Evaluation to Mitigate Secondary System Peak Pressure for Loss of Condenser Vacuum Event

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1. Introduction

The control systems are generally credited for the safety analysis if the analysis produces conservative results. However, in most of all non-loss of coolant accident (non-LOCA) events, the control system helps to mitigate a transient state. Accordingly, the safety analysis of non-LOCA assumes the control systems are in the manual mode of operation.

The loss of condenser vacuum event (LOCV) is a typical anticipated operational occurrence (AOO) which results in an increase in primary and secondary system pressure. The pressurizer (PZR) pressure control system (PPCS) will function to reduce the primary system pressure increase during the transient. Therefore, it is assumed to be in manual mode and credit is not taken for its functioning. However, crediting the function of PPCS has been found to be more conservative with regard to the secondary system pressure. This is due to the delay of the reactor trip on high pressurizer pressure (HPP) and results in an increase in secondary pressure.

In this paper, countermeasures to compensate the increased secondary pressure are introduced and evaluated.

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2. Methods and Results

This section will explain a various method to reduce the secondary system peak pressure. The initial conditions and basic assumptions used for evaluation are the same.

2.1 Main Steam Safety Valve (MSSV) Flow Rate

The MSSV is a valve to limit the pressure of secondary system. Generally, the minimum MSSV flow rate presented in interface requirement (IR) is conservatively used in the safety analysis. However, the MSSV flow rate provided by vendor, which is ASME certifying flow rate, is used for LOCV event instead of that in IR. The usage of ASME certification flow rate decreases the secondary system peak pressure during LOCV event because it is bigger than IR minimum flow rate. The ASME certification flow rate is 90% of the tested flow rate, which is still conservative.

2.2 MSSV Accumulation Opening Pressure

Table I shows the MSSV opening set-pressure values. As shown in Table I, both the opening set-pressures are the same, but the full opening set-pressures are changed due to difference of calculation method. This would mitigate the results of safety analysis. However, the maximum valve drift [1] and the maximum uncertainty [2] are considered for safety analysis. Therefore, these values are still conservative assumptions.

Table I: MSSV opening set-pressure

Parameter	Previous	Changed
Opening set-pressure, psia	1,235.7/1,267.9/1,293.9	Same
Full opening set-pressure, psia	1,272.8/1,306.0/1,332.8 [{Set-pressure (psig) x 1.04 (Uncertainty)}+14.7 (psia)] x1.03 (accumulation)	1,272.3/1,305.5/1,332.3 {Set-pressure (psig) x 1.04 (Uncertainty)} x 1.03 (accumulation) +14.7 (psia)

2.3 Maximum Pressurizer Spray Flow Rate

The PPCS prevents the primary system pressurization by operating PZR spray when the primary system pressure is increased. This is a conservative assumption with regard to secondary system peak pressure because a PZR spray flow rate delays the reactor trip on HPP, which makes more heat transfer from the primary system to the secondary system. The maximum spray flow rate calculated from the actual pipe design and uncertainty is used for safety analysis instead of maximum spray flow rate in IR. This is able to reduce the secondary peak pressure by the early reactor trip on HPP.

2.4 Initial Steam Generator Level

In LOCV event, the lower steam generator (SG) level is a bit conservative because the secondary system temperature (pressure) increasing rate is high at lower SG level. However, very low SG level (LSGL) is not a conservative because the reactor trip by LSGL occurs early before the secondary system pressure is sufficiently increased. Therefore, the SG level is determined by sensitivity study. In the previous evaluation, it is used to the SG level of 63%WR decided with regard to primary peak pressure. However, SG level of 72%WR, decided through independence sensitivity study with regard to secondary peak pressure,

is used. Table II shows the previous SG level and changed SG level.

Table II: Limiting SG level with regard to secondary system peak pressure

Parameter	Previous	Changed
SG Level, %WR	63	72

2.5 PZR Spray Valve Operating Time Delay

When the primary system pressure is increased to the PZR spray operating set-pressure, the PZR spray is actuated to prevent the primary system pressurization. The PZR spray has small time-delay for actuation after the PZR pressure reaches its actuating set-pressure. An early initiation of the PZR spray delays reactor trip on HPP, which is conservative because the total heat transferred from the primary system to the secondary system is increased. Therefore, the real time-delay of signal to operate PZR spray valve and the PZR spray valve actuation delay time are considered to mitigate secondary system peak pressure.

2.6 Sensitivity Study Results

Table III shows the influence of pressure drop with parameter combinations. As shown in Table III, the secondary system peak pressure is decreased about 14 psia. This compensates the increased secondary system peak pressure due to PPCS consideration.

Table III: Influence of each parameters to mitigate conservatism with regard to secondary system peak pressure

Case	Pressure drop, psia
1[1)]	8
2[2)]	+1
3[3)]	+2
4[4)]	+1
5[5)]	+2
Total	14

Note 1) Case 1 is same with the previous case + PPCS except MSSV area. In this case, it is used the MSSV area calculated by ASME certification flow rate instead of IR minimum flow rate of MSSV.

Note 2) Case 2 is same with the case 1 except accumulation pressure of MSSV. ASME code states that MSSV have to be fully opened within 103% of opening set-pressure. Therefore, the full opening pressure is calculated from gauge pressure.

Note 3) Case 3 is same with the case 2 except PZR spray flow rate. The PZR spray flow rate is calculated from the actual pipe design and the uncertainty.

Note 4) Case 4 is same with the case 3 except SG level. The SG level is decided with regard to secondary system peak pressure.

Note 5) Case 5 is same with the case 4 except PZR valve opening time-delay.

3. Conclusions

From the standpoint of the secondary system pressurization, consideration of the PPCS may result in a conservative secondary system peak pressure. To compensate the increased pressure, MSSV capacity and/or set point, PZR spray or initial SG water level should be carefully adjusted.

REFERENCES

[1] ASME Code, Division 1, Subsection NC-7512, Safety Valve Operating Requirements.

[2] ASME OM Code, Subsection Appendix I, Inservice Testing of Pressure Relief Devices in Light-Water Reactor Nuclear Power Plants, 2004 edition.