Experimental study for Natural Circulation Flow regime Map of ATLAS

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1. Introduction

Since 2007, the ATLAS facility has been extensively utilized to address the major design basis accidents of the APR1400. It has also contributed to a verification of the safety of operating or advanced nuclear power plants as well as to a validation of the system-scale safety analysis codes. ATLAS has been recognized as one of the important IET facilities worldwide since the ISP-50 was successfully completed in 2011[1].

A scaling of IET is one of the important issues to validate the experimental data from IET. Previous research [2] discussed some of the problems involved when scaling similar phenomena measured in differently scaled facilities to the actual PWRs using Natural Circulation (NC). The NC scenarios occurring at different values of the primary system mass inventory were taken as a reference. NC in a PWR occurs due to the presence of a heat source (core) and sinks (steam generators), which in a gravity environment, create driving forces leading to flow rates in the loops and core cooling. The previous data measured in the SEMISCALE, LOBI, SPES, PKL, BETHSY and LSTF facilities were analyzed, and this database has been used to establish a natural circulation flow map (NCFM), as shown in Fig. 3. The ATLAS NC characteristics were compared with the previous experimental data and discussed in the present study.

2. Experimental condition and Results

An NC test for the ATLAS facility was considered to start with single-phase natural circulation and arrive at two-phase conditions in the primary loop through subsequent fluid drainages, which are shown on Fig.1 and Fig.2. The degraded secondary heat transfer is not considered and the secondary loop was operated under nominal conditions. The test conditions are summarized in Table I.

Table I. Summary of NC test conditions for the ATLAS

Primary loop	Volume	1.636 m^3 (includes pressurizer)
	Core power (% of APR1400)	0.976 MW (4.98%) 0.358 MW (1.82%)
	Pressure	15.5 MPa
	Initial core inlet temperature	290 ℃
	Pump	Free rotor
Secondary loop	Pressure	7.83 MPa
	Hydraulic level	5.0 m

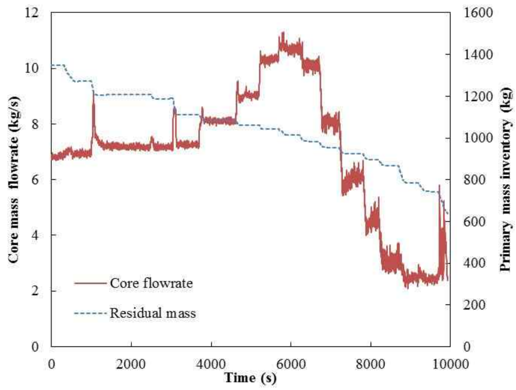

Fig. 1. Core mass flow rate and Residual mass (primary mass inventory) (4.98% power)

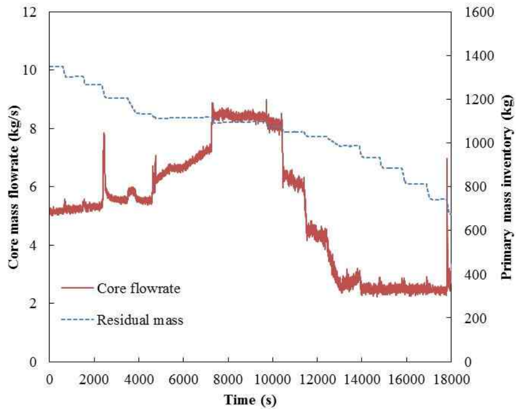

Fig. 2. Core mass flow rate and Residual mass (primary mass inventory) (1.82% power)

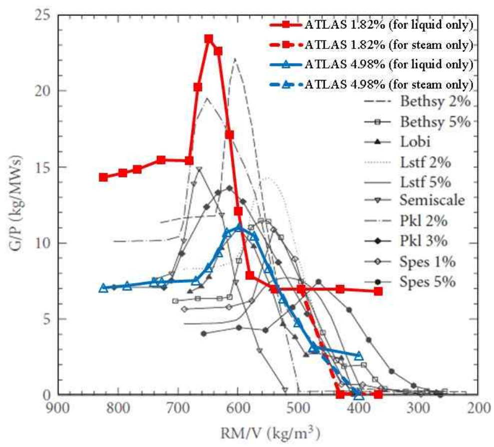

Fig. 3. Natural circulation flow map. NCFM of ATLAS and previous researches [2]

Fig. 1 and Fig. 2 show sets of residual mass, which is the primary mass inventory, and Core mass flow rate, which is the sum of flow rates in cold leg, for P=4.98% and 1.82%. The measured values of the core inlet flow rate (G, kg/s), core power (P, MW), primary system fluid mass inventory (RM, kg), and net volume of the primary system (V=constant, m^3) have been used for setting up the NCFM. Fig. 3 shows the NCFM of ATLAS and previous researches.

The G/P values for both experiments of ATLAS go out from the map because of the characteristics of a flow rate measurement system. The fluid flow rates in the cold legs were measured using an average bi-directional flow tube (BDFT) [3]. The BDFT was designed for a single phase and two phases; however, the ATLAS system assumes that a flow is only a liquid phase and measures the liquid flow rate in a cold leg with BDFT. For this reason, post-processing was required for a two-phase condition in the cold leg. In this case, a two-phase point was estimated when the levels in the intermediate leg decreased (Fig. 4). Because the intermediate legs are between the lower plenum of the steam generator and cold leg, this method to predict two phases in a cold leg is conservative criteria. In addition, for the flow rate after a two phase point, we assumed that steam filled the cold leg for a conservative condition. The dashed lines in Fig. 3 indicate a flow rate when the cold leg is filled only with steam. The real values are between the solid and dashed lines.

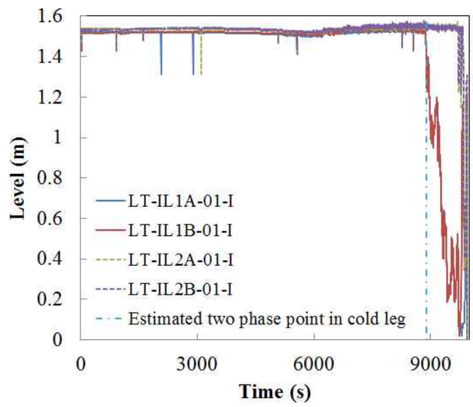

Fig. 4. Level of intermediate legs of ATLAS and An estimated two phase point for 4.98% power case

In the case of 4.98% power, ATLAS shows the suitability of NCFM. In the case of 1.82% power, however, the G/P value at the initial point was relatively higher than the other data. In spite of the different initial point, the peak and decreasing rate were similar to the envelope of curves. Therefore, the overall transient-trend of ATLAS for NC is suitable.

3. Conclusions

A NCFM, which is one of the analysis tools for the scaling of IET, was performed for the ATLAS facility. In the case of 4.98% power, the NCFM of ATLAS is similar to previous researches. In the case of 1.82% power, however, the G/P value at the initial point was the upper side of the previous data. In spite of the different initial point, the peak and decreasing rate were similar to the envelope of curves. Therefore, the overall transient-trend of ATLAS for NC is suitable.

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