An Evaluation of Severe Accident Mitigation Strategy for LOFW in Wolsong Plant

Soo Yong Park, Young Ho Jin, See Darl Kim, Yong Mann Song
Thermal Hydraulic and Safety Research Division
Korea Atomic Energy Research Institute
150 Yusong, Dukjin, Daejon, Korea 305-353
sypark@kaeri.re.kr

1. Introduction

Severe accident management guidance(SAMG) for the Wolsong heavy water reactor is being developed at KAERI. The guidance includes six individual accident management strategies: (1) Injection into primary heat transport system (2) Injection into calandria vessel (3) Injection into calandria vault (4) Reduction of fission product release (5) Control of reactor building condition (6) Reduction of reactor building hydrogen. Figure 1 shows the Diagnostic Flow Chart (DFC) of generic SAMG for Wolsong plants. The paper provides some analysis results of mitigation effect of above severe accident management strategies. The thermal hydraulic and severe accident phenomenological analyses for the evaluation have been performed using ISAAC(Integrated Severe Accident Analysis Code for CANDU Plant)[1] computer program.

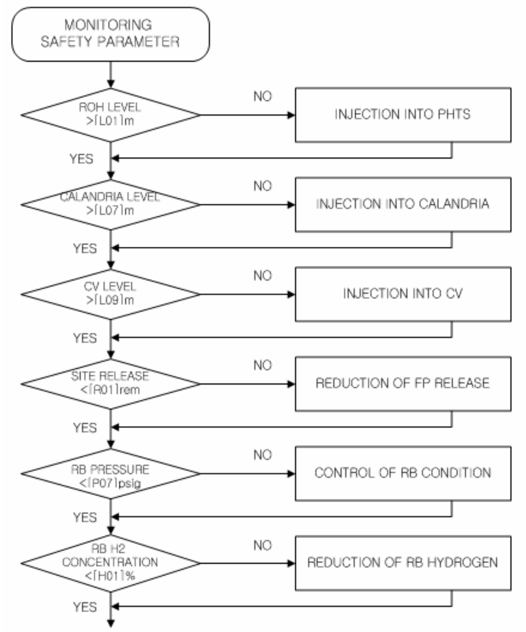

Figure 1 Diagnostic Flow Chart of generic SAMG for Wolsong plants (Part of DFC)

2. Analysis and Results

2.1 Description of Analyzed Scenarios

Base case scenario is a total loss of feedwater without any recovery action by operator based on the severe accident management guidance. All the emergency core cooling(ECC) systems, the moderator cooling system and the end-shield cooling system are assumed to be inoperable to simulate the severe core damage cases. Four additional scenarios have been analyzed to evaluate the effects of the mitigation stratifications. Each additional scenario includes one or two recovery strategy of SAMG. Table 1 represents the analyzed cases and the evaluated strategies.

Table 1. Strategies applied to each calculation case

	Base Case	LF-MPI	LF-CTI	LF-CVI	LF-VENT
Injection into PHTS	X	O	X	X	X
Injection into calandria	X	X	O	X	X
Injection into CV	X	X	X	O	O
Reduction of FP release	X	X	X	X	X
Control of RB condition	X	X	X	X	O
Reduction of RB H2	X	X	X	X	X

2.2 Results

Following the total loss of feed water accident, the core uncovered after steam generators have dried out. Since the moderator cooling system is not working, the moderator temperature and pressure increase due to the heat transferred from PHTS. After the calandria rupture tube fails, eventually the SAMG entry condition, which is defined by the coolant thermal margin and the moderator level, has been reached at 10,172 seconds. Since there is no recovery action for the base case, the core melt and relocation, the calandria vessel failure and the reactor building failure are occurs in turn. The calculation results based on ISAAC program are summarized in Table 2.

The medium pressure ECC system is working for LF-MPI case, thus the core relocation and the calandria vessel failure are much delayed. However, the reactor building failed earlier than base case due to the additional steam generation.

In LF-CTI case for which the moderator has injected from the makeup system, the corium accumulation on the bottom of calandria is delayed.

For LF-CVI case, a long-term supply of cooling water into the calandria vault is assumed to be possible via the expansion tank to which the demineralized water can be provided as make-up. Under severe accident conditions, large quantities of molten core material may relocate to the bottom of the calandria vessel where it interacts with water and vessel structures. The heat transfer from the molten debris causes evaporation of any remaining water and heatup of the vessel wall. Since the calandria vault is flooded before the melt relocation onto the bottom of calandria vessel, the vessel wall would be initially cool and the outer vessel temperature would remain close to the water saturation temperature of the calandria vault. Nucleate pool boiling of the vault water is an efficient mechanism for heat removal from the molten debris in the calandria vessel bottom. Assumed that adequate heat removal could be achieved, and the local heat flux at the vessel wall would not exceed the critical heat flux, the calandria vessel failure has not be expected as long as the cooling water provided.

For LF-VENT case, not only the calandria vault injection but also the reactor building vent through an isolation system of 30 inch diameter are simulated. The valve is opened and closed repeatedly between 54.7 and 64.7 psia of the building pressure. In this case, no calandria vessel failure or reactor building failure has been occurred.

3. Summary

Four generic SAMG strategies developed in KAERI have been tested on the total loss of feed water scenarios for Wolsong plant. Based on the ISAAC calculation, the long-term external vessel cooling strategy and the vent strategy seem to be very feasible and effective mitigation measures for the Wolsong plants.

Acknowledgements

This study has been carried out under the nuclear R&D program planned by the Korean Ministry of Science and Technology(MOST).

REFERENCES

[1] KAERI/RR-1573/95," Development of Computer Code for Level 2 PSA of CANDU Plant ", December 1995.

Table 2. Accident progression summary for the calculation cases

Event	Base Case	LF-MPI	LF-CTI	LF-CVI	LF-VENT
Reactor Scram	17.7				
Steam Generator Dryout	2,748				
Spray Injection	3,263				
Dousing Tank Depleted for Spray	4,072				
Core Uncovered	4,533				
Core Empty in loop1/loop2	6,779/6,749				
Calandria Rupture Valve Opened	10,074				
SAMG Entry Condition Reached	10,172				
D2O Makeup on	N/A	N/A	10,254	N/A	N/A
Pressure Tube Ruptured	10,509	10,491	10,476	10,491	10,491
LOCA Signal Received	10,516	10,498	10,483	10,491	10,491
MPI on	N/A	10,498	N/A	N/A	N/A
Dousing Tank Depleted for MPI	N/A	11,246	N/A	N/A	N/A
Corium Relocation Start	12,437	17,709	12,309	12,409	12,409
Corium in Calandria Bottom	12,872	18,486	22,438	12,855	12,855
Water Dryout in Calandria	25,870	45,722	41,576	25,865	25,865
Calandria Vault Makeup on	N/A	N/A	N/A	54,378	54,378
Calandria Vessel Failed	135,164	151,273	146,917	N/A	N/A
Reactor Building Vent Start	N/A	N/A	N/A	N/A	110,978
Reactor Building Failed	135,240	104,784	121,023	149,897	N/A
Corium Concrete Interaction Start	153,234	152,070	146,921	N/A	N/A