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Water Hammer Mitigation on Postulated Pipe Break of Feed Water System

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1. Introduction

The Feed Water (FW) system supplies feedwater from the deaerator storage tank to the Steam Generators(S/G) at the required pressure, temperature, flow rate, and water chemistry. The part of FW system, from the S/G to Main Steam Valve House just outside the containment building wall, is designed as safety grade because of its safety function. According to design code [1,2] the safety related system shall be designed to protect against dynamic effects that may results from a pipe break on high energy lines such as FW system. And the FW system should be designed to minimize bolwdown volume of S/G secondary side during the postulated pipe break. Also the FW system should be designed to prevent the initiation or to minimize the effects of water hammer transients which may be induced by the pipe break [3]. This paper shows the results of the hydrodynamic loads induced by the pipe break and the optimized design parameters to mitigate water hammer loads of FW system for Shin-Kori Nuclear Power Plant Unit 3&4 (SKN 3&4).

2. System Description

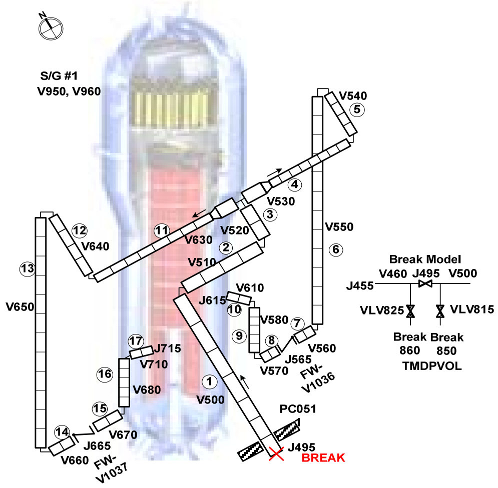
The FW system is composed of three feedwater booster pumps, three feedwater pumps, feedwater heater, valves, and piping. Each combination of feedwater booster pump and feedwater pump can provide a maximum of 55% of the flow requirements for the FW system of SKN 3&4. The feedwater flow to each steam generator splits into an economizer and a downcomer feedwater line. Each economizer and downcomer feedwater line contains redundant controlled closure check valves between the main feedwater isolation valves and the steam generator. The last check valve is physically located as close to the steam generator as practical. These check valves preclude blow down of both steam generators in the event when there is a feedwater pipe rupture. The controlled closure feature should be designed to minimize pressure surge and potential water hammer caused by valve closure.

3. Modeling and Analyses

The break case at S/G economizer line is more severe because the flow rate is higher and the pipe size is larger than those of the downcomer line. Fig. 1 shows the analysis model for the FW line from S/G economizer nozzle to the containment penetration of SKN 3&4 using RELAP5/MOD3.1 computer code [4].

The pipe breaks could be postulated during the normal plant operation at the anchor points such as the S/G nozzle and the containment penetration. In this paper, the results of analyses are shown at the break case of the containment penetration.

Fig.1. Schematic and RELAP5 Modeling of the FW line to S/G Economizer



The following Table 1 shows the system conditions of 100% normal power operation and modeling parameters [5].

Table 1. Operating Condition and Modeling Parameter

Parameter	100% Normal	Modeling
Mass Flow to Economizer Nozzle	844.19 kg/sec (6.7E6 lbs/hr)	1020.58 kg/sec (8.1E6 lbs/hr)
Pressure at S/G Economizer	7276.7 kPa (1055.4psia)	Same as LHS
Temp. of FW	232.2 ^{o}C (450 ^{o}F)	237.8 ^{o}C (460 ^{o}F)
Temp. of S/G Economizer	-	232.2 ^{o}C (492.6 ^{o}F)
Pipe Size	60.96cm and 35.56cm (24 inch and 14 inch)	Same as LHS

The transient analyses are performed to study the effects of closing times and Cv characteristics of the last controlled closure check valve (CCCV). Cv is defined as flow rate per unit pressure drop. The pipe break is simulated to occur at 10.0 second which is enough time to reach the steady state condition in this modeling.

The S/G and atmosphere are modeled as TMDPVOL, and piping system is modeled with a series of components such as PIPE, SNGLJUN in RELAP5, as shown in Figure 1. The FW pump is modeled as a TMDJUN (junction 455) having constant flow rate to achieve the mass flow of 1020.58 kg/sec (8.1E6 lbs/hr) at the steady state condition. The MTRVLV is used to model the closing times and characteristics of the last CCCV. A pipe break is modeled with the open/close of the VALVE component. The hydraulic data such as pressure, velocity, density and void fraction from the results of RELAP5 code are used as inputs to the REFORC-DEC post-processing code [6] to obtain hydrodynamic loads.

4. Results and Discussions

The comparison analyses are performed for three cases of different closing times which are 0.4s, 0.7s and 1.4s, and two cases of Cv characteristics of the CCCV.

Figure 2 shows the comparison of the hydrodynamic loads for the different closing times while pipe break occurs. The first peaks induced by the pipe break are not affected significantly by the different closing times, because these hydrodynamic loads are dependent on the hydraulic parameters at the break point. However the second oscillating water hammer loads of the Figure 2 are affected significantly by the different closing times. The CCCV is started to close by reverse flow when the pipe break occurs, and is finished to close after closing times. The water hammer is occurred when the CCCV is finished to close as shown in Figure 2.

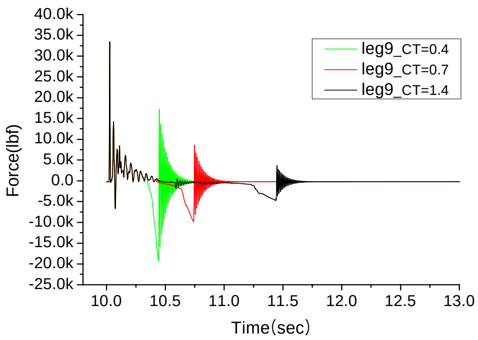


Figure 2. Hydrodynamic Loads by Closing Times

Also, the analyses are performed to find the effects of the different Cv characteristics as shown in Figure 3 and these results are shown in Figure 4. The black and solid line of the Figure 4 shows the hydrodynamic loads profile using the Cv characteristics which are provided by the valve vendor at preceding construction plants. The red and dotted line is the results of pressure profile using another Cv characteristics which are assumed as more sharper at the end of closure than those of the preceding vendor data. Figure 4 shows the water hammer hydrodynamic loads are affected significantly by Cv characteristics of check valve. For the SKN 3&4 the effect of the actual Cv characteristics will be confirmed and reviewed after receiving the vendor data.

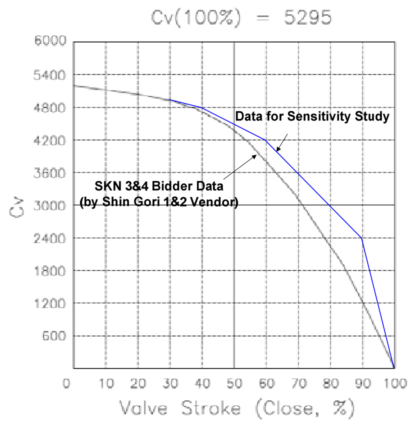


Figure 3. Cv Characteristics of the CCCV(V1036,V1037)

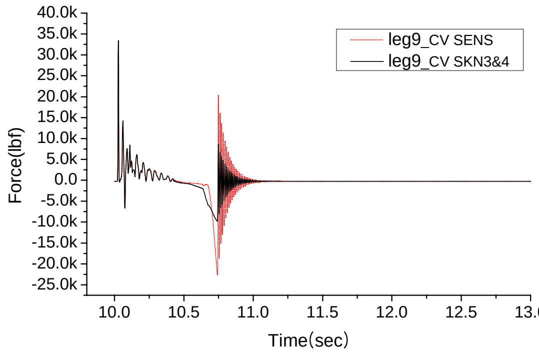


Figure 4. Hydrodynamic Loads by Cv Characteristics

5. Conclusion

The sensitivity analyses are performed to find the optimized design parameters to mitigate water hammer loads when the postulated pipe break occurs. It has been concluded that the closing time and Cv characteristics of CCCV are important design parameters to mitigate water hammer loads without loss of capabilities in FW system. The optimized closing time of the CCCV has been determined to 1.4s from these analyses using RELAP5 computer code.

REFERENCES

[1] 10 CFR Part 50, Appendix A, General Design Criterion 4, “Environmental and Dynamic Effects Design Basis”

[2] USNRC, “Postulated Rupture Locations in Fluid System Piping Inside and Outside Containment,” NUREG-0800 SRP 3.6.2 BTP MEB 3-1, Rev. 2, 1987.

[3] USNRC, “Design Guidelines for Avoiding Water Hammers in Steam Generators,” NUREG-0800 SRP 10.4.7 BTP ASB 10-2, Rev.3, 1984

[4] USNRC, “RELAP5/MOD3 Code Manual,” NUREG/CR 5535, 1995.

[5] KOPEC, “NSSS Interface Requirements for the Main Steam and Feedwater Systems,” 3L186-FS-IR310, Rev.0, 2003.

[6] Sargent & Lundy, “REFORC-DEC: A Computer Program for Calculating Fluid Forces Based on RELAP5 Results,” S&L Program Number REF 03.7.483-1.0, 1994.