Multi-dimensional Aspects of the 50% DVI Line Break Test with the ATLAS Facility

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1. Introduction

Small break LOCAs at the DVI line have been investigated with the ATLAS (Advanced Thermal-Hydraulic Test Loop for Accident Simulation) facility, which is a large scale thermal-hydraulic integral effect test facility for the APR1400 at KAERI [1]. The 50% DVI line break selected as a test item for an OECD/CSNI ISP-50 was successfully carried out. Multi-dimensional aspects of the observed thermal hydraulic phenomena are investigated in this paper, in particular focusing on the core and down-comer regions.

2. Experimental Results and Discussions

2.1 Measured sequence of events

The test was performed at 193.0 s after steady state data were achieved. The major sequence of events observed during the whole test period is summarized in Table 1.

Table 1 Measured sequence of events

Event	DAS time (sec)	Remarks
Data logging starts	-10.0	
Break valve open	193.0	
MSSV of SG-2 open (1st)	217.0	PT-SGSD2-01>8.1 MPa
MSSV of SG-1 open (1st)	217.0	PT-SGSD1-01>8.1 MPa
LPP	218.0	PT-PZR-01 <10.72 MPa
Pressurizer heater off	218.0	LPP + 0.0 sec
Main steam isolation	218.0	LPP + 0.1 sec
RCPs trip	218.0	LPP + 0.35 sec
Main feed water isolation	225.0	LPP + 7.0 sec
Core power starts to decay	226.0	
SIP-2 injection	247.0	LPP + 28.3 sec
MSSV of SG-2 open (2nd)	250.0	PT-SGSD2-01>8.1 MPa
MSSV of SG-1 open (2nd)	255.0	PT-SGSD1-01>8.1 MPa
MSSV of SG-2 open (3rd)	306.0	PT-SGSD2-01>8.1 MPa
MSSV of SG-1 open (3rd)	311.0	PT-SGSD1-01>8.1 MPa
1st loop seal clearing	383.0	Only in loop 1A/1B
SIT actuation (high flow)	661.0	PT-DC-01 <4.03 MPa
2nd loop seal clearing	1429.0	Loop 2B
SIT low flow conversion	-	did not occur
Test stops	3126.0	

LPP: Low Pressurizer Pressure trip

2.2 Primary and secondary pressures

The measured primary and secondary pressures are shown in Figure 1. An enlarged figure between 100.0 and 600.0 s were included inside the figure for clear observation. The pressurizer pressure, PT-PZR-01 was used as a reference pressure for the primary system. It rapidly dropped to about 8.2 MPa from its initial pressure of 15.6 MPa on break. The primary pressure showed some oscillation for about 150.0 s and it decreased again from 390 s.

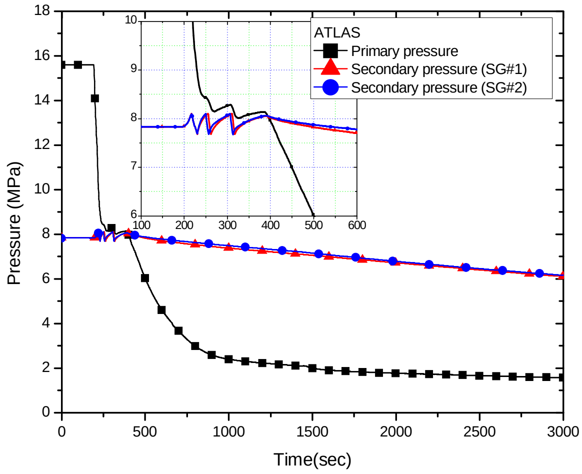

Fig. 1 Measured primary and secondary pressure

2.3 Peak cladding temperatures

Among the 264 T/Cs installed to measure the surface temperatures of the heater rods, 44 heater rods were fitted to measure the surface wall temperature.

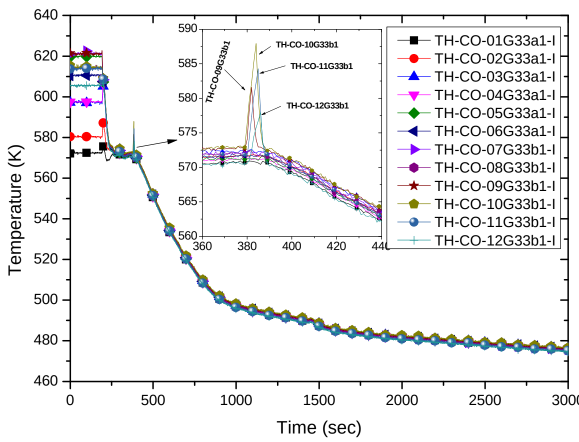

Fig. 2 Measured PCT of the heaters in G33a1 and G33b1

It was found that there was no significant difference in the measured surface temperature of the heater rods between hot leg-1 and hot leg-2 directions. Thus, symmetric assumption can be applied to this direction. However, a slight asymmetry was observed between 0 degree and 90 degree directions. Before the break, initial wall temperatures show a variation between 570K and 620K due to a chopped cosine axial power profile. During the transient, no increase in the PCT was observed in the heater group 1. On the other hand, an increase in the PCTs was measured in the other groups 2 and 3. The typical wall temperature trends of the heater rods in the group 3 were plotted in Figure 2 for sub-group G33. Four heater rods experienced an increase in the PCT at 9th, 10th, 11th, and 12th elevations. The maximum temperature was observed at the 10th elevation. Similar to the heater group 2, the heaters in the sub-group G33 showed higher temperatures than those in the sub-group G31. The measured maximum PCT was 587.7K in the group 3. Based on this measurement, two-dimensional non-uniformity in the PCTs was observed in the present test. In general, the heater rods located at 90 degree from the hot leg direction showed a higher increase in the PCT than those at the hot leg direction. Unfortunately, water level measurement in the core region was done in a one-dimensional manner. So, water level comparison in the azimuthal direction could not be done.

2.4 Multi-dimensional behavior in the down-comer

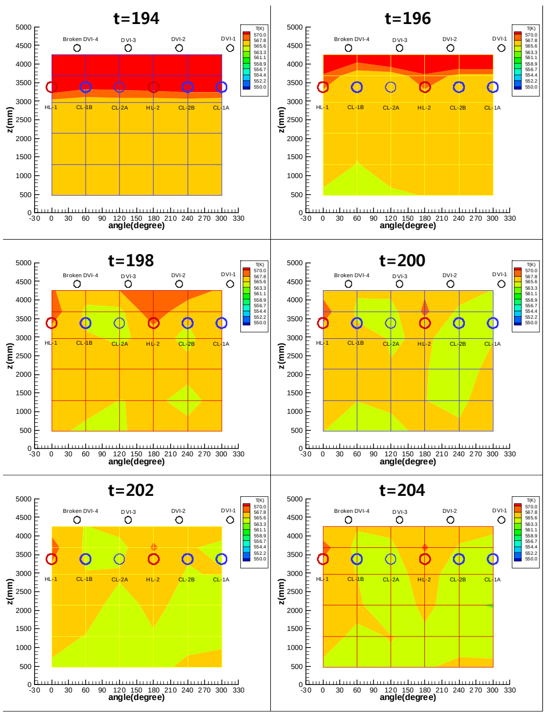

Fig. 3 Fluid temperature contour in the down-comer

In order to investigate the fluid temperature distribution in the down-comer region, two-dimensional contour plots on an expanded down-comer domain just after the break were plotted as shown in Figure 3. Before the break, vertical temperature stratification was observed but the fluid temperature was uniform in the azimuthal direction. On break, there observed great two-dimensional temperature distribution in the down-comer region. The flow direction changed from downward to upward for the fluid to be discharged through the broken nozzle, DVI-04. Much fluid seemed to be directed to the broken nozzle. Near the hot leg, blockage effects in the annulus down-comer region were also observed as seen in the figure at time of 198 seconds.

2.5 Asymmetric loop seal clearing

Only two loop seals in the loop 1 were cleared at 383 s followed by the second loop seal clearing in the loop 2B at 1429 s. The remaining loop seal in the loop 2A was not cleared during the test period. The differential pressures along the inclined hot legs, DP-HL1-02 and DP-HL2-02 were compared to investigate asymmetric loop seal clearing behavior. There existed a great asymmetric difference during the period between the 1st loop seal clearing and the 2nd loop seal clearing. Upon the 1st loop seal clearing occurred, DP-HL2-02 showed a great decrease and it was recovered on the 2nd loop seal clearing. This pressure increase was due to the pressure buildup inside the U-tube. The pressure increased due to the reverse heat transfer in SG. This fact was also confirmed by the primary temperature difference inside the U-tubes.

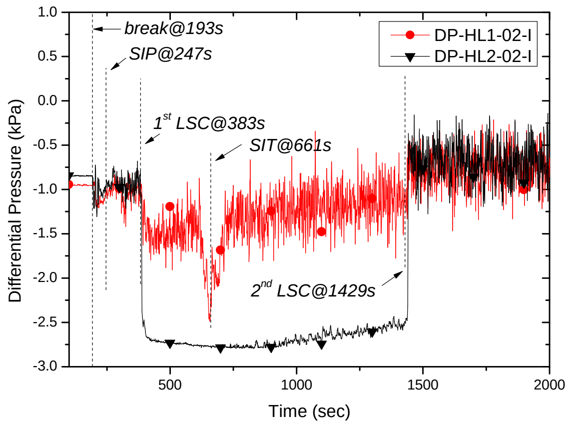

Fig. 4 Differential pressures in the hot leg 1 and 2

3. Conclusions

The 50% DVI line break test in the ATLAS showed a great multi-dimensional behavior in particular in the PCT, down-comer behavior. This multi-dimensional behavior seemed to cause the asymmetric behavior of the loop seal clearing. This obtained integral effect data will be used for extending our physical understanding of the small break at the DVI nozzle and for verifying safety analysis codes.

REFERENCES

[1] K.Y. Choi et al., "Experimental Simulation of a Direct Vessel Injection Line Break of the APR1400 with the ATLAS," Nuclear Engineering and Technology, V.41, No.5, 2009.