1/5-Scale Air Water Test for ECC Bypass

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1. Introduction

In ECCS of SMART reactor, a safety injection pump discharges cooling water into the annulus region to maintain the water level by filling the mount of loss of coolant under emergency situation such as SBLOCA. The pressure discharge into the break nozzle in the annular region induces the reversed steam-water flow from RCP pump discharge by evaporation. Then, the safety injection water could be bypassed by the shear force and drag force of the cross flow.

In this study, a visualization test was performed with air-water flow as a working fluid for the safety injection and mixture flow discharge. The complex phenomena such as film breakup, multiple liquid films, droplet entrainment and direct bypass were observed. The onset of sweep out was also checked. And the amount of bypass fraction was measured by controlling the water level.

2. Test Facility and Experiments

The test section was designed by 1/5-linear scaling method for the SMART330. The test section considers the downcomer annulus only. The test loop consists with the test section, two pumps, and four blowers as shown in Fig. 1. The diameter of break nozzle for this cold air-water test facility was enlarged to simulate the high pressure choking conditions.

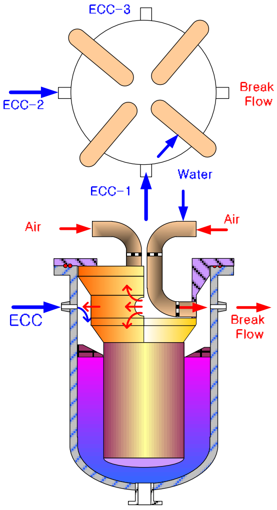


Fig.1 Schematic Diagram of Test Section

The test cases for the visualization and bypass measurement are as follows;

(a) Only SI injection with air discharge to the RCP,
(b) Air-water mixture flow discharge to the RCP,
(c) Air-water mixture flow discharge and one SI injection.

Here, the velocity of water and air was determined considering the scaling methods of the 1/5-scale linear and the modified linear scaling methodology [1]. During all experiments except sweep out test, the water level of the downcomer was controlled by a flow control valve.

3. Results and Discussions

3.1. Sweep out test

First, the sweep out was examined in the present experiments. It was observed that the water level of sweep out became lower as the air velocity increases.

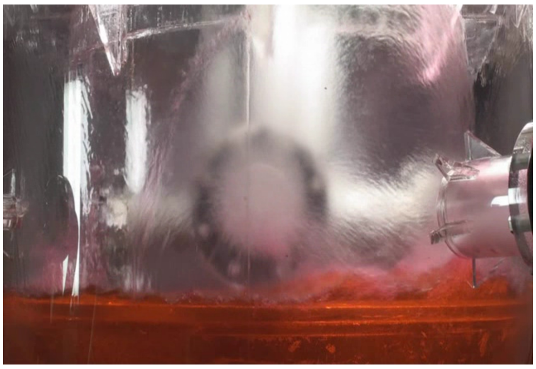
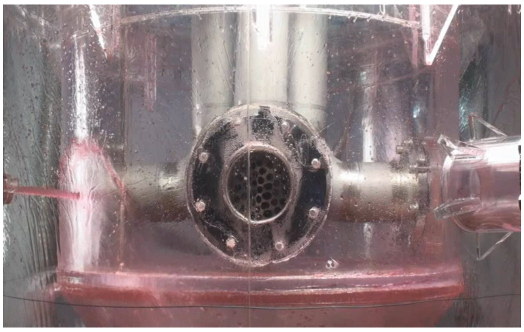


Fig. 2 Visualization of Sweep out

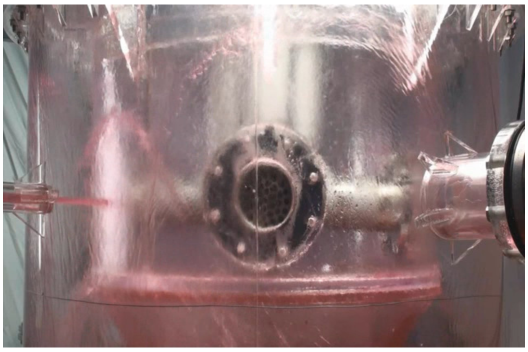
3.2. ECC water bypass

The bypass of ECC water is judged to be related to the velocities of air and injection water from the experimental observation. Three different conditions were compared as shown in Fig. 3. Fig. 3(a) shows the flow pattern for the condition of 3 m/s water velocity. At that velocity, impinging jet was not broken. So there is no secondary film at the inner wall of outer vessel. If it is compared with Fig. 3(b) and (c), the amount of bypass was rare due to the absence of secondary film. According to Fig. 3(b) and (c), the secondary film was bypassed directly. And it was also observed that the air velocity influenced the stretching of secondary film toward the break nozzle.



(a) $V_{water} = 3.6$ m/s; $V_{air} = 20$ m/s

(b) $V_{water} = 8$ m/s; $V_{air} = 10$ m/s



(c) $V_{water} = 8$ m/s; $V_{air} = 20$ m/s

Fig. 3 Visualization of ECC water bypass

3.3. Mixture flow direct bypass

To consider behavior of steam-water at scaled down test, air-water mixture was injected into annulus region through the air injection nozzle. The mixture flow spread extensively after the mixture was impinged at the inner wall of outer vessel. And the mixture flow was bypassed directly. From investigations at various test conditions, it was predicted that the bypass fraction was mainly affected by water mass flow rate and air velocity. Fig. 4 shows the direct bypass of mixture flow at maximum air velocity.

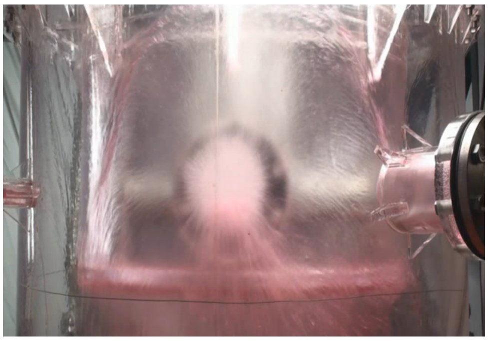


Fig. 4 Visualization of direct bypass of mixture flow

3.4. Bypass fraction measurement

In Fig. 5, the bypass rate was summarized. The air velocity corresponds to about 12.5 m/s and 20 m/s if the modified linear scaling and linear scaling were applied, respectively. All bypass rates were below 10% and ECC bypass rate was smaller than 5% regardless of the jet nozzle and air water flow.

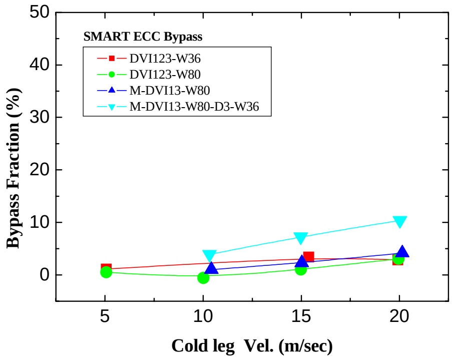


Fig. 5 Bypass fractions with air velocity

4. Conclusions

From the visual observation and measurement, the ECC bypass and direct bypass of mixture flow was found to be dependent on the width and thickness of liquid film nearby the break nozzle at the inner wall of the outer vessel. However, the amount of bypass rate of both cases was not significant although the rate could be changed according to the air velocity and the flow regime of the impinging jet. It was measured that the maximum bypass rate was below 10% in linear scaling as well as modified linear scaling method. Therefore, considering the conservatism of scaled down test, it can be judged that ECCS in SMART reactor have a good performance.

REFERENCES

[1] B. J. Yun, H. K. Cho, D. J. Euh, C. H. Song and G. C. Park, “Scaling for the ECC Bypass Phenomena During the LBLOCA REflood Phase”, Nucl. Eng. Des. Vol. 31, 315, 2004