

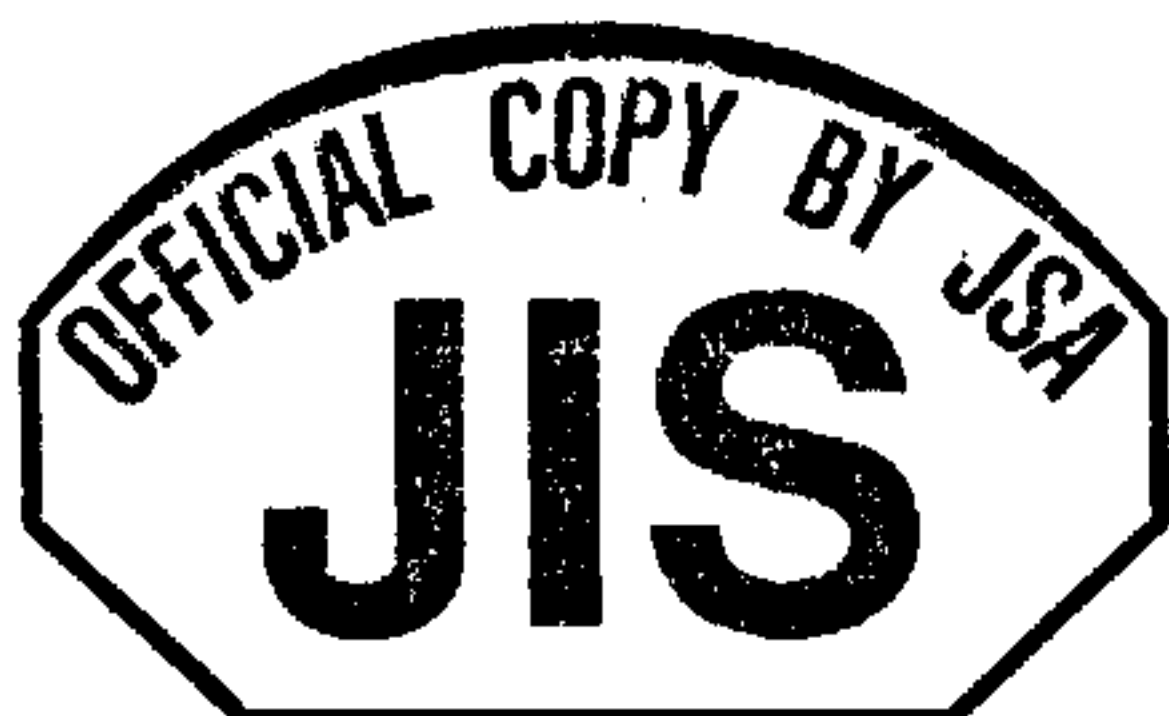
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JAPANESE INDUSTRIAL STANDARD

Measuring Methods of Quantity of Natural Gas

JIS M 8010-1977



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Japanese Industrial Standard

MEASURING METHODS OF
QUANTITY OF NATURAL GAS

JIS M 8010 - 1977

1. General Rules1.1 Extent of Application

This standard prescribes measuring methods of natural gas (1) (hereinafter called "gas").

Note (1): Natural gas prescribed in this standard is inflammable gas produced naturally, having hydrocarbons as major constituents.

Remarks: Units and numerical values with { } in this standard are according to the International System of Units (SI), and are included additionally as reference.

1.2 Meaning of Terms

Meaning of principal terms used in this standard are as follows:

- (1) Orifice Type Flowmeter A meter for measuring flow rate of gas, which is installed in the pipe line and reduces cross-sectional area of the pipe line, thereby measuring differential pressure generated fore and aft of the meter.
- (2) Volumetric Flowmeter A meter for measuring volume of gas passing through, by filling bags of a fixed volume or spaces of rotor displacement with gas and sending the gas to outlet with the motion of rotor or bag, thereby relaying the number of bags or spaces displaced by rotor to the indicating mechanism.
- (3) Orifice to Pipe Diameter Ratio Ratio (d/D) of orifice diameter (d) to inner diameter of the pipe line (D).
- (4) Orifice to Pipe Area Ratio Ratio (m/M) of sectional area of the orifice (m) to sectional area of the pipe line (M).
- (5) Differential Pressure Difference in pressure between upstream and downstream of the orifice.
- (6) Differential Pressure Gauge Meter which indicates, directly for indirectly, the differential pressure transferred through connecting pipe.

- (7) Normal Condition At temperature of 0°C (273.15K), absolute pressure of 760 mmHg (1.0332 kgf/cm²) {101.325 kPa}, and in dry condition.
- (8) Standard Condition At temperature of 15.6°C, absolute pressure of 760 mmHg (1.0332 kgf/cm²) {101.325 kPa}, and in steam-saturated condition.
- (9) Specific Gravity of Gas Ratio of specific gravity of gas at normal condition to specific gravity of air at normal condition.

1.3 Method of Expression

Volumetric flow rate and passing volume are expressed as follows.

- (1) Volumetric flow rate of gas in normal condition is expressed in m³/h or m³/d, and to clearly indicate this, a unit symbol of Nm³/h or Nm³/d is used.
- (2) Volumetric flow rate of gas in standard condition is expressed in m³/h or m³/d, and to clearly indicate this, a unit symbol of Sm³/d is used.
- (3) Passing volume of gas in normal condition is expressed in m³, and a unit symbol of Nm³ is used to clearly indicate this.
- (4) Passing volume of gas in standard condition is expressed in m³, and a unit symbol of Sm³ is used to clearly indicate this.

1.4 Category of Measuring Methods

Flow rate of gas is measured by the following method.

- (1) Method by Means of Orifice Type Flowmeter
Reference 1 This method can conveniently measure flow rate of gas at comparatively wide range of temperature and pressure.
- (2) Method by Means of Volumetric Flowmeter
Reference 2 This method can measure passing volume of gas, regardless of specific gravity of gas, with little pressure loss.

1.5 General Items Necessary for Measuring

- (1) The gas to be measured should be sufficiently free of impurities/admixtures such as dust or condensate, by having them removed in advance using appropriate equipment.
- (2) The gas to be measured should be of a single phase.
- (3) For the case of orifice type flowmeter, the gas flow should be of steady flow.

- (4) The pipe preceding and following an orifice type flowmeter should be of circular section.
- (5) Ratio of absolute pressure in downstream to absolute pressure in upstream, of the orifice respectively, should be more than 0.75.
- (6) The pipe line for a length of 2D upstream from the upstream face of orifice should be of circular section, and it is desirable that each diameter measured is within $\pm 0.3\%$ of the average value.
- (7) Average value of the diameter in pipe line for a length of 2D downstream from the upstream face of orifice should be within $\pm 2\%$ of average value of the diameter in the upstream.

2. Method by Means of Orifice Type Flowmeter

Flow rate of gas is measured by use of an orifice meter.

2.1 Construction of Orifice Meter

An orifice meter measures flow rate of gas by inserting an orifice plate having an orifice placed concentrically in the pipe line. Throttling of the gas flow by the orifice generates differential pressure which permits measurement of gas flow rate. It consists of orifice plate, leading pipe line, pressure gauge, differential pressure gauge and thermometer.

For drawing differential pressure generated fore and aft of the orifice plate, flange taps, corner taps and vena contracta taps are used.

2.2 Conditions for Use of Orifice Meter

Orifice meters are used under conditions shown in Table I.

Table I Inner Diameter of Pipe Line and
Orifice to Pipe Diameter Ratio

<u>Method of Drawing Differential Pressure</u>	<u>Inner Diameter of Pipe Line (D) mm</u>	<u>Orifice to Diameter Ratio (β)</u>
Flange Tap	50 - 760	0.1 - 0.75
Corner Tap	50 - 1,000	0.22 - 0.8 ⁽²⁾
Vena Contracta Tap	50 - 760	0.1 - 0.8

Note (2): In case of the corner tap, $\beta^4 = 0.0025 - 0.41$

2.3 Construction of Orifice Plate

- (1) Dimensions are shown in Fig. 1. Portions constituting part of the pipe line shall meet the conditions shown in (2)-(12) below.
- (2) The upstream surface shall be flat. The upstream surface of the orifice plate shall be finished adequately smooth.
- (3) Roughness of the upstream surface, particularly within at least a diameter of $1.5d$ from center of the orifice plate, shall be below $0.0003d$.
- (4) The downstream surface shall be parallel to the upstream surface.
- (5) The orifice shall be of cylindrical shape, and allowance of the diameter d shall be $\pm 0.001d$.
- (6) Value of the orifice diameter shall be taken as an average of more than 4 measurements taken at approximately equal angular intervals.
- (7) Edge thickness (e) shall be $0.005D \leq e \leq 0.02D$. However, when $\beta < 0.2$, it shall be $0.005D \leq e \leq 0.1d$. This value shall not deviate more than $0.001D$ when measured at any point.
- (8) Orifice plate thickness (H) shall be $e \leq H \leq 0.05D$. This value shall not deviate more than $0.005D$ when measured at any point.
- (9) When the orifice plate thickness exceeds the edge thickness, the angle of relief (F) shall be provided. When $H \leq 0.02D$, it is not necessary to provide the angle of relief.
- (10) The angle of relief shall be $30^\circ \leq F \leq 45^\circ$.
- (11) The upstream edge of the measuring orifice shall be square and sharp so that it will not reflect a beam of light when viewed.
- (12) The orifice plate, which may be used in a flow of reverse direction, shall meet the following terms.
 - (a) Angle of relief shall not be provided.
 - (b) The downstream surface shall be made as the upstream surface.
 - (c) The orifice plate thickness shall be equal to the edge thickness.
 - (d) The edge on downstream shall be made as the edge on upstream.

2.4 Position of Drawing Differential Pressure

- (1) Flange Tap As shown in Fig. 2 (a), the pressure drawing outlets shall be provided at 25.4 ± 0.8 mm respectively of upstream and downstream surface of the orifice plate.
- (2) Corner Tap As shown in Figs. 2 (b) and 2 (c), the pressure drawing outlets shall be provided immediately fore and aft of the orifice plate.

- (3) Vena Contracta Tap As shown in Fig. 2 (d), center of the upstream pressure drawing outlet shall be $1 \pm 0.1D$ from the upstream surface of the orifice plate, and center of the downstream pressure drawing outlet at positions shown in Table II from the orifice plate.

Table II Position of Drawing Downstream
Pressure for Vena Contracta Tap

<u>Orifice to Pipe Diameter Ratio (β)</u>	<u>Position of Drawing Downstream Pressure</u>
0.10	$0.84 D \pm 30 \%$
0.15	$0.82 D \pm 30 \%$
0.20	$0.80 D \pm 30 \%$
0.25	$0.78 D \pm 30 \%$
0.30	$0.76 D \pm 30 \%$
0.35	$0.73 D \pm 25 \%$
0.40	$0.70 D \pm 25 \%$
0.45	$0.67 D \pm 25 \%$
0.50	$0.63 D \pm 20 \%$
0.55	$0.59 D \pm 20 \%$
0.60	$0.55 D \pm 15 \%$
0.65	$0.50 D \pm 15 \%$
0.70	$0.45 D \pm 10 \%$
0.75	$0.40 D \pm 10 \%$
0.80	$0.34 D \pm 10 \%$

2.5 Installation

- 2.5.1 Orifice Plate To be installed in the straight portion of the pipe line. As shown in Fig. 2, the orifice plate shall be installed concentrically in the pipe line, so that its central axis and the central axis of the pipe line shall coincide with each other within $0.015D (1/\beta - 1)$ and that the angle between its upstream surface and the central axis of the pipe line shall be a right angle within $\pm 1^\circ$.

2.5.2 Outlets for Drawing Differential Pressure

(1) Flange Tap and Vena Contracta Tap

- (a) In the case of flange tap and vena contracta tap, the opening of outlets shall be circular and be in the same face as the inner wall of the pipe line. There shall be no burrs on its fringe, and the fringe may have a roundness of within $1/10$ of the hole diameter.

- (b) The hole diameter shall be below 0.08D. It is, however, desirable that it is 6 - 13 mm.
- (c) The drawing outlets shall be of cylindrical shape for the length of at least twice the hole diameter from inner wall of the pipe.
- (d) Central axis of the drawing outlets shall intersect with the central axis of the pipe at a right angle.

(2) Corner Tap

- (a) There are two categories in the method of drawing pressure; single hole as shown in Fig. 2 (b) and the annular type as shown in Fig. 2 (c).
- (b) Hole diameter (a) of a single hole and slit with (a) of the annular ring have the following values.

For $\beta \leq 0.65$: $a \leq 0.03D$

For $\beta > 0.65$: $0.01D \leq a \leq 0.02D$

Regardless the value of β , the following must also be satisfied.

$$1 \text{ mm} \leq a \leq 10 \text{ mm}$$

- (c) The annular space shall be connected to the inside of pipe through a ring-shaped slit provided on the entire periphery. However, it can also be connected with at least four slits of more than 12 mm² in area, spaced at equal interval.
- (d) Axis of the single hole shall intersect with the central axis of the pipe at an angle as close to 90° as possible.
- (e) When more than two single holes are provided in the same plane of either upstream or downstream, the central axis of those single holes are to be arranged at an equal angle.
- (f) Slit thickness (f) shall be such that $f \geq 2a$.
- (g) The drawing outlets connecting annular space to leading pipe pressure shall be of cylindrical shape, and their diameter (j) shall be such that $4 \text{ mm} \leq j \leq 10 \text{ mm}$.
- (h) Center of pressure drawing outlets both upstream and downstream shall be located at a distance equal to 1/2 of single hole diameter (a) or 1/2 of slit width (a) from upstream surface and downstream surface of the orifice plate.

2.5.3 Pressure Leading Pipe The pipe for leading pressure shall be so piped as to eliminate any hindrance to transmission of pressure due to presence of condensate.

- Remarks:
1. It is recommended to eliminate horizontal piping and to provide some slope in the piping, and there should be a drain plug at the lowest point of pressure leading pipe. It is desirable that slope of the leading pipe be more than 1/10.
 2. It is desirable that the pressure leading pipe shall be so piped as not to be affected by the surrounding temperature, etc.

- 2.5.4 Differential Pressure Gauge It shall be installed so as to show the differential pressure accurately without any leakage.
- 2.5.5 Straight Pipe Portion There shall be adequate length of straight pipe line preceding and following the orifice plate. The minimum lengths of straight pipe required depending on the conditions of the pipe line are shown in Figs. 3 (a) - (e).
- 2.5.6 Straightening Vanes When it is necessary to eliminate swirls and cross currents set up by pipe fittings, valves, etc. installed in the straight pipe portion preceding the orifice plate, straightening vanes as shown in Fig. 4 shall be installed. Inner diameter of the small pipes (vanes) shall be less than $1/4$ of inner diameter of the outer pipe (containing pipe), and their length shall be more than 10 times the inner diameter of the small pipes (vanes). Openings between small pipes shall be less than $1/16$ of the cross-sectional area of the containing pipe. Both ends of the small pipes (vanes) shall be tapered.
- 2.6 Measurement
- 2.6.1 Measurement of Differential Pressure Differential pressure shall be measured with a differential pressure gauge which has been calibrated in advance.
- 2.6.2 Measurement of Pressure Pressure of gas in flowing condition shall be measured by providing a branched pipe on the pressure leading pipe on either upstream or downstream of the orifice plate.
- 2.6.3 Measurement of Temperature Temperature is measured by inserting a thermometer into the pipe line. The place for inserting thermometer shall be more than a distance of B downstream of the orifice plate as shown in Figs. 3 (a)-(e). When straightening vanes are used, the place for inserting thermometer can be more than 1D upstream of the straightening vanes.
- 2.6.4 Determination of Gas Properties
- (1) Specific Gravity Specific gravity of gas (including humidity) shall be calculated by using analytical values of gas components as well as humidity values, or shall be actually measured with specific gravity meter.
 - (2) Viscosity To be actually measured, or the viscosity at flowing temperature and normal pressure shall be obtained by Equation (1) using values in Fig. 5 (a).

$$\eta = \frac{\sum_{i=1}^n \eta_i x_i \sqrt{M_i}}{\sum_{i=1}^n x_i \sqrt{M_i}} \dots\dots\dots(1)$$

where η : Viscosity of gas at flowing temperature and normal pressure (cP).

η_i : Viscosity of gas having component i at flowing temperature and normal pressure (cP).

x_i : Molar fraction of gas having component i

M_i : Molecular weight of gas having component i

Viscosity of gas at flowing condition η_f shall be obtained by using η from Equation (1), with correction for pressure from Fig. 5 (b).

By the International System of Units (SI)

$$\eta = \frac{\sum_{i=1}^n \eta_i x_i \sqrt{M_i}}{\sum_{i=1}^n x_i \sqrt{M_i}} \dots\dots\dots(1)'$$

where η : Viscosity of gas at flowing temperature and normal pressure {mPa·s}

η_i : Viscosity of gas having component i at flowing temperature and normal pressure {mPa·s}

(3) Compression Coefficient Compression coefficient (Z) at flowing temperature and flowing pressure shall be obtained from Table 1.

(4) Humidity To be measured with a hygrometer which has been calibrated in advance.

2.7 Equation for Calculating Flow Rate

Flow rate of gas volume shall be obtained by Equation (2).

$$Q = A_Q K_o P Y F_G F_z F_T F_M F_v \sqrt{P_1 h} \dots\dots\dots(2)$$

where Q: Flow rate of gas volume (m³/h)

A_Q : Coefficient depending on condition of expression.

$A_Q = 0.1790$ when flow rate is expressed in normal condition

$A_Q = 0.1926$ when flow rate is expressed in standard condition.

K_o : Flow rate coefficient at limit Reynolds number (3).

d: Orifice diameter (mm).

Y: Expansion correction factor of gas.

F_G : Specific gravity correction factor of gas.

F_Z : Correction factor of gas for deviation from the ideal gas law.
 F_T : Temperature correction factor of gas.
 F_M : Humidity correction factor of gas.
 F_r : Correction factor due to Reynolds number.
 P_f : Absolute pressure of gas in flowing condition (kgf/cm²).
 h : Differential pressure generated by orifice (kgf/m²).

Note (3): Limit Reynolds number is the upper value of the Reynolds number usable for flow rate measurement.

By the SI

$$Q = A_Q K_o d^2 Y F_G F_Z F_T F_M F_r \sqrt{P_f h} \dots\dots\dots (2)'$$

where A_Q : Coefficient depending on condition of expression.

$A_Q = 0.005772$ when flow rate is expressed in normal condition.

$A_Q = 0.006211$ when flow rate is expressed in standard condition.

P_f : Absolute pressure of gas in flowing condition { kPa }

h : Differential pressure generated by orifice { Pa }

(1) Flow Rate Coefficient at Limit Reynolds Number

- (a) Flow rate coefficient of flange tap (K_o) shall be obtained from Table 2, using inner diameter of the pipe line (D) and the orifice to pipe diameter ratio (β).
- (b) Flow rate coefficient of corner tap (K_o) shall be the values for the Reynolds number (ReD) at 10^7 in Table 3.
- (c) Flow rate coefficient for vena contracta tap (K_o) shall be obtained from Table 4, using inner diameter of the pipe line (D) and the orifice to pipe diameter ratio (β).

(2) Expansion Correction Factor of Gas

(a) For Flange Tap

- (i) Y_1 obtained from Equation (3) shall be used as the expansion correction factor of gas (Y), when absolute pressure at the upstream drawing outlet is used for P_f .

$$Y_1 = 1 - (0.41 + 0.35 \beta^4) \frac{\chi_1}{\kappa} \dots\dots\dots (3)$$

$$\text{where } \chi_1 = \frac{h}{1000 P_{f1}}$$

P_{f1} : Absolute pressure of gas at the upstream drawing outlet (kgf/cm²)

κ : Ratio of specific heat at constant pressure to specific heat at constant volume of the gas.
It is recommended to use 1.3 as an approximate value.

By the SI

$$Y_1 = 1 - (0.41 + 0.35\beta^4) \frac{x_1}{k} \dots\dots\dots (3)'$$

$$\text{where } x_1 = \frac{h}{1000 P_{f1}}$$

P_{f1} : Absolute pressure of gas at upstream drawing outlet {kPa}

h : Differential pressure generated by the orifice {Pa}

(11) Y_2 obtained from Equation (4) shall be used as the expansion correction factor of gas (Y), when absolute pressure at the downstream drawing outlet is used for P_f .

$$Y_2 = \sqrt{1+x_2} - (0.41 + 0.35\beta^4) \frac{x_2}{k\sqrt{1+x_2}} \dots\dots\dots (4)$$

$$\text{where } x_2 = \frac{h}{10000 P_{f2}}$$

P_{f2} : Absolute pressure of gas at the downstream drawing outlet (kgf/cm²)

By the SI

$$Y_2 = \sqrt{1+x_2} - (0.41 + 0.35\beta^4) \frac{x_2}{k\sqrt{1+x_2}} \dots\dots\dots (4)'$$

$$\text{where } x_2 = \frac{h}{1000 P_{f2}}$$

P_{f2} : Absolute pressure of gas at downstream drawing outlet {kPa}

h : Differential pressure generated by the orifice {Pa}

(b) For Corner Tap Expansion correction factor (Y) shall be obtained from Equation (5) or Table 5, using absolute pressure at the upstream drawing outlet for P_f .

$$Y = 1 - (0.3707 + 0.3184\beta^4) \left[1 - \left(\frac{P_{f2}}{P_{f1}} \right)^{1/\kappa} \right]^{0.935} \dots\dots\dots (5)$$

where P_{f1} : Absolute pressure of gas at upstream drawing outlet (kgf/cm²)

P_{f2} : Absolute pressure of gas at downstream drawing outlet (kgf/cm²)

κ : Ratio of specific heat at constant pressure to specific heat at constant volume of the gas. It is recommended to use 1.3 as an approximate value.

By the SI

$$Y = 1 - (0.3707 + 0.3184\beta^4) \left[1 - \left(\frac{P_{f2}}{P_{f1}} \right)^{1/4} \right]^{0.935} \dots\dots\dots (5)'$$

where P_{f1} : Absolute pressure of gas at upstream drawing outlet {kPa}

P_{f2} : Absolute pressure of gas at downstream drawing outlet {kPa}

(c) For Vena Contracta Tap Y_1 obtained from Equation (3) shall be used as the expansion correction factor of gas (Y), using absolute pressure at the upstream drawing outlet for P_f .

(3) Specific Gravity Correction Factor of Gas

To be obtained from Equation (6) or Table 6.

$$F_G = \frac{1}{\sqrt{G}} \dots\dots\dots (6)$$

where F_G : Specific gravity correction factor of gas

G : Specific gravity of gas

(4) Correction Factor for Deviation from Ideal Gas Law

To be obtained from Equation (7) or Table 7, using compression coefficient (Z) obtained from 2.6.4 (3).

$$F_Z = \frac{1}{\sqrt{Z}} \dots\dots\dots (7)$$

where F_Z : Correction factor of gas for deviation from the ideal gas law.

Z : Compression coefficient of gas at flowing condition.

(5) Temperature Correction Factor of Gas

To be obtained from Equation (8) or Table 8.

$$F_T = \frac{1}{\sqrt{T_f}} \dots\dots\dots (8)$$

where F_T : Temperature correction factor of gas

T_f : Absolute temperature of gas at flowing condition (K)

(6) Humidity Correction Factor of Gas

To be obtained from Equation (9) or Tables 9 (a) and (b).

$$F_M = \frac{P_f - \phi P_D}{P_f} \dots\dots\dots (9)$$

where F_M : Humidity correction factor of gas
 P_f : Absolute pressure at flowing condition (kgf/cm²)
 P_D : Saturated steam pressure at flowing temperature (kgf/cm²). To be obtained from Table 10.
 φ : Relative humidity of gas

By the SI

$$F_M = \frac{P_f - \varphi P_D}{P_f} \dots\dots\dots (9)'$$

where P_f : Absolute pressure at flowing condition {kPa}
 P_D : Saturated steam pressure at flowing temperature {kPa}
 To be obtained from Table 10.

(7) Correction Factor due to Reynolds Number

(a) Correction factor (F_r) due to Reynolds number shall be obtained by Equation (10).

$$F_r = \frac{K}{K_0} \dots\dots\dots (10)$$

where K : Flow rate coefficient at flowing condition. This coefficient shall be obtained as follows, using Reynolds number (Re_D) which can be obtained from inner diameter of the pipe line (D), orifice to pipe diameter ratio (β) and Equation (11).

For flange tap: Figs. 6 (a)-(j)

For corner tap: Table 3

For vena contracta tap: Tables 11 (a)-(h)

Here, for the corner tap, the flow rate coefficient from Table 3 shall be corrected for roughness of inner surface using Tables 12 and 13.

K_0 : To be obtained from 2.7 (1).

(b) Reynolds number (Re_D) shall be obtained by Equation (11).

$$Re_D = \frac{458 G Q'}{D \eta_f} \dots\dots\dots (11)$$

where G : Specific gravity of gas

Q' : Approximate value of flow rate of gas volume (Nm³/h)

$$Q' = 0.1790 K_0 d^2 Y F_c F_z F_T F_M \sqrt{P_f h} \dots\dots\dots (12)$$

D : Inner diameter of pipe line (mm)

η_f : Viscosity of gas at flowing condition (cP)

By the SI

$$R_{\text{D}} = \frac{458 GQ'}{D \eta_f} \dots\dots\dots (11)'$$

where

$$Q' = 0.005772 K_0 d^2 Y F_0 F_2 F_T F_M \sqrt{P_i h} \dots\dots\dots (12)'$$

 η_f : Viscosity of gas at flowing condition { mPa·s }

3. Method by Means of Volumetric Flowmeter

Volumetric flowmeters for measuring flow rate of gas which flows through a pipe line shall be of the following types.

- (1) Actual Measuring Dry Gas Meter
- (2) Actual Measuring Wet Gas Meter
- (3) Rotary Displacement Gas Meter

3.1 Preparation for Measurement

- (1) Range of Flow Rate The range of flow rate to be measured shall conform to the range of measurement which has been determined possible by official certification or calibration test.
- (2) Installation Due attention shall be paid to install the meter in horizontal level and not to strain the meter when attaching the outlet/inlet pipes.
- (3) Measurement of Pressure, Temperature and Humidity When it is necessary to correct for pressure, temperature and humidity, the meter for measuring pressure, temperature and humidity of gas shall be attached to the upstream of the flowmeter. However, for the wet gas meter, the thermometer and the hygrometer shall be attached to the downstream.
- (4) Leakage Test Leakage test shall be conducted upon completion of installation.

3.2 Matters to be Noted for Measurement

- (1) Pressure Difference between Outlet/Inlet Pressure difference between outlet/inlet of volumetric flowmeter shall be within the range of designated values.
- (2) Confirmation of Proper Working At the time of measurement, when vibration, abnormal noise, etc., are noticed, the meter shall be immediately checked, and any of their causes shall be removed.

3.3 Measurement

The pointer at commencement and termination of the measurement is read, and the difference in readings shall be the passing volume of gas indicated by the volumetric flowmeter.

Correction of the passing volume shall be by Equation (13).

$$V = A_v I (1 + E) (P_f - \varphi P_D) \frac{1}{T_f} \cdot \frac{1}{Z} \dots\dots\dots (13)$$

where V: Corrected passing volume of gas (m³)

A_v: Coefficient depending on condition of expression.

A_v = 264.4 when passing volume is expressed in normal condition

A_v = 284.5 when passing volume is expressed in standard condition

$$I = I_2 - I_1$$

I: Passing volume of gas as indicated by volumetric flowmeter (m³)

I₁, I₂: Readings of the indicator at beginning and ending of respective measuring

E: Correction factor of flowmeter

P_f: Absolute pressure of gas at flowing condition (kgf/cm²)

φ: Relative humidity

P_D: Saturated steam pressure at flowing temperature T_f.
To be obtained from Table 10.

T_f: Absolute pressure of gas at flowing condition (K)

Z: Compression coefficient of gas at flowing condition

By the SI

$$V = A_v I (1 + E) (P_f - \varphi P_D) \frac{1}{T_f} \cdot \frac{1}{Z} \dots\dots\dots (13)'$$

where A_v: Coefficient depending on condition of expression.

A_v = 2.696 when passing volume is expressed in normal condition

A_v = 2.901 when passing volume is expressed in standard condition

P_f: Absolute pressure of gas at flowing condition {kPa}

P_D: Saturated steam pressure at flowing temperature T_f {kPa}. To be obtained from Table 10.

3.4 Calibration Test

The volumetric flowmeter shall be officially certified or alternatively shall undergo a calibration test. The calibration test shall be carried out by connecting it in series with a standard meter which has been calibrated in advance.

Before the testing, the air in the system shall be removed by passing gas for more than 5 minutes with a maximum flow rate within a range of working flow rate of the meter. In the testing, while maintaining constant flow rate, respective readings of the

standard meter and the meter to be tested are obtained at various flow rates, and the indicated passing volume of the meter to be tested and the indicated passing volume of the standard meter are compared, and then a range of working flow rate of the meter shall be determined by obtaining correction factor from Equation (14).

$$E = \frac{T_f}{T_B} \frac{P_B}{P_f} \frac{V_B(1+E_B)}{I} - 1 \dots\dots\dots(14)$$

where E: Correction factor

T_f : Absolute temperature of passing gas in meter to be tested (K)

T_B : Absolute temperature of passing gas in standard meter (K)

P_B : Absolute pressure of passing gas in standard meter (kgf/cm²)

P_f : Absolute pressure of passing gas in meter to be tested (kgf/cm²)

V_B : Indicated passing volume of standard meter (m³)

F_B : Correction factor of standard meter. When air is used for calibration test, this should include correction for natural gas.

I: Indicated passing volume of meter to be tested (m³)

By the SI

$$E = \frac{T_f}{T_B} \frac{P_B}{P_f} \frac{V_B(1+E_B)}{I} - 1 \dots\dots\dots(14)'$$

where P_B : Absolute pressure of passing gas in standard meter {kPa}

P_f : Absolute pressure of passing gas in meter to be tested {kPa}

Reference Anticipated Error

1. When flow rate is measured by an orifice meter, the anticipated error of measuring values of the flow rate (x_Q) can be obtained from the following equation:

$$x_Q = \pm \left\{ \sqrt{x_{Q1}^2 + x_{Q2}^2 + \frac{1}{4}x_{Q3}^2 + \frac{1}{4}x_{Q3}^2 + \frac{1}{4}x_{Q3}^2 + \frac{1}{4}x_{Q3}^2 + 0.5^*} \right\} \dots\dots\dots(1)$$

where x_{Q1} : Anticipated error of flow rate coefficient (%)

x_{Q2} : Anticipated error of correction factor for expansion of gas (%)

x_{Q3} : Anticipated error in differential pressure measurement (%)

- x_{Q4} : Anticipated error in measuring specific gravity of gas (%)
- x_{Q5} : Anticipated error in gas temperature measurement (%)
- x_{Q6} : Anticipated error in measuring absolute pressure of gas

Note * The 0.5% added to the anticipated error does not need be added, when straight pipe portion is more than twice the value shown in 2.5.5.

1.1 Anticipated Error in Flow Rate Coefficient

- (1) Anticipated error in flow rate coefficient for flange tap shall be obtained from the following table:

	<u>Anticipated Error (%)</u>
$0.2 \leq \beta \leq 0.7$	± 0.60
$0.1 \leq \beta < 0.2$	$\pm (1.6 - 5.0 \beta)$
$0.7 < \beta \leq 0.75$	$\pm (5.0 \beta - 2.90)$

- (2) Anticipated error in flow rate coefficient for corner tap shall be obtained from the following equation:

$$\pm 0.5 \left[1 + 2\beta^4 + 100(r_{\text{tr}} - 1) + \beta^2 + \frac{50}{D} \right] \dots\dots\dots (2)$$

where D: Pipe diameter (mm)

- (3) Anticipated error in flow rate coefficient for vena contracta tap shall be obtained from the following table:

	<u>Anticipated Error (%)</u>
$0.2 \leq \beta \leq 0.7$	± 0.5
$0.1 \leq \beta < 0.2$	$\pm (1.5 - 5 \beta)$
$0.7 < \beta \leq 0.8$	$\pm (5 \beta - 3.00)$

1.2 Anticipated Error of Correction Factor for Expansion of Gas

- (1) Flange Tap

	<u>Anticipated Error (%)</u>
$0.2 \leq \beta \leq 0.75$	$\pm 4 \Delta P/P$
$0.1 \leq \beta < 0.2$	$\pm 8 \Delta P/P$

(2) Corner Tap

	<u>Anticipated Error (%)</u>
$0.22 \leq \beta \leq 0.75$	$\pm 4 \Delta P/P$
$0.75 < \beta \leq 0.8$	$\pm 8 \Delta P/P$

(3) Vena Contracta Tap

	<u>Anticipated Error (%)</u>
$0.2 \leq \beta \leq 0.75$	$\pm 4 \Delta P/P$
$0.1 \leq \beta < 0.2$	$\pm 8 \Delta P/P$
$0.75 < \beta \leq 0.8$	$\pm 8 \Delta P/P$

1.3 Anticipated Error in Differential Pressure Measurement

Anticipated errors will differ by the differential pressure meters used. Therefore, anticipated error of each meter should be checked in advance.

Remarks 1. Anticipated error of differential pressure meters for industrial use is in the order of $\pm (0.5 \text{ to } 1.0)\%$.

1.4 Anticipated Error in Measuring Specific Gravity of Gas

This will depend on measuring method, temperature and pressure at which measurement was made, and precision of measurement.

Remarks 2. According to JIS K 2304 (Method for Measuring Specific Gravity of Fuel Gas), the anticipated error is in the order of $\pm (1.0 \text{ to } 2.0)\%$.

1.5 Anticipated Error in Measuring Temperature of Gas

Anticipated errors will differ by the thermometers used. Therefore, anticipated error of each thermometer should be checked in advance.

Remarks 3. Anticipated error of industrial thermocouples, liquid expansion thermometers (glass), or resistance thermometers is in the order of $\pm (0.5 \text{ to } 1.0)\%$.

1.6 Anticipated Error in Measuring Absolute Pressure of Gas

Anticipated errors will differ by the pressure gauges used. Therefore, anticipated error of each gauge should be checked in advance.

Remarks 3. Anticipated error of industrial bellows, diaphragms, or Bourdon tube gauge is in the order of $\pm (1.0 \text{ to } 2.0)\%$. Anticipated error of U tubes is in the order of $\pm (0.5 \text{ to } 1.0)\%$.