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Evaluation for Increasing Pressurizer Inventory during Feedwater Line Break Accident

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1. Introduction

The pilot operated safety relief valve (POSRV) is installed to mitigate overpressurization of the reactor coolant system (RCS) in the advanced power reactor 1400 (APR1400). In overpressure transient states such as a feedwater line break (FLB), pressurizer pressure and water volume will be dramatically increased, and the POSRV can be opened to decrease the RCS pressure. Due to this depressurization, some portion of water in the pressurizer would vaporize immediately. This phenomenon called 'flashing' may result in additional increase of pressurizer water level during the FLB accident. If an increased water level reaches the elevation of the POSRV nozzles, water could be discharged through the POSRV. Although the POSRV is qualified for discharging steam and/or water, it is desirable not to discharge water and worth to evaluate whether the pressurizer water level does not reach the POSRV nozzle.

This study analyzed the FLB accident from the viewpoint of the pressurizer water level increase using the CESEC-III [1] code and the SPACE [2] code. The methodology to evaluate pressurizer water level increase is referred from a similar study for pressurizer level control system malfunction event [3].

2. FLB Accident

The FLB accident is one of events which belong to a category of 'decrease in heat removal by secondary system'. When the FLB accident occurs as shown in Figure 1, steam generator (SG) inventory will be depleted in a short time. It means the RCS temperature and pressure will be rapidly increased by reduction in primary to secondary heat transfer capability. After that, a reactor trip may occurred by high pressurizer pressure (HPP). Then, the POSRV is opened due to rapid RCS pressure increase which results from the turbine trip after the reactor trip. The POSRV opening results in abrupt depressurization and a flashing phenomenon may occur in the pressurizer.

3. Analysis for Pressurizer Level Increase

3.1 Analysis Method

In this analysis, some conditions maximize the pressurizer level during the FLB transient are assumed as follows:

The maximum allowable pressurizer water level is selected as an initial condition. The pressurizer spray is not credited to actuate since it reduces the pressurization rate during pressurizing transients. The other initial conditions and conservative assumptions are similar to those used in the existing FLB analysis.

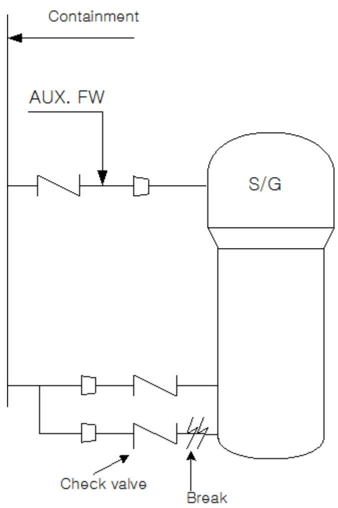

Fig. 1. Feedwater line break accident

To evaluate the increasing pressurizer inventory, the maximum water volume is calculated by computer code and volumetric expansion due to the flashing phenomenon is obtained by hand calculation based on a temperature increase during the transient and a change in thermal-hydraulic condition before and after the POSRV actuation. In calculating a temperature increase by each computer codes, results may be different because each code has dissimilar modeling for pressurizer. The CESEC-III code simply models pressurizer as one node and two regions. Water in subcooled or saturated state, and steam in superheated or saturated state are separated. So, the pressurizer temperature calculated by CESEC-III code is represented by only one value regardless of location in that region. The SPACE code, meanwhile, the pressurizer is modeled with multiple nodes from bottom to top. So, the SPACE code calculates the temperature at each node and the temperature distribution can be obtained. Therefore, maximum temperature increases calculated by above codes are evaluated whether difference values could affect to getting a pressurizer water volume with the flashing.

3.2 Analysis Result

Firstly, the pressurizer water volume during the FLB transient has been calculated using the CESEC-III code. As shown in Figure 2, the pressurizer water volume behavior (net water volume) has been increased due to pressurizer surge line flow into pressurizer and depressurization by the POSRV. The maximum value has been evaluated as 1,815 ft^3.

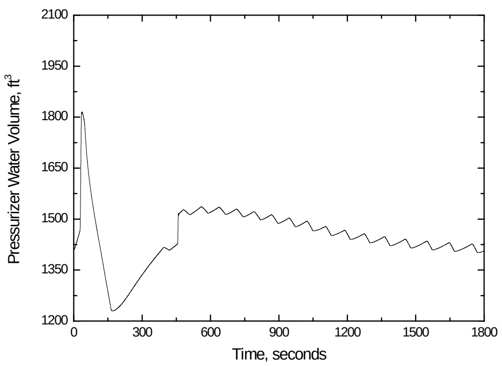

Fig. 2. Pressurizer water volume vs. Time (CESEC-III)

As mentioned above, in the FLB transient, obtaining the maximum temperature increase is necessary to calculate the water volume increase portion by flashing. Steam and water temperatures rise until the POSRV opening. The maximum temperature increase of the pressurizer water has been calculated not to be greater than 1.8°F and difference between the CESEC-III code and the SPACE code are not considerable.

For conservatism in this work, the maximum temperature increase of the pressurizer water has been assumed as 3.0°F in calculating the water volume increase by flashing. This temperature increase has been used to calculate the enthalpy at the time point of the POSRV opening. Also, the enthalpy at the POSRV closing setpoint is considered. Then, a flashing fraction is calculated to get volume increase. Relevant thermal-hydraulic conditions are listed in Table I.

Table I: Relevant Thermal-hydraulic Conditions

Pressure	Temperature	Enthalpy, h_f	Remark
2,270.0 psia	653.98 °F (sat.temp)	703.65 Btu/lbm	Initial condition
2,519.4 psia	656.98 °F	704.91 Btu/lbm	Condition at POSRV open

Table II summarizes the analysis result and the resultant maximum pressurizer water volume evaluated considering flashing phenomenon as 2,238.5 ft^3.

Since the volume below the POSRV is 2,361.0 ft^3 for the APR1400 plant and is greater than the evaluated maximum pressurizer water, it is expected that the pressurizer water does not discharge through the POSRV during the FLB transient.

Table II: Summary of Analysis Result

Net water volume, ft^3 (A)	Flashing water volume, ft^3 (B)	Water volume with flashing phenomenon, ft^3 (A+B)	Water volume below POSRV nozzle, ft^3
1,815.6	422.9	2,238.5	2,361.0

3. Conclusion and Further Study

In this work, the flashing phenomenon of pressurizer water is evaluated with conservative assumptions for the FLB accident by the computer codes and hand calculation. The analysis result shows that the water volume including flashed water is smaller than the water volume below the POSRV nozzle, and type of computer code does not significant effect on a calculated value. Consequently, it is concluded that there is no possibility for the pressurizer water to be discharged through the POSRV during the FLB accident.

In order to obtain more realistic result, the analysis using a computational fluid dynamic (CFD) code or an actual experiment remains as further studies.

REFERENCES

[1] CENPD-107, “CESEC Digital Simulation of a Combustion Engineering Nuclear Steam Supply System”, April 1974
[2] TR-KHNP-0029, “Non-LOCA Safety Analysis Methodology for Typical APR1400 with the SPACE Code”, 2017.
[3] S. S. Lee, “A Study on Degree of Conservatism of PZR Inventory during Event Analysis”, Korean Nuclear Society Autumn Meeting, 2016.