Study on the primary side heat loss effect for ATLAS integral effect test facility

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1. Introduction

Heat loss phenomena is a measure of the total heat transfer of heat either from conduction, convection, radiation or any combination of the these. Newton's law of cooling states that the rate of heat loss of an object is directly proportional to the difference in the temperature between the object and its surroundings. Especially under the experiment conditions of high temperature and high pressure, the heat loss is likely to increase because of the temperature difference between the experiment component and surroundings atmosphere. This physical phenomena can affect the heat transfer experiment and plays an important role in the performance of the system. The heat loss is a function of area in accordance with convective heat transfer equation.

According to the design document, the ATLAS facility has a relatively large surface area to volume ratio in accordance with the design characteristic [1]. For this reason, the evaluation of the heat loss effect is essential to predict the performance of experiment using thermal hydraulic system code. This paper describes the methods and the results of sensitivity analysis of the heat loss on the thermal hydraulic integral test facility using SPACE code. Especially, it is confirmed weather the heat loss proportion of the components which are composed of primary side affect the experiment transient behavior or not.

2. Methods and Results

As mentioned in introduction, the experiment which is performed on ATLAS facility is selected for heat loss effect. The selected experiment scenario, the modeling information of heat structures for heat loss simulation, sensitivity cases and sensitivity analysis result are briefly described in this section.

2.1 Selection of experimental scenario

The experiment information which is provided by KAERI was utilized [2]. The target scenario for the experiment is the Multiple Steam Generator Tube Rupture (MSGTR) with a Passive Auxiliary Feed-water System (PAFS) actuation and asymmetric cooling. Experiment transient was initiated by opening of initiation valve with reactor coolant pump trip and pressurizer heater off. Coincidently with the high steam generator level signal occurrence, the main feed-water isolation valves and the main steam isolation valves for two steam generators were closed. Main steam safety valves on the steam line opened due to the increase of broken steam generator pressure and these valves are in cyclic operation of opening and closing to protect the primary and secondary systems from over-pressurization. The accident causes the depressurization of RCS and reaches the low pressurizer pressure set-point. The safety injection pumps are operated after delay times. It is assumed that the only one safety injection pump per train is only operated for the experiment scenario. In accordance with experiment assumption, the SIP-1 and SIP-3 are available. To simulate an accident management measure by cooling performance of PAFS during an MSGTR, the PAFS was supplied to an intact SG-2 instead of auxiliary feed-water after water level of an intact steam generator becomes lower than PAFS actuation set point due to the decay power. Additionally, it is assumed that the active auxiliary feed water system don't work for assessment of PAFS cooling capability.

2.2 Modeling for heat loss

To confirm the heat loss effect, the heat structure was modeled as shown in red line of figure 1. The total heat loss of the primary loop is about 97.1 kW according to the reference 2. To distribute the heat loss, the primary side is simulated with the 8 heat structure groups. These groups consist of upper head/upper annular region/down-comer of RPV, hot leg, Intermediate legs with reactor coolant pump, cold leg, primary side of steam generator, and pressurizer. Inputs for surrounding atmosphere temperature and convective heat transfer coefficient on heat structure groups are applied using the 'TABL' function of SPACE code. Through the trial and error method, the heat loss was finally calculated by varying the heat transfer coefficient input for each heat structure groups. And, the heat loss portion of 97.1 kW was applied as illustrated in figure 2.

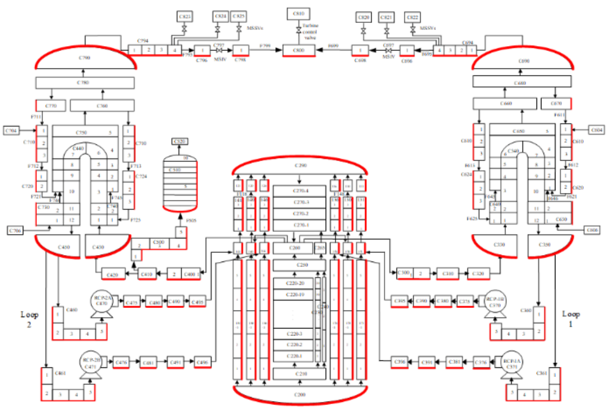

Fig. 1. Heat structure modeling for heat loss effect on the ATLAS facility.

2.3 Initial conditions for sensitivity case

The information of total heat loss on primary side is applied in accordance with the experiment information [2] and the heat loss portion of each heat structure groups was designed using the information of reference [3]. For sensitivity analysis, the information of heat loss proportion on component of primary side was applied for base case and 1-1 case as described in table 1, respectively. It is assumed that all components on primary side have equal surrounding temperature and heat transfer coefficient to the atmosphere in base case and 1-1 case of that is applied the information of reference [3]. The 1-2 case did not consider heat loss and the total power excludes the power corresponding to total heat loss on primary side.

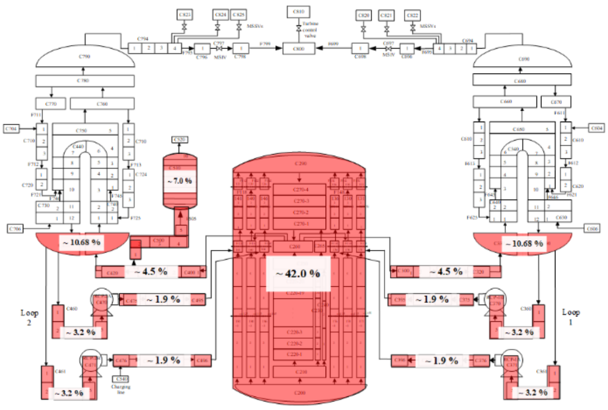

Fig. 2. Heat loss proportion of components on primary side for sensitivity analysis.

Table I: Cases for primary side heat loss

	Core power	Heat loss proportion
Base	1.627 MW	Average
1-1		Figure 2
1-2	1.53 MW	Not consider

2.4 Analysis results

The fluid temperature on primary side error versus experiment results at steady state is described in table 2. As described in table 2, all calculation results are underestimated by the experiment results. And, the base case which evenly distributed heat loss has the greatest error compared to experiment results.

The PAFS actuation time which is major event in this experiment is as shown in figure 3. As shown in figure 3, the time to initiate the PAFS are significantly different depending on the sensitivity cases. This calculation result in the 1-2 case which did not consider the heat loss is faster than other cases. These results show that the heat loss modeling can significantly affect the calculation results. In this paper, only heat loss on primary side is considered, not secondary side. The difference of PAFS operation time following the heat loss on secondary side is described in reference [4].

Table II: Fluid temperature error results versus experiment results at steady state condition

	Base	1-1	1-2
Core inlet	- 1.33 %	- 0.79 %	- 0.07 %
Core outlet	- 1.13 %	- 0.70 %	- 0.73 %
Hot leg	- 1.10 %	- 0.64 %	- 0.64 %
Cold leg	- 1.20 %	- 0.55 %	- 0.31 %

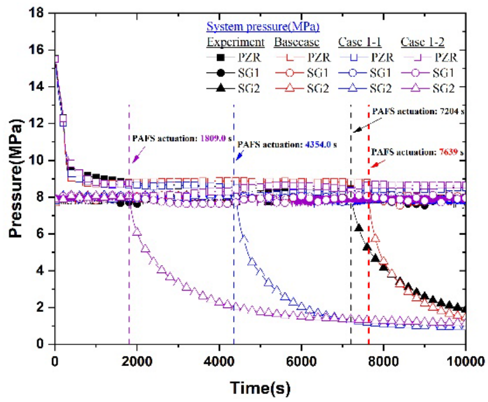

Fig. 3. The pressure on primary and secondary side with time to initiate the PAFS operation.

3. Conclusions

In this paper, the sensitivity analysis is performed to confirm the heat loss effect on primary side. Steady state condition results show that the fluid temperature varied depend on whether heat loss was considered. And, it is also showed that the transient behavior and major event sequence time are significantly different by the heat loss proportion of components on primary side. As a results, it is concluded that the heat loss modeling method is one of important process to predict the large scale heat transfer experiment using thermal hydraulic codes.

ACKNOWLEDGMENT

This work was performed within the program of the fifth ATLAS Domestic Standard Problem (DSP-05), which was organized by the Korea Atomic Energy Research Institute (KAERI) in collaboration with the Korea Institute of Nuclear Safety (KINS) under the national nuclear R&D program funded by the Ministry of Education (MOE) of the Korean government. The authors are as well grateful to the fifth ATLAS DSP-05 program participants: KAERI for the experimental data and to the council of the fifth DSP-05 program for providing the opportunity to publish the results.

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