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Effect of Operating Conditions of Main Steam System on the Hydrodynamic Loads

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1. Introduction

The structures, systems, and components (SSCs) important to safety shall be designed to accommodate the effects of the environmental conditions associated with postulated accidents, and shall be appropriately protected against dynamic effects that may results from equipment failures [1]. As one of the equipment failures, pipe break should be postulated on the high energy lines such as Main Steam (MS) system [2], and the loads due to the pipe break shall be considered in the design of piping system to protect the SSCs important to safety. In this paper, the hydrodynamic loads induced by the pipe breaks are calculated for the MS line inside containment of Shin-Kori Nuclear Power Plant Unit 3&4 (SKN 3,4), and the loads are compared to investigate the effects of the operating conditions on the loads.

2. System Description

In the design of SKN 3,4, main steam of each Steam Generator (S/G) is conveyed to the main steam header through two separated steam lines with 31 inches (78.7 cm) nominal pipe size. In each steam line, four piping segments are routed from the S/G nozzle to an anchor at the containment penetration (PC0611), as shown in Figure 1. In addition, the fluid conditions of the S/G secondary side during the normal plant operation vary with respect to the reactor power. The maximum expected pressure of the S/G nozzle outlet is decreased to 1013 psia (6.98 MPa) at 100% power from 1100 psia (7.58 MPa) at 0% power, while the steam flow for each steam line is increased to 1246.5 lbm/sec (565.4 kg/sec) from 0.0 lbm/sec (0.0 kg/sec), respectively [3].

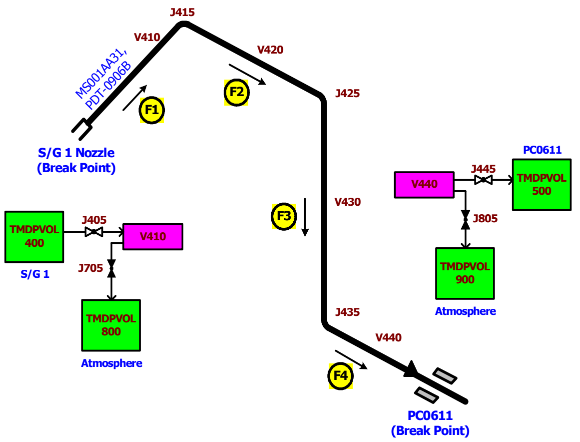

Figure 1. Schematic and RELAP5 Modeling of the MS line inside containment

3. Analyses Cases and Modeling

Generally, the fluid condition at which the pipe break occurs is one of the major factors to affect the hydrodynamic loads induced by the fluid transients. Therefore, four analyses cases are selected to study the effects of operating conditions on the break loads, as described in Table 1. The pipe breaks are postulated during the normal plant operation at the anchor points such as the S/G nozzle and the containment penetration.

Table 1. Analyses Cases for Pipe Break Loads Calculations

Cases	Break Point	Operating Conditions		
		Power (%)	Pressure (psia)	Mass Flow (lbm/sec)
1	PC0611	100	1013	1246.5
2		0	1100	0.0
3	S/G Outlet Nozzle	100	1013	1246.5
4		0	1100	0.0

The hydraulic data such as pressure, velocity, density and void fraction due to the fluid transients are generated using RELAP5/MOD3.1 computer code [4]. The S/G and atmosphere are modeled as TMDPVOL, and piping system is modeled with a series of components such as PIPE, SNGLJUN, as shown in Figure 1. To achieve the mass flow of 1246.5 lbm/sec (565.4 kg/sec) at the steady state condition (Case 1 and 3), the atmosphere connected to the PC0611 is modeled as a TMDPVOL (component 500) having constant pressure during the whole transient. A break is modeled with the open/close of the VALVE component. To obtain hydrodynamic loads, the data from the RELAP5 code are used as inputs to the REFORC-DEC post-processing code [5].

4. Results and Discussions

The hydrodynamic loads are calculated and compared for the pipe breaks occurred at the same break point.

For the breaks at the containment penetration, segment 3 loads are compared in Figure 2. Segment 3 piping is about 50 ft long and having a downward direction. Figure 2 shows that the loads at 0% power are greater than those at 100% by about 50%. The main reason for the higher loads at the 0% power is attributed to the higher operating pressure than that at the 100% power. In addition, the decreased pressure at the 100% power from the S/G to the break point (PC0611) due to the existence of initial steam flow of the 1246.5 lbm/sec (565.4 kg/sec) may be another reason for the smaller loads. These pressure differences also cause the steeper variance of the system mass flow for the case at 0% power as shown in Figure 2. The comparisons for the other segments of the Cases 1 and 2 show similar trends to those on the segment 3.

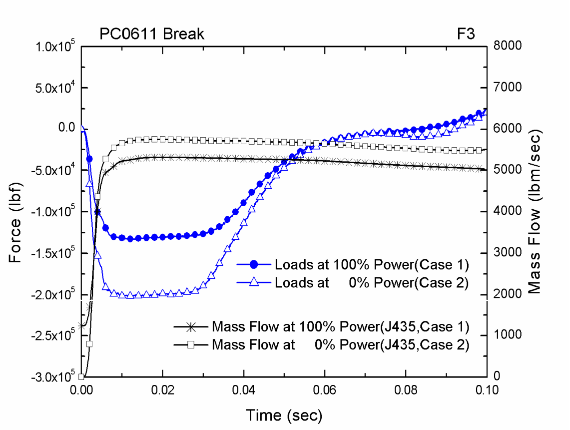

Figure 2. Comparison of Hydrodynamic Loads for Breaks at Containment Penetration (PC0611)

As one of comparisons for the other break cases, the loads for the S/G nozzle break are presented in Figure 3. Contrary to the containment penetration break cases, it can be seen from the figure that the loads at 100% is slightly greater than those at 0% power, even though pressure is lower at the 100% power. This result comes from the fact that the momentum changes after break for the break cases at the S/G nozzle are having different trends compared to those of the containment break cases. For example, the formation of the reverse flow after the break is presumed to be one of the reasons for the higher loads at 100% power. Figure 3 also shows, due to the existence of initial flow of 1246.5 lbm/sec (565.4 kg/sec), the variation of the mass flow at 100% power during the first 0.05 sec is slightly higher as 4641.3 lbm/sec (2105.3 kg/sec) than 4428.4 lbm/sec (2008.7 kg/sec) at 0% power, which results in the slightly greater loads at 100% power during that time. The comparisons for the other segment loads of the Cases 3 and 4 also show similar trends to those on the segment 3.

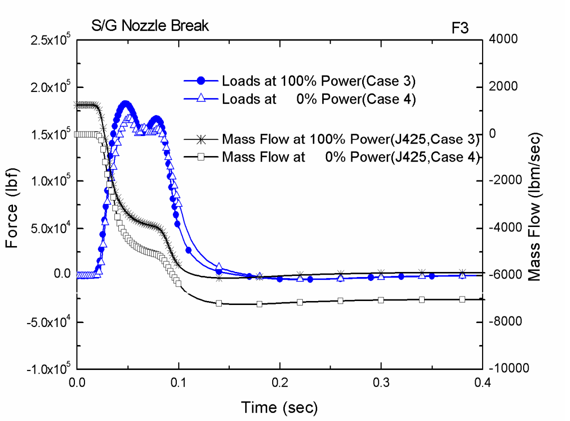

Figure 3. Comparison of Hydrodynamic Loads for Breaks at S/G Nozzle

3. Conclusion

Hydrodynamic loads induced by pipe breaks are calculated for four cases, and compared to study the effects of the operating conditions. It is concluded from these comparisons that the fluid conditions and the break points are major factors to affect the hydrodynamic loads induced by pipe breaks. Especially, it is identified that the system pressure and the existence of the initial steam flow can significantly affect the break loads. Therefore, it is necessary for those factors to be considered in the calculation of the hydrodynamic loads for the design of piping system to protect SSCs important to safety.

REFERENCES

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

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

[4] Carlson, K. E., et al., “RELAP5/MOD3 Code Manual Volume 1: Code Structure, System Models, and Solution Methods (Draft),” EG&G Idaho, 1990.

[5] 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.