Thermal-hydraulic Characteristics in the Reactor Coolant System of the ATLAS during LBLOCA Test of LB-CL-15

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1. Introduction

A separate effect test was performed under a low reflooding rate condition by using the ATLAS. The ATLAS is a thermal-hydraulic integral effect test facility constructed and operated by KAERI. Several Integral tests for the reflood phase of a large break loss of coolant accident (LBLOCA) have been performed with the ATLAS. However, the tests were performed under high reflooding rate conditions. Its simulation is considered to be very difficult by using the conventional best-estimate thermal-hydraulic analysis code such as the RELAP5/MOD3. The present test, named as LB-CL-15, is performed to validate the RELAP5/MOD3 reflood models for a core quenching phenomenon under a low flow rate of ECC injection condition. The separate effect test data peculiar to the APR1400 could be obtained by using the ATLAS, which has the DVI injection, reverse heat transfer from steam generators and steam binding effect, etc. The experimental results showed a gradual reflooding in the core and a cooling of the core heater rods and the downcomer wall of the reactor pressure vessel. The experimental data could be used to evaluate and revise the reflood models of safety analysis codes such as RELAP5/MOD3.

This paper contains experimental results and discussion on thermal-hydraulic characteristics of the ATLAS reactor coolant system during the LBLOCA test of LB-CL-15.

Table 1 Summary of the initial and boundary conditions for LB-CL-15

Variables	Target Value	Test Results	Description
Power (kW)	490.48	388.5 & 466.6	-
	1.02*ANS79	1.02*ANS79	After reflood
Pressure (MPa)	0.1	0.10 ~ 0.15	RPV downcomer
	5.0	4.3 ~ 4.7	SG steam dome
	0.1	0.10 ~ 0.12	CS PCV downstream
ECC (kg/s)	0.30	0.29 / 0.31 / 0.30 / 0.31	HPSI-1 2, 3 & 4
Temperature (oC)	150	190	RPV wall
	50	58	RWT-1
	300	300	Maximum heater rod surface temperature
Level (m, %)	0.534	0.50	RPV lower plenum
	50	50	RWT-1

2. Experiments

The initial and boundary conditions were determined based on the analysis results of the existing KAERI reflood tests and sensitivity analysis of the 6-by-6 bundle tests by using the MARS. The determined initial and boundary conditions for LB-CL-15 is presented in Table 1.

3. Results and Discussion

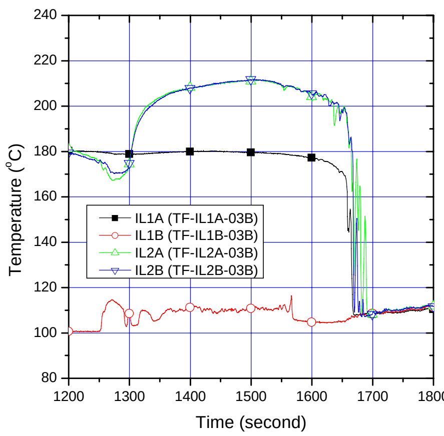

Figure 1 A variation of the fluid temperatures in the upper section of horizontal pipes of intermediate legs

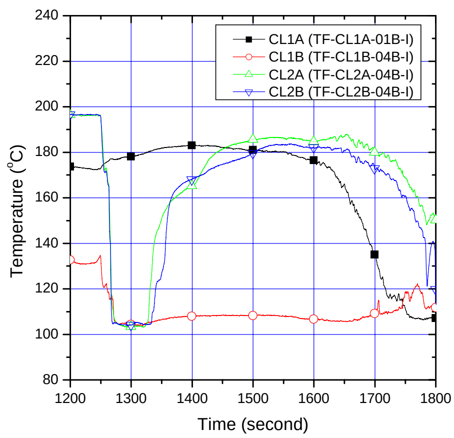

Figure 2 A variation of the fluid temperatures in the upper section of horizontal pipes of cold legs

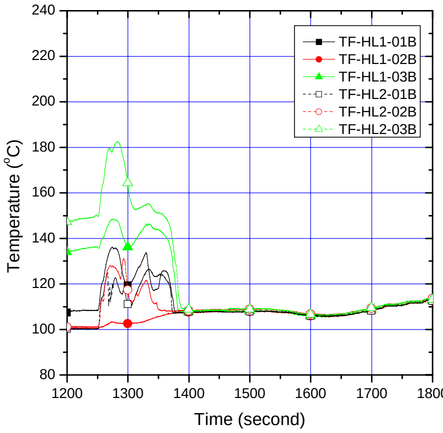

Figure 3 A variation of the fluid temperatures in the upper section of horizontal pipes of hot legs

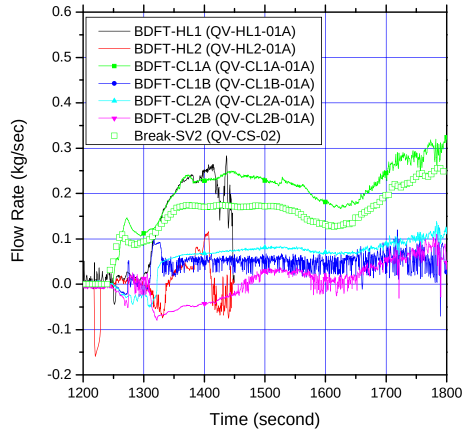

Figure 4 A variation of the steam flow rates in the RCS measured by using BiFlow flow meters

The flow rates in the ATLAS RCS are measured by using the BiFlow flow meter which is a bi-directional flow tube. The BiFlow flow meter was used to provide the flow rate in the hot legs and cold legs assuming the pure steam flow throughout the present test. The flow conditions in the RCS loops were checked to validate the assumption of pure steam and to check the fluid conditions by using installed thermocouples.

Fig. 1 through Fig. 3 shows variations of the fluid temperatures in the lower section of horizontal pipes of intermediate legs, cold legs and hot legs. From the Fig. 1 it could be presumed that the steam is highly superheated in the intermediate legs except for the IL-2B piping throughout the present test until they are quenched rapidly at around 1670 seconds after the test.

As shown in Fig. 2, all the cold legs are quenched with the reflood start at 1245 seconds. After it elapsed about 100 seconds, the fluids in cold legs of CL1A, CL2A and CL2B became superheated steam until they are quenched at the end of the test, but those in a cold leg of CL1B maintained their saturated temperatures.

Fig. 3 shows that the fluids in hot legs are a little superheated until about 1370 seconds after the test and they are quenched thereafter.

Fig. 4 shows a variation of the steam flow rates in the RCS measured by the BiFLOW flow meters. The measured flow rate data by the BiFlow flowmeter of QV-CL1A-01A was compared with the break flow rate through the RCP side (QV-CS-02). It showed the similar overall trend to but about 19 ~ 45% higher steam flow rates than the measured break flow rate.

The steam flow rates in both hot legs are fluctuating during the initial 100 seconds and they increased very rapidly until the flow was blocked by the water in the horizontal piping. As the steam in hot legs begins to be quenched at around 1370 seconds after the test, as shown in Fig. 3, the data acquired after 1450 seconds was not used in the present discussion. The flow trend in a cold leg of CL1B can not be applicable because the assumption of pure steam is obeyed as shown in Fig. 2. The flow trend in a cold leg of CL2B decreases until 1330 seconds after the test and then increases steadily. The flow trend in a cold leg of CL2A is quite different from that of CL2B. The flow rate is negative until 1330 seconds after the test and then it jumps to a positive flow and it fluctuates a little according the variation of the pressure.

4. Conclusions

Thermal-hydraulic characteristics of the ATLAS reactor coolant system was conducted during the LBLOCA test of LB-CL-15. These results will be dealt for the direction and mass flow rate decision of the break flow with differential pressure data. The BiFlow flow meter did not show good agreement with break flow for the difficulty of void fraction measuring in the loop system in this time, but it can be used qualitatively.

REFERENCES

[1] W.P. Baek, C.H. Song, B.J. Yun, et al. “KAERI Integral Effect Test Program and the ATLAS Design,” *Nuclear Technology*, 152, 183 (2005).

[2] K.Y. Choi, H.S. Park, D.J. Euh, et al., “Simulation Capability of the ATLAS Facility for Major Design-Basis Accidents,” *Nuclear Technology*, 156, 256 (2006).

[3] H.S. Park, K.Y. Choi, S. Cho, et al., “Recent ATLAS Test Results on the Late Reflood Period of the Large-Break LOCA for APR1400,” IAEA Topical Meeting on Advanced Safety Assessment Methods for Nuclear Reactors, Daejeon, Korea, Oct. 30-Nov.1 (2007).

[4] H.S. Park, K.Y. Choi, S. Cho, et al., “An Integral Effect Test on the Reflood Period of a Large-Break LOCA for the APR1400 Using the ATLAS,” Proceedings of ICAPP ‘08, Anaheim, CA USA, June 8-12 (2008).