A Study on Degree of Conservatism of PZR Inventory during Event Analysis

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1. Introduction

The pressurizer safety valves (PSVs) are installed in OPR1000 plants. While the pressurizer pilot operated safety relief valve (POSRV) of APR1400 is designed to discharge steam and/or water, the PSV is designed to discharge steam only. To check degree of conservatism of a PZR water level during PSV operation, a study has been performed using a computer code, RELAP5/ MOD3.3. Degree of conservatism is described herein, and the results are shown to evaluate degree of conservatism.

2. Methods and Results

The sensitivity study includes the responses of the PZR water level to the change of the temperature during event. In this section the sensitivity study results are given.

2.1 Relevant Event Analysis

The basis event for the study is a pressurizer level control system (PLCS) malfunction [1], and typical OPR1000 data for this event are assumed as follows;

- Pressurizer pressure high trip setpoint : 2,407 psia
- PSV opening setpoint : 2,575 psia including PSV opening setpoint uncertainty of 3%
- MSSV opening setpoint: 1,333.2/1,375.2/1,385.7 psia including MSSV opening setpoint uncertainty of 5%

PLCS malfunction causes an increase in reactor coolant system inventory initiated by a maximum charging pump flow coupled with a letdown flow of 0 gpm. With the pressurizer pressure control system (PPCS) in the manual mode with the PZR sprays off, the increase in RCS inventory results in a PZR pressure increase to the reactor trip analysis setpoint of 2,407 psia.

The increase in pressure is also aggravated by the slight power increase that results from the injection of cold charging flow. In addition, all PZR heaters are assumed to be unavailable to delay the reactor trip.

Figure 1 shows the maximum PZR water volume behavior during the transient (collapsed volume) based on CESEC-III.

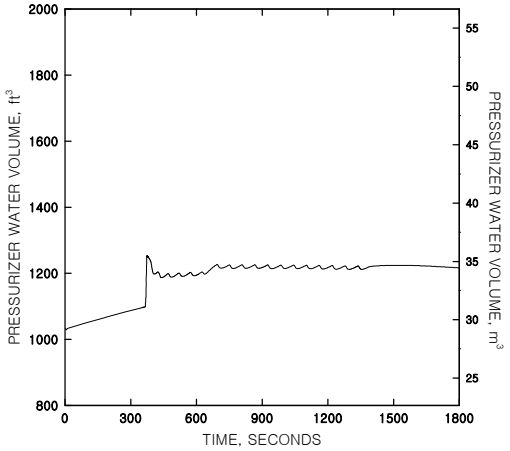

Fig. 1. PZR Water Volume vs Time

2.2 Pressurizer Model

RELAP5/MOD3.3 is used to consider the flashing phenomena, and to verify the relation between the steam phase and liquid phase. Sections 2.2 through 2.5 provide the relevant information.

Figure 2 shows PZR model which are consist of 11 nodes including PZR upper region node. This model is used to check the temperature distribution, the maximum temperature increase on the liquid phase nodes, and the liquid fraction of each node.

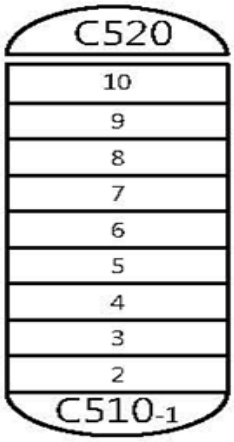

Fig. 2. PZR Modeling

2.3 Temperature and Void Distribution for Each Node

Figures 3 and 4 show the long and short term temperature distribution for each node, respectively, and the maximum temperature increase on the liquid phase nodes (Nodes 2 through 7) is about 4.1˚F.

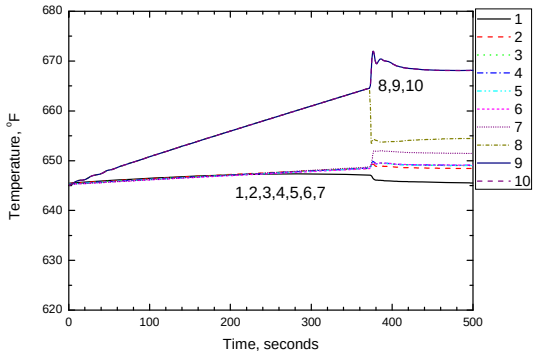

Fig. 3. Node Temperature vs Time (long term)

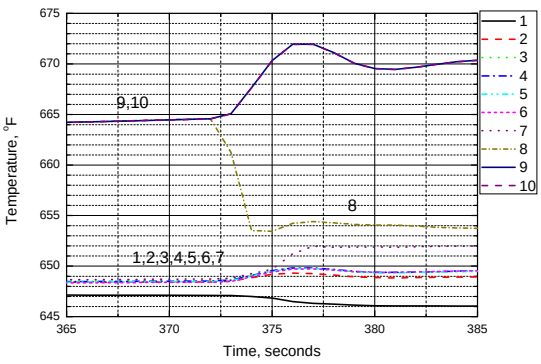

Fig. 4. Node Temperature vs Time (short term)

Figure 5 shows the liquid fraction of each node. The mixed phase with the steam and the liquid is simultaneously presented on Nodes 7 and 8, and it means that two phase level is existed only upto Node 8 with the flashing.

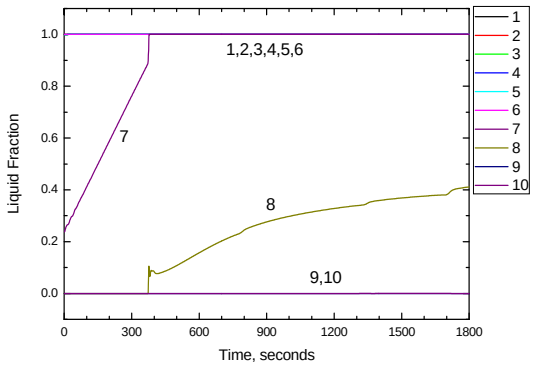

Fig. 5. Node Liquid Fraction vs Time

Figure 6 shows the collapsed level of PZR with RELAP5/MOD3.3, and the maximum level is about 71%. This level means that there is no possibility the liquid goes through PSVs during the relevant event considering the flashing phenomena. For CESEC-III, the collapsed level is about 72%.

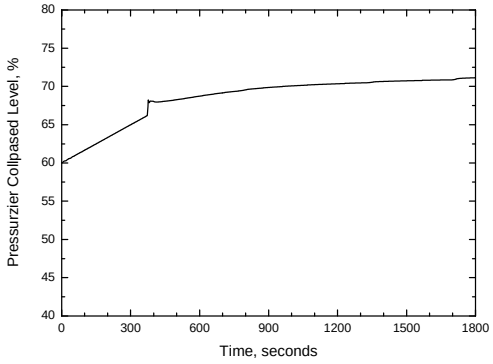

Fig. 6. Collapsed Level vs Time

2.4 Calculation Procedures and Values

To evaluate degree of conservatism, the following procedures are taken;

① Calculate the water volume below PSV
② Calculate the maximum water volume flashed based on the enthalpy increase
③ Compare the water volume calculated in item ① with the water volume in item ②

Total PZR volume is 1,815 ft^3 for OPR1000 plants, and the water volume below PSV is calculated as 1,798.79 ft^3.

2.5 Maximum Water Volume Flashed

The maximum water volume flashed is calculated based on the enthalpy on the relevant pressure (PSV open) and temperature (the temperature increase of RELAP5/MOD3.3 plus some margin).

Table 1. Enthalpy at the Relevant Conditions

Pressure	Temperature	Enthalpy, h_f	Remark
2,325.0 psia	657.4˚F	710.12 Btu/lbm	Initial Condition
2,575.0 psia	663.9˚F	718.72 Btu/lbm	6.5˚F Margin

The initial pressure for the flashing is defined as the relevant pressure on the calculated enthalpy. Table 1 shows the relevant pressure, temperature and enthalpy. The pressure corresponding to the enthalpy of 718.72 Btu/lbm is about 2,400 psia and this pressure is defined as the initial pressure for the flashing. Table 2 shows the flashing water volume and the resultant PZR water

volume with flashing phenomena based on CESEC-III. The final PZR inventory ensures that the liquid does not go through PSVs during the relevant event based on the conservative assumptions.

Table 2. PZR Inventory (ft^3)

Collapsed Water Volume	Flashing Water Volume	PZR Water Volume with Flashing Phenomena	Water Volume below PSV Nozzle
1,253.3	544.0	1,797.3	1,798.79

3. Conclusions

Degree of conservatism is evaluated with respect to the PZR inventory for OPR1000 plant. It could be concluded that there is no possibility the liquid goes through PSVs during PLCS malfunction, because the expected maximum PZR inventory would remain below PSV nozzle based on the conservative assumptions.

With the site specific PSV characteristics, a degree of conservatism would be determined to guarantee the PSV integrity during the event. To guarantee the PSV integrity, an independent analysis is recommended.

REFERENCES

[1] HBN 3&4 FSAR