Design Concept of DVI+

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1. Introduction

A new design feature of DVI+, to mitigate an ECC bypass fraction and to prevent switching an ECC inlet to a break outlet during a DVI line break, is presented for an advanced DVI system. The injected ECC water into the downcomer is easily shifted to the broken cold leg by a high steam cross flow which is coming from the intact cold legs during the late reflood phase of a LBLOCA with a smooth annulus of the downcomer in the current DVI system[1, 2]. The performance of the ECC penetration duct is evaluated by LOCA PCT behaviors for a LOCA and an ECC penetration flow shape for a nominal working condition. The MARS code and CFX code are applied for this evaluation.

2. A shape of DVI+

2.1 Duct shape

For a protective ECC flow down channel from a high-speed cross flow in a downcomer, a 4-duct which is called an ECC penetration duct is installed at the outside of a core barrel as shown in Fig. 1. The ECC penetration duct has a gap(height to the radial direction) of 3/25~7/25 of the downcomer annulus gap. As shown in Fig. 2, the ECC penetration duct prevents strong steam-water interactions in a typical downcomer annulus during a LBLOCA. The ECC penetration duct is a fully separated ECC water downflow channel in the downcomer annulus. The injected ECC water flows downward into the lower downcomer through the ECC penetration duct without a strong entrainment to a steam cross flow. The outer downcomer annulus of the ECC penetration duct is the major steam flow zone coming from the intact cold leg during a LBLOCA. The alpha is 35^{o} degrees and the beta is 15^{o} degrees in Fig. 1.

The DVI nozzle and the ECC penetration duct are only connected by the ECC water jet which is called a hydrodynamic water bridge during an ECC injection period, otherwise these two components are disconnected from each other without any piping. The diameter of the ECC water capturing holes at the ECC penetration duct are about 2 times that of the DVI nozzle diameter[3]. The ECC water jet flows into the ECC penetration duct inlet holes which have the same elevation and angle as the corresponding DVI nozzles while the ECC water is activated. The hydrodynamic water bridge is disconnected during a DVI line break due to a loss of injection momentum of the ECC water.

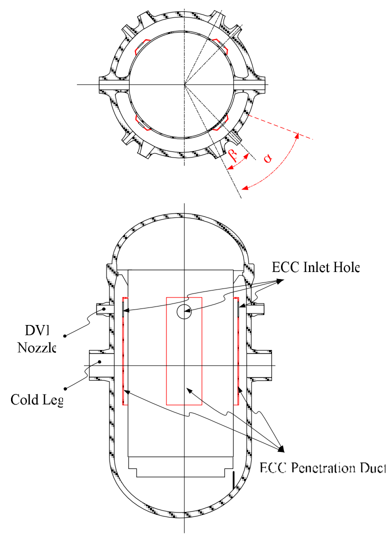
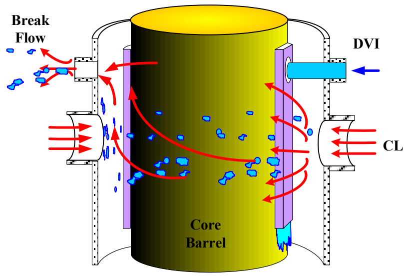
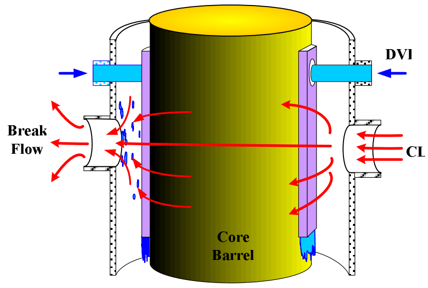


Fig.1 Duct shape



(a) DVI Line Break



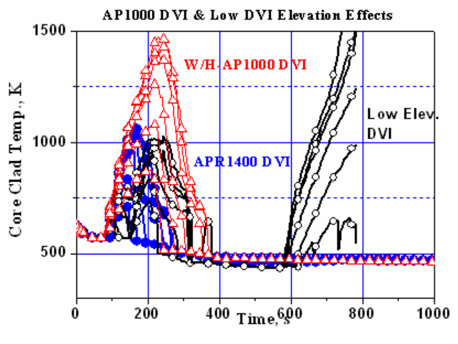
(b) LBLOCA

Fig. 2 Flow pattern of downcomer with ECC penetration duct

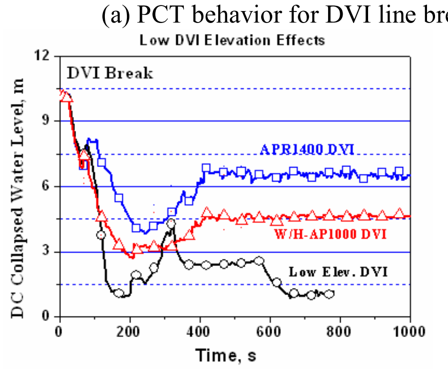
3. Results

3.1 MARS Results (no indent)

The MARS simulation results show that the Peak cladding temperatures of a DVI line break for both the low DVI elevation which was located at between the CL center line and the Flow skirt elevation, and AP1000's elevation of the DVI are increased over the design limit of 1204^{o}C as shown in Fig. 3. Therefore, the elevation of the DVI nozzle should be at above the centerline of the cold leg or higher. The PCT behavior for the current DVI design where the DVI nozzle is connected to the ECC penetration duct in the downcomer annulus will increase over the design limit during the DVI line break.



(a) PCT behavior for DVI line break



(b) DC collapsed water level

Fig. 3 DVI line break for DVI elevation change

3.2 *3-Dimensional CFX and MRAS analysis*

A 3-dimensional fine mesh calculation for an ECC penetration shape was performed using the CFX code for a nominal working condition. Fig. 4 shows the stream line of the ECC water penetration in the ECC duct. The injected ECC water into the ECC penetration duct flows down to the lower downcomer. This result shows that the ECC water inside the duct flows to the lower downcomer well during the RCP working.

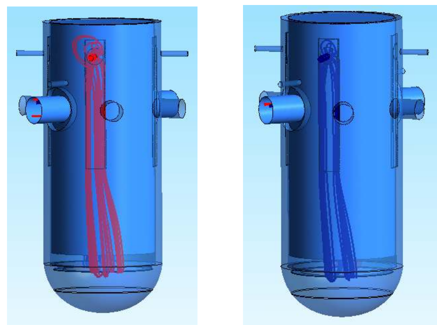


Fig. 4 ECC penetration shape of ECC duct

4. Conclusion

The feasibility of DVI+ has been tested to evaluate the LOCA performance using the MARS and CFX codes. The test results show that the ECC water flows to the lower downcomer well. The peak cladding temperature increases over the design limit during a DVI line break in the AP1000's DVI and a low elevation of the DVI design features.

REFERENCES

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[2] T. S. Kwon, C.-H. Song, B. J. Yun, and H. K. Cho, Effect of the Yaw Injection Angle on the ECC Bypass in Comparison with the Horizontal DVI, Nuclear Engineering and Design (NED), Vol. 225, pp.295-304, 2003.

[3] Tae-Soon Kwon, Chul-Hwa Song, and Won-Pil Baek, An Advanced Design Concept of a Direct Vessel Injection, ICAPP, Reno, NV USA, June 4-8, 2006.