Experimental Investigation of the Trapping Efficiency of an Intermediate Trap for ECCS Recirculation Strainer

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1. Introduction

The suction head of the safety injection pumps should be maintained after hypothetical loss of coolant accident of the nuclear power plant because the high energy jet force from the break fragments the thermal insulation and protective coatings into particulate pieces and then may block the ECCS recirculation strainer. The fine holes of the fiber insulation pieces can be filled up by particles of coating, which can produce higher head loss. Therefore, most existing strainers should be replaced with larger and more efficient strainers in order to provide sufficient suction flow even when particles accumulate on the strainer. For a cost-effective design change, the concept of intermediate trap (IT), a pre-filter, can be considered. The IT is installed in a specific location of the flow path over the reactor building floor upstream of the ECCS strainer. It reduces the flow velocity and thus ultimately sinks most of the particles before reaching the strainer. This paper describes an experimental method pertaining to the trapping efficiency of the intermediate trap to verify its performance and to elucidate the trapping mechanism of the coating debris with the plant-specific parameters.

2. Experimental Methods

2.1 Test Flume Design

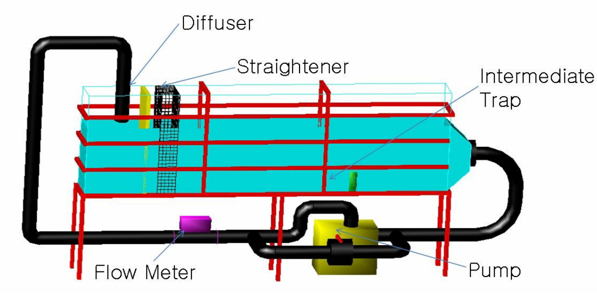

Fig.1 Test Flume Components.

The test flume consists of a flume containing diffuser (porous media), a flow straightener, a simulated IT, a recirculation pump and piping, as shown in Fig. 1. The flume is 5m in length, 0.5m in width and 1.5m in height. The diffuser is installed near the water inlet to make a uniform flow of water over the cross-section of the test flume. The flow straightener is installed directly behind the diffuser to dampen and straighten the flow that is incoming from the diffuser, before it enters the main test region of the flume.

2.2 Test Conditions

The test matrix used in this paper is summarized in Table 1. The porosity of the hole-type IT (IT7) is 0.35%.

Table 1. Test Matrix of the Present Test

Test #	Flow Velocity (cm/s)	Size of Coating Simulant (mm)	Type and Size of Mesh (mm)
IT1	9, 12	1.0 ~ 3.0	net type, 0.12
IT2	9, 12	1.0 ~ 3.0	net type, 0.20
IT3	9, 12	1.0 ~ 3.0	net type, 0.50
IT4	9, 12	0.1 ~ 3.0	net type, 1.00
IT5	9, 12	0.1 ~ 3.0	net type, 1.50
IT6	9, 12	0.1 ~ 3.0	net type, 2.30
IT7	9, 12	0.1 ~ 3.0	hole type, 2.30

The size distribution of the coating stimulant is determined from plant data [1]. Three size classes are used. Their percentage in the mixture is presented in Table 2.

Table 2. Size Distribution of the Coating Simulant

Size (mm)	Percentage (%)
0.1~0.5	76.7
0.5~1.0	9.3
1.0~3.0	14.0

2.3 Test Procedure

The trapping efficiency tests are performed according to the following procedure:

a. Deterimine the amount of coating simulant and prepare the coating simulant mixture according to the ratio presented in Table 2.
b. Spread the coating simulant uniformly through 2.7~3.5 m region on the test flume floor
c. Place the intermediate trap at 4 m downstream on the test flume floor
d. Fill the water up to 1.0 m height of the test flume
e. Set up a video camera that can easily capture the movement of the simulant
f. Increase the flow rate until it reaches the specified velocities
g. Keep the flow rate constant and observe the movement of the coating simulant (This usually takes about 16~18 hours)
h. If the coating simulant movement reaches a steady

state, drain the water

i. Collect the coating simulant that has accumulated on the flume floor upstream of the intermediate trap and dry the collected simulant in an oven
j. Measure the dried coating simulant mass and calculate the trapping efficiency of the intermediate trap

3. Results and Discussion

A series of tests are performed to characterize the coating dynamic properties of the tumbling and lifting velocities. The tumbling and lifting properties are the threshold fluid conditions necessary to induce the tumbling of the coating fragments on the reactor building floor and induce the lifting of the coating fragments over the IT structure, respectively. Table 3 shows the test results of the tumbling and lifting velocities for each size class. If the simulant size ranges from 0.1 to 0.15 mm, the tumbling velocity is approximately 3 cm/sec; if the size is larger than 1 mm, the tumbling velocity is 4.3 ~ 4.5 cm/sec. The test results also show that the lifting velocity is nearly twice as large as the tumbling velocity for each case. Compared with previous tests [2, 3], the present test results show comparatively small tumbling velocities because spherically shaped particle-type silica is used. This type of silica has a smaller contact surface with the floor compared to chip-shaped material. The spherically shaped particle results in moving behavior with less flow velocity compared to chip-shaped material.

Table 3. Tumbling and Lifting Velocities for Each Size Class of Silica Simulant

Tumbling velocity (cm/s)	Silica simulant size (mm)	Lifting velocity (cm/s)
2.92 ~ 3.17	0.10 ~ 0.15	5.24 ~ 5.56
3.84 ~ 3.97	0.20 ~ 0.50	7.46 ~ 7.81
4.06 ~ 4.13	0.50 ~ 1.00	7.97 ~ 8.25
4.25 ~ 4.51	1.00 ~ 3.00	8.67 ~ 9.21

Seven (7) tests are performed to measure the trapping efficiency while varying the average velocity of the flow in the flume, the screen type and the size of the simulated IT. 43kg of silica power is used as the stimulant particles. The test results for each IT screen mesh and flow velocity are summarized in Table 4. It can be deduced from these tests that ITs with a smaller mesh size for large coating particles may give rise to more screen blockage and backflow which settles the coatings farther away from the IT. Therefore the trapping efficiency is high (above 99%) but depends little on the mesh size for large particles.

For a broader simulant size distribution as expected in actual plants, the trapping efficiencies largely depend on the mesh size of ITs (IT4 ~ IT7). If the average flume flow velocity is 9 cm/sec, the trapping efficiency ranges from 80 to 92 % according to the mesh sizes. Smaller simulant particles than the size of mesh of the IT penetrate the mesh holes of the IT or bypass over the IT structure. At a flow velocity of 12 cm/sec, the trapping efficiency is greatly reduced to approximately 70 % because of the lifting of the particles in the flume.

The results of this study show that although the flow velocity is three times larger than the tumbling velocity of the coatings, an intermediate trap positioned nearest to the ECCS strainer can settle more than 80% of the coating particles with a mesh size less than 2.3mm. In a plant application, the IT can keep more than 80% of the coating particles from being transported to the ECCS strainer if it is located in a region where the average flow bulk velocity is about or less than 9.0 cm/sec. These results are currently being referenced in the preparation of the design specifications of a trap for a domestic plant

Table 4. Measurement Results for Trapping Efficiency

Test #	Flow Velocity 9 cm/sec	Flow Velocity 12 cm/sec
IT1	100	99.6
IT2	100	99.5
IT3	100	99.0
IT4	92.5	70.1
IT5	89.5	-
IT6	80.1	-
IT7	82.3	66.3

3. Conclusions

To verify the function and elucidate the trapping mechanism of the coating debris, test methods and a test flume are developed by measuring coating dynamic properties of the tumbling and lifting velocity along with the trapping efficiency of an intermediate trap.

The results of this study are currently being referenced in the preparation of the design specifications of a trap for a domestic plant. Additional uses are expected for the future. The intermediate trap size and the trapping efficiency data obtained from this study can be used for the design of ITs for modifications in different plants when the data is expanded to a wide range of coating sizes and water flow conditions.

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