Effect of Water Column Type of DVI Injection on the Direct ECC Bypass

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1. Introduction

The direct ECC bypass fraction is strongly dependent on the ECC injection angle and the regional flow characteristics in the reactor downcomer annulus[1,2]. The ECC film spreading width is dependant on the linear momentum of ECC water and the wall resistance in the downcomer. If the ECC water is injected into the downcomer annulus as a water column rather than forming a film shape by impinging jet, the wall resistance becomes to be minimized compared to that of the impinging injection mode. In this experiment, the ECC water column is injected into the downcomer from the cap of the downcomer annulus. Also, the relative angle between the cold leg and the vertical DVI nozzle is varied from -15 degrees to +52 degrees to investigate the regional dependency on the direct bypass of ECC water in a downcomer annulus.

2. Methods and Results

2.1 Test conditions

The relative ECC injection angle from the broken cold leg to hot leg is varied with -15, +7, +30, and +52 degrees. The tests are performed in the air-water separate effect test facility (DIVA), which is a 1/5 linearly scaled-down model of the APR1400 nuclear reactor. The injection velocity of ECC water is fixed at 0.89m/sec. The air velocity of the cold leg is varied from 5 m/sec to 20 m/sec step 5m/sec. The performance with the injection angle is compared to the ECC direct bypass fraction. The single nozzle injection of DVI is considered for all tested cases. The test condition is summarized at Table 1. The tested relative vertical injection angle is 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 shapes of water column with the variation of relative injection angle are shown in Figs 2 to 5. Fig. 2 shows a typical shape of corresponding ECC flow at the same injection angle of the horizontal DVI in the APR1400. The ECC flow shape for the relative angle of -15 degrees and +7 degrees, as shown in Fig. 2, are form at near the suction zone of the broken cold leg. Therefore, most of the injected ECC water into the downcomer is bypassed throughout the broken cold leg. Fig. 4 shows the effect of the wakes of the hot leg. The ECC water column is shifted to the broken cold leg due to the momentum of the cross air flow in the downcomer. The column shape is maintained from top to half elevation between the DVI nozzle and the hot leg. After that location, the water column is broken up as a water slug and small drops. Fig. 5 shows the breakup mode of the water column. By a large spiral swirling flow shape, the ECC water drops and slug are pulled out through the broken cold leg. But, the major part of the ECC water is penetrated into the lower downcomer region. Therefore, the relative azimuthal injection angle between the broken cold leg and the DVI nozzle is preferred to be larger than +30 degrees to avoid the strong suction zone of the broken cold leg.

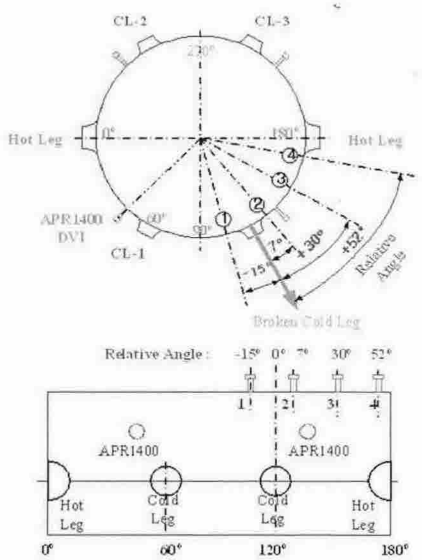

Fig. 1. Relative azimuthal angle of ECC injection

2.3 ECC Bypass Fraction

The ECC bypass fraction with the vertical injection angle of ECC water is shown in Fig. 6. The ECC water columns of the relative angle of -15 degrees and +7 degrees are all bypassed out through the broken cold leg. The direct ECC bypass fraction is over 0.8 to 0.95 for both cases. If an azimuthal injection angle between the broken cold leg and the ECC injection nozzle is increased, the direct ECC bypass fraction is much reduced. The direct ECC bypass, as shown in Fig. 6 for the velocity of 20 m/sec, is not more than 35%. Fig. 7 shows that the loss of wall resistance does not contribute to the ECC bypass above the velocity of 15 m/sec for the relative injection angle of +30 degrees.

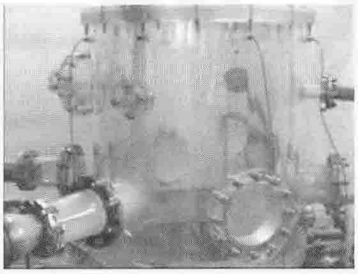

Fig. 2ECC bypass shape at +7 degrees(V=15 m/s).

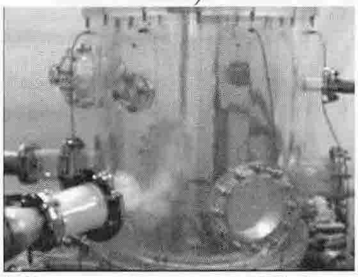

Fig. 3ECC bypass shape at +30 degrees(V=20 m/s).

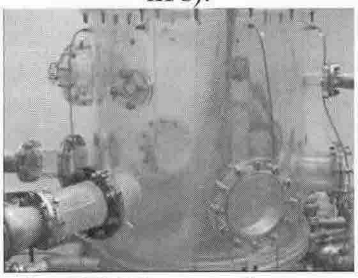

Fig. 4 ECC bypass shape at +52 degrees(V=20 m/s).

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

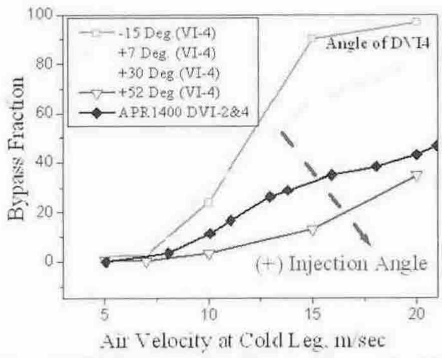

Fig. 6 Direct ECC bypass fraction with vertical injection angle from the broken cold leg.

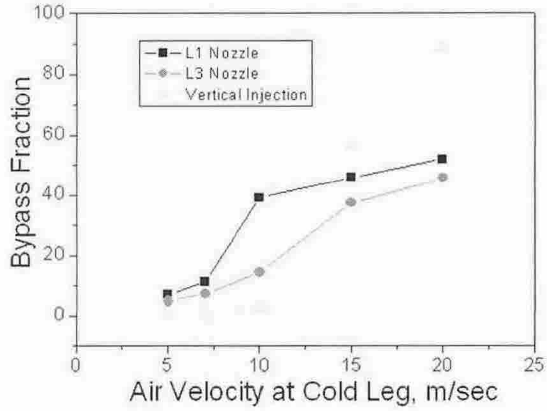

Fig. 7 Comparison of direct ECC bypass fraction between vertical and horizontal injection for relative angle of 30 degrees.

3. Conclusion

The effect of water column type of vertical injection mode have been tested to evaluate the performance in reducing the direct ECC bypass compared to the standard type of horizontal DVI in the APR1400. The test results show that the azimuthal injection angle is the most effective parameter to reduce the direct ECC bypass even in a water column type of DVI injection. The loss of wall resistance does not contribute to the ECC bypass above the velocity of 15 m/sec for the relative injection angle of +30 degrees. Additionally, the azimuthal angle of attached DVI nozzles is a parameter of considerable importance to reduce the direct ECC bypass fraction.

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