Evaluation on Entry Condition of the Severe Accident Management Guidance for OPR1000

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1. Introduction

The objective of the EOP (Emergency Operator Procedure) is to cool down the core during a design basis accident, but the objective of the SAMG (Severe Accident Management Guidance) is to prevent a release of radioactive material into the environment during a severe accident. For this reason, when the SAMG is started, the EOP is ended. The change point from the EOP to the SAMG is an entry condition of the SAMG. The entry condition of the SAMG is very important for the operator action to have sufficient time to mitigate the severe accident. In general, the entry condition of the SAMG is the core exit temperature, as follows:

- Combustion Engineering PWR = 480 ℃
- OPR 1000 = 650 ℃[1]
- Westinghouse PWR = 650 ℃
- Uljin 1,2 = 700 ℃
- EDF PWR = 1,100 ℃

As the entry condition of the SAMG is different from the plant type, it is necessary to evaluate this in the proper operator action timing point for severe accident mitigation. In this study, the SAMG entry condition of the OPR1000 in various severe accident sequences has been evaluated in detail by using the SCDAP/RELAP5/MOD3.3 computer code [2].

2. SCDAP/RELAP5 Input Model

The input model for the SCDAP/RELAP5 calculation of the OPR1000 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 model, the reactor core was simulated as 3 channels to evaluate the thermal-hydraulic behavior in detail, and each channel was composed of 10 axial volumes, as shown in Fig. 1. A surge line and a pressurizer were attached to one of the hot legs in the primary coolant loop. Four SITs (safety injection tank) were connected to the cold legs. As a secondary feed system during the transient, the auxiliary feedwater system was modeled.

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 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.

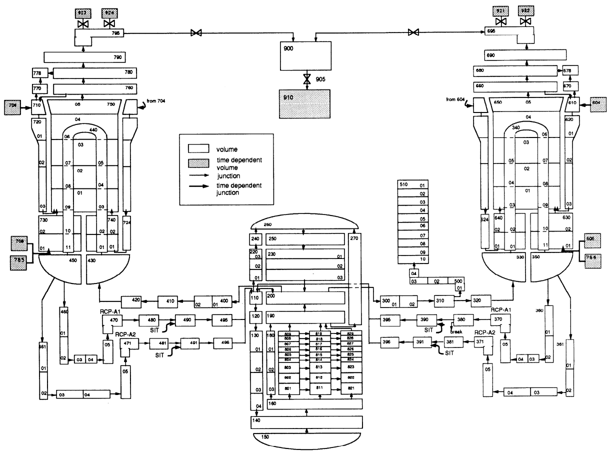

Fig.1. SCDAP/RELAP5 input model for the OPR1000.

3. Results and Discussion

In this study, the following dominant severe accident sequences for the OPR1000 were evaluated with a comparison of other entry conditions of the SAMG.

- SBO(Station Blackout)
- T LOFW(Loss of Feed Water)
- SBLOCA(Small Break Loss of Coolant Accident) without SI(Safety Injection)
- MB(Medium Break) LOCA without SI
- LB(Large Break) LOCA without SI

Table I shows the SCDAP/RELAP5 results on the significant events for the OPR1000. In most sequences, the time difference of the core exit temperature to reach between 650 ℃ and 700 ℃ is approximately 55-98 seconds. However, the time difference is 264 seconds in the LBLOCA without SI, because of the SIT actuation effect. In most sequences, the time difference of the core exit temperature to reach between 480 ℃ and 650 ℃ is approximately 184-494 seconds. However, the time difference is 9,230 seconds in the MBLOCA without SI. In this sequence, 480 ℃ of the core exit temperature for the SAMG entry condition is too early.

As shown in Table I, the time of the core exit temperature to reach 1,000 ℃ in all sequences is faster than that of the fuel cladding temperature to reach 930 ℃, which is a starting point of fuel cladding oxidation. So, 1,000 ℃ of the core exit temperature for the SAMG entry condition is too late.

Table I. SCDAP/RELAP5 Results on significant events for the OPR1000.

Events		SBO	T LOFW	SBLOCA	MBLOCA	LBLOCA
Core Exit Temperature	480 °C	6,126	3,768	4,210	770	1,960
	650 °C	6,580	4,172	4,548	10,000	2,144
	700 °C	6,678	4,224	4,624	10,064	2,408
	1,000 °C	7,224	4,576	4,993	10,598	-
	1,100 °C	7,272	4,632	5,033	10,714	-
Fuel Cladding Temperature	930 °C	6,893	4,370	4,796	10,174	2,192
	1,530 °C	7,264	4,631	4,999	10,458	2,462
Fuel Melting Time		7,432	4,750	5,094	10,538	3,102
Melted Fuel Relocation Time		8,473	6,074	6,106	12,088	3,657
Reactor Vessel failure Time		8,570	6,130	6,215	12,580	4,700

As the time difference between the core exit temperature to reach 650 ℃ and the reactor vessel failure is approximately 1,591-2,292 seconds, the operator has sufficient time for severe accident mitigation. So, the SAMG entry condition of the core exit temperature of 650 ℃ for the OPR1000 is suitable for the operator action time to mitigate a severe accident.

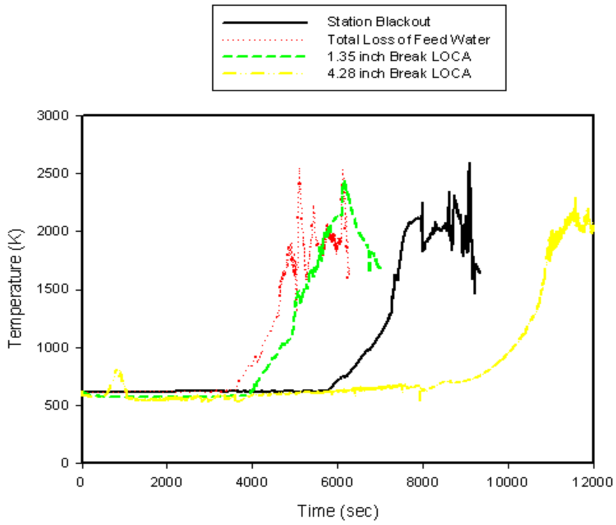

Fig. 2. SCDAP/RELAP5 results on the core exit temperature of the OPR1000.

Fig. 2 shows SCDAP/RELAP5 results on the core exit temperature of the OPR1000. In general, the core exit temperature is similar to the maximum fuel cladding surface temperature. When the fuel cladding temperature rises to 930 ℃, a fuel cladding oxidation begins. Following this time, the core exit temperature rises abruptly due to heat generation associated with fuel cladding oxidation. The fuel cladding temperature rises abruptly due to a vigorous core oxidation heat generation when the fuel cladding temperature reaches 1,530 ℃. This temperature rise stops when the fuel cladding temperature reaches 2,300 ℃ because the ZrO_2 becomes molten and relocated to the lower core.

4. Conclusion

The SAMG entry condition of the OPR1000 in various severe accident sequences was evaluated in detail with the comparison of other SAMG entry conditions by using the SCDAP/RELAP5/MOD3.3 computer code. The results show that the SAMG entry condition of the core exit temperature of 650 ℃ for the OPR1000 is suitable for the operator action time to mitigate a severe accident.

ACKNOWLEDGMENTS

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