Application of RELAP5/MOD3.3 to Calculate Thermal Hydraulic Behavior of the Pressurizer Safety Valve Performance Test Facility

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1. Introduction

The increase of the acceptance tolerance of Pressurizer Safety Valve (PSV) test is vital for the safe operation of nuclear power plants because the frequent tests may make the valves decrepit and become a cause of leak. Recently, Korea Hydro and Nuclear Power Company (KHNP) is building a PSV performance test facility to provide the technical background data for the relaxation of the acceptance tolerance of PSV including the valve pop-up characteristics and the loop seal dynamics (if the plant has the loop seal in the upstream of PSV) [1]. The discharge piping and supports must be designed to withstand severe transient hydrodynamic loads when the safety valve actuates. The evaluation of hydrodynamic loads is a two-step process: first the thermal hydraulic behavior in the piping must be defined, and then the hydrodynamic loads are calculated from the thermal hydraulic parameters such as pressure and mass flow. The hydrodynamic loads are used as input to the structural analysis.

In this paper the thermal hydraulic behavior is calculated using RELAP5/MOD3.3 and compared to the EPRI/CE No.917 Test [2] to validate its applicability to the hydrodynamic analysis for the KHNP PSV performance test facility.

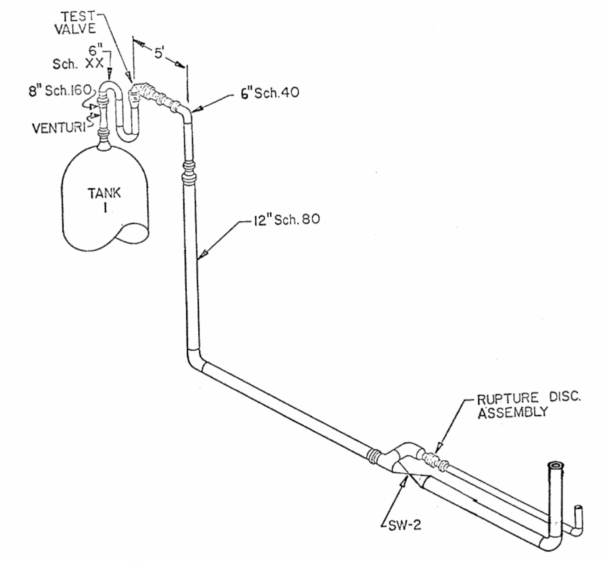

Fig.1 EPRI/CE Test Facility Discharge Piping.

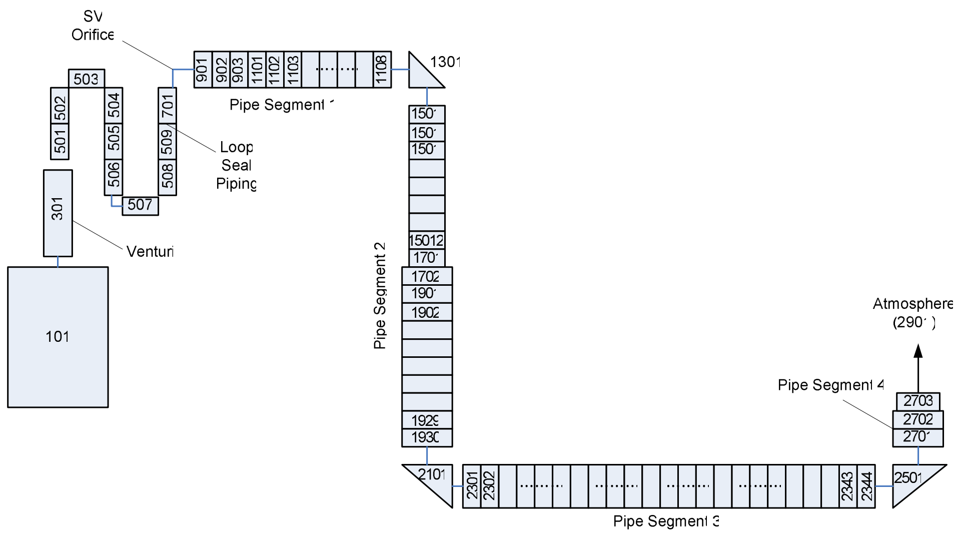

Fig. 2 RELAP5/MOD3.3 Model.

2. RELAP5 Analysis Model

EPRI/CE test facility piping and corresponding RELAP5 model are shown in Figs. 1 and 2, respectively. Test No.917 was conducted to simulate a hot water loop seal discharge followed by steam discharge through the Crosby 6M6 PSV. The loop seal liquid temperature prior to the transient is about 300 °F at the valve inlet and 655 °F at the about 8 ft upstream. The safety valve inlet piping is 6-in schedule XX piping having a cross-sectional area of 0.1308 ft^2 and a loop seal volume of approximately 1.2 ft^3. Nine volumes are used to represent the loop seal inlet piping to permit an adequate representation of the initial loop seal water temperature gradient. A total of 105 volumes are used to represent the 80-ft of discharge pipe in the EPRI/CE system.

During test 917, the valve begin opening when the accumulator pressure reached 2460 psia. However the valve stem does not go immediately to the full-open position but rather oscillated at about 300 Hz for approximately 0.69 sec (simmering) and proceeded to the full-open position 0.02 sec thereafter. By the time the valve reached full open, the accumulator pressure increases to 2650 psia. The valve simmering is not simulated in RELAP5/MOD3.3 model but the valve is assumed to start opening at 0.62 sec and to reach to full-open position at 0.71 sec in a linear rate. The valve full-open flow area used in the model is 0.0204 ft^2, which is determined from the steady flow data of EPRI/CE Test. The discharge pipe initial fluid conditions are assumed to be air at 14.7 psia and 80°F.

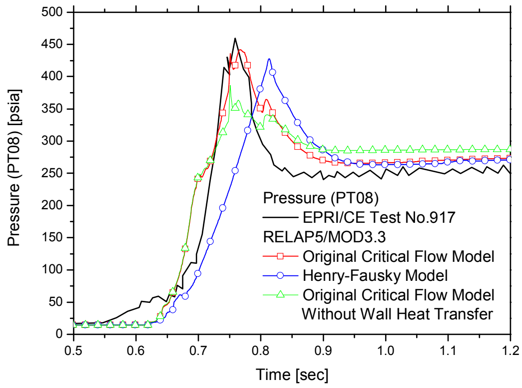

Fig.3 Comparison of RELAP5/MOD3.3 calculated pressure win PT08 experimental data.

3. Results and Discussion

Figure 3 shows the calculated pressure at the exit of PSV. Two critical flow models, i.e., original RELAP5 critical flow model and Henry-Fauske model, are compared with EPRI/CE No.917 test data. The magnitude and trend of pressure at the discharging pipe is one of important parameters for the calculation of hydrodynamic loads. RELAP5/MOD3.3 with original critical flow model shows good agreement in the magnitude and the trend of the calculated pressure with the data. With Henry-Fauske model the time of pressure peak is delayed due to loop seal water clearing. This delay with Henry-Fauske critical flow model can be avoided by adequate modeling the oscillatory valve opening behavior during simmering. However, the actual simmering behavior is unknown in the design phase of PSV performance test facility. Therefore, the use of RELAP5/MOD3.3 with original critical flow model is more suitable for the purpose of calculation of hydrodynamic loads. Figure 4 shows comparison of the calculated mass flowrate and the experimental data of venturi flowmeter at the loop seal inlet. The delay of the full flow build-up is also observed with Henry-Fauske critical flow model.

In the present study, the piping wall heat transfer into atmosphere is considered using HEAT STRUCTUE model. Figure 3 shows comparison of calculated pressure with and without wall heat transfer model. The magnitude of peak pressure is underestimated without piping wall heat transfer. The mass flow is not affected by the piping wall heat transfer as shown in Fig.4. The results presented here show that accounting for piping heat transfer produces significant differences in computed pressure and forces.

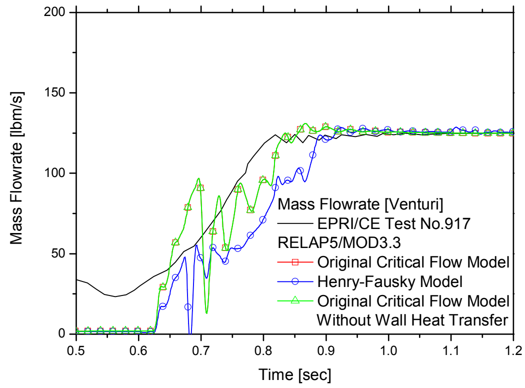

Fig.4 Comparison of RELAP5/MOD3.3 calculated mass flowrate at the loop seal inlet with the experimental data.

4. Conclusions

Thermal hydrodynamic behavior is calculated using RELAP5/MOD3.3 and compared to the EPRI/CE No.917 Test [2] to validate its applicability to the hydrodynamic analysis for the KHNP PSV performance test facility. RELAP5/MOD3.3 with original RELAP5 critical flow model shows good agreement with the EPRI/CE test data accounting for the wall pipe wall heat transfer. It is concluded that RELAP5/MOD3.3 can be used for the calculation of the thermal hydraulic behavior and the hydrodynamic loads of the KHNP PSV performance test facility.

Acknowledgment

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REFERENCES

[1] C. H. KIM et al., Development of the Pressurizer Safety Valve Test Facility, Trans. Korea Nuclear Society, Jeju, Korea, May 10-11, 2007.
[2] EPRI NP-2270-LD Vol.6 EPRI/CE Safety Valve Test Report, Vol.6: Test Results for Crosby Safety Valve, 1983.