Transactions of the Korean Nuclear Society Spring Meeting
Taebaek, Korea, May 26-27, 2011

Comparison of Severe Accident Scenarios for an Advanced PWR using MELCOR Codes

Tae-Woon Kim*, Jin-Ho Song, Sung-Won Cho
Korea Atomic Energy Research Institute,1045 Daedeokdaero, Yusong,, Daejeon 305-353
** Corresponding Author: twkim2@kaeri.re.kr*

1. INTRODUCTION

The research and development for identify the bottom head failure mechanisms is one of the long term issues for the establishment of severe accident management strategies for light water reactors after TMI 2 accident. The LBLOCA, SBLOCA, and SBO scenarios for an advanced power reactor developed is analyzed in order to obtain an overall insight into a severe accident progression from an initiating event to the reactor vessel failure in detail by using the MELCOR Versions 1.8.5 and 1.8.6 computer codes.

2. NODALIZATION BY MELCOR CODE

A large LBLOCA scenario as an example for the advanced power reactors developed Korea is analyzed with MELCOR code to understand the bottom head failure phenomena, to get the idea for designing severe accident mitigation hardware such as cavity flooding or ex-vessel core catcher, and finally to establish the severe accident management strategy. In this analysis MELCOR versions 1.8.5 and 1.8.6 is used. The nodalization model (control volumes) of the reactor coolant system of APR-1400 for the MELCOR code is modeled as of Figure 1.
The active fuel is modeled as to have 5 radial rings and 10 axial nodes (50 cells). The lower head is modeled as to have 5 radial rings and 5 axial nodes (25 cells). If the active core is melt and dropped to lower head, the corium is dispersed at the lowest axial cells. If some cell is heated to a certain temperature, the equivalent cell of bottom head is molten and the corium is dropped to cavity bottom. The lower head is modeled as cylinder in MELCOR 1.8.5 and hemisphere in MELCOR 1.8.6. The modeling of the oxidic and metallic molten pools in the upper core and lower plenum is incorporated in MELCOR 1.8.6. The MELCOR 1.8.5 has only particle debris modeling.

Notations of Control Volumes of Containment and Reactor Cavity ;
CV001 : Reactor Cavity (Rx Cavity + ICI Chase)
CV002 : Corium Chamber Room (Corium Chamber Room + Cavity Access Area)
CV003 : Reactor Vessel Annulus
CV011 : HVT (Hold-up Volume Tank)
CV012 : IRWST (In-containment Refueling Storage Tank)

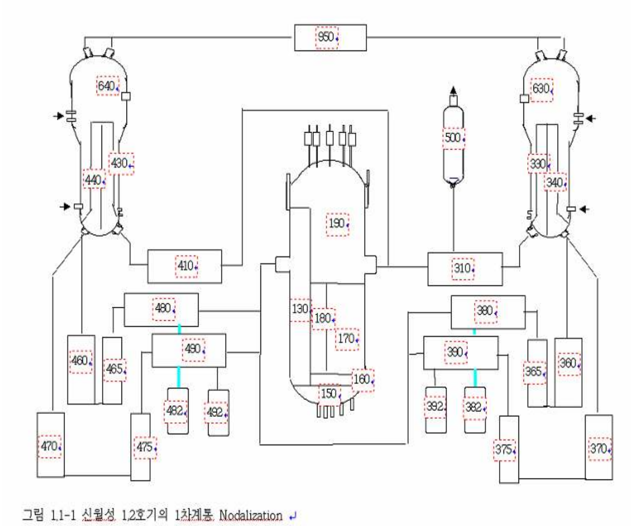

Figure 1. MELCOR Nodalization for Reactor Coolant System of Advanced Power Reactor

Initial Core Masses are as follows.
UO2 MASS = 117,800 Kg
ZIRCALOY MASS = 28,375 Kg
STEEL MASS = 34,276 Kg
INCONEL MASS = 156.8 Kg
CONTROL POISON MASS = 1,287 Kg
Total initial core mass = 182,700 Kg

3. ANALYSIS OF A LBLOCA SCENARIO

A double ended break, the size of which is 0.5 ft2 (0.0465 m2), is occurred at time 0 second at a cold leg which is connected to the pressurizer. Table 1 shows the chronology of this event analyzed by MELCOR code.
If LOCA occurrs the reactor and turbine trip by the high containment pressure signal. The decay heat is assumed to be generated according to the ANS 79 curve. The main feed water and auxiliary feedwater is assumed to be tripped. The safety injection system is assumed to be not working. It is assumed that the four safety injection tanks are only working to make up the inventory of reactor coolant system which is lost by the break.

Table 1. Chronology of Event (0.5 ft2 LOCA)

Time (sec)	Event Description
0.0	LOCA occurs
7.25	STOP TO SUPPLY MFW
7.75	REACTOR TRIP
30.4	RCP Trip
176.8	START CORE UNCOVERED
177.1	START TO INJECTION SIT-392
987.2	SIT-392 : INVENTORY EXHAUSTED
2,848	CORE SUPPORT PLATE HAS FAILED IN CELL 113
3,066	START TO MELT FUEL
3,499	UO2 RELOCATED TO LOWER HEAD
7,830	START OF DEBRIS QUENCH IN RADIAL RING 1
8,156 - 8,568	LOWER HEAD PENETRATION FAILURE IN RADIAL RING 2, 3, 1, 4, RESPECTIVELY.
8,156	BEGINNING OF DEBRIS EJECTION TO CAVITY
8,218 8,433	START OF DEBRIS QUENCH IN RADIAL RING 3, & 4
9,600 – 10,740	END OF DEBRIS QUENCH IN RADIAL RING 1 to 5

As time goes on, the pressure and the water level of RCS are continuously decreasing. At 177 seconds into the transient the water level decreased to top of active fuel. At this time the water of SIT starts to enter into the RCS. But the water inventory of SIT is exhausted at 798 seconds. At about 2,000 second into the transient, the fuel temperature starts to increase due to the decreased water level. The core support plate starts to melt at 2,848 seconds. At 3,066 seconds the fuel starts to melt due to the uncovery of the core fuels. At this time about 598 kg of ZrO2 and about 174 kg of steel oxide are generated by the metal-water reaction. About 400 kg of hydrogen gas is also produced by the metal-water reaction. At 3,499 seconds the melted fuel and structural materials (corium) start to be relocated from the active core volume (axial nodes 6 to 15) to the lower plenum volume (axial nodes 1 to 5).

From 8,156 seconds the lower head ICI (In-Core Instrumentation) tube penetrations start to melt and the corium dropped to the floor of cavity. When the lower head penetration occurs, the initial diameter of the hole is assumed as 0.1524 meter. That is the size of the ICI cable penetration. When the temperature of penetration reaches 1275K, the penetration is assumed to be failed. It is shown in Figure 2 that the penetration tubes in radial rings 1 to 4 fails at around 8,000 seconds, but the penetration tubes radial ring 5 fails about 13,000 seconds. From about 8,000 to about 15,000 seconds into the transients, you can see the multiple pours of corium release to the reactor cavity. This is because the failure times of ICI tube penetraitions are different among the 5 radial rings of bottom head of the reactor.

Figure 3 shows the core materials ejection times for SBO, SBLOCA, and LBLOCA scenarios calculated with MELCOR version 1.8.5. Figure 4 shows the comparison result of core materials ejection times for SBO scenario between MELCOR version 1.8.5 and version 1.8.6.

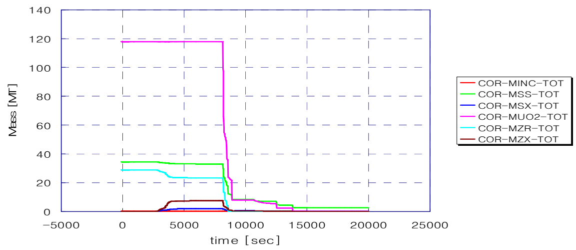

Figure 2. Total Mass of Core Materials melted and ejected to cavity in LBLOCA with MELCOR Version 1.8.5

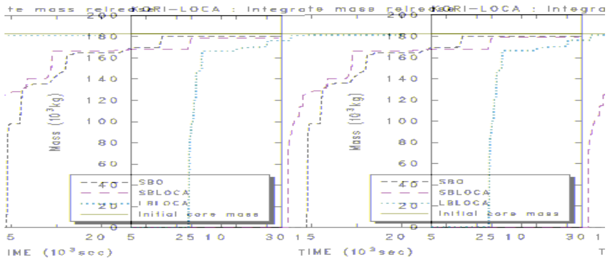

Figure 3. Core Materials Ejection Times for SBO, SBLOCA, and LBLOCA with MELCOR Version 1.8.5

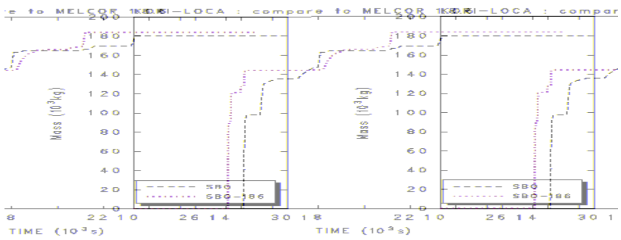

Figure 4. Comparison of Core Materials Ejection Times for SBO between MELCOR Version 1.8.5 and Version 1.8.6

4. CONCLUSIONS

The present results (the amount of molten corium) would be used as input for the establishment of severe accident management strategies or for the design of core catcher of advanced power reactor. The MELCOR results showed that the lower head instrumentation tube penetration model and internal structure in the advanced reactor had influence on the amount of corium ejected and the timing of reactor vessel failure. There is only time difference between MELCOR 1.8.5 and 1.8.6 comparison simulations. They give similar results in the lower head penetration failure shapes.

REFERENCES

[1] "MELCOR Computer Code Manuals," Ver. 1.8.5. Rev.2 [2000] & Ver. 1.8.6. Rev.3 [2005], NUREG/CR-6119, SAND2005-5713, Sandia National Laboratories