Effect of Azimuthal Injection Angle on the Direct ECC Bypass in a DVI System

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1. Introduction

The direct ECC bypass fraction is strongly dependent on the relative ECC injection angle because the wake region of hot leg has the characteristics of ECC penetration due to the stagnant vortex behind the hot leg while the cold leg suction zone has the characteristics of ECC bypass (Kwon et al., 2002). Thus the azimuthal injection angle from the broken cold leg is most important parameter. In the APR1400, the DVI nozzles are located at the cold legs with the relative angle of 15 degrees. Therefore, the ECC film is formed at near a suction zone of the broken cold leg. If the relative angle between the cold leg and the DVI nozzle is increased to 45 degrees from the current relative angle of 15 degrees, the ECC film is also shifted to the upper region of the hot legs wake instead of the suction zone of the broken cold legs. Thus the ECC penetration will be increased with the relative azimuthal injection angle increasing. In this study, the effect of the azimutal injection angle on the direct bypass has been investigated by air-water test.

2. Methods and Results

2.1 Test condition

The relative azimutal injection angle of ECC from the broken cold leg to the hot leg is varied with -15,+7,+30, and +52 degrees. The tests are performed using air-water separate effect test facility (DIVA), which is a 1/5 linearly scaled-down model of the APR1400 nuclear reactor. The velocity of ECC injection is fixed at 0.89 m/sec. The single nozzle injection of ECC-4(broken cold leg side) is considered for all tested cases. The elevation of nozzle L-1 is for the simulation of the APR1400's DVI, while the L-3 is for the simulation of lower elevation injection. The test conditions are summarized at Table 1. The tested relative azimuthal injection angle and the elevation are shown in Fig. 1.

Table 1. Test conditions

Components	Flow Condition	Velocity
Fluid	Air, Water	-
ECC	DVI-4 Only	0.89 m/sec
Cold Leg	CL-1,CL-2,CL-3	5~20 m/sec STEP 5 m/sec

2.2 Visualization

The overall film shapes with the variation of the relative azimuthal injection angle are shown in Figs 2 to 5. Fig. 3 shows the typical film shape of the APR1400. The ECC films for the relative azimuthal angle of -15 degrees and +7 degrees are form at near the suction zone of the broken cold leg. Figs 4 and 5 show that the ECC films are formed at the wake of the hot leg. The left hand side of the ECC film is only formed at near the suction zone of the broken cold leg. The other parts of the ECC film are penetrated through the penetration zone of the wake behind the hot leg. Therefore, the relative azimuthal injection angle from the broken cold leg is a most important parameter for the direct ECC bypass. To reduce the direct ECC bypass fraction, the large relative azimuthal ECC injection angle is required.

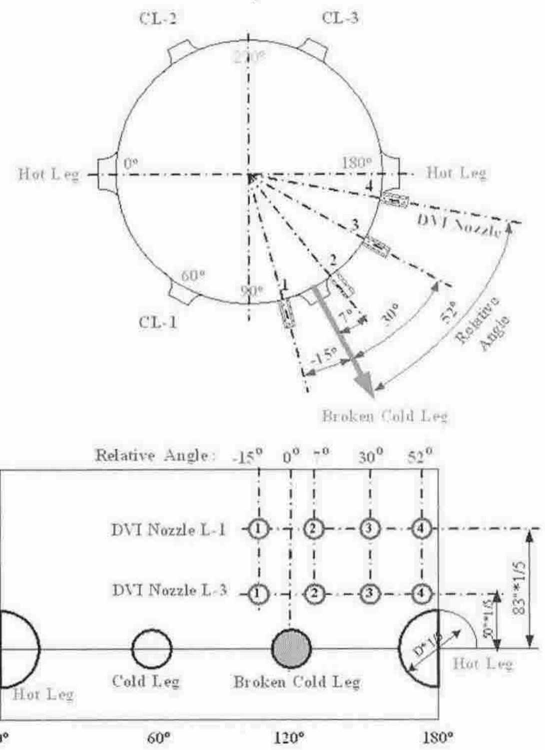

Fig. 1 Relative azimuthal injection angle tested.

2.3 ECC Bypass Fraction with Azimuthal Angle

Fig. 6 shows the ECC direct bypass fraction with the variation of the relative azimuthal injection angle of the ECC nozzles L-1. The elevation of DVI nozzle L-1 is to evaluate the nozzle elevation of 2.1m in the APR1400. The relative azimuthal injection angle of the APR1400 is +15 degrees. The test results show that if the ECC water is injected into the suction zone of the broken cold leg within the relative azimuthal injection angle of ± 15 degrees from the center of the broken cold, the ECC bypass fractions are greatly increased compared to those of the high relative azimuthal injection angle. The azimuthal injection angle of +52 degrees, which is injected on the upper part of the hot leg, has the lowest ECC direct bypass fraction.

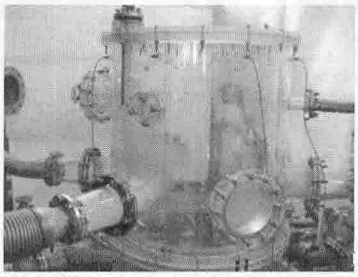

Fig. 2 ECC Film shape at -15 degrees(V=20 m/s).

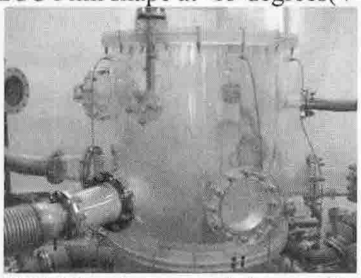

Fig. 3 ECC Film shape at +7 degrees(V=20 m/s).

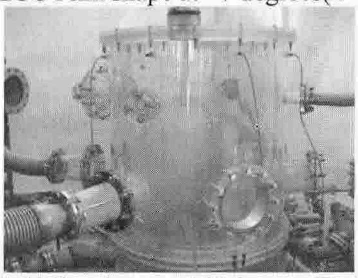

Fig. 4ECC Film shape at +30degrees(V=20 m/s).

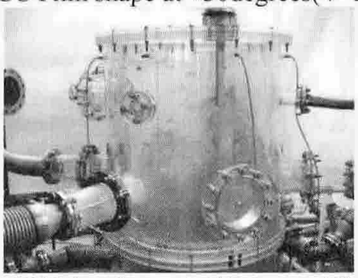

Fig. 5 ECC Film shape at +52degrees(V=20 m/s).

2.4 Elevation Effect

Fig. 7 shows the effects of the injection elevation. If the elevation of ECC injection nozzle is reduced to half ratio compared to the model of the APR1400's, the bypass fraction is little increased for the azimuthal angle of $\pm$15 degrees. However, the direct ECC bypass fraction is much reduced for the azimuthal angle of +52 degree. Thus, the large relative azimuthal injection angle is required to decrease the direct ECC bypass fraction when the ECC is injected at low elevation. Otherwise, the direct ECC bypass is increased because the ECC nozzle is closed to the broken cold leg.

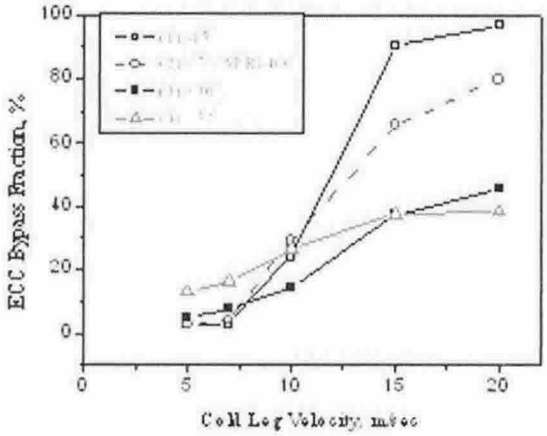

Fig. 6 Direct ECC bypass fraction for L-1 Nozzle.

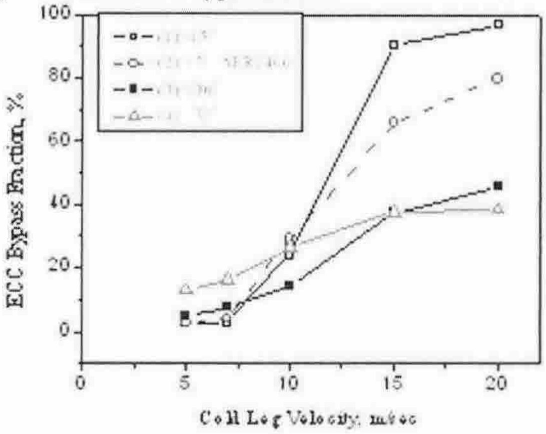

Fig. 7 Direct ECC bypass fraction for L-3 Nozzle.

3. Conclusion

The effect of azimuthal injection angles in a vertical DVI injection mode have been tested to evaluate the performance in reducing the direct ECC bypass compared to the standard design. The test results show that the azimuthal injection angle is the most effective parameter to reduce the direct ECC bypass. The elevation of the injection nozzles is also an important parameter to reduce the direct bypass. The azimuthal angle of attached DVI nozzles is recommended to move toward the hot leg even while keeping the elevation to reduce the direct ECC bypass fraction.

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