

JIS

JAPANESE INDUSTRIAL STANDARD

**Testing Methods of Turbo
Blowers and Compressors for
Gases by Loop Arrangement**

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In the event of any doubt arising,
the original Standard in Japanese is to be final authority.

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Testing Methods of Turbo Blowers and
Compressors for Gases by Loop ArrangementB 8345-1976
(Reaffirmed: 1984)1. Scope

This Japanese Industrial Standard specifies methods for test and inspection carried out in loop arrangement using specified gas or test gas, to examine performances of blowers and compressors, hereinafter referred to as the "compressors", which are of centrifugal, axial flow or mixed flow type with a pressure ratio of approximately 1.1 or more, and serve for gases other than air or air the suction condition of which remarkably differs from ordinary temperature and ordinary pressure, hereinafter referred to as the "gases".

In the test carried out under special situation or in the test of compressor which is difficult to satisfy the requirements of this Standard, agreement shall be made between the parties concerned with the acceptance, and this Standard shall be applied after appropriate retrenchment and supplementation.

Remark: The units and numerical values shown in { } in this Standard are in accordance with the International System of Units (SI) and with the unit which can be used with SI unit and are appended for informative reference.

Applicable Standards:

JIS B 0132-Glossary of Terms for Fans, Blowers and Compressors

JIS B 7505-Bourdon Tube Pressure Gauges

JIS B 7521-Portable Chronometric Tachometers

JIS B 8340-Testing Methods for Turbo-Blowers and Compressors

JIS C 1602-Thermocouples

JIS K 0050-General Rules for Chemical Analysis

JIS K 0061-Testing Methods for Specific Gravity of Chemical Products

JIS K 0114-General Rules for Analytical Method in Gas Chromatography

JIS K 0117-General Rules for Infrared Absorption Photometric Analysis

JIS K 0118-General Rules for Mass Spectrometric Analysis

JIS Z 8704-Electrical Methods of Temperature Measurements

JIS Z 8705-Method of Temperature Measurement by Liquid-in-Glass
Thermometers

JIS Z 8710-General Rules for Temperature Measurements

JIS Z 8762-Measurement of Fluid Flow by Means of Orifice Plates and
Nozzles

JIS Z 8763-Measurement of Fluid Flow by Means of Venturi Tubes

2. Definitions

For the purpose of this Standard, in addition to the definitions of JIS B 0132, the following principal definitions shall apply:

- (1) perfect gas The gas which satisfies the following characteristic equation:

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

where

P : absolute pressure (kgf/m²){Pa}

v : specific volume (m³/kgf){m³/kg}

R : gas constant (kgf·m/kgf·K){J/kg·K}

T : absolute temperature (K)

- (2) real gas The gas which does not satisfy the conditions of perfect gas (see Explanation Table 4).
- (3) specified gas The gas which is agreed between the parties concerned with the acceptance and used in actual running.
- (4) test gas The gas which is used as the substitute for specified gas at the time of carrying out performance test.
- (5) total condition The condition which appears when the flow of gas is interrupted isentropically.
- (6) gas volume The volume of gas discharged from a compressor per unit time, expressed in the volume at compressor suction opening under total condition calculated by conversion.
- (7) suction total pressure The total pressure of gas in the vicinity of suction flange of a compressor.
- (8) discharge total pressure The total pressure of gas in the vicinity of discharge flange of a compressor.
- (9) pressure ratio The ratio of absolute discharge total pressure and absolute suction total pressure.
- (10) suction total temperature The total temperature of gas in the vicinity of suction flange of a compressor.
- (11) discharge total temperature The total temperature of gas in the vicinity of discharge flange of a compressor.
- (12) temperature ratio The ratio of absolute discharge total temperature and absolute suction total temperature.
- (13) volume ratio The ratio of volume rate of flow of gas at suction opening and volume rate of flow of gas at discharge opening in a compressor.

- (14) isentropic head The work (head) necessary to transfer the weight per unit volume {mass per unit volume} of a gas by compression from the inlet to the outlet in reversible adiabatic compression process from the suction pressure to the discharge pressure.

Remark: This is also called adiabatic head in general.

- (15) polytropic head The reversible work (head) necessary to transfer the weight per unit volume {mass per unit volume} of a gas by compression in polytropic compression process.

- (16) theoretical isentropic power The power necessary to discharge a gas volume by carrying out isentropic compression from the suction pressure to the discharge pressure.

Remark: This is also called theoretical adiabatic power, in general.

- (17) theoretical polytropic power The power corresponding to the reversible work in the power necessary to discharge a gas volume by carrying out polytropic compression from the suction state to the discharge state.

- (18) internal power The power necessary to compress and discharge a gas without including the mechanical loss.

- (19) shaft power The input to main shaft of a compressor.

Remark: Where a compressor is driven by such drive as variable speed gear, the input to the drive shall be taken as the shaft power of compressor, if the measurement of power loss of the drive is difficult.

- (20) mechanical loss The power consumed by the mechanical friction working on the bearing, shaft seal part, etc., not including the power consumed by fluid friction such as disk friction.

- (21) overall efficiency The ratio of theoretical isentropic power or theoretical polytropic power to shaft power.

Remark: In general, efficiency of compressor means either one of the efficiencies prescribed above.

- (22) internal efficiency The ratio of theoretical isentropic power or theoretical polytropic power to internal power.

- (23) machine Reynolds number The number defined by the following formula:

$$Re_m = \frac{UB}{\nu} \text{ or } \frac{UL}{\nu} \dots\dots\dots(2)$$

where Re_m : machine Reynolds number

U : peripheral speed of the outside diameter of impeller or of tip of rotor blade, in first stage (m/s)

B : delivery width of first stage impeller in centrifugal type (m)

L : chord length of first stage rotor blade tip in axial flow type (m)

ν : kinematic viscosity of gas at suction opening of compressor (m²/s)

- (24) machine Mach number The ratio of the peripheral speed of the outside diameter of impeller or tip of rotor blade in the first stage, to the sonic speed in the gas at suction opening of a compressor.

- (25) specified point The point on performance curve determined between the parties concerned with the acceptance, at the time of carrying out performance test in accordance with this Standard.

- (26) specified speed The speed of rotation determined in the contract between the parties concerned with the acceptance. The number of revolution of a compressor per unit time where the compressor is run under the specified power supply conditions in the case of motor drive, or under the specified running conditions in the case of other prime mover drive.

Remark: Where the speed varies to some extent corresponding to the discharge pressure of compressor, the speed of compressor main shaft at the specified discharge pressure shall be taken as the representative value if indication of the value is necessary.

- (27) guarantee point The point on performance curve at which the manufacturer guarantees the performance.

3. Test Items and Inspection Items

3.1 Test Items The test items shall be as follows:

Gas volume, suction pressure and discharge pressure, suction temperature and discharge temperature, weight per unit volume of gas {density of gas}, speed of rotation, shaft power and surging limit.

3.2 Inspection Items The inspection items shall be as follows:

Gas volume, pressure rise (pressure ratio), shaft power and overall efficiency.

4. Classification of Tests

4.1 Class 1 Test This is the test carried out under the specified running conditions using the specified gas.

4.2 Class 2 Test This is the test other than Class 1 test and the following tests are the subject:

- (1) The test in which the specified gas is used but the running conditions differ from the specified conditions.
- (2) The test in which the running conditions are as specified but a gas differ from the specified gas is used.
- (3) The test in which both of the running conditions and the test gas differ from those specified.

The Class 2 test shall be carried out at the equivalent test speed and the volume ratio (flow-rate ratio) obtained from the following formula:

(3.1) Equivalent Test Speed

$$N_{eq} = N_{sp} \sqrt{\frac{\left[T_1 Z_1 R \left(\frac{n}{n-1} \right) \left(r_p^{\frac{n-1}{n}} - 1 \right) \right]_{eq}}{\left[T_1 Z_1 R \left(\frac{n}{n-1} \right) \left(r_p^{\frac{n-1}{n}} - 1 \right) \right]_{sp}}} \dots\dots\dots (3)$$

where

N_{eq} : equivalent test speed (rpm)

N_{sp} : specified speed (rpm)

T_1 : suction total temperature (K)

Z_1 : compressibility factor of gas under suction condition

R : gas constant (kgf·m/kgf·K){J/kg·K}

n : polytropic exponent in the Pv curve

r_p : pressure ratio = $\frac{P_2}{P_1}$

(3.2) Volume Ratio (Flow-Rate Ratio)

$$(r_v)_{eq} = (r_v)_{sp} \dots\dots\dots (4)$$

where r_v : volume ratio

Remark: Calculate the volume ratio from the following formula:

$$r_v = \frac{v_1}{v_2} = \frac{Q_1}{Q_2} \dots\dots\dots (5)$$

where r_v : volume ratio

v_1 : specific volume at suction opening
under total condition (m^3/kgf) { m^3/kg }

v_2 : specific volume at discharge opening
under total condition (m^3/kgf) { m^3/kg }

Q_1 : gas volume at suction opening under
total condition (m^3/min)

Q_2 : gas volume at discharge opening
under total condition (m^3/min)

5. Test Conditions5.1 Test Gas

5.1.1 Physical Characteristic Value Such physical characteristic values as gas constant R , ratio of specific heats C_p / C_v , compressibility factor Z and vapor pressure of the test gas shall be correctly known or easily obtained from the analysis and measurement in laboratory.

If the physical characteristic values of gas differ from the values previously agreed, the test results shall be ignored.

Remark: Measurement of Composition and Physical Characteristic Value of Gas The measurement of composition and physical characteristic values of gas, if unknown, shall be as follows:

- (1) As a rule, the physical characteristic values of gas shall be measured during the test. However, the measurement may be made after the test, if it is recognized that the physical characteristic values of the gas collected during the test do not change.
- (2) The physical characteristic values of gas consisting of two or less kinds may be obtained by measuring the specific gravity using a gas specific gravity measuring equipment ⁽¹⁾.

Note ⁽¹⁾ This measurement shall comply with JIS K 0061.

- (3) The physical characteristic values of gas consisting of three or more kinds shall be measured by spectrochemical analysis⁽²⁾, chromatograph analysis⁽³⁾, mass spectrometric analysis⁽⁴⁾ or chemical analysis⁽⁵⁾.

Notes (2) In accordance with JIS K 0117.

(3) In accordance with JIS K 0114.

(4) In accordance with JIS K 0118.

(5) In accordance with JIS K 0050.

- (4) Where two kinds of gas other than air are used, the physical characteristic values may be obtained by measuring the specific gravity using a gas densimeter, if it is possible to measure the mixing ratio of air remaining in the loop duct independently.

5.1.2 Compliance with Test Running Conditions In the case of testing with a test gas, the intended volume ratio at specified point shall be obtained and the machine Mach number and machine Reynolds number within the permissible deviations from the respective designed values shall be obtained under the equivalent test speed⁽⁶⁾.

If the mechanical loss exceeds 10 % of the total shaft power, the compliance of such case shall be agreed between the parties concerned with the acceptance.

Note (6) See Explanation 4. and Explanation Tables 1 to 3.

5.2 Test Speed (of rotation) The test shall be carried out at a speed close enough to specified speed (N_p) or equivalent test speed (N_q) according to the kind of test.

5.3 Measurement Point The measurement point shall be as follows:

- (1) The measurements under stable running conditions shall be carried out for the gas volume at specified point and for the gas volumes at two or more different points between which the specified point falls.
- (2) The measurements at specified point shall be carried out within the range where the ratio of gas volume to speed [(gas volume)/(speed)] is 96 % to 104 % of the specified value.
- (3) When the performance at a point other than specified point is obtained in Class 2 test, the speed may not necessarily be adjusted to the equivalent test speed at that point. However, for the measured values at a point outside of the range where the value of (gas volume)/(speed) is within 96 % to 104 % of the expected value, the management of such values shall be agreed between the parties concerned with the acceptance.
- (4) The verification test for surging limit shall be carried out, and as a rule, the measurement shall be carried out at the minimum stable gas volume close to the surging limit (see 7.8).

6. Test Equipment

The test equipment shall be capable of correctly measuring various values necessary to represent performances of compressors. The loop circuit shall consist of suction and discharge testing ducts, gas volume measuring duct, connecting duct, throttle valve, cooler, etc., and the basic arrangement of such apparatus shall be as shown in Fig. 1.

(1) Suction and Discharge Testing Ducts The suction and discharge testing ducts shall be as follows:

- (1.1) The suction and discharge testing ducts shall be circular straight pipes with smooth inner surface having, as a rule, the same diameter as the suction opening and discharge opening of compressor, respectively. The length shall be at least four times the pipe diameter for suction testing duct, and three times for discharge testing duct.
- (1.2) Measuring holes for suction static pressure or discharge static pressure and temperature shall be provided on the suction and discharge testing ducts respectively.
- (1.3) In general, four static pressure holes shall be provided on the same cross section at least two times the pipe diameter apart from the flange face of compressor, at circumferential intervals of 90° , in the midway of the suction and discharge testing ducts.
- (1.4) In general, four temperature measuring holes shall be provided on the same cross section 300 mm apart from the flange face of compressor, at circumferential intervals of 90° staggered from the static pressure holes by 45° .
- (1.5) If the average dynamic pressure calculated from the gas volume is 5 % or more of the pressure rise, two holes for movable dynamic pressure measuring apparatus shall be provided on a cross section 150 mm downstream the cross section on which the static pressure holes are provided at circumferential interval of 90° .
- (1.6) If there is a bent tube or throttle valve at an upstream position within $6D$ (duct diameter) from the suction testing duct and the average dynamic pressure calculated from the gas volume is 1 % or more of the static pressure (absolute), a perforated plate shall be attached to the upstream flange of suction testing duct. At least 50 holes shall uniformly be drilled at a rate of 500 holes or more per 1 m^2 on the perforated plate, and the ratio of opening (ratio of area of holes to sectional area of duct) shall not exceed 0.5.
- (1.7) If voltex or turbulence appears in the suction or discharge testing duct, the voltex or turbulence shall be prevented by the use of straightening vanes or the like. If such a voltex breaker is provided in compressor side of the static pressure measurement point, the expected pressure loss due to the breaker shall be previously agreed between the parties concerned with the acceptance.

- (2) Gas Volume Measuring Duct The gas volume measuring duct shall be as follows:
- (2.1) The gas volume measuring duct shall be a circular straight pipe with smooth inner surface capable of accommodating straightening vanes and gas volume measuring apparatus (orifice plate, nozzle or venturi tube).
 - (2.2) The construction, dimensions and location of straightening vane shall be as specified in 5.1 and 5.4 of JIS B 8340.
 - (2.3) The locations of gas volume measuring apparatus shall be as specified in 5.1 and Figs. 1 to 6 of JIS B 8340, and the gas volume measuring duct shall have an appropriate length to the apparatus.
- (3) Loop Connecting Duct Bending, throttle or others causing pressure loss shall be avoided as far as possible in the ducts connected with compressor, suction and discharge testing ducts, gas volume measuring duct, cooler, etc. Especially if the ducts connected with compressor and suction and discharge testing ducts consist of a bent tube, diffusing tube with an angle of 7° or more, or choke tube with an angle of 10° or more, agreement shall be made previously between the parties concerned with the acceptance.