An Experimental Study on the Passive Residual Heat Removal System of the SMART-P

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1. Introduction

A set of experiments has been performed on the thermal-hydraulic characteristics of the passive residual heat removal system (PRHRS) for an advanced integral type reactor, SMART-P (Chang, et al., 2002), using the high temperature and high pressure thermal-hydraulic test facility, the VISTA facility (Lee et al., 2001). Park et al. (2004a, 2004b) performed experiments on the thermal-hydraulic characteristics of the PRHRS for the SMART-P. In this paper the effects of the design parameters on the performance of the PRHRS are tested.

2. VISTA PRHRS

The PRHRS of the VISTA facility is composed of a train for the cooling subsystem, which includes an emergency cooldown tank (ECT), a heat exchanger (HX), a compensating tank (CT), several valves and related piping. It is designed to have the same pressure drop and heat transfer characteristics and is arranged to have the same elevation and position as those of the reference system, SMART-P. The VISTA PRHRS is described by Park et al. (2004a) in detail. The VISTA facility is designed to be operated by a combination of a manual and automatic operation. Once the major thermal-hydraulic parameters reach a steady state condition, they are switched over to be controlled automatically by PID feedback control logics to maintain the achieved steady state condition. During the PRHRS operation the predetermined power from the programmed ANS-73 decay curve is given to the core simulating heater.

3. Test Matrix

After reaching a steady state condition for a given power of about 50% of the rated power, the PRHRS is immediately triggered to start opening the bypass valves which connect the PRHRS to the secondary system and closing the secondary system isolation valves which isolate the secondary system from the feedwater supply tank and the silencer.

The experimental test matrix includes PRHRS-P-R1, PRHRS-P-R1-A2, PRHRS-P-R1-C2, and PRHRS-P-R1-D2. The test of PRHRS-P-R1 is the reference test which simulates the core decay heat and its initial core power. Its initial feedwater flow rate was 50% of the rated values and its initial primary flow rate was 100% of the rated flow rate. The scaled 100% flow rates of the primary system are 19.6 m^3/hr at the pressure and temperature of 147 bar and 310°C, respectively, and the scaled 100% flow rates of the secondary system are 0.25 kg/s. In the reference test of PRHRS-P-R1 both the PRHRS bypass valves and the secondary system isolation valves were operated simultaneously, the initial water level of the CT was 80% of the full level, and the initial pressure of the CT was 4.5 MPa.

While both the PRHRS bypass valves and the isolation valves of the secondary system actuate simultaneously during the reference test, the PRHRS bypass valves are opened 10 seconds earlier than the opening of the isolation valves of the secondary system during the test of PRHRS-P-R1-A2. PRHRS-P-R1-C2 and PRHRS-P-R1-D2 are different from the reference test in that they have a different initial water level of 16% and an initial pressure of 0.1 MPa, respectively.

4. Results and Discussions

4.1 The Reference Test (PRHRS-P-R1)

During the operation period of the PRHRS the maximum flow rate of the natural circulation was 0.018 kg/s and the flow rate maintains a constant value by the operation of the CT. The initial maximum system pressure was about 5.3 MPa, and the CT water level increases temporarily and decreases gradually as the CT pressure increases above the initial pressure of 4.5 MPa. The reference test results are described in detail by Park et al. (2004b).

4.2 Effect of an Opening Delay of the PRHRS Bypass Valves (PRHRS-P-R1-A2)

Figure 1 shows that the initial feedwater flow rate is about 0.1125 kg/s (45% of the rated flow rate) and that it decreases rapidly to about 0.02 kg/s, which is about 8% of the scaled secondary flow rate. The flow begins to oscillate around 2800 sec, which coincides with the time of the drain of the CT.

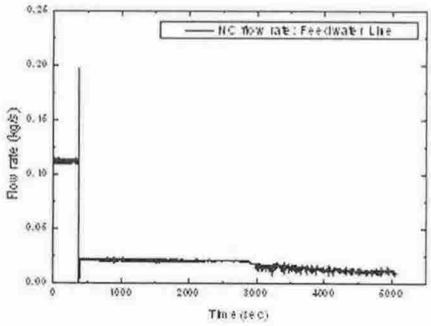

Figure 1. Variation of the Natural Circulation Flow Rate during the PRHRS Operation (PRHRS-P-R1-A2)

As shown in Figure 2, the initial maximum system pressure was about 4.8 MPa, which is lower than that of the reference test. It seems that it is affected by the opening delays of the PRHRS bypass valves by 10 seconds.

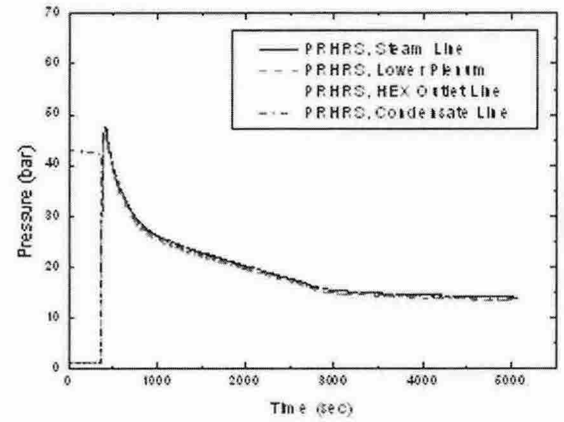

Figure 2. Variation of the PRHRS Pressure during the PRHRS Operation (PRHRS-P-R1-A2)

The primary system pressure decreased rapidly with the operation of the PRHRS and gradually in the later stages. The temperature in the hot leg decreases to 205°C at the time of 5000 second.

4.3 Effect of the Initial Level of the CT (PRHRS-P-R1-C2)

The thermal hydraulic trend is similar to the reference test. As the initial level of the CT is as low as 16%, the CT is dried up earlier than the reference case and the flow oscillation begins earlier as well. The initial feedwater flow rate was about 0.125 kg/s (50% of the rated flow rate) and it decreased rapidly to about 0.028 kg/s, which is about 11% of the scaled secondary flow rate. The flow begins to oscillate around 560 seconds and it stops around 1600 seconds. The initial maximum system pressure was about 5.2 MPa, which is similar to the reference test.

4.4 Effect of the Initial Pressure of the CT (PRHRS-P-R1-D2)

The natural circulation fails to continue. The natural circulation flow stops as the condensate water stops being supplied from the PRHRS side. Figure 3 shows that the water level maintains a higher level than 80% throughout the test, or that the water is not supplied from the CT to the secondary side of the steam generator, in the steam which is only heated by the decay heat transferred through the steam generator helical tube. As the decay heat is not removed by the failed operation of the PRHRS, both the pressure and temperature of the primary system increase gradually.

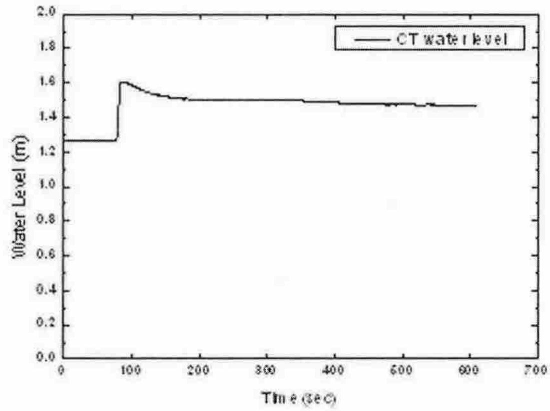

Figure 3. Variation of the Water Level of the CT during the PRHRS Operation (PRHRS-P-R1-D2)

5. Conclusion

A set of experiments have been performed to investigate the performance of the PRHRS using the VISTA facility which simulates the SMART-P. In this paper the effects of the opening delay of the PRHRS bypass valves, and the initial water level and the initial pressure of the CT are investigated experimentally.

REFERENCES

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