SBLOCA Mass and Energy Release Analysis for UCN 3&4

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1. Introduction

The current small break loss of coolant accident (SBLOCA) mass and energy (M/E) release analysis methodology for the pressurized water reactor (PWR) was developed based on the evaluation method of the emergency core cooling system[1]. The method is somewhat deterministic and includes conservative modeling assumptions. KOPEC has developed a new M&E release calculation methodology, KIMERA[2] including SB-LOCA methodology to model the containment response more realistically.

This paper demonstrates a new methodology for SBLOCA M/E release analysis and provides the results for Ulchin nuclear power plant units 3 and 4 (UCN 3&4). Also, the results are compared with UCN 3&4 FSAR[1].

The more realistic M/E release data are generated for the containment design and environmental qualification of equipment.

2. Analysis Methodology

2.1 Analysis Tools

The new methodology of M/E release analysis has been developed as a unified computer code system, KIMERA [2] which couples RELAP5/MOD3.1/K and CONTEM-PT4/MOD5, with addition of the conservative model for enhanced M/E release and the long-term model. This new code system predicts the thermal hydraulic behavior more realistically by processing the M/E release data and the containment back pressure simultaneously. In addition, the separate and simplified boil-off model is applied for the long-term thermal hydraulic behavior.

2.2 Analysis Model

UCN 3&4 are 1000 MWe 2-loop plants with the safety injection system which consists of the 4 safety injection tanks (SITs), 2 high-pressure safety injection (HPSI) and 2 low-pressure safety injection (LPSI) pumps. During the long-term recirculation after safety injection phase, the LPSI pumps inject the coolant from the containment sump to the cold leg. Fig. 1 shows the RELAP5/MOD3 nodal scheme for the primary and secondary systems for UCN 3&4.

3. Analysis Results

3.1 Initial Conditions and Major Assumptions

Sensitivity studies for the main parameters of M/E release have been accomplished for UCN 3&4[2]. The major assumptions and initial conditions for the conservative M/E release are such as 102% core power, no U-tube plugging and selecting the conservative value of operating parameters.

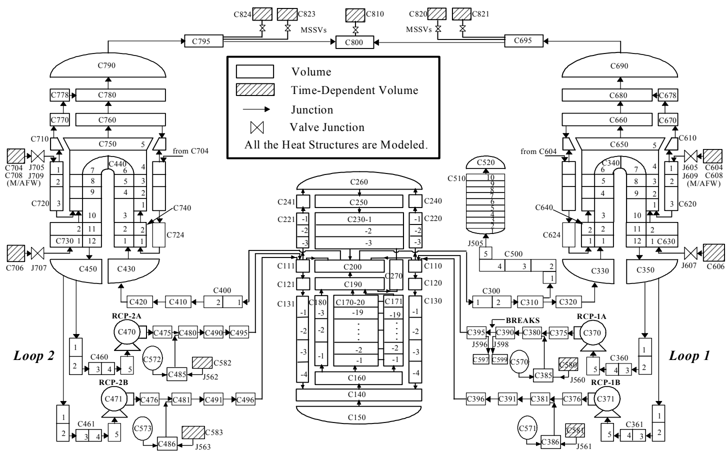

Fig.1. RELAP5 Model of UCN 3&4 for SBLOCA M/E Analysis

The plant initial conditions and assumptions used in the SBLOCA M/E release analysis are provided in Table 1 [1]. To increase M/E release, CONTEMPT4 input has been adjusted for the minimum containment back pressure.

Table 1. Plant Initial Conditions and Assumptions

Plant Parameters	Operating Range	Analysis Value
Thermal Power (MWt)	2815	2815 * 1.02 = 2871.3
Pressurizer Press (psia)	2130~2325	2325.0
Pressurizer Level (%)	21.9~60	60
RCS Loop Flow (%)	95~116	95
RCS Inlet Temp (°F)	550~572	572
SG Press (psia)	-	1088
SG Level (%)	35~98.2	98
Containment free vol. (ft^3)	-	2.877 x 10^6(min)
Containment press (psia)	-	14.53
Containment Temp (°F)	-	50

3.2 M/E Release Result

SBLOCA M/E analysis for UCN 3&4 is performed for various break sizes and locations. Comparison of mass release rates for 6 inch break with different location (CLB, cold leg; SLB, suction leg; HLB, hot leg) is depicted in Fig. 2. In hot leg break, M/E release rate is lower than others due to density difference by boiling. Table 2 shows the event sequence for 6 inch cold leg (pump discharge) break. Reactor is tripped at 21.04 seconds on low PZR pressure signal.

Table 2. Event Sequence for 6 Inch Cold Leg Break

Time(sec)	Event Sequence
0.0	Event initiation
19.89	Reactor trip & SI setpoint (Lo PZR Pr)
21.04	Reactor trip (Lo PZR Pr), turbine trip and loss of offsite power
26.04	Main feedwater isolation
51.3	Start of safety injection
158.0	Reverse heat transfer from SG secondary side
342.0	Start of SIT injection
426.0	End of SIT injection
900.0	End of post-core recovery (EOPR)
920.0	Switch of SI water source (RWST → Sump)
1800.	ADV open by operator

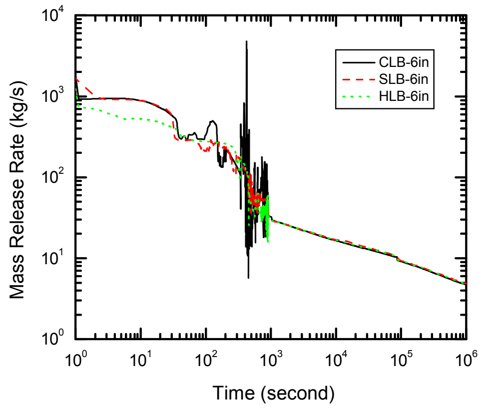

Fig. 2. Comparison of Break Mass Release Rate for 6 inch Breaks

The mass and energy release rates depending on the break size for cold leg break are illustrated in Figs. 3 and 4, respectively. In the early period, M/E release rates decrease as the break sizes are decreasing. In long-term cooling period after EOPR (about 1000 sec), M/E release rate are similar for all cases which are calculated by using the new methodology. However, M/E release of UCN 3&4 FSAR (0.5 ft^2 (= 9.5 inch) cold leg break) are much higher than new ones after EOPR in Figs. 3 and 4.

This shows that the current M/E release analysis methodology is too conservative, and new methodology gives reasonable and somewhat conservative results.

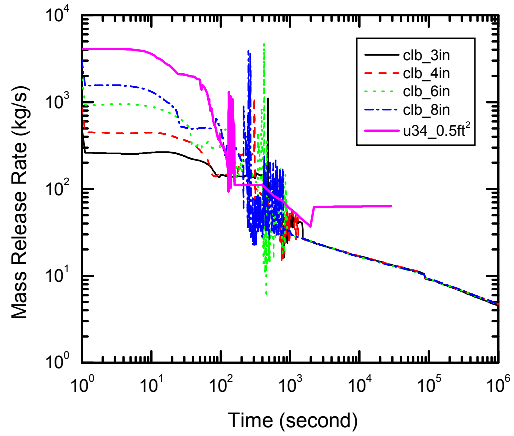

Fig. 3. Comparison of Break Mass Release Rate

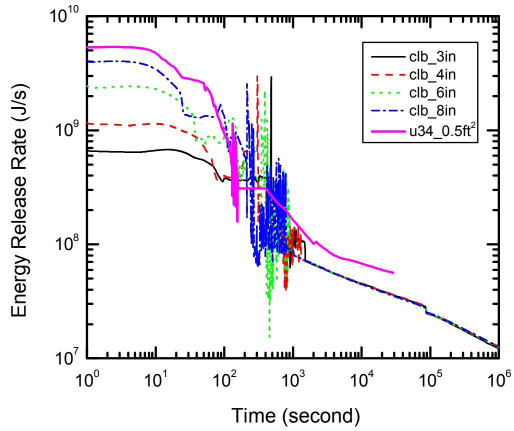

Fig. 4. Comparison of Energy Release Rate

4. Conclusion

Using the newly developed methodology, KIMERA, SBLOCA M/E release analysis is performed for UCN 3&4. The M/E release rate at the early stage provides different trends depending on the break size. However, the difference decreases at the late stage.

In long-term cooling stage, the calculated M/E release rate is less than the previous results in FSAR. The reduced M/E could contribute to the design optimization of containment and environmental qualification of equipment.

References

[1] UCN 3&4 FSAR, KEPCO
[2] Topical Report, "KOPEC Improved Mass and Energy Release Analysis Methodology," KOPEC/NED/TR, Dec 2007.