Application of KIMERA Methodology to APR1400 M/E Analysis

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1. Introduction

KIMERA, KOPEC improved mass and energy (M/E) release analysis methodology has been developed and approved by Korea regulatory authority on December 10, 2007 for OPR1000 and 3 loop of Westinghouse type plant [1]. This is a new methodology of the M/E release analysis using the best estimate code for system simulation of design basis accidents for the containment design.

To apply the KIMERA methodology to the APR1400 plant, some modifications of the computer code are required to account the special design features of APR1400, such as IRWST and SIT with fluidic device.

The purpose of this study is to justify the applicability of KIMERA methodology to APR1400. The modified KIMERA methodology is applied to the Shin Kori Nuclear Units 3&4 (SKN 3&4) to calculate the mass and energy release for LBLOCA and MSLB. The results of the containment peak pressure and temperature (P/T) are compared with those of PSAR [2].

2. Model Modification

2.1 IRWST Model

The RWT modeled as TMDPVOL of RELAP5 should be connected to the containment pool during the transient. To model this situation 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.

3.2 FD-SIT Model

To model the SIT with fluidic device (FD-SIT), the accumulator model is changed 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.

3. Major Assumptions and Initial Conditions

Major assumptions and initial conditions for the M/E release analysis using the KIMERA methodology are the same as those of KIMERA TR [1] and SKN 3&4 PSAR [4]. Conservative initial conditions for the M/E release analysis are provided in Table 1. However, the nominal PZR pressure (2250 psia) and nominal core inlet temperature (555 ^{o}F) are used in this study.

The other design features of SKN 3&4 are also applied such as SIP (safety injection pump – high head) without low head safety injection, direct vessel injection (DVI) of SI nozzle higher than the cold leg.

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	563 ^{o}F (568.15 K)	Max
PZR Water Level	60 % span	Max
RCS Flow Rate	95% of design flow	Min
SG Secondary Water Level	95% NR (79% 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 mass and energy release analysis for the double ended break of RCP discharge leg for SKN 3&4 is performed and the peak containment pressure and temperature are calculated. The containment peak P/T are compared with those of SKN 3&4 PSAR to verify the applicability of the KIMERA methodology to the APR1400 plant.

Since the results of CONTEMPT4 and CONTEMPT/LT are much similar as described in KIMERA topical report [1], CONTEMPT4/MOD5 is used to calculate the containment peak pressure and temperature whereas CONTEMPT-LT/028 which is the typical code used for the licensing calculation was used in the SKN 3&4 PSAR.

4.1 LOCA Results

The LOCA mass and energy release analysis is performed for the double ended RCP discharge leg break LOCA at 102% power with maximum emergency core cooling system (ECCS) flow for SKN 3&4.

The SIT flow behavior is quite similar to the design condition as provided in Figure 1. The safety injection flow is divided into the high flow and low flow periods as expected. The results of the peak containment P/T for the DEDL (double ended discharge leg) LOCA are provided and compared with those of PSAR [2].

Figure 2 shows behavior of the containment pressure and temperature for LOCA. The blowdown result using the KIMERA M/E data is much similar to PSAR as in UCN 3&4 [3,4]. However, for the post-blowdown period, the pressure and temperature is much lower than those of PSAR and maintained a little higher than the KIMERA results of OPR1000 [3,4]. The higher M/E release during post-blowdown for PSAR provided higher sump temperature than KIMERA. For the long term period (about 4000 seconds later), much higher P/T behaviors are obtained in KIMERA methodology due to the IRWST which has higher enthalpy than the plant having RWT outside containment.

Figure 1 SIT Flow Rate

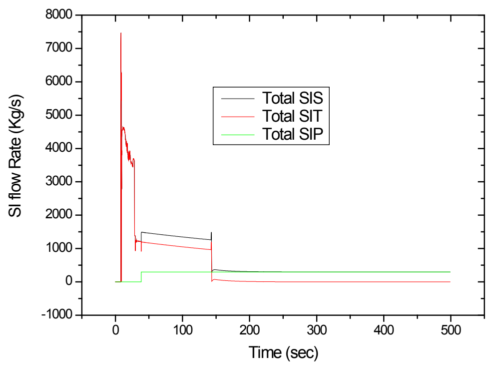
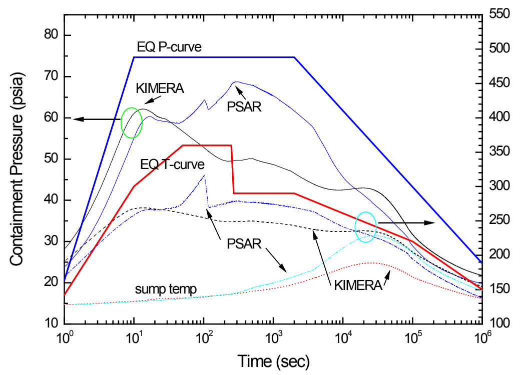


Figure 2 Containment Pressure and Temperature Behavior (LOCA DEDL with maximum ECCS)



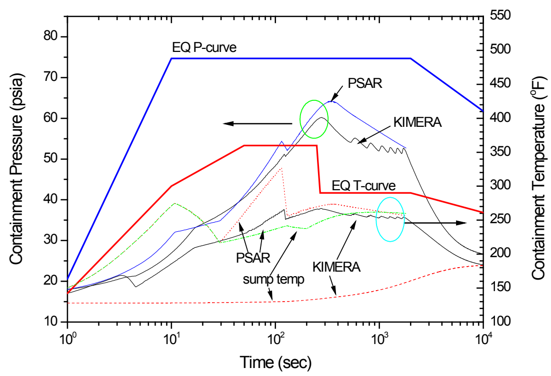
The peak P/T of KIMERA for DEDL LOCA is 62.14 psia and 269.13 ^{o}F, respectively. The peak values are obtained during the blowdown period. The transient behavior of the containment P/T seems to be appropriate and thus the modified KIMERA methodology can be used for the APR1400 design.

4.2 MSLB Results

The MSLB M/E analysis is performed for the double ended main steam line break at the steam nozzle of the steam generator (SG) at 102% power with a loss of containment cooling (LCC) for SKN 3&4.

The containment P/T results are compared with those of PSAR in Figure 3. As shown in this figure, the pressure behavior during blowdown is much similar to PSAR whereas the temperature is continuously increased before spray unlike PSAR. The peak pressure and temperature are quite lower than those of PSAR. The pressure oscillation occurs 500 seconds after break due to the empty of the affected SG. The sump temperature of the PSAR case is unrealistically higher than KIMERA since PSAR did not model IRWST for the containment P/T analysis.

Figure 3 Containment Pressure and Temperature Behavior (MSLB 102% LCC)



The peak P/T of MSLB is 60.18 psia and 267.13 ^{o}F, respectively. The peak pressure and temperature of LOCA are slightly higher than those of MSLB.

The transient behavior of the containment P/T for MSLB using the modified KIMERA methodology is also appropriate for the APR1400 design.

5. Conclusion

The containment pressure and temperature behavior during the LOCA blowdown period is similar to PSAR result of SKN 3&4. However, there is no distinct second peak and thus much lower peak containment pressure and temperature than those of SKN 3&4 during the post-blowdown period as in the UCN 3&4. This margin can be used for optimization of the containment design. The behavior of P/T for MSLB are much similar to those of OPR1000 predicting much lower peak P/T than those of PSAR. The sensitivity study for the LOCA and MSLB will be required to select the limiting cases.

In conclusion, the modified KIMERA for APR1400 is applicable to the mass and energy release analysis for the containment design for APR1400 plant design.

REFERENCES

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