Experimental Study on the Natural Circulation Characteristics in the Primary Loop of the SMART Reactor by using the VISTA Facility

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1. Introduction

The SMART [1] uses a two-phase natural circulation in the PRHRS loop to remove the heat from the steam generators to the PRHRS heat exchangers, while a single-phase natural circulation occurs in the primary loop to transfer the decay heat from the core to the steam generator. Natural circulation operation with a power range of 20 ~ 25% was considered for SMART and nowadays the possibility of increasing the power level during the natural circulation operation is being investigated.

Previously Park *et al.* [2] performed several experiments by using the VISTA facility [3] on the thermal-hydraulic characteristics of the PRHRS for the SMART-P, which includes a single-phase natural circulation in the primary loop. From the analysis with the TASS-SMR code [4] it was shown that the reference temperature for the primary steam generator inlet temperature should be increased in order to compensate for the decreased core flow.

To investigate the possibility of an increase of the power and reference temperature, it is necessary to get experimental data to characterize the natural circulation phenomena in the primary loop of the SMART. In this paper, the characteristics of natural circulation in the primary loop are experimentally investigated during various operational conditions by using the VISTA facility.

2. Description of the VISTA Facility

The VISTA facility is described by Lee *et al.* [3] in detail. The primary circuit of the VISTA facility is composed of a reactor vessel with core simulating heater, a main coolant pump, a steam generator, and the interconnecting hot leg and downcomer. The three pressurizers simulating the upper annular cavity, intermediate cavity, and the end cavity are connected by pipes and the top of the end cavity and the bottom of the upper annular cavity are connected to the gas cylinder and to the hot leg of primary loop. They are 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. Also 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.

3. Test Matrix

The VISTA facility has the scaled full power of 682.3 kW, which is 1/96 of the reference plant. The scaled 100% flow rates of the primary system are 19.6 m^3/hr at a pressure and temperature of 147 bar and 310 ^oC, respectively, and the scaled 100% flow rates of the secondary system are 0.25 kg/s.

Tests are performed by changing the core power and the feed water flow rate simultaneously. The initial core power and feed water flow rate are 25%. During a natural circulation operation both the core power and feed water flow rate are changed from 20% to 50%. Table 1 shows the test matrix for the natural circulation tests. The given parameters are the core power and feed water flow rate and the resultant natural circulation flow rates are listed.

Table 1 Test matrix for the natural circulation tests

Test ID	Heater power (%)	Feed Water Flow Rate (%)	Test Results (NC flow rate)
NC1	T-Control	20	Oscillation
NC2	Fixed, 20	20	about 14.25%
NC3	Fixed, 25	25	about 17.0%
NC4	Fixed, 30	30	about 17.25%
NC5	Fixed, 40	40	about 18.75%
NC6	Fixed, 50	50	about 20.0%

4. Results and Discussions

As shown in Table 1, a variety of core power levels and feed water flow rates are given as boundary conditions. After a steady state is achieved, the main coolant pump is tripped and the primary coolant is circulated by a natural circulation as the core heater simulates the decay heat as a source and the steam generator functions as a heat sink. The coolant in the primary loop circulates naturally and the decay heat is removed through the steam generator and the injected secondary coolant is evaporated and heated to keep it at a superheated state.

Figure 1 shows the flow rates across the core for the tests of NC1 through NC6. As the core power and the feed water flow rate are increased, there is an increase in the natural circulation flow rate through the core. As the natural circulation starts, there is a rapid drop of the flow rate and then it recovers to a steady natural circulation flow rate. The flow rate fluctuates a little and it increases with an increase of the core power from about 14.25% for NC2 (20% power) to about 20% for NC6 (50% power).

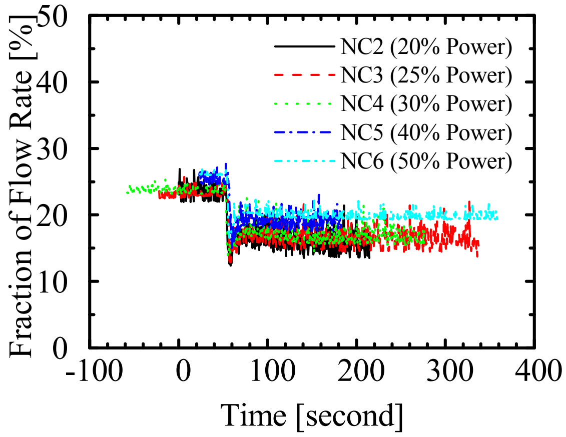

Fig. 1 Core Flow Rates for the Natural Circulation Tests

The main steam superheat was a function of the core power and the feed water flow rate. The increase of the feed water flow rate tended to decrease the main steam superheat. However, even for the test of NC6 the degree of superheat of the main steam is always higher than 35°C.

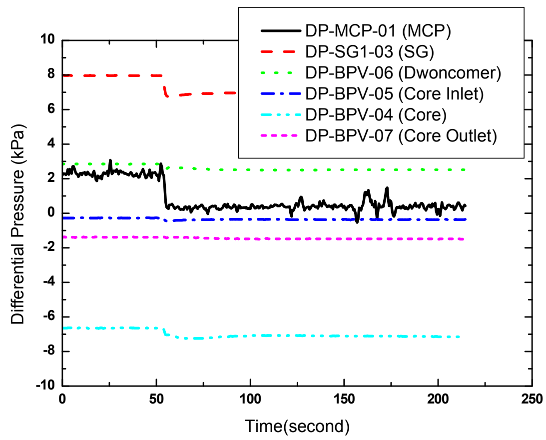

Fig. 2 Differential Pressure Distribution in the Primary Loop for the Test of NC2

Figure 2 shows the distribution of the differential pressure in the primary loop for the test of NC2. A natural circulation begins as the main coolant pump stops. During the natural circulation operation the pressure drop through the core increases but the pressure drop through the steam generator decreases.

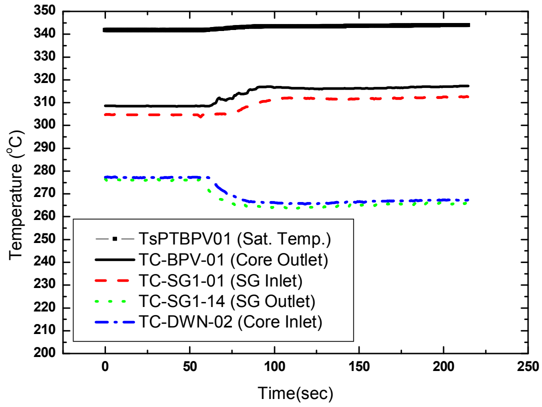

Fig. 3 Fluid Temperature Distribution in the Primary Loop for the Test of NC2

Figure 3 shows the distribution of the fluid temperature in the primary loop for the test of NC2. The saturated fluid temperature is increased a little with the natural circulation operation as the system pressure is increased. The fluid temperatures are highly subcooled throughout the primary loop but the degree of subcooling is reduced at the steam generator inlet during the natural circulation operation.

5. Conclusion

A set of natural circulation experiments has been performed to investigate the thermal-hydraulic characteristics in the primary loop of the SMART reactor by using the VISTA facility. The distributions of the differential pressure and fluid temperature in the primary loop were analyzed to characterize the natural circulation phenomena of the SMART reactor. The experimental results showed that the natural circulation flow rate increases with an increase of the core power and feed water flow rate. In addition, the main steam was always superheated throughout the natural circulation operation.

REFERENCES

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