Hybrid SIT for Passive Safety System

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1. Introduction

The current Safety Injection Tank (SIT) is designed for a LBLOCA late reflood phase. The injection pressure of the current SIT is about 4 MPa. Therefore, the SIT is not available during a high pressure SBLOCA or Station Black Out (SBO) accident because the RCS pressure is higher than that of the SIT. In addition, the AC-powered High Pressure Safety Injection (HPSI) System driven by an emergency diesel generator is not available during a SBO accident. However, as the RCS mass inventory is continuously decreased by releasing steam through the pressurizer safety valves after reactor trip[1,2], a high pressure safety injection is needed to mitigate the accident.

2. Hybrid SIT

Recently, a new design concept of a hybrid SIT both for safety injections at a low pressure (for SBLOCA or LBLOCA) and high pressure accidents (for smaller size SBLOCA or SBO accident) was introduced[1,2].

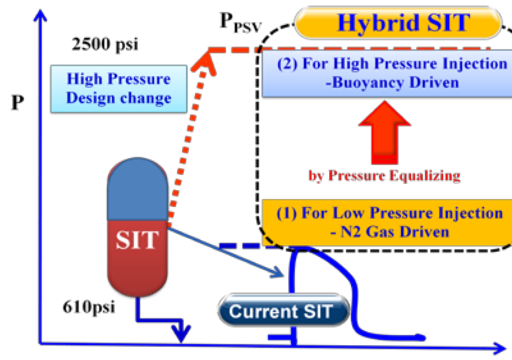


Fig. 1 Design concept of hybrid SIT

Figure 1 shows the design concept of the hybrid SIT, and Fig. 2 shows the effect of the hybrid SIT to extend the time of core melting during a SBO accident. For the low pressure accident such as LBLOCA or medium and large size SBLOCA, the ECC water of SIT is injected by the nitrogen gas while it is injected by a gravitational(buoyancy) force for a high RCS pressure accident such as SBO accident or small size SBLOCA. To drive a hybrid SIT, battery driven isolation valves for SBO condition and a pressure equalizing line between the SIT and pressurizer, hot leg, or reactor vessel is needed. Figure 3 shows the connection point of pressure equalizing line.

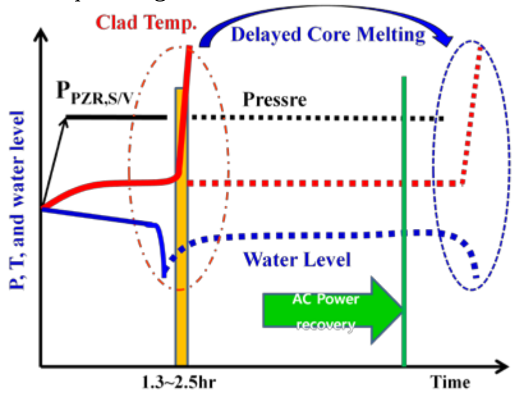


Fig. 2 Effects of hybrid SIT for delayed core melting

The SG or steam line is not suitable for the pressure equalizing line because the SG pressure is lower than that of the primary system.

The Euler equation between the pressurizer and the SIT after pressure equalization is given as follow;

$$\gamma_{SIT}H_{SIT} - \gamma_{PZR}H_{PZR} + \gamma_{DVI}H_{DVI} = H_{Loss} + \frac{1}{2}\rho_{SIT}V_{Inj,DVI}^{2} \quad (1)$$

where,

$$H_{Loss} = \left(f\frac{L}{D} + K\right)\frac{1}{2}\rho_{SIT}V_{Inj,DVI}^{2}$$

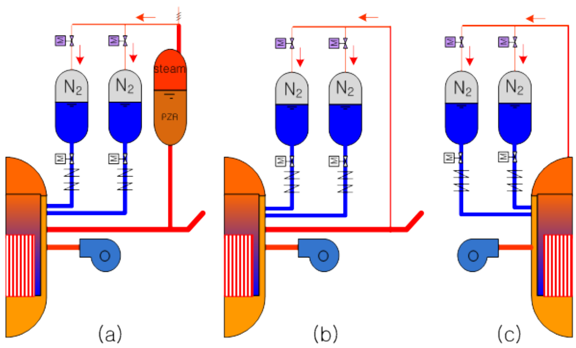


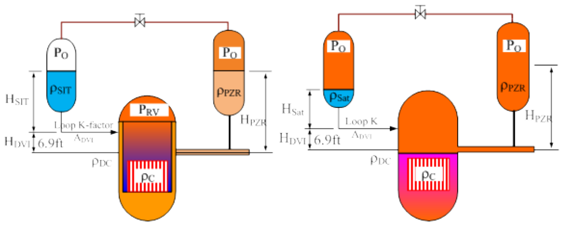
Fig. 3 Connection type of pressure equalizing line: Connection to (a) PZR, (b) HL, and (3) Rx

Then, the injection velocity of the water from a SIT becomes;

$$V_{Inj,DVI} = \left\{\frac{2g}{f\frac{L}{D} + K + 1} * H\right\}^{1/2} \quad (2)$$

where,

$$H = \left[H_{SIT} + \frac{\rho_{DVI}}{\rho_{SIT}} H_{DVI} - \frac{\rho_{PZR}}{\rho_{SIT}} H_{PZR} \right]$$



(a) Initial Condition (b) Final Condition

Fig. 4 RCS condition after pressure equalization

1) If $H_{SIT} + H_{DVI} = H_{PZR}$;

As shown in Fig. 4 (a), the initiation injection velocity of the water from the hybrid SIT for a high pressure saturated condition after pressure equalization between SIT and PZR becomes,

$$V_{Inj,DVI} = \left\{ \frac{2g}{f\,{}^{L}\!/\!{}_{D} + K + 1} * (1 - \frac{\rho_{RCS}}{\rho_{SIT}}) H_{SIT} \right\}^{1/2}$$
$$= \left\{ \frac{2g}{f\,{}^{L}\!/\!{}_{D} + K + 1} * 0.13 * H_{SIT} \right\}^{1/2} \quad (3)$$

where,

$$H_{initia} = \left[H_{SIT} + \frac{\rho_{RCS}}{\rho_{SIT}} H_{DVI} - \frac{\rho_{RCS}}{\rho_{SIT}} H_{PZR} \right]$$
$$= \left[(1 - \frac{\rho_{RCS}}{\rho_{SIT}}) H_{SIT} \right]$$

$$\frac{\rho_{DVI,atSBO}}{\rho_{SIT}} = \frac{859\,{}^{kg}\!/\!{}_{m^3}}{988\,{}^{kg}\!/\!{}_{m^3}} \approx 0.87$$

$$\rho_{DVI,atSBO} = \rho_{PZR,atSBO} = \rho_{RCS,atSBO} = \rho_{RCS,atPsat}$$

2) The maximum injection velocity for RCS voiding;

The RCS as shown in Fig. 4(b) is filled with saturated steam except the core and SIT. The saturated ECC water is injected into downcomer by a buoyancy force between the liquid phase of SIT and steam phase of downcomer.

$$V_{Inj,DVI} = \left\{ \frac{2g}{f\,{}^{L}\!/\!{}_{D} + K + 1} * H_{Sat} \right\}^{1/2} \quad (4)$$

where,

$$\frac{\rho_{DVI}}{\rho_{SIT}} = \frac{\rho_{PZR}}{\rho_{SIT}} = \frac{\rho_{steam}}{\rho_{SIT}}$$

Figures 5 and 6 show the non-dimensionalized ratio of injection velocity by the buoyancy force at DVI nozzle as functions of k-factor and H_{SIT}.

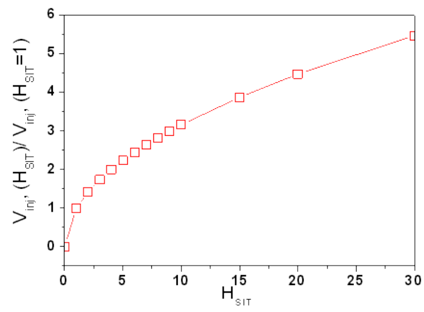


Fig. 5 Injection velocity vs. H_{SIT}

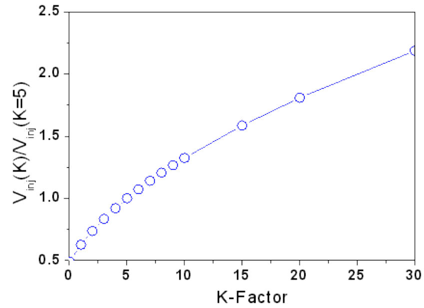


Fig. 6 Injection velocity vs. K-factor

3. Summary

The major design concept of the hybrid SIT both for the passive high pressure safety injection and low pressure safety injection by N_2 gas is introduced. The major design parameters are evaluated to estimate the gravity driven injection velocity by buoyancy force in the hybrid SIT at the DVI nozzle. This design concept of the hybrid SIT is applicable for the APR1400, APR+, and passive pressurized light water nuclear reactor system for LOCA and beyond DBA including SBO accident.

Acknowledgement

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REFERENCES

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[2] Tae-Soon Kwon, Gravity Driven Injection Velocity of Hybrid SIT, *KNS Autumn Meeting Gyeongju, Korea, Oct. 27-28, 2011*