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Test of Emergency Cooling water Injection for the HANARO Fuel Test Loop

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1. Introduction

A fuel test loop (FTL) for fuel and material irradiation tests has been developed in the HANARO. The fuel test loop provides operational conditions similar to the normal operational pressures, temperatures, and water chemistries of commercial PWR plants. The design of the fuel test loop was completed in October 2004. The construction of the facility was done from July 2006 to March 2007. The cold function tests were performed since April 2007 and the hot function tests were completed by May 2009.

This paper deals with the test of emergency cooling water injection for the fuel test loop. This test was carried out to ensure that the emergency cooling water system had appropriate safety functions for anticipated operational occurrences.

2. Design of Emergency Cooling Water System

The emergency cooling water system provides emergency cooling water to the in-pile test section (IPS) subsequent to anticipated operational occurrences (AOOs) and design basis accidents (DBAs). The decay and sensible heat of the IPS is removed by the emergency cooling water during an early stage of design basis events, and by the primary coolant of the HANARO in the hexagonal flow tube during a long-term-cooling stage.

The emergency cooling water system (ECWS) consists of two accumulators, safety injection valves, discharge valves, and associate pipes. Accumulator A and B are connected by safety injection pipes to the hot and cold legs of the main cooling water system respectively. The waste storage tank is connected by discharge pipes to the hot leg. The pipes are designed as two trains. Each train has two valves in series [1].

The coolant in the accumulators is pressurized with nitrogen gas. The accumulators supply emergency coolant to the IPS for about a minimum of 25 minutes in case of loss-of-coolant accidents. To prevent injecting nitrogen into the IPS, the water level is measured with three level switches and the safety injection valves are closed if a low level trip occurs. The low level trip is actuated by the 2 out of 3 rule. The safety injection and discharge valves are solenoid-operated valves, and the stroke times are less than 0.2 second.

The waste storage tank (WST) performs safety functions of receiving the discharge flow from the main cooling water system in order that the emergency cooling water is injected to the IPS.

3. Determination of ECW Injection Scenario

Several anticipated operational occurrences were taken into consideration for the design of the fuel test loop. In this commissioning an inadvertent closure of loop isolation valve was tested among the AOOs. The fuel test loop has four loop isolation valves in the main cooling water system. They are open in normal operation and closed by safety injection signal in emergency states. The loop isolation valves isolate the nuclear safety components and structures from the non-nuclear safety components and structures.

The inadvertent closure of loop isolation valves could be taken place by malfunction of the valves and human error. Safety analysis showed that the most severe result turned out in the AOO in terms of the design criteria on test fuels and emergency cooling water system [2].

4. Results

The test of emergency cooling water injection was carried out based on the procedures permitted by the HANARO operational organization [3] and the regulatory body attended the whole test as an auditor.

The emergency cooling water injection was initiated at normal operational conditions. The coolant pressure, temperature, and flow rate at the inlet of the IPS were 15.2 MPa, 300℃, and 1.66 kg/s, respectively. All components such as pumps, heaters, and valves in the fuel test loop were under operational states. However the reactor was not operated and dummy fuels were installed in the IPS so that the coolant temperature was maintained by the heater of the main cooling water system.

The test of emergency cooling water injection was initiated as one loop isolation valve was closed manually. The major events of the fuel test loop were as follows:

(1) One loop isolation valve closed,
(2) Low flow actuated reactor trip,
(3) Low-low flow signal actuated safety injection,
(4) Undamaged loop isolation valves closed, and safety injection valves and discharge valves open,
(5) Emergency cooling water injected,
(6) Safety injection valves closed by low level signal of the accumulators, and
(7) Safety injection ended.

The safety injection signal also stops some pumps and heaters, and closes isolation valves. The isolation valves are to protect or mitigate anticipated release of radioactive material to reactor hall and to maintain coolant inventory of the main cooling water system.

System response after the inadvertent closure of loop isolation valve was checked by the test procedures. It was found that all components worked well except three valves. The position status of three valves was improperly displayed on the operator's monitor. However the emergency cooling water injection was completed appropriately. It was found that electrical contact signal to inform the disk position of the valves worked wrong. And then the electrical device was repaired.

Figure 1 shows the flow rates at the main cooling water pump and at the inlet of the IPS. Figure 2 and 3 are the coolant levels and pressures of the accumulators and WST respectively. The pump discharge flow decreases rapidly due to the pump stop and the flow rate at the inlet of the IPS also decreases abruptly by the closure of loop isolation valve. And then the IPS flow remains nearly constant as the safety injection begins. The safety injection was maintained during around 2 hours untill the coolant level of the accumulators reached the trip set point. The transients of the levels and pressures as shown in Figure 2 and 3 correspond with the flow rate of emergency cooling water injection. Figure 2 shows that the safety injection from the accumulator B is ended faster than that from the accumulator A. This is very resonable result. The accumulator B is connected to the hot leg so that the coolant in the accumulator B is discharged directly to the WST not via the IPS. While the coolant in the accumulator A is discharged to the WST via the IPS.

5. Summary

The test of emergency cooling water injection for the HANARO fuel test loop was carried out to ensure that the system had appropriate safety functions for anticipated operational occurrences. It was also checked if all the components in the fuel test loop responded to the safety injection signal appropriately or not. Finally it was found that the emergency cooling water system functioned appropriately to the anticipated operational transients and that all the components actuated by the safety injection signal worked properly.

REFERENCES

[1] S. K. Park, et. al., Safety Design Features of the HANARO Fuel Test Loop, NUTHOS-7, Seoul, Korea, October 5-9, 2008.

[2] S. K. Park, et al., HANARO Fuel Test Loop Safety Analysis Report, KAERI/TR-3898/2009, Korea Atomic Energy Research Institute, 2009.

[3] S. K. Park, Procedures of Emergency Cooling Water Injection, HAN-FL-S-062-DO-K114, 2008.

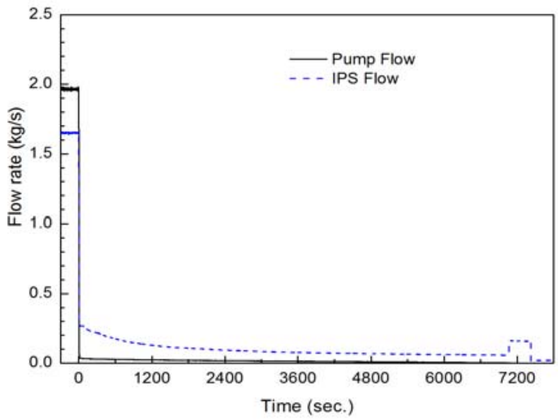

Fig.1. Flow rates at the pump and the inlet of the IPS.

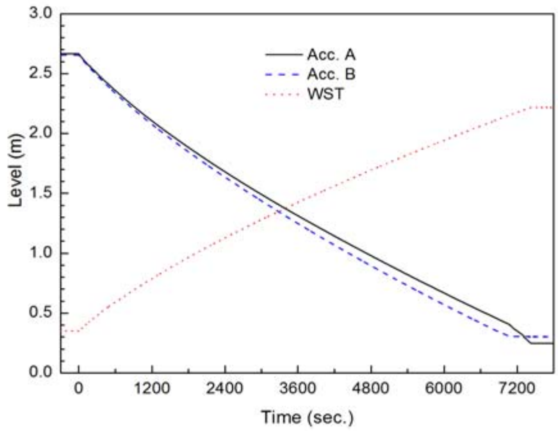

Fig.2. Coolant levels of the accumulators and WST.

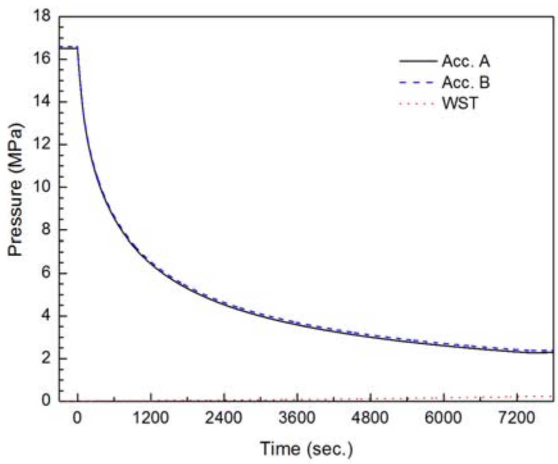

Fig.3. Pressures of the accumulators and WST.