Evaluation of inadvertent PRHRS operation for REX-10

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1. Introduction

As a development of industry, energy demands are greatly increased and environmental problems are issued. Reflecting the situation, a conceptual reactor, REX-10 was designed by RERI (Regional Energy Research Institute) in 2005[1]. The REX-10 adapts natural circulation for core cooling and passive feature for hydraulic components such as PRHRS (Passive Residual Heat Removal System). But PRHRS is an innovative system, so it should be evaluated. To achieve a better knowledge about PRHRS, inadvertent operation of PRHRS was analyzed by TASS/SMR-S code[2].

2. Inadvertent PRHRS operation

2.1. General Description of REX-10

REX-10 is a small-scale passive reactor with 10 MW thermal power. Natural circulation is induced for core cooling and integrated design adapted for primary systems. So the reactor coolant pump is eliminated and steam generator is accommodated in reactor vessel. The schematic diagram of REX-10 is shown as Fig. 1.

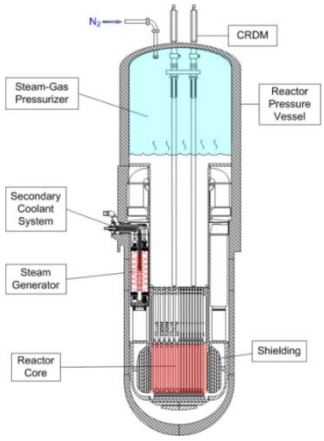

Fig. 1 Schematic Diagram of REX-10

2.2. Passive Residual Heat Removal System

PRHRS is a safety system that removes residual heat of primary coolant system. The system is composed of a heat exchanger, pipes and valves. The schematic diagram of PRHRS is shown as Fig. 2.

In normal operation, feedwater comes from feedwater line and steam goes through steam line. Secondary loop is composed with feed line, SG and steam line (Red and Green line).

But steam and feedwater line is isolated and PRHRS Actuation valve is opened with PRHRS actuation signal. Then PRHRS loop is closed with SG and heat exchanger (Red and Blue line) and Residual heat is transferred from primary system to containment pool.

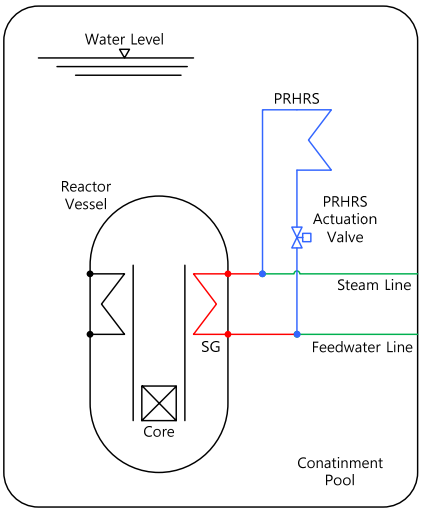

Fig. 2 Schematic Diagram of PRHRS

2.3. Inadvertent operation of PRHRS

Inadvertent operation of PRHRS is initiated from inadvertent opening of PRHRS actuation valve. So wrong PRHRS actuation signal and mechanical valve failure can cause inadvertent PRHRS operation. The inadvertent operation of PRHRS brings additional heat removal through PRHRS and causes a transient state.

3. Analysis of Inadvertent PRHRS operation

3.1. REX-10 Nodalization

The transient is analyzed with TASS/SMR-S code that analyzes thermal hydraulic system with node and path. So REX-10 is nodalized as Fig. 3.

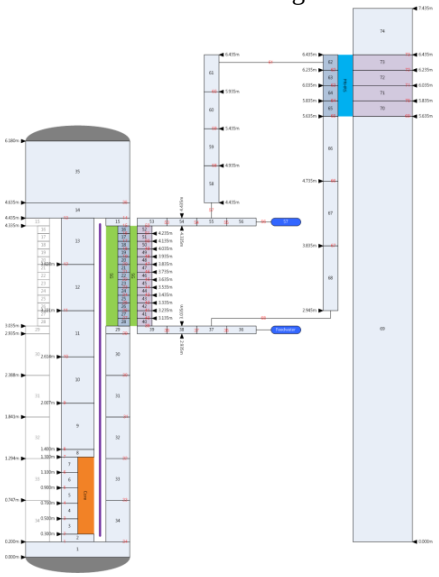

Fig. 3 Nodalization of REX-10

3.2. Steady State

Before transient analysis, steady state calculation had been performed. With the calculation, thermal hydraulic variables are derived. They are tabulated as Table 1.

Table 1. Steady state for REX-10

Variables	***Design***	***Code***
Core Power, MWt	*10.0*	*10.0*
Coolant Flow Rate, kg/sec	*64.9*	*65.5*
Primary Pressure, MPa	*2.0*	*2.0*
Core Inlet Temp., K	*438.15*	*441.62*
Core Outlet Temp., K	*473.15*	*476.12*
Feedwater Flow Rate, kg/sec	*6.2*	*6.2*

3.3. Transient Analysis

From the previous steady state, transient calculation starts with the PRHRS actuation valve opening. Then PRHRS transferred heat from secondary system to the containment pool. Fig. 4 shows the heat balance of reactor coolant system.

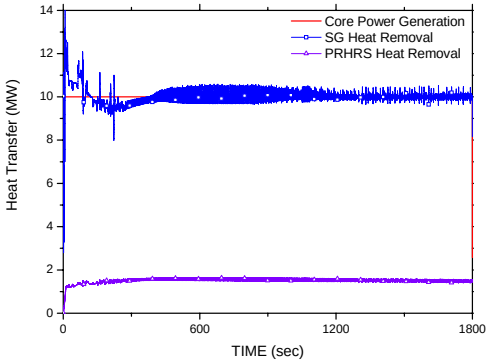

Fig. 4 Heat Balance of Reactor Coolant System.

The reactor coolant system is stabilized in a quasi-steady state that has been balanced between heat generation and SG heat removal. It took about 500 sec to reach the quasi-steady state. The quasi-steady state was observed in primary coolant temperature as Fig. 5.

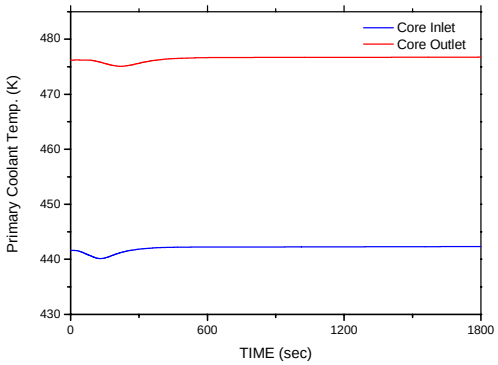

Fig. 5 Primary Coolant Temperature

Inadvertent PRHRS operation causes a quasi-steady state and initiates no reactor trip. So it is assumed that the inadvertent PRHRS operation would be detected by operator in 1800sec and the reactor tripped immediately.

3.4. Reactor Trip

Inadvertent PRHRS operation is detected by operator and reactor is tripped manually. Then the core would be shut down and secondary system would be isolated. Residual heat of the primary system is transferred to the containment pool through PRHRS. Then the primary coolant temperature decreases. The Fig. 6 and 7 show the heat balance of reactor coolant system and coolant temperature for 3600 sec.

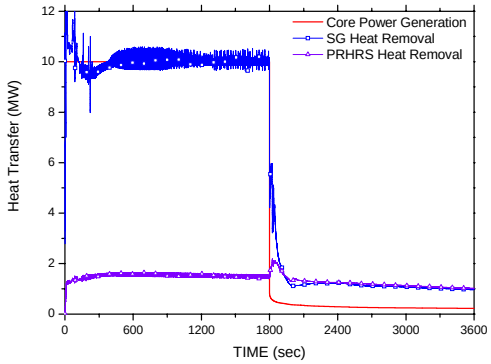

Fig. 6 Heat Balance of Reactor Coolant System.

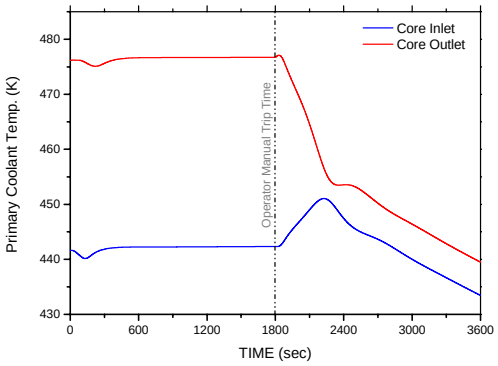

Fig. 7 Primary Coolant Flow Rate

5. Conclusion

In this study, thermal hydraulic effects of inadvertent operation of PRHRS were analyzed. The inadvertent PRHRS operation caused a quasi-steady state and initiated no trip signal. So reactor was tripped manually in 1800 sec. PRHRS operated with reactor trip, residual heat of primary system removed gradually. The thermal hydraulic behavior and PRHRS capability are proven in this study. But the slope of temperature change is greater than that of a commercial reactor. So it should be considered in further steps of design.

REFERENCES

[1] Jong Won Kim, “Researches for Development of Regional Energy Reactor, REX-10”, 25th Korea Atomic Annual Meeting, May 2010

[2] Young Jong Chung, et al., TASS/SMR Code Topical Report for SMART Plant, Vol. I: 911-TH464-001, KAERI, KAERI/TR-3640/2008, 2008.