Break Size Effects on MSLB event using the ATLAS

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1. Introduction

Simulated main steam line break experiments have been performed using the ATLAS test facility to investigate a non-symmetric thermal hydraulic behaviour in the primary loop of APR1400. The MSLB program of the ATLAS consists of six experiments as shown in Table 1 considering the major test parameters such as the core power ratio, LOOP (Loss of offsite power), and break size. The present descriptions are focused on the break size effect during the MSLB events by comparing of the SLB-GB-01 and SLB-PB-01.

Table 1 Test Matrix of MSLB

No.	Test I.D	Break Size (APR1400)	Break Size (ATLAS)	Condition	SI Injection	AF Injection
1	SLB-GB-01	Guillotine (FR area 2*30% of MSL Area)	Guillotine (FR area, 60 % of SL Area)	APR1400 100 % Core Power from the 8 % simulation /with LOOP /FR=choking nozzle (I.D.=38.6 mm)	SIP-1, -3	SG1 (LSGL)
2	SLB-GB-02	"	"	APR1400 8 % Core Power /w/o LOOP /FR=choking nozzle	SIP-1, -3	SG1 (LSGL)
3	SLB-GB-03	"	"	APR1400 8 % Core Power /with LOOP /FR=choking nozzle	SIP-1, -3	SG1 (LSGL)
4	SLB-PB-01	20 % of MSL Area	I.D.=22.28 mm (20 % of SL Area)	APR1400 100 % Core Power from the 8 % simulation /with LOOP /FR=unchoking nozzle (I.D.=45.9 mm)	SIP-1, -3	SG1 (LSGL)
5	SLB-PB-02	"	"	APR1400 8 % Core Power /w/o LOOP /FR=unchoking nozzle	SIP-1, -3	SG1 (LSGL)
6	SLB-PB-03	"	"	APR1400 8 % Core Power /with LOOP /FR=unchoking nozzle	SIP-1, -3	SG1 (LSGL)

2. Descriptions on the test facility

The break sizes of the present experiments consist of the double-ended guillotine break and 20 % of the main steam line area. For the case of the guillotine break, the maximum break area is restricted by the flow restrictor installed at the top of the SG. Even though two flow restrictors were installed a SG in the APR1400, only one flow restrictor has been installed in the ATLAS. The flow area of a flow restrictor of the APR1400 is 30 % of the steam line area. Therefore, the flow area of the flow restrictor of the ATLAS is up to 60 % of the flow area of the main steam line. For the case of the guillotine break with the critical flow condition, the minimum diameter of the flow restrictor is 38.6 mm. On the other hand, in the 20 % break case, the critical flow condition is not occurred in the flow restrictor. Therefore, the minimum diameter of the flow restrictor for the 20 % break size without choking condition is 45.9 mm. For the 20 % break case, the break nozzle is installed at the near-downstream on the steam line from the unchoking flow restrictor. The diameter of the break nozzle for the 20 % break case is 22.3 mm. The detailed descriptions on the ATLAS test facility can be found in Kang, et al. [1].

3. Test method and sequence

Initial and boundary conditions of the present test were obtained by properly scaling down the conditions of the SLB-GB-01 and SLB-PB-01 with a consideration on the major design parameters as indicated in Table 1. The calculated initial and boundary conditions of the SLB-GB-01 can be observed in Table 2.

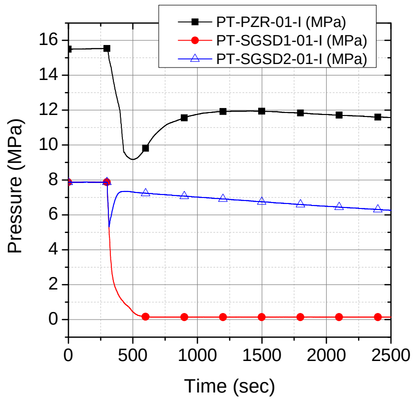
The experiment has been started by opening of the break simulation quick-opening gate valves, OV-BS-09 (only used for the guillotine break case) and -10. With the opening of the break valve, RCP stop, turbine trip, and feed water isolation were actuated for the assumption of the LOOP condition. Then, MSIS and AFAS could be occurred by the LSGP and LSGL signal, respectively. The LPP signal actuated the SIP-01 with the 28.28 s delay. The SITs were not actuated in the present experiments. The core power was controlled to start its decay in 12.3 s after the LSGP signal.

Table 2 Initial and boundary conditions for SLB-GB-01

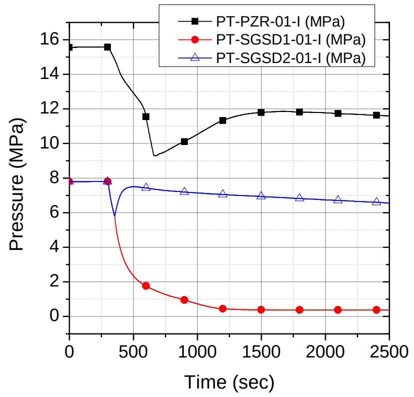
Design parameters	APR1400 (Steady State)	ATLAS (Steady State)	ATLAS (SLB-GB-01)
Reactor vessel			
Normal power, MWt	3983.0	1.56	1.56
Pressurizer pressure, MPa	15.5	15.50	15.5
Core exit temp, °C	324.2	324.2	325.4
Core inlet temp, °C	291.3	290.7	290.2
Temp. rise, °C	32.9	33.50	35.2
Core flow, kg/s	20275.0	7.99	9.05
Steam generator			
Steam flow rate, kg/s (SG-1)	1152.4	0.44	0.432
Steam flow rate, kg/s (SG-2)	1152.4	0.44	0.434
Saturated steam pressure, MPa	6.9	7.83	7.87
Steam temp., °C	284.9	293.5	293.5
Primary piping			
Hot leg flow, kg/s	10496.0	3.99	4.51
Cold leg flow, kg/s	5540.1	1.99	4.54
Hot leg temp., °C	323.3	323.8	325.7
Cold leg temp., °C	291.3	289.6	292.2

4. Experimental results and discussions

The main steam line break causes a rapid depressurization of the affected SG, which leads to increased heat removal from the primary to the secondary side. This excessive heat removal rate results in a fast cooldown transient on the primary loop. The guillotine break case leads a faster transient in the primary pressure than that of the 20 % break case as shown in Figure 1. With a decreasing of pressure of the broken SG, the primary pressure was decreased due to the excessive heat removal to the secondary side. The pressure of the intact SG tends to restore with the closure of the MSIV, and then it shows a linearly decreasing trend.



(a) SLB-GB-01



(b) SLB-PB-01

Figure 1 System pressure behavior

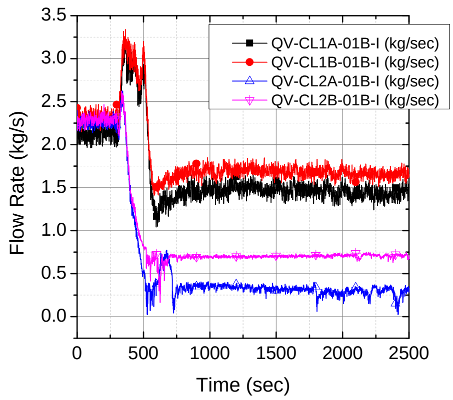
Figure 2 shows the flow rate in the four cold legs. From the figures, asymmetric flow pattern in the primary loop can be observed. In the broken loop, SG-1 side, more active natural circulation flow was built up by larger heat transfer rate than that of the intact loop, SG-2 side. Figure 3 compares the fluid temperatures in the cold legs for the SLB-GB-01, which shows a strong asymmetric effect on the intact and broken loop. The fluid temperatures in the broken SG side, CL-1A and -1B, are lower than those of the intact SG side.

5. Conclusions

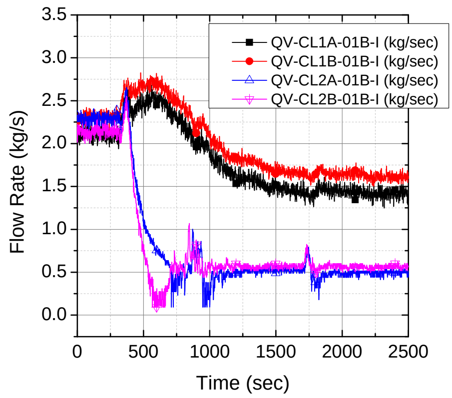
In the present paper, the thermal hydraulic integral effect test results in the MSLB accident have been presented and briefly discussed. The double-ended guillotine break and 20 % of SL area break case were compared. With the sizing of the break, the transition rates of the system pressure and flow rate in the primary loop are changed. Finally, the asymmetric thermal hydraulic behavior between the intact and the broken loop was experimentally observed.

REFERENCES

[1] K.-H. Kang, S.-K. Moon, H.-S. Park, S. Cho, K.-Y. Choi, et al., "Detailed description Report of ATLAS facility and instrumentation," KAERI, KAERI/TR-4316/2011, 2011.



(a) SLB-GB-01



(b) SLB-PB-01

Figure 2 Flow rate in the cold legs

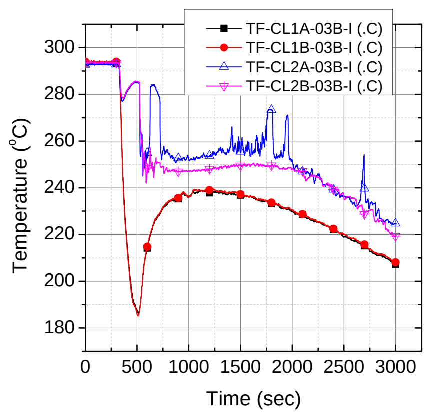


Figure 3 Fluid temperatures in the cold legs for the SLB-GB-01