Proposal of a Dual Core Barrel for New Safety Injection Concept

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1. Introduction

The direct ECC bypass fraction is strongly dependent on the circumferential gas velocity in the reactor vessel (RV) downcomer with DVI nozzles. The ECC entrainment and the film break-up are also highly dependent on the cross flow in the downcomer. The ECC flow channel, which is protected from such a high-speed cross flow, is a considerable design feature to reduce the ECC bypass fraction. In this study, newly proposed is the dual core barrel cylinder located between the RV vessel wall and the core barrel in the downcomer annulus, which leads to a new downcomer annulus with two annulus zones. The dual core barrel annulus, located between the core barrel outer wall and the dual core barrel cylinder, playa a role of a downward ECC flow channel. The RV downcomer annulus is located between the RV inner wall and the dual core barrel. The gap of the dual core barrel annulus is narrow compared to that of a typical downcomer annulus.

2. Methods and Results

2.1 Test conditions

For a protected ECC flow annulus from the high-speed cross flow in the RV downcomer, thin plate cylinder was installed at the outside of the core barrel. The narrow gap annulus which is called the dual core barrel annulus has a gap of 6mm in this study. The scaled down gap size of 6mm is corresponding to 30 mm in a prototype scale. The thickness of dual core barrel cylinder is 1 mm; this is corresponding thickness of 5mm in APR1400. If the DVI nozzles are extended directly from the upper downcomer to the lower downcomer, the downcomer suction occurs from the lower downcomer through the extended DVI nozzle in case of a DVI line break accident. Thus, there should be no solid pipe connection between DVI nozzle and the dual core barrel to prevent such a reverse break flow in a new concept.

The DVI nozzle and the dual core barrel is only connected by the ECC water jet which is called the hydrodynamic water bridge during an injection mode, otherwise two components are disconnected. The diameter of ECC water capturing hole at the dual core barrel wall is about 130 mm for the hydrodynamic water bridge. The ECC water jet flows into the dual core barrel hole which is the corresponding each DVI nozzle while ECC water is activated. For the hydrodynamic water bridge, the ECC nozzle and the catching hole of the dual core barrel are aligned well so as to flow the ECC water into the dual core barrel annulus.

The conceptual shape of a dual core barrel is shown in Figs 1 and 2. The geometry is 1/5 linearly scaled down compared to the APR1400. The injection velocity of ECC water is 0.89m/s. The air velocity of the cold leg is varied from 5 m/sec to 20 m/sec step 5m/sec. The test conditions are summarized at Table 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,and CL-3	5~20 m/sec (STEP 5 m/sec)

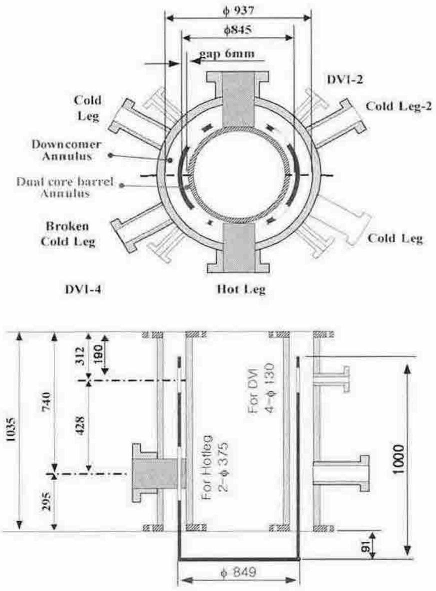

Fig. 1 Conceptual shape of a dual core barrel

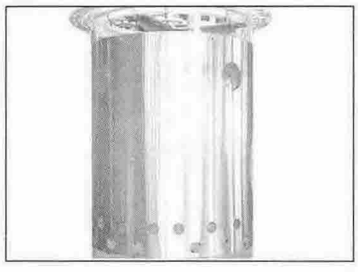

Fig. 2 Dual core barrel

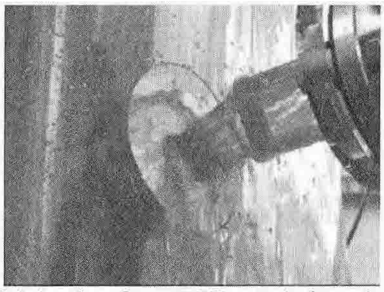

Fig. 3 ECC injection from DVI nozzle into the dual core barrel cylinder at the upper downcomer

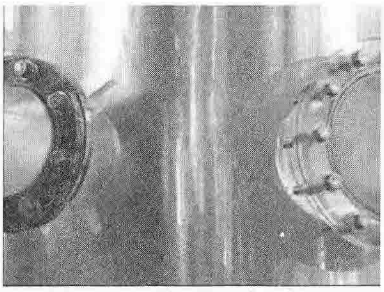

Fig. 4 ECC bypass shape at broken cold leg

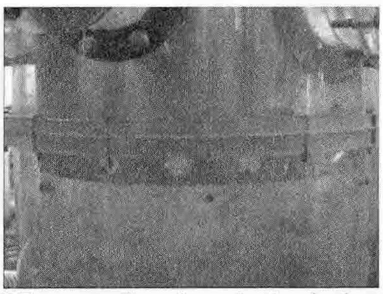

Fig. 5 ECC penetration shape in the dual core barrel

2.2 Flow Visualization

Fig, 3 shows a typical shape of ECC injection. The ECC water is spread well in the dual core barrel annulus. The ECC water film flows well into the dual core barrel annulus without spillage. Fig. 4 shows a flow pattern at the broken cold leg. No ECC film or slugs are appeared in the downcomer annulus. Small drops come from the gap between the hot leg and the dual core barrel. Fig. 5 shows the ECC penetration through the dual core barrel annulus. The major part of ECC water is penetrated into the lower downcomer. From these figures, it seems that the ECC flow channel to prevent liquid entrainment against the high-speed cross flow is very effective to reduce the direct ECC bypass.

2.3 Direct ECC Bypass

Fig. 6 represents the performance of the dual core annulus 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 dual core barrel annulus is about 10% while the typical single downcomer annulus has 40%. The bypass fraction of DVI-4, in Fig. 6, is quite low typically compared to an equivalent standard downcomer. The dual core barrel is the most contributable features to reduce the direct ECC bypass near the broken cold leg by suction because the ECC water flows down while isolated through the dual core barrel annulus cylinder.

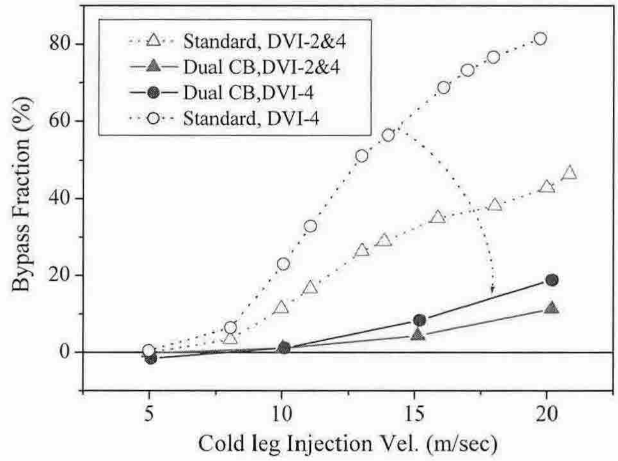

Fig. 6 Direct ECC bypass fraction

3. Conclusion

The effect of a dual core barrel concept has been demonstrated to evaluate the performance in view of reducing the direct ECC bypass compared to a standard type of DVI injection. The test results show that the dual downcomer annulus shape is a very effective concept to reduce the direct ECC bypass even though that concept should be investigated thoroughly from the thermo-mechanical points of view later.

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