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Estimation of Aging Effects on LOHS for CANDU-6

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1. Introduction

The assessment on Wolsong Unit One's capability to respond to the loss of safety functions was performed under the assumption of the electrical power system and the ultimate heat sink loss conditions that occurred in the disaster of the Fukushima Daichi nuclear power plant. To evaluate the plant's capacity to respond to large-scale natural disaster exceeding design, the loss of heat sink(LOHS) accident accompanied by loss of all electric power is simulated as a beyond design basis accident.

This analysis is considered the aging effects of plant as the consequences of LOHS accident. Various components of primary heat transport system(PHTS) get aged and some of the important aging effects of CANDU reactor are pressure tube(PT) diametral creep, steam generator(SG) U-tube fouling, increased feeder roughness, and feeder orifice degradation. These effects result in higher inlet header temperatures, reduced flows in some fuel channels, and higher void fraction in fuel channel outlets.

Fresh and aged models are established for the analysis where fresh model is the circuit model simulating the conditions at retubing and aged model corresponds to the model reflecting the aged condition at 11 EFPY after retubing.

CATHENA computer code[1] is used for the analysis of the system behavior under LOHS condition.

2. Methods and Results

2.1 Initial conditions of System

The steady state conditions at 100% full power are generated using the circuit model at fresh and aged conditions. The initial conditions of important system parameters at steady states are summarized in Table 1.

Table 1 Steady States at 100%FP

System Parameters	Initial conditions	
	Fresh	Aged
RIH Pressure(MPa(a))	11.24	11.16
ROH Pressure(MPa(a))	10.01	10.03
RIH Temperature(℃)	265.0	267.0
Core Pass Flow(kg/s)	2106	2047
ROH Void	0.077	0.202

2.2 Analysis Model

For the simulation of LOHS condition, all electric powers, including emergency power, are assumed un-available due to earthquake. At this condition, only the passive components are operable and the other systems are assumed to be failed. Thus, only the inventories remained in the PHTS and SG can be used for the removal of decay heat.

Best-estimate analysis is applied for assessing the system behavior. At the start of the simulation, all primary heat transport (PHT) pumps and feedwater pumps stop and the reactor and turbine are also tripped. The PHTS pressure and inventory control system, such as feed and bleed system, pressurizer heater and pressurizer steam bleed valves are assumed to be unavailable. The liquid relief valves (LRVs) are assumed failed open from the start of simulation and remains open until the end of the simulation.

In this accident, the degasser condenser relief valves (DCRVs) and main steam safety valves (MSSVs) are credited.

2.3 System Behavior

The feedwater to SG secondary side is not supplied any more due to total loss of electric power. As long as the coolant remains in the SG secondary side, the decay heat is well removed through steam generator U-tubes.

As the inventory of steam generator secondary side is depleted at about 5,000s, the decay heat cannot be removed and pressure and temperature of PHTS system starts to increase. Figure 1 shows the SG inventory and Figure 2 shows the heat transfer through SG u-tubes from the core.

As the LRVs are failed open from the initiation of the transient, the coolant in the PHTS discharges to the degasser condenser tank (DCT) and the pressure of DCT is increased to almost the same pressure as the reactor outlet header (ROH). The pressure of DCT is increased, as the LRV discharge flow stops until the pressure of PHTS starts to increase after the depletion of SG inventory.

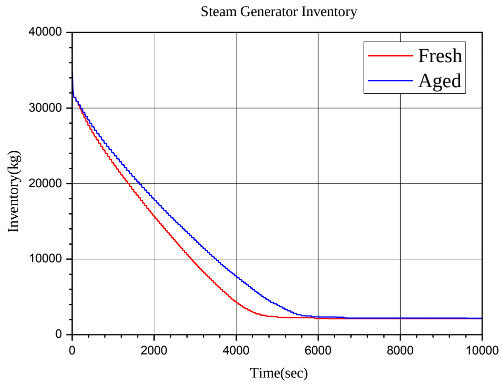

Figure 1 Steam Generator Inventory

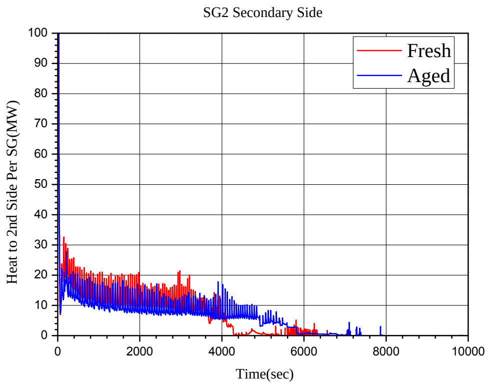

Figure 2 Heat Transfer Through SG U-tubes

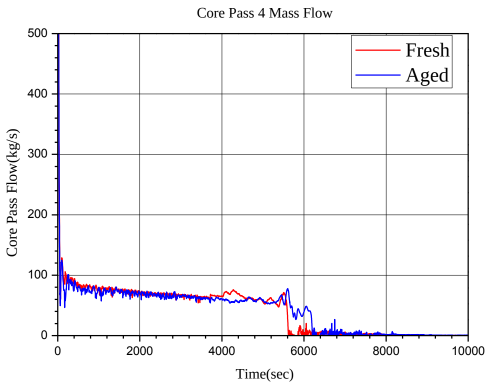

Figure 3 Core Pass Flow

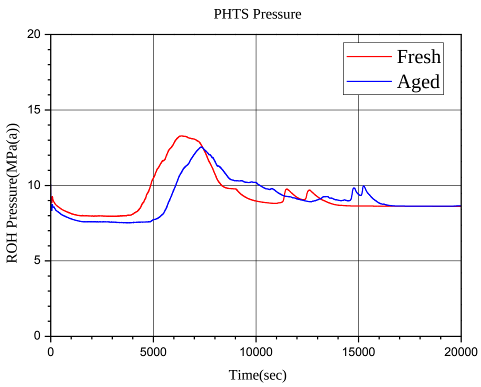

Figure 4 Primary Heat Transport System(PHTS) Pressure

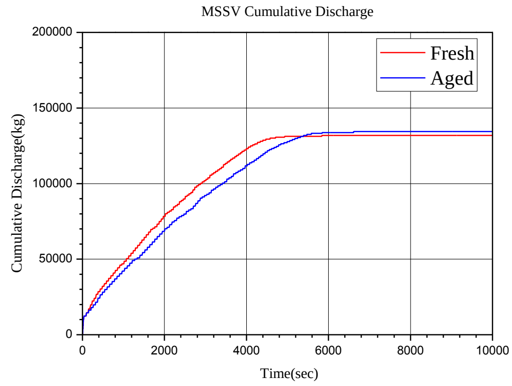

Figure 5 MSSV Cumulative Discharge

The core pass flow is shown in Figure 3. After PHTS pumps trip, the coolant flow is formed by natural circulation. After the inventories in SGs are depleted through passive operation of MSSVs, the heat transfer is not available and the PHTS pressure starts to increase. Figure 4 shows the PHTS pressure. As the PHTS pressure increases, the coolant in PHTS flows into the DCT and pressurizer. Then the average core flow decreases rapidly and fuel channel starts to heat up and fail eventually. The channel failure time is dependent on the channel characteristic and can be assessed from single channel analysis[2]. The detailed system behavior is described in Reference 3.

2.4 Aging Effect

As shown in Figure 1, the inventory in SG is depleted for fresh core about 1,000s earlier than the aged core.

The decay heat and the heat transfer efficiency through U-tubes are reduced as plant ages. The decay heat is transferred to SG and the coolant in SG secondary side heats up. Then, the SG secondary side is pressurized and steam is discharged through passive operation of MSSV. Cumulated discharge flows through MSSV for fresh and aged models are shown in Figure 5. The integrated MSSV discharge flow for fresh model is larger than aged core as more decay heat is transferred for fresh model. Thus, the SG for fresh model is dried earlier than aged model.

As the inventory in SG secondary side gets depleted the decay heat cannot be removed. Anymore as shown in Figure 2, the transferred heat for fresh model is greater than aged model until SG inventory is depleted.

As the decay heat is not transferred to SG due to SG inventory depletion, the natural circulation induced flow is stopped and fuel channel starts to heat up. If any effective operator action to mitigate the accident is not done, the fuel channel is eventually ruptured. As the inventory for fresh model is dried earlier than aged model, the channel failure time is also predicted earlier than aged core.

3. Conclusions

The LOHS accident is analyzed for fresh and aged models using CATHENA thermal hydraulic computer code. The decay heat removal is one of the most important factors for mitigation of this accident.

The major aging effect on decay heat removal is the reduction of heat transfer efficiency by steam generator. Thus, the channel failure time cannot be conservatively estimated if aged model is applied for the analysis of this accident.

4. Acknowledgements

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REFERENCES

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