Counter-Part Test Results of the LSTF SB-CL-18 using the ATLAS

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1. Introduction

Special kinds of experiments are the so-called counter-part tests. These are similar experiments performed in differently scaled facilities. It is well clear that transient scenarios measured in the experimental rigs cannot be directly extrapolated to plant conditions. Nevertheless one of the objectives of counter-part tests is to evaluate the influence of the geometric dimensions of the loops upon the evolution of a given accident. A counter-part test, SB-LSTF-01, was carried out using the ATLAS to investigate not only a scaling effect between the ATLAS and the LSTF but also a different loop configuration. Target test of the present counter-part test is SB-CL-18 which was performed for a 5 % cold-leg small break LOCA experiment conducted in the ROSA-IV Large Scale Test Facility (LSTF). The SB-CL-18 of the LSTF was carried out for the ISP-26 (the 26th International Standard Problem) which was approved by the OECD/NEA/CSNI in November 1988. In the present paper, scaling method of initial and boundary conditions of the present test to simulate the SB-CL-18 of the LSTF will be described and experimental results will be compared and discussed with that of the SB-CL-18 of the LSTF.

2. Descriptions on the test facility

The LSTF is a 1/48 volumetrically scaled model of a Westinghouse-type 3423 MWt 4x4 loop PWR. The LSTF has the same major component elevations as the reference PWR. The four primary loops of the reference PWR are represented by two equal-volume loops. The hot and cold legs were sized to conserve the volume scaling and ratio of the length to the square root of pipe diameter, $L/\sqrt{D}$, for the reference PWR.

The ATLAS is a 1/288 volumetrically scaled model of a typical 3983 MWt PWR, APR1400. The ATLAS has the 1/2-height, 1/144-area scales and has the same 2x4 loop features as the APR1400. According to the scaling law, the reduced height scaling has time-reducing results in the model. For the one-half-height facility, the time for the scaled model is $\sqrt{2}$ times faster than prototypical time. The scaling of the ATLAS has been performed according to the three-level scaling methodology of Ishii et al., .

The both test facilities were designed to be operated at the same high pressure and temperatures as the reference PWR. In Table 1, major design features of the ATLAS are compared with those of the LSTF.

3. Scaling method and test sequence

The initial and boundary conditions of the present test were obtained by properly scaling down the conditions of the SB-CL-18 of the LSTF with a consideration on the major design parameters as indicated in Table 1. To obtain experimental conditions equivalent to those of the SB-CL-18, a power-to-volume scaling method was adopted. Because these two test facilities have a design feature for the full pressure simulation, the density difference needs not to be considered. For this same pressure condition, the power-to-volume scaling method will lead the same results with those of the power-to-mass scaling method [1].

Table 1 Major design features of the ALTAS and the LSTF

	Unit	ATLAS	LSTF	ATLAS/LSTF Ratio
Scaling Ratio	-	1/288	1/48	0.167
Time Scale	-	0.707	1.00	0.707
Core Power of reference PWR	MW	3987	3423.00	1.165
Core Power of ITL facility	MW	1.56	10.00	0.156
Scaled Full Power	MW	19.58	71.31	0.275
Power Ratio of Scaled Full Power	%	8.00	14.00	0.571
Primary Fluid Volume (ITL)	m^3	1.63	7.23	0.225
Primary Fluid Volume (PWR)	m^3	446	347.00	1.285
Power-to-Volume ratio of Test Facility	MW/m^3	0.96	1.38	0.692
Power-to-Volume ratio PWR	MW/m^3	8.94	9.86	0.906
Core Inlet Flow	kg/s	7.96	48.80	0.163
Downcomer Gap	m	0.026	0.05	0.491

From the power-to-volume scaling method, the following three equations were derived;

$$\left(\frac{\tau\, m_{out}}{M_o}\right)_R = 1,\quad \left(\frac{\tau\, m_{in}}{M_o}\right)_R = 1,\quad \left(\frac{\tau Q}{M_o h_c}\right)_R = 1, \qquad (1)$$

where

$$M_{o,R} = \frac{M_{ATLAS}}{M_{LSTF}} = \frac{1.63}{7.23} = 0.22545, \quad and \quad \tau_R = \frac{\tau_{ATLAS}}{\tau_{LSTF}} = \frac{1}{\sqrt{2}}$$

From Eq. (1), break area, safety injection flow rate, and core power could be determined.

- Break Area Scaling

From the first equation of Eq. (1),

$$m_{out,R} = \frac{M_{o,R}}{\tau_R} = \frac{m_{out,ATLAS}}{m_{out,LSTF}} = \frac{A_{out,ATLAS}}{A_{out,LSTF}} = \frac{D_{out,ATLAS}^{\,2}}{D_{out,LSTF}^{\,2}} \qquad (2)$$

From Eq. (2) and in the case of choking, Mach number similarity is maintained. Thus, for equal-pressure system, the break flow velocity is prototypical. Thus, break diameter can be calculated by the following relation;

$$D_{out,ATLAS} = D_{out,LSTF} \bullet \sqrt{\frac{M_{o,R}}{\tau_R}} = 22.5 \bullet \sqrt{0.3188} = 12.7\,mm \quad (3)$$

- Safety Injection Flow Rate Scaling

$$m_{in,R}\tau_R = M_{o,R}$$
$$m_{in,ATLAS} \cdot \tau_{ATLAS} = M_{o,R} \cdot m_{in,LSTF} \cdot \tau_{LSTF} \quad (4)$$

- Core Power Scaling

For the case of a full pressure simulation, the enthalpy is prototypical. Thus the core power can be calculated by the following equation;

$$Q_R\tau_R = M_{o,R}h_{c,R} = M_{o,R}$$
$$Q_{ATLAS} \cdot \tau_{ATLAS} = M_{o,R} \cdot Q_{LSTF} \cdot \tau_{LSTF} \quad (5)$$

In the SB-CL-18 of the LSTF, the high-pressure safety injection system was not actuated. The accumulator safety injection flow was initiated at 4.51 MPa and the low-pressure injection was started at 1.29 MPa. However, the low-pressure injection system was not actuated during the SB-CL-18 test. In the present test, owing to the incapability of the injection flow rate from the SIT (Safety Injection Tank), the accumulator injection flow of the LSTF was simulated using the SIP (high-pressure Safety Injection Pump).

4. Experimental results and discussions

Figure 1 compares the primary pressure trend during the transient. As can be observed in Fig. 1, for the ALTAS, the loop seals were cleared in a more delayed time than those of the LSTF. The loop seal clearing times of LSTF and ATLAS were 138 s and 155 s after the break, respectively. However, after the loop seal clearing, the primary pressure showed a more steep decrease than that of the LSTF.

The collapsed water levels in the core and the downcomer region are shown in Fig. 2. For the LSTF, the core water level was significantly depressed just before the LSC (Loop Seal Clearing). However, the core water level was restored with the LSC. For the ALTAS, the collapsed water level of the core region, showed a similar trend. However, the degree of the level depression was relatively smaller than that of the LSTF. The effect of this difference in the degree of the water level depression between the two facilities can be observed in Fig. 3 which shows the cladding temperature behavior during the test period.

For the LSTF, the cladding temperatures show a large increase more than 460 ^{o}C around the LSC instant. On the other hand, for the ATLAS, small temperature excursion around the LSC instant was observed.

5. Conclusions

As a counter-part test for the SB-CL-18 of the LSTF, the SB-LSTF-01 using the ATLAS was performed. For the appropriate simulation of the initial and boundary conditions, the power-to-volume scaling method was adopted. The trend of the primary pressure and the collapsed water level of the two tests showed a relatively good agreement. However, the degree of the collapsed water level depression in the core region showed a different behavior, and resultantly, it affected the cladding temperature excursion.

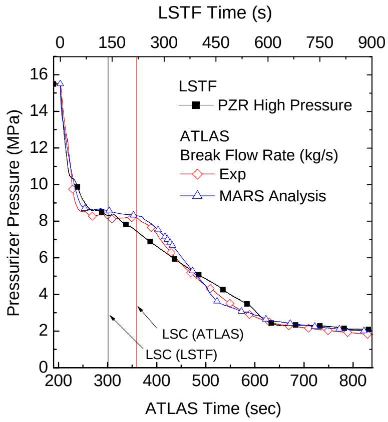

Fig. 1 Primary pressure trend during the transient

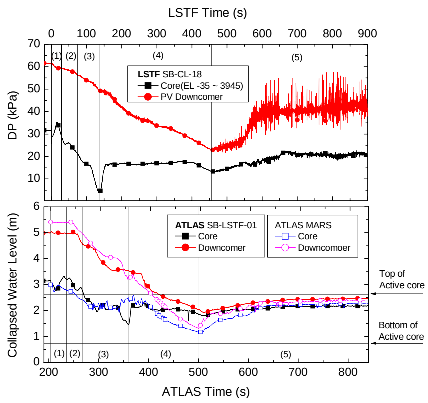

Fig. 2 Collapsed water level in the core and downcomer

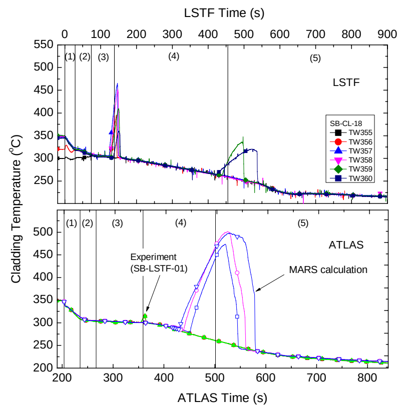

Fig. 4 Cladding temperature during the test period

REFERENCES

[1] B.-U. Bae, K.-H. Lee, Y.-S. Kim, B.-J. Yun, G.-C. Park, " Scaling methodology for a reduced-height reduced-pressure integral test facility to investigate direct vessel injection line break SBLOCA," *Nucl. Eng. Des.*, **238**, 2197, 2008.