Preliminary Analysis for the SMART LTOP(Low Temperature Over-Pressure Protection)

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1. Introduction

The pressure boundary of the RCS(Reactor Coolant System) during normal operation is protected by pressurizer safety valves. But reduction of toughness of reactor vessel at low temperature could lead to brittle fracture, that is, pressure boundary of the RCS is much vulnerable to pressure at low temperature than at high temperature. Therefore RCS pressure should be limited at low temperature as specified in the 10 CFR 50 APP. G [1] and ASME code section III APP. G [2]. LTOP system is used for overpressure protection at low temperature and the design requirements are specified in the NUREG 0800 BTP 5-2[3]. The relief valves in the SCS(Shutdown Cooling System) are used as LTOP for the SMART plant. Analysis of SMART (System-Integrated Modular Advanced ReacTor) LTOP was performed against the event mostly pressurizing the RCS most at low temperature.

2. Analysis Method

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2.1 Computer Code

TASS/SMR[3] code developed by KAERI was used to perform analysis of LTOP for the SMART. As a thermal-hydraulic system code to simulate RCS, secondary steam/feed water system and PRHR system of the SMART plant, TASS/SMR code has been developed to calculate normal and abnormal conditions, as well as the accident conditions.

2.2 Acceptance Criteria

The peak pressure occurring during at low temperature should be limited to below 20% of the hydrostatic pressure (25 % of design pressure) to protect the reactor vessel from a brittle fracture in accordance with the 10 CFR 50 APP. G [1] and ASME code section III APP. G [2].

2.3 Design Basis Events

To evaluate the capacity of the SMART LTOP valves , all potential events should be considered in the analysis of the LTOP. Considering single failure one train of SCS LTOP valves should be sufficient to limit the peak pressure below SMART P-T requirement. The most limiting case for pressurizing RCS is mass addition by all four safety injection pumps and 3 charging pumps when the RCS is in solid operation at low temperature.

Fig 1 shows RCS maximum pressure response following mass addition if RCS has not equipped with the LTOP valves.

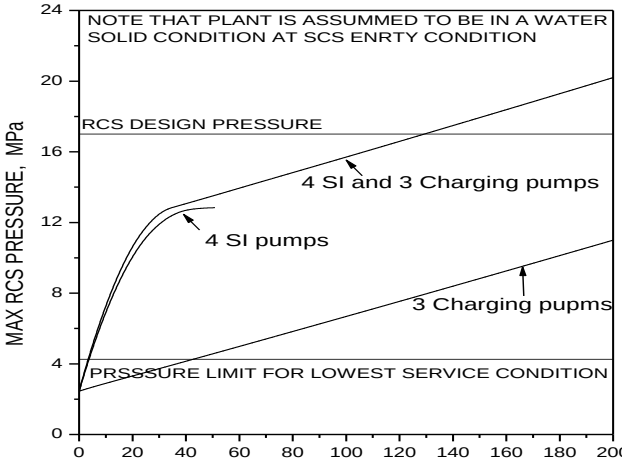

Fig. 1. RCS maximum pressure behavior during mass addition at low temperature without LTOP

3. Initial Conditions and Assumptions

The analysis methodology and assumptions in this study were considered properly in accordance with the NUREG 0800 BTP 5-2[3].

3.1 Initial Condition

The initial conditions and parameters ranges used for mass addition during RCS solid operation at low temperature are as follows;

(1) RCS is in solid operation.
(2) The initial pressurizer pressure is 2.3 MPa (SCS entry condition pressure).
(3) The primary SG inlet temperature is 200 ~ 90 ^{o}C.
(4) The reactor power is 0.01308% of 330 MWt (the power level of decay heat 28 hours after reactor trip).

3.2 Assumptions

(1) The operational characteristic of the LTOP valves is assumed as shown in the Figure 2.
(2) There is no heat transfer between the RCS and the SG secondary side for conservatism.
(3) To maximize flow to the RCS, all 4 SI pumps.

and 3 charging pumps are operating simultaneously.
(4) The temperature of safety injection water is assumed at 5 ~ 90 °C and that of the charging water 15.6 °C ~ 49 °C.
(5) The RCPs are assumed to be in operation, which maximizes the increase of the RCS peak pressure.

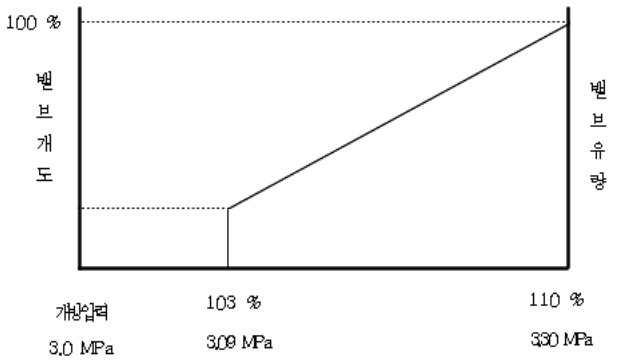

Fig. 2. Operational characteristic of the SCS relief valves

4. Analysis Results

The sensitivity studies showed that the case of the high RCS temperature, high safety injection water temperature and RCP running produced the most severe result.

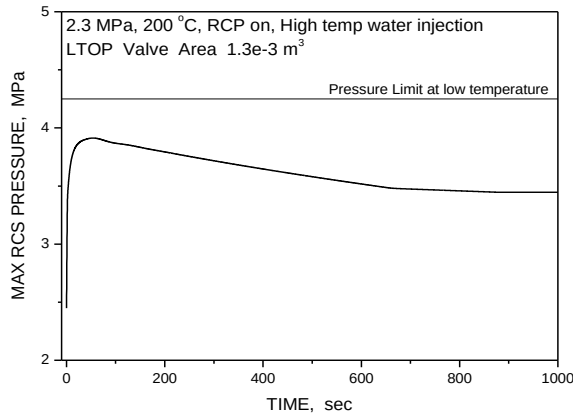

Fig. 3. Pressure behavior of RCS during mass addition

Figure 3 shows the RCS pressure response following a mass addition with initial conditions specified above. As shown in the Figure 4, $1.5e^{-3}m^2$ of the LTOP relief area is sufficient to limit the peak pressure below the pressure requirements. Another simple approach to quantify an overall capacity of the LTOP valves is to solve a mass conservation equation.

$$\frac{dM}{dt} = \dot{m}_{SI} + \dot{m}_{CP} - \dot{m}_{LTOP} \quad \text{------ (1)}$$

where $\dot{m}_{LTOP}$ represents flow rate through the LTOP valves (see figure 2). The all terms in the equation (1) are only function of pressure so pressure can be found. The results using equation (1) for 380 m^3/hr flow capacity of LTOP valves is shown in the figure 5.

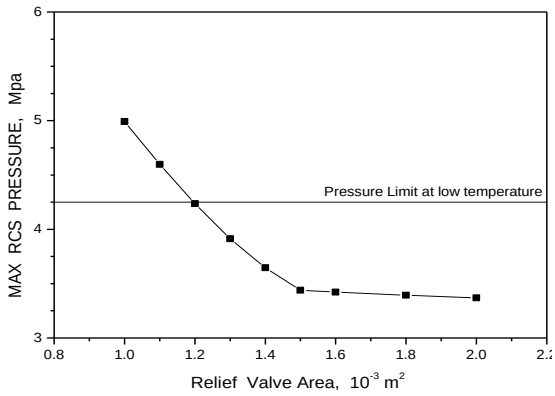

Fig. 4. Change Maximum RCS pressure with LTOP area

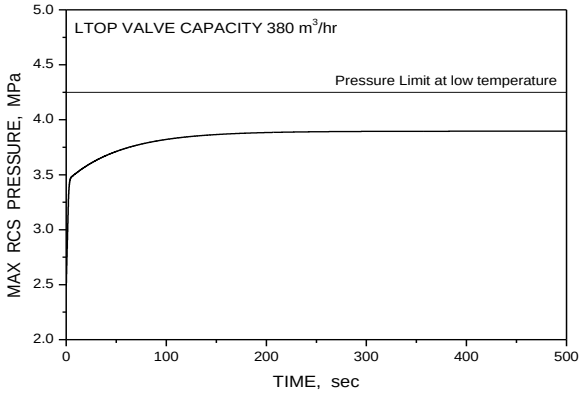

Fig. 5. RCS Pressure behavior during mass addition with equation (1)

5. Conclusions

Analysis for the SMART LTOP during the RCS solid operation at low temperature has been performed. As shown in the figure 4, $1.5e^{-3}m^3$ of the LTOP valve capacity is sufficient to limit the peak pressure below 4.25 MPa during mass addition below 4.25 MPa, which RCS pressure requirement at low temperature.

REFERENCES

[1] 10 CFR 50, APP. G. "Fracture Toughness Requirements"
[2] ASME Boiler and Pressure Vessel Code Section III, App. G NQA-1, 1994.
[3] NUREG-0800, USNRC SRP BTP 5-2, Overpressurization Protection of Pressurized-Water Reactor While Operating at Low Temperature, Rev.03, March 2007.
[4] KAERI/TR-3640/2008, TASS/SMR Code Topical Report for SMART Plant.