The Analysis of Loop Seal Purge Time for the KHNP Pressurizer Safety Valve Test Facility Using the GOTHIC Code

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1. Introduction

The pressurizer safety valves (PSV) in Pressurized Water Reactors are required to provide the overpressure protection for the Reactor Coolant System (RCS) during the overpressure transients. Korea Hydro and Nuclear Power Company (KHNP) plans to build the PSV test facility for the purpose of providing the PSV pop-up characteristics and the loop seal dynamics for the new safety analysis. When the pressurizer safety valve is mounted in a loop seal configuration, the valve must initially pass the loop seal water prior to popping open on steam. The loop seal in the upstream of PSV prevents leakage of hydrogen gas or steam through the safety valve seat. This paper studies on the loop seal clearing dynamics using GOTHIC-7.2a code [1] to verify the effects of loop seal purge time on the reactor coolant system overpressure.

2. Methods and Results

In this section the PSV test facility and the analysis of loop seal water clearing dynamics are described. To calculate the loop seal purge time GOTHIC-7.2a code is used. The GOTHIC (**G**eneration of **T**hermal-**H**ydraulic **I**nformation for **C**ontainments)[1] code is an integrated, general purpose thermal-hydraulics software package for design, licensing, safety and operating analysis of nuclear power plant equipments, pipes and containments.

2.1 PSV Test Facility Modeling

A schematic diagram of the PSV test facility is shown in Fig.1. The test facility is designed to test the pop-up and lifting characteristics of the safety valves. The facility is able to test all types of PSVs including loop seals of the Westinghouse type plants. The facility consists of the accumulator, test vessel, pressure relief tank (PRT), loop seals, safety valves, pumps, pipes, and so on. The accumulator includes the heater to provide the steam to the system. The pressure of test vessel is controlled by the control valve installed between the accumulator and the test vessel.

The design pressure and temperature are 220 kg/cm^2 (21.57 MPa) and 372.1 ^{o}C, respectively. The operating pressure and temperature are assumed as 200 kg/cm^2 (19.61 MPa) and 364.6 ^{o}C, respectively. The volume of accumulator and the PRT is 10 m^3 and the volume of test vessel is 5 m^3. The two loop seals will be made by the same size as in the Kori 3,4 and the average value of the Kori 1,2. The Crosby safety valve (HP-BP-86, 6M6) will be tested. Its set pressure is 2,485 pisg (174.7 kg/cm^2) and rated relieving temperature is 353.5 ^{o}C. The steam discharged capacity of PSV is 420,000 lbm/hr (52.9 kg/s) [2] at 3% overpressure.

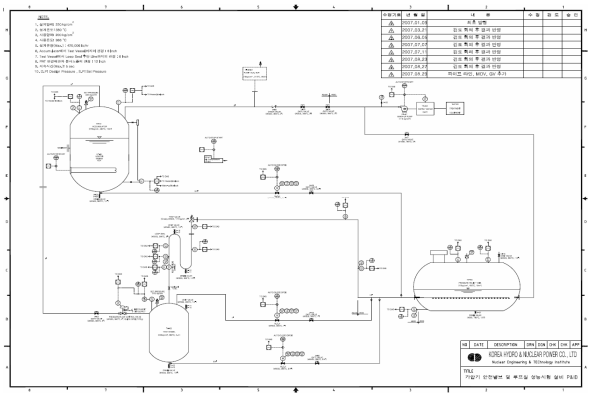

Figure1. The Schematic Diagram of the KHNP PSV Test Facility

2.2 Analysis of the Loop Seal Purge Time

The calculations of the loop seal water purge time and the reseating time are performed using GOTHIC-7.2a code to verify the effect on the test vessel pressure. The loop seal purge delay is defined the time that occurs between the initial opening on water and the popping point on steam. The accumulator supplies higher pressure steam to the test vessel. The operating condition of the accumulator is assumed as the saturated condition at the pressure and temperature of 200 kg/cm^2 (19.61 MPa) and 364.6 ^{o}C, respectively. The initial condition of test vessel is assumed at the pressure and temperature of 160 kg/cm^2 (15.69 MPa) and 346.3 ^{o}C, respectively. When the stem position of a control valve between two vessels is 33% until 2 sec and 100 % after 2 sec, the pressure rate of test vessel is about 330 psi/sec. The water-filled loop seal configuration is shown in Fig.2.

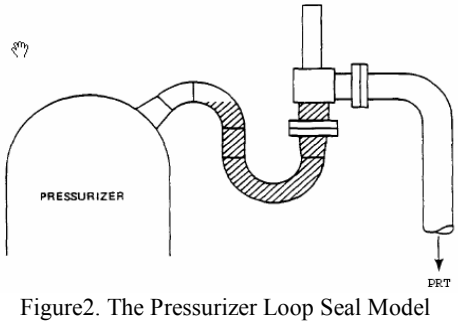

Figure2. The Pressurizer Loop Seal Model

In this simulation the size and capacity of loop seal is used the same value as in Kori 1. In 1980's the Electric Power Research Institute (EPRI) performed the tests for each plant and valve to provide the valve dynamics [3, 4]. The flow rate of steam for the test vessel pressure uses the data of EPRI test number 917 results [4].

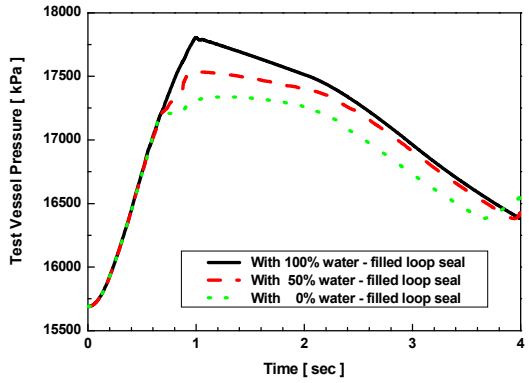

Figure 3. Pressure transient behavior of the test vessel with 100%, 50% and 0% water-filled loop seal

The transient behavior of the test vessel is simulated and shown in Fig.3. The water capacity of the loop seal caused the difference of maximum pressure for the test vessel. That is, the loop seal purge delay caused by the loop seal water effects on the pressure of the system. So, the data for water purge time is needed to increase the safety margin in the protection of the reactor coolant system against overpressure transients.

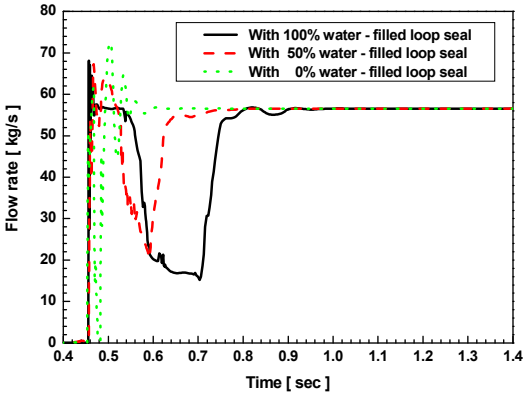

Figure 4. Flow rate of steam and water discharged through the loop seal

The flow rate of steam and water is shown in Fig. 4. The loop seal purge time of the 100 % water-filled loop seal is about 1.2 sec. The PSV pop-up pressure is the 2577.47 psia. The flow rate of loop seal water in this simulation used the steam flow rate because GOTHIC code can't distinguish the flow phase. But the water flow rate is actually different from the steam. Typically, the water flow rate in the piping analysis is assumed 40% of the steam volumetric flow rate [3]. Then the water mass flow rate is 2 times of the steam mass flow at the PSV set pressure. So, the real loop seal purge time could be expected about 0.6 sec. This result is shorter than the average value 0.87 sec of the EPRI test results.

3. Conclusion

The time delay of loop seal water purge effects on the pressure of reactor coolant system. Generally the loop seal purge time is used 1.4 sec for the safety analysis. But the results of EPRI tests have the shorter purge time. So, the data of loop seal purge time is needed to increase the safety margin of safety analysis. In this study the loop seal purge time for KHNP PSV test facility has been analyzed with GOTHIC code. This simulation results will be further evaluated with the test data in the near future.

Acknowledgment

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REFERENCES

[1] Numerical Applications Inc., GOTHIC Containment Analysis Package, Technical Manuals, 2006.
[2] ANDERAON GREENWOOD CROSBY SAFETY VALVE (HP-BP-86, 6M6) Data Sheet
[3] E.M. Burns, P.B. Oeegan, K.S. Howe and L.C. Smith, "Review of Pressurizer Safety Valve Performance as Observed in the EPRI Safety and Relief Valve Test Program", WCAP-10105, 1982.
[4] "EPRI/C-E Power Safety Valve Test Report, NP-2770-LD, Volume6, Research Project V102-2, 1983.