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Advanced Methodology for Containment M/E Release Analysis

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1. Introduction

Recently, a new mass and energy (M/E) release analysis methodology for the equipment environmental qualification (EEQ) on loss-of-coolant accident (LOCA) has been developed [1] and adopted on small break LOCA (SBLOCA) [2, 3]. This new M/E release analysis methodology for EEQ is extended to the M/E release analysis for the containment design for large break LOCA (LBLOCA) and main steam line break (MSLB) accident.

The advanced methodology of the M/E release analysis for the containment design includes the same engine as the M/E methodology for EEQ [1], however, conservative approaches for the M/E release such as break spillage model and multiplier on heat transfer coefficient (HTC) etc. are added. The computer code systems used in this methodology are RELAP5K/CONTEMPT4 (or RELAP5-ME) like KREM (KEPRI Realistic Evaluation Model) which couples RELAP5/MOD3.1/K and CONTEMPT4/MOD5. RELAP5K is based on RELAP5/MOD3.1/K and includes conservatisms for the M/E release and long-term analysis model.

The advanced methodology adopting the recent analysis technology is able to calculate the various transient stages of a LOCA in a single code system and also can calculate the M/E release analysis during the long term cooling period with the containment response.

This advanced methodology for the M/E release is developed based on the LOCA and applied to the MSLB. The results are compared with the Ulchin Nuclear Unit (UCN) 3&4 FSAR [4].

2. Advanced M/E Release Analysis Methodology

The major model and assumptions of the advanced methodology for M/E release analysis are as follows:

- Transient simulations are performed based on the realistic evaluation using RELAP5/MOD3.1/K linked with CONTEMPT4/MOD5.
- Conservative approach for the major thermal hydraulic model is performed using the multiplier on HTC, break flow and interfacial area for the enhanced M/E release.
- Break spillage models such as flashing at break and direct spillage on LBLOCA are developed for conservative M/E release.
- Long term analysis model is based on the simple boil-off assumption of injected liquid in the reactor vessel. This model was developed for M/E release for EEQ.
- The limiting break location for LOCA and the limiting break size and reactor power for MSLB are used.
- The operating conditions and parameters including containment parameters are assumed to provide the limiting results with respect to the containment peak pressure.

3. Comparison of the Results

The advanced methodology for M/E release analysis is applied for the UCN 3&4 for LBLOCA and MSLB. The major assumptions and initial conditions introduced in the UCN 3&4 FSAR analysis are used in this analysis.

3.1 Comparison of LOCA Results

Initial conditions and assumptions used in the LBLOCA M/E release analysis are the same as those provided in UCN 3&4 FSAR such as 102% power, maximum pressurizer pressure, maximum core inlet temperature, minimum core flow, maximum safety injection with a loss-of-offsite (LOOP) power and the containment input for minimum back pressure. As shown in Figure 1, the M/E release rates during post-blowdown period are nearly constant with respect to that for blowdown period. The resultant containment P/T responses are provided in Figure 2 by comparing with the FSAR results.

The results during LOCA blowdown period are similar to FSAR results, however, unlike FSAR, the containment pressure for the post-blowdown period has no distinct second peak, and the temperature responses are settled down after blowdown due to a smaller M/E release. Unlike over-conservative and non-physical model of the post-blowdown period in UCN 3&4 FSAR, the advanced methodology uses the realistic evaluation. Therefore, the advanced methodology provides a peak containment P/T during blowdown period. The peak pressure is 57.06 psia at 25 sec. (65.4 psia in FSAR and 63.0 psia in re-analysis at 385 sec.) and the peak temperature is 262.2 °F at 25 sec. (294.5 °F at 95 sec. in FSAR). The peak P/T are quite smaller than those in FSAR. This margin can be used for the optimization of the containment design.

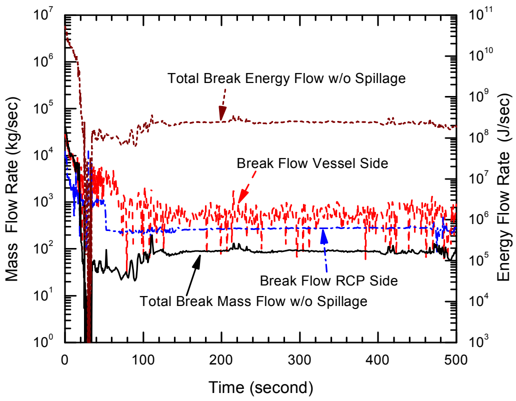

Figure 1 M/E Release Rate for LOCA

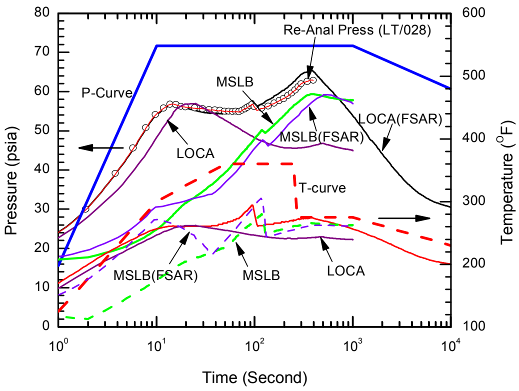

Figure 2 Containment P/T Responses for LOCA/MSLB

3.2 Comparison of MSLB Results

Various power level and break size spectrum analyses are performed for MSLB M/E release analysis. The major assumptions and initial conditions are the same as those of UCN 3&4 FSAR, such as maximum core inlet temperature and pressurizer pressure, maximum steam header and feedwater line volume, minimum steam line K-factor with a loss-of-containment cooling, etc. The initial steam generator (SG) pressure is assumed as 1180 psia whereas 1112 psia in FSAR. The 50% of core power with the medium size break (Cd=0.4) which is a little larger than the steam nozzle throat area is determined as the limiting condition. This break size is much smaller than that assumed in FSAR, but similar to the break size used in WH type plant which assume the throat area.

The M/E release rates for MSLB are provided in Figure 3 and the resultant containment P/T are provided in Figure 2. The M/E release rates are monotonically decreased and stabilized at about 400 seconds. As shown in Figure 2, the pressure behavior is very similar to that of the FSAR whereas the temperature behavior is different from the FSAR. The peak pressure is 59.5 psia at 375 sec. (vs. 59.3 psia at 504 sec. in FSAR) and the peak temperature is 280.1 °F at 117 sec. (vs. 309.3 °F at 112 sec. in FSAR). The peak pressure is nearly the same as that of FSAR and is higher than the peak pressure of LOCA whereas the peak temperature is smaller than the peak of FSAR and LOCA.

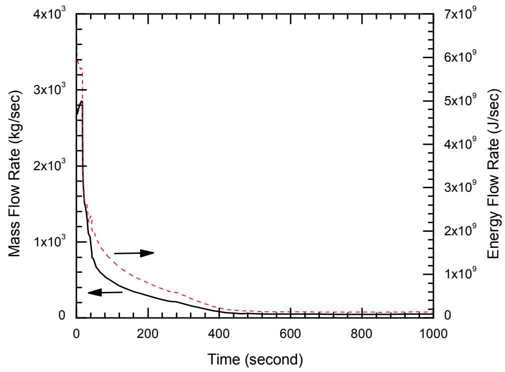

Figure 3 Containment M/E Release Rate for MSLB

4. Conclusion

The advanced M/E release analysis methodology for LOCA for UCN 3&4 provided much different M/E release results and resultant containment P/T responses during post-blowdown period. The results during LOCA blowdown period are similar to FSAR results, however, unlike FSAR, the containment pressure for the post-blowdown period has no distinct second peak which is much lower than the first peak during blowdown.

The results for the MSLB are very similar to those of FSAR. The resultant containment peak pressure is nearly the same as the peak pressure of FSAR. However, the smaller break size (Cd=0.4) provided higher containment peak pressure than the full break area selected in FSAR. In addition, MSLB is predicted to be more limiting than LOCA for the peak containment pressure.

In conclusion, the proposed advanced methodology for M/E release analysis using the realistic evaluation code can be used for the M/E release analysis for the containment design.

References

[1] C. W. Kim et al., "Development of LOCA M/E Release Analysis Methodology for Equipment Qualification," 2004 Autumn Conference, KNS.

[2] H. R. Choi at al., "Mass and Energy Release Analysis on Small Break LOCA for Environmental Equipment Qualification of Kori NPP Unit 1," 2003 Autumn Conference, KNS.

[3] C. W. Kim et al., "SBLOCA Mass and Energy Release Analysis for EEQ of Kori 2," 2005 Spring Conference, KNS.

[4] Ulchin Nuclear Units 3&4, FSAR, KEPCO.