

JIS

JAPANESE INDUSTRIAL STANDARD

**General Rules for Rotating
Electrical Machines**

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General Rules for Rotating
Electrical Machines

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1. General

1.1 Scope This Japanese Industrial Standard specifies the general requirements common to various rotating electrical machines, hereinafter referred to as the "rotating machines". A rotating machine is an electrical machine which has a rotating member and depending on electromagnetic induction, generates, converts or transforms ⁽¹⁾ electrical energy (including reactive power), or converts electrical energy into mechanical energy.

Note ⁽¹⁾ The converts of electrical energy includes the conversion between a.c. and d.c., that of frequency or number of phases, etc. The transforms is that of voltage alone, not accompanying the conversions as above.

Remark: In this standard the units and numerical values given in { } are in accordance with the International System of Units (SI), and appended for reference only.

1.2 Relation to Standards for Particular Types of Rotating Machines The specific requirements for each type of rotating machines are to be specified by the respective standard.

Applicable Standard and Reference Standards: See page 62.

2. Definitions

For the purpose of this standard the following definitions shall apply:

- (1) stator The major stationary portion of a rotating machine.
- (2) rotor The rotating portion of a rotating machine.
- (3) armature, armature winding The portion of a rotating machine which carries a winding or windings in which electromotive force is induced by the relative motion to the field. This winding is called armature winding.

Remark: The induction machine has the primary armature winding and secondary armature winding, and the former is generally connected to a constant voltage power source. Both are abbreviated to the primary winding and secondary winding respectively.

- (4) field winding A winding which excites the magnetic poles.
- (5) generator A rotating machine which converts mechanical power into electrical power.
- (6) motor A rotating machine which converts electrical power into mechanical power.
- (7) d.c. machine A rotating machine which generates or transforms d.c. power, or converts d.c. power into mechanical power.
- (8) a.c. machine A rotating machine which generates or converts a.c. power (including reactive power) or converts a.c. power into mechanical power.
- (9) synchronous machine An a.c. machine which rotates at the synchronous speed in steady operation state.
- (10) asynchronous machine An a.c. machine which runs at speeds different from the synchronous speed in steady operation state.
- (11) induction machine An asynchronous machine in which the stator and the rotor have armature windings independent from each other, and one winding works receiving power from the other by induction.
The induction machine has no commutator.
- (12) a.c. commutator machine An asynchronous machine with a commutator.
- (13) rotary converter A rotating machine with a single armature winding having a commutator and slip rings, which converts a.c. power on the slip-ring side into d.c. power on the commutator side or vice-versa.
- (14) motor generator set A rotating machine set which consists of a motor mechanically coupled to a generator.

- (15) rotary condenser A rotating machine running without mechanical load which provides either leading reactive power or lagging reactive power by regulating the excitation. One which runs at the synchronous speed is called synchronous condenser and that runs at a synchronous speed is called asynchronous condenser.
- (16) booster A rotating machine used for regulating the circuit voltage with its armature winding connected to an external circuit in series.
- (17) frequency converter A rotating machine which converts a.c. power supplied at one frequency to a.c. power at another frequency. A machine which simultaneously converts not only frequency but also number of phases of a.c. power is also called a frequency converter.
- (18) phase converter A rotating machine which converts a.c. power supplied having a given number of phases into a.c. power of another number of phases but the same frequency.
- (19) double-current generator A generator having a single armature winding or two or more armature windings wound on a single armature core which simultaneously generates two or more different kinds of power.
- (20) dynamotor A rotating machine having two armature windings on a single armature, one acting as a motor and the other as a generator.
- (21) generator/motor A rotating machine which operates as a generator or motor. The term generally denotes a machine used in pump-storage power generating station.
- (22) torque motor A motor whose torque exerted through a limited travel or in a stalled position is utilized.
- (23) breakaway torque (of an a.c. motor) The smallest torque developed at the shaft end by the motor when at rest and when it is supplied at the rated voltage and frequency. This torque value applies after the disappearance of transient phenomena.
- (24) breakaway starting current (of an a.c. motor) The highest r.m.s. current absorbed by the motor when at rest and when it is supplied at the rated voltage and frequency. This current value applies after the disappearance of transient phenomena.
- (25) smallest torque (of an a.c. motor) The smallest torque developed at the shaft end by the motor between zero speed and the speed which corresponds to the maximum torque when the motor is supplied at the rated voltage and frequency. This definition does not apply to those asynchronous machines of which the torque continually decreases with increase in speed.

- Remarks 1. This value applies to the usual mean torque characteristic which excludes electrical transient effect.
2. This torque is called the pull-up torque in the case of induction motors.

- (26) maximum torque (of an a.c. motor) The highest torque that the motor can develop at the shaft end while running at the rated voltage and frequency (and rated excitation in the case of synchronous motors). This definition does not apply to those asynchronous machines of which the torque continually decreases with the increase in speed.

Remark: This value applies to the usual mean torque characteristic which excludes electrical transient effects.

- (27) stored energy constant (H) The quotient of the kinetic energy stored in the rotor running at the rated speed and of the rated apparent power (the product of rated voltage and current, in the case of d.c. machines).

Remark: The stored energy constant (H) is represented by the following formula:

$$H = \frac{J \omega_n^2}{2S_n} \cdot 10^{-3} (\text{s})$$

where J : moment of inertia of rotor ($\text{kg} \cdot \text{m}^2$)

$$J = GD^2/4$$

GD^2 : flywheel effect ($\text{kg} \cdot \text{m}^2$)

ω_n : rated angular speed (rad/s)

$$\omega_n = \frac{2\pi}{60} \cdot n_n$$

n_n : rated speed (rpm)

S_n : rated apparent power (kVA)

- (28) factor of inertia (FI) The ratio of the total load moment of inertia (referred to the motor shaft) plus the motor moment of inertia, to the motor moment of inertia.

Remark: The factor of inertia (FI) is represented by the following formula:

$$FI = \frac{J_m + J_l}{J_m}$$

where J_m : moment of inertia of motor

J_l : moment of inertia of load referred to the motor shaft

- (29) acceleration time (T_J) The time required to accelerate the rotor from rest to rated speed by the constant accelerating torque corresponding to the rated output at the rated speed.

Remark: The acceleration time (T_J) is represented by the following formula:

$$T_J = \frac{J \omega_n^2}{P_n} \cdot 10^{-3} (\text{s})$$

where J : moment of inertia of rotor ($\text{kg} \cdot \text{m}^2$)

$$J = GD^2/4$$

GD^2 : flywheel effect ($\text{kg} \cdot \text{m}^2$)

ω_n : rated angular speed (rad/s)

$$\omega_n = \frac{2\pi}{60} \cdot n_n$$

n_n : rated speed (rpm)

P_n : rated output (kW)

3. Classification of Rotating Machines

3.1 Classification by Characteristics

3.1.1 Constant Voltage Machine A rotating machine providing electrical output, whose output terminal voltage is nearly constant irrespective of load, when either or both of the supply voltage and speed are maintained constant.

Example: Separately excited d.c. generator with constant excitation, flat-compounded d.c. generator.

3.1.2 Adjustable Voltage Machine A kind of constant voltage machine, whose output terminal voltage is adjustable over a wide range.

Example: Separately excited d.c. generator whose excitation is adjustable.

3.1.3 Varying-Voltage Machine A rotating machine providing electrical output, whose output terminal voltage varies over a wide range with the variation in load, irrespective of that either or both of the supply voltage and speed are maintained constant.

Example: Differential compound d.c. generator.

3.1.4 Drooping Characteristic Machine A kind of varying-voltage machine having such a characteristic that the output terminal voltage remarkably falls with the increase in load current.

Example: d.c. generator for electric arc welding.

3.1.5 Constant Current Machine A kind of varying-voltage machine whose load current is maintained nearly constant, irrespective of value of load resistance or impedance.

Example: Constant current third brush generator.

3.1.6 Constant Speed Motor A motor which runs at a constant or substantially constant speed over its normal range of load.

Example: Synchronous motor, induction motor with small slip, d.c. shunt motor with constant excitation.

3.1.7 Multi-Constant Speed Motor A kind of constant speed motor of which the speed is variable in a few steps.

Example: Pole-changing induction motor.

3.1.8 Adjustable Constant Speed Motor A kind of constant speed motor of which the speed is adjustable over a wide range.

Example: d.c. shunt motor the speed of which is adjustable over a wide range by adjusting the field, a.c. shunt commutator motor.

3.1.9 Varying Speed Motor A motor the speed of which appreciably varies with the load, even if the supply voltage (and also frequency, for a.c. machine) is maintained constant.

Example: d.c. series motor, repulsion motor, squirrel-cage motor with high secondary resistance.

3.2 Classification by Degrees of Protection Rotating machines are classified by the degrees of protection of their enclosures designated by the combination of the following protective degrees:

- (1) Degrees of protection as regards persons and ingress of solid foreign bodies
- (2) Degrees of protection of machines against ingress of water

Remark: Special regulations, if exist, shall apply to the degrees of protection of machines in a harmful atmosphere such as explosion-proof type, corrosion-proof type, tropical-weather-proof type and so on.

3.2.1 Degrees of Protection as Regards Persons and Ingress of Solid Foreign Bodies The degrees of protection of persons against contact with live or moving parts inside rotating machines and the degrees of protection of rotating machines against ingress of solid foreign bodies are classified into the five as given in Table 1.

Table 1. Degrees of Protection as Regards Persons and Solid Foreign Bodies

Type	Characteristic numeral	Description	Test
Non-protected	0	No special protection of persons against contact with live or moving parts and no special protection of machine against ingress of solid foreign bodies.	No test is required
Semi-protected	1	Protection against accidental or inadvertent contact with live and moving parts inside the enclosure by a large surface of the human body, for example, a hand. Protection against ingress of solid foreign bodies of diameter greater than 50 mm.	See Table 4, 1
Protected	2	Protection against contact by finger with live or moving parts inside the enclosure. Protection against ingress of solid foreign bodies of diameter greater than 12 mm.	See Table 4, 2
Totally enclosed	4	Protection against contact with live or moving parts inside the enclosure by tools, wires, or such objects of thickness greater than 1 mm. Protection against ingress of solid foreign bodies of a diameter greater than 1 mm, excluding the ventilation openings (intake and discharge of external fans) and the drain hole, which may have the numeral 2 protection.	See Table 4, 4
Dust-proof	5	Complete protection against contact with live or moving parts inside the enclosure. Protection against harmful deposits of dust. The ingress of dust is not totally prevented, but dust cannot enter in an amount sufficient to interfere with satisfactory operation of the machine.	See Table 4, 5

Remark: Tests shall be made in accordance with Table 4, and other necessary matters shall be agreed between the parties concerned.

Reference: The type corresponding to the numeral 3 is not specified in accordance with IEC Publication 34-5.

3.2.2 Degrees of Protection against Ingress of Water The degrees of protection of rotating machines against ingress of water are classified into the eight as given in Table 2.

The construction which enables outdoor operation by preventing the ingress of rain, snow and airborne particles or reducing it to an amount is defined as the outdoor type with the symbol W.

The explosion-proof type is designated by the symbol E and the type of protection against harmful atmosphere by the symbol C.

The tests to check protection of machines against the ingress of water shall be made in accordance with Table 5 and other necessary matters shall be agreed between the parties concerned.

Table 2. Degrees of Protection against Ingress of Water

Type	Characteristic numeral	Description	Test
Non-protected	0	No special protection against the ingress of water.	No test is required
Drip-proof	2	Drops of water falling at any angle up to 15° from the vertical have no harmful effect.	See Table 5, 2
Spray-proof	3	Water falling as a spray at an angle equal to or smaller than 60° with respect to the vertical has no harmful effect.	See Table 5, 3
Splash-proof	4	Water splashed against the machine from any direction has no harmful effect.	See Table 5, 4
Water-jet-proof	5	Water projected by a nozzle against the machine from any direction has no harmful effect.	See Table 5, 5
Sea-wave-proof	6	Water strongly projected by a nozzle from any direction does not enter the machine in a harmful quantity.	See Table 5, 6
Immersion-proof	7	Ingress of water in the machine in a harmful quantity is not possible when the machine is immersed in water under stated conditions of water depth and time.	See Table 5, 7
Submersible	8	Normal operation of the machine in water is possible.	See Table 5, 8

Reference: The degree of protection corresponding to the characteristic numeral 1 which is defined in IEC Publication 34-5 has been omitted because it has little commercial value.

3.2.3 Designation of Degree of Protection by Types or Characteristic Numerals The designation by types or characteristic numerals used for the degree of protection of rotating machines shall be made by arranging the types or characteristic numerals in 3.2.1 and 3.2.2 in that order. The former is called the first type or characteristic numeral and the latter the second type or characteristic numeral.

The characteristic numerals shall be headed by the letters "JP".

The designation shall be followed by the letter S when the protection against ingress of water was tested with the machine at rest, or by the letter M when tested with the machine in operation. The absence of such letter means that the protection was tested in both cases, the machine at rest and running.

When all parts of a machine have not the same degree of protection, the designation of the lowest degree shall be shown first, followed by other designations in the order of degree with reference to the part to which each protection applies.

Between JP and the characteristic numerals, W shall be inserted for the outdoor type, E for explosion-proof type, and C for the degree of protection against other harmful atmosphere. When two or more of the symbols W, E, C are to be inserted, they shall be shown in the order of W, E, C.

Table 3 shows the most frequently used degrees of protection.

Table 3. Most Frequently Used Degrees of Protection

Second characteristic numeral (second type) First characteristic numeral (first type)	0 (Non-protected)	2 (Drip-proof)	3 (Spray-proof)	4 (Splash-proof)	5 (Water-jet-proof)	6 (Sea-wave-proof)	7 (Immersion-proof)	8 (Submersible)
0 (Non-protected)	JP 00			×	×	×	×	
1 (Semi-protected)	JP 10	JP 12 S			×	×	×	
2 (Protected)	JP 20	JP 22 S	JP 23 S	JP 24	×	×	×	
4 (Totally enclosed)	×			JP 44				
5 (Dust-proof)	×			JP 54				

Remarks 1. The mark × indicates an almost impracticable combination.

2. JP 00 and JP 10 may be abbreviated to non-protected type and semi-protected type respectively.

3.2.4 Tests to Check Degree of Protection

- (1) The tests to check protection as regards persons and solid foreign bodies shall be made in accordance with Table 4, and shall, as a rule, be type tests.

All tests shall be made with the machine at rest.

Table 4. Tests to Check Protection as Regards
Persons and Solid Foreign Bodies

First characteristic numeral	Test
0	No test is required.
1	The test is made with a sphere of 52.5 mm diameter applied against the enclosure with a force of 5.1 kgf {50 N}. The test is deemed satisfactory if the sphere does not enter the enclosure and cannot touch live or moving parts inside the enclosure.
2 (2)	(1) Live parts The test is made using a metallic contact finger such as the one shown in Fig. 1, connected by an incandescent lamp to one pole of a supply of at least 40 V, the other pole of the supply being connected to the parts intended to be live in normal service, electrically connected together during the test. The lamp shall not light when the test finger is placed in every possible position in the enclosure. For these tests, conducting parts incompletely insulated parts (covered only with varnish or protected by oxidation) and completely insulated windings shall be covered with a metal foil electrically connected to those parts live in normal service. The rated voltage of the lamp is equal to that of the source used for the test. (2) Moving parts Except for shafts and similar smooth parts, the test finger shall not touch internal moving parts when the machine is rotating. For that test, the rotor is slowly rotated by hand. (3) The enclosure must not admit a sphere of 12.5 mm diameter.
4 (2) (3)	A steel wire of 1 mm diameter shall not be able to enter the enclosure.

Table 4 (Continued)

First characteristic numeral	Test
5 ⁽²⁾ ⁽³⁾ ⁽⁴⁾	The test shall be made using the equipment shown in Fig. 2. The talcum powder used is to pass a square-meshed sieve whose nominal wire diameter is 50 μm and the nominal width between wires is 75 μm. The amount of talcum powder to be used is 2 kg per cubic metre of the test chamber. The enclosure of the machine under test is connected to a vacuum pump which maintains inside the enclosure a differential pressure equivalent to not more than 200 mm water {1960 Pa}. The test shall be continued for not less than 2 h, and until the volume of the air drawn in reaches 80 times the volume of air in the enclosure under test. However, the duration need not be more than 8 h. Dust which has been deposited on the insulating paths between live parts or between live parts and earth shall not have harmful effect on the machine. The test is carried out only on machines of shaft height up to 132 mm. For machines of shaft height over 132 mm, the result of the test carried out on a machine of comparable design is considered sufficient.

Notes ⁽²⁾ In the case of machines cooled by means of an external fan, the fan shall be so protected as to prevent contact of the blades or spokes of the fan with the standard test finger (Fig. 1). However, at the outlet of the fan, the test finger is not inserted past the 50 mm diameter guard.

⁽³⁾ In the case the enclosure has a hole, or the drain plug of a dust-proof machine is open, a ball of 12.5 mm diameter shall not enter into the machine through such holes.

A straight steel wire of 1 mm diameter shall not be able to enter the enclosure.

⁽⁴⁾ When the nature of the dust (dimensions of particles, their nature) is known, test conditions should be determined by agreement between the parties concerned.

(2) The tests to check the protection of machines against ingress of water shall be carried out in accordance with Table 5, and shall, as a rule, be type tests. For degrees of protection of the second characteristic numerals 2, 3 and 4 in Table 5, a study of drawing is generally sufficient. In case of doubt, the test is carried out.

The tests in Table 5 shall be made on machines not running. They may be made on running machines for the degrees of protection of the second characteristic numerals 4, 5 and 6.

All the tests are made with fresh water.

The amount of water which has entered the machine during the tests in Table 5 shall not be capable of interfering with its satisfactory operation. For example, the windings and live parts shall not be wet and no accumulation of water which could reach them shall occur inside the enclosure. It is however permissible for the blades of fans inside rotating machines to be wet.

Also leakage along the shaft is allowable if provisions is made for drainage of this water.

In the case of a test on a machine not running, the machine shall be operated under no-load conditions with rated voltage for 15 min, then submitted to a high-voltage test. The test voltage is 50 % of the test voltage in Table 12 (but not less than 125 % of the rated voltage). These check shall show no damage. In the case of a test on a running machine the operation under no-load conditions for 15 min is not required.

Table 5. Tests to Check Protection
against Ingress of Water

Second characteristic numeral	Test
0	No test is required.
2	The test is made by dripping water from a height 200 mm above by means of the equipment shown in Fig. 3, adjusted so that the discharge of water is 3 mm/min. The machine under test is tilted up to an angle of 15° with respect to its normal operating position. The total duration of the test is 10 min ⁽⁵⁾ .
3	The test is made by spraying the machine at the rate of not more than 9 l/min by means of an equipment such that the streams of water fall on the machine from various directions, the angle of which may reach up to 60° from the vertical. The distance from the holes to the machine is approximately 1 m. The water pressure is approximately 816 gf/cm ² {approx. 8×10^4 Pa}. The duration of the test is 10 min ⁽⁶⁾ .
4	The test is made in the same way as for the degree of the protection of the second characteristic numeral 3, except that the machine is splashed from every direction. The support for the machine under test shall be grid-shaped in order to avoid acting as a baffle against the splash from below.

Table 5 (Continued)

Second characteristic numeral	Test
5	The test is made by applying a stream of water from a nozzle of 12.5 mm inside diameter on the machine in all directions. The nozzle should be held at a distance of approximately 3 m away from the machine under test, the water pressure is 306 gf/cm^2 $\{3 \times 10^4 \text{ Pa}\}$, the water flow approximately 50 l/min , and the duration of the test 10 min ⁽⁷⁾ .
6	The test is made in the same way as for the degree of the protection of the second characteristic numeral 5, except that the water pressure is 1020 gf/cm^2 $\{10^5 \text{ Pa}\}$ and water flow approximately 100 l/min ⁽⁸⁾ .
7	The test is made by completely immersing the machine in water so that the head of water above the mounting plane of the machine is not less than 1 m and the upper part of the machine is at least 15 cm below the surface of water. The duration of the test is 30 min.
8	Test conditions are subject to an agreement between the parties concerned.

Notes ⁽⁵⁾ Regulate the water discharge rate by the valve referring to the water level (H).

Be careful not to leave air space when filling the tank with water (it is preferable to provide a conical part at the outlet to U-tube).

⁽⁶⁾ To maintain the water pressure at 816 gf/cm^2 $\{\text{approx. } 8 \times 10^4 \text{ Pa}\}$, it may be regulated with reference to the height of water to which stream from the spray nozzle freely rises. In this case the height of water stream is approximately 2 m.

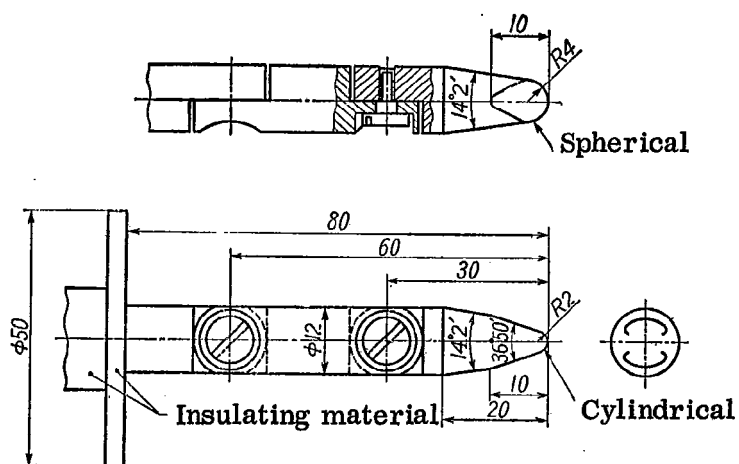
⁽⁷⁾ To maintain the water pressure at 306 gf/cm^2 $\{3 \times 10^4 \text{ Pa}\}$, it may be regulated with reference to the height of water to which stream from the spray nozzle freely rises. In this case the height of water stream is approximately 2.5 m.

⁽⁸⁾ To maintain the water pressure at 1020 gf/cm^2 $\{10^5 \text{ Pa}\}$, it may be regulated with reference to the height of water to which stream from the spray nozzle freely rises. In this case the height of water stream is approximately 8 m.

Remark: In the case where the machine under test is so large that the whole of its surfaces cannot be subjected to water at a time, the joints, bearings and so forth may be separately subjected to water, provided the water flow and duration of test satisfy the conditions given in Table 5.

Fig. 1. Standard Test Finger

Unit: mm



Tolerances

on angles	$\pm 5'$
on linear dimensions	
- under 25 mm	$- 0.05$
- over 25 mm	± 0.2

Fig. 2. Equipment to Prove Protection against Dust

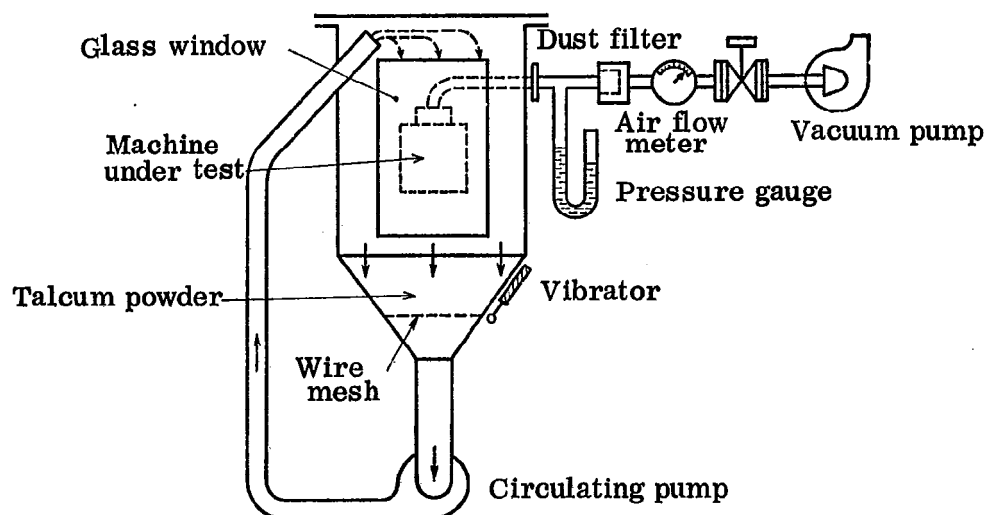


Fig. 3. Equipment to Prove Protection against Drops of Water

Unit: mm

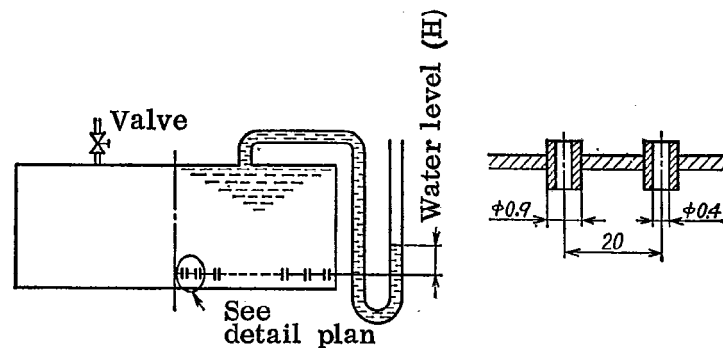
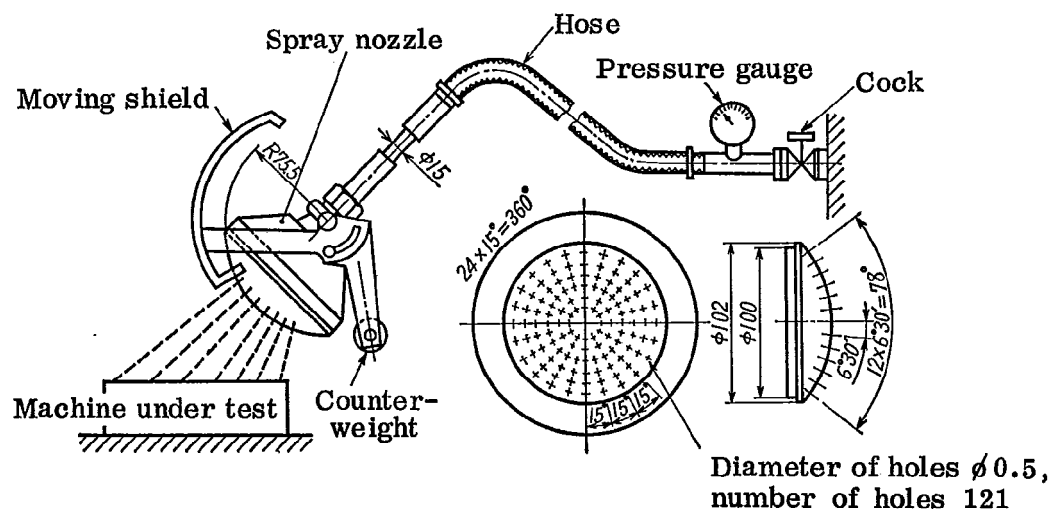


Fig. 4. Equipment to Prove Protection against Spraying and Splashing Water

Unit: mm



3.3 Classification by Cooling Methods Rotating machines are classified by the methods of cooling designated by the combination of the following types:

- (1) Types by the nature of cooling media (hereinafter referred to as the "coolants")
- (2) Types of circuit of coolant and types of heat removal
- (3) Types of circulating coolants

A medium which is in contact with a part of a machine and removes heat from that part is defined as the primary coolant, and a medium which removes the heat given up by this primary coolant by means of a heat exchanger is defined as the secondary coolant.

The method of cooling conductors by drawing the coolant in either hollow conductors or tubes which form an integral part of the winding is defined as the direct cooling or inner cooling.

3.3.1 Types by Nature of Coolant Rotating machines are classified by the nature of coolant into the five as given in Table 6.

Table 6. Types by Nature of Coolant

Type	Symbol
Air-cooled	A
Hydrogen-cooled	H
Water-cooled	W
Oil-cooled	U
Others	Designated by the name of coolant, instead of any symbol

3.3.2 Types of Circuit of Coolant and Types of Heat Removal Rotating machines are classified by the types of coolant circuit and heat removal into the seven as given in Table 7.