System and method of drip test device for testing waterproof performance of large equipment

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Abstract. At present, the drip test device used in drip test is limited by the difficulty and cost of structural layout, so it is difficult to actively rotate the electrical equipment with large volume and weight, and can not meet the test requirements of various products. In view of the defects of the existing technology, this paper provides a waterproof performance drip test device, system and method. Through the active rotation of the drip pan, the rotation relative to the large-scale test equipment is generated, so as to meet the needs of the equipment waterproof performance test; and the corresponding equipment support is configured to make the equipment form the required angle state during the dripping test, which is convenient for large size Water proof test operation of electrical equipment. At the same time, it makes the test process easy for the staff to operate, has strong economic value and social significance, and can be widely used in testing units.

Key words: Drip test; waterproof performance; equipment support; angle state; waterproof test.

1. Introduction
As an important part of power system user side, low-voltage switchgear is widely used in daily life, and its protection level is an important factor to ensure the safe operation of users and the safe power supply of the system [1]. At present, the dripping test device for IPX1 and IPX2 drip test is limited by the difficulty and cost of structural layout. The size of drip test can not exceed 1000mm × 1000mm, which can only meet the test requirements of small electrical equipment such as distribution box and household appliances. However, for large electrical equipment, such as large transformers, commercial refrigerators, commercial refrigerators, etc For electrical equipment with large volume and heavy weight, on the one hand, its drip test scope can not completely cover large electrical equipment; on the other hand, due to the influence of weight and internal structure, some electrical equipment is difficult to rotate actively during drip test; the existing drip test equipment is difficult to meet the test requirements of various products.

At present, there is not much research on the protection level at home and abroad, mainly on the standard analysis, system design and method research. Reference [1] introduces in detail the grading system of enclosure protection grade for low voltage electrical switchgear. Reference [2] mainly describes the relevant information of protection level test and precautions before the test. Reference [3]
compares the provisions on IP number in GB/T 4208-2008 standard. Reference [4] focuses on the
differences between IEC 60529:2001 and IEC 60598:2008 in terms of inspection, and makes a
comparative analysis. The ISO 20653 standard is interpreted in references [5] to [6]. In reference [7],
the design scheme of small and medium-sized rain test system is introduced in detail from the aspects
of hardware system, software system and electrical system.

In view of the defects of the existing technology, this paper provides a water-proof performance
dripping test device, system and method. Through the active rotation of the drip pan, the rotation relative
to the large-scale test equipment is generated, so as to meet the needs of the equipment waterproof
performance test; and the corresponding equipment support is configured to make the equipment form
the required angle state during the dripping test, which is convenient for large-scale electricity Water
proof test operation of gas equipment.

2. Technical requirement
The second characteristic number of enclosure protection class (IP code) specified by electrical
equipment indicates the protection against harmful effects of water entering the enclosure on the
equipment[8]. GB/T 4208-2017/IEC 60529:2013 Enclosure Protection Class (IP Code) stipulates that
electrical equipment shall be subjected to waterproof test with the second characteristic number of 1
(IPX1). It is required that there shall be no harmful effect of dripping in the vertical direction, the water
flow shall be 10+0.5mm/min, and the test duration shall be 10min; for the waterproof test with the second
characteristic number of 2 (IPX2), when each vertical surface of the enclosure is inclined 15° on four
fixed positions, it is required to conduct the waterproof test, The vertical drip shall have no harmful
effect. The water flow rate is 30+0.5mm/min, and the test duration is 2.5min at each inclined position, that
is to say, the test is conducted for 2.5min at the front, back, left and right sides of the shell, and the total
test duration is 10min.

3. Test device system and method

3.1. Test device system
The drip test device for water-proof performance provided in this paper mainly includes frame, drip tray
mechanism, driving mechanism and water supply mechanism. The drip tray mechanism is rotationally
installed on the rack, and the driving mechanism is installed on the rack, which drives the drip tray
mechanism to rotate. The water supply mechanism connects the drip tray mechanism through the
pipeline, and outputs water drops through the drip tray mechanism Cover the test equipment. The
schematic diagram of drip test device is as follows:

![Schematic diagram of drip test device](image)

**Figure 1.** Schematic diagram of drip test device

The water-proof performance drip test system includes equipment support and water-proof
performance drip test device. The equipment support is a frame structure, including the top bearing
surface, which is set at an angle between the bearing surface and the horizontal plane, which is used to
carry the test equipment and make it in an inclined state.

3.1.1. Drip tray mechanism. The drip tray mechanism includes a drip tray, in which there is a water
storage cavity, and the bottom surface of the drip tray is provided with a drip hole needle. The water
supply mechanism is connected with the left water inlet and the right water inlet respectively through the left water supply pipe and the right water supply pipe, so as to connect the water storage cavity. The water hole needle outputs water droplets. The structure diagram of drip pan and driving mechanism is as follows:

![Figure 2. Structure diagram of drip tray and driving mechanism](image)

3.1.2. **Drip tray water supply organization.** When the water supply mechanism is connected with the drip tray, the rotation state of the drip tray and the frame is not interfered, and can still rotate under the action of the driving mechanism.

The drip hole array is arranged on the bottom surface of the drip tray, and the other side opposite to the bottom surface is connected with the rack, which is used to make the drip tray hang on the rack. The rack is provided with a plurality of installation holes for matching the drip tray. The vertical spacing between the drip tray and the rack is adjusted by matching with different mounting holes. The needle head of the drip hole and the drip hole are coaxial inserted and matched, and the cavity of the drip tray is connected with the outside through the drip hole and the drip hole needle.

The water supply diagram of drip tray is as follows:

![Figure 3. Water supply diagram of drip tray](image)

3.1.3. **Flow control system.** The flow control flow chart of the water supply mechanism is shown as follows: the water inlet is connected with the water pump and water storage tank in turn through the pipeline, and the pipeline is equipped with flow valve and flowmeter; the water supply mechanism also acts as the flow control mechanism, including pressure transmitter, flowmeter, electric actuator, motor, centrifugal pump, water storage tank and programmable liquid crystal controller. The PLC is connected with pressure transmitter, flowmeter, electric actuator, motor and centrifugal pump respectively. The electric actuator is connected with pressure transmitter and flowmeter to control the flow of drip tray. The working time of drip tray can be set by PLC. The parameters are set by the controller and monitored through the touch screen on the controller. After setting the current flow rate, the centrifugal pump and motor start to work by touching the start key. The flow rate required for the test is automatically adjusted by the electric actuator and pressure transmitter.
Figure 4. Flow chart of flow control

The flow meter is used to measure the flow data; the water storage tank is used to store and supply the test water; the flow regulation principle of the flow control system is to turn on the power supply AC380V to supply power to the touch screen and PLC module. The input module of PLC module first detects whether the alarm point is normal. If the alarm point is normal, the output signal is used to control the opening of valve and water pump.

When the corresponding control valve is opened, the signal of flowmeter and pressure transmitter is fed back to the analog input module for reading. When reading, the flow signal is fed back to the controller according to the flow parameters set by the touch screen.

The controller will output the signal to the electric valve, the opening of the electric valve will be larger, the corresponding water flow will be larger, and the flow reading will be larger. The flow signal will be fed back to the analog input module, and then compared and adjusted again until it reaches the set value to complete the automatic flow regulation.

3.1.4. Electrical system. The driving mechanism is also equipped with corresponding electrical system, including electrical control cabinet, motor, primary reducer and secondary reducer, which is driven by motor and connected with drip tray through two-stage deceleration. Frequency converter is set in the electrical control cabinet, and control keys are set on the panel. Through frequency modulation control of frequency converter, the speed of drip tray is 1r/min, and the corresponding action of motor can be realized by control button; The buttons on the electrical control cabinet are forward rotation, reverse rotation, stop, emergency stop and start.

3.1.5. Rack and equipment support. The equipment support is a frame structure, including the top bearing surface, which is set at an angle between the bearing surface and the horizontal plane, which is used to carry the test equipment and make it in an inclined state. The equipment support includes not only front and rear tilt support and left and right tilt support, but also horizontal support, which is convenient for equipment test. The tilt angle of the tilt bracket is 15° and the tilt angle is 15° for the front, back, left and right sides of the electrical equipment with the maximum specification of 1400 (W) mm × 2400 (H) mm.

There are detachable legs, retaining rings, baffles, fixing holes and fastening bolts on the front and rear inclined 15° bracket and the left and right inclined 15° bracket. The size of the bracket is 3000 (L) mm × 1500 (W) mm, and the material is 316 stainless steel. The detachable leg is the retaining rod matching with the equipment support.

The detachable leg is used to realize the test requirement that the sample is fixed on an inclined 15° bracket; the retaining ring and baffle are used to fix the sample to prevent the sample from overturning due to tilt, and avoid the potential safety hazard of sample and personnel.

The fixing hole can further stabilize the sample by inserting the fixing rod; the size of the fastening bolt is M16, which is used to fix the detachable leg.

For the inclined support, the end of the bearing surface of the equipment support is matched with a stop bar, which is used to resist the pressure and prevent the equipment from leaving the bearing surface.

For the frame, the inner dimension of the mechanical frame is 2500 (L) mm × 1500 (W) mm × 3800 (H) mm, and the material is 316 stainless steel.
There is a mounting hole with a modulus of 20mm on the mechanical frame, and the drip tray can be moved up and down by adjusting the fixed rod, so as to meet the test requirements that the distance between the highest point of the top surface of the electrical equipment with different heights and the lowest point of the dripping hole needle is 200 mm.

The structure diagram of the frame and drip tray is as follows:

![Figure 5. Structure diagram of frame and drip tray](image)

3.2. Test method

3.2.1. System test method. The test method of water-proof performance drip test system is to move the rack to drive the drip pan to adjust to the top of the test equipment; water is injected into the cavity of the drip tray through the water inlet to make the water output from the end of the dripping hole needle; when the output water drops on the test equipment, it drives the drip tray to rotate around the connection position between the drip tray and the frame, making the drip tray rotate relative to the test equipment; After the water drops output from the drip tray act on the test equipment for a set time, adjust the area of the drip tray acting on the test equipment, and repeat the above process until the whole test area of the test equipment is covered; when the drip tray moves above the test equipment, adjust the inclination angle of the test equipment so that the test area of the test equipment is set at an angle with the horizontal plane.

3.2.2. IPX1 waterproof test method. For IPX1 waterproof test method, the details are as follows:

1) The water pipe at the outlet of the water storage tank in the flow control system is connected to the total water inlet of the drip tray. After the total water inlet of the drip tray enters into the water storage layer of the drip tray, the bottom of the water storage layer of the drip tray is fixed and evenly distributed with the drip hole base, and the needle head of the drip hole is inserted into the base of the drip tray. The outlet end of the electrical control cabinet in the electrical system is connected to the motor reducer.

2) Place the sample placed in the sample area on the horizontal support with a crane, and then use the forklift to move the horizontal support to transport the tested sample to the test area, push the mechanical frame to the appropriate position, and place the sample under the drip tray; adjust the fixed rod to make the lowest point of the drip hole needle and the highest point of the tested equipment top 200 mm apart, and set it on the electrical control cabinet. The speed of inverter control panel is 1r/ min. Press the start button on the electrical control cabinet to realize the speed of drip tray is 1r/ min. The water flow of drip tray is set as 10+0.5mm/min through the touch screen of PLC, and the test duration is 10min. The vertical dripping has no harmful effect on the equipment.

3) When the bottom of the drip pan is smaller than the tested shell, the universal wheel is used to move the mechanical frame to divide the tested shell into several parts for separate test. The surface size of each part of the shell should be sufficient for the drip tray to cover it. The test is carried out until all the surface of the shell drips to the specified time.
3.2.3. IPX2 waterproof test method. The IPX2 waterproof test method is as follows:

1) The water pipe at the outlet of the water storage tank in the flow control system is connected to the total water inlet of the drip tray. After the total water inlet of the drip tray enters into the water storage layer of the drip tray, the bottom of the water storage layer of the drip tray is fixed and evenly distributed with the drip hole base, and the needle head of the drip hole is inserted into the base of the drip tray. The outlet end of the electrical control cabinet in the electrical system is connected to the motor reducer;

2) Front test of equipment under test
   The sample in the sample area is placed on the bracket inclined 15° back and forth with a crane, and the back of the sample is placed on the side close to the detachable leg. At this time, the bracket is equipped with detachable legs, and the support bracket of the detachable leg is in a horizontal state. Insert the fixing rod into the fixing hole, and wrap the sling and rope to the retaining ring and baffle plate to ensure the stability of the sample, and then use the forklift to move the support in order to transport the sample to the test area. The test personnel fixed the forklift to support the test sample, and removed the detachable leg from the bracket with a torque wrench, so that the sample was in front of the sample and kept at 15° tilt. Then push the mechanical frame to the appropriate position, and place the sample under the drip tray. By adjusting the fixed rod, the distance between the lowest point of the dripping hole needle and the highest point of the top surface of the tested equipment is 200 mm. Through the touch screen of the programmable liquid crystal controller, the water flow and operation time of the drip tray are set to ensure that the dripping flow of the dripping hole needle is 30+0.5mm/min and the test duration is 2.5min. The drip tray water storage layer can store water. Even if the power supply of the electrical system is cut off, the water will continue to drip until there is no water in the water storage layer. Therefore, the mechanical frame can be directly removed to ensure the test dripping time. At the same time, touch the PLC to stop the water supply. Dripping water in the vertical direction has no harmful effect on the sample.

3) Back test of equipment under test
   The tested sample is placed on the bracket inclined 15° back and forth with a crane, and the front of the sample is placed on the side close to the detachable leg, and the remaining operation is the same as that in step 2);

4) Left side test of equipment under test
   The tested sample is placed on the left and right inclined 15° bracket by crane, and the right side of the sample is placed on the side close to the detachable leg, and the remaining operation is the same as step 2);

5) Right side test of equipment under test
   The sample is placed on a 15° left-right tilt bracket with a crane, and the left side of the sample is placed on the side close to the detachable leg, and the remaining operation is the same as step 2);

6) When the bottom of the drip pan is smaller than the tested shell, the universal wheel is used to move the mechanical frame to divide the tested shell into several parts for separate test. The surface size of each part of the shell should be sufficient for the drip tray to cover it. The test is carried out until all the surface of the shell drips to the specified time.

4. Advantages and effects
To sum up, compared with the existing technology, the advantages and effects of the device are mainly reflected in the following aspects:

(1) It solves the problem that the existing device can not test the waterproof performance of IPX1 and IPX2 for large-scale equipment. The flow control system is used to ensure the accurate and automatic control of water flow, which meets the requirements of national standard for detection. A universal wheel is installed at the bottom of the device to facilitate the detection of large-scale equipment;
(2) By rotating the drip tray, the relative rotation state between the drip tray and the test equipment can be formed, which can meet the requirements of large-scale equipment for IPX1 waterproof performance test;

(3) The equipment support is configured, and the placement state of the equipment to be tested is adjusted to make the test surface of the equipment to be tested and the horizontal plane present a set angle. With the stop bar, the test equipment can maintain an inclined state, so that the state of the equipment receiving water drops can meet the requirements of IPX2 waterproof performance test.

5. Conclusion

The innovation of this paper is to provide a water-proof performance dripping test device, system and method for the defects of existing technology, which solves the problem that the existing device can not test the waterproof performance of IPX1 and IPX2 for large-scale equipment, which is convenient for the test of large-scale equipment. At the same time, it makes the test process easy for the staff to operate, has strong economic value and social significance, and can be widely used in testing units.

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