Analysis on Roles for Components of Passive Emergency Core Cooling System

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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+.

When unfavorable accidents such as Station Black Out(SBO) 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 proper design combinations especially during SBO.

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.

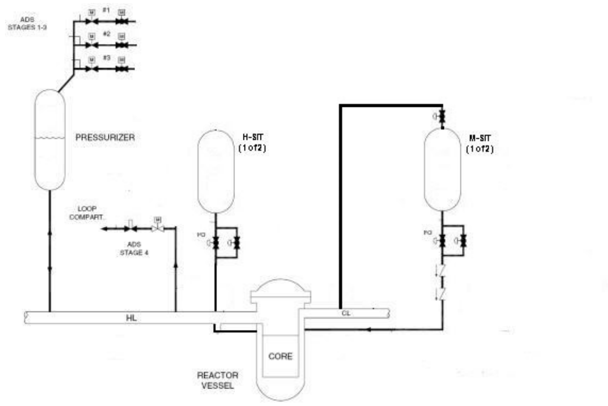


Fig. 1 Outline of PECCS

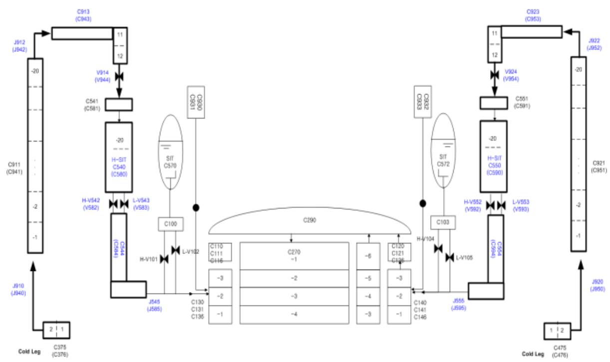


Fig. 2 PECCS nodalization

3.2 Transient scenarios

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

1. Initial event
   - Station Black Out accident
2. RCP stop/ MFW isolation/ MSIV isolation
3. 2 H-SITs model and 2 M-SITs model
4. 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.

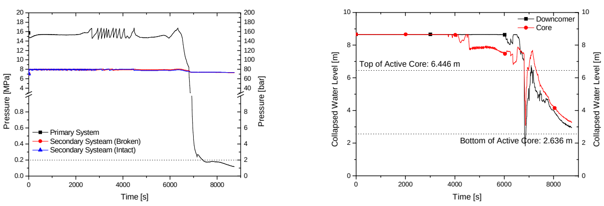
1) Reactor pressure should be lowered below the IRWST injection pressure(about 2bar) for long term cooling.
2) Peak Cladding Temperature(PCT) should be limited within the safety criterion(1477K).

3.3 Results

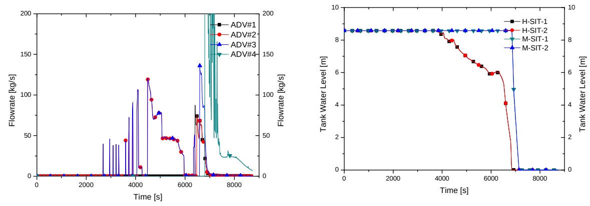
Fig. 3 and Fig. 4 show the result of base case where PAFS are unavailable. After SBO, primary system pressure increased rapidly and then the POSRVs opened to limit the primary pressure, as shown in Fig. 3(a) and 4(a). RCS inventory is reduced because the reactor coolant is released through the POSRVs. The H-SITs inject cold water into the primary system when low SG level and high hot leg temperature are 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 2bar) 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 the–case where PAFS are available. After SBO, SG level decreased rapidly and then reached the PAFS actuation setpoint. PAFS cools down the steam generator’s secondary side, and eventually removes the decay heat from the reactor core. Consequently, RCS inventory and pressure are reduced by cooling. When primary system pressure reaches 100bar, the H-SITs injects as much as the amount of condensation. It is shown in Fig. 5(b).

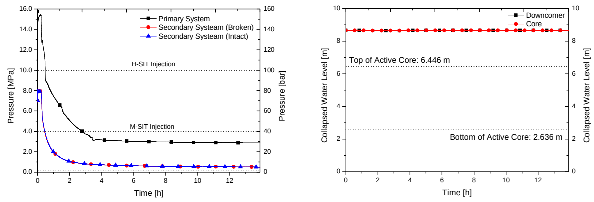
RCS cool down continuously until the PCCT dry out. At this time, ADV must not open. If the ADVs open, SBO will change into the LOCA. For non-LOCA events, use of the ADVs is prohibited. For these events, injection of cold water into the core from the H-SITs may be required for RCS makeup. However, the amount of water necessary should not reduce the level in the H-SITs to ADV actuation setpoint.



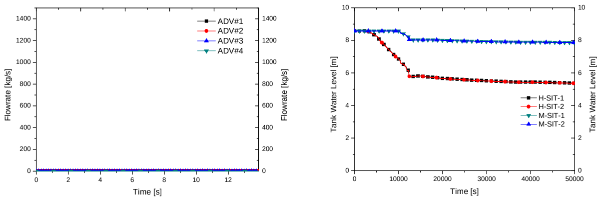
(a) (b)
Fig. 3 Primary Pressure (a) and Core Level (b)



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



(a) (b)
Fig. 5 Primary Pressure (a) and Core Level(b)



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

4. Conclusions

In this study, the applicability of PECCS and analysis on roles of components during SBO were assessed. RELAP5 calculations show that PECCS can make up the core and then prevent the core from being damaged during SBO with PAFS unavailable. Resultant analysis shows the role of the ADV for RCS depressurization, and SITs for RCS making up. When PAFS is available, ADVs is not required. Further study is required to sensitivity analysis such as actuation signal and setpoint.

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