Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 25-26, 2012

Containment Behavior in MSLB with FIV Malfunction

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1. Introduction

In case of Main Steam Line Break(MSLB) accident, sustained high feedwater flow would cause additional cooldown of primary system. Therefore, in addition to the normal control action that closes the main feedwater valves, a safety injection signal rapidly closes all Feed -water Control Valve(FCV)s and Feedwater Isolation Valve(FIV)s, trips the main feedwater pumps, and closes the feedwater pump discharge valves. With a single failure of FCVs, FIVs should act as back-up protection measures [1]. However, in a certain plant, the FIVs are not automated. If the FIVs could not be credited, the trip of main feedwater pumps can be act as back-up protection measures for the single failure of FVCs. In that case, un-isolated feedwater which is contained in the pipe between the main feedwater pump and the upstream of the FCV might be flash and be supplied to the broken steam generator. The containment integrity was studied for this case.

2. Methods and Results

LOFTRAN code was used to calculate the mass and energy discharges into the containment and CONTEMPT-LT/28 was used to calculate the peak pressure and temperature in the containment.

2.1 Assumptions

Westing House design 2-loop plant was studied for the primary & secondary system thermal hydraulic behavior and containment behavior. Double Ended Rupture (DER) with flow area of 1.4 ft^2 was assumed in one of the two loops. With a single failure of FCVs, two cases were assumed for the feedwater flow supplied to the broken steam generator. The first one is that the feedwater flow as much as steam flow discharged through break point was supplied to the broken steam generator till the reactor trips (MODEFW=8). The other one is that the feedwater flow was supplied for 60 seconds with linear decrease (MODEFW=10) [2]. For the shutdown margin, also two cases were assumed. The first one conventional value of 1.8% for the safety analysis and the other one is 2.0% considering the design value of 2.15% for a certain fuel cycle of a certain plant. 1.9% was also applied for the sensitivity study. Except for those, conventional assumptions for the Westing House design 2-loop plant safety analysis were applied.

2.2 Un-isolated Volume

Feedwater contained in the upstream of FCVs would be flashed to steam and supplied to the broken steam generator due to the single failure of FCVs. Conservatively, volume of pipes and feedwater heaters from the outlet of booster feedwater pump to the steam generator inlet was considered. Volume of each component was shown in Table I.

Table I: Un-isolated Volume

Component	Ø (ft)	Length (ft)	Volume (ft^3)
BFP Outlet – Outlet Common Line	1.6	95.4	192.8
Outlet Common Line	1.6	59.8	121.0
Outlet Common Line-FWHTR5 Inlet	1.27	166.2	210.8
FWHTR5	1.27	86.0	109.1
FWHTR5 Outlet- HTR Outlet Common Line	1.27	398.8	506.0
HTR Outlet Common Line	1.60	76.0	153.6
HTR Outlet Common Line-MFP Inlet	1.60	104.0	210.3
MFP Outlet-Common Line	1.19	107.9	120.6
Common Line	1.49	118.0	207.1
Common Line-FWHTR6 Inlet	1.19	135.1	151.0
FWHTR6	1.19	86.0	96.1
FWHTR6 outlet-HTR Outlet Common Line	1.19	33.3	37.2
HTR Outlet Common Line-FCV Inlet Common Line	1.34	86.9	123.3
FCV Inlet Common Line-VFW-12A	1.49	3.8	6.6
VFW-12A-IFV-466(FCV)	1.19	12.0	13.5
FCV-S/G Inlet	-	-	300.0
Total	-	-	2559.0

2.3 Analysis Results

Various initial power levels were studied, but 102%FP is the most limiting case. Reference results shown in this paper were analyzed with 102%FP initial power level, shutdown margin of 2.0% and MODEFW=8.

Feedwater supply conditions for each case after safety injection signal are shown in Fig. 1. Until about 10 seconds, feedwater flow rate of reference case is a little higher than that of MODEFW=10 case. But the total integrated feedwater mass of MODEFW=10 case is a little bit more as shown in Fig. 2.

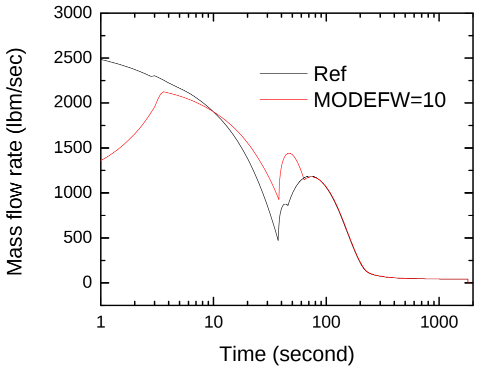

Fig. 1. Feedwater mass flow rate.

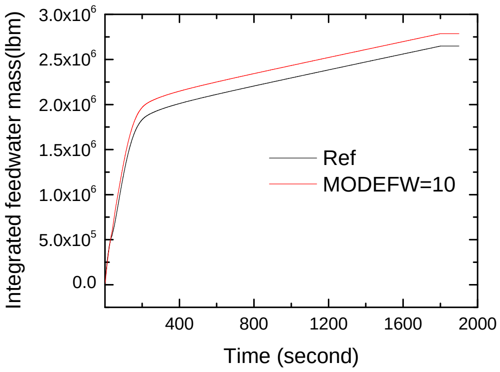

Fig. 2. Integrated Feedwater mass.

As the enthalpy of discharged steam of each case is almost the same, the containment peak pressure of MODEFW=10 case is higher than that of reference case. But there is still some margin to design pressure as shown in Fig. 3.

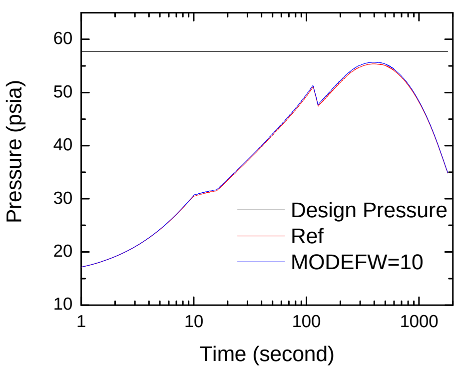

Fig. 3. Containment Peak Pressure Sensitivity to Feedwater Supply Mode

Containment peak pressure analysis results for various shutdown margin are shown in Fig. 4. Up to 1.9% of shutdown margin, containment peak pressure doesn't exceed the containment design pressure.

If un-isolated volume were reduced to 1055ft^3, then containment peak pressure would not exceed the design pressure even with shutdown margin of 1.8%. Containment peak pressure of this case is shown in Fig. 5.

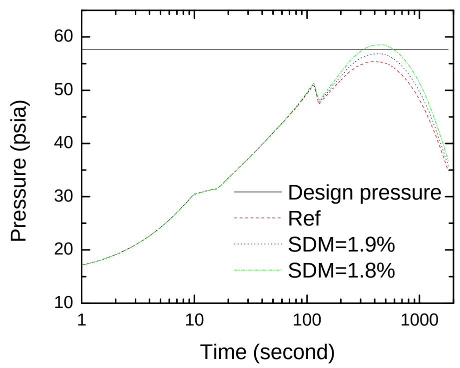

Fig. 4. Containment Peak Pressure Sensitivity to Shutdown Margin

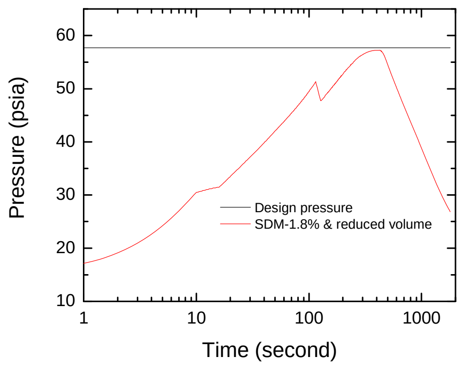

Fig. 5. Containment Peak Pressure of the Case with SDM of 1.8% & un-isolated volume of 1055ft^3

3. Conclusions

Even in case of FIVs could not do back-up protection action for the single failure of FCVs event, if main feedwater pumps stop within 60 seconds after safety injection signal triggered, then the containment peak pressure doesn't exceed the design limit under the condition of application of shutdown margin provided be nuclear design. But, to fully satisfy the safety criteria and have more containment pressure margin, the automation of FIVs is needed to give them a credit.

REFERENCES

[1] KORI Unit 1 FSAR, 15.4.2.1.1.
[2] LOFTRAN Code Description and User's Manual, WCAP-7878 Rev.6, February 2003.