Experimental Results of A1.2 Test for OECD-ATLAS Project

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1. Introduction

In order to meet the international interests in the multiple high-risk design extension conditions (DECs) raised after the Fukushima accident, KAERI (Korea Atomic Energy Research Institute) is operating an OECD/NEA project (hereafter, OECD-ATLAS project) by utilizing a thermal-hydraulic integral effect test facility, ATLAS (Advanced Thermal-hydraulic Test Loop for Accident Simulation) [1]. Considering the importance of the SBO scenario and the related accident mitigation measures, a prolonged SBO scenario was selected as the first test subject worthy of investigation in the OECD-ATLAS project as summarized in Table 1. As for a prolonged SBO transient of the OECD-ATLAS project, two tests, named A1.1 and A1.2, were determined to be performed.

Table I: Test Matrix for the OECD-ATLAS Project

Topics	Tests	Remarks
A1-Prolonged SBO - Asymmetric 2nd cooling - Asymmetric passive 2nd cooling	 1 1	 Asymmetric FW supply and additional failure Asymmetric passive FW supply (ex. PAFS)
A2-SBLOCA during SBO - SBO+RCP seal failure - SBO+SGTR	 1 1	 Effects of leakage flow rate TISGTR
A3-TLOFW - 1ry & 2nd bleed + 1ry feed	1	With additional failure such as stuck open POSRV, ATWS, and a SGTR
A4-MBLOCA - PZR surge line break (10-inch)	1	Safety injection through cold leg (or DVI)
A5-Open items	2	Counterpart test for addressing scaling issues
Total	**8**	

In particular, passive safety systems are considered as the most promising alternatives to reinforce the safety and reliability of an ultimate heat removal system without any operator actions in the SBO transients. As one of the new safety improvement concepts to mitigate an SBO accident efficiently, a cooling and operational performance of the passive auxiliary feedwater system (PAFS) is investigated in the framework of the OECD-ATLAS project to produce clearer knowledge of the actual phenomena and to provide the best guidelines for accident management. PAFS is intended to completely replace the conventional active auxiliary feedwater system of a pressurized water reactor (PWR) to cope with an SBO scenario [2]. It cools down the secondary side of the steam generator and eventually removes the decay heat from the reactor core by utilizing a natural driving force mechanism, i.e., condensing, boiling, and natural circulation as shown in Fig. 1.

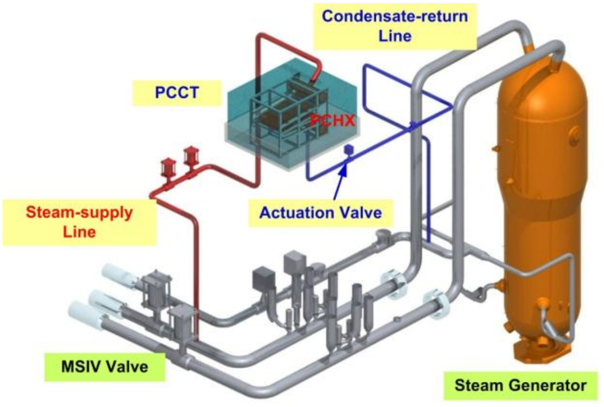

Fig. 1. Schematic diagram of passive auxiliary feedwater system

In this study, The second test of the OECD-ATLAS project, named A1.2, was performed with an aim of simulating a prolonged station blackout (SBO) with asymmetric secondary cooling through the supply of passive auxiliary feedwater only to steam generator number 2 (SG-2).

2. Description of the A1.2 Test

The target scenario for the A1.2 test is a prolonged SBO with asymmetric secondary cooling through the supply of passive auxiliary feedwater only to SG-2. In the A1.2 test, any active component such as a safety injection pump (SIP) was unavailable. However, passive components such as a pilot-operated safety relief valve (POSRV) and a main steam safety valve (MSSV) were assumed to be available. Passive auxiliary feedwater was supplied when the secondary level of SG reaches a wide-range of 25%. Contrary to the A1.1 test, any intentional delayed supply of passive auxiliary feedwater was not considered in the present A1.2 test.

When the reactor was tripped, both the RCP and the turbine were stopped. Coincidently with the reactor trip, the main feedwater pumps stopped and a main feedwater isolation signal (MFIS) was generated to close the main feedwater isolation valves (MFIVs). The main steam isolation valves (MSIVs) were also closed at the initiation of the transient.

While the active auxiliary feedwater is supplied in a periodic manner depending on the secondary level of the SG-2, the passive auxiliary feedwater is supplied continuously depending on the steam flow rates generated from the SG-2. The injection location of the passive auxiliary feedwater was the economizer nozzle, which is the same as the main feedwater supply. The temperature, pressure, and flow rates of the passive auxiliary feedwater were determined by the system conditions in the SG-2.

The decay heat was simulated to be 1.2-times that of the ANS-73 decay curve from a conservative point of view. The initial heater power was controlled to be maintained at about 1.637 MW, which was equal to the sum of the scaled-down core power (1.565 MW) and the heat loss rate of the primary system (about 80 kW). The heater power was then controlled to follow the specified decay curve after 12.07 seconds from the reactor trip.

3. Experimental Results

3.1 Overall Thermal-Hydraulic Behaviors

Overall system behaviors observed in the A1.2 test is shown in Fig. 2. With the start of the SBO, the reactor, all four RCPs, a turbine, a MFIV, and a MSIV were tripped simultaneously. The failure of the main feedwater supply and the closure of MSIV led to an increase in the secondary system pressure until the set point of the opening of the MSSV. The secondary side inventory of the steam generators was discharged into the condensation tank through MSSVs, and when the secondary level of SG-2 reached a wide-range of 25%, the passive auxiliary feedwater was supplied to only SG-2. A collapsed water level in SG-2 stopped to be draining and kept a constant level after the supply of passive auxiliary feedwater.

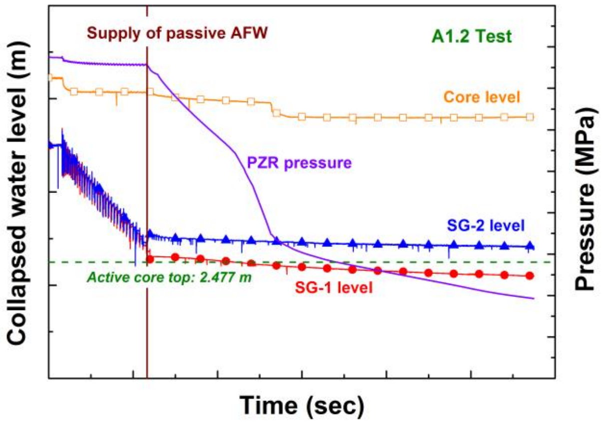

Fig. 2. Overall system behaviors observed in the A1.2 test

After the supply of passive auxiliary feedwater to SG-2, the secondary system pressure started to decrease without any opening of MSSV in SG-2. Due to the heat removal through SG-2, the primary system decreased stably. The collapsed water levels in the reactor pressure vessel (RPV) showed a stable behavior. Depending on the heat removal capacity of the steam generators, the natural circulation flow characteristics showed different trends in the primary loops. A single-phase natural circulation flow was enhanced in cold leg-2A and -2B after supply of the passive auxiliary feedwater. On the other hand, contrary to cold leg-2A and -2B, degradation of natural circulation flow was clearly observed in cold leg -1A and -1B.

3.2 Natural Circulation Characteristics in PAFS

The mass flow rates in the steam-supply line and the water-return line in PAFS are shown in Fig. 3. The initial peak of the flow rate is attributed to the inflow of the original inventory remaining inside the water-return line and the PCHX. After the abrupt drainage of the coolant in the water-return line and the PCHX, a stable natural circulation flow in the steam-supply line and the water-return line was established until the end of the transient. That is, the steam flow from SG-2 was condensed by the heat transfer at the PCHX, and the condensate liquid was then returned back to SG-2 through the economizer nozzle. During the whole test period, no flow instability in the PAFS loop was observed.

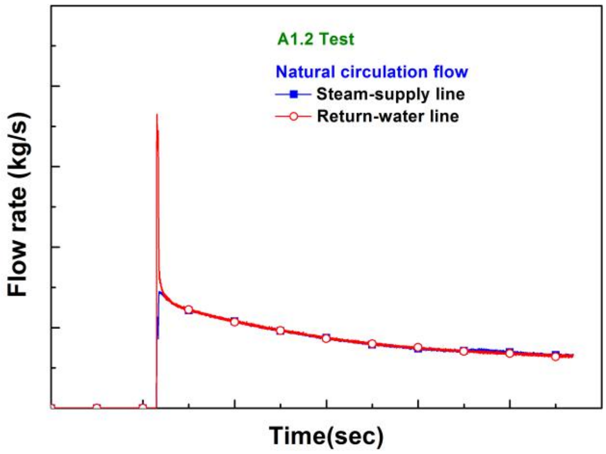

Fig. 2. Natural circulation flow rates in the PAFS

4. Conclusions

As the second test of the OECD-ATLAS project, the A1.2 test was conducted to simulate a prolonged SBO with asymmetric secondary cooling through the supply of passive auxiliary feedwater only to SG-2. When the collapsed water level of steam generator reached a wide range of 25%, PAFS was actuated. PAFS played a key role in cooling down the primary system by the heat transfer and the natural circulation. With the actuation of PAFS, the fluid temperatures at the core inlet and outlet started to decrease without any excursion of the maximum heater surface temperature in the core.

This integral effect test data of A1.2 test can be used to evaluate the prediction capability of existing safety analysis codes and identify any code deficiency for an

SBO simulation with an operation of a passive system such as PAFS.

Acknowledgements

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