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A Best-Estimate Base Calculation of a LBLOCA in a ZION NPP

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1. Introduction

The objectives of the BEMUSE programme are to evaluate the practicability, quality and reliability of best-estimate methods including uncertainty evaluations in applications relevant to nuclear reactor safety and to promote and facilitate in their use by the regulator bodies and the industry. This programme is mainly divided into two steps: one step (phase 1~3) is the uncertainty evaluation of the LOFT L2-5 test and the other step (phase 4~6) is sensitivity studies and an uncertainty evaluation for the NPP-LBLOCA (nuclear power plant-large break loss of coolant accident)[1]. While, the Zion RELAP5 input deck has been built by modifying a general input deck for a PWR for simulating a SBLOCA received from NRC in order to run the BEMUSE phase 4 exercise[2]. This paper dealt with the base calculation of a LBLOCA in a Zion NPP during the activities of phase 4. Also, to establish the multi-dimensional phenomena in the reactor vessel, we have developed the MARS input deck by using the MULTID component instead of the 1D RELAP5 input deck.

2. Methods and Results

2.1. MARS modeling for ZION NPP

Figure 1 shows the MARS nodalization diagram of a Zion NPP where the reactor vessel is modeled by using the MULTID component for the analysis of a LBLOCA.

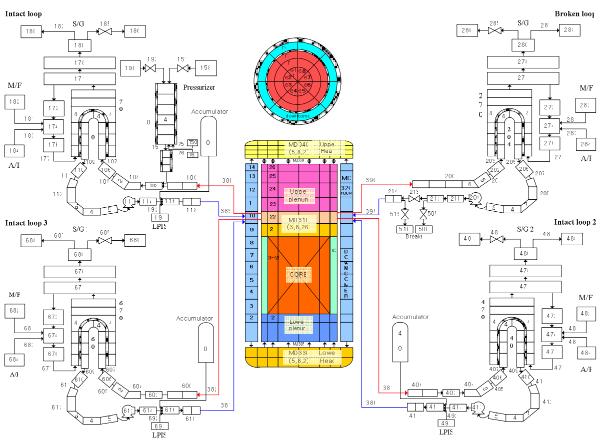

Figure 1. MARS Nodalization for ZION NPP.

Table 1 shows the comparison of the number for the total volume, the number for the total junction, the mass for the total system and the volume for the total system. When the MULTID model is compared to the 1D model, the MULTID model is 4 times that of the number for the volume, 9 times that of the number for the junction and 7 times that of the number for the heat structure greater than those of the 1D model. There are few differences in the system mass and volume but these are negligible.

The eight azimuthal sectors correspond to the four nozzles connecting the loop and the vessel. Sector 1 corresponds to the intact loop1 hot leg, sector 2 to the intact loop1 cold leg, sector 3 to the intact loop3 cold leg, sector 4 to the intact loop3 hot leg, sector 5 to the intact loop2 hot leg, sector 6 to the intact loop2 cold leg, sector 7 to the broken loop cold leg and sector 8 to the broken loop hot leg.

Table 1. Geometries both of 1D and Multi-D model.

	Volume	Junction	Heat structure	Total mass	Total volume
Unit	No.	No.	No.	kg	m^3
1D	252	257	216	488190	1134.4
3D	1116	2432	1621	488948	1135.4
3D/1D	4.4	9.5	7.5	1.0015	1.0008

One outer radial ring represents the downcomer and other the three inner radial rings correspond to the peripheral zone, average zone, hot zone, hot fuel assembly, hot rod and bypass regions of the core. The axial nodalization of each component was based on the one-dimensional model, resulting in 2 levels in the lower head, 2 in the lower plenum, 18 levels in the core, 6 levels in the upper plenum and 4 levels in the upper head regions. The core fuel rods were modeled with 48 heat structures for an assembly located in a given ring and sector. The hot rod was simulated in the inner ring and sector1 of the intact loop1 hot leg side. The multiple junctions were used to connect the multi-dimensional components.

2.2. Results

To obtain the initial condition for a 1D operating condition, the steady-state calculation was performed for 400 seconds in order to simulate a Zion NPP-LBLOCA. The results of the MULTID case were well matched when compared to those of the 1D model.

A postulated LBLOCA is initiated by opening break valves, 505 and 515, on the cold-leg and isolating the flow path between volumes 212 and 214. This simulation has been performed until 1000 seconds while the CPU time was for 13 hours 26 minutes 44 second under the condition of the safety injection water being injected through the three low pressure injection nozzles by three low pressure injection tanks.

Figure 2 shows the peak cladding temperature of the hottest rod both for the MULTID and the 1D case. In this figure, the PCT did not exceed the allowable criteria, 1477K, in any of the cases. The PCT of the 1D case is 1297K and the PCT of the MULTID case is 1176K. This shows a difference of the PCT. During the blowdown/refill phase, the peak cladding temperature of the MULTID case is suddenly 113K larger than that of the 1D case after the accident at 3~5 seconds. But after 5 seconds, the PCT of the MULTID case becomes lower than that of the 1D case. Also, the quenching of the hottest rod for the MULTID case takes place earlier than that of the 1D case.

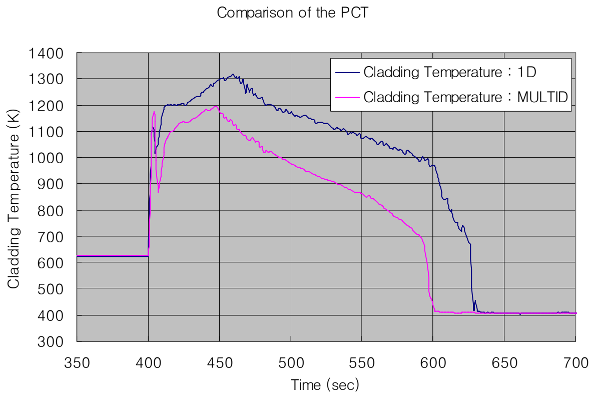

Figure 2. Comparison of the PCT.

Figure 3 shows the comparison of the broken loop hot-leg flow for both cases. In the early seconds of the accident, the mass flow of the inlet of the broken loop hot-leg in the MULTID case is greater than that of the 1D case. The reason for this difference is the pressure drop at the inlet of the broken loop hot-leg due to the multi-dimensional characteristics of the core upper plenum. It was identified that the pressure of the inlet of the broken loop hot-leg was lower than that of the inlet of three intact loops.

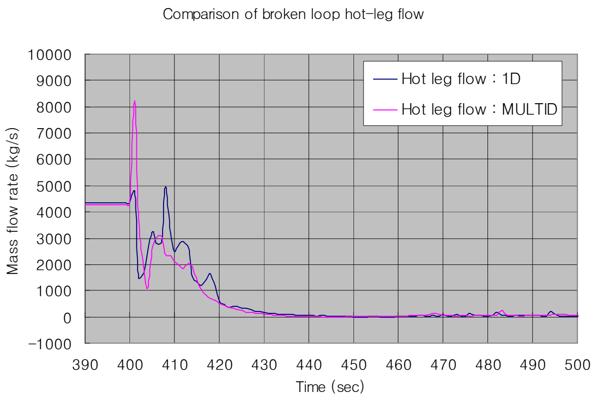

Figure 3. Comparison of broken loop hot-leg flow.

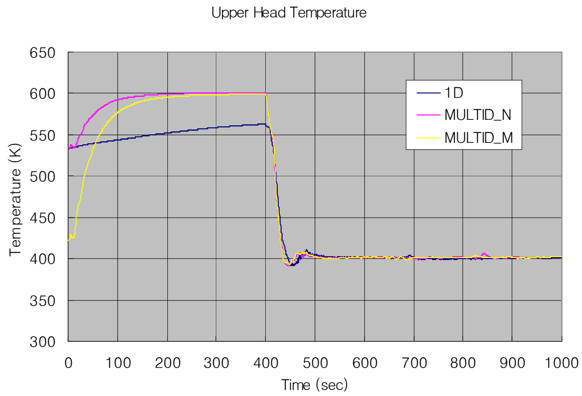

Figure 4. Comparison of upper head temperature.

Lastly, Figure 4 shows the comparison of the temperature at the upper head region. In this figure, the MULTID cases are different from the initial temperature. An initial temperature of the MULTID_N is set at 500K the same as the 1D case and an initial temperature of the MULTID_M is set at 300˚K. During the steady-state condition, the MULTID_M case becomes equal to the temperature with the MULTID_N case. But, the 1D case is processed steadily at the lower temperatures than the others. There are two reasons for this. One reason for this situation is that the mass flow rate of the MULTID case in downcomer is lower than that of the 1D case when the coolant flows from the downcomer to the upper head region. The other reason is the multi-dimensional phenomena, that is, a thermal mixing is developed at the upper head region in the case of the MULTID model.

3. Conclusion

The MARS code, which was used to model the reactor vessel in a Zion NPP by using the MULTID component, can calculate the flow fields in the system such as the multi-dimensional phenomena.

REFERENCES

[1] A. Petruzzi, F. D'Auria., "BEMUSE Phase 2 REPORT: Re-analysis of the ISP-13 Exercise, Post Test Analysis of the LOFT L2-5 Test Calculation", NEA/CSNI/R(2006)2.

[2] M.Perez, F.Reventos, LI.Batet., "Input and Output Specifications-Rev1 for the ZION Nuclear Power Plant. Phase 4 of BEMUSE program", Universitat Polotecnia de Catalunya, 2006.