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Preliminary Accident Progression Analysis of Multiple Steam Generator Tube Rupture in PHWR Plants

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1. Introduction

The ISAAC 1.x (Integrated Severe Accident Analysis Code for CANDU plants), which is a fully integrated severe accident computer code [1], is used to simulate multiple SGTR (Steam Generator Tube Rupture) scenarios at a pressure suppression containment type of CANDU-6 plants. The analysis is preliminary because updated version of ISAAC 2.x is to be applied finally in a near future which has improved models for channel relocation and suspended debris bed in the calandria tank (or vessel).

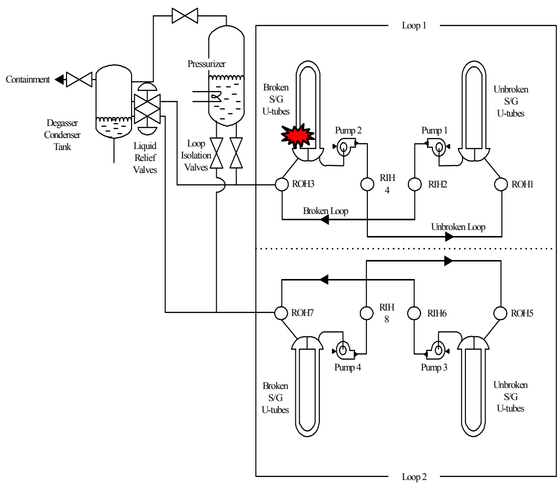

Fig.1 Tube Break Position in ISAAC PHTS Schematic

The selected multiple SGTR scenario for a base case is a transient sequence initiated by the simultaneous guillotine break of 10 steam generator tubes. A total break area of 0.0029225 m^2 is assumed to occur at the bottom of the tubesheet in Loop-1 (refer to Figure 1). It is assumed for a base sequence that ECCS injection, moderator cooling function, and shield cooling function are not available, and the failure of auxiliary feedwater without crash cooldown operation (CC) is further assumed. As the crash cooldown system is designed to open main steam safety valves (MSSVs) upon receiving a LOCA signal, if the crash cooldown operation succeeds, the SG pressure decreases rapidly. Without CC, all MSSVs are closed initially and they open at the setpoint of 5.11 MPa(a). The local air coolers are assumed to be unavailable to see the R/B (reactor building) failure time while the passive dousing sprays were available. All the analysis is performed for 3 days that is based on the containment failure around 27 hours occurring from steam overpressurization beyond 420 kPa(g) and is enough time to include the R/B response.

2. Accident Progression Analysis

Key event timing for Wolsong plants are summarized in Table 1 below.

Time [sec]		Events
Base	old	(L-1/2 = Loop-1/2)
0	0	10 U-tubes rupture in L-1, ECCS/moderator cooling/ Shield cooling unavailable
80	63	MSSV open in L-1/Broken
158	59	Reactor trip, MSIV close, SG MFW/AFW off
239	147	LOCA signal generated
260	168	Pressurizer isolated
269	177	CC operation fail
2821	5324	Calandria rupture disc fail
2899	3190	Dousing sprays on
3312	6043	Moderator saturated
3534	3319	SG dry out in L-2
4127	2970	LRV first open
4327	4976	Fuel channel empty in L-1
5276	5152	Dousing tank depleted
5599	10140	Pressure tube fails in L-1
6654	13397	Pressure tube fails in L-2
6667	6562	Fuel channel empty in L-2
16501	19944	SG dry out in L-1 Broken
31646	33863	Calandria tank dry out
95572	97481	Containment fails
127099	130142	Calandria tank fails
145481	148545	Calandria vault dry out
155319	158440	MCCI begins in CV
259200	259200	Calculation end

Table.1 Key Event Timing for Wolsong Plants

When the U-tubes break in Loop-1, the pressure in Loop-1 decreases and balances with the setpoint of the MSSVs until the pressure tubes fail after 1.6 hours as shown in Figure 2. Following the pressure tube failure in Loop-1, there is a reverse flow from the secondary side to the primary loop through the break, causing the water level to increase in Loop-1 as shown in Figure 3. The pressure in Loop-2 rises to the PHTS liquid relief valve (LRV) setpoint (= 10.34 MPa(a)) due to the reduced heat transfer to the secondary side as SG water dry out. It oscillates until the pressure tubes fail after 1.9

hours, as in Figure 2. The water inventory in Loop-2 increases initially due to surge flow from the pressurizer.

Figures 4 and 5 indicate the pressure and water level in the secondary side, respectively. Initially, the secondary side pressure increases to the setpoint of MSSVs due to heat transfer from the primary side. After the pressure tube failure in Loop-1, broken SG pressure follows the primary system pressure which balances with the calandria tank pressure. The unbroken SG pressure in Loop-1 decreases after a pressure tube rupture and increases again because of the heat transfer from the PHTS gas in Loop-1. The broken SG water level in Loop-1 decreases due to outflow through the MSSV and then drops down due to outflow from the SG to the primary side after the pressure tube failure. After loop isolation at 260 seconds, the pressure and water level in Loop-2 correspond to those of the high pressure (e.g. SBO) sequences.

The core starts melting after 2.2 hours following the moderator level decrease after calandria rupture disc failure at 0.8 hours and the moderator dries out at 8.8 hours. The high gas temperature inside the calandria tank heats up the calandria vault shield water, resulting in a water evaporation and depletion at 40 hours after corium relocation. Until the dousing water is depleted at 1.5 hours, the R/B pressure is controlled. Then it increases continuously until the moderator dryout at 8.2 hours. Along with the steaming from the calandria shield water, the pressure rises again and reaches the containment failure pressure at 27 hours before the calandria tank failure when a late peak pressure occurs from rapid steam generation as the corium relocates into the shield water.

For the last, the old calculation results [2] are shown in Table.1 additionally to compare with the updated results. In the old calculation, the reactor scram occurred due to PHTS high pressure (> 10.65 MPa) but the new one due to the pressurizer low level according to the FSAR analysis. From this, the trip time delay of 100 seconds affected the accident progression thereafter.

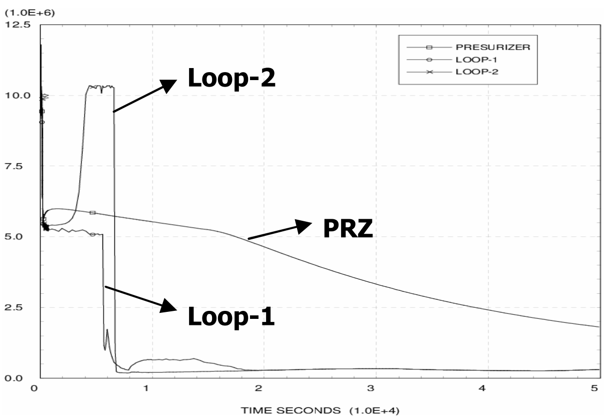

Fig.2 Primary Pressure [Pa]

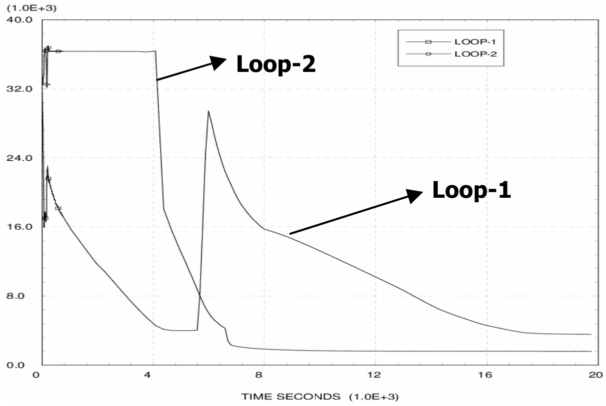

Fig.3 Primary Coolant Mass [Kg]

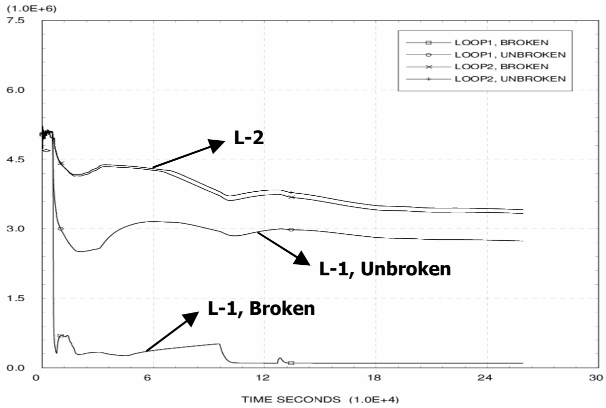

Fig.4 S/G Pressure [Pa]

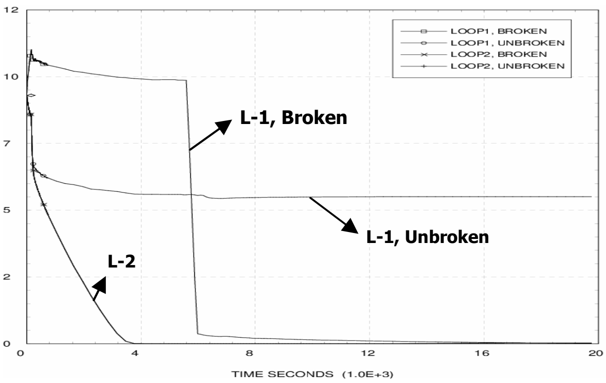

Fig.5 S/G Water Level [m]

3. SUMMARY

The multiple SGTR sequences are analyzed according to the trip coverage in the FSAR and the accident progression is compared with a old one.

ACKNOWLEDGMENTS

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REFERENCES

[1] KAERI, Development of Computer Code for Level 2 PSA of CANDU Plant, KAERI/RR-1573/95, 1995.
[2] Yong-Mann Song, "Impact of Crash Cooldown on Source Term Release During SGTR at PHWRs," IAEA second workshop on PSA for PHWR, 2001.