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Thermal Hydraulic Assessment for Loss of SDCS Event During the Outage of CANDU Reactor

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1. INTRODUCTION

During the outage(overhaul) of the nuclear power plant, there are several operating states other than the full power state, that is "Hot-Zero Power", "Depressurized-Cooldown", and "Partially Drained". Until now safety assessment has not been done much for this operating state of CANDU type reactor worldwide. For the accuracy and confidence of PSA for the CANDU outage, the safety analysis is necessary. At the first stage, we analyzed the thermal hydraulic characteristics and safety of the postulated event of loss of shutdown cooling system (SDCS) during the partially drained state which is the longest one in the middle of outage period.

As an analysis tool, this study uses the best estimate thermal hydraulic code, RELAP5/CANDU which was modified according to the CANDU specific characteristics and based on RELAP5.Mod3

2. PARTIALLY DRAINED STATE

During the partially drained (down to the reactor header level) operating state, the primary coolant is depressurized to 0.5MPa and cooled down to 327 K. After the steam generator manway is opened for the steam generator (SG) maintenance, the pressure is further lowered to atmospheric pressure. And the PHTS pumps are stopped and ECCS and pressurizer are isolated from the coolant loops. Instead, the core which is heated by the decay heat(less than 1%FP) is cooldowned through the SDCS (pump and heat exchanger). Fig. 1 shows the PHTS which is partially drained and linked with SDCS. The blue nodes are filled with coolant and the empty nodes (including all nodes of steam generator) are the one drained. The green nodes represent the SDCS which is linked with the reactor inlet and outlet headers.

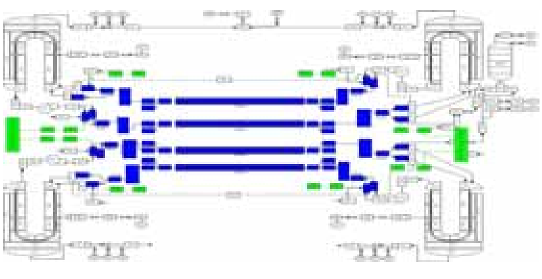

Fig.1 Partially drained PHTS and SDCS
(RELAP5/CANDU Nodalization)

The coolant flow rate by the SDCS pumps is assumed to be 71kg/s considering the heat balance. To protect the overpressure of the PHTS, the liquid relief valves (LRVs) are assumed to be available.

3. Loss of SDCS

The postulated event of loss of SDCS is assumed to be the failure of SDCS pump, resulting in the completely loss of coolant flow. Accordingly the coolant is boiled, the fuel is heated up, and finally the integrity of core (fuel and fuel channel) is damaged. The boiling of coolant is decided to occur when the void fraction of channel is beyond 0.001(0.1%). The criteria for fuel and fuel channel damage are 1073 K of fuel sheath temperature and 873 K of pressure tube temperature, respectively, which are the same criteria in the FSAR of Wolsong Unit 234. The outage PSA requires the time at which the core damage occurs after loss of SDCS.

4. RESULTS

Following the failure of SDCS pumps, the coolant flow rate is abruptly reduced to 0kg/sec and the fuel is cooled by the pool cooling, rather than the flow cooling. (Fig.2) But the channel flow is recovered a little by the effect of standing start after 500 sec.

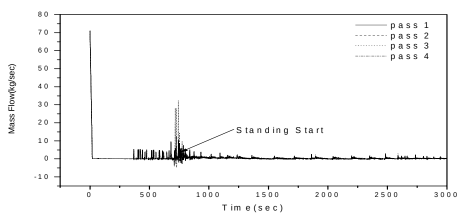

Fig.2 Coolant flow rate after the failure of SDCS pumps

The pressure and temperature of the coolant increase after loss of coolant flow. But the increased pressure is maintained between LRV opening setpoint (10.24 MPa) and closing setpoint (10.00MPa). (Fig.3 & Fig.4)

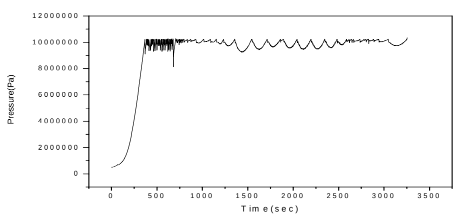

Fig.3 Pressure of the coolant in the ROH

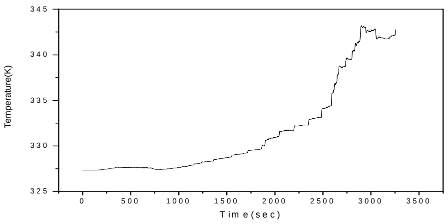

Fig.4 Temperature of the coolant in the ROH

The channel coolant is subcooled by the pool cooling for a while. At 682 sec after the loss of the SDCS, the coolant starts to boil. Following the nucleate boiling the void fraction abruotly increases to the value of more than 0.8 abruptly. (Fig.5)

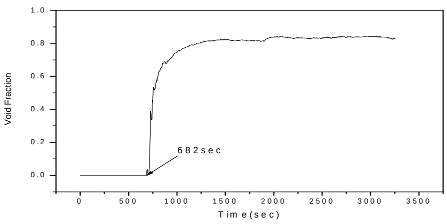

Fig. 5 Void fraction in the channel

The fuel sheath temperature increases right after the SDCS failure and exceeds the integrity criteria of 1073 K at 1975 sec.The pressure tube temperature reaches the criteria of 873 K at 2452 sec. (Fig.6 & Fig. 7)

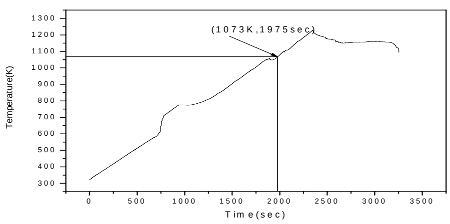

Fig. 6 Fuel sheath temperature

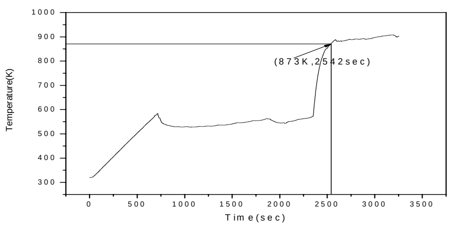

Fig. 7 Pressure tube temperature

The above result is referring to the case of before SG manway open, that is, the pressure is maintained at 0.5MPa. After the manway open, when decay heat is lowered as time goes, the coolant pressure becomes near to the atmospheric pressure. So the coolant state has the instability such as reverse flow and boiling starts earlier than above case. (Fig.8)

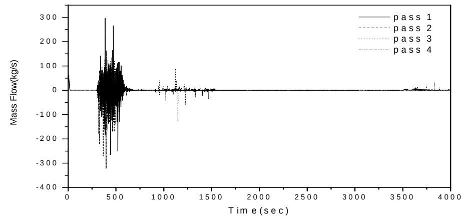

Fig.8 Coolant flow rate after SG manway open

The Table 1 summarizes the sequence of coolant boiling and channel damage for each case of before and after the SG manway opening.

Table.1 The sequence of the boiling and channel damage (Before & After the SG manway opening)

	Before	After
Coolant Boiling	682 sec	297 sec
Fuel Damage	1975 sec	2208 sec
PT Damage	2542 sec	3096 sec

5. CONCLUSION

For the first, we model the steady state of the partially drained period of CANDU reactor outage, analyze the transient behavior for the postulated event of loss of SDCS, and calculate the time at which the core is damaged in the aspect of boiling and fuel damage.

Now we are studying on the thermosyphoning phenomena using the SG as an alternative heat sink after loss of SDCS and expanding to the other periods of the outage. (Hot-zero power & Depressurized-cooldown)

6. ACKNOWLEDGMENT

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7. REFERENCES

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