Evaluation of the Containment Integrity Effect for the SIT Fluidic Device Design of SKN 3&4

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1. Introduction

Shin Kori Nuclear Power Plant Unit 3&4 (SKN 3&4) is the first plant that is designed based on the Advanced Pressurized water Reactor 1400 (APR 1400). A fluidic device (FD) is employed for the control of safety injection tank (SIT) flow during a large break loss of coolant accident in the SKN 3&4. It is installed in the safety injection tank and provides two stages of safety injection tank flow injection, initially high flow injection and then low flow injection after the reactor vessel downcomer annulus full. This allows a more effective use of safety injection tank water inventory during the accident and eventually will improve the LOCA thermal margin for the fuel performance. However, the fluidic device may have an adverse impact on the mass and energy (M/E) release during the accident. That is, the steam mass and energy release will be increased by a considerable amount because the safety injection tank low flow injection via fluidic device is not credited to condense the steam flows through intact cold loop. The increased mass and energy releases have an impact on the peak pressure and temperature (P/T) of the containment.

This effect of the fluidic device is analyzed to get a quantitative result of the mass and energy release and to show that the containment peak pressure and temperature are still satisfying the licensing criteria.

2. Analysis Method

2.1. Description of the Fluidic Device Feature

The FD in the SIT passively controls the SIT injection flow according to the SIT water level, a high FD flow for the SIT water level above the entrance of stand pipe and a low FD flow for the SIT level below the stand pipe entrance. When the SIT injection is initiated during the blowdown period, the fluidic device makes a high flow, which is almost the same as that of a conventional SIT without the fluidic device. Due to the sustained SIT injection, the SIT water level decreases below the entrance of the stand pipe during the reflood period and the SIT FD makes the low flow which is about 30% of the high flow.

However, since the FD low flow is not sufficient to condense all of the steam in the intact side RCS loop during an LBLOCA, the steam condensation is not credited at all. The loss of the steam condensation yields the increase of the mass and energy release in comparison with the case of conventional SIT injection. The condensation fraction of 42% is employed as the ratio of the condensed steam mass to the core generated steam mass during the conventional SIT injection [1].

2.2. Methodology and Assumptions

The mass and energy release analysis is performed in accordance with the stages of LOCA. The CEFLASH-4A code for the blowdown stage and the FLOOD3 code for the post-blowdown stage, are used for this analysis on workstation system. For the containment pressure and temperature analysis, the CONTEMPT-LT code [2] is used. These codes are for licensing analyses that have been approved by the US NRC and Korean Regulatory Authority for this application.

The analysis was performed on the cases such as, double ended equivalent discharge leg slot (DEDLS) break, double ended equivalent suction leg slot (DESLS) break. The hot leg break case is not affected by the FD, because the analysis of post-blowdown period is not required. Thus, this case was excluded from this analysis.

The option of SI pump flow, maximum or minimum, is considered for each case. All the initial conditions and the assumptions are given conservatively in the same directions as the licensing analysis of UCN 3&4 plant. The initial containment pressure is determined by a sensitivity study and assumed to be constant during the reflood and post-reflood stage. The major assumptions for the SIT FD used in this mass and energy release analysis are as follows:

(1) The high flow of SIT FD is assumed to be the same as that of conventional SIT which has no FD in it.

(2) The high flow via SIT FD is assumed to condense 42% of total steam flow in the reactor vessel annulus. The low flow via SIT FD is assumed not to condense the steam flow at all.

(3) Credit is not taken for the condensation of steam unless the reactor vessel downcomer annulus is full.

3. Analysis Result and Conclusion

The results show that the limiting case is the DEDLS with the maximum SI pump flow, which has the highest containment peak pressure.

Table 1 shows the integrated mass and energy release data at end of blowdown (EOB), end of reflood (EOR) and end of post-reflood (EOPR) and the containment peak pressure and temperature for the limiting case. The results of the case with FD are compared with those of corresponding cases without FD. In this result, no differences are shown in the integrated mass and energy releases at EOB between the cases with FD and without FD. This is for the reason that the SIT FD maintains the high flow until the EOB. The FD flow turn-down from the high flow to the low flow occurs after the EOB. Since the FD high flow is the same as that of conventional SIT, no differences are shown at EOB.

At the time of EOR and EOPR, the parameters of the case with FD are larger than those of the case without FD. This is due to the decrease of steam condensation by the SIT FD flow turn-down in the reflood period. This enables more steam mass and energy to be released through the break. That is worse result.

Evaluations are performed by calculating the design margin. The criteria of the construction permit (CP) for the plant requires the design margin should be larger than 10%. The result of this analysis with FD satisfies the criteria.Table 1. M/E Comparison for the Limiting Case

	DEDLS max.SI	
	with FD	without FD
M/E at EOB , lbm M Btu sec	691666 429.97 @ 20.21	691666 429.97 @ 20.21
M/E at EOR , lbm M Btu sec	129361 166.33 @ 190.21	108378 139.50 @ 215.5
M/E at EOPR, lbm M Btu sec	239212 299.06 @ 532.21	222368 277.54 @ 561.6
Peak Pressure, psia	68.7 @ 298 sec	65.4 @ 365 sec
Design Margin, %	11.1	18.3

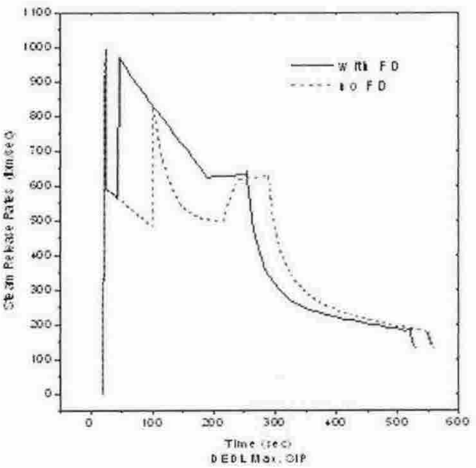

Figure 1. Mass Release Rate vs. Time

Figure 1 shows the behaviors of the mass release rate during the post-blowdown period. The figure shows that the steam flow in the RCS is condensed during the period between the reactor downcomer full and the FD flow turn-down time for the cases with FD and between the reactor downcomer full and the SIT empty for the case without FD. The steam condensation period of the case with FD is much shorter than that of the case without FD. This means that the case with FD makes more steam release than the case without FD. For the DEDLS case without FD, the mass release after SIT empty decreases very fast due to the small amount of the SI pump flow. The low pressure safety injection pump (LPSIP) is not employed in SKN 3&4. For the DEDLS case with FD, the mass release after SIT FD turn-down doesn't decrease so fast because the SI pump flow and the SIT FD low flow are enough to maintain the RV downcomer annulus level during the reflood period.

Figure 2 shows the behaviors of the containment pressure and temperature. The peak pressure occurs in the post-reflood period. The worse results, the higher peak pressure and temperature, are predicted for the case with FD. The difference between the case with and without FD is shown in Figure 10, which begins at the time of FD turn-down.

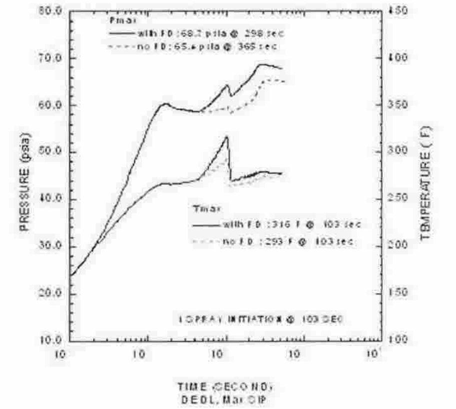

Figure 2. Containment P/T vs. Time

As a conclusion, the employment of the fluidic device has an adverse impact on the LOCA mass and energy release and the subsequent containment peak pressure and temperature. However, the evaluation of the results satisfies the acceptance criteria for SKN 3&4 plant.

REFERENCES

[1] CESSAR-FSAR, ABB-CE

[2] "CONTEMPT-LT/028-A, "A Computer Program for Predicting Containment Pressure-Temperature Response to a LOCA," INEL, March 1979.