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Analysis of LOCA M/E and Containment P/T using KIMERA Methodology for APR1400

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1. Introduction

The extended KIMERA methodology, KEPCO E&C improved mass and energy (M/E) release analysis methodology for APR1400 (Advanced Power Reactor 1400) [1] has been developed for the M/E analysis and applied to LOCA (loss of coolant accident) for the Shin Kori 3&4 Nuclear Power Plants (SKN 3&4). This new methodology, APR1400 KIMERA uses the best estimate code for system simulation and is modified from KIMERA [2, 3] to apply the special design features of APR1400, such as IRWST (in-containment refueling storage tank) and SIT (safety injection tank) with fluidic device (FD). The large break LOCA is selected in this paper since the special design features of APR1400 will impact significantly on the LOCA M/E release.

This paper compares the resultant containment pressure and temperature (P/T) of APR1400 KIMERA methodology and those of SKN 3&4 PSAR [4] during a large break LOCA. As in the KIMERA methodology for OPR1000 (Optimized Power Reactor 1000) [2, 3], APR1400 KIMERA showed lower peak P/T than the SKN 3&4 PSAR.

2. Model Modification

The IRWST modeled as TMDPVOL of RELAP5 should be connected to the containment pool during the transient. To model the IRWST, the connection information to the containment pool is added before and after long term (LT) cooling stage. And the model is optionally added with modification of the LT model.

The accumulator model is changed to conduct the SIT with fluidic device (FD-SIT) using the different forward and reverse loss coefficient depending on the water level. The high flow region uses the existing K-factor and the new K-factor is added for the low flow region.

The other design features of SKN 3&4 such as SIP (safety injection pump – high head) without low head safety injection and direct vessel injection (DVI) of SI nozzles at the higher location than the cold leg are also applied by input modeling.

3. Major Assumptions and Initial Conditions

Major assumptions and initial conditions for the M/E release analysis using the APR1400 KIMERA methodology are basically the same as those of KIMERA topical report [2]. And the initial conditions are the same as SKN 3&4 PSAR [4]. The major assumptions used in the LOCA M/E analysis are as follows:

- EOPR (end of post reflood) time: 2000 seconds
- Minimum containment back pressure conditions
- Loss of offsite power (LOOP)
- Maximum SI flow
- Maximum SIAS (safety injection actuation signal) set point with minimum delay
- No single failure for the M/E analysis
- One emergency diesel generator (EDG) failure for the containment P/T analysis

Conservative initial conditions for the M/E release analysis are assumed as Table 1. In addition, the minimum SIT inventory, the minimum initial pressure and the maximum temperature of SIT are assumed based on the sensitivity study.

Table 1 Conservative Combination of Initial Conditions

Parameters	Values	Remark
Core Power	4063 MWt (102% of 3983 MWt)	Max
PZR Pressure	2325 psia (16.03 MPa)	Max
Core Inlet Temperature	572 ^{o}F (573.15 K)	Max
PZR Water Level	60 % span	Max
RCS Flow Rate	95% of design flow	Min
SG Secondary Water Level	98.2% WR	Max

KIMERA uses RELAP5-ME computer code which is based on the RELAP5 and linked with CONTEMPT4. RELAP5-ME includes the long-term analysis model and the enhanced M/E release models such as break spillage model and multiplier on HTC and inter-phase area.

4. Analysis Results

Using the modified RELAP5-ME (version 2), the large break LOCA mass and energy release analysis for SKN 3&4 is performed and the resultant containment P/T are calculated. The containment peak pressure and temperature are compared with those of SKN 3&4 PSAR to verify the applicability of the KIMERA methodology to the APR1400 plant.

The CONTEMPT-LT/028 which is the typical computer code used for the licensing calculation of the SKN 3&4 is used to calculate the containment peak P/T.

The LOCA mass and energy release analysis is performed for the double ended RCP discharge leg (DEDL) break, the double ended RCP suction leg

(DESL) break and the double ended hot leg (DEHL) break at 102% power with maximum emergency core cooling system (ECCS) flow for the SKN 3&4.

4.1 Comparison with SKN 3&4 PSAR for DEDL LOCA

Figure 1 shows behavior of the containment P/T for DEDL LOCA by comparing with that of SKN 3&4 PSAR. The blowdown result using the KIMERA M/E data is much similar to PSAR as in the draft result [1]. However, for the post-blowdown period, the peak P/T are much lower than those of PSAR and predicted second peak similar to blowdown peak with plateau between 1000 and 1800 seconds. The second peak quite differs from the draft result [1] which has no distinct secondary peak. The containment sump temperature is much lower than that of PSAR. For the long term period, the P/T behavior showed lower than that of PSAR and the draft result.

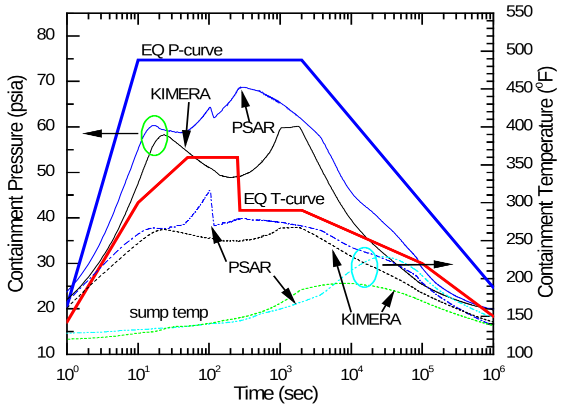

Figure 1 Comparison of P/T Behavior with SKN 3&4 PSAR (LOCA DEDL with maximum ECCS)

4.2 Results of M/E Release and Containment P/T

Figure 2 compares the integrated M/E release for DEDL, DESL and DEHL break with LOOP cases. As seen in the figure, the DEHL break has more initial M/E release than cold leg break cases whereas the much less M/E release after blowdown. The DESL break has more M/E release up to 1000 seconds than DECL break. After 1000 seconds, the DEDL break shows the most M/E release among three cases.

Figure 3 provides the comparison of the resultant containment P/T behaviors. The highest peak P/T occurred during the blowdown period of DEHL break. The DEDL and DESL break cases give a little bit higher the second peak P/T than the first peak. However, the DEHL break has no second peak. The second peak for the cold leg break cases is appeared due to the lower SI flow rate than OPR1000.

The highest peak pressure is 61.13 psia (421.5 kPa) for the DEHL break case with LOOP and the highest peak temperature is 273.4 °F (407.3 K). The transient behavior of the containment P/T seems to be appropriate and thus the extended KIMERA methodology can be applicable to the APR1400 design.

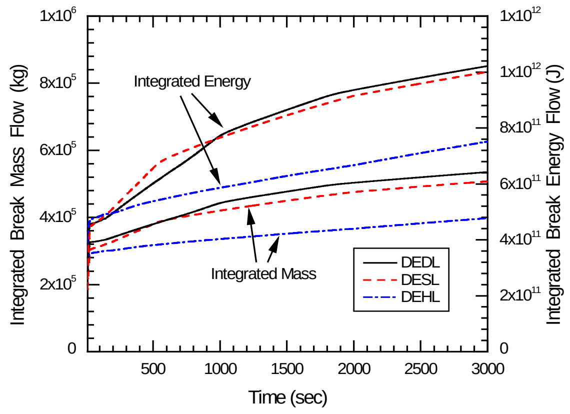

Figure 2 Comparison of Integrated M/E Release Depending on Break Location

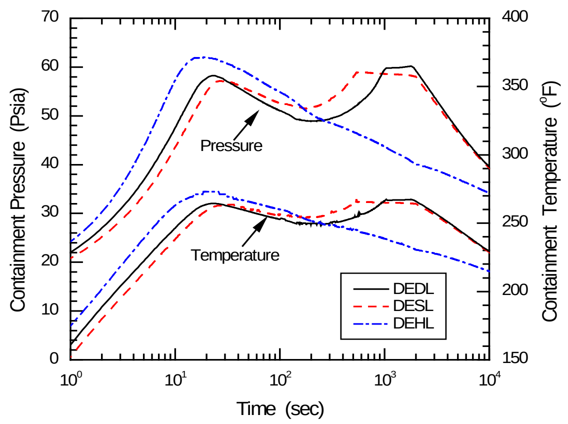

Figure 3 Comparison of Containment P/T Behavior Depending on Break Location

5. Conclusion

The containment P/T behavior during the large break LOCA blowdown period is similar to the result of SKN 3&4 PSAR. There is a second peak plateau for cold leg breaks whereas there is no second peak for the hot leg break. The peak P/T are much lower than those of SKN 3&4 PSAR. This margin can be used for the optimization of the containment design since the peak will be lower than that of the main steam line break.

In conclusion, the extended KIMERA, APR1400 KIMERA is applicable to the M/E release analysis for APR1400 plant design.

REFERENCES

[1] Cheol Woo Kim et. al., “Application of KIMERA Methodology to APR1400 M/E Analysis,” 2010 KNS Autumn Conference, October 2010.

[2] Topical Report, "KOPEC Improved Mass and Energy Release Analysis Methodology (KIMERA)," KOPEC/NED/TR/06-005, Rev.0, Dec. 2007.

[3] Cheol Woo Kim, et. al., “Improved M/E Release Analysis Methodology, KIMERA,” 25th KAIF/KNS Annual Conference, April 2010.

[4] Shin Kori Nuclear Units 3&4, PSAR, KEPCO.