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Testing methods for turbo-fans

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Foreword

This translation has been made based on the original Japanese Industrial Standard revised by the Minister of Economy, Trade and Industry through deliberations at the Japanese Industrial Standards Committee in accordance with the Industrial Standardization Law. Consequently **JIS B 8330 : 1981** is replaced with **JIS B 8330 : 2000**.

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Testing methods for turbo-fans

Introduction The body of this Standard specifies the testing methods for turbo-fans which have been conventionally specified in the Japanese Industrial Standard, and the Annex of this Standard has been prepared based on the first edition of **ISO 5801** *Industrial fans—Performance testing using standardized airways* published in 1997 without any modification in technical contents.

The concept of **ISO** Standard differs largely from that of the conventional **JIS** by adopting almost all test apparatus structures specified in respective original test standards of European countries and USA which are currently used, in consideration of the fact that test apparatus, especially that for a large-sized fan, is very expensive. Accordingly, **ISO** Standard specifies the fan test apparatus not limited to one kind, but adopts, although it varies according to each installation type, seven or eight kinds of the test apparatus used in European countries and USA. For choosing which test apparatus among them to use, **ISO** Standard adopts a selection system of test apparatus and calculation method, where the choice is left to the standard-using side. Therefore, this Standard adopts a selection system between the body and Annex, where the body of the conventional **JIS** used widely in Japan and Southeast Asia is applied as it is, and the performance test may be carried out according to the Annex.

1 Scope This Japanese Industrial Standard specifies the test and inspection method for centrifugal fans, axial flow fans, mixed flow fans, etc. (hereafter referred to as “fans”) of about less than 1.3 pressure ratio⁽¹⁾ performed at works using air at room temperatures and normal pressures. In the case of the test and inspection for fans having a special structure or fans to be used under special gases or other special conditions, the agreement between the parties concerned with delivery shall be made and this Standard shall suitably apply by accepting or rejecting or supplementing it.

Furthermore, the performance test may be carried out according to the Annex.

Note ⁽¹⁾ This pressure ratio indicates the case where a fan is tested using the room temperature air. When the pressure ratio exceeds this value when using the room temperature air, **JIS B 8340** shall apply.

Remarks : The corresponding International Standard of this Standard shall be as follows:

ISO 5801 : 1997 *Industrial fans—Performance testing using standardized airways*

2 Normative references The following standards contain provisions which, through reference in this Standard, constitute provisions of this Standard. The most recent editions of the standards (including amendments) indicated below shall be applied.

JIS B 0132 *Glossary of terms for fans, blowers and compressors*

JIS B 8340 *Testing methods for turbo blowers and compressors*

JIS B 8346 *Fans, blowers and compressors—Determination of A-weighted sound pressure level*

JIS C 9603 *Ventilating fans*

JIS Z 8762 *Measurement of fluid flow by means of orifice plates, nozzles and Venturi tubes inserted in circular cross-section conduits running full*

3 Definitions For the purposes of this Standard, the following definitions and those given in **JIS B 0132** apply.

- a) **characteristic equation of air** The characteristic equation of air shown by the formula (1),

$$Pv = RT \dots\dots\dots (1)$$

where

$P^{(2)}$: absolute pressure of air (Pa) $P = Pa + p$

Pa : atmospheric pressure (Pa)

$p^{(2)}$: gauge pressure of air (Pa)

T : absolute temperature of air (K) $T = 273 + t$

t : air temperature (°C)

v : specific volume of air at $P \cdot T$ (m³/kg)

$$R: \text{gas-constant of air} = \frac{287}{1 - 0.378 \phi \frac{P_s}{P}} \text{ [J/(kg} \cdot \text{K)]}$$

where

P_s : saturated vapour pressure (Pa)

ϕ : relative humidity (decimal)

Note (2) In this Standard, P indicates an absolute pressure and p a gauge pressure.

Remarks: The value of gas constant R of air under the standardized inlet condition shall be regarded as 289. This value may be applied to the atmospheric air of -15 °C to 40 °C.

- b) **standardized inlet condition** An inlet condition in the case where fans suck the humid air of the temperature of 20 °C, absolute pressure of 101.3 kPa, relative humidity of 65 %. The air density under the standardized inlet condition shall be regarded as 1.20 kg/m³.
- c) **total air power** Theoretical power required for a fan to compress a specified air volume up to a specified total fan pressure.
- d) **static air power** Theoretical power required for a fan to compress a specified air volume up to a specified static fan pressure.
- e) **fan air volume** A value obtained by converting the air volume calculated by the test into the volume under the standardized inlet condition (when especially specified, under the specified condition).

Remarks: In this Standard, even in the case of handling the gas except air it shall be called an air volume.

- f) **specified fan rotational speed** A rotational speed of fan shaft per unit time under the specified power-condition in the case of the electric motor drive, under the specified operational condition in the case of the other prime mover drive.

Remarks : Since this rotational speed changes somewhat according to the fan air volume, when the numerical value is required to be indicated, the fan rotational speed shall be taken at the specified air volume as a representative.

- g) **Pitot tube** A Pitot tube called the Pitot-static tube in **JIS B 0132**.

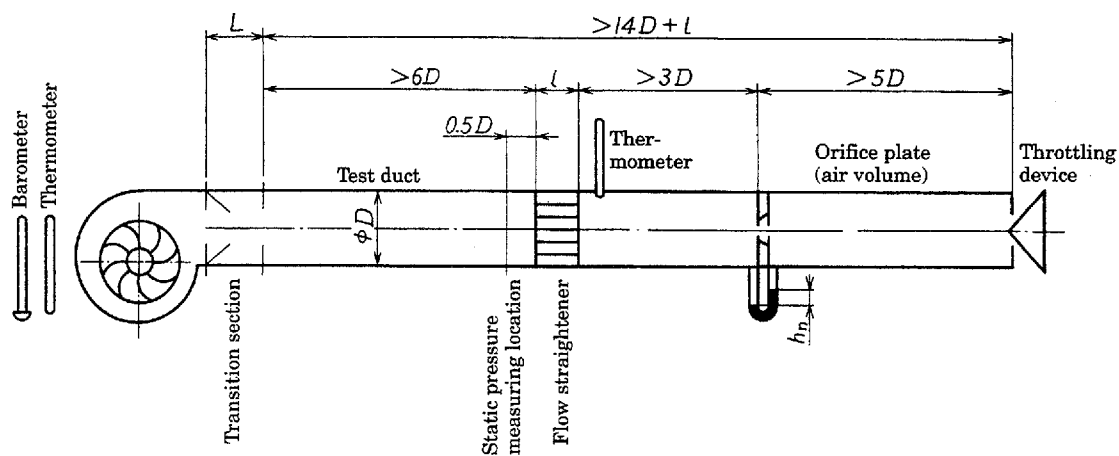
4 Test items The fan test items shall be as follows:

Temperature, fan total pressure, fan static pressure, air volume, rotational speed, shaft power, noise and operational condition.

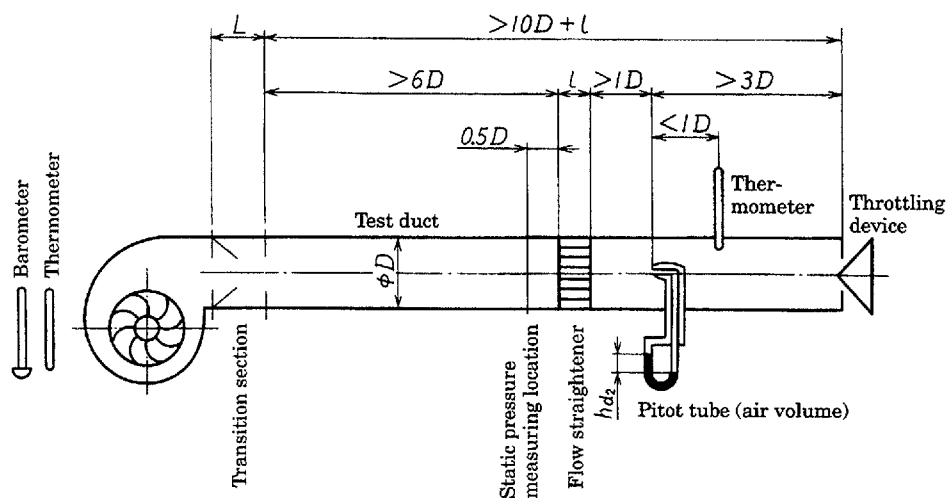
5 Test apparatus

5.1 Test apparatus The test apparatus shall be capable of measuring accurately the value required for indicating the performance and operational condition of fans under the working operational condition or the condition near it. The layout of the test apparatus⁽³⁾ and measuring devices shall be in accordance with figures 1 to 4.

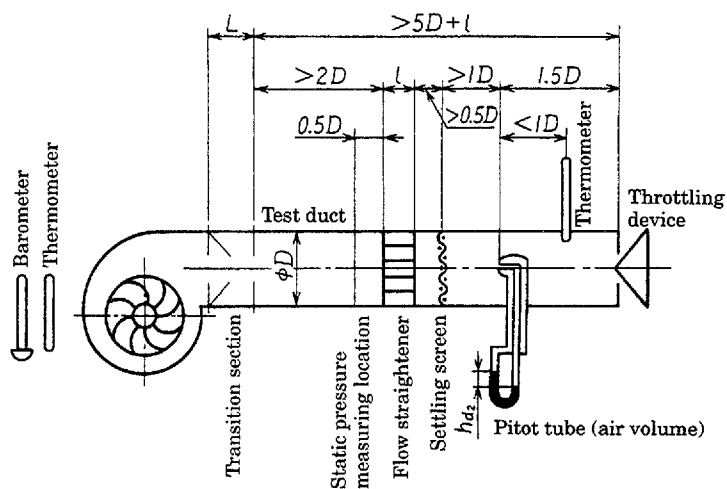
Note ⁽³⁾ The center of the fan inlet or the test duct inlet should be separated by not less than $1D$ (D is the diameter of the fan inlet or the test duct inlet) from the wall or the floor.



a) When using orifice plate



b) When using Pitot tube



c) When using Pitot tube and settling screen

Figure 1 In the case of fans with only ducted outlet under the working condition

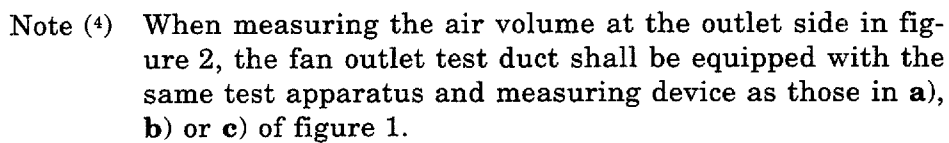


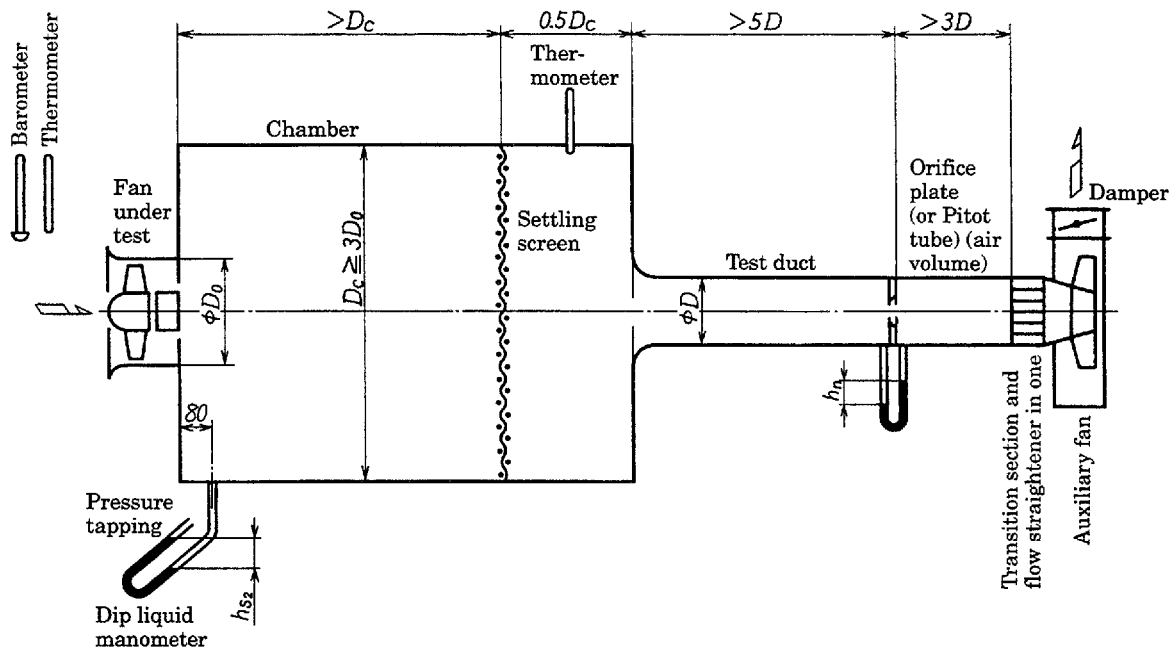
Figure 2 In the case of fans with both ducted outlet and ducted inlet under the working condition

The diagram illustrates a flow system for velocity measurement. The flow starts from a reservoir on the right, passes through a transition section, then a pitot tube (air volume) with dimensions h_{d_1} and h_{s_1} . The flow then passes through a flow straightener, a test duct of diameter ϕD , and a throttling device. A barometer and thermometer are connected to the test duct. The distance from the flow straightener to the throttling device is labeled $> 4.5 D$. The distance from the flow straightener to the pitot tube is labeled $> 8.5 D + l$. The distance from the pitot tube to the throttling device is labeled $> 1 D$. The distance from the pitot tube to the transition section is labeled $< 1 D$. The distance from the transition section to the throttling device is labeled $> 3 D$.

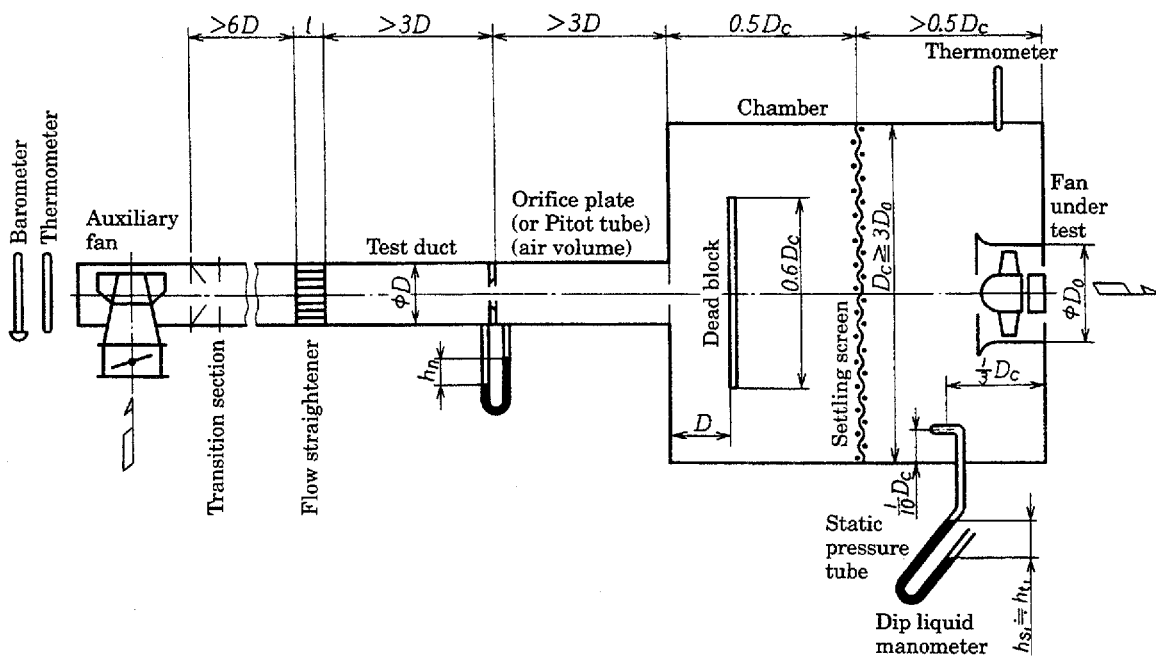
Even in this case, the exact measured values are not obtained as the air volume becomes small.

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Unit : mm



a) In the case of forced draft fan



b) In the case of induced draft fan

Note (6) The performance test of an axial fan without a guide vane with the impeller outside diameter of 1 250 mm or less should be carried out in accordance with figure 4. The performance test shall be carried out according to a) in the case of fans used for forced draft, and b) in the case of fans used for induced draft. Even when the outside diameter exceeds 1 250 mm, this Standard may apply.

In addition, the test apparatus for the ventilating fans used in a home or an office, of which the axial-type vane is driven by an induction motor may be used in accordance with JIS C 9603.

Figure 4 In the case of fans without both ducted outlet and ducted inlet under the working condition (6)

5.2 Test duct The test duct of which the internal surface is smooth, and which is the straight duct (internal diameter D) with the circular cross sectional area which is equal to that of the fan inlet or fan outlet should be used. When the shape or cross sectional area is different unavoidably, the transition section shall be used between the fan and the test duct. The test duct of which the cross sectional area is less than 0.7 or more than 1.3 of that of the fan inlet or fan outlet shall not be used. However, in the case of figure 4, since the test duct is not related to the fan under test, this limit shall not apply.

5.3 Transition section When the transition section moves from the circular shape to the circular shape or from the rectangular shape to the circular shape or from the circular shape to the rectangular shape, the following shall apply.

- a) When the transition section moves from the circular shape to the circular shape, the angle between the transition section and the axis shall be not more than 14° when using as a broadening tube, and not more than 30° when using as a thinning tube (see figure 5).

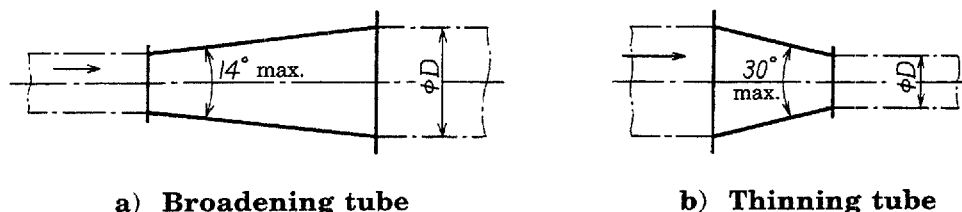


Figure 5 Transition section

- b) When the transition section moves from the rectangular shape to the circular shape, the formulae (2), (3) shall apply (outlet side).

$$\text{Thinning tube } (m \leq 1): \quad L/D \geq 1.8 \left(\frac{1}{\sqrt{m}} - 1 \right) + 0.4 \frac{a}{b} \quad \dots\dots\dots (2)$$

$$\text{Broadening tube } (m \geq 1): \quad L/D \geq 4 \left(1 - \frac{1}{\sqrt{m}} \right) + 0.4 \frac{a}{b} \quad \dots\dots\dots (3)$$

- c) When the transition section moves from the circular shape to the rectangular shape, the formulae (4), (5) shall apply (inlet side).

$$\text{Thinning tube } (m \geq 1): \quad L/D \geq 1.8 \left(1 - \frac{1}{\sqrt{m}} \right) + 0.4 \frac{a}{b} \quad \dots\dots\dots (4)$$

$$\text{Broadening tube } (m \leq 1): \quad L/D \geq 4 \left(\frac{1}{\sqrt{m}} - 1 \right) + 0.4 \frac{a}{b} \quad \dots\dots\dots (5)$$

where

L : length of transition section

D : internal diameter of test duct

m : area ratio = $\frac{\pi D^2}{4ab}$

a : length of long side of rectangle

b : length of short side of rectangle
(see figure 6).

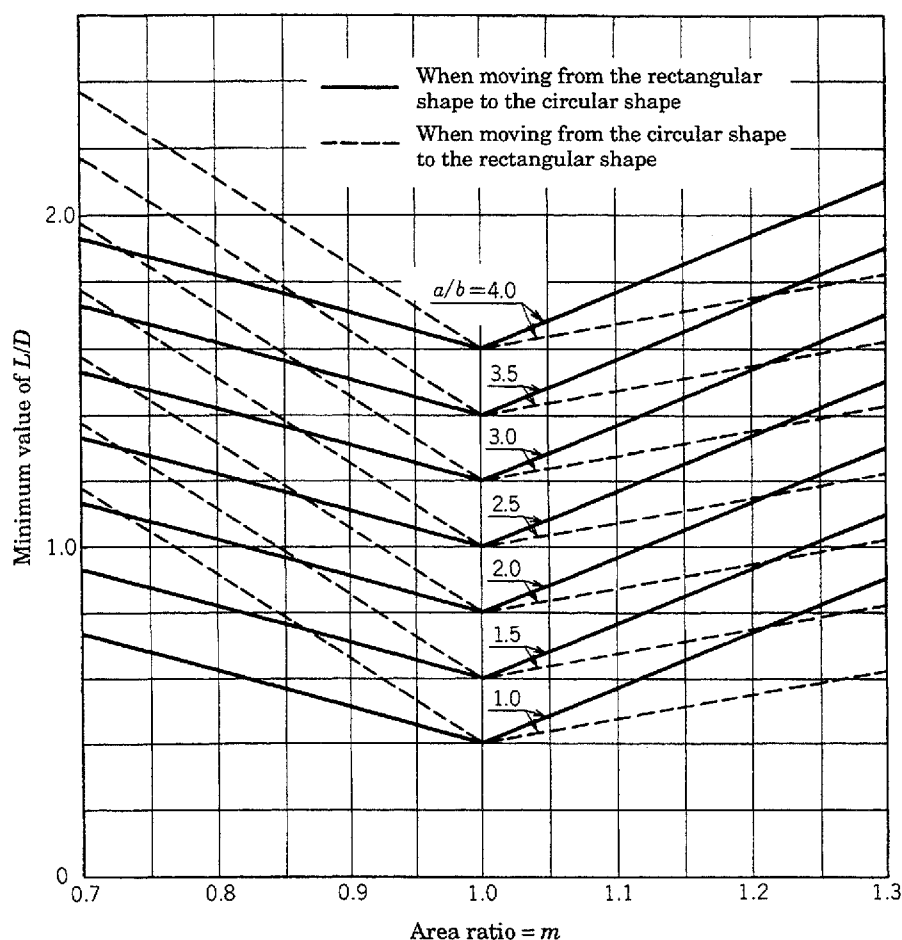


Figure 6 Length of transition section

5.4 Chamber The chamber shall be as follows:

- The chamber shall be a circular tank (internal diameter D_c) or a square tank (length of one side D_c) with a uniform cross sectional area.
- The cross sectional area of the chamber shall be determined so that the average speed is 2 m/s or under. However, when the fan static pressure is 70 Pa or under, it shall be determined so that the average speed is 1.5 m/s or under.
- The settling screen is used for making the flow uniform in accordance with 4.7.1, and the passing speed through the settling screen shall be made so as not to exceed 3 m/s, and when the fan static pressure is 70 Pa or under, it shall be made so as not to exceed 2 m/s.
- When the fan inlet has a bell-mouth, or it has an inlet duct at the time of working, the bell-mouth shall be attached to the fan under test. When the fan inlet has not a bell-mouth, or it has not an inlet duct at the time of working, the bell-mouth shall not be attached to the inlet of the fan under test.

5.5 When performing test using chamber Air volume shall be adjusted by the rotational speed of auxiliary fan or the damper so that the pressure in the chamber becomes positive in the case of figure 4 a), and negative in the case of figure 4 b).

5.6 Flow straightener The length in the axial direction of the flow straightener l shall be not less than 3 times one side length of a mesh (square) of flow straightener δ as shown in figure 7. δ shall be $\frac{1}{4}$ to $\frac{1}{12}$ of internal diameter D of the test duct.

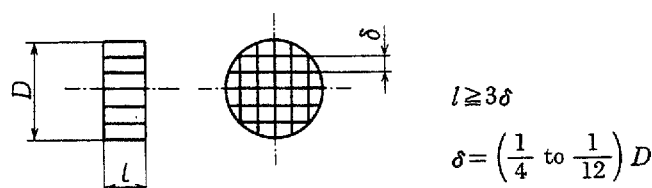


Figure 7 Dimensions of flow straightener

5.7 Settling screen

5.7.1 For the settling screen installed in the chamber in figure 4, the value of $\frac{d}{t}$ should be about 0.13 in accordance with figure 8.

5.7.2 For the settling screen installed in the test duct in figure 1 c), the value of opening ratio μ shall be 0.6 to 0.45. μ shall be determined according to the following formula.

$$\mu = \left(1 - \frac{d}{t}\right)^2 \dots\dots\dots (6)$$

where

d : wire diameter of settling screen (mm)

t : pitch of settling screen (mm)

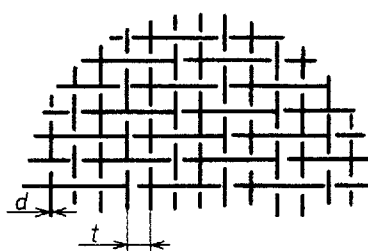


Figure 8 Settling screen

5.8 Adjustment device of air volume The adjustment of air volume shall be performed by installing the throttling device such as a damper when adjusting air volume of the outlet test duct, and it shall be performed by using the throttling device such as a circular plate, a circular cone installed symmetrically with respect to the shaft centre of the test duct when adjusting air volume of the inlet test duct. The throttling device such as a damper, a circular plate, a circular cone installed in these test ducts shall be kept at the suitable distance away from the wall, floor, etc. so as not to exert a bad influence on the measurement.

5.9 Hygrometry instrument A psychrometer shall be used for measuring humidity.

5.10 Atmospheric-pressure measuring instrument A Fortin barometer shall be used for measuring atmospheric pressure.

6 Test method

6.1 Test condition

6.1.1 Inlet condition The inlet air condition, unless otherwise specified, shall be the standardized inlet condition.

6.1.2 Test rotational speed The test shall be performed at the specified rotational speed⁽⁷⁾.

Note (7) When it is difficult to operate a fan with a specified speed on account of a power source, a facility, etc., the test shall be performed at the rotational speed within $\pm 20\%$ of the specified rotational speed, and the result may be converted into the specified rotational speed. The conversion of performance values in this case shall be performed in accordance with 7.2.

When the test can not be performed due to the large size or the large power, a model test shall be performed. The acceptance or rejection of the test result shall be subjected to the agreement between the parties concerned with delivery.

6.1.3 Point of measurement The point of measurement shall be determined according to the classification of fans.

- a) For the centrifugal fans, perform the test on at least 5 different air volumes which extend from the close condition or the surging point to the largest air volume as far as possible, and with respect to at least one air volume, perform the test at the lower pressure than the specified fan total pressure or static pressure.
- b) For the mixed flow fans, perform the test on at least 5 different air volumes which include the specified air volume, and extend from the smallest air volume to the largest air volume as far as possible.
- c) For the axial flow fans, perform the test on at least 5 different air volumes which extend from the smallest air volume as far as possible to the open condition, and with respect to at least one air volume, perform the test at the higher pressure than the specified fan total pressure or static pressure.

6.1.4 Rotation test of high-revolution object Since for the rotation test of a revolution object when the peripheral speed of an impeller exceeds 25 m/s, the article 149 section 8 of Ordinance on Industrial Safety and Health (Showa 47.9.30 Notification, Ministerial Ordinance No. 32) is applied, perform the test after confirming safety.

6.2 Test device and measuring method

6.2.1 Temperature The measurement of temperature shall be performed as follows:

For the measurement of temperature, use a mercury thermometer with the maximum scale of 100 °C and the minimum scale of -10 °C at not more than 1 °C of scale spacing calibrated beforehand or a thermocouple thermometer.

Put the thermometer at the location which is capable of measuring the temperature of air in the fan inlet side and air in the fan outlet side correctly, and perform the measurement to the nearest 1 °C.

6.2.2 Pressure The measurement of pressure shall be performed as follows:

- a) **Manometer** For the measurement of static pressure, dynamic pressure, pressure just before and after the inlet nozzle and orifice plate, use the U-tube or other liquid manometer. However, other manometers which are capable of calibrating by comparing with the liquid manometer may be used.

Use water or alcohol of which the specific gravity was measured beforehand as the liquid of liquid manometer.

The internal diameter of glass tube of liquid manometer shall be 6 mm to 12 mm, and the internal diameters of U-tube in the left side and in the right side shall be almost equal and uniform. For the liquid manometer, the scale spacing shall be set to 1 mm.

In addition, when measuring the pressure of 500 Pa or under, use a dip liquid manometer or a micromanometer.

For the measurement of the pressure of orifice plate and inlet nozzle, read at least to the nearest $\frac{1}{100}$ of the measured value. When the indicator of the liquid manometer shakes intensely, the duct may be thinned in such an extent that an error is not caused.

- b) **Pitot tube, static pressure tube and static pressure tapping** When measuring the dynamic pressure and static pressure simultaneously, use the Pitot tube, and when measuring only the static pressure, use the static pressure tube or the static pressure tapping which is opened perpendicularly to the tube wall.

The structure of Pitot tube (figure 9), static pressure tube (figure 10), and static pressure tapping (figure 11) shall be as follows.

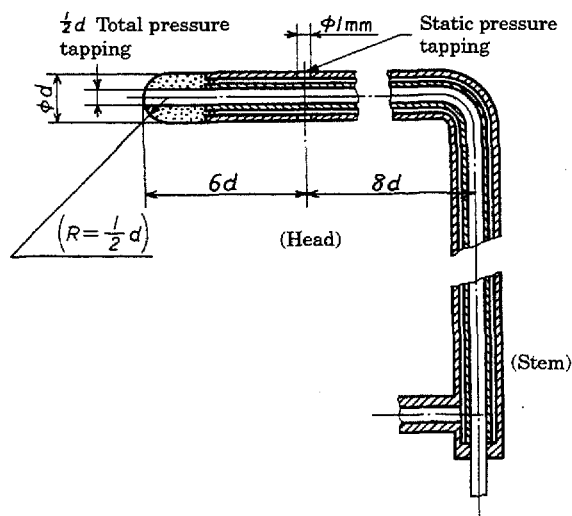


Figure 9 Pitot tube

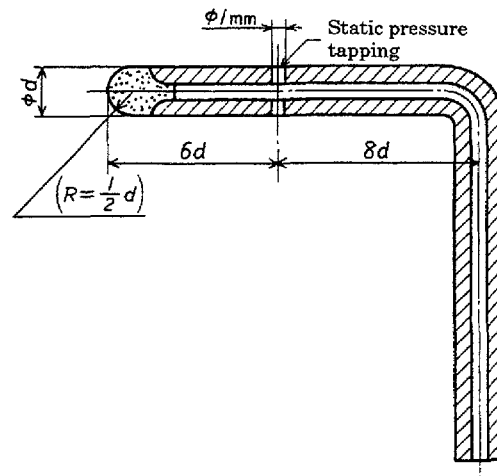


Figure 10 Static pressure tapping

Unit : mm

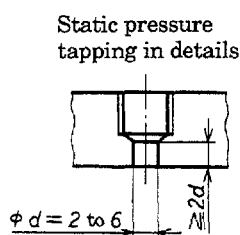


Figure 11 Static pressure tapping

- 1) The head of Pitot tube shall be the smooth brass tube or stainless-steel tube of which the outside diameter d is 5 mm to 20 mm, and the outside diameter of stem shall be 1 to 3 times that of the head.
- 2) The static pressure tube shall be the smooth brass tube or stainless-steel tube of which the outside diameter d is 5 mm to 10 mm
- 3) The internal diameter of the static pressure tapping shall be 1 mm, and its number shall be almost the same as the number which expresses the outside diameter of head in mm and these tapings shall be dispersed at even intervals along the circumference.
- 4) The surface of head shall be finished to be smooth enough and especially, no burrs shall remain in the end face of the total pressure tapping and static pressure tapping.
- 5) For the static pressure tapping, the static pressure drawing port shall have the structure which is suitable for connecting the duct in accordance with figure 11.
- 6) For the Pitot tube, its head shall be arranged in parallel with the flow direction, and the point of measurement shall be in accordance with following formulae, 10 points on each diameter, 20 points in total, shown on the diameters (figure 12) which are perpendicular each other on the cross section of test duct (see attached table 2).

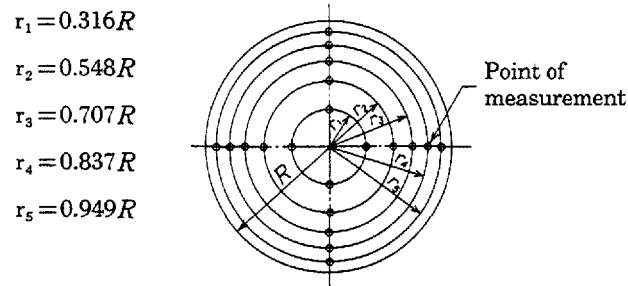


Figure 12 Point of measurement of Pitot tube

When the internal diameter of test duct is 400 mm or under, the orifice plate or inlet nozzle should be used if possible.

- 7) When measuring the static pressure using the static pressure tube or the static pressure tapping, measure at the two locations at the left and right side of the tube wall, respectively, and obtain the average value of these. When the difference between both sides is remarkable, confirm the cause producing an error, or measure and compare at another location.

In addition, the measuring method for the static pressure, and the reference point shall be as shown in figure 13.

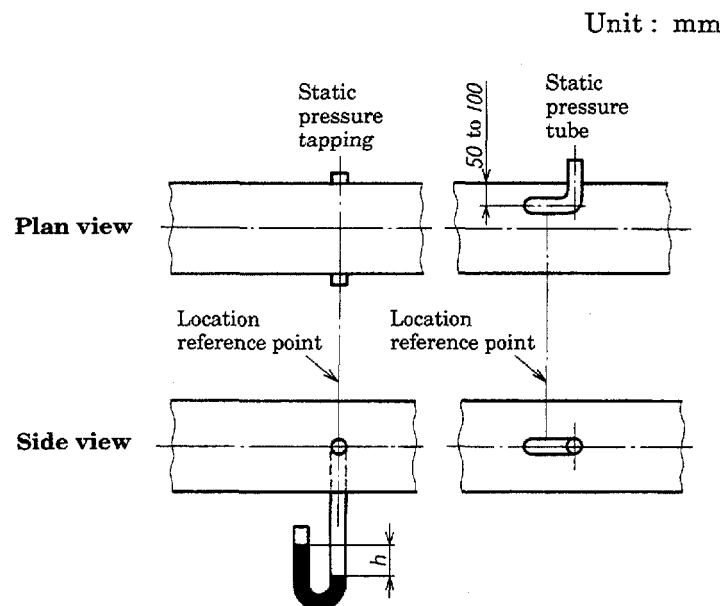


Figure 13 Measurement of static pressure

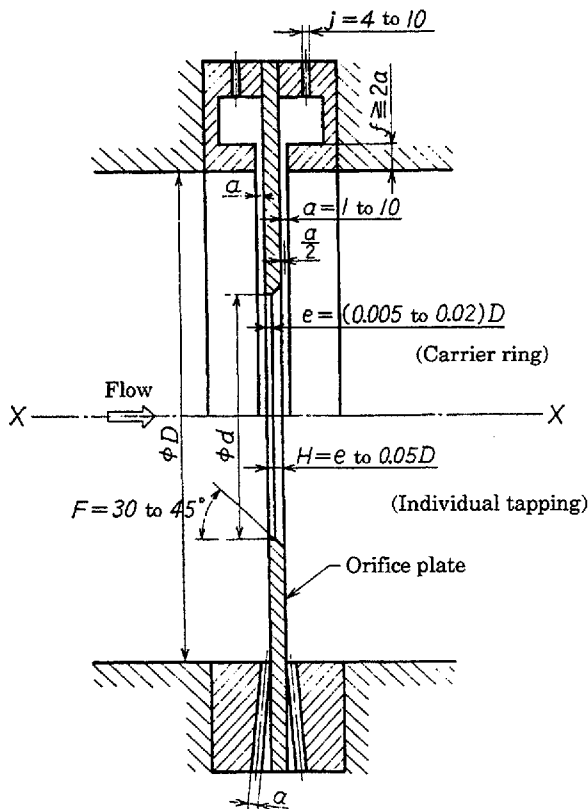
6.2.3 Air volume The measurement of air volume shall be performed as follows:

- a) **Method using Pitot tube** The Pitot tube shall be that specified in 6.2.2 b).
- b) **Method using orifice plate** The orifice plate shall be as follows:
 - 1) The structure of orifice plate shall be in accordance with **JIS Z 8762**, and its shape and dimensions shall be as shown in figure 14.
 - 2) The pressure drawing method shall be in accordance with the corner tap in **JIS Z 8762**, and the structure and location of the pressure drawing port

shall be as shown in figure 14. When using the contraction taps or flange taps unavoidably, it shall be in accordance with provisions of **JIS Z 8762**.

- 3) The orifice plate of which the internal diameter of duct is 50 mm to 1 000 mm, and the throttled area ratio $\beta^2 = \left(\frac{d}{D}\right)^2$ is 0.05 to 0.64 shall be used. It should be selected so that the pressure difference becomes 500 Pa or over.

Unit : mm



D : Internal diameter of duct 50 mm to 1 000 mm

a : Diameter of individual tapping or slit width

In the case of $\beta \leq 0.65$ $a \leq 0.03D$

In the case of $\beta > 0.65$ $0.01D \leq a \leq 0.02D$

Irrespective of the value of β $a = 1$ mm to 10 mm

f : Thickness of slit

j : Diameter of hole connecting pressure duct

d : Diameter of throttling hole

H : Thickness of orifice plate

c : Thickness of edge

F : Angle of relief

XX : Rotational centre shaft of orifice plate

Figure 14 Orifice plate

- 4) Measure the pressure just before and after the orifice plate. For the measurement, read at least to the nearest $\frac{1}{100}$ of the measured value. When the indicator of the liquid manometer shakes intensely, the duct may be thinned in such an extent that an error is not caused.

Furthermore, when Reynolds number is smaller than 1×10^5 at the time of measurement of the small air volume, correct in accordance with **JIS Z 8762**.

- c) **Method using inlet nozzle** The dimensions of inlet nozzle shall be as shown in figure 15, and its internal surface shall be made smooth as far as possible. The internal diameter of inlet nozzle shall be the average value of the diameter measured at the four or more locations, and an error of each diameter shall be within $\pm 0.005D$ to the average value.

In addition, keep the inlet port at the suitable distance away from the wall and floor, and take measures so that the inlet port may not be exposed to a natural wind.

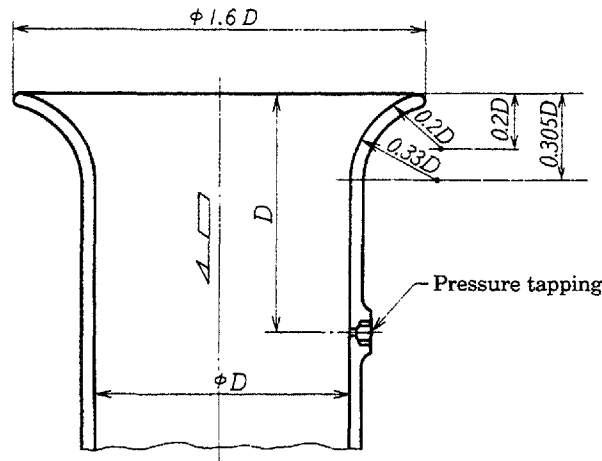


Figure 15 Inlet nozzle

6.2.4 Rotational speed For the measurement of rotational speed, the direct reading tachometer, revolution counter, and electric tachometer which have been calibrated beforehand shall be suitably selected and used. The full scale of the tachometer shall be 3 times or under the revolution number to measure.

Perform the measurement of rotational speed 3 times or over at the same condition, and read to the nearest $\frac{1}{200}$, and obtain the average value.

When using the revolution counter, the time of measurement shall be 30 s or longer.

6.2.5 Shaft power For the measurement of shaft power, the dynamometer shall be used or the prime mover with the performance made clear by the correct test shall be used. When driving fans using a transmission gear, the transmission gear actually attached shall be used, and when the measurement of the loss power of transmission gear is difficult, this shall be regarded as a part of shaft power of fans.

All measured numerical values required for calculating the shaft power shall be read to the nearest $\frac{1}{100}$ of the measured numerical values.

6.2.6 Noise The measurement of noise shall be performed in accordance with **JIS B 8346**.

6.2.7 Operational condition The test of operational condition shall be performed as follows:

- a) Operate continuously until the bearing temperature becomes constant at the specified air volume, and investigate the bearing temperature at that time using a thermometer on the bearing housing.

For the fans having the cooling system, investigate whether the temperature of the cooling water of a cooler fully attains the purpose of cooling even at the highest temperature under the working condition.

- b) Investigate whether the oil of bearing is lubricated smoothly and does not leak outside. Since the oil of bearing installed near the fan inlet may leak according to an air current, investigate especially carefully.

- c) Investigate the oscillation caused by wind speed, wind pressure, and revolution.
In addition, investigate the oscillation of bearing on the bearing housing using a vibrometer.
- d) Investigate whether air leaks out or leaks in through the joint of casing of fan, etc. For the fans handling special gases, investigate especially the airtightness of shaft sealing section.
- e) For the transmission gear, investigate whether the transmission condition is calm and reliable.
- f) Investigate the existence of the abnormal noise under the regular operational condition.

6.3 Calculation method of characteristic value

6.3.1 Symbol, definitions and unit The symbol, definitions and unit used for calculation of characteristic value shall be as shown in table 1.

Table 1 Symbol, definitions and unit

Symbol	Definitions	Unit
A_1, A_2	Cross sectional area of inlet test duct and outlet test duct	m ²
A_1', A_2'	Cross sectional area of fan inlet and fan outlet	m ²
A_n	Area of circular hole of orifice plate $\left(= \frac{\pi}{4} d^2 \right)$	m ²
D_1, D_2	Internal diameter of inlet test duct and outlet test duct	m
d	Internal diameter of circular hole of orifice plate	m
g	Acceleration of free fall	m/s ²
$\bar{h}_d$	Average value of dynamic pressure of test duct	Pa
$\bar{h}_{d1}, \bar{h}_{d2}$	Average value of dynamic pressure of inlet test duct and outlet test duct	Pa
$h_1, h_2, \dots$	Measured value of dynamic pressure by Pitot tube	Pa
h_n	Pressure difference just before and after orifice plate or negative pressure of inlet nozzle	Pa
L_1, L_2	Length of test duct between static pressure measuring location and fan inlet and fan outlet	m
L, L_T, L_S	Shaft power, total pressure air power and static pressure air power	kW
P_1, P_2	Absolute static pressure just before and after orifice plate	Pa
P_T, P_S	Fan absolute total pressure and fan absolute static pressure	Pa
P_{T1}, P_{T2}	Inlet fan absolute total pressure and outlet fan absolute total pressure	Pa
P_{S1}, P_{S2}	Inlet fan absolute static pressure and outlet fan absolute static pressure	Pa
p_T, p_S	Fan total pressure and fan static pressure	Pa
p_{t1}, p_{t2}	Inlet total pressure and outlet total pressure	Pa
p_{s1}, p_{s2}	Inlet static pressure and outlet static pressure	Pa

Table 1 (concluded)

Symbol	Definitions	Unit
p_{d1}, p_{d2}	Inlet dynamic pressure and outlet dynamic pressure	Pa
Q_1, Q_2	Inlet air volume and outlet air volume	m ³ /min
R_D	Reynolds-number = $\bar{v}D/\nu$	
T_1, T_2	Absolute temperature of air of fan inlet and fan outlet	K
$\bar{v}_1, \bar{v}_2$	Average speed in inlet test duct and outlet test duct	m/s
$\bar{v}$	Average speed in test duct	m/s
α_0	Flowrate coefficient of inlet nozzle = 0.99	
α_n	Flowrate coefficient of orifice plate (see figure 16)	
Δ_1, Δ_2	Loss pressure of inlet test duct and outlet test duct	Pa
ε	Expansibility factor (see figure 17)	
η_T, η_S	Total efficiency and static efficiency	%
κ	Ratio of specific heat (in the case of the room temperature air, 1.40)	
ν	Kinematic viscosity	m ² /s
ρ	Air density in test duct	kg/m ³
ρ_1, ρ_2	Air density in inlet test duct and outlet test duct	kg/m ³
ρ_n	Air density just before orifice plate	kg/m ³
Subscript: T	Fan total pressure	
t	Total pressure	
S	Fan static pressure	
s	Static pressure	
d	Dynamic pressure	
n	Related to orifice plate	
1	Fan inlet side and just before orifice plate (excluding h_1)	
2	Fan outlet side and just after orifice plate (excluding h_2)	

6.3.2 Determination of fan total pressure and fan static pressure The fan total pressure p_T and fan static pressure p_S shall be determined according to the following formulae.

If the area of fan inlet and fan outlet are equal, the fan total pressure and fan static pressure are offset since the dynamic pressure is almost equal. However, when the pressure ratio exceeds 1.03, the difference of dynamic pressure between the inlet and the outlet shall be taken into consideration.

$$p_T = p_{t2} - p_{t1} = (p_{s2} + p_{d2}) - (p_{s1} + p_{d1}) \quad (7)$$

$$p_S = p_T - p_{d2} = p_{s2} - (p_{s1} + p_{d1}) \quad (8)$$

$$p_{t2} = h_{s2} + \bar{h}_{d2} + \Delta_2 \quad (9)$$

$$p_{t1} = h_{s1} + \bar{h}_{d1} - \Delta_1 \quad (10)$$

$$\Delta_2 = 0.025 \frac{L_2}{D_2} \bar{h}_{d2} \quad (11)$$

$$\Delta_1 = 0.025 \frac{L_1}{D_1} \bar{h}_{d1} \dots\dots\dots (12)$$

a) **When using Pitot tube⁽⁸⁾**

$$\bar{h}_d = \frac{1}{n} (h_1 + h_2 + h_3 \dots\dots + h_n)$$

Note ⁽⁸⁾ For the average wind speed in the test duct $\bar{v}$, it is ideally correct that the wind speed in each point of measurement is determined from the dynamic pressure in each point of measurement and the average value is obtained. Since the method of this Standard is a kind of simplified method, when the exact calculation is required, the following formulae should be used. However, even if the method of this Standard is used, an error of not less than +1 % is not produced for the general and practical test.

$$\bar{h}_d = \frac{\rho \bar{v}^2}{2}$$

$$\bar{v} = \frac{1}{20} \sqrt{\frac{2}{\rho}} (\sqrt{h_1} + \sqrt{h_2} + \dots\dots + \sqrt{h_{20}})$$

b) **When using orifice plate**

$$\bar{h}_{d1} = \frac{\rho_1}{2} \left(\frac{Q_1}{60A_1} \right)^2$$

$$\bar{h}_{d2} = \frac{\rho_2}{2} \left(\frac{Q_2}{60A_2} \right)^2$$

When using the test apparatus in figure 1 and figure 2 (in the case of figure 2, the loss pressure of inlet test duct is omitted), i.e. when the fan with only ducted outlet under the working condition and the inlet is open to atmospheric air, the fan total pressure shall be the sum of outlet static pressure and outlet dynamic pressure. The fan static pressure shall be expressed by the outlet static pressure only in this case.

$$p_{t1} = 0$$

$$p_T = p_{t2} = p_{s2} + p_{d2} \dots\dots\dots (7')$$

$$p_S = p_{t2} - p_{d2} = p_{s2} \dots\dots\dots (8')$$

When using the test apparatus in figure 3, i.e. when the fan with only ducted inlet under the working condition and the outlet is open to atmospheric air, the fan total pressure shall be expressed by the inlet static pressure. The fan static pressure in this case is not obtained unless the inlet dynamic pressure is added to the inlet static pressure (negative pressure).

$$p_{t2} = p_{d2}$$

$$p_T = p_{d2} - p_{t1} = -p_{s1} \dots\dots\dots (7'')$$

$$p_S = -p_{t1} = -p_{s1} + p_{d1} \dots\dots\dots (8'')$$

$$p_{d2} = \frac{\rho_2}{2} \left(\frac{Q_2}{60A'_2} \right)^2 \dots\dots\dots (13)$$

$$p_{d1} = \frac{\rho_1}{2} \left(\frac{Q_1}{60A'_1} \right)^2 \dots\dots\dots (14)$$

For the fan with both ducted inlet and ducted outlet under the working condition, the dynamic pressure of the inlet and the outlet shall be regarded as being equal at the pressure ratio of 1.03 or under, and the difference between the outlet static pressure and the inlet static pressure becomes the fan total pressure. In this case, the fan static pressure is not obtained unless the outlet dynamic pressure is further subtracted from the difference between the outlet static pressure and the inlet static pressure.

When using the test apparatus in figure 4

In the case of a) The fan static pressure p_s is equivalent to h_{s2} .

In the case of b) The fan static pressure p_s is equivalent to $-h_{s1}$.

6.3.3 Determination of air volume

a) The determination in the case of Pitot tube shall be performed as follows:

$$Q_1 = 60A \bar{v}_1 = 60A_1 \sqrt{\frac{2\bar{h}_{d1}}{\rho_1}} \dots\dots\dots (15)$$

$$Q_2 = 60A \bar{v}_2 = 60A_2 \sqrt{\frac{2\bar{h}_{d2}}{\rho_2}} \dots\dots\dots (16)$$

The conversion of the outlet air volume Q_2 into the inlet air volume Q_1 shall be performed according to the formulae (17), (18).

$$Q_1 = \frac{60A_2}{\rho_1} \sqrt{2\rho_2 \bar{h}_{d2}} \dots\dots\dots (17)$$

$$\rho_1 = \rho_2 \frac{P_{s1}}{P_{s2}} \cdot \frac{T_2}{T_1} \dots\dots\dots (18)$$

In addition, when the pressure ratio is 1.03 or less, ρ_1 shall be regarded as being equal to ρ_2 .

b) The determination in the case of orifice plate shall be performed as follows:

$$Q_1 = 60\alpha_n \varepsilon A_n \sqrt{\frac{2h_n}{\rho_1}} \dots\dots\dots (19)$$

$$Q_2 = 60\alpha_n \varepsilon A_n \sqrt{\frac{2h_n}{\rho_n}} \dots\dots\dots (20)$$

The conversion of the outlet air volume Q_2 into the inlet air volume Q_1 shall be performed according to the formula (21).

$$Q_1 = \frac{60\alpha_n \varepsilon A_n}{\rho_1} \sqrt{2\rho_n h_n} \dots\dots\dots (21)$$

The relation between ρ_1 and ρ_2 shall be according to the formula (18).

The value of the flowrate coefficient of orifice plate α_n to the area ratio $\beta^2 = \left(\frac{d}{D}\right)^2$ is shown in figure 16. The applicable range shall be as follows:

- 1) $10^5 \leq R_D \leq 2 \times 10^6$
- 2) $0.05 \leq \beta^2 \leq 0.64$
- 3) $50 \leq D \leq 1\,000 \text{ mm}$

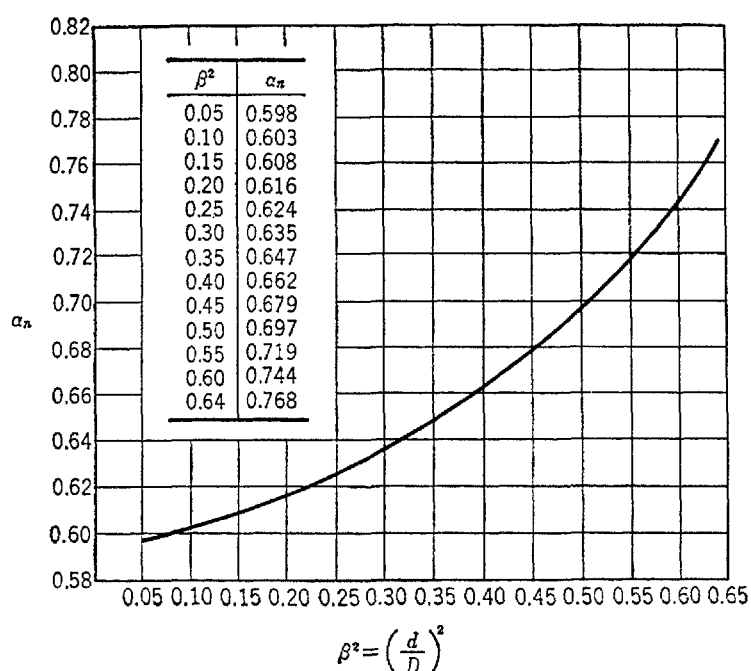


Figure 16 Flowrate coefficient of orifice plate

The value of expansibility factor ε to the pressure ratio $\frac{P_2}{P_1}$ just before and after the orifice plate is shown in figure 17.

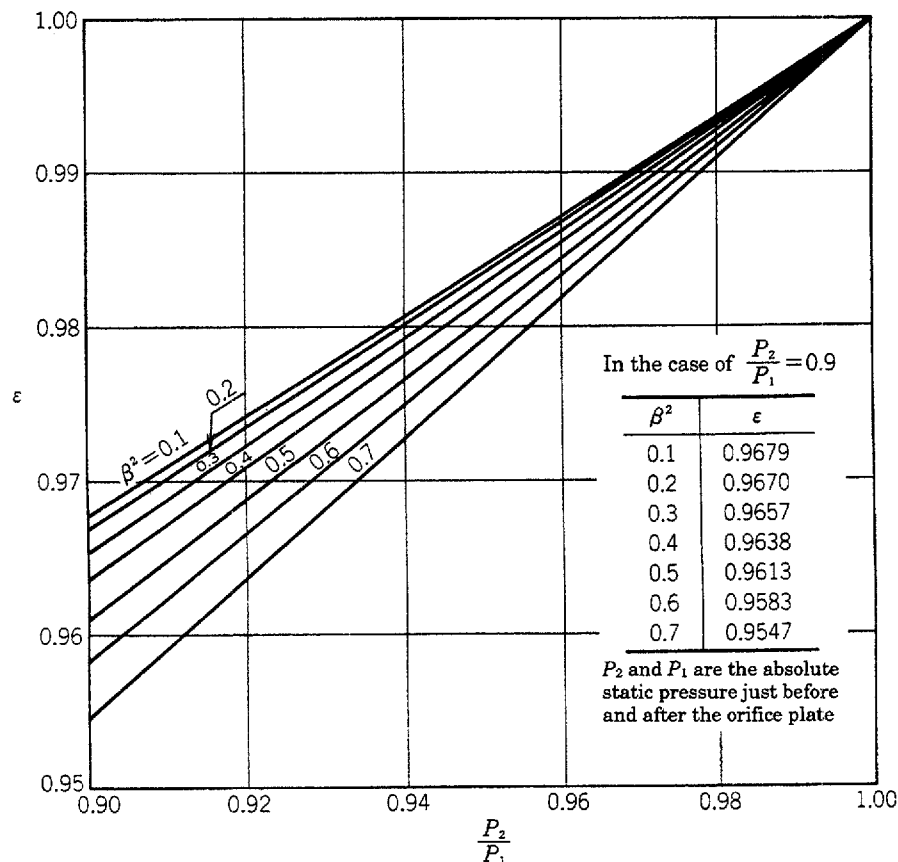


Figure 17 Expansibility factor of orifice plate
($\kappa = 1.40$)

- c) The determination in the case of inlet nozzle shall be performed as follows:

$$Q_1 = 60 \alpha_0 A_1 \sqrt{\frac{2h_n}{\rho_1}} \dots\dots\dots (22)$$

In addition, it shall apply to $R_D \geq 5.5 \times 10^4$.

Information : The error range in this case is $\pm 1 \%$.

6.3.4 Determination of total efficiency⁽⁹⁾ The total efficiency shall be determined as follows:

$$\text{Total efficiency } \eta_T = \frac{\text{Total air power}^{(10)} L_T (\text{kW})}{\text{Shaft power } L (\text{kW})} \times 100 (\%) \dots\dots (23)$$

Notes ⁽⁹⁾ For the static efficiency η_s , see Information.

⁽¹⁰⁾ The total air power shall be determined according to the formula (24).

$$\text{Total air power } L_T = \frac{\kappa}{\kappa - 1} \cdot \frac{P_{T1} Q_1}{6 \times 10^4} \left[\left(\frac{P_{T2}}{P_{T1}} \right)^{\frac{\kappa-1}{\kappa}} - 1 \right] (\text{kW}) \dots\dots\dots (24)$$

When the pressure ratio $\frac{P_{S2}}{P_{S1}}$ is not more than 1.03, it shall be determined according to the formula (25).

$$\text{Total air power } L_T = \frac{Q_1}{6 \times 10^4} [(P_{S2} - P_{S1}) + (p_{d2} - p_{d1})] \text{ (kW) } \dots\dots (25)$$

Remarks : When the test rotational speed is different from the specified rotational speed, it shall be converted in accordance with 6.2.

$$\text{Information : Static air power } L_S = \frac{\kappa}{\kappa - 1} \cdot \frac{P_{S1} Q_1}{6 \times 10^4} \left[\left(\frac{P_{S2}}{P_{S1}} \right)^{\frac{\kappa-1}{\kappa}} - 1 \right] \text{ (kW) } \dots\dots\dots (26)$$

When the pressure ratio $\frac{P_{S2}}{P_{S1}}$ is not more than 1.03, it shall be determined according to the formulae (27), (28).

$$\text{Static air power } L_S = \frac{Q_1}{6 \times 10^4} [(P_{S2} - P_{S1}) - p_{d1}] \text{ (kW) } \dots\dots\dots (27)$$

$$\text{Static efficiency } \eta_s = \frac{\text{Static air power } L_S \text{ (kW)}}{\text{Shaft power } L \text{ (kW)}} \times 100 \text{ (\%)} \dots\dots\dots (28)$$

7 Conversion when density, rotational speed, and temperature and pressure of air are different

7.1 When density is different When the density of gas handled differs from the value of density of the test air, the test result shall be converted by the following formulae. For the pressure conversion when the pressure ratio exceeds about 1.1, it shall be determined according to the calculation formulae for the case that the inlet temperature is different specified in **JIS B 8340**.

Air volume of gas handled = air volume of test air

Fan total pressure or static pressure of gas handled = $\left(\frac{\rho_0}{\rho_1} \right) \times$ (fan total pressure or static pressure in the case of test air)

Air power of gas handled = $\left(\frac{\rho_0}{\rho_1} \right) \times$ (air power of test air)

Shaft power of gas handled = $\left(\frac{\rho_0}{\rho_1} \right) \times$ (shaft power of test air)

Efficiency of gas handled = efficiency of test air

where

ρ_0 = Density of gas handled (kg/m³)

ρ_1 = Density of test air (kg/m³)

7.2 When rotational speeds are different When the fan is tested at the rotational speed (n_t) other than the specified rotational speed (n), the result shall be converted by the following formulae. For the pressure conversion when the pressure ratio exceeds about 1.1, it shall be determined according to the calculation formulae for the case that the rotational speed is different specified in **JIS B 8340**.

Air volume at specified rotational speed = (air volume at test rotational speed) $\times \left(\frac{n}{n_t}\right)$

Fan total pressure or static pressure at specified rotational speed = (fan total pressure or static pressure at test rotational speed) $\times \left(\frac{n}{n_t}\right)^2$

Air power at specified rotational speed = (air power at test rotational speed) $\times \left(\frac{n}{n_t}\right)^3$

Shaft power at specified rotational speed = (shaft power at test rotational speed) $\times \left(\frac{n}{n_t}\right)^3$

Efficiency at specified rotational speed = efficiency at test rotational speed

Noise level at specified rotational speed [dB (A)] = (noise level at test rotational speed) [dB (A)] + $50 \log_{10} \left(\frac{n}{n_t}\right)$

Information : The conversion formula of noise level is an empirical formula, and not always applied in all cases.

8 Test report The test report shall be as follows:

- a) The test result shall be filled in the fan test report and the fan performance curve sheet.
- b) The fan manufacturer's name, type, product number, test number, orderer's name, specified item and test result for this, test method and apparatus, power transmission system, dimensions of test duct, testing date, tester's name, dynamometer used for test or matters related to prime mover, etc. shall be stated clearly (see attached table 1 and attached table 2).
- c) All the test reports converted into the specified condition shall be shown diagrammatically in the performance curve sheet with air volume as abscissa against as fan total pressure or fan static pressure, shaft power, efficiency, rotational speed, etc. as ordinate, and the specified main points shall be indicated with the symbol like  (see attached table 1).
- d) When the operational condition is as described in the following, these shall be filled in the remarks column of the test report and performance curve sheet.
 - 1) When the bearing temperature is higher than the specified temperature, or unless specified, when it is higher than the air temperature by 40 °C or higher.
 - 2) When an oscillation is intense and operation is not smooth.
 - 3) In addition, when there are matters which are not accepted to be normal for the prime mover, transmission gear, etc.

9 Inspection method

9.1 Inspection item The inspection item shall be as follows:

The fan total pressure or fan static pressure and air volume, shaft power, total efficiency, noise, operational condition.

9.2 Fan total pressure or fan static pressure and air volume The test shall be performed in accordance with clause 6, and the inspection shall be performed as follows:

- a) The fan total pressure or fan static pressure and air volume shall be judged at the specified point according to the following criterion I or criterion II.

Criterion I In the case of the general air blasting which is not restricted with respect to the fan total pressure or fan static pressure, or a permissible range of air volume, the air volume of the fan total pressure or fan static pressure is accepted if only it is not less than the specified air volume.

Criterion II In the case of the general air blasting which is especially restricted with respect to the fan total pressure or fan static pressure, or a permissible range of air volume, the performance curve shall meet either of the following conditions.

- 1) The air volume of the specified fan total pressure or fan static pressure shall be within the range between 100 % to 110 % of the specified air volume.
 - 2) The total pressure or static pressure of the specified air volume shall be within the range between 100 % to 106 % of the specified fan total pressure or fan static pressure.
- b) Unless agreed beforehand, the difference between the air volume of the surging point and the air volume of the assumed surging point shall be not more than 25 % of the difference between the specified air volume and the air volume of assumed surging point.

Remarks : When the test rotational speed is different from the specified rotational speed, the conversion shall be performed in accordance with 7.2.

9.3 Shaft power The test shall be performed in accordance with 6.2.5, and the required power shall not exceed the specified power of prime mover at the specified air volume. Also it shall not exceed the specified power at the air volume of the intersection point of the system resistance curve of apparatus to be used (when there is the specified or assumed system resistance curve, the system resistance curve) and the fan performance curve. However, when it is obvious that the adjustment operation can be performed so that the using air volume does not exceed the specified air volume, the required power may exceed the specified power at the air volume which exceeds the specified air volume.

Remarks : The test rotational speed is different from the specified rotational speed, the conversion shall be performed in accordance with 7.2.

9.4 Total efficiency When the total efficiency is specified, the specified value η_n shall be satisfied. Even when the value of total efficiency η_T (%) obtained by the test is lower than the assured total efficiency η_n (%), the total efficiency is accepted if only $\eta_T \geq \eta_n - (6 - 0.05\eta_n)$ is satisfied.

9.5 Noise The noise test shall be performed in accordance with 6.2.6, and any abnormal noise shall not be allowed. For reference, the noise value is shown in figure 18 to figure 22. However, it is not applied to the fan built in a machine, or the fan built in a package.

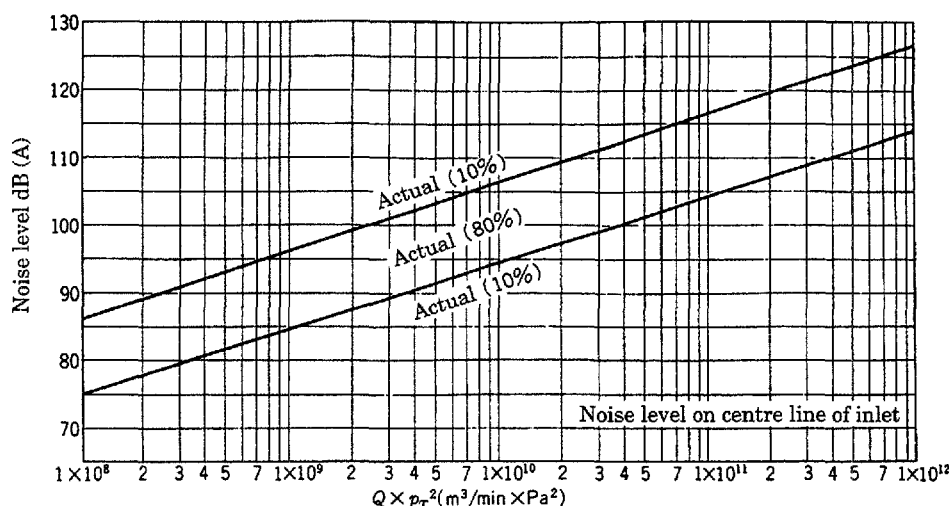


Figure 18 Noise level of backward fan (informative)
(Maximum efficiency point)

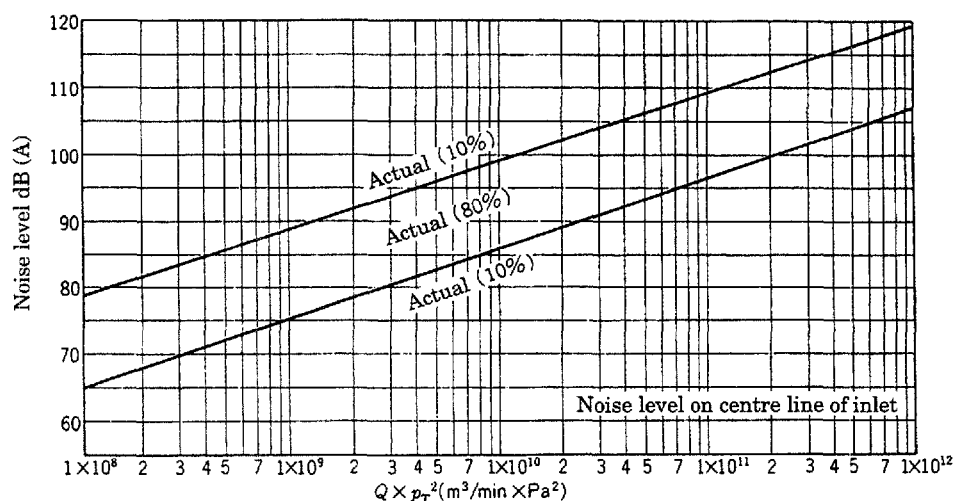


Figure 19 Noise level of airfoil fan (informative)
(Maximum efficiency point)

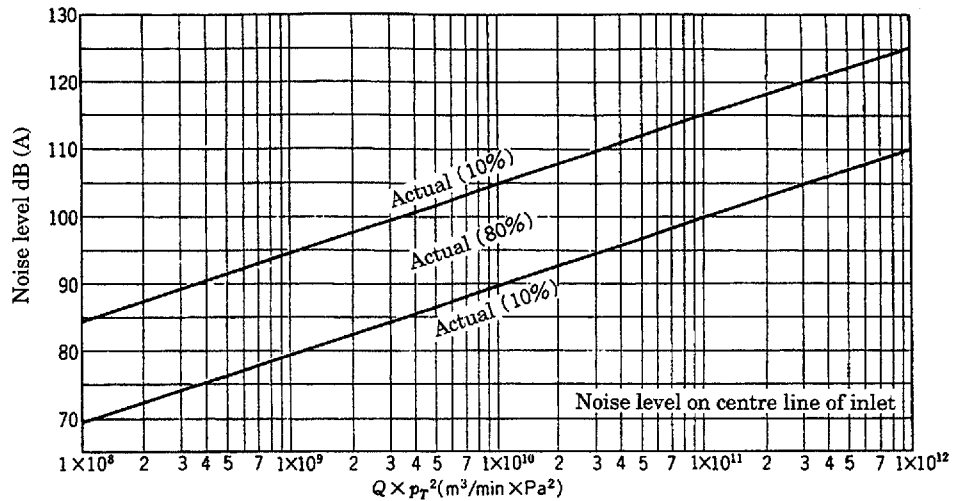


Figure 20 Noise level of radial fan (informative)
(Maximum efficiency point)

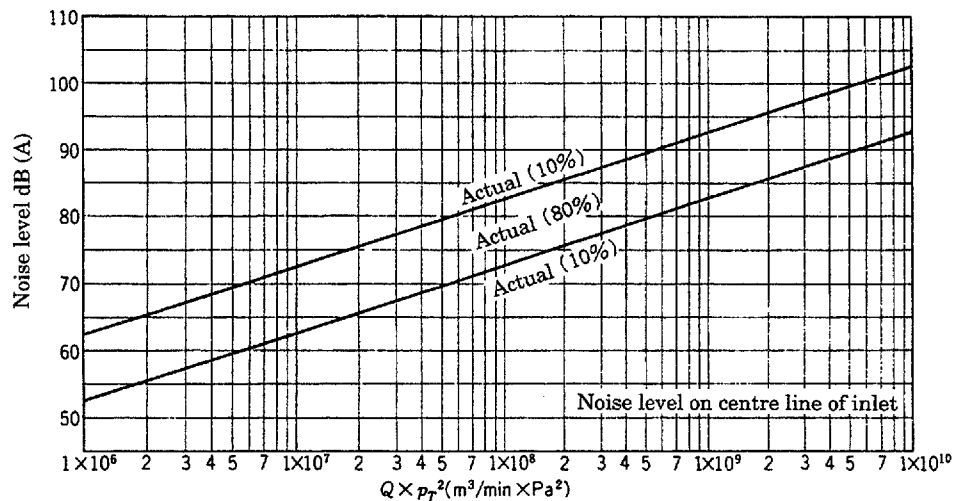


Figure 21 Noise level of multiblade fan (informative)
(Maximum efficiency point)

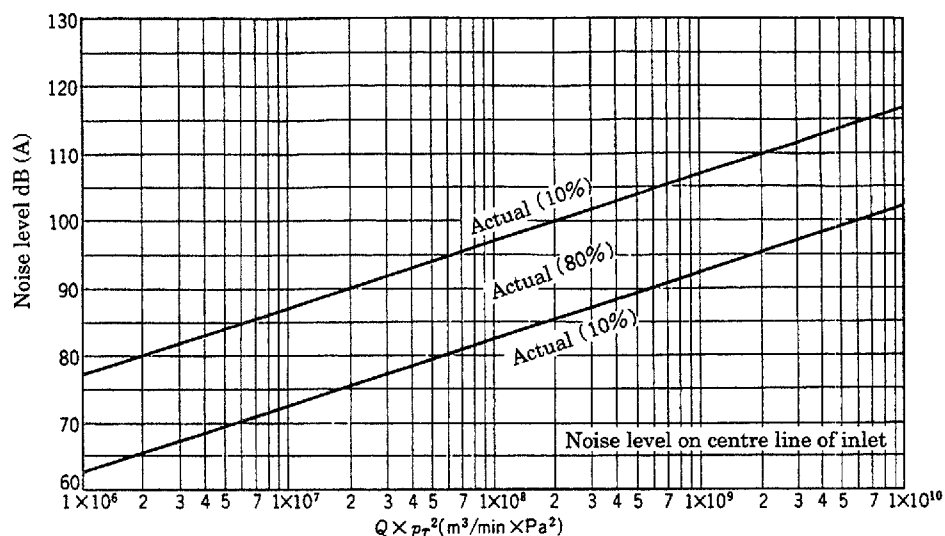


Figure 22 Noise level of axial flow fan (informative)
(Maximum efficiency point)

9.6 Operational condition The test of operational condition shall be performed in accordance with 6.2.7 and the operational condition shall be as follows:

- When the bearing temperature is not specified, the temperature higher than the surrounding air temperature by not less than 40 °C shall not be allowed.
- The oscillation at each part shall be slight, and the operation shall be smooth. For reference, the permissible value of oscillation is shown in figure 23.

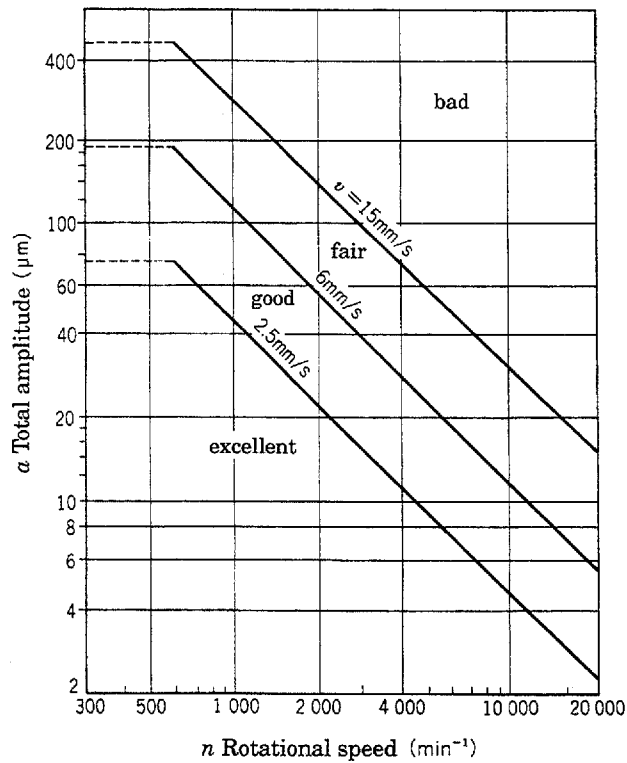


Figure 23 Tolerance of oscillation (informative)
(On the bearing housing)

Remarks : Since the oscillation at the prime mover side may have an effect on the fan, for the shaft coupling, care shall be taken sufficiently.

Information : The relation between the total amplitude a (μm) and the oscillating velocity v (mm/s) is as follows:

$$v = \frac{a\omega}{2 \times 10^3} = \frac{a\pi n}{6 \times 10^4}$$

where

$$\omega : \text{angular velocity} = \frac{2\pi n}{60} \text{ (rad/s)}$$

Attached Table 1 Fan test report

Orderer's name _____ Manufacture number _____ Test date _____
 Size and type _____ Use _____ Test (reference) number _____
 Observer _____

Specified item	Air volume m ³ /min	Fan total (static) pressure Pa (gauge pressure)	Rotational speed min ⁻¹	Power kW	Gas density kg/m ³	Temperature	Gas humidity	Total efficiency
Measuring item								
Air volume	Reading of instrument	Pa	1	2	3	4	5	6
	Flowrate coefficient							
	Air temperature	°C						
	Air volume	m ³ /min						
Pressure (gauge pressure)	Inlet static pressure	Pa						
	Outlet static pressure	Pa						
	Dynamic pressure	Pa						
	Fan dynamic pressure	Pa						
	Test duct loss pressure	Pa						
	Fan static pressure	Pa						
	Fan total pressure	Pa						
Theoretical air power		kW						
Electric motor	Rotational speed	min ⁻¹						
	Voltage	V						
	Current	A						
	Efficiency	%						
	Output	kW						
Efficiency of transmission gear		%						
Fan rotational speed		min ⁻¹						
Shaft power		kW						
Total (static) efficiency		%						
Converted into specified condition	Air volume	m ³ /min						
	Pressure (gauge pressure)	Pa						
	Shaft power	kW						
	Rotational speed	min ⁻¹						
Bearing temperature	Shaft coupling side	°C						
	Opposite side	°C						
Oscillation	Shaft coupling side	μm						
	Opposite side	μm						
Atmospheric air	Pressure	kPa						
	Temperature	°C						
	Relative humidity	%						

Electric motor item
(for attachment and test)

Type

Output kW

Frequency Hz

Voltage V

Current A

Rotation min⁻¹

Manufacture number

Manufacturer's name

Air volume instrument

Dimensions of
instrument above

Test apparatus

Volt meter scale factor

Ammeter scale factor

Wattmeter scale factor

At startup

At shutdown

Continuous operational
period of time

Noise

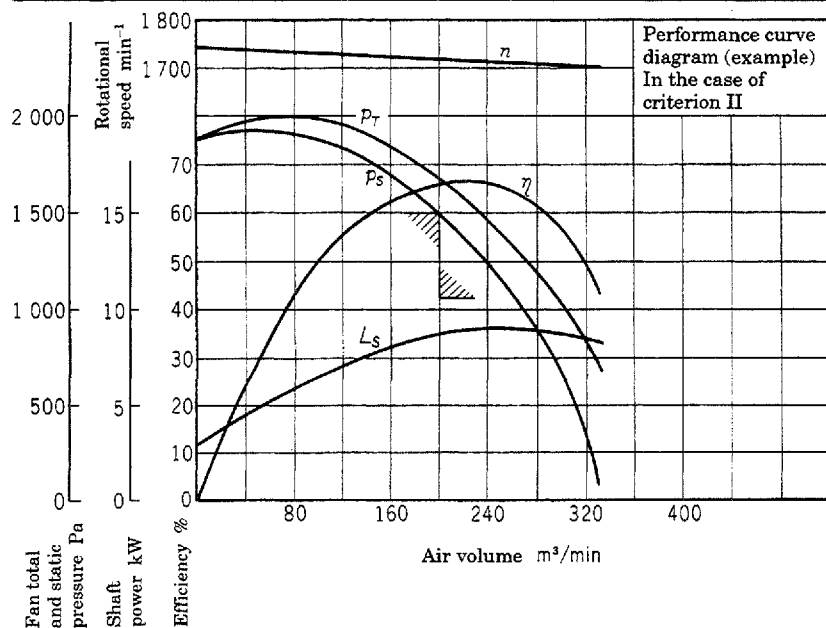
Remarks

Brief

Curve diagram converted into
specified condition

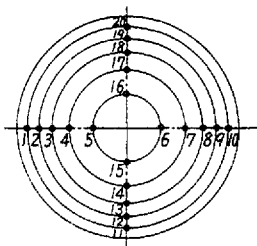
Manufacturer's name

Tester's name



Attached Table 2 Fan test report

																	Manufacturer's name				
																	Test date				
																	Observer				
																	Person in charge of test				
Orderer's name				Product number				Test number													
Specified item	Type					Nozzle size				Fan total (static) pressure				Pa (gauge pressure)							
	Air volume	m ³ /min				Temperature				°C				Humidity		%					
	Rotational speed	min ⁻¹				Electric motor				kW				Total (static) efficiency		%					
Measurement number	Measurement time	Measured value																Loss pressure Pa			
			Measurement location number from windward side																		Average value
			1	2	3	4	5	6	7	8	9	10		16	17	18	19				
1		Static pressure Pa																			
		Static pressure Pa																			
2		Static pressure Pa																			
		Static pressure Pa																			
		(hereafter, as stated above)																			
Brief																					
Remarks																					



(see figure 12)

Chart for reference

Annex (informative)

Industrial fans—Performance testing using standardized airways

Foreword This Annex is the Japanese Industrial Standard prepared based on ISO 5801 published in 1997 without any modification in technical contents.

This Annex has the following annexes.

Annex A (normative) Fan pressure and fan installation types

Annex B (normative) Fan-powered roof exhaust ventilators

Annex C (normative) Direct calculation of p_{sgn} and p_n at section n of the fan—
Installation types B, C and D

Annex D (informative) Fan outlet elbow in case of a non-horizontal discharge
axis

Annex E (informative) Bibliography

Introduction This Annex is the comprehensive compilation of discussions, comparative tests and detailed analyses for about 30 years by the leading experts and research institutions of the fan industry of each country.

It had been pointed out from times past that the fan performance test standard established by each country had not always reached the same result.

The necessity for the International Standard was called for over many years, and ISO/TC 117 made a start on the work in 1963. Since then the significant progress has been seen, and although the International Standard itself has not yet been published, the marked unification came to be obtained by the revision of standard of each country after that.

At present the International Standard which is the original of this Annex was summarized based on the agreement of some important points. In consideration of the test apparatus, especially that of a large-sized fan being very expensive, it was necessary to adopt various kinds of the apparatus construction in the standards of each country for the current standard to authorize their future use. Therefore, this Annex is a voluminous document as it is.

The main descriptions of this Annex are as follows.

a) Types of installation

Since the connection of outlet and/or inlet of fan and duct affects a performance, it was agreed that the types of installation were classified into four types of standard installation.

To be more precise,

Type A: free inlet and free outlet

Type B: free inlet and ducted outlet

Type C: ducted inlet and free outlet

Type D: ducted inlet and ducted outlet

The fan which is suitable for two or more types of installation indicates that it has the two or more standardized performance characteristics. The user should select from the types available the one which is closest to his application.

b) Common segments

The difference of results obtained by testing the same fan according to various test standards depends mainly on the flow pattern of fan outlet, and it is usually slight, but may become remarkable. In general, all standard test air ways used for fans have the common segments near the inlet and/or outlet, and therefore, there is an agreement that it is enough to assure the consistency of fan pressure determination.

The difference of shapes of common segments is strictly limited. However, some specific situations have reached the conventional agreement.

- 1) In the case of centrifugal fans or cross flow fans which do not produce an outlet swirl, when discharging to atmospheric air or to the test chamber, the simplified outlet duct without a flow straightener described in **30.2 f)** may be used.
- 2) In the case of large fans (of which the outlet diameter is 800 mm or over), it is difficult to perform the test using the common standard airway including the flow straightener at the outlet side. In this case, the fan performance may be measured using the apparatus described in **30.2 f)** having the duct of $2D$ in length at the outlet side by agreement of parties concerned. However, the result obtained by this method, especially when a large whirl is produced according to fans, differs by some degrees from the result obtained by using the regular installation type D. There is no other way but to expect a future research for confirming the degree of the difference value which may occur.

c) Determination

The fan pressure is defined as the difference between the stagnation pressure at the outlet of the fan and the stagnation pressure at the inlet of the fan. The compressibility of air shall be taken into consideration in order to obtain a high accuracy. However, when the reference Mach number does not exceed 0.15, the simplified method may be used.

The determination of the stagnation pressure at the reference cross section and the fluid pressure or static pressure is specified in Annex C according to the study of the specially set-up group of **ISO/TC117/SC1** subcommittee.

For the determination of the theoretical air power or efficiency of the fan, three methods are proposed. These three methods give the same results within a few parts of thousand for a pressure ratio equal to 1.3.

d) Measurement of flowrate

The determination of flowrate is separated from the determination of fan pressure completely. The various standardized methods are available.

1 Scope This Annex deals with the determination of the performance of industrial fans of all types except those designed solely for air circulation e.g. ceiling fans and table fans.

Estimates of uncertainty of measurement are provided and rules for the conversion, within specified limits, of test results for changes in speed, gas handled and, in the case of model tests, size and given.

2 Normative references The following standards contain provisions which, through reference in this text, constitute provisions of this Annex. 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.

- ISO 3966 : 1977 *Measurement of fluid flow in closed conduits—Velocity area method using Pitot static tubes*
- 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 : 1998 *Measurement of fluid flow—Evaluation of uncertainties*
- ISO 5221 : 1984 *Air distribution and air diffusion—Rules to methods of measuring air flowrate in an air handling duct*
- IEC 60034-2 : 1972 *Rotating electrical machines—Part 2 : Methods for determining losses and efficiency of rotating electrical machinery from tests (excluding machines for traction vehicles)*
- IEC 60051-2 : 1984 *Direct acting indicating analogue electrical-measuring instruments and their accessories—Part 2 : Special requirements for ammeters and voltmeters*
- IEC 60051-3 : 1984 *Direct acting indicating analogue electrical-measuring instruments and their accessories—Part 3 : Special requirements for wattmeters and varmeters*
- IEC 60051-4 : 1984 *Direct acting indicating analogue electrical-measuring instruments and their accessories—Part 4 : Special requirements for frequency meters*

3 Definitions For the purposes of this Annex, the definitions given in **ISO 5168** and the following definitions apply.

NOTE 1 All the symbols used in this Annex are listed with their units in clause 4.

3.1 area of the conduit section, A_x : Area of the conduit at section x .

3.2 fan inlet area, A_1 : Surface plane bounded by the upstream extremity of the air-moving device.

The inlet area is, by convention, taken as the gross area in the inlet plane inside the casting.

3.3 fan outlet area, A_2 : Surface plane bounded by the downstream extremity of the air-moving device.

Fan outlet area is, by convention, taken as the gross area in the outlet plane inside the casting.

3.4 temperature, t : Air or fluid temperature measured by a temperature sensor.

3.5 absolute temperature, Θ : Thermodynamic temperature.

$$\Theta = t + 273.15$$

NOTE 2 In this document, Θ represents the absolute temperature and t represents the temperature in degrees Celsius.

3.6 specific gas constant, R : For an ideal dry gas, the equation of state is written

$$\frac{p}{\rho} = R\Theta$$

$$R = 287 \text{ J} \cdot \text{kg}^{-1} \cdot \text{K}^{-1} \text{ for dry air.}$$

3.7 isentropic exponent, κ : For an ideal gas and an isentropic process,

$$\frac{p}{\rho^\kappa} = \text{constant}$$

$$\kappa = 1.4 \text{ for atmospheric air.}$$

3.8 specific heat capacity at constant pressure, c_p : For an ideal gas,

$$c_p = \frac{\kappa}{\kappa - 1} R$$

3.9 specific heat capacity at constant volume, c_v : For an ideal gas,

$$c_v = \frac{1}{\kappa - 1} R$$

3.10 compressibility factor, Z : For an ideal gas, $Z = 1$

For a real gas,

$$Z = \frac{p}{\rho R \Theta}$$

and Z is a function of the ratios p/p_c and Θ/Θ_c

where

p_c is the critical pressure of the gas;

Θ_c is the critical temperature of the gas.

3.11 stagnation temperature at a point, Θ_{sg} : Absolute temperature which exists at an isentropic stagnation point for ideal gas flow without addition of energy or heat.

The stagnation temperature is constant along an airway and, for an inlet duct, is equal to the absolute ambient temperature in the test enclosure.

3.12 static or fluid temperature at a point, Θ : Absolute temperature registered by a thermal sensor moving at the fluid velocity.

For a real gas flow,

$$\Theta = \Theta_{sg} - \frac{v^2}{2c_p}$$

where v = fluid velocity at a point, in metres per second ($\text{m} \cdot \text{s}^{-1}$).

In a duct, when the velocity increases the static temperature decreases.

3.13 dry-bulb temperature, t_a : Air temperature measured by a dry temperature sensor in the test enclosure, near the fan inlet or airway inlet.

3.14 wet-bulb temperature, t_w : Air temperature measured by a temperature sensor covered by a water-moistened wick and exposed to air in motion.

When properly measured, it is a close approximation of the temperature of adiabatic saturation.

3.15 stagnation temperature at a section x , Θ_{sgx} : Mean value, over time, of the stagnation temperature averaged over the area of the specified airway cross-section.

3.16 static or fluid temperature at a section x , Θ_x : Mean value, over time, of the static or fluid temperature averaged over the area of the specified airway cross-section.

3.17 absolute pressure at a point; absolute pressure, p : Pressure, measured with respect to absolute zero pressure, which is exerted at a point at rest relative to the air around it.

3.18 atmospheric pressure, p_a : Absolute pressure of the free atmosphere at the mean altitude of the fan.

3.19 gauge pressure, p_e : Value of the pressure when the datum pressure is the atmospheric pressure at the point of measurement.

It may be negative or positive.

$$p_e = p - p_a$$

3.20 absolute stagnation pressure at a point, p_{sg} : Absolute pressure which would be measured at a point in a flowing gas if it were brought to rest via an isentropic process:

$$p_{sg} = p \left(1 + \frac{\kappa - 1}{2} Ma^2 \right)^{\frac{\kappa}{\kappa - 1}}$$

where Ma is the Mach number at this point (see 3.23).

3.21 Mach factor, F_M : Correction factor applied to the dynamic pressure at a point, given by the expression

$$F_M = \frac{p_{sg} - p}{p_a}$$

The Mach factor may be calculated by

$$F_M = 1 + \frac{Ma^2}{4} + \frac{(2-\kappa)Ma^4}{24} + \frac{(2-\kappa)(3-2\kappa)Ma^6}{192} + \dots$$

3.22 dynamic pressure at a point, p_d : Pressure calculated from the velocity v and the density ρ of the air at the point.

$$p_d = \rho \frac{v^2}{2}$$

3.23 Mach number at a point, Ma : Ratio of the gas velocity at a point to the velocity of sound.

$$Ma = \frac{v}{\sqrt{\kappa R_w \Theta}} = \frac{v}{c}$$

where

c is the velocity of sound, $c = \sqrt{\kappa R_w \Theta}$

R_w is the gas constant of humid gas.

3.24 gauge stagnation pressure at a point, p_{esg} : Difference between the absolute stagnation pressure p_{sg} and the atmospheric pressure p_a .

$$p_{esg} = p_{sg} - p_a$$

3.25 mass flowrate, q_m : Mean value, over time, of the mass of air which passes through the specified airway cross-section per unit of time.

NOTE 3 The mass flow will be the same at all cross-sections within the fan airway system excepting leakage.

3.26 average gauge pressure at a section x , p_{ex} : Mean value, over time, of the gauge pressure averaged over the area of the specified airway cross-section.

3.27 average absolute pressure at a section x , p_x : Mean value, over time, of the absolute pressure averaged over the area of the specified airway cross-section.

$$p_x = p_{ex} + p_a$$

3.28 average density at a section x , ρ_x : Fluid density calculated from the absolute pressure p_x and the static temperature Θ_x .

$$\rho_x = \frac{p_x}{R_w \Theta_x}$$

where R_w is the gas constant of humid gas.

3.29 volume flowrate at a section x , q_{vx} : Mass flowrate at the specified airway cross-section divided by the corresponding mean value, over time, of the average density at that section.

$$q_{vx} = \frac{q_m}{\rho_x}$$

3.30 average velocity at a section x , v_{mx} : Volume flowrate at the specified airway cross-section divided by the cross-section area A_x .

$$v_{mx} = \frac{q_{vx}}{A_x}$$

NOTE 4 This is the mean value, over time, of the average component of the gas velocity normal to that section.

3.31 conventional dynamic pressure at a section x , p_{dx} : Dynamic pressure calculated from the average velocity and the average density at the specified airway cross-section.

$$p_{dx} = \rho_x \frac{v_{mx}^2}{2} = \frac{1}{2\rho_x} \left(\frac{q_m}{A_x} \right)^2$$

NOTE 5 The conventional dynamic pressure will be less than the average of the dynamic pressures across the section.

3.32 Mach number at a section x , Ma_x : Average gas velocity divided by the velocity of sound at the specified airway cross-section.

$$Ma_x = v_{mx} / \sqrt{\kappa R_w \Theta_x}$$

3.33 average stagnation pressure at a section x , p_{sgx} : Sum of the conventional dynamic pressure p_{dx} corrected by the Mach factor coefficient F_{Mx} at the section and the average absolute pressure p_x :

$$p_{sgx} = p_x + p_{dx} F_{Mx}$$

NOTE 6 The average stagnation pressure may be calculated by the expression

$$p_{sgx} = p_x \left(1 + \frac{\kappa - 1}{2} Ma_x^2 \right)^{\frac{\kappa}{\kappa - 1}}$$

3.34 gauge stagnation pressure at a section x , p_{esgx} : Difference between the average stagnation pressure, p_{sgx} , at a section and the atmospheric pressure, p_a .

$$p_{esgx} = p_{sgx} - p_a$$

3.35 inlet stagnation temperature, Θ_{sg1} : Absolute temperature in the test enclosure near the fan inlet at a section where the gas velocity is less than $25 \text{ m} \cdot \text{s}^{-1}$.

In this case the stagnation temperature may be considered as equal to the ambient temperature Θ_a .

$$\Theta_{sg1} = \Theta_a = t_a + 273.15$$

3.36 stagnation density, ρ_{sg1} : Density calculated from the inlet stagnation pressure p_{sg1} and the inlet stagnation temperature Θ_{sg1} :

$$\rho_{sg1} = \frac{p_{sg1}}{R_w \Theta_{sg1}}$$

3.37 inlet stagnation volume flowrate, q_{Vsg1} : Mass flowrate divided by the inlet stagnation density.

$$q_{Vsg1} = \frac{q_m}{\rho_{sg1}}$$

3.38 fan pressure, p_F : Difference between the stagnation pressure at the fan outlet and the stagnation pressure at the fan inlet.

$$p_F = p_{sg2} - p_{sg1}$$

When the Mach number is less than 0.15,

$$p_F = p_{tF} = p_{t2} - p_{t1}$$

NOTE 7 Fan pressure should be referred to the installation type A, B, C or D.

3.39 fan dynamic pressure, p_{d2} : Average dynamic pressure at the fan outlet calculated from the mass flowrate, the average gas density at the outlet and the fan outlet area.

$$p_{d2} = \rho_2 \frac{v_{m2}^2}{2} = \frac{1}{2\rho_2} \left(\frac{q_m}{A_2} \right)^2$$

3.40 fan static pressure, p_{sF} : Conventional quantity defined as the fan pressure minus the fan dynamic pressure corrected by the Mach factor.

$$p_{sF} = p_{sg2} - p_{d2} \cdot F_{M2} - p_{sg1} = p_2 - p_{sg1}$$

NOTE 8 Fan static pressure should be referred to the installation type A, B, C or D.

3.41 mean density, ρ_m : Arithmetic mean value of inlet and outlet densities.

$$\rho_m = \frac{\rho_1 + \rho_2}{2}$$

3.42 mean stagnation density, ρ_{msg} : Arithmetic mean value of inlet and outlet stagnation densities.

$$\rho_{msg} = \frac{\rho_{sg1} + \rho_{sg2}}{2}$$

3.43 fan work per unit mass, y : Increase in mechanical energy per unit mass of fluid passing through the fan.

$$y = \frac{p_2 - p_1}{\rho_m} + \alpha_{A2} \frac{V_{m2}^2}{2} - \alpha_{A1} \frac{V_{m1}^2}{2}$$

y may be calculated as in 3.47, i.e.

$$y = \frac{P_u}{q_m}$$

The value obtained differs by only a few parts per thousand of the value given by the above expression:

NOTE 9 y should be referred to the installation type A, B, C or D.

3.44 fan static work per unit mass, y_s :

$$y_s = \frac{p_2 - p_1}{\rho_m} - \alpha_{A1} \frac{V_{m1}^2}{2}$$

NOTE 10 y_s should be referred to the installation type A, B, C or D.

3.45 fan pressure ratio, r : Ratio of the average absolute stagnation pressure at the outlet section of a fan to that at its inlet section.

$$r = p_{sg2}/p_{sg1}$$

3.46 compressibility coefficient, k_p : Ratio of the mechanical work done by the fan on the air to the work that would be done on an incompressible fluid with the same mass flow, inlet density and pressure ratio.

The work done is derived from the impeller power on the assumption of polytropic compression with no heat transfer through the fan casing.

k_p is given by the expression

$$k_p = \frac{Z_k \log_{10} r}{\log_{10} [1 + Z_k(r - 1)]}$$

where

$$Z_k = \frac{\kappa - 1}{\kappa} \cdot \frac{\rho_{sg1} P_r}{q_m P_r}$$

NOTE 11 k_p and ρ_{sg1}/ρ_{msg} differ by less than 2×10^{-3} .

3.47 fan air power, P_u : Conventional output power which is the product of the mass flow by the fan work per unit mass, or the product of the inlet volume flow, the compressibility coefficient k_p and the fan pressure.

$$P_u = q_m y = q_{Vsg1} \cdot p_F \cdot k_p$$

NOTE 12 P_u should be referred to the installation type A, B, C or D.

3.48 fan static air power, P_{us} : Conventional output power which is the product of the mass flowrate q_m by the fan static work per unit mass or the product of the inlet volume flowrate, the compressibility coefficient k_{ps} and the fan static pressure p_{sF} ; k_{ps} is calculated using $r = p_2/p_{sg1}$.

$$P_{us} = q_m \gamma_s = q_{Vsg1} \cdot k_{ps} \cdot p_{sF}$$

NOTE 13 P_{us} should be referred to the installation type A, B, C or D.

3.49 impeller power, P_r : Mechanical power supplied to the fan impeller.

3.50 fan shaft power, P_a : Mechanical power supplied to the fan shaft.

3.51 motor output power, P_o : Shaft power output of the motor or other prime mover.

3.52 motor input power, P_e : Electrical power supplied at the terminals of an electric motor drive.

3.53 rotational speed of the impeller, N : Number of revolutions of the fan impeller per minute.

3.54 rotational frequency of the impeller, n : Number of revolutions of the fan impeller per unit time.

3.55 tip speed of the impeller, u : Peripheral speed of the impeller blade tips.

3.56 peripheral Mach number, Ma_u : Dimensionless parameter equal to the ratio of tip speed to the velocity of sound in the gas at the stagnation conditions of fan inlet:

$$Ma_u = u / \sqrt{\kappa R_w \Theta_{sg1}}$$

3.57 fan impeller efficiency, η_r : Fan air power divided by the impeller power P_r .

$$\frac{P_u}{P_r}$$

NOTE 14 η_r shall be referred to the installation type A, B, C or D.

3.58 fan impeller static efficiency, η_{sr} : Fan static power divided by the impeller power.

NOTE 15 η_{sr} should be referred to the installation type A, B, C or D.

3.59 fan shaft efficiency, η_a : Fan air power divided by the fan shaft power.

NOTES 16 Fan shaft power includes bearing losses, whilst fan impeller power does not.

17 η_a should be referred to the installation type A, B, C or D.

3.60 fan motor shaft efficiency, η_o : Fan air power P_u divided by the motor output power P_o .

NOTE 18 η_o should be referred to the installation type A, B, C or D.