Experimental study of ECC duct bypass for development of an advanced DVI+

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1. Introduction

A full scale ECC injection tests were performed for an advanced and optimized direct vessel injection system(DVI+) applied on the APR+ (Advanced Power Reactor plus). The DVI+ adopts an extended ECC penetration duct to increase the penetration of injected ECC flow [1].

Recently, the ECC penetration duct has been tested by using the 1/5 scaled air-water test facility DIVA. The estimated performance to reduce ECC direct bypass shows that the ECC duct has a improved capability of reduction in the direct ECC bypass when compared with that of a standard type of a DVI injection system adopted in APR1400[2~3].

The purpose of the present study is to investigate the ECC water spillage fraction in the full scale duct for the design optimization of the duct inlet.

2. Experiments

2.1 Scaling and Test Model

The scale ratio is summarized in Table 1.

The inner diameter of DVI nozzles in the APR1400 is 8.5 inch (215.9mm). The injection velocity of ECC nozzle for the condition of minimum injection for a LBLOCA reflood phase (run out condition) is 1.6 m/s. The downcomer is also 10 inch (250mm). Therefore, the test conditions were set up at the same condition of those values of the APR1400 in respect of momentum hydraulics.

2.2 Experimental Apparatus

The test facility consists of a test section, water supply system, instruments, control system and data acquisition system. Fig. 2 shows a schematic configuration of the test facility.

Table 1: Scaling ratio

Parameter	Scale ratio
Velocity ratio, v_R	1/1
Mass Injection Ratio, m_R	1/1
Downcomer gap, $Gap_{R,Duct}$	1/1
Duct With , W_R	1/1
Duct Height , H_R	1/1

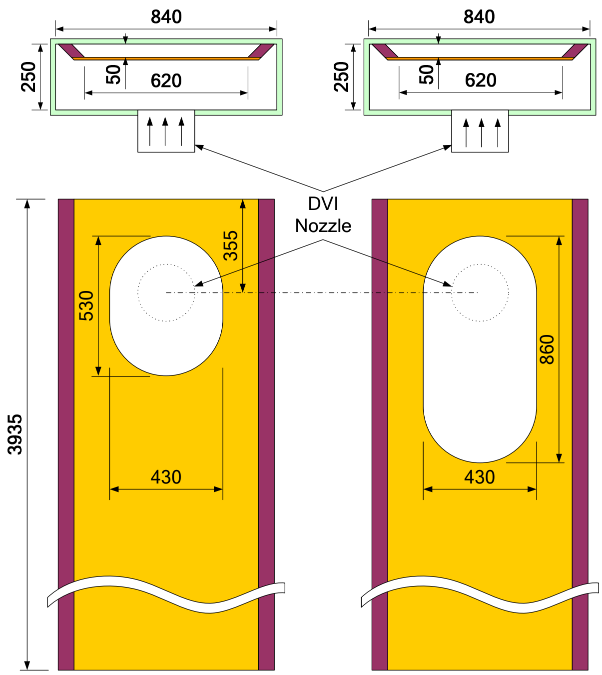

Fig. 1. Dimension of the ECC penetration duct

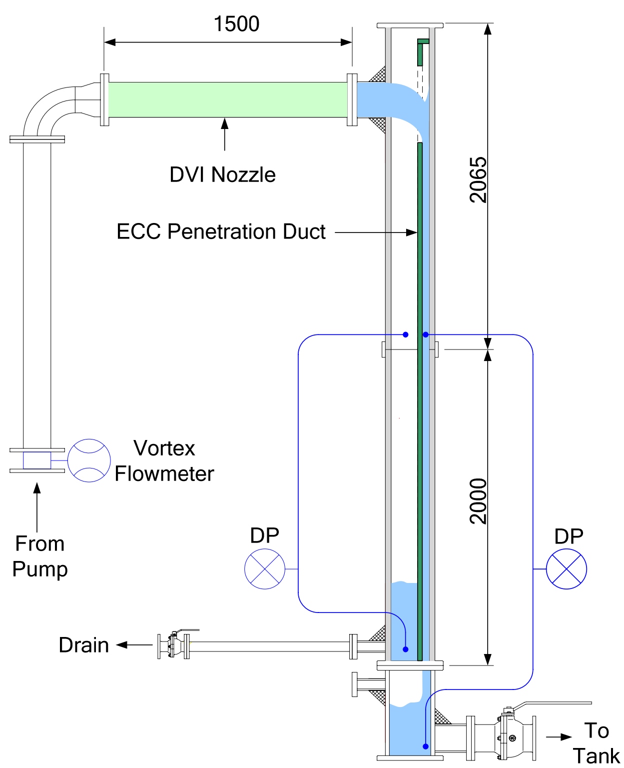

Fig. 2. Schematic of test section

The ECC duct separates two flow zones in the D/C section (test section). The inner zone of the D/C (DVI nozzle side) is ECC penetration region. The outer zone of the D/C (core barrel side) is ECC spillage region.

In this test, the injection flow rate and the spillage fraction were measured. The injection flow rate of ECC water was measured by a vortex flow meters and the variation of water level was measured by differential pressure transmitter in the test section.

2.3 Test Parameters and Test Procedure

The test was performed at the condition of atmospheric pressure and room temperature. The injection velocity of the ECC water was controlled.

The injected water flow rate was set at desired values by a speed control of the injection pump. When the desired ECC water injection velocity reaches at the steady conditions, the data logging starts for the total ECC water injection and the accumulated water level at the spillage region of the duct. Then, the total ECC water spillage to the outside the duct (spillage region) can be measured.

The ECC water spillage fraction is defined by Eq. (1).

$$\text{ECC spillage fraction (\%)} = \frac{m_{spill}}{m_{in}} \times 100 \qquad (1)$$

where, m_{in} is the integrated injected mass of the ECC water, and m_{spill} is the integrated spillage mass.

2.4 Experimental Results

Table 2 shows the ECC water spillage fraction according to a variation of the ECC water injection velocity and to the ECC intake shape of the duct. Fig. 3 shows an ECC flow pattern for the circular shaped intake.

The ECC water spillage fraction increased with ECC water injection velocity. Incase of the circular shaped intake duct has a lower spillage fraction than that of the elliptical shaped intake duct.

The reflection of the ECC water at the core barrel surface is increased when the ECC injection velocity is increased. This phenomena increase the ECC spillage fraction. Incase of the circular shaped intake duct, the ECC spillage fraction is reduced due to the minimized water reflection from the duct when compared with elliptical shaped intake duct.

Table 2: ECC water spillage fraction

ECC Duct intake shape	Average Injection Velocity (m/s)	Spillage Fraction (%)
Elliptical	1.792	12.102
	1.641	5.886
	1.566	4.770
Circular	1.757	4.013
	1.584	3.181

Fig. 3. ECC flow pattern (Circular, v_{in} =1.58 m/s)

From the governing equation of flow motion, the deflection of the ECC is estimated about 7cm at the outer surface of the duct when the ECC water is injected with 1.6m/s at the DVI nozzle. However, in these experiments, the deflection of the ECC jet was about 11cm. In the case of elliptical shaped intake duct, the complicated flow phenomena by the interaction between the accumulated water and the injection water in the duct inside enhanced the ECC water spillage. To minimize the ECC water spillage fraction, the elevation and diameter of the intake should be adjusted.

3. Conclusions

The ECC water spillage fraction of the ECC penetration duct was measured using the full scale duct test facility. The results show that the ECC water spillage fraction is sufficiently low. Therefore the current design of ECC penetration duct satisfies the requirement of efficient ECC injection.

REFERENCES

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