An Advanced DVI to Minimize the Direct ECC Bypass

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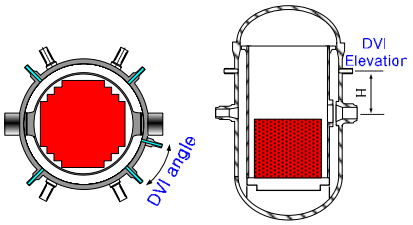
1. Introduction

In the APR1400, the direct ECC bypass behaviors in the reactor vessel downcomer are governed by steam coming from the intact cold legs and ECC injection location during the late reflood phase of a LBLOCA [1]. The direct ECC bypass rate around the suction region of a broken cold leg may determine the total ECC bypass fraction. If the ECC water is injected into the weak steam flow region in the downcomer, the ECC water bypass fraction will decrease [2,5]. Thus, the relative DVI angle between the cold legs and the DVI nozzles is an important parameter to decrease the ECC bypass fraction [3]. The regional steam flow characteristics such as the hot leg wakes, velocity direction and strength, and the ECC film shape in the reactor vessel downcomer annulus are also considerable parameters to decrease the ECC bypass fraction. In this study, advanced DVI features which have minimized the ECC bypass fraction are newly proposed [4].

2. Methods and Results

2.1 DVI Relative Azimuthal Angle and Elevation Effects



(a)DVI Angle Change (b)DVI Elevation Change

Fig. 1 Relative azimuthal DVI angle and elevation

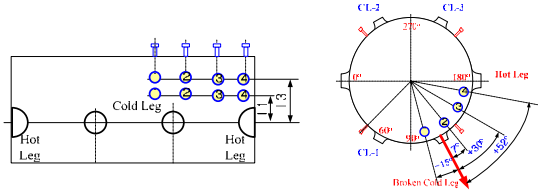


Fig.2 Tested relative azimuthal DVI angle

The relative ECC injection angle between the cold leg and the DVI nozzle, or the elevation of a DVI nozzle is a major parameter to change the injection region of the ECC film from a broken cold leg. Fig.1 and Fig.2 show the variation of the azimuthal DVI angle and the elevation. If the ECC film is formed far away from the suction region of the broken cold leg, the direct ECC bypass fraction will decrease to compare with the current APR1400's DVI features. Fig.3 shows the variation of the direct ECC bypass fraction for the relative DVI angle changing from a cold leg to a hot leg. The relative angle is varied with -15, +7, +30, and +52 degrees. The single DVI nozzle is considered for all the test cases. The injection velocity of the 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 high ECC bypass reduction rate is comparable. Fig.4 shows the ECC bypass reduction trend for the variation of the azimuthal DVI angle and the elevation. The azimuthal angle and the elevation of the DVI nozzle are considerable combinations to decrease the direct ECC bypass fraction.

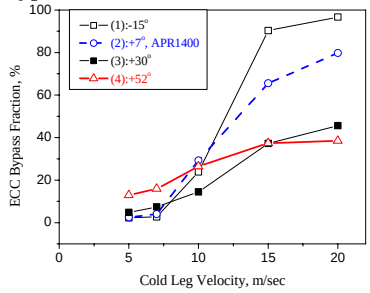


Fig. 3 Direct ECC bypass fraction for L-3 elevation.

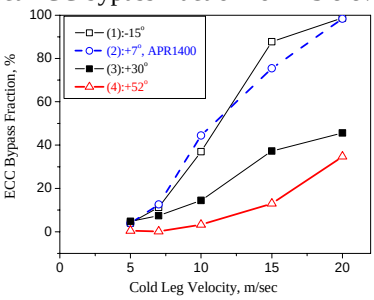


Fig. 4 Direct ECC bypass fraction for L-1 elevation.

2.2 Vertical ECC Injection

The ECC film breakup at around a broken cold leg enhances the entrainment rate of the droplets. If the ECC water is injected into the reactor downcomer without an ECC film breakup or wall skin friction, the downward penetration momentum of the ECC water will increase. Though, the ECC water column is injected into the suction region of the broken cold leg, the ECC water will flow out through the broken cold leg. The ECC flow shape is important at around the broken cold leg. But, the regional dependency is more dominant in the ECC bypass phenomena. The ECC water columns of the relative angle of -15 degrees and +7 degrees are all bypassed out

through the broken cold leg. The current relative DVI angle of the APR1400 is +15 degrees. The direct ECC bypass fraction is over 80% to 95% for both cases. If the azimuthal DVI injection angle between the broken cold leg and the ECC injection nozzle is increased, the direct ECC bypass fraction is considerably reduced. The direct ECC bypass, as shown in Fig. 6 for the velocity of 20 m/sec, is not more than 35%. The loss of a wall resistance does not contribute to the ECC bypass above the velocity of 15 m/sec for the relative injection angle of +30 degrees. Therefore, the relative azimuthal injection angle between the broken cold leg and the DVI nozzle should be larger than +30 degrees to avoid a strong suction zone of the broken cold leg.

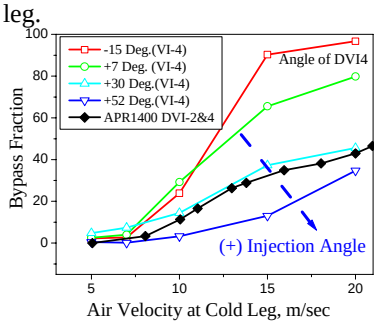


Fig.6. Bypass fraction with relative vertical DVI angle

2.3 Dual Core Support Barrel

Fig. 7 shows the conceptual shape of a dual core barrel. The dual core barrel has a role of a separator between the high speed steam flow and ECC flow in the reactor vessel downcomer. The dual core barrel annulus, between the core support barrel and the additional dual core barrel cylinder, plays a role of a downward ECC flow channel. The gap of the dual core barrel annulus is narrow when compared to that of a typical downcomer annulus. Fig. 7 shows the performance of the dual core barrel cylinder to reduce the direct ECC bypass. The bypass fraction of the dual core barrel is much lower than that of a typical DVI injection with a single downcomer annulus. The direct bypass fraction of the dual core barrel annulus is about 10% while the typical single downcomer annulus is 40%. The dual core barrel is the most contributable feature to reduce the direct ECC bypass near the broken cold leg by a suction flow out. The ECC water flows down through the new separated and isolated dual core barrel annulus in the reactor vessel downcomer from a high steam flow.

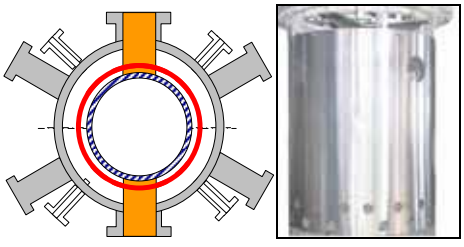


Fig. 7 Dual core support barrel

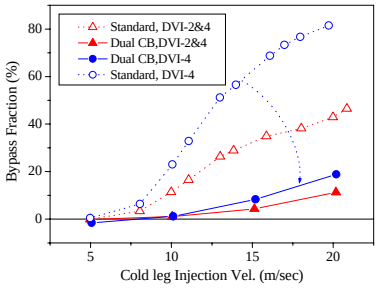
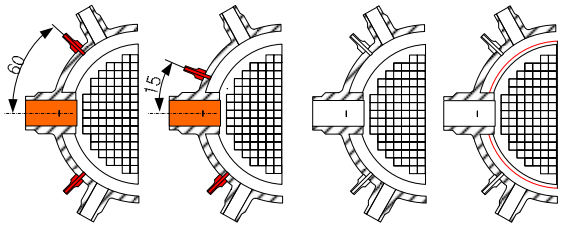


Fig.8. Bypass fraction with dual core support barrel

3. Conclusion

The test results show that the azimuthal injection angle variation and the dual core support barrel are the most effective methods to reduce the direct ECC bypass in the APR1400 DVI features. The shifted DVI relative azimuthal injection angle to the hot leg considerably reduces the ECC direct bypass fraction. Fig.9 shows the proposed new DVI features for the relative azimuthal injection angle and the dual core support barrel to minimize or to reduce the direct ECC bypass fraction.



(a) New DVI angle of 15^{o} (b) New Dual Core barrel

Fig.9 Proposed New DVI Features

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[3] T. S. Kwon, Y.S. Shin, S.H. Hwang, C.H. Song., "Effect of Azimuthal Injection Angle on the Direct ECC Bypass in a DVI System"

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