# An Evaluation of a Coolant Injection into the In-Vessel with a RCS Depressurization during the Total Loss of Feed Water in OPR1000

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## 1. Introduction

Coolant injection into the in-vessel with a RCS (reactor coolant system) depressurization is a very important strategy to prevent a reactor vessel failure during a severe accident. This can be achieved by the operation of the safety injection system with a RCS depressurization by using the safety depressurization system (SDS) and the steam generator. The positive effects of this strategy are to cool down the core, to prevent a reactor vessel failure, and so on. The negative effect of this strategy is more hydrogen generation and so on. For this reason, this strategy of a severe accident management should be evaluated in detail.

The coolant injection into the in-vessel with a RCS depressurization to prevent a reactor vessel failure in OPR (Optimized Pressure Reactor) 1000 has been evaluated by using the SCDAP/RELAP5 computer code[1]. In this study, a total loss of coolant accident (LOFW) was selected as initial events, because this is dominant severe accident sequence in the OPR1000. The safety injection into the in-vessel with a direct primary depressurization by using the SDS has been evaluated for the total LOFW. Sensitivity studies on coolant injection timing and its capacity have been performed to determine the proper operation time.

## 2. SCDAP/RELAP5 Input Models

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 SCDAP and COUPLE input models, respectively. In the RELAP5 models, 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) are connected to the cold legs. Two SDS valves for a direct depressurization of the RCS are connected to the top of the pressurizer. Four high and low pressure safety injection trains are connected to four cold legs.

In the SCDAP input model, the component numbers for the fuel and the control rods were 3 and 3, respectively, in this study. 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.

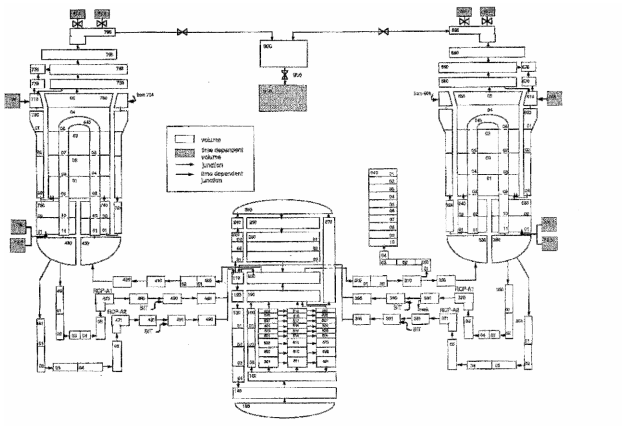

Figure 1. SCDAP/RELAP5 input model for OPR1000.

## 3. Results and Discussion

The total LOFW transient is initiated when the main and auxiliary feedwater are lost at 0 second. Since the main and auxiliary feedwater are not supplied, the steam generator secondary side water level decreases due to the steam generation by boiling and finally the steam generators can not act as effective heat sinks when the steam generator secondary sides dry up. The reactor and the reactor coolant pump (RCP) are tripped due to the low steam generator level and coolant sub-cooling margin, respectively. Since the core decay heat is not completely eliminated by the steam generators due to the decreased steam generator secondary side's water level, the pressure and temperature of the RCS increases. The SRVs (Safety Relief Valves) of the steam generator regulates the pressure of the secondary side. The RCS pressure increases up to 17.2 MPa, which is the opening pressure of the pressurizer SRV. Following this time the RCS pressure fluctuates between the opening (17.2 MPa) and closing pressure (14.1 MPa) of the pressurizer SRV.

Table 1 shows the SCDAP/RELAP5 results on the significant events for the total LOFW of the OPR1000. From a previous study[2], an opening of two SDS valves at 40 minutes after initial opening of the SRVs can depressurize the RCS sufficiently and postpone the reactor vessel failure time by approximately 5 hours. The opening of one SDS valve can not depressurize the RCS sufficiently. For this reason, sensitivity studies on a safety injection train number of one to three and its actuation time with opening of two SDS valves have been performed.

Table 1. Significant events for the total LOFW of the OPR1000.

| Case | SI Actuation Time (s) | First Relocation Time to the LP (s) | Large Relocation to the LP (s) | RV Failure Time (s) | RCS Pressure at RV Failure (MPa) |
|---|---|---|---|---|---|
| Base | - | 6,062 | 6,062 | 6,115 | 15.2 |
| SDS2- 40 minutes | (SIT, 4,572) | (23,388) | | | (0.41) |
| SDS2- 40 minutes, SI1-SI Sig. | 4,132 | No RV Failure& Core Melting to 50,000 sec | | | |
| SDS2-40 minutes, SI1-18872sec | 18,872 | No RV Failure & Core Melting to 50,000 sec | | | |
| SDS2-40 minutes, SI1-20208sec | 20,208 | No RV Failure to 50,000 sec (Core Melting: 19,917, No Relocation to LP) | | | |
| SDS2-40 minutes, SI1-21000sec | 21,000 | 21,807 | 21,807 | 22,225 | 0.9 |
| SDS2-40 minutes, SI3-21000sec | 21,000 | 21,828 | 22,285 | 22,285 | 1.0 |
| SDS2-40 minutes, SI1-23000 sec | 23,000 | 21,486 | 21,486 | 22.005 | 1.3 |

As shown in Table 1, only one train operation of a high pressure safety injection at 20,208 seconds with a RCS depressurization by using two SDS valves at 40 minutes after an initial opening the SRV prevents a reactor vessel failure. As shown in Fig.2, the pressurizer pressure rapidly decreases after the initial opening of the two SDS valves. Figure 3 shows the core collapsed water level history for the total LOFW. A proper actuation of the high pressure safety injection train and time maintains the proper collapsed water level.

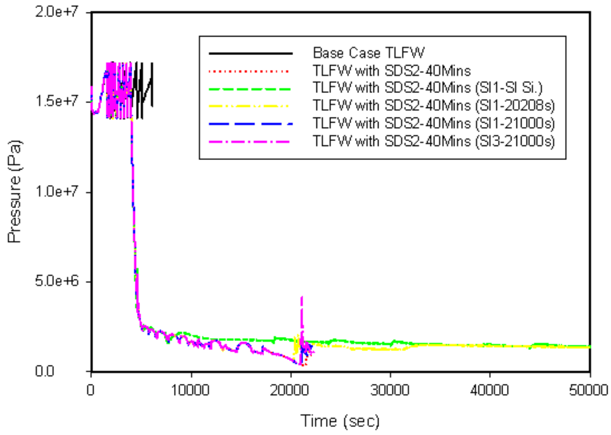


Figure 2. RCS pressure history in the total LOFW.

## 4. Conclusion

A coolant injection into the in-vessel with a RCS depressurization to mitigate a reactor vessel failure has been evaluated during a total LOFW in the OPR1000. The SCDAP/RELAP5 results have shown that only one train operation of a high pressure safety injection with a RCS depressurization by using two SDS valves prevents a reactor vessel failure.

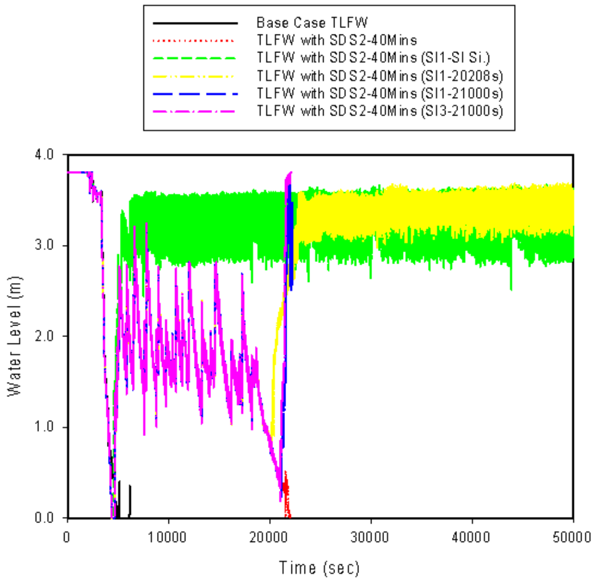


Figure 3. Core collapsed water level history in the TLFW.

## ACKNOWLEDGMENTS

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## REFERENCES

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

[2] R. J. Park, S. B. Kim, H. D. Kim, "An Evaluation of the RCS Depressurization Strategy using the SCDAP/RELAP5 Computer Code" KNS Spring Meeting, May 2006.