Thermal Hydraulic Behavior for Transient Operations of the SMART-P

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1. Introduction

Thermal hydraulic behavior for transient operations of the SMART-P are experimentally investigated by using an integral effect test facility of Korea Atomic Energy Research Institute, named VISTA, which is a full height and 1/96 volume scaled test facility based on the design features of the SMART-P.[1,2] The considered transient operations include startup, cooldown, power change and MCP speed change. Two kinds of core power control methods, i.e., a T control or a T+N control, are selectively used and theirs effects on the overall thermal hydraulic behavior are experimentally investigated.

2. Control System and Logics

2.1 Control System

The VISTA facility was designed to be operated by a combination of a manual and an automatic operation. For an automatic control, several PID control logics are installed into a programmable logic controller (PLC) in the control system. The major automatic control components include the core heaters, the MCP, the secondary feedwater control valve and the steam generator pressure control valve. Optimized PID values for each control component are determined by trial and error by considering the system's characteristics. [3]

2.2 Control Logics

The core is simulated by three groups of an electrical heater assembly in the VISTA facility. The core power of the VISTA facility is selectively controlled by either a T-control or a T+N control method. The T-control method is a control method to adjust the core power according to the core exit coolant temperature and is designed to be used for high primary coolant conditions. On the other hand, the T+N control method is for low primary coolant conditions and it uses the core exit temperature as well as the core power as control inputs.[4]

The power change is carried out by changing the feedwater flow rate in the secondary system. In the current study, the change rates of 1%/sec or 3%/sec are taken into account. The feedwater flow control is done by adjusting the lift position of the feedwater control valve in the secondary system. The steam pressure from the reference power-steam pressure program is also controlled by steam pressure control valve in the main steam line. The MCP transient operations were implemented by changing the rotational speed of the MCP from one operation mode to another mode. The considered MCP operation modes are natural circulation, low, mid, and high speed mode.[5] The considered rate of the speed change is 30rpm/sec or 60rpm/sec.

3. Results and Discussion

Table 1 shows a test matrix in the current study. The power change operations can be divided into three groups depending on the MCP speed. The MCP speed change operations means that the MCP speed is changed from one operation mode to another mode. Also, either the T-control or the T+N control method is used to control the core power for all cases and its effects are investigated. The heatup and cooldown operations have not been carried out yet.

Table 1 A test matrix

#	Test IDs	Description
1	H-UP-R40(100)	Heatup operation (rate of 40 or 100 °C/hr)
2	H-DN-R40(100)	Cooldown operation (rate of 40 or 100 °C/hr)
3	H-LP-R1(3)-20-25-T(TN)	Low power change with MCP at 25%, rate 1 or 3%/sec, (T or T+N control)
4	H-MP-R1(3)-20-50-T(TN)	Mid power change with MCP at 50%, rate 1 or 3%/sec, (T or T+N control)
5	H-HP-R1(3)-20-100-T(TN)	High power change with MCP at 100%, rate 1 or 3%/sec, (T or T+N control)
6	H-MCP-LN-R30(60)-T(TN)	MCP change with power at 25%, rate 30 or 60 rpm/sec, (T or T+N control)
7	H-MCP-LM-R30(60)-T(TN)	MCP change with power at 25%, rate 30 or 60 rpm/sec, (T or T+N control)
8	H-MCP-MH-R30(60)-T(TN)	MCP change with power at 50%, rate 30 or 60 rpm/sec, (T or T+N control)

3.1 Power change operation

Figure 1 shows typical results for power change operation. The core power is raised from 20% to 50%

and then reduced to 20% at 3%/sec with the main coolant pump running at the mid speed mode of 50%. The T control method was used in this case. When the power returns back to 20%, the oscillation of the main feedwater flow is observed but it slowly disappears. The upper graph of the Figure 1 shows feedwater flow rate and the lift position of the feedwater control valve. The middle graph shows the trends of the primary and the secondary pressure during the same operation. The variation of the core power can be seen in the lower graph along with the core inlet and exit temperatures. The pressure peak is observed when the power reduces to 20% as shown in the middle graph.

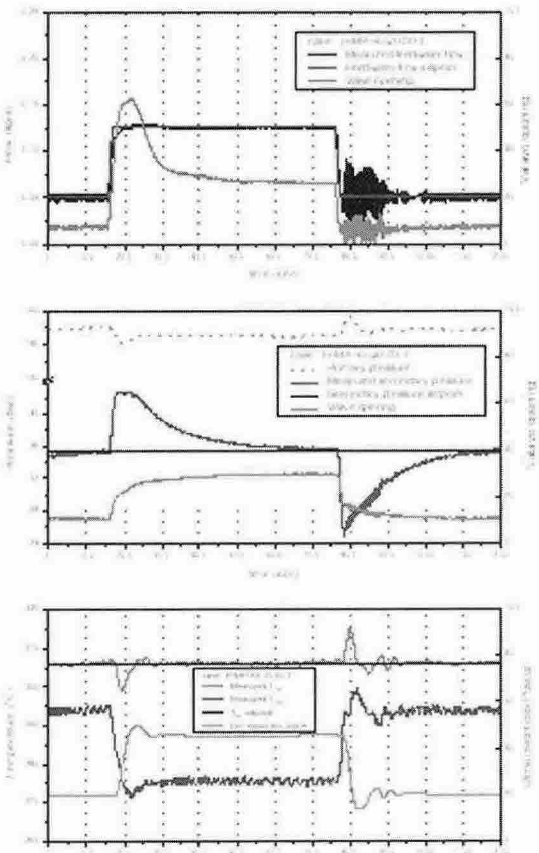

Figure 1. A trend of major parameters for the case of H-MP-R3-20-50-T

Figure 2 shows the variation of the core inlet and exit temperatures and the core power when the core power is controlled by the T+N control method. As shown in this figure, the core exit temperature variation is much smooth compared with the case of the T-control method. The overshooting of the power observed in the T control case is not observed in this case. The primary pressure peak is also osbserved to be small. It is due to the effects of the dead band embedded in the T+N control method. Therefore, the T+N control method has an effect of mitigating abrupt changes of the major thermal hydraulic parameters.

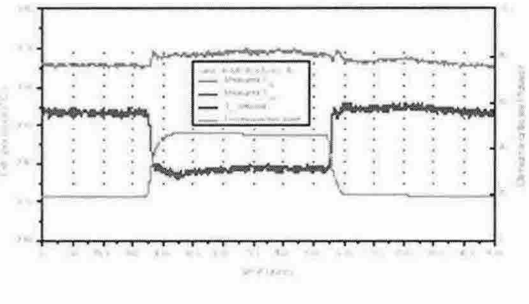

Figure 2. Primary temperature trend for the case of H-MP-R3-20-50-TN

3.2 MCP speed change operation

Several MCP speed change operations were carried out at 30 or 60rpm/sec as summarized in Table 1. When the MCP speed increases, the core exit temperature decreases at first due to the increased primary coolant flow rate. Then, it causes the core power to increase because the core power is controlled to maintain the programmed core exit temperature in case of T-control method. During this process, the primary pressure shows a peak. However, the peak is not so great to threat the safety limit of the SMART-P. On the other hand, when the core power is controlled by the T+N control method, the pressure peak is not observed.

4. Conclusion

It was found that the T+N control mitigates the abrupt power change but it requires a longer time to reach another steady state and disturbs a fine control due to the dead band effect. On the other hand, it was verified that the T-control method is a preferred control method in the high primary coolant condition in order to secure a prompt and precise control performance.

Several MCP transient tests were successfully carried out among the low, mid, and high speed mode. When the core power was controlled by the T control method, a primary pressure peak is observed but it is not so great to threat the safety limit.

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