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Effectiveness of ECI in Very Small LOCA for Wolsong-1 NPP

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1. Introduction

Emergency coolant injection(ECI) is powerful heat sink for most large and small loss of coolant accident(LOCA). For the credible actuation and the prevention of spurious actuation of ECI, conditional signal is adopted into Emergency core cooling system (ECCS). The conditional signals for ECI in Wolsong-2,3,4 are reactor building(R/B) high pressure, moderator high level and sustained primary coolant low pressure. But for Wolsong-1, reactor building high temperature is used instead of sustained primary coolant low pressure. The effectiveness of ECI conditional signal in very small LOCA for CANFLEX loaded Wolsong-1 is examined here.

2. Analysis Methods

Small LOCA is defined as the accident in which the break size is less than 2.5% of reactor header. Reactor building high pressure trip is primary trip in large break size LOCA because the pressure of containment is increasing fast in large LOCA. But in very small break LOCA, the pressure increase in containment is too slow to actuate trip and to meet emergency coolant injection condition. Emergency coolant can not be injected into the core in very small LOCA even though the inventory of coolant is decreasing. The integrity of fuel and fuel channel can be damaged without ECI. The thermal-hydraulic behavior in very small LOCA is analyzed with CATHENA and consequent pressure behavior in reactor building is analyzed with PRESCON.

2.1. T/H behavior

The base T/H circuit model for small LOCA is developed at 103%FP. Steady state nominal value for some parameter is shown in Table 1. Effective trip parameters for small LOCA are R/B high pressure trip, coolant low pressure trip and pressurizer low level trip. Among ECI conditional signal for Wolsong-1, the effective signal is R/B high pressure(R/B HP) which has same set-point as the R/B high pressure trip(RBH). But for very small break size less than 1.0% reactor header, the discharged coolant inventory is too small to reach the set-point of R/B pressure trip and R/B HP conditional signal. For three kinds of break sizes, the trip times for the effective trips are shown in table 2. For 1.2% RIH break, the pressure in reactor building triggers first trip and ECI condition. But for 0.8% and 0.4% break sizes, emergency coolant can not be injected into the core. The discharged coolant flows for different break sizes are shown in Figure 1.

Table 1 Steady state value at 103% FP

Parameters		Value
Outlet head pressure (MPa(a))	ROH 1	11.36
	ROH 3	11.36
	ROH 5	11.36
	ROH 7	11.36
Inlet head pressure (MPa(a))	RIH 2	10.03
	RIH 4	10.02
	RIH 6	10.02
	RIH 8	10.03
S/G drum pressure (MPa(a))		4.69
Inlet coolant temperature (℃)		268
Outlet coolant temperature (℃)		311
Core flow per pass (kg/s)		1,898
Pressurizer level (m)		12.5
Pressurizer pressure (MPa(a))		9.98

Table 1 Trip time and ECI condition

	1.2 % break	0.8 % break	0.4 % break
1st trip	RBH (90)	LP (264)	PLL(520)
2nd trip	LP (160)	PLL (266)	LP (562)
R/B HP for ECI condition	met	Not met	Not met

( ) : trip time in second
RBH : Reactor Building High pressure trip
LP : PHT Low Pressure trip
PLL : Pressurizer Low Level trip

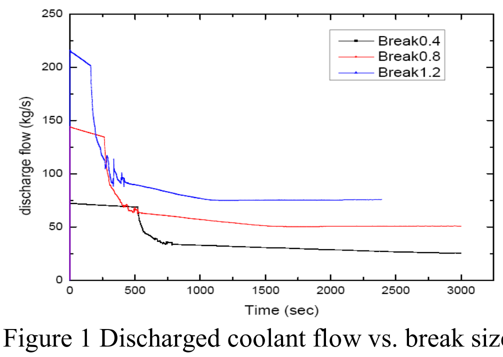

Figure 1 Discharged coolant flow vs. break size

2.2. Pressure behavior in R/B

The discharged hot coolant makes the pressure in the reactor building increase. The larger the break size, the higher the pressure in reactor building. As shown in figure 2 and 3, R/B HP set-point (3.45kPa) is not reached for break sizes less than 1% break while R/B HP is met for 1.2% break. Fuel integrity can be impaired without ECI for very small break less than 1%.

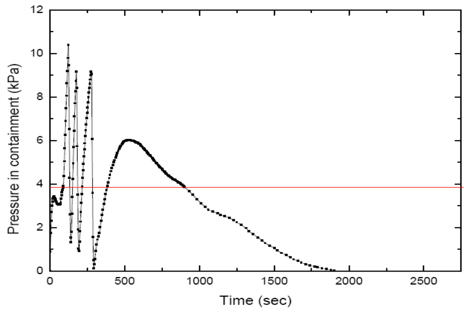

Figure 2 Reactor building pressure for 1.2% break

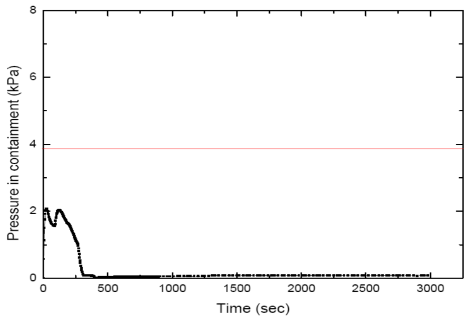

Figure 3 Reactor building pressure for 0.8% break

2.3. ECI effectiveness

The amount of void occurring during 0.4% break is compared between ECI available and ECI unavailable in figure 5. It can be seen that for the ECI unavailable case, the void in the fuel channel is very high at the time beyond 1,000 sec and fuel is expected to fail. There is two way to make it possible to inject emergency coolant into the circuit for Wolsong-1. One is to lower R/B HP ECI condition set-point and RBH trip set-point from 3.45kPa to 1.0kPa. The other is to install additional ECI conditional signal. Usually sustained reactor coolant low pressure (SLP) is very effective for very small break LOCA while R/B HP is effective for large break LOCA.

2.3.1 R/B HP set-point

The lowering of R/B HP ECI conditional set-point to 1kPa is simulated in 0.4% break LOCA for the confirmation of reactor cooling effectiveness. ECI condition is met around 3 sec and emergency coolant is injected into the core at 646 sec after break [Figure 4] and coolant channel flow also increases at the corresponding time. The increased flow prevents fuel heatup and the integrity of fuel is shown to be conserved from the amount of channel void [Figure 5].

2.3.2 Sustained reactor coolant low pressure (SLP)

Addition of SLP to ECI conditional signal is assumed. The set-point for SLP is 5.52 MPa(a) with 10 minutes sustained time. The actuation time for ECI is shown to be 1380 sec and fuel sheath temperature is decreasing to the stable condition with ECI as shown in Figure 6.

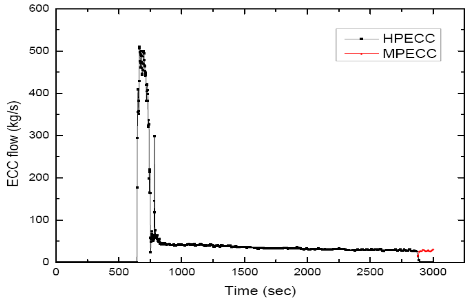

Figure 4 ECC flow at 0.4% break

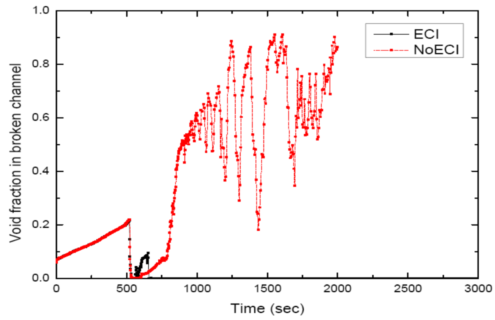

Figure 5 Void fraction at 0.4% break

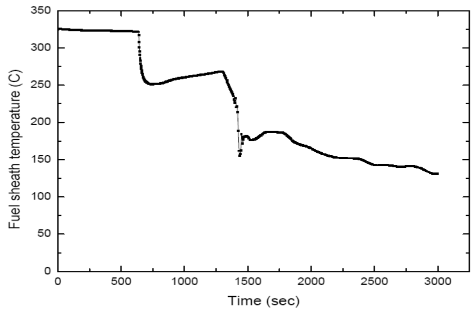

Figure 6 Fuel sheath temperature with SLP at 0.4% break

3. Results

The effectiveness for ECI is assessed for very small break LOCA in Wolsong-1 NPP. Successful injection of emergency coolant is crucial for the fuel and fuel channel integrity. Low reactor building pressure from very small LOCA is not enough to actuate conditional signal for ECI. Among the conditional signal, lowering of R/B HP set-point (from 3.45kPa to 1.0kPa) and installment of sustained reactor coolant low pressure can be a solution for successful emergency coolant injection into the core.

REFERENCES

[1] CATHENA Mod-3.5c Input Reference, 1999, AECL
[2] FSAR for Wolsong-2,3,4
[3] 86-03500-AR-035 Analysis report for small LOCA