Development of ECC Safety Injection Method Using Direct Vessel Inclined Injection System

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1. Introduction

When a large break loss-of-coolant accident (LOCA) occurs, the core cooling plays a key role in assessing the progression of the accident. Therefore, a study about the reduction of the emergency core cooling (ECC) water bypass ratio and simple design concept is a very hot issue in a safety injection (SI) system. In the APR1400, the Direct Vessel Injection (DVI) system will be used as a SI system. During the large break LOCA in the APR1400, the thermal hydraulic phenomena in the downcomer annulus are expected to be different from that of the Korean Standard Nuclear Reactor (KSNP) because of a new SI system, the DVI. DVI into the downcomer was occurred the mount of the ECC water bypass by the droplet. To be effective Emergency Core Cooling system (ECCS) during a large break LOCA in the APR1400, direct vessel inclined injection (DVII) is considered. In the DVII test, The multi-dimensional flow phenomena that is occurred in the APR1400 downcomer during the late reflood phase were studied experimentally using the full height of the 1/7 scale-down model of the APR1400. And the separate effect tests were performed in order to clarify the mechanism of the direct bypass and to derive the scaling parameters affecting the ECC direct bypass rate. The various flow regimes and their distribution in the downcomer have been identified and mapped. And the direct ECC bypass rate has been measured under the various air injection conditions. In the current study, the existing flow behaviors in the APR1400 downcomer during the reflood phase were proved experimentally using the 1/7 linearly scale-down model of the APR1400.

2. Experiment

2.1 Experimental apparatus

The experimental apparatus composes outer vessel and inner vessel of linearly scale-down APR1400 model. The outer vessel is separated into three parts in order to change the middle apparatus easily. To visualize the multi-dimensional flow phenomena, experimental apparatus makes acryl. Experiments are performed about three cases of angle (like this, 30°, 45° and 60°). And for comparison, DVI experiment takes part in same condition. Figure 1 illustrates the experimental apparatus with schematic and Table 1 shows a design parameter of experimental apparatus and APR1400.

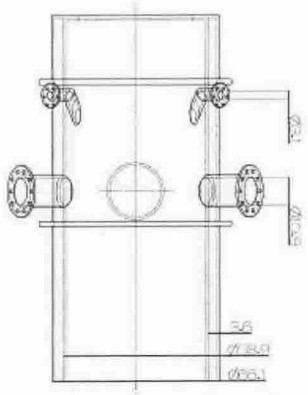

Fig 1. Schematic of DVII experimental apparatus

Table 1. Design parameter of DVII experimental apparatus

Design Parameter	APR1400 (m)	1/7 Test model (m)	DVII-THETA (m)
Elevation of upper plenum	12.750	1.82	1.47 (Except lower plenum)
Elevation of CL centerline	7.884	1.126	0.77 (Except lower plenum)
Elevation of DVI centerline	9.986	1.427	1.07 (Except lower plenum)
Outer vessel inner diameter	4.630	0.661	0.661
Inner vessel outer diameter	4.122	0.589	0.589
Downcomer gap	0.254	0.036	0.036
CL Inner diameter	0.762	0.109	0.109
HL outer diameter	1.6	0.23	0.23
DVI inner diameter	0.216	0.031	0.031

2.2 Experimental condition

When experiment start, ECC water penetrate in the downcomer with 0.805 m/s at each four nozzle. And Air is injected three cold legs with various velocities. Air velocity varies with six cases(to 5m/s from 30m/s, 5m/s summed each case). Air and water make a two-phase flow region and its mixture goes through out break. Fragment ECC water keep in a downcomer. Bypass ratio can acquire by inlet ECC water minus remaining ECC water as followed,

$$BypassRatio(\%) = \frac{Water_{inlet} - Water_{annulus}}{Water_{inlet}} \times 100$$

2.3 Experimental Results

From the DVII experiment and DVI experiment, we can make a comparative study of data. Figure 2 shows that each experiment measure bypass ratio. According to increase the air velocity, bypass ratio is increase. We can see that DVII is fewer bypasses than DVI.

Especially, an angle of 60 degrees is the most effective than other angle.

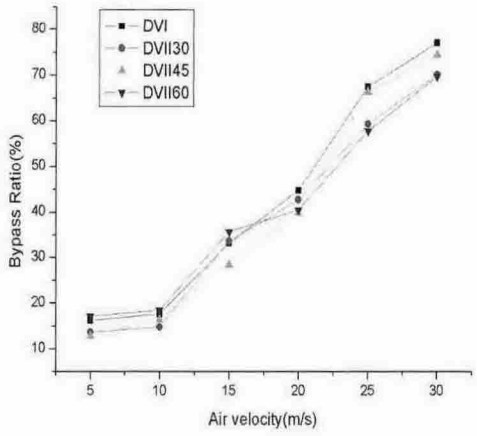

Fig 2. Comparison of bypass ratio in DVII and DVI experimental results

3. Conclusion

In this DVII experiment, a number of interesting hydraulic phenomena are observed. Figure 3 shows the bypass phenomena. A first distinguished phenomenon is that liquid film width become narrow because of stagnation point is lower than DVI nozzle and liquid film is thicker. Second, according to increasing the axial direction momentum, droplet flow at upper plenum is decreased distinctly than DVI experiment. Last, experimental data tell us that inclined injection is more effective than direct injection when we take a side view of bypass ratio.

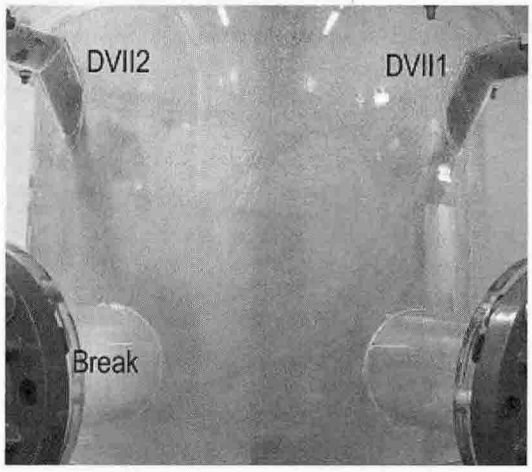

Fig3. Bypass phenomena in DVII60

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