Hybrid High Pressure Safety Injection Tank for SBO

Tae-Soon Kwon[a*], Dong-Jin Euh[a], Jun-Ho Bae[a], Chun-Kyung Park
Korea Atomic Energy Research Institute, P.O.Box 105, Yuseong, Daejon, 305-600, Korea
[*]Corresponding author: tskwon@kaeri.re.kr

1. Introduction

The recent nuclear power plant accidents imply that the RCS depressurization and core make up at high RCS pressure condition is very important. Because the AC-powered pumping safety features driven by emergency diesel generator are not available during a Station Black Out (SBO) accident, the RCS mass inventory is decreased by steam releasing through the pressurizer safety valves after reactor is tripped. Even in the current passive reactors, such as CARR(CP1300) [1] and AP600, the CMT cannot supply a high flowrate of core cooling water into the RCS for a LOCA condition due to the low PZR pressure after a large break LOCA. Both designs adapt two SITs and two CMTs respectively.

In the new design concept of hybrid High Pressure Safety Injection Tank (HPSIT) for both low and high pressure safety injection, the nitrogen gas serves a charging pressure for the low pressure LOCA injection mode, while the PZR high pressure steam provides an equalizing pressure for SIT. Then the safety water of SIT is passively injected by gravity head for the SBO situation. In order to make the pressure to equalize between the low pressure SIT and high pressure PZR during the SBO condition, a battery driven motor valve has been adapted in the HPSIT configuration for the SBO condition.

2. Design Concept of HPSIT

Figure 1 shows the schematic diagram of the CARR's SIT and CMT system. The 2 SITs are pressurized by nitrogen gas, while the CMTs are pressurized by PZR or RCS pressure. The CMT does not supply a high flow injection to refill a reactor vessel by gravity force because the RCS is rapidly depressurized after LBLOCA. But, the CMT can supply a core makeup flow on a high RCS pressure condition.

Figure 2 shows the schematic diagram of the HPSIT. The equalizing valve is a kind of motor driven valve having a battery system for the SBO condition. For the current LOCA condition, however, it needs the low pressure safety injection driven by nitrogen gas. The HPSIT is conserved the low pressure safety injection characteristics during LBLOCA because the SIT is charged with low pressure nitrogen gas while the HPSIT is additionally pressurized with the high pressure PZR steam during the SBO accident only by manual mode. For SBO condition, the HPSIT supplies the core makeup flow by the gravity head after the SIT pressure equalized with PZR at high pressure.

For better design to prevent the nitrogen gas releasing into the RCS, the pressure equalizing line has two connection piping lines between PZR top and SIT. The nitrogen gas release line is connected between the SIT top nozzle and the safety valve line of PZR. The SIT discharging line is connected between PZR vessel and SIT vessel. Due to the high velocity in the safety valve line, the static pressure is decreased. Hence, the pressure difference between two lines is formed and it drives the N2 gas of SIT to release into the safety valve line from the SITs.

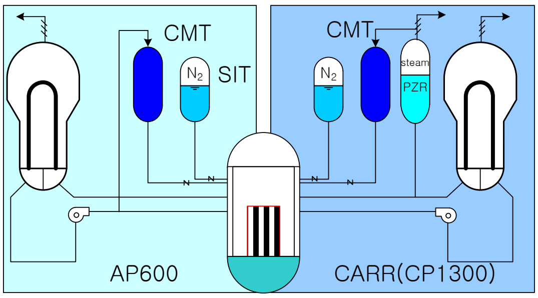

Fig. 1 Design concept of AP600 and CARR CMT

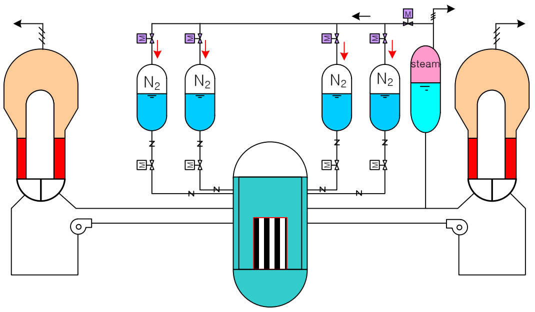

Fig. 2 Design concept of hybrid HPSIT

Table 1 Design conditions

	Current SIT	CARR CMT AP600 CMT	HPSIT (New design)
Component	**4-SIT**	**2-SIT+2-CMT**	**4-SIT**
Pressure	**Low**	**High**	**High**
Charging	**N2 Gas**	**RCS pressure**	**N2 gas & PZR pressure**
Application	**LOCA**	**LOCA and SBO**	

3. Performance Verification

For the performance verification of HPSIT, the RCS make up capability has been evaluated using MARS-KS code for the SBO condition of APR1400.

The main purpose of the SBO simulation is to verify the high pressure safety injection driven by the gravity force after the pressure equalizing action for HPSIT.

For the SBO condition, only passive valves are considered to be working. The other AC-powered features are assumed to be failed. The following sequences are applied for the performance analysis.

- Reactor trip
- Offsite power off (No Diesel generator)
- RCP , main- and aux-feed water trip
- No ECC(SIT and HPSI), No spray
- Only battery available
- HPSIT on for SBO condition

As shown in Fig. 3, the SIT pressure is sharply increased up to the high RCS pressure after the equalizing valve is opened. Fig. 4 shows the flow rate of equalizing pipe line and the gravity driven SIT injection flow rate for the high RCS pressure condition during the SBO accident without AC-power. Fig. 5 shows the cladding temperature. The core temperature increases over the core melting temperature when the core uncovering is occurred. However, the core temperature does not increase after HPSIT's core make up water injection. Fig. 6 reflects that the D/C collapsed water level is recovered by HPSIT's gravity-driven core make up water. The reactor downcomer water level is decreased by the safety valve steam dumping after the SBO without any core makeup water supply. However, the D/C water level does not decrease after HPSIT injection.

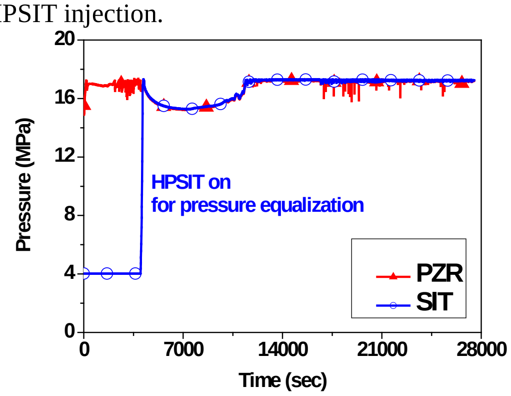

Fig.3 HPSIT high pressure equalizing

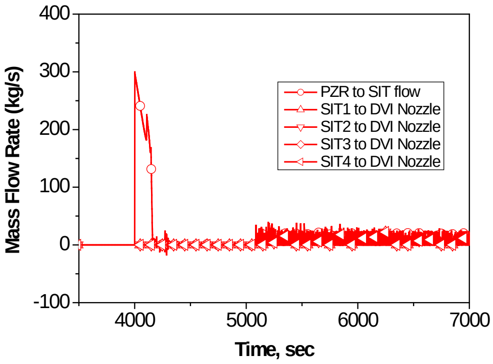

Fig.4 Gravity driven HPSIT flow at high pressure

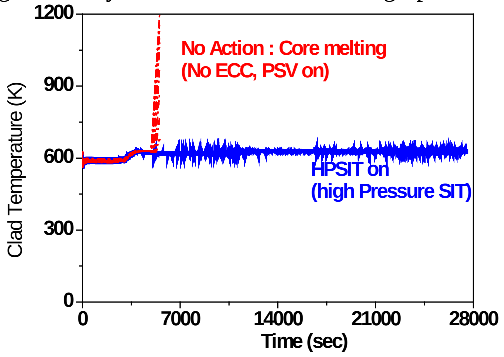

Fig.5 Cladding temperature quenched by HPSIT

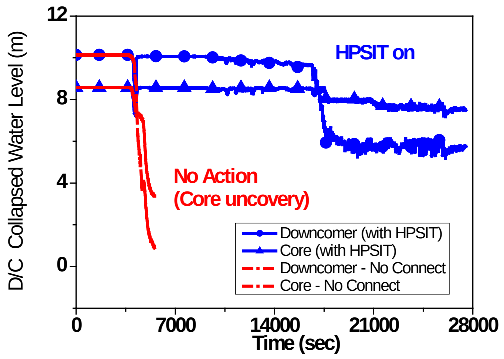

Fig.6 Reactor water inventory recovery by HPSIT

4. Conclusion

The MARS-KS code was applied to analyze the APR1400 SBO performance with HPSIT in order to verify the effectiveness of the HPSIT design feature to mitigate of SBO accident. The results showed a considerable margin in the D/C water level and fuel cladding temperature.

Acknowledgement

This research has been performed as a part of the nuclear R&D program supported by the Ministry of Knowledge Economy of the Korean government.

REFERENCES

[1] Sang-il Lee, Hee-Cheon No, et al., Assessment of RELAP5/MOD3.1 for gravity-driven Injection Experiment in the Core Makeup Tank of the CARR Passive Reactor(CP-1300), NUREg/IA-0134, 1996

[2] Jinzhao Zhang et al., Application of the WCOBRA/TRAC best-etimate methodology to the AP6000 large-breal LOCA analysis, NED, Vol 186, p279-301, 1998.

[3] Michael M. Corletti, Nuclear Reactor with Makeup Water Assist From Residual Heat Removal System, US Patent 5268943, 1993.