EVALUATION OF A DRYER IN A STEAM GENERATOR

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ABSTRACT

The hooked-vane-type dryer is used in vertical, natural circulation steam generators used in PWR-type nuclear power stations. It separates the fine droplets of water carried by steam so that the steam generator outlet steam moisture is below 0.25%. Such low moisture is demanded to ensure a safe and economic operation of the unit. The dryer is composed of hooked vanes and a draining structure. A series of tests to screen different designs were performed using air-water mixture .

The paper presents the results of the investigation of the effect of the number of drainage hooks , the bending angle , distance between two adjacent vanes, and other geometrical parameters on the performance of a hooked-vane-type steam dryer. It indicates that the dryer still works effectively when the moisture of the steam at the dryer inlet changes in a wide range, and that the performance of the dryer is closely related to the geometry of the draining structure . On the basis of the results of this program, a draining structure with an original design was selected and it is presented in the paper. The performance of the selected draining structure is better than that of similar structures in China and abroad .

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1. THE EXPERIMENTAL SETUP AND TEST METHOD

The air-water test facility is shown in Figure 1. Because of the limited capacity of the air blower, only a part of dryer was tested .

The hooked vane and draining structure can be assembled and dismantled easily. The wet steam is imitated by a mixture of air and atomized water . The mixing chamber for air and atomized water is sufficiently large to ensure production of a homogeneous mixture. The mixture travels up from the mixing chamber, turns 90 ° , and is passed to the test body. After being separated, the air turns 90 ° and travels up into the salt collection box. The design of above facility considers the simulation of actual flowing of wet steam in a steam generator. The polymethyl observation windows are installed on both the mixing chamber and the walls before and behind the test body. The draining pipes joined with the water collection trough are U-typed pipes with certain height. This height can form enough water sealing to prevent air from escaping from the pipes.

Carry-over K indicates the separating effect of the test component. It is measured through salt collection method.

Some big droplets of water are entrained by air from the bottom of the test component and fall to the bottom of the facility again. The weight of them are determined by measuring the flow rate of water drained behind the test component. The weight also indicates the separating effect of test component. The test indicates that the smaller the weight is, the smaller the carry-over is and the better the separating effect is, vice versa. .

Na_3po_4 is added into circulation water , which makes circulation water maintain sodium ion concentration around 400 mg/kg .The pure water is obtained by the method of ion exchange. It is used for absorbing salt water from the wet air passing the salt collection box . The weight of the pure water in the salt collection box is 15 kg . The sodium concentration is measured through sodium concentration digit meter. One test condition continues 20 minutes, and the data are recorded a time every 5 minutes .

2. TEST COMPONENT AND TEST CONDITION

The hooked-vane-type dryer test component is shown in Figure 2. The structural dimension of test component and test conditions are listed in table 1 and table 2 .

Only one of the geometrical parameters of the dryer is changed for every test component .

The vanes and hooks are made of 1 mm thickness zinc-plating steel plates. The plates are stamped forging. The hooks are spot welded on vanes . There are 14 mm long flat segments in both ends of vanes . The test component is assembled by location rods at 4 angles of vanes .

A perforated plate is installed before vane assembly. The diameter of the holes in the perforated plate is 8 mm. The area of the holes is 16% of the area of the plate.

Table 1 Hooked-vane-type Dryer Test Component Structural Dimension

Item	I	II	III	IV	V
Bending Angle, α	30°	30°	30°, 38°, 45°	30°	30°
Wavelength, t, mm	35	35	35, 47, 42	35, 52	35
Number of Hooks, n	5, 7, 9, 11	9	9	9	9
Pocket Gap, c, mm	2	1,2,3	2	2	2
Width of Vane, L, mm	87.5, 122.5, 157.5, 192.5	157.5	157.5, 211.5, 189	157.5, 234	157.5
Distance Between Two Adjacent Vanes, a, mm	11	11	11	11	11, 13, 15

Table 2 Test Condition

Item	Screening Test	Inlet Moisture Test
Test Pressure, P	Atmosphere	Atmosphere
Air Flow Rate, Q, m^3/h	2000~3700	2570~3700
Inlet Air Velocity, W, m/s	7~13	9~13
Water Atomizing Pressure, P_n, MPa	0.6	0.6
Water Flow Rate, G, kg/h	1500	900~1800
Inlet Moisture, ω, %	28	19~32

3. ANALYSIS ON TEST RESULTS

3.1 Number of Drainage Hooks

The vane assemblies with the number of drainage hooks of 5, 7, 9 and 11 were tested. Figure 3 presents the steam carry-over, K, as a function of inlet air velocity, W, for various number of drainage hooks, n. The threshold inlet air velocity increases significantly from n=5 to n=7, then it increases a little from n=5 to n=7, after which there is a small decrease from n=9 to n=11. For n smaller than 9, the separation of water increases with the number of drainage hooks because the number of hooks is proportional to the wet surface area. For n larger than 9, because of the increasing pressure drop, the air passes through the water collection trough increasing the carry-over.

3.2 Pocket Gap

Increasing the pocket gap, c, is beneficial from a point of view of the efficiency of water collection. But, as shown in Figure 4, when the distance between the two adjacent vanes is fixed, increasing the pocket size decreases the efficiency. This is because both the resistance of hooked-vane assembly and the air flow rate decrease with decreasing pocket gap. The decrease of the resistance is beneficial to drainage. The decrease of the air flow rate reduces the carry-over.

The vanes capture the water droplets mostly in the inlet region of the vane. If the pocket gap in the inlet region of the vane is increased appropriately, and the pocket gap in vane outlet section is gradually decreased, the water drops will be captured effectively and the air velocity at the drainage hooks will be lowered. This possibly modifies the separating effect of the vanes.

3.3 Bending Angle

As shown in Figure 5, the increase in the bending angle, α, significantly increases the threshold inlet air velocity. Its effect on the resistance of the test component is even more pronounced. In principle, increasing the bending angle should increase the efficiency of the vanes for water drop capture. But increasing the bending angle also decreases the cross-sectional area available for the air flow between the vanes. As a result, the air velocity increases in the vane assembly even though the mass flow rate of the air is unchanged. This increased air velocity increases the entrainment of the water captured by the vanes and ultimately reduces the efficiency of the separation.

3.4 Distance Between Adjacent Vanes

If the variation of the distance between the adjacent vanes is restricted so as to ensure that the drainage hooks of the adjacent vanes overlap, then increasing the distance between the adjacent vanes may increase the efficiency of the separation. This is because increasing the distance may increase the cross-sectional area available for the flow and lower the inlet velocity of the air. Lower velocity is beneficial for air-water separation.

3.5 Effect of Changing Inlet Moisture

Ass shown in Figure 6, a significant change in the inlet moisture causes a small change in the threshold air velocity. This test indicated that the inlet air moisture may change significantly in a hooked-vane-type dryer. The test setup still performed effectively when the inlet air moisture reached 32%.

3.6 Draining Structure

For a dryer, it is demanded not only that the vertical vane has a good separating performance, but also that the draining structure can drain effectively and instantaneously. The design of a draining structure is as important as that of the separating assembly. The water collection trough must be sufficiently deep to ensure that the water level is below the bottom of the vanes even at the highest steam load, so that overflow does not occur. Figure 7 shows a baffle that is installed in the trough. The baffle divides the trough into two chambers that drain independently. This structure can prevent the air from hampering the drainage that occurs when the air flow is short -circuit in the trough. The tests indicated that the drainage efficiency of this structure was better than that of similar structures in China and abroad.

4. SUMMARY OF THE RESULTS

It was shown that:

(1) The optimum structure of the hooked vane had the following geometry: α =30°,n=9,c=1 mm .

(2) The wavelength of the hooked-vane had only a very small effect on the separating efficiency .

(3) The optimized hooked-vane showed a better efficiency also under the conditions of high inlet air moisture.

(4) The draining capacity of the draining structure can be increased by installation of a baffle in the water collection trough. The baffle divides the trough into two parts that drain independently .

Figures:

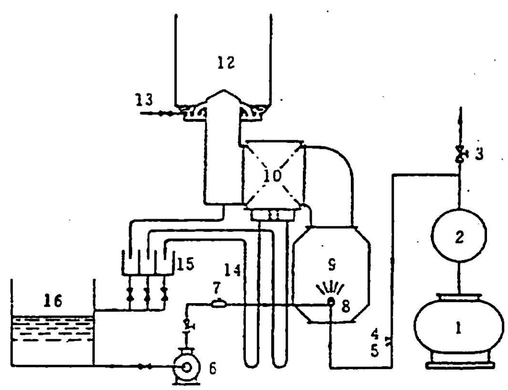

Fig.1 The air-water test facility

1—Air-blower ; 2—Air pressurizer ; 3—Air flow rate control valve ;4—Bamboo flute type tube ; 5—Thermometer ; 6—Water pump ;7—Orifice meter ; 8—Atomizing nozzle ; 9—Mixing chamber ;10—Test body ; 11—Trough ; 12—Salt collection box ;13—Sampling tube ; 14—U-typed drainage pipe ;15—Drainage measuring box ; 16—Circulation water box.

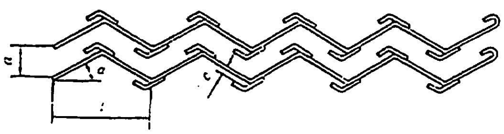

Fig. 2 Hooked-vane-type dryer test component

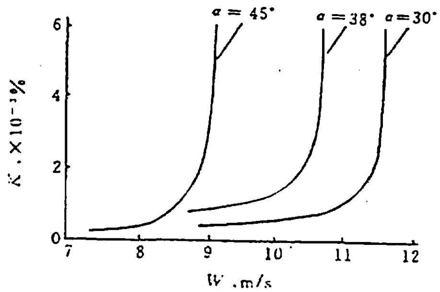

Fig. 5 Carry-over as a function of inlet air velocity for various bending angles

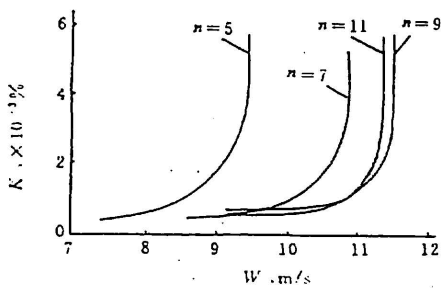

Fig.3 Carry-over as a function of inlet air velocity for various numbers of drainage hook

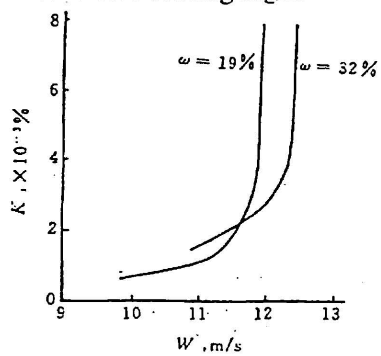

Fig. 6 Carry-over as a function of inlet air velocity for various inlet air moistures

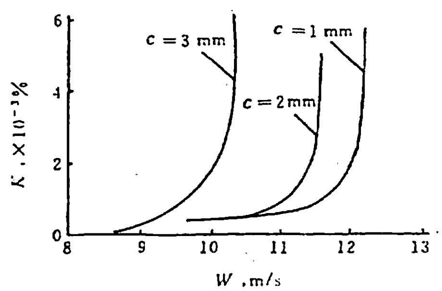

Fig. 4 Carry-over as a function of inlet air velocity for various pocket gaps

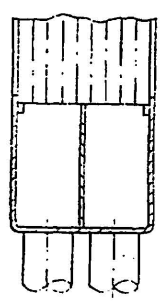

Fig. 7 Draining structure