Improved Methodology of LOCA M/E Release Analysis for OPR1000

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1. Introduction

A new LOCA mass and energy (M/E) release analysis methodology called KIMERA (KOPEC Improved Mass and Energy Release Analysis) has been developed [1]. This is a realistic evaluation methodology for the M/E release analysis for the containment design for large break LOCA (LBLOCA) and main steam line break (MSLB) accident. This is also applicable to the M/E release for the equipment environmental qualification (EEQ) on LOCA [2]. KIMERA as the M/E release analysis methodology has the same engine as the M/E methodology for EEQ [2] and several supplementary conservative models for the M/E release such as break spillage model and multiplier on heat transfer coefficient (HTC). The code calculation process in this methodology is performed interactively between the RELAP5K and CONTEMPT4 like KREM (KEPRI Realistic Evaluation Model) [3]. RELAP5K is based on RELAP5/MOD3.1/K and includes conservatism for the M/E release and long-term analysis model. The two codes, RELAP5K and CONTEMPT4/MOD5 are coupled and interactively calculate thermal hydraulic data and containment data, respectively.

This code system is able to calculate the various transient stages of a LOCA in a single calculation.

The sensitivity study on the LOCA M/E release was performed to account for the effect of each parameter on the containment condition using this advanced methodology. The results are compared with those of the Ulchin Nuclear Unit (UCN) 3&4 FSAR [4].

2. Analysis Method

KIMERA is used for LBLOCA M/E release for the UCN 3&4 plant. Major models and assumptions of the improved methodology for M/E release analysis are the same as those of Reference [2] and [4]. Detailed items are as follows:

- The long term cooling analysis is not performed because the purpose of the calculation is to investigate the containment peak pressure until the end-of-post-reflood (EOPR).
- The initial containment back pressure is calculated in CONTEMPT4 code and transferred to RELAP5K as a boundary condition, where as the back pressure is assumed to be constant in FSAR analysis.
- The initial conditions of the plant parameters are selected within the plant operating range.
- The first sensitivity study was performed on some initial condition parameters. The conservative parameter values were combined into an input and the second sensitivity study on the break location is performed using the combined input as in UCN 3&4 FSAR.
- The first sensitivity parameters : Core power, Decay heat, PZR pressure, Core inlet temperature, RCS flow, PZR level, SG level, Core physics parameters and SIT parameters.
- The second sensitivity parameters : Discharge leg break, Suction leg break, Hot leg break and maximum/minimum SI flow for each break case

3. Analysis Results

3.1 Sensitivity Study of Initial Condition Parameters

The results of the first sensitivity study show that the conservatisms of the initial conditions used in this analysis are in the same directions as those provided in UCN 3&4 FSAR such as 102% power, maximum pressurizer pressure, maximum core inlet temperature, minimum core flow and the high core decay heat. The effects of the core physics parameters are so small as to be negligible. The maximum SIT pressure and water temperature have conservative effect on the containment pressure and temperature, but it is not significant. The minimum SIT water inventory is conservative to the post-blowdown M/E release but it does not impact on the peak pressure. Table 1 presents the containment P/T results of those sensitivity cases.

The behaviors of the integrated break flows and containment P/T are very similar to each other in both the blowdown and post-blowdown stage. Since the containment pressure and temperature reach the peak values in a short time within the blowdown period unlike FSAR, the effects of parameters on the peak pressure are small. Thus, the containment P/T of those cases shows the similar behaviors and decreases continuously after the blowdown stage. The second peak is not distinct or has much lower value than the first one in those cases.

The peak P/T are quite lower than those in FSAR.

3.2 Sensitivity Study of Break Location and SI flow

The results of the second sensitivity study for the break location and SI flow are provided in Table 2. In all the cases, the containment pressure has reached the peak during the blowdown period and the safety injection pump starts after the end-of-blowdown. Though the maximum safety injection flow may have conservative effect on the containment P/T in the long-term basis, it does not affect on the peak pressure during the blowdown period.

The results of break location sensitivity show a remarkable difference in the limiting case with the FSAR results. The hot leg break case has the highest peak pressure and earliest peak time, which makes the limiting case, whereas the limiting case in FSAR was discharge leg break case. If the containment pressures of the cases reach the peak in a similar time, the determination of the limiting case is dependent on the high pressure and high enthalpy of the break flow. The resultant containment P/T responses of hot leg break case are provided in Figure 1 by comparing with the FSAR results.

Table 1 P/T Results of Initial Condition Sensitivity

Unit : Peak Pressure : psia @sec, Temp.: F @sec

Case 1 Power 102%	Case 2 Nominal	Case 3 Decay ANS 79	Case 4 PZR 2325	Case 5 T_in 572 F	Case 6 Flow 95%, T_in 564.5 F
53.65 @19.4	53.524 @19.0	53.519 @18.6	53.792 @18.8	**54.116** @18.4	53.82 @18.6
256 @19.4	256.39 @20.0	255.78 @18.6	256.235 @18.8	256.77 @18.4	257.02 @20.5
Case 7 L_pzr 60%	Case 8 L_SG 95%NR	Case 9 β neutron	Case 10 M Δ ρ min MTC	Case 11 a Dplr Δ ρ LN	Case 11 b Dplr Δ ρ MN
53.767 @19.4	53.582 @19.0	53.80 @19.0	53.584 @18.6	53.855 @18.6	53.67 @19.0
256.19 @19.4	256.53 @20.5	256.89 @20.0	256.42 @21.0	257.09 @20.5	256.03 @19.0
Case 12: max P, max T	Case 13: min P, min T	Case 14: Max Water	Case 15: Min Water		
53.874 @19.2	53.705 @18.8	53.588 @18.8	53.784 @19.0		
257.09 @20.5	256.08 @18.8	255.89 @18.8	256.22 @19.0		

Table 2 P/T Results Compared with UCN 3&4 FSAR

	DEDL max ECCS	DEDL min ECCS	DESL max ECCS	DESL min ECCS	DEHL max ECCS	DEHL min ECCS
UCN 3&4 FSAR						
Pressure, psig @sec	**50.7** @380	48.9 @670	45.1 @ 96	45.1 @ 96	44.4 @ 10.8	
Temp., F @sec	294 @380	293 @670	**299** @ 96	**299** @ 96	265 @ 10.8	
KIMERA						
Pressure, psig @sec	39.78 @19	39.78 @19	40.22 @24	40.22 @24	**42.64** @12.2	**42.64** @12.2
Temp., F @sec	257.38 @19	257.38 @19	258.09 @24	258.09 @24	**263.43** @11.4	**263.43** @11.4

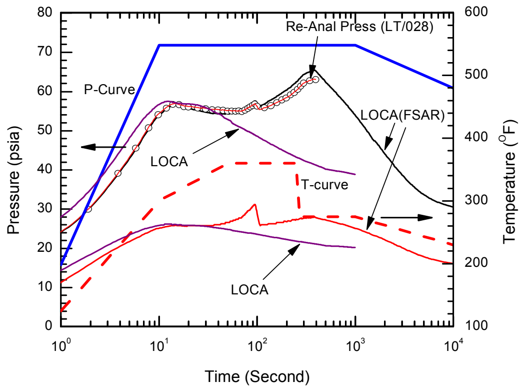

Figure1 Containment P/T Responses for LOCA

4. Conclusion

The results of the sensitivity study shows that the conservatism of the initial conditions used in this analysis are in the same directions as those provided in UCN 3&4 FSAR. However, the behavior of M/E release and resultant containment P/T responses during the post-blowdown period are much different from those of UCN 3&4 FSAR. The containment pressure for the post-blowdown period has no distinct second peak which is much lower than the first peak during blowdown. Unlike over-conservative and non-physical model of the post-blowdown period in FSAR, the improved methodology uses the realistic evaluation model. Therefore, this improved methodology provides a peak containment P/T during blowdown period.

The results of break location sensitivity study show that the limiting case is hot leg break case unlike discharge leg break case in FSAR. However, the value of peak P/T are quite lower than those in FSAR. This margin can be used for the optimization of the containment design.

In conclusion, the proposed improved methodology for M/E release analysis, KIMERA using the realistic evaluation code is applicable to the M/E release analysis for the containment design.

References

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