Analysis of Primary External Cooling Water Injection Mass during Extended SBO in Wolsong #1

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1. Introduction

The targets of severe accident management are to remove continuous core heat, to maintain containment integrity, and to minimize fission product (FP) release into the environment. The strategy for ceaseless removal of core heat is a key method, because severe accident progression can be mitigated and FP released outside fuels can be scrubbed due to cover fuels with water. One of government requirements according to inspected results of all nuclear power plants in Korea following Fukushima accident is to install external cooling water injection paths for core cooling.

The purpose of this paper is to analyze mass of primary external cooling water injection which is going to be installed in Wolsong #1.

2. Methods and Results

In this section, a plan related to external cooling water path in Wolsong#1 was explained according to government requirements, and effectiveness of the underway scheme was analyzed with regard to severe accident. Integrated Severe Accident Analysis code for CANDU plants (ISAAC) for the analysis was used.

2.1 Scheme of External Cooling Water Path in Wolsong#1

Wolsong#1 (CANDU reactor) was designed for core cooling using emergency water supply system (EWS) that can provide cooling water to steam generators, primary heat transport system (PHTS), and an emergency core cooling system (ECCS) heat exchanger. Accordingly, external cooling water paths were connected to EWS, as shown in Fig.1.

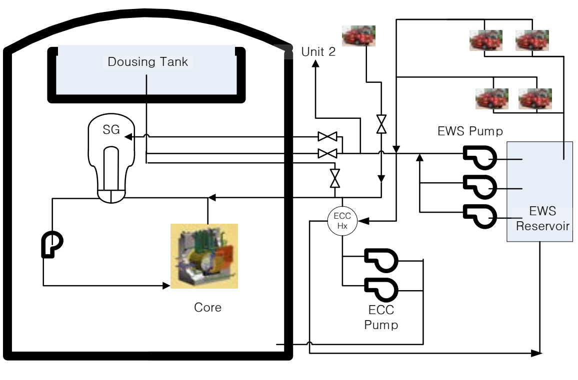

Fig.1. Scheme of external cooling water path in Wolsong#1

The external cooling water injection line (ECWIL) connected to EWS can provide cooling water to steam generators and PHTS, and the other ECWIL connected to ECCS can only provide for PHTS [1].

CANDU reactors do not need to depressurize PHTS during severe accident because pressure tubes as a pressure boundary rupture if severe accident occurs, and PHTS pressure decreases as a result of that. It is an advantage for sufficient supply of core cooling water. The feature is useful for supply of external cooling water.

2.2 Analysis of Extended SBO for Wolsong#1

Extended station blackout (ESBO) assumed that fixed AC power and DC power failed during seven days. According to assumption of ESBO, severe accident management guidelines (SAMG) [2] entered at 4.4 hours after occurrence of the ESBO shown in Table1, and primary heat transport system pressure decreased to atmospheric pressure shown in Fig.2. Severe accident progression of Wolsong #1 was delayed due to much inventory of cooling water, while time of containment failure which occurred before Calandria failure was faster than other type plants because of low containment design pressure.

Table1. Results of ESBO analysis for Wolsong#1

Events	Time [hr]	Remarks
Steam generators dry	2.7	
Pressure tubes ruptured	3.9	Primary heat transport system depressurization
SAMG entry	4.4	Calandria level decreased
No water in Calandria	12.6	
Containment failed	21.1	
Calandria failed	44.0	
Reactor vault floor melt through	149.6	

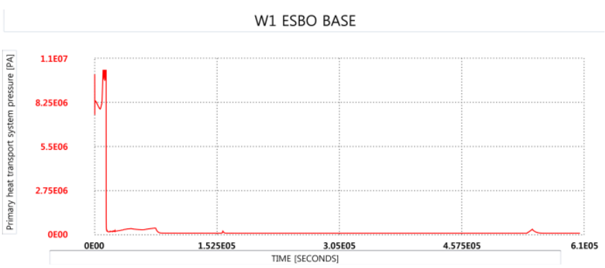

Fig.2. Primary heat transport system pressure

Containment pressure and Calandria level according to severe accident progression were shown in Fig.3 and Fig.4. Containment failure at 21.1 hours and Calandria failure at 44.0 hours occurred. Reactor vault melt through occurred at 149.6 hours.

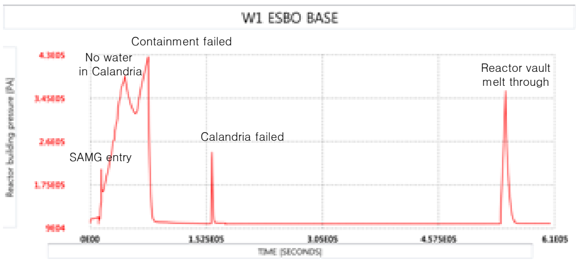

Fig.3. Containment pressure

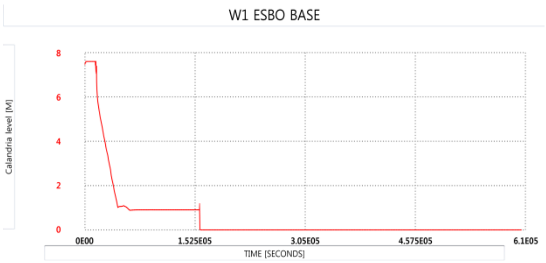

Fig.4. Calandria level

2.3 Analysis of Primary Cooling Water Injection with ECWIL

Objective of the analysis is to know how much cooling water is needed for primary cooling water injection during seven days. The analysis method was to provide primary cooling water according to Calandria level. First cooling water injected to Calandria at 14.4 hours (10 hours after SAMG entry time), and primary cooling water shown in Fig.5 injected below 2.0 m of Calandria water level and stopped the injection over 6.8 m after first injection. Injection flow for the analysis was about 19 kg/s according to ECWIL design [1].

The results of the analysis provided Table2. Six injections of primary cooling water were implemented during the analysis time. Each of injection masses and injection period decreased and the necessary time from 6.8 m to 2.0 m in Calandria increased due to decease in core heat generation as time passed. Also, though injection for core cooling was taken, containment failure cannot be prevented.

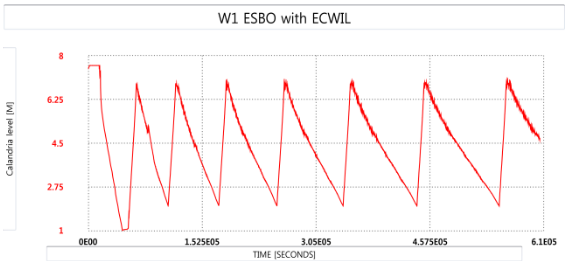

Fig5. External Cooling Water Injection in Calandria

Table2. Comparison of ESBO and ESBO with ECWIL

Events	ESBO [hr]	ESBO+ECWIL[hr]	Injection mass[ton]
Steam generators dry	**2.7**	**2.7**	
Pressure tubes ruptured	**3.9**	**3.9**	
SAMG entry	**4.4**	**4.4**	
No water in Calandria	**12.6**	**12.6**	
ECWIL first started	-	14.4	
ECWIL stop	-	17.7	234.4 t
Containment failed	**21.1**	**21.1**	
ECWIL secondary started	-	29.6	
ECWIL secondary stop	-	32.4	195.8 t
Calandria failed	**44.0**	-	
ECWIL third started	-	48.4	
ECWIL third stop	-	51.2	192.6 t
ECWIL fourth started	-	70.1	
ECWIL fourth stop	-	72.8	190.4 t
ECWIL fifth started	-	94.7	
ECWIL fifth stop	-	97.4	187.2 t
ECWIL fifth started	-	122.2	
ECWIL fifth stop	-	124.8	185.3 t
Reactor vault floor melt through	**149.6**	-	
ECWIL sixth started	-	152.8	
ECWIL sixth stop	-	155.4	183.7

3. Conclusions

The purpose of the analysis is to identify necessary cooling water mass during seven days. Six injections for the analysis period need to remove primary core heat, and total mass for six injections is about 1370 tones. ECWIL is useful for severe accident mitigation except containment failure. Methods for decrease in containment pressure with ECWIL are needed for preventing from containment failure.

REFERENCES

[1] Wolsong#1 External Cooling Water Injection Line Installation design report, KHNP, 2013.
[2] Wolsong#1 Severe Accident Management Guidelines, KHNP, 2013