Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 29-30, 2009

Preliminary Analysis of the Total Loss of Feed Water for an Integral Type Reactor by using SCDAP/RELAP5

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1. Introduction

The accident sequence of an integral type reactor has been evaluated to have overall insight into a severe accident progression from an initiating event to the reactor vessel failure. The main components of the reactor coolant pump, the steam generators, and the pressurizer are located inside the reactor vessel in the integral type reactor. A preliminary analysis on a dominant severe accident sequence of the total loss of feed water (TLOFW) has been performed by using the SCDAP/RELAP5/MOD3.3 computer code [1].

2. SCDAP/RELAP5 Input Model

The input model for the SCDAP/RELAP5 calculation of the integral type reactor was a combination of the RELAP5, SCDAP, and COUPLE input models. Heat structures for the fuel rods and the lower part of the reactor vessel in the RELAP5 input model were replaced by the SCDAP and COUPLE input models, respectively. In the RELAP5 input models, the reactor core was simulated as 1 channel, which was composed of 10 axial volumes, as shown in Fig. 1. The pressurizer was attached to the top of the upper core region. The POSRV (Power Operated Safety Relief Valve) for the prevention of RCS over pressurization is modeled in the top of the pressurizer. There are a lot of structures inside the reactor vessel in the integral type reactor. These were simulated by heat structure models. A secondary feed and a main steam system was modeled for steady state simulation.

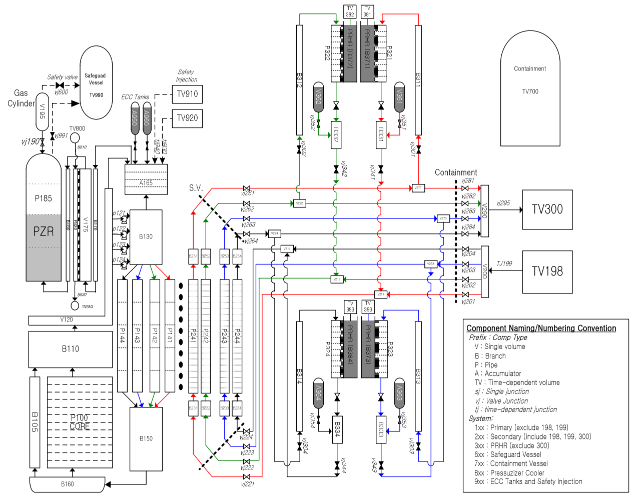

Fig. 1. SCDAP/RELAP5 nodalization for the integral type reactor.

In the SCDAP input model of this study, the component numbers for the fuel and the control rods were 3 and 3. The axial node number of the fuel and control rods was 10 in each, and the radial node numbers for the fuel and the control rods were 6 and 2, respectively. In the COUPLE input, the lower part of the reactor vessel was divided into 234 nodes and 204 elements. The thermal power was 330 MW_{th}.

3. Results and Discussion

Table I shows the SCDAP/RELAP5 results on the significant events for the TLOFW. In this preliminary analysis, since the in-vessel component structures are very influence on the reactor vessel failure time, no simulation of these was performed. The total LOFW transient is initiated when the main feedwater is lost at 0 second. Since the core decay heat is not completely eliminated by the steam generators, the pressure and temperature of the RCS increases. Oxidation of the fuel cladding begins when the cladding surface temperature reaches approximately 1,000 K at 7,634 seconds. Fuel melting begins at 9,896 seconds. However, the fuel temperature begins to decrease, because of heat transfer from the fuel to the internal structures. Finally, the reactor lower head vessel failure occurs by creep at 33,145 seconds, which is a very late time. In no simulation of the in-vessel structure, the reactor vessel failure occurs at 8,545 seconds, which is a very early time. This result is very similar to the typical PWR results.

Table I. SCDAP/RELAP5 results on the significant events for the T LOFW of the integral type reactor.

Sequence	Base Case (sec)	No Model of Int. Structure (sec)
Transient Initiated	0.0	0.0
Initial Water Release through POSRV	2.0	2.0
Full Liquid of Pressurizer	2,786.0	1,352.0
Core Uncovery	5,896.0	4,600.0
Cladding Oxidation Begins	7,634.0	6,086.0
Fuel Melting	9,896.0	7,072.0
Corium Relocation to the Lower Plenum	-	8,496.0
Reactor Vessel Failure by Creep	33,145.0	8,545.0

Fig. 3 shows SCDAP/RELAP5 results on the pressurizer pressure and secondary pressure. The RCS pressure increases up to the set pressure of the POSRV, and then the RCS inventory is lost through the opened POSRV. When the RCS pressure decreases to the closing set pressure of the POSRV, the POSRV closes and the pressure builds up again. The RCS pressure fluctuates between the opening (17.5 MPa) and closing set pressure (13.9 MPa) of the POSRV

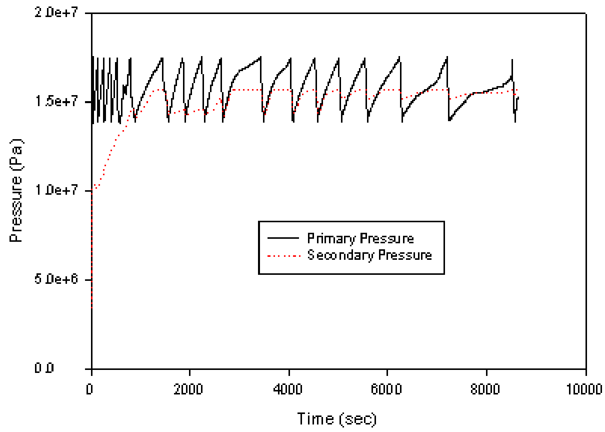

Fig. 3. SCDAP/RELAP5 results on the primary and secondary pressures for the T LOFW.

Fig. 4 shows SCDAP/RELAP5 results on the normalized collapsed water level in the pressurizer. The pressurizer water level follows the RCS pressure until the RCS pressure increases up to the set pressure of the POSRV. The pressurizer water level increases due to the RCS pressure increase, and finally the pressurizer is filled with water (water solid state). The overall pressurizer water level decreases due to the continued RCS inventory loss through the POSRV, and finally the pressurizer is voided.

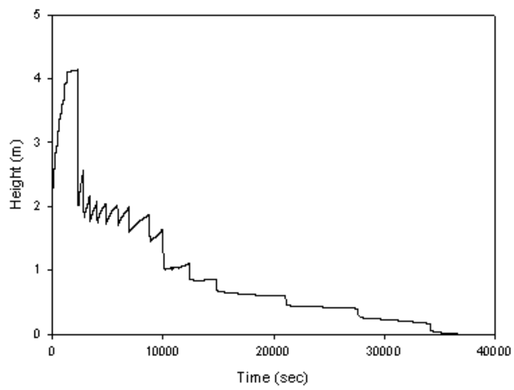

Figure 4 SCDAP/RELAP5 results on the pressurizer level for the TLOFW.

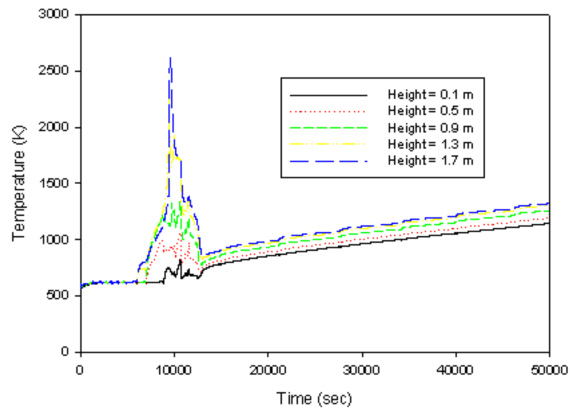

Fig. 5. SCDAP/RELAP5 results on the fuel cladding surface temperature for the TLOFW.

Fig. 5 shows fuel cladding maximum surface temperatures. The fuel cladding surface temperature is slightly higher than the surrounding coolant temperature until the coolant in the core volume corresponding to each fuel rod is vaporized. The fuel cladding surface temperature at the top of the fuel rods rises when core uncovery occurs at the top of the core. When the fuel cladding temperature rises up to 1000 K, fuel cladding oxidation begins. This time, the fuel cladding temperature rises abruptly due to the core oxidation heat generation. The fuel cladding temperature rises abruptly due to the vigorous core oxidation heat generation when the fuel cladding temperature reaches 1700 K. This temperature rise stops when the fuel cladding temperature reaches 2500 K because ZrO_2 is ruptured by melting and relocated to the lower core. However, the fuel temperature begins to decrease because of heat transfer from the fuel to the internal structures. After that, the temperature increases gradually.

4. Conclusion

A preliminary analysis on the total LOFW of the integral type reactor was performed by using SCDAP/RELAP5. The results show that the internal structure is very influence on the melt progression and the reactor vessel failure time. For this reason, a detailed analysis will be necessary to analyze the internal component structure effects on the melt progression.

ACKNOWLEDGMENTS

This work funded by the Korean government (MEST).

REFERENCES

[1] L. J. Siefken et al., “SCDAP/RELAP5/MOD3.3 Code Manual, Vol. I-V,” NUREG/CR-6150, 2001.