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# Performance Analysis on Passive Emergency Core Cooling System in the Low Power and Shutdown Operation

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## 1. Introduction

International nuclear industry has been adopting a passive safety system to enhance safety and reliability of nuclear power plant with an advanced technology. Also, domestic nuclear industry issued the necessity for the development of key technologies for passive safety system design. It is necessary to develop the original technology for the improved technology, economics, and safety features. For this purpose, a Passive Emergency Core Cooling System (PECCS) is to be adopted as an improved safety design feature of APR+.

During plant Shutdowns, certain maintenance and testing activities require a drain down of the RCS to a partially filled condition. And Shutdown Cooling System(SCS) is placed into service to accomplish Reactor coolant system(RCS) cooldown to refueling temperatures. If SCS operation is not re-established, core boiling and pressurization can produce rapid core uncovery. When unfavorable accidents such loss of SCS happen, the PECCS should be able to make up the core and then cool down the core. This study discusses the applicability of PECCS and the performance analysis during loss of SCS or RCS inventory.

## 2. Design of PECCS

The design concept of PECCS is shown in Fig. 1. PECCS consists of Safety Injection Tanks (SITs), which are classified into high pressure SITs (H-SITs) and mid pressure SITs (M-SITs), and Automatic Depressurization System (ADS)[1].

M-SITs are same to the conventional SIT and H-SITs new concept. H-SITs are the passive safety system that is connected to the cold leg[2]. In normal operation, the pressure balance line(connection from the RCS (Reactor Coolant System) to the upper part of SIT) is normally closed by the isolation valve. In accident, the isolation valve is opened by safeguard signal. H-SITs inject cold water into the primary system, so make up and then cool down the core.

The ADS performs a function of sudden depressurization of primary system. The ADS consists of four valve systems: ADV#1, ADV#2, ADV#3 have a common inlet header connected to the top of the pressurizer. The outlets of all ADV#1, #2, and #3 combine into a common discharge line to spargers in the in-containment refueling water storage tank. The ADV#4 is connected directly to the top of hot leg and vent directly to the steam generator compartment. The ADV#4 is interlocked so that it can’t open until primary system pressure has been substantially reduced.

## 3. Performance Analysis and result

### *3.1 RELAP5 modeling*

For the analysis, the RELAP5/Mod3.3 code was used. Nodalization for PECCS is shown in Fig. 2. This PECCS model is applied into the APR+ model and used for the performance analysis.

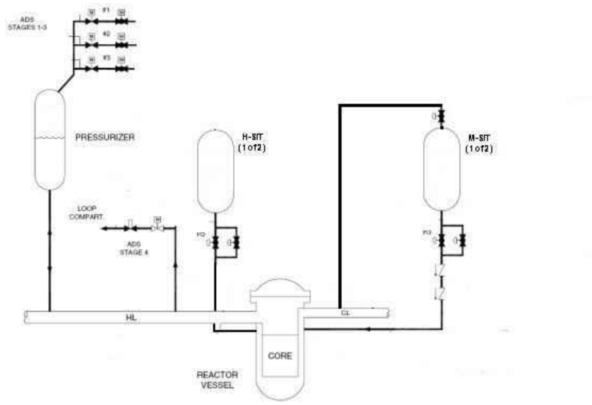



Fig. 1 Outline of PECCS

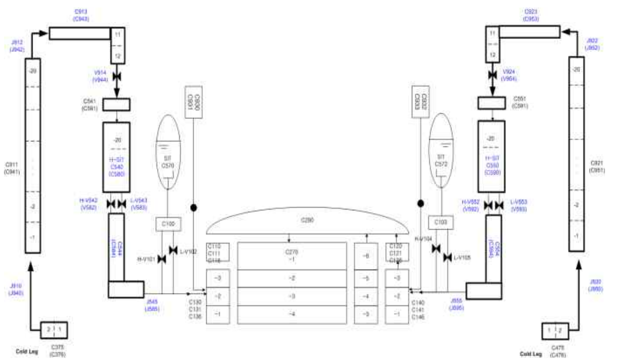


Fig. 2 PECCS nodalization

### *3.2 Transient scenarios*

For analysis, assumptions are described as follows[3]:

1. Initial event
   - Loss of SCS, Stuck open LTOP valve.
2. Shutdown cooling operation
3. Bypasses of engineered safety features actuation

4. 2 H-SITs model , 2 M-SITs are isolated.
5. ADS

| ADS | Effective area ($m^2$) | Open signal |
|---|---|---|
| ADV#1 | 0.0022(POSRV) | H-SIT Level 40% |
| ADV#2 | 0.0022 | ADV#1 + 70sec |
| ADV#3 | 0.0045 | ADV#2 + 120sec |
| ADV#4 | 0.0993 | Low RCS pressure + H-SIT Level 1.8m |

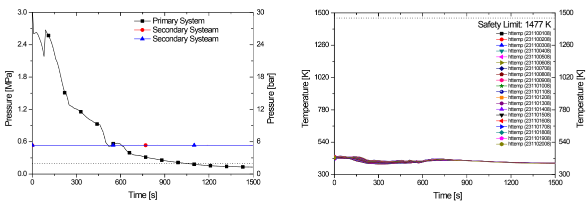
Performance requirements which must be confirmed by analysis are following.

1) Reactor pressure should be lowered below the IRWST injection pressure(about 2bar) for long term cooling.
2) Peak Cladding Temperature(PCT) should be limited within the safety criterion(1477K).

### *3.3 Results*

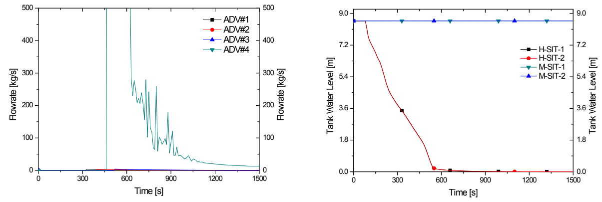
Fig. 3 and Fig. 4 show the result of stuck open the LTOP valve. After the accident, primary system pressure decreased rapidly and RCS inventory is reduced because the reactor coolant is released through the LTOP valve, as shown in fig. 3(a). The H-SITs inject cold water into the primary system when low pressurizer level is signaled. The ADV#1 blowdown phase starts when the H-SIT level reaches the 40%. Then, the ADV#2 and the ADV#3 open in a timed sequence thereafter. Despite ADV#1~3 open, the pressure is not reduced below the IRWST injection pressure(about 2 bar) for long term cooling. As shown in Fig. 4, the ADV#4 is activated when the H-SIT level reaches 1.8m and a large amount of steam release through the ADV#4. Finally, primary system is depressurized below IRWST gravity injection pressure.

Fig. 5 and Fig 6 show the result of loss of SCS. After the accident, primary system pressure increased rapidly and then the LTOP valves opened to limit the primary pressure, as shown in Fig. 5(a) and 6(a). RCS inventory is reduced because the reactor coolant is released through the LTOP valves. But LTOP valve do not provide sufficient vent capability to allow gravity injection of water from IRWST. So, ADV#4 are required to be operable in these conditions. As shown in Fig. 4, the ADV#4 is automatically opened by low hot leg level signal. Finally, primary system is depressurized below IRWST gravity injection pressure.



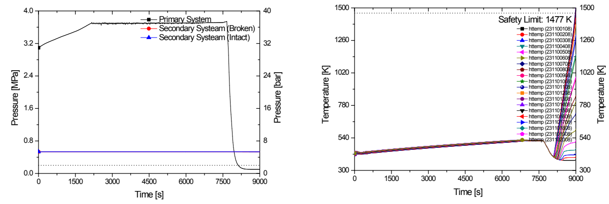

(a) (b)

Fig. 3 Primary Pressure (a) and Cladding Temperature (b)



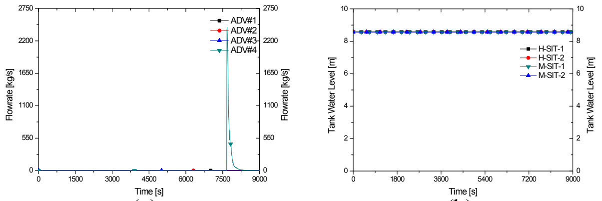

(a) (b)

Fig. 4 ADV flow (a) and SIT Level (b)




(a) (b)

Fig. 5 Primary Pressure (a) and Cladding Temperature (b)




(a) (b)

Fig. 6 ADV flow (a) and SIT Level (b)

## 4. Conclusions

In this study, the applicability of PECCS and analysis performance during loss of SCS or RCS inventory were assessed. RELAP5 calculations show that PECCS can make up the core and then prevent the core from being damaged. Resultant analysis shows the role of the ADV for RCS depressurization, and SITs for RCS making up.

## ACKNOWLEDGMENT

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