.5 Voltage-Free Contact

If a voltage-free contact is provided, its operation shall represent a volume being a decimal sub multiple 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.

10.6 Electrical Pulse Output

The number of pulses per cubic metre indicated by the counter shall be stated on the meter.

10.7 Electrical Safety

Meters equipped with electrical or electronic equipment shall satisfy IS 2148, if intended for use with combustible gas or in a hazardous atmosphere.

11 MARKING

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

a) Manufacturer's name or trade-mark;

b) Serial number;

c) Maximum flowrate, q_{Max} in actual volume units;

d) Maximum allowable operating pressure; and

e) Minimum flowrate, q_{Max} at 1.2 kg/m^3 fluid density.

11.1 BIS Certification Marking

The product may also be marked with the Standard Mark.

11.1.1 The use of the Standard Mark is governed by the provisions of the *Bureau of Indian Standards Act,* 1986 and the Rules and Regulations made thereunder. The details of conditions under which the licence for the use of Standard Mark may be granted to manufacturers or producers may be obtained from the Bureau of Indian Standards.

ANNEX A

(*Foreword* and *Clause* 1)

RECOMMENDATIONS FOR USE

A-1 GENERAL

Turbine meters should operate 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 over speed 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 may seriously damage turbine meters. Strainers are recommended when the presence of damaging foreign material in the gas stream is anticipated. Strainers shall be sized so that a 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 may 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 OVER RANGE PROTECTION

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

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 may 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 over speeding. The restriction shall be installed in the piping downstream of the meter and should be sized to limit the meter loading to

approximately 20 percent above its q_{Max}. Generally, a critical flow orifice will result in a 50 percent pressure loss and a sonic Venturi nozzle will result in a 5 to 20 percent pressure loss.

A-5 BYPASS

If interruption of the gas supply cannot be tolerated, a bypass should be installed so that the meter may 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 require more frequent attention than those used with clean gas, and inspection periods should reflect this aspect.

A-7 STRAIGHTENING VANES

The turbine meter is velocity measuring device. The piping configuration immediately upstream of the meter shall be such that the flow profile entering the meter has a uniform distribution and is without jetting or swirl. Since the turbine meter construction is designed to direct the flow to the annular passage upstream of the rotor, it effectively tends to average the velocity profile of most normal flow conditions. Thus minimizing the influence of minor flow distortions on meter performance.

Straightening vanes are recommended; however, regardless of location they will not eliminate the effect of strong jetting. Integral straightening vanes installed in the entrance to a meter and a part of the meter design will eliminate minor swirl conditions. Straightening vanes located in the upstream meter piping in accordance with piping configurations will eliminate most normal flow swirl conditions.

The installation of a throttling device such as a regulator or partially closed valve is not recommended in close proximity to the meter. Where such installations are necessary, the throttling device shall be placed an additional eight nominal pipe diameters upstream or an additional two nominal pipe diameters, downstream in the in-line recommended installation in Fig. 2. In installation configurations illustrated in Fig. 3, 4 and 5; the throttling device shall be placed eight additional nominal pipe diameters ahead of the inlet vertical riser or an additional two nominal pipe diameters downstream of the outlet vertical riser. Placement of such a device in closer proximity to the meter may result in accuracy degradation and/or reduced bearing life.

The particle size shall be not more than 5 microns for turbine meters.

The purpose of a straightening vane is to eliminate swirls and cross currents set up by the pipe fittings, valves, or regulators proceeding the meter inlet piping. While the specifications which follow apply particularly to the type of vanes shown in Fig. 6, venues of other designs can be used if they meet these specifications.

In construction of vanes the maximum transverse dimension, 'a' of any passage through the vanes should not exceed one-fourth the inside diameter, 'D' of the pipe. Also, the cross-sectional area, 'A', of any passage within the assembled vanes should not exceed one-sixteenth of the cross-sectional area of the containing pipe. The length, 'L', of the vanes shall be at least 10 times the maximum inside dimension, 'a'.

The vanes may be built of standard weight pipe or thin-walled tubing, either welded together and securely attached into the meter inlet piping, or mounted into two end-rings small enough to slip into the pipe. The amount of passage blockage caused by the end-rings shall be kept as small as practical. All tubes shall be reamed as thin as practical at both ends.

Square, hexagonal, or other shaped tubing may be used in making the vanes. It is not necessary that all the vane passages be of the same size, but their arrangement shall be symmetrical.

A-7.1 Installation Configurations (Minimum Lengths)

A-7.1.1 *Recommended Installation for In-line Meters*

The recommended installation requires a length of 10 nominal pipe diameters upstream with the straightening vane outlet located at five nominal pipe diameters from meter melt as shown in Fig. 2. A length of five nominal pipe diameters is recommended downstream of the meter. Both inlet and outlet pipe should be of the same nominal size as the meter.

A-7.1.2 *Optional Installations for In-line Meters*

The use of optional installations may result in some degradation in meter accuracy.

A-7.2 Optional Short-Coupled Installation

In those instances where the required space for the recommended installation of Fig. 2 is not available, a short-coupled installation may be employed as shown in Fig. 3. This configuration utilizes a minimum of four nominal pipe diameters upstream with straightening vanes located at the inlet of the piping. The distance between the straightening vane outlet and the meter inlet should be a minimum of two nominal pipe diameters. The meter is connected to the vertical risers using a
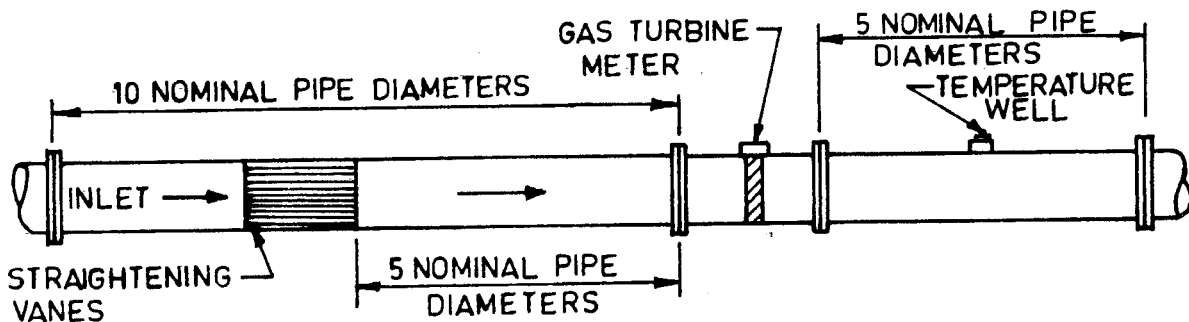
FIG. 2 RECOMMENDED INSTALLATION OF AN IN-LINE GAS TURBINE METER (MINIMUM LENGTHS)
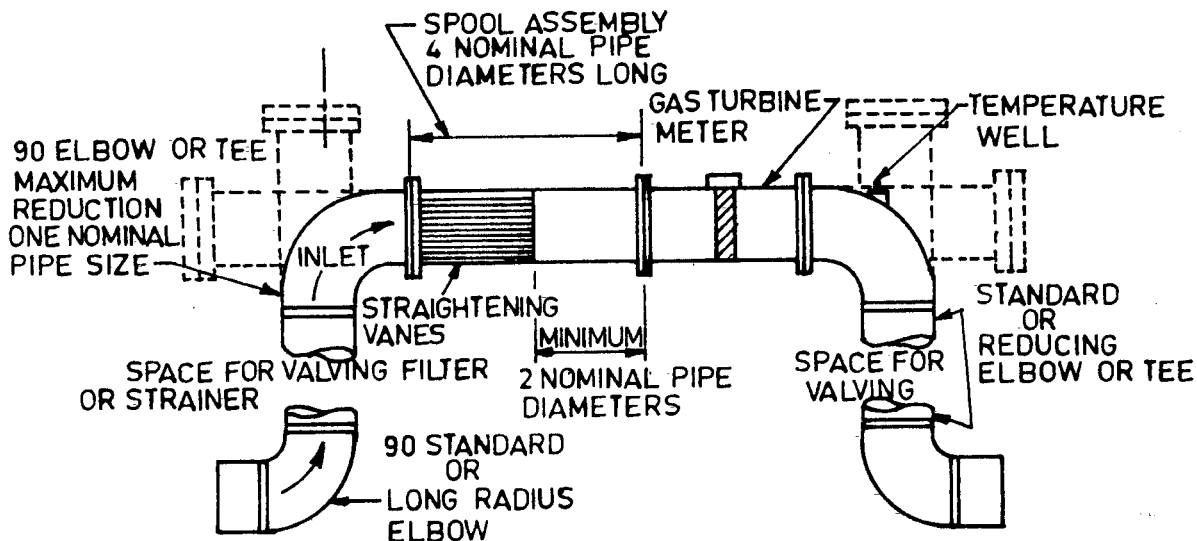
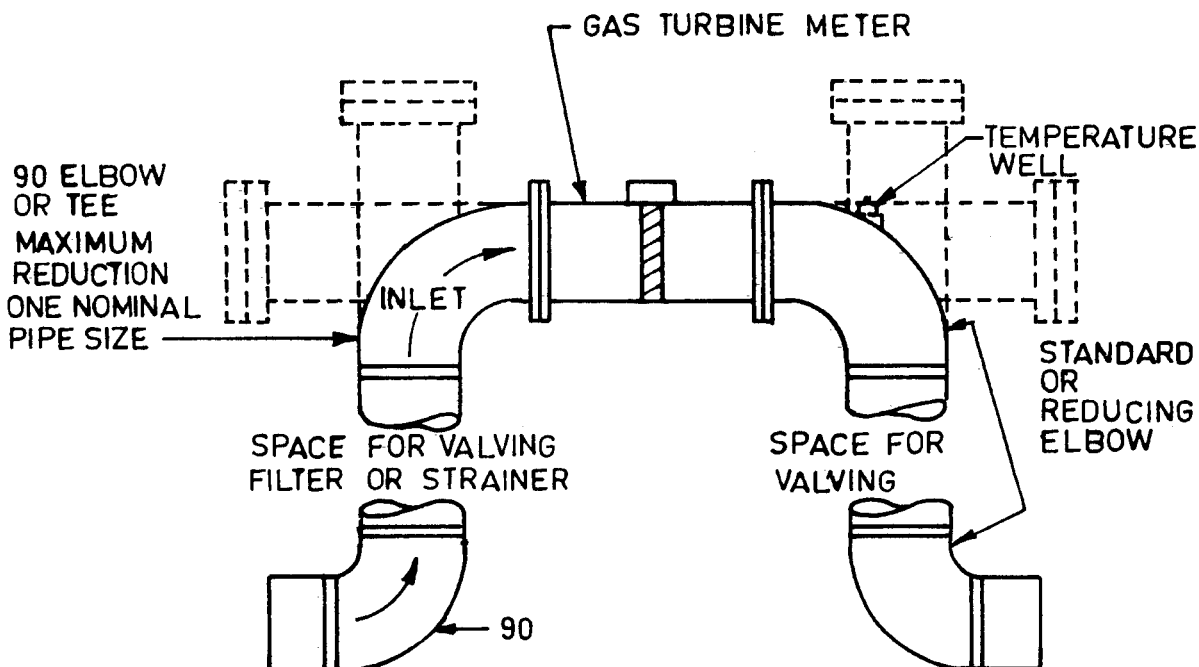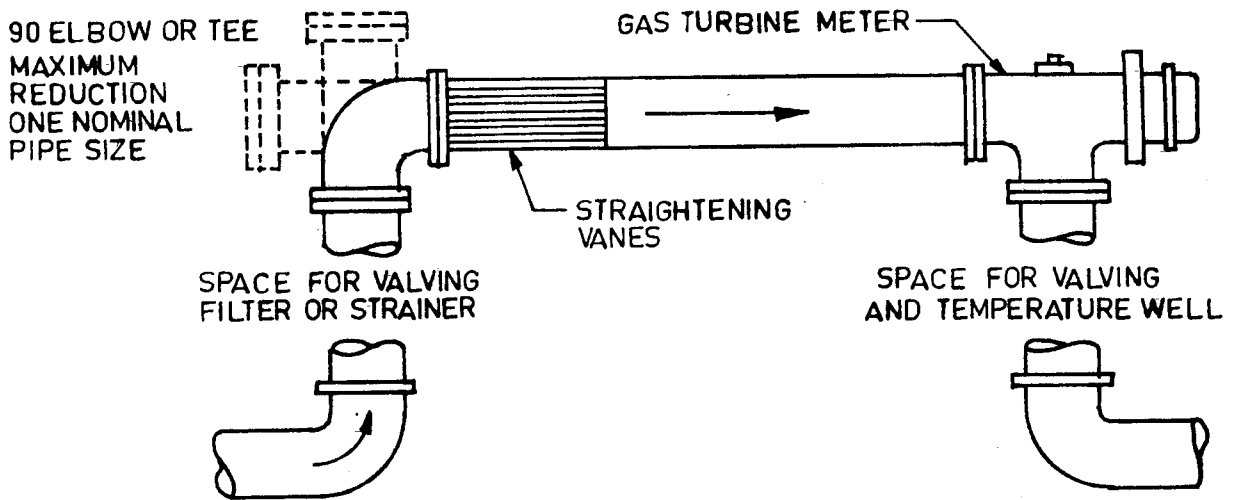FIG. 3 SHORT-COUPLED INSTALLATION OF AN IN-LINE GAS TURBINE METER (MINIMUM LENGTHS)

FIG. 4 CLOSE-COUPLED INSTALLATION OF AN IN-LINE GAS TURBINE METER
WITH INTEGRAL STRAIGHTENING VANES

INLET PIPING 10 NOMINAL PIPE DIAMETERS LONG
(5 NOMINAL PIPE DIAMETERS WITH STRAIGHTENING VANES)

90 ELBOW OR TEE
MAXIMUM
REDUCTION
ONE NOMINAL
PIPE SIZE

GAS TURBINE METER

STRAIGHTENING
VANES

SPACE FOR VALVING
FILTER OR STRAINER

SPACE FOR VALVING
AND TEMPERATURE WELL

HORIZONTAL INSTALLATION (INLET IN HORIZONTAL PLANE OUTLET DOWN)

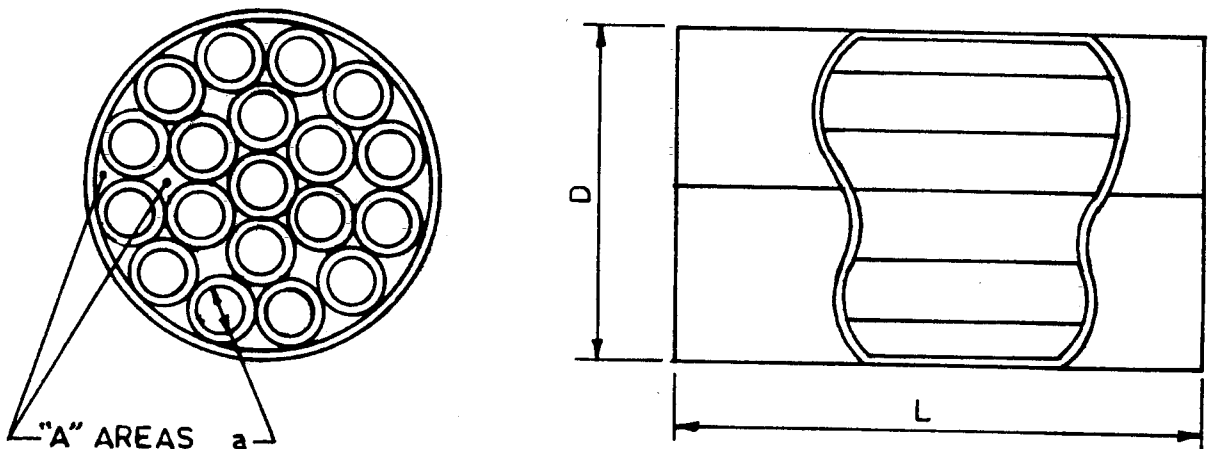FIG. 5 RECOMMENDED INSTALLATION OF AN ANGLE BODY GAS TURBINE METER

"A" AREAS a

FIG. 6 STRAIGHTENING VANES

standard tee or elbow. The maximum pipe reduction to the risers is one nominal pipe size. Valving, filters, or strainers may be installed on the risers.

A-7.3 Optional Close-Coupled Installation

Close-coupled installation of a gas turbine meter is shown in Fig. 4. The meter design must incorporate integral straightening vanes upstream of the rotor. The installation should be used where the available space for a meter installation is critical and design considerations have eliminated jetting and abnormal swirl conditions. The meter is connected to the vertical risers using a standard tee or elbow. The maximum pipe reduction to the risers is one nominal pipe size. Valving, filters, or strainers may be installed on the risers.

A-7.4 Recommended Installation for Angle Body Meters

The recommended installation for an angle body meter is shown in Fig. 5. It is recommended that the meter inlet piping be connected to the riser using a 90° elbow or tee. Valving, filter or a strainer may be installed on the riser. When straightening vanes are not used the upstream.

A-7.5 Meter Inlet Pipe

Meter inlet piping length should be 10 nominal pipe diameters. When straightening vanes are used, the length of upstream pipe may be reduced to five nominal pipe diameters. The straightening vane inlet shall be

five nominal pipe diameters from the meter inlet. There are no restrictions on the downstream piping except that the companion. Flange attached to the meter outlet must be full-size. A vertical installation may be used and the same basic piping configuration applied as used in the horizontal installation.

A-7.6 Other Installation Considerations

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

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

b) Use care to ensure a concentric alignment of the pipe connections with the meter inlet and outlet connections;

c) Prevent gasket and/or weld bead protrusion into the bore, which could disturb the flow pattern;

d) If liquid could be encountered, installations shall be sloped to provide continual draining of the meter, or the meter shall be installed in the vertical position. In cases where a considerable quantity of liquid is expected, it is recommended that a separator be installed upstream of the meter. Flow distortion by the separator shall be taken into consideration in the piping recommendation; and

e) Turbine meters should not be used where frequently interrupted and/or strongly fluctuating flow or pressure pulsations at present.

A-8 INSTALLATION OF ACCESSORIES

Accessory devices used for converting the indicated volume to baseline conditions or for recording operating parameters shall be installed properly and the connections made as follows.

A-8.1 Temperature Measurement

Since upstream disturbances shall be kept to a minimum, the recommended location for a thermometer well is downstream of the turbine wheel. It shall be located as closely as possible downstream of the turbine wheel, but within 5 pipe diameters from the turbine wheel and upstream of any outlet valve or flow restrictions. The thermometer well shall be installed such that the temperature measured is the real temperature corresponding to flowrates between q_{Min} and q_{Max} and is not influenced by heat transfer from the piping or well attachment.

A-8.2 Pressure Measurement

The pressure tapping marked 'p_m' on the meter body shall be used as the pressure sensing point for recording or integrating instruments.

A-8.3 Density Measurement

The conditions of the gas in the density meter should represent the conditions in the turbine wheel over the operating flow rates of the meter. Consideration shall be given to the possible presence of unmetered gas when using purged density meter. Density meters installed in the piping should preferably be installed downstream of the turbine wheel.

A-8.4 Gas Sampler

The location of samplers for gas analysis shall in the downstream of the meter and in close proximity to the meter.

ANNEX B

(*Foreword* and *Clauses* 1 *and* 9.5)

OTHER METER PERFORMANCE CHARACTERISTICS

B-1 GAS CONDITIONS

Generally, it is desirable to know the quantity of gas in terms of mass or in terms of volume at certain conditions. In all cases this quantity is derived from the measurement of volume at metering conditions, taking into account the meter reading and measurement of the metering conditions.

B-1.1 Metering Conditions

See 3.1.7. Symbols related to these conditions have the subscript '*m*'.

B-1.2 Specified Conditions

See 3.1.9. Symbols related to these conditions have the subscript '*s*'.

B-1.3 Base Conditions

See **3.1.8**. Symbols related to these conditions have the subscript '*b*'.

B-2 PRESSURE LOSS

The pressure loss over a turbine meter is determined by the energy required for driving the meter mechanism, the losses due to friction of internal passage, and changes in flow velocity and direction. The pressure loss is measured between a point one pipe diameter upstream and a point one pipe diameter downstream of the meter on piping of the same size as that of the meter. Care shall be taken in selecting and manufacturing the pressure points to ensure that flow pattern distortions do not affect the pressure readings.

The pressure loss basically follows the turbulent flow loss relationship (except at very low flow rates):

$$\Delta p_m = c\rho_m q^2_m$$

From the pressure loss at specified conditions and from the equation of state of an ideal gas, it follows that:

$$\Delta p_m = \Delta p_s \left(\frac{\rho_m}{\rho_s}\right)\left(\frac{q_m}{q_s}\right)^2$$

and

$$\Delta p_m = \Delta p_s \left(\frac{d_m}{d_s}\right)\left(\frac{p_m}{p_s}\right)\left(\frac{T_s}{T_m}\right)\left(\frac{Z_s}{Z_m}\right)\left(\frac{q_m}{q_s}\right)^2$$

B-3 MAXIMUM AND MINIMUM FLOWRATES

Gas turbine meters are generally designed for a maximum flowrate, q_{Max} in order not to exceed a certain turbine wheel speed and a certain pressure loss. This maximum flowrate of the meter remains the same, unless stated otherwise, for all metering conditions up to the stated maximum allowable operating pressure.

From the minimum flowrate, pressure, temperature and fluid composition as specified by the manufacturer, the minimum flowrate can be written as:

$$q_{m,Min} = q_{s,Min}\sqrt{\frac{\rho_s}{\rho_m}}$$

B-4 WORKING RANGE

Since the maximum flowrate generally does not change and the minimum flowrate can change (*see* **C-3**), the working range ψ, of a gas turbine meter changes essentially with the square root of the gas density:

$$\psi_m = \psi_s\sqrt{\frac{\rho_m}{\rho_s}}$$

B-5 EFFECTS OF TEMPERATURE AND PRESSURE

Changes in meter performance can occur when the operating temperature and pressure are very different from the calibration conditions (*see* **9.2.2**). These changes may be due to changes in dimensions, bearing friction or to physical phenomena.

ANNEX C

(*Foreword* and *Clauses* 1 *and* 9)

DATA COMPUTATION AND PRESENTATION

C-1 EQUATIONS FOR VOLUME CALCULATION

Since the turbine meter measures volumes at metering conditions, the equation of state of ideal gases may be applied to convert the indicated volume to a volume at baseline conditions, when these conditions are constant.

The following equations convert the gas volume indicated by the gas turbine meter at metering conditions into gas volume at baseline conditions (baseline pressure and baseline temperature):

for metering conditions

$$p_m V_m = Z_m NRT_m$$

and for baseline conditions

$$p_b V_b = Z_b NRT_b$$

Since R is a constant for the gas regardless of pressure and temperature, for a number of moles N of gas, the two equations can be combined to yield:

$$V_b = V_m \left(\frac{p_m}{p_b} \right) \left(\frac{T_b}{T_m} \right) \left(\frac{Z_b}{Z_m} \right)$$

Above Equation can be used for the specific conditions at the meter.

For non-constant metering conditions:

$$V_b = \int q_m \left(\frac{p_m}{p_b} \right) \left(\frac{T_b}{T_m} \right) \left(\frac{Z_b}{Z_m} \right) dt$$

C-2 EQUATION FOR CALCULATION OF MASS

$$m = V_b \rho_b = V_m \rho_m$$

Gas at varying densities

$$m = \int q_m \rho_m \, dt$$

$$\frac{p_m}{\rho_m} = Z_m (R / M) T_m$$

The densities ρ_m and ρ_b may be determined by measurement or by computation from the composition and conditions of the gas.

C-3 PRESENTATION OF CALIBRATION DATA

The meter calibration data shall be plotted as a function of the actual flowrate, baseline flowrate or pipe Reynolds number. The actual or baseline flow conditions for pressure and temperature as well as the test fluid shall be stated in the calibration data.

ANNEX D

(Foreword and *Clause* 1)

FIELD CHECKS

D-1 GENERAL

The most commonly applied field checks for turbine meters are visual inspection and the spin time test. Information can often be gained from meters in operation by observing the noise or vibrations generated.

Severe vibration of the meter usually indicates damage which has unbalanced the turbine wheel; this may lead to complete meter failure. Turbine wheel rubbing and poor bearings can often be heard at relatively low flowrates at which such noises are not masked by normal flow noise.

D-2 VISUAL INSPECTION

During visual inspection, the turbine wheel shall be inspected for missing blades, lubrication mechanism (if provided), accumulation of solids, erosion or other damage that would affect the turbine wheel balance and the blade configuration. Meter internals should also be checked to ensure there is no accumulation of debris.

D-3 SPIN TIME TEST

The spin time test determines the relative level of the mechanical friction present in the meter in relation to a previous test. If the mechanical friction has not significantly changed, if the meter area is clean, and if the internal portions of the meter show no damage, the meter should display no change in accuracy. A significant increase in the mechanical friction indicates that the accuracy characteristic of the meter at low flowrates has degraded. Typical spin times for meters can be provided by the manufacturer on request.

The spin time test must be conducted in a draught free area with the measuring mechanism in its normal operating position. The turbine wheel is rotated at a reasonable speed, that is, a minimum speed of approximately 1/20 of the rated speed corresponding to q_{Max} and is timed from the initial motion until the turbine wheel stops.

Spin tests shall be repeated at least three times and the average time taken. The usual cause for a decrease in spin time is increased turbine wheel shaft bearing friction. It shall be noted, however, that there are other causes of mechanical friction which affect spin time, such as heavily lubricated bearings, low ambient temperature, draughts and attached accessories.

NOTE — Other methods of conducting a spin time test are possible, as long as the method is specified.

ANNEX E

(*Foreword* and *Clauses* 1, 9.6 *and* A-3.1)

PERTURBATIONS

E-1 GENERAL

This Annex provides guidance for flow disturbances that may affect meter performance and standardized tests to assess the effects of such disturbances.

E-2 SWIRL EFFECT

If the fluid at the meter inlet has significant swirl, the turbine wheel speed may be influenced. A swirl at the turbine wheel in the direction of rotation increases the turbine wheel speed, whereas a swirl in the opposite direction decreases the turbine wheel speed. For high accuracy flow measurement, such a swirl effect shall be reduced to an insignificant level by proper installation of the meter.

E-3 VELOCITY PROFILE EFFECT

The gas turbine meter is designed for and calibrated under conditions which approach a uniform velocity profile at the meter inlet. In case of significant deviation from this profile, the turbine wheel speed at a given flowrate can be affected by the actual velocity profile at the turbine wheel. For a given average flowrate, a non-uniform velocity profile generally results in a higher turbine wheel speed than a uniform velocity profile. For high-accuracy flow measurement, the velocity profile at the turbine wheel shall be ensured to be essentially uniform by proper installation of the meter.

E-4 PERTURBATION TESTING

E-4.1 Tests

Tests to determine the sensitivity of meter to installation conditions should be carried out a close to atmospheric conditions with air flowrate of 0.25 q_{Max}.

The installations that satisfy the specifications in **9.6** shall be described for each meter.

E-4.2 Low Level Perturbations

The piping configurations shown in Fig. 7(a) and (b) consisting of a pipe with nominal size DN_1 and length of $5D_1$, two elbows of diameter equal to D_1 in two perpendicular planes, and a concentric expander from DN_1 to DN and a length between D and $1.5 D$ can be considered to be representative of low level perturbations produced by piping elements such as bends, tees, convergent and divergent sections.

The values of DN_1 are listed in Table 4.

Nominal sizes of pipe components are defined in ISO 6708.

Table 4 Relationship of DN_1 to DN

Sl No.	Meter DN	Pipe DN_1
(1)	(2)	(3)
i)	50	40
ii)	80	50
iii)	100	80
iv)	150	100
v)	200	150
vi)	250	200
vii)	300	250
viii)	400	300
ix)	500	400
x)	600	500
xi)	750	600
xii)	1 000	750

E-4.2.1 If the elements shown in Fig. 7(a) and (b), installed $2D$ upstream of the meter inlet [*see* Fig. 7(c)] cause an error shift at atmospheric conditions not exceeding the difference mentioned in **9.6**, no flow conditioner or additional length of upstream pipe is required in service if only low level perturbations occur at a distance of $2D$ or more upstream of the meter inlet.

E-4.2.2 If the error difference is greater than the value given in **9.6**, tests should be carried out with a longer upstream straight pipe and/or flow conditioner, preferably of the; types mentioned in ISO 5167-1, to determine the inlet section configuration necessary to keep the error differences within the limits given in **9.6**. The flow conditioner should be installed in pipe of diameter D with the end of the flow conditioner at least $2D$ from the meter inlet.

E-4.3 High Level Perturbations

E-4.3.1 To determine the sensitivity of a meter to high level perturbations caused by regulators or other; throttling devices, tests should be carried out with the piping configurations shown in Fig. 7 but with a half-pipe area plate as shown in Fig. 8 installed between the two elbows, with the opening towards the outside radius of the first bend.

E-4.3.2 If the error difference is greater than that stated in **9.6**, the procedure described in **E-4.2.2** should be carried out to determine the upstream configuration that satisfies the requirements of **9.6**.

E-4.3.3 These tests are not representative of all situations

where a regulator produces a strong eccentric outlet jet. Great care is needed when turbine meters are used downstream of regulator produces a strong eccentric outlet jet. Great care is needed when turbine meters are used downstream of regulators operating with large pressure reductions. Also, for piping systems having an unknown potential influence on meter performance, it is recommended that a flow conditioner as shown in Fig. 9 be installed at a minimum of $4D$ from the conditioner outlet to the meter inlet connection.

NOTE — A flow conditioner of this type causes a relatively large pressure loss. Ion those cases where such a pressure loss can be handled, installation of such a flow conditioner is advised downstream of a regulator.

In those cases where the pressure drop across the flow conditioner in Fig. 9 cannot be tolerated, installation of a flow conditioner as shown in Fig. 10 may also be used.

NOTE — Free area: 20 percent of pipe area. For this area ratio, the pressure loss at q_{Max} is approximately 0.07 times the static pressure for a nominal pipe diameter DN according to 7.4 and for a relative gas density of 0.64.

The whole pattern shall be such that the holes on adjacent plates do not provide a straight path for the flowing fluid.

The perforated plates are attached to a sleeve such that all fluid passes through the plates.
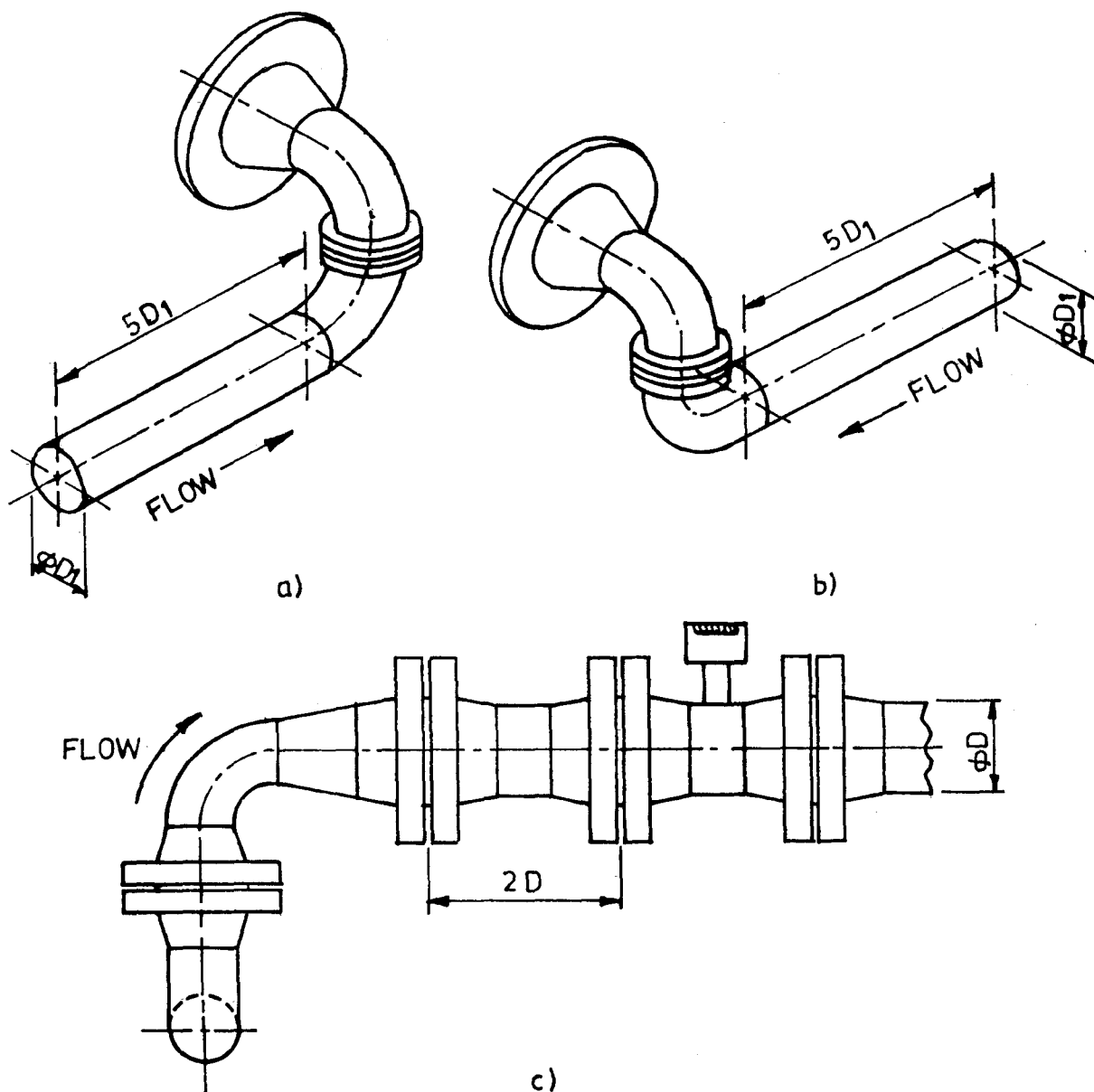
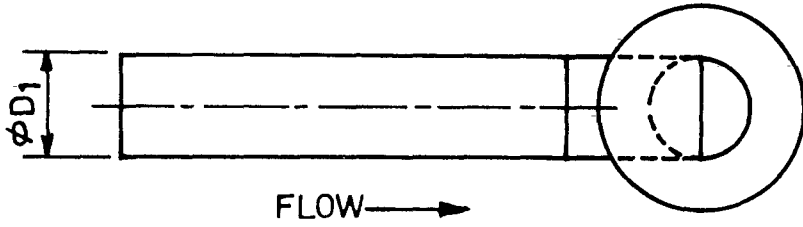FIG. 7 PIPING CONFIGURATIONS FOR TESTS AT LOW LEVEL PERTURBATION

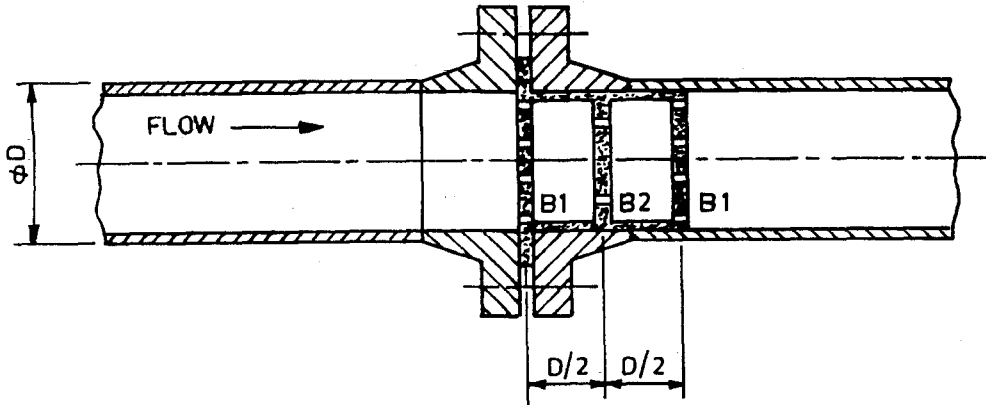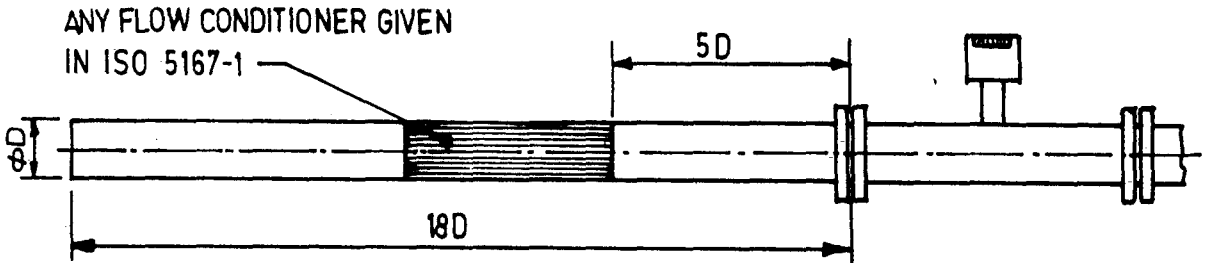FIG. 8 LOCATION OF HALF-AREA OPENING FOR TEST AT HIGH LEVEL PERTURBATION

FIG. 9 FLOW CONDITIONER TO DAMP OUT HIGH LEVEL PERTURBATION

NOTE — The straight lengths specified are minimum values.

FIG. 10 ALTERNATIVE FLOW CONDITIONER CONFIGURATION TO DAMP OUT HIGH LEVEL PERTURBATION

E-5 SIMILARITY

If similarity of design exists in the meter inlet section for various size meters, a minimum of two meter sizes shall be tested. If the results are similar, it can be assumed other meter sizes would produce the same results.

Similarity can be assumed to exist if the values of H/D and S/L for any meter are equal to or less than those for the tested meters (*see* Fig. 11).
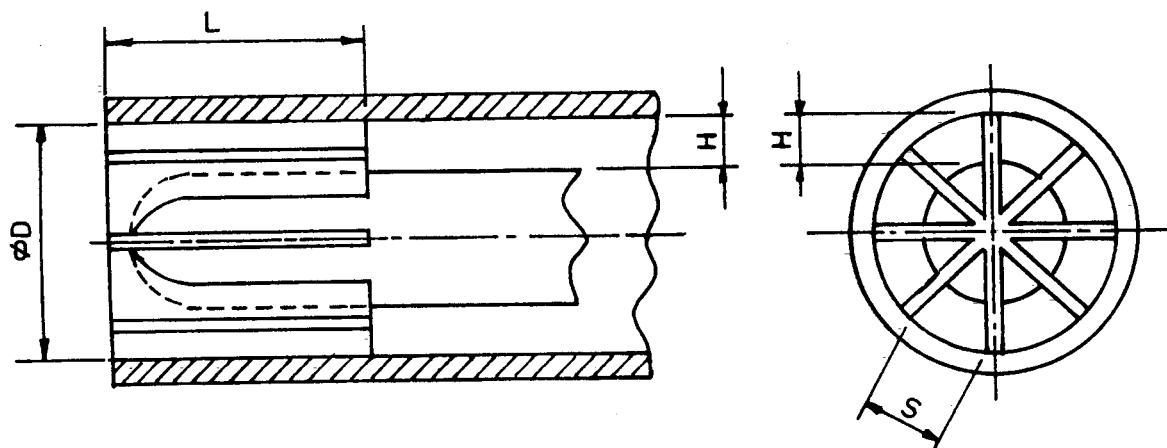
Fig. 11 Meter Dimensions Defining Similarity for Various Size Meters

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AMENDMENT NO. 1 DECEMBER 2007
TO
IS 15676 : 2006 FLOW MEASUREMENT OF
NATURAL GAS BY TURBINE METERS

(*Foreword, third para, line* 3) — Substitute 'American Gas Association' *for* 'American gas authority'.

(PG 26)