Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 29-30, 2014

Analysis for Conceptual Design Combination of Passive Emergency Core Cooling System

Soon Il Chung [a], Soon Joon Hong [a], Sang Hee Kang [b], Han Gon Kim [b]*
[a]FNC Tech., Heybgdeok IT Valley Bldg. 32F, 13, Heungdeok 1-ro, giheung-gu, Yongin-si, S. Korea
[b]Korea Hydro & Nuclear Power Co., Ltd. 1312, Yuseong-daero, Yuseong-Gu, Daejeon, 305-343, S. Korea
**Corresponding author: soonil@fnctech.com*

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 Small Break Loss of Coolant Accident(SBLOCA) 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 specially during SBLOCA.

2. Conceptual 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-SIT is same to the conventional SIT and H-SIT is new concept. H-SIT is the passive safety system that is connected with the cold leg [2]. SIT injects cold water into the primary system, so make up the core and then cool down the core.

The ADS performs a function of sudden depressurization of primary system initiated by H-SIT low level signal. The ADS consists of four valve systems: ADV#1, ADV#2, ADV#3, and ADV#4. ADV#1~#3 use POSRVs installed in a pressurizer top and ADV#4 is installed hot leg.

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. 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.

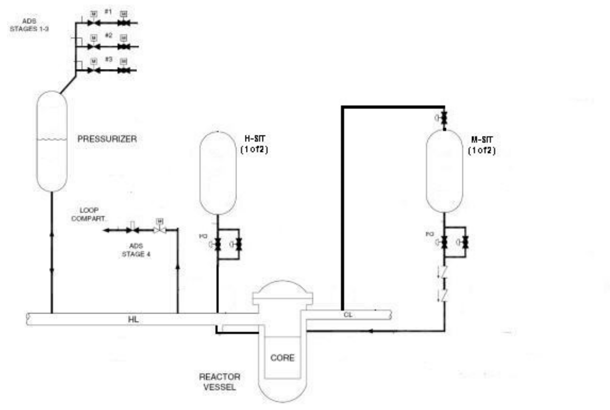


Fig. 1 Outline of PECCS

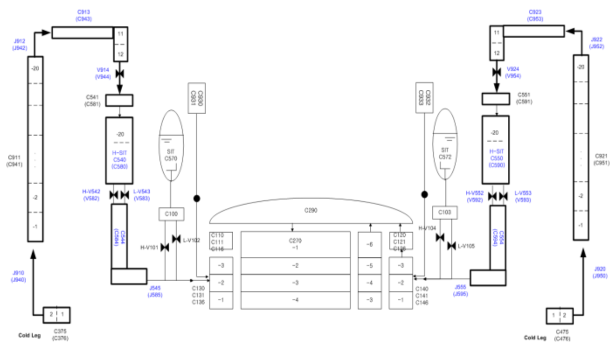


Fig. 2 PECCS nodalization

3.2 Transient scenarios

For analysis, the sensitivity parameters are selected as Table 1 and assumptions are described as follows:

1. Initial event
   - Small break loss of coolant accident
2. RCP stop/ MFW isolation/ MSIV isolation
3. 2 H-SITs model and 2 M-SITs model
4. System conditions
   - 4 HPSIs are unavailable.
   - 2 H-SITs perform only M-SIT function.
   - PAFS is unavailable.
   - ADV#1,2,3 are unavailable.

Table 1. Sensitivity variable

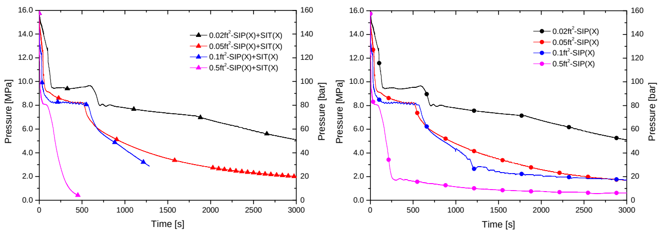
Title	***Variable***
M-SIT	*(1) available* *(2) unavailable*
ADV#4 *(open signal : SIT low water level)*	*(1) available* *(2) unavailable*
Break size	*(1) 0.02 ft^2* *(2) 0.05 ft^2* *(3) 0.1 ft^2* *(4) 0.5 ft^2*
Break location	*(1) RCP discharge* *(2) RCP suction* *(3) hotleg* *(4) DVI*

3.3 Results

Figs. 3 and 4 show the effect of HPSIs and M-SITs on the primary system pressure and core level. Figure 3 (a) and 4 (a) show the primary system pressure and core level in case where HPSIs, M-SITs and ADS are unavailable. In these cases, the secondary system component such as PAFS and MSSVs are actuated to reduce the primary pressure. The MSSVs open to limit the main steam system pressure and then close after PAFS actuation. Finally, primary system pressure can be reduced below the M-SITs injection pressure without ADSs. Nevertheless, if the additional depressurization system is unavailable, the core level decreases and then the core temperature increases finally.

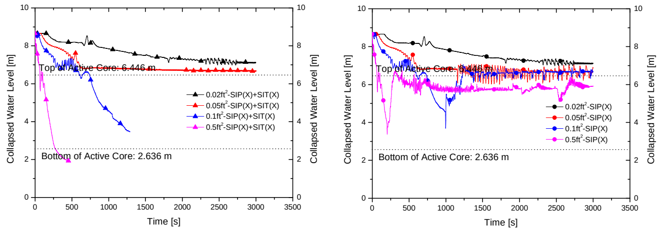
Fig.3 (b) and Fig.4 (b) show the results of using M-SITs. By favor of M-SITs' discharging, the primary system pressure decreases and the core level is limited without core damage. Despite actuating M-SITs, it is difficult that the pressure is reduced below the IRWST injection pressure (about 2bar) for long term cooling. For the further mitigation of accident, ADSs must be used for primary system pressure to reduce below IRWST injection pressure.

Fig. 5 shows behavior of the primary pressure and core level in the case of ADSs actuation. According to this result, following exhaustion of M-SITs inventory, the additional depressurization using ADV #4 from release of a large amount of steam through the ADV#4, is necessary for IRWST injection pressure to reach the final depressurization of primary system. However, if ADV#4 not opened or ADV#4 area is less than a sufficient value, the pressure is not reduced below the IRWST injection pressure.



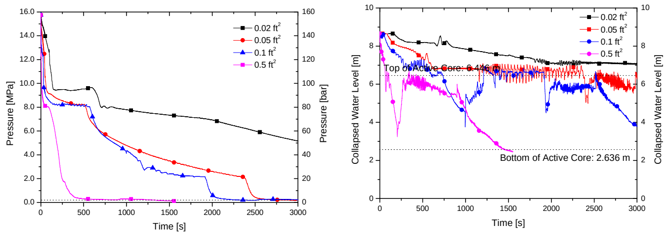
(a) (b)

Fig. 3 Primary Pressure; Both HPSIs and M-SITs are unavailable (a) and HPSIs only are unavailable



(a) (b)

Fig. 4 Core level; Both HPSIs and M-SITs are unavailable (a) and HPSIs only are unavailable (b)



(a) (b)

Fig. 5 Primary Pressure (a) and core level (b)

4. Conclusions

In this study, the applicability of PECCS and the proper design combinations during SBLOCA were assessed. RELAP5 calculations show that PECCS can make up the core and then prevent the core from being damaged during SBLOCA using 4 M-SITs without HPSIs and the ADV#4. HPSIs turned out not to play an important role in SBLOCA mitigation. Resultant design combination for the PECCS against SBLOCA appears a PAFS for RCS cooling, ADV#4 for RCS depressurization, and M-SITs for RCS making up. Further study is required to additional sensitivity analysis such as other accidents and various variables.

ACKNOWLEDGMENT

This work was supported by the Nuclear Power Core Technology Development program of the Korea Institute of Energy Technology Evaluation and Planning(KETEP) granted financial resource from the Ministry of Trade, Industry & Energy, Republic of Korea. (No. 20131510101670)

REFERENCES

[1] KHNP, The performance test of passive emergency cooling system for the development of passive safety system, meeting material, 2013

[2] IAEA, 4th Research Coordination Meeting of the IAEA CRP on Natural Circulation Phenomena, Modeling and Reliability of Passive Systems that Utilize Natural Circulation, 2007

[3] RELAP5 Mod 3. Code Manual,