Database Generation of Severe Accident Responses for KSNP Medium LOCAs using MAAP4

Dong Ha Kim,[a] Young Choi,[a] Soo Yong Park,[a] Kwang Il Ahn,[b]
a Thermal Hydraulic & Safety Research Division. KAERI, dhkim8@kaeri.re.kr
b Integrated Safety Assessment Division, KAERI

1. Introduction

The Level 2 PSA that was previously performed for the Korean Standard Power Plants (KSNPs) took into account just the necessary sequences for the assessment of containment integrity and source term analysis. From the viewpoint of severe accident management (SAM), however, more sequences that may lead to severe core damage need to be analyzed and arranged systematically. The main purpose of this paper is to give a database of various severe accident responses obtained from the MAAP4 code for the KSNP medium LOCA whose break sizes are in between 0.2 and 0.02 ft^2.

2. Base Cases Analyses

The Level 1 accident sequence analysis for the medium LOCA shows that the representative 6 sequences out of 20 plant damage state event tree end points takes about 99.8% of the medium LOCA frequency [1]. Table 1 summarizes the initial and boundary conditions of each medium LOCA sequence with the corresponding frequency. For example, the sequence S03 whose frequency is 2.022E-07/ry allows high-pressure safety injection until refueling water storage tank depletes and then recirculation mode is available only for 2 hours due to boron precipitation in the core. The containment spray is available throughout the accident.

Table 1 Initial/Boundary Conditions of Medium LOCAs

Seq.	Freq. (fraction)	Safety sys. injection		Safety sys. recirculation		Containment Spray	
		HPI	LPI	short	long	inj	recir
S02	1.786E-07 (28.15%)	O	-	O (HP)	O (HP)	O	X
S03	2.022E-07 (31.87%)	O	-	O (HP)	X	O	O
S05	6.391E-08 (10.07%)	O	-	O (LP)	X	O	O
S08	6.195E-08 (9.8%)	O	-	X	X	O	X
S09	1.212E-07 (19.10%)	X	O	O (LP)	X	O	O
S19	4.842E-09 (0.76%)	X	X	X	X	X	X

MAAP4 calculations were performed for the above-mentioned sequences. Table 2 summarizes the brief behavior of safety systems and major events for the base input cases. The MAAP4 analysis showed that except for the sequence S02 where high-pressure safety injection and recirculation operation are available, the RPV fails in the rest sequences. While the RPV ex-vessel cooling was not considered for the base runs, its effect is discussed in Chapter 3.

Table 2 Comparison of Major Events in Base cases (hr)

Seq.	LPI Off	HPI off	Spray On	RPV Failure	Containment failure
S02	6.4	NA[1]	NA[3]	No failure	69.6
S03	6.4	8.4	9.0	14.4	No failure
S05	8.4	6.4	8.5	14.2	No failure
S08	6.4	6.4	NA[3]	12.6	71.0
S09	4.7	NA[2]	0.3	10.6	No failure
S19	NA[2]	NA[2]	NA[2]	5.8	No failure

NA[1]: always available; NA[2]: initially dead;
NA[3]: RWST empty on demand

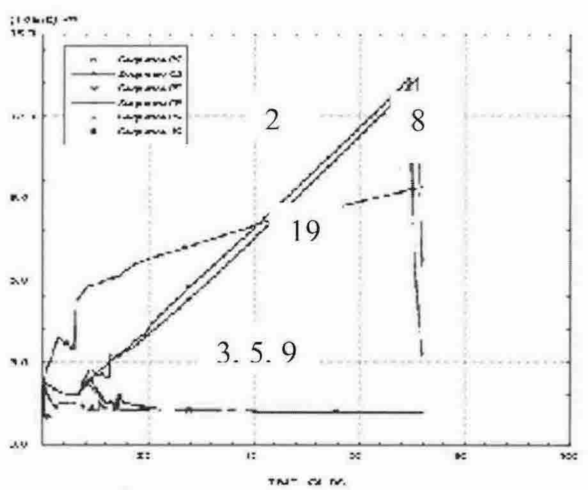

Figure 1 Containment pressure for medium LOCAs

The containment pressure behavior with time is shown in Figure 1. When the containment sprays works all the time, as shown just in cases of S03, S05, and S09, the containment integrity maintains. However, when the long-term spray fails in cases of S02 and S08, containment fails. Though S19 has the most severe initial conditions (no water supply into the core due to safety system failure), containment remains intact because of insufficient steaming source in the containment.

3. Sensitivity Analyses

Though some sensitivity runs were done in the PSA study, they do not show the effect of safety parameters on accident progression systematically. From the viewpoint of accident management, this information can be useful to anticipate how the accident goes in the end. Table 3 shows the parameters for the base case and the sensitivity runs for medium LOCA sequences.

Table 3 Sensitivity Parameters for Medium LOCAs

Parameters	Base case	Sensitivity case
Break size	0.2 ft2	0.1, 0.08, 0.06, 0.05, 0.03
Break location	Cold leg	Hot leg, Intermediate leg
Charging pump flow rate	0 gpm	88 132
No of safety injection lines	1	2
No of containment spray lines	1	2
Recirculation operation time	2 hrs	3 hrs
No of safety injection tanks	4	2 3
RPV ex-vessel cooling	Off	On

3.1 Effect of Break Size

As the medium LOCA is defined for the break sizes of 0.2 to 0.02 ft^2, sensitivity runs were done for various break sizes. The important timings like core uncovery, vessel and containment failure vary in the range of maximum 9 hours for vessel failure and 7 hours for containment failure. This variation was closely related with the containment spray initiation time (that is connected to the safety injection period) and the safety injection tank injection time.

3.2 Effect of Break Location

Hot leg break accelerates the accident progression than in cold leg or intermediate leg break generally. The RPV failure occurs earlier in the range from 2 hours to 7 hours. For the cases of S03, S05, and S08, when the safety injection is allowed, about 7 hours difference is estimated. When the accident goes faster without high-pressure safety injection like in S09 and S19, about 2 to 3 hours difference was estimated.

3.3 Effect of Charging Pump Flow Rate

The effect of charging pump flow is mainly shown in S08 and S19, when core injection flow is limited. When the charging pump flows of 88 and 132 gpm are considered, the RPV failure time in S08 is delayed about 10 to 13 hours. When there is no safety action, its effect seems significant. That is, when 88 gpm is injected for S19, containment is expected to fail (in the base case, it was intact) due to over-pressurization from steaming from the core.

3.4 Effect of RPV ex-vessel Cooling Option

If the RPV ex-vessel cooling option is adopted in MAAP4, the RPV failure does not occur when the RPV is submerged in the reactor cavity due to heat loss to the coolant through the nucleate boiling process. For the KSNP whose safety systems work from RWST, reactor cavity is filled with water and the RPV is submerged naturally. Therefore, for the sequences of S03, S05, S08, and S09, which allow safety injection from RWST, the RPV remains intact. In S19, RPV fails even with this option as the water level in the cavity is not high enough to touch the RPV.

3.5 Effect of Other Factors

The other factors like number of safety injection lines, containment spray lines, recirculation operation period, or no of safety injection tanks are found not to affect much on the accident progression.

3. Conclusion

Both the base case and sensitivity runs have been performed to generate the severe accident progression data for the KSNP medium LOCAs using MAAP4. The impacts of the break sizes, locations, and charging pumps flow on the accident progression have been assessed to be important in the present analysis. Deeper studies for the effect of the RPV ex-vessel cooling model embedded in MAAP4 on the RPV integrity, however, are needed to get more reasonable insights into the severe accident consequences. All these results are being collected as database sets of a severe accident database for the KSNP medium LOCAs, which will be systematically managed with a severe accident database system [2].

REFERENCES

[1] Ulchin Units 3&4 Final Probabilistic safety Assessment Report, Korea Electric Power Corporation, 1998.3

[2] Kwang-Il Ahn and Dong Ha Kim, "Implementation of Database Management System for the Comprehensive Use of Severe Accident Risk Information," Progress in Nuclear Energy (to be published in 2004).