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JAPANESE INDUSTRIAL STANDARD

Testing Methods for
Displacement Compressors

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Testing Methods for Displacement Compressors

B 8341-1983

1. Scope

This Japanese Industrial Standard specifies the testing methods for reciprocating and rotary compressors having pressure ratio of about 2 or more, hereinafter referred to as the "compressors" including vacuum pumps, at industrial plants by using air at ordinary temperature and ordinary pressure.

In the case of testing and inspecting compressors under special conditions or to be used for special gases, this standard shall be applied by appropriate selection and supplementation on agreement between the parties concerned with the delivery. However, for compressors used for air charging or small-size compressors having shaft powers of 11 kW or less, their performance may be judged by means of the air tank charging method or the method of using a float type area flowmeter or a flowmeter of equivalent precision as specified in Appendix of this standard.

Remark: The units and numerical values given in { } in this standard are in accordance with the Gravitational System of Units, and are appended for reference.

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2. Definition

The main terms used in this standard mean as follows:

- (1) condition formula of air The condition formula expressed by the following formula:

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

Reference: In the case of adiabatic changes, there is additionally the following relation:

$$Pv^k = \text{Constant} \dots \dots \dots (2)$$

where

P : absolute pressure of air (MPa) {kgf/m²} = $P_a + p$

P_a : atmospheric pressure (MPa) {kgf/m²}

p : gauge pressure of air (MPa) {kgf/m²}

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

t : temperature of air (°C)

v : specific volume of air (m³/kg) {m³/kgf}

R : gas constant of air

$$= \frac{287}{1 - 0.378\phi \frac{P_{ws}}{P}} [J/(kg \cdot K)] = \left\{ \frac{29.27}{1 - 0.378\phi \frac{P_{ws}}{P}} \right\} [kgf \cdot m/(kgf \cdot K)]$$

where P_{ws} : saturated vapor pressure of water (MPa) {kgf/m²}

P : absolute pressure of air (MPa) {kgf/m²}

ϕ : relative humidity (expressed in decimal number)

k : adiabatic exponent of air

The value of gas constant R of air in the standard suction condition shall be regarded as 288 J/(kg · K) {29.44 kgf · m/(kgf · K)}, and the value of adiabatic exponent k shall be regarded as 1.4. These values may be applied to atmospheric air at temperature from -15°C to +40°C.

- (2) standard suction condition The suction condition in which the compressor sucks wet air at the temperature of 20°C, absolute pressure of 101.3 kPa (760 mmHg), and relative humidity of 65 %.

Remarks 1. The density of air in the standard suction condition shall be regarded as 1.20 kg/m³ (weight per unit volume, 1.20 kgf/m³).

2. The reference conditions mean the conditions of dry air at the temperature of 0°C and absolute pressure of 101.3 kPa (760 mmHg), and the density of air under such conditions shall be regarded as 1.29 kg/m³ (weight per unit volume, 1.29 kgf/m³).

- (3) pressure of air The static pressure (gauge pressure) of air unless otherwise noted.

Remark: Static pressure is the pressure of air exerted on the wall surface parallel to the flow and is measured at a hole drilled perpendicularly to the wall surface.

- (4) air quantity of compressor The air quantity calculated from the test results and to be expressed by converting to the volume in the suction condition (atmospheric pressure, P_a ; temperature of suction air, t_a).

- (5) specified number of revolutions of compressor The number of revolutions per unit time of the compressor shaft obtained when the compressor is operated under the specified power source conditions in the case of an electric driven compressor, and under the specified operation conditions in the case of a compressor driven by other prime mover.

Remark: Because this number of revolutions may change in some degree according to the pressure of the compressor, where such numerical value is required to be indicated, it shall be representatively indicated by the number of revolutions of the compressor at the specified pressure.

- (6) shaft power of compressor The input to the shaft end of the compressor.

Remark: Where the measurement of the power loss of the transmission device is difficult in the case of compressors driven through a transmission device, the input to the transmission device shall be regarded as the shaft power of the compressor.

- (7) noise of compressor The noise level measured in the close surroundings of the compressor body being operated.

3. Testing and Inspection Items

3.1 Test Items The test items shall be as follows:

Temperature, pressure, air quantity, number of revolutions, shaft power, noise, state of operation, safety valve, and unloader.

3.2 Inspection Items The inspection items shall be as follows:

Pressure, air quantity, shaft power, overall adiabatic efficiency, volumetric efficiency, state of operation, safety valve, and unloader.

4. Test Conditions

Compressors shall be tested at the specified number of revolutions according to the following methods. However, where it is difficult, for reasons of power source, related equipment, or the like, to operate them at the specified number of revolutions, the testing may be performed at a number of revolutions within +10 % and -5 % of the specified number of revolutions.

- (1) The tests shall be performed at one point of the specified pressure. However, if preliminarily required, the tests shall be performed at 3 points of pressure including the specified pressure.
- (2) The compressor shall be operated under the required conditions and measurements shall be carried out after confirming that the temperatures of respective parts have reached approximately constant value.
- (3) For compressors having intercoolers, the temperature of air at the outlet of the intercoolers shall be adjusted to close to the design temperature by adjusting the quantity of cooling water.

5. Test Apparatus

5.1 Test Apparatus The test apparatus used shall be capable of measuring correctly the values required to indicate the performance and the state of operation of the compressor. The arrangement of the test apparatus for the compressor and the measuring apparatus shall be as shown in Figs. 1 to 4 as a rule.

The precision of the main measuring instruments shall be as specified in Appended Table 1.

Fig. 1. Where Variation in Suction Air Quantity of Compressor Is Large

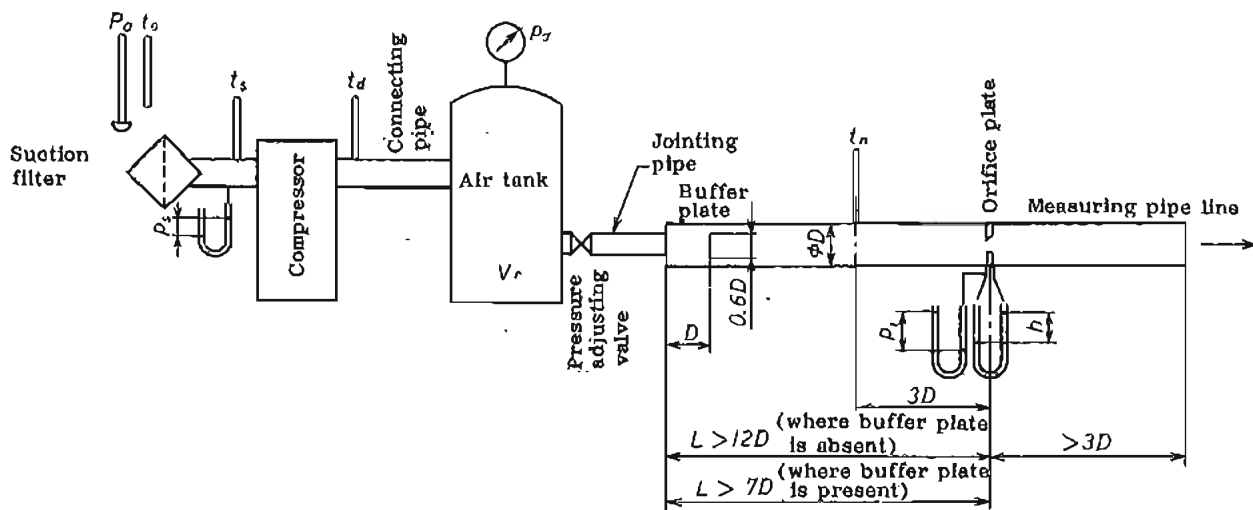


Fig. 2. Where Variation in Suction Air Quantity of Compressor Is Very Small

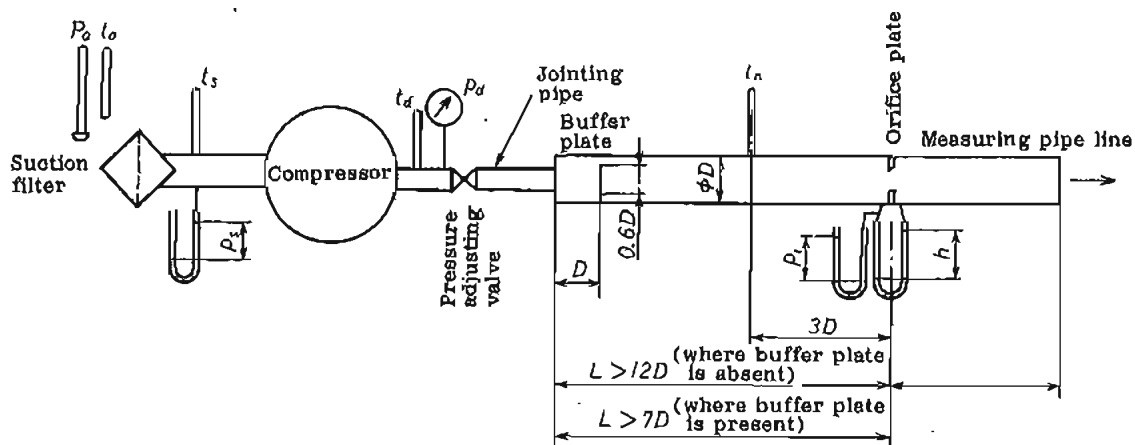


Fig. 3. Where Variation in Suction Air Quantity of Vacuum Pump Is Large

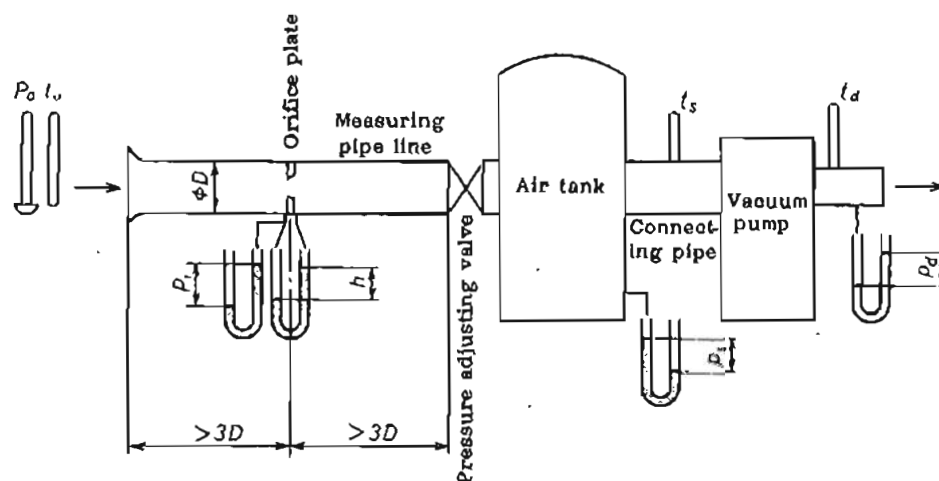
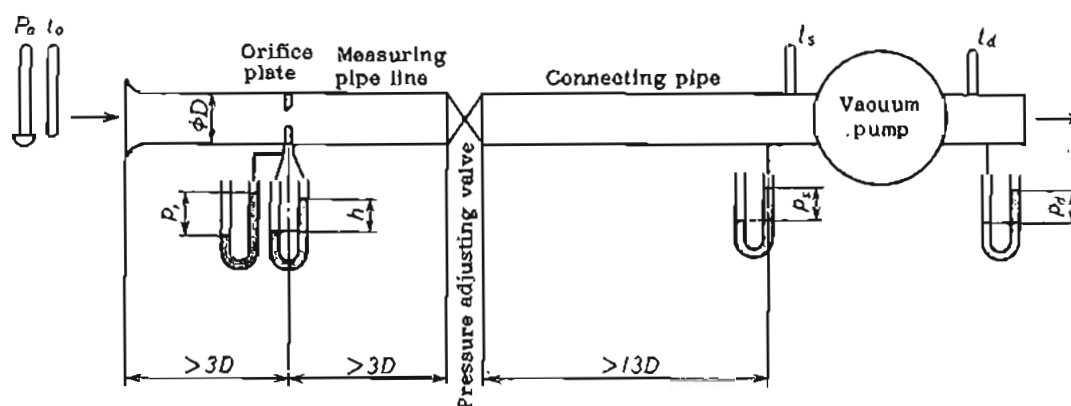


Fig. 4. Where Variation in Suction Air Quantity of Vacuum Pump Is Very Small



5.2 Connecting Pipe The pipe used for connection between the compressor and air tank shall be selected so that it is free, as far as possible, from bends, contractions of area and other causes of pressure loss and has a length which does not cause resonance. The length which does not cause resonance shall be obtained from the following formulas:

$$L_{p1} \leq 10 \frac{a}{N} - \frac{V}{A_o} \text{ (where } Z \text{ is not more than 1) } \dots\dots\dots (3)$$

or

$$L_{p2} = (20 \text{ to } 40) \frac{a}{N} - \frac{V}{A_o} \text{ (where } Z \text{ is between 1 and 2) } \dots\dots\dots (3')$$

$$L_{p3} = (50 \text{ to } 70) \frac{a}{N} - \frac{V}{A_o} \text{ (where } Z \text{ is between 2 and 3) } \dots\dots\dots (3'')$$

where $L_{p1}, L_{p2}, \dots\dots$: length of connecting pipe not causing resonance (m)

a : sound velocity in pipe (m/s) = $331 \sqrt{\frac{273+t_1}{273}}$
(sound velocity at $t_1^\circ\text{C}$)

N : number of times of discharge (suction) per minute

V : volume between discharge valve (suction valve) of compressor and connecting pipe at discharge opening (suction opening) of compressor (m^3)

A_o : cross-sectional area of pipe (m^2)

Z : dimension of vibration 1, 2, ...

Remark: $L_p = 15(2Z-1) \frac{a}{N} - \frac{V}{A_o} \dots\dots\dots$ length for causing resonance (m)

5.3 Air Tank The volume of the air tank (refer to Fig. 1) used for testing reciprocating compressors shall be not less than the volume calculated from the following formula:

$$V_r = \frac{200 V_c}{R_d} \dots\dots\dots (4)$$

where

V_r : volume of air tank (m^3)

V_c : volume of single-side stroke of last stage piston (m^3)

R_d : pressure ratio of last stage = (absolute pressure of last stage discharge air) / (absolute pressure of last stage suction air)

5.4 Measuring Pipe Line The measuring pipe line shall be a straight pipe of circular cross-section having smooth inner surfaces, and the length from its inlet to the orifice plate shall be as shown in Figs. 1 to 4.

5.5 Jointing Pipe The jointing pipe shall be a straight pipe of circular cross-section, and its length from the pressure adjusting valve to the measuring pipe line shall be about the length which does not cause drifts in the measuring pipe line.

The pressure adjusting valve shall preferably be of a type causing little drifting in the jointing pipe.

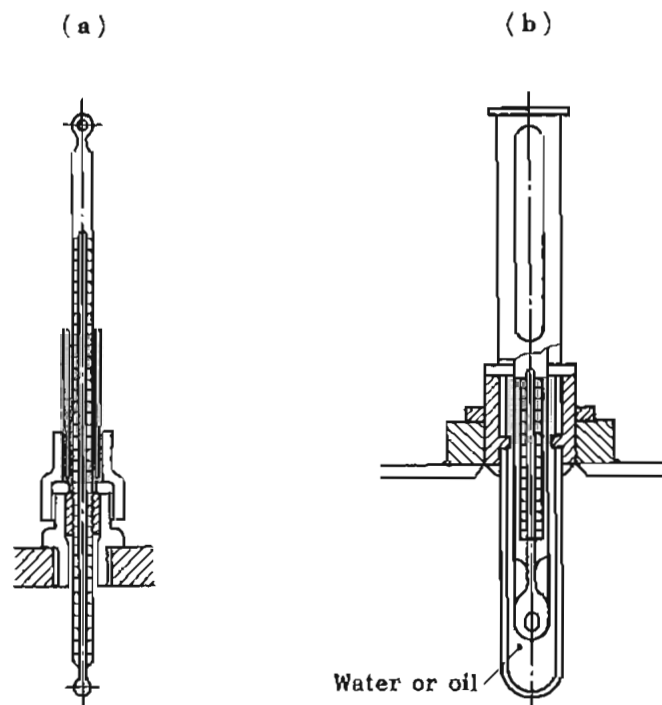
5.6 Measuring Instruments for Atmospheric Pressure and Humidity
A Fortin barometer shall be used for measuring atmospheric pressure, and a psychrometer shall be used for measuring humidity.

6. Test Methods

6.1 Temperature

6.1.1 Measuring Instrument The measuring instrument used shall be a calibrated bar thermometer having scale interval of 1°C or less, thermoelectric thermometer, resistance thermometer, thermistor thermometer etc. The detecting head of the thermometer for measuring the temperature of flowing air shall be projected directly in the air flow [refer to Fig. 5 (a)]. However, in the case where there is the risk of the thermometer being damaged, or the risk of the thermometer dropping out due to a high pressure, a protecting tube containing water or oil may be used [refer to Fig. 5 (b)]. The inner diameter of the protecting tube shall be about 2 times the outer diameter of the thermometer. The thermoelectric thermometer, resistance thermometer, thermistor thermometer, etc., when used, shall be calibrated each time when they are used.

Fig. 5. Method of Mounting Thermometer (Example)



6.1.2 Testing Measurement shall be carried out at the respective positions of the test apparatus shown in Figs. 1 to 4 when the respective temperatures have stabilized for each operation condition.

Care shall be taken to prevent heat propagation through the walls and the influence of radiant heat from the surroundings.

6.2 Pressure

6.2.1 Measuring Instruments The measuring instruments used shall be as follows:

- (1) Pressure Gauge For the measurement of pressures between stages and discharge pressure, a calibrated Bourdon tube pressure gauge shall be used, as a rule. The Bourdon tube pressure gauge used shall have a maximum scale value of 1.5 incl. to 2 incl. times the specified pressure.

For measuring pressure not exceeding 100 kPa {1.02 kgf/cm²}, a mercury pressure gauge shall preferably be used. In this case, the specific gravity of mercury shall be regarded as 13.55 at a temperature of 0 to 40°C.

- (2) U-Tube Pressure Gauge The difference between the pressures directly before and directly behind the orifice plate shall be measured, as a rule, with a U-tube pressure gauge by using water as the liquid for the U-tube pressure gauge. In this case, the specific gravity of water shall be regarded as 1 at a temperature of 0 to 40°C.

The inner diameter of the U-tube pressure gauge shall be 6 to 12 mm and be almost equal and uniform for the right and left sides.

6.2.2 Measurement The pressure difference at the orifice plate shall be read correctly at least to 1/100 of the measured value.

Where the oscillation of the pointer of the Bourdon tube pressure gauge or the oscillation of the liquid surface of the mercury column pressure gauge is remarkable, the gauge cock or the jointing pipe may be constricted to the extent within which there is no risk of causing errors.

6.3 Air Quantity

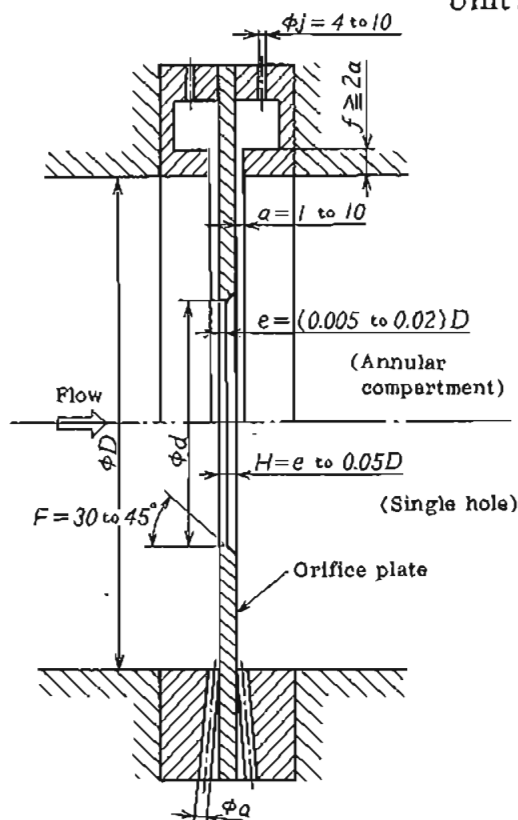
6.3.1 Apparatus The apparatus used shall be as follows:

- (1) Orifice Plate The orifice plate used shall be as follows:
 - (a) The construction of the orifice plate shall conform to JIS Z 8762 and its shape and dimension shall be as shown in Fig. 6.
 - (b) The method of taking-out pressure shall be the method of using corner taps as specified in JIS Z 8762, and the construction and positioning of the taps shall be as shown in Fig. 6. Where contraction taps or flange taps are used, they shall conform to those specified in the corresponding items of JIS Z 8762.

- (c) The size of the orifice used shall be such that the inner diameter of the pipe is 50 to 1000 mm and the restriction area ratio $\beta^2 = \left(\frac{d}{D}\right)^2$ is 0.05 to 0.64. The pressure difference shall preferably be selected to be not less than 500 Pa {51 mmAq}.

Fig. 6. Orifice Plate

Unit: mm

 D : inner diameter of pipe, 50 to 1000 mm a : diameter of single hole or width of slitIn 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 $a = 1$ to 10 mm f : thickness of slit j : diameter of pressure conducting tube
connecting hole d : hole diameter of restrictor H : thickness of orifice plate e : thickness of edge F : angle of relief

- (2) Flowmeter A calibrated flowmeter having a precision of within $\pm 2\%$ (refer to Appendix) shall be used.

6.3.2 Measurement The measurement shall be carried out by means of an orifice plate by using a test apparatus as shown in Figs. 1 to 4. However, in the case of a small-size compressor, a float type area flowmeter or a flowmeter of equivalent precision may be used.

6.3.3 Calculation Calculation shall be carried out from the following formula: