A Study on Containment Flooding Strategy during Severe Accidents in PHWR

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1. Introduction

Several benefits can be realized by flooding the containment for pressurized water reactors. First, the external reactor vessel cooling can be established. Second, any core material which remains in the vessel after RPV failure will be cooled. Third, water on the containment floor may quench the core debris following vessel failure preventing basemat melt-through. Fourth, fission products released from core debris on the containment floor will be scrubbed. For this reason, containment flooding or cavity flooding is chosen as one of the severe accident management strategies in WOG SAMG[1] and CEOG SAMG[2]. This paper examined that these benefits can be realized in the CANDU 6 plant, too.

2. Analysis of Flooding Strategy

Flooding strategy is evaluated based on the feasibility, the effectiveness, and the adverse effects.

2.1 Feasibility of the strategy

Containment flooding means a supply of water to the containment basement intentionally so that the core debris in the basement can be covered with water for CANDU 6 plant. There are two means which can deliver water to the basement. One is a dousing spray which is inside of the containment. The other is an emergency water supply system (EWS)[3] which is located outside of the containment.

2.2 Effectiveness of the strategy

The corium mass in the basement becomes approximately 980 metric tons (UO_2 : 99 ton, Zircaloy 43 ton, others including abraded concrete : 849 ton) and the depth of corium is about 30 cm. The heat flux of the corium is low enough to be cooled when it is covered with water regardless of its thickness. The initial temperature of the corium is about 1500 K and becomes below 400 K soon (see Fig. 1). So the containment flooding may cool the corium and prevent the core concrete interaction at the basement.

2.3 Adverse effect of the strategy

The equipment locations in the basement are designed so that all the equipment is safe even though water in the containment are spilled and accumulated in the basement. But if the additional water is introduced in the containment using the EWS, then vital equipment can be submerged in the water. Caution should be taken if the containment flooding is achieved by the EWS.

3. Necessity of Flooding Strategy

There is a lot of water in the containment. PHTS, calandria, calandria vault contains water. If these systems are not cooled by the their secondary systems, the water evaporates and the pressure in the containment increases. If local air coolers (LACs) are not operating, the containment will fail eventually due to the high pressure even if the spray system is operated. When the containment fails, the corium is still within the calandria vault. So the containment flooding strategy is not needed. If LACs are operating, the steam in the containment atmosphere condenses to water and the containment maintains its integrity. The condensed water flows to the basement. When the corium reaches the basement, the water in the PHTS, the calandria, and the calandria vault evaporates to the containment atmosphere and condensed by LACs, and accumulated in the basement. The water level in the basement is shown in Figure 2. The water level exceeds 1 m even though the spray is not operated (see Case 2 in Figure 2). Even if we assume the some water is lost to somewhere in the containment, still the corium will always be covered by water. So the corium in the basement always can be cooled without the addition of water to the basement using the spray system or the EWS while the LACs are operating. All analysis were done using ISAAC code[4].

4. Conclusions

Containment flooding strategy was evaluated for Wolsong plant. When LACs are not operating, the containment fails long before the corium reaches the basement. When LACs are operating, the corium in the basement is always covered with water even if the spray system did not operate. The water in the basement comes from the condensation of the steam in the containment atmosphere which is from the PHTS, the calandria, and the calandria vault by boil off. So it can be concluded that the intentional containment flooding is not needed for the Wolsong plant.

REFERENCES

[1] "Severe Accident Management Guidance," Westinghouse Owners Group, 1994
[2] "Generic Accident Management Guidelines," Combustion Engineering Owners Group, 1994
[3] "Emergency Water Supply System," Design Manual 8602-34610/34611-DM-000, Rev.1, 1995
[4] "ISAAC Computer Code User's Manual," KAERI/TR-3645/2008, KAERI

Table 2. The timing of the major events during a severe accident progression

	Case 1*	Case 2*	Case 3*
Reactor scram	0	0	0
LAC turn OFF	-	-	0
SG dry (loop 1)	4151	4151	4078
SG dry (loop 2)	4151	4151	4072
Dousing spray starts	**4944**	**-**	**4449**
Core uncover (loop 1)	6333	6324	6209
Core uncover (loop 2)	6329	6328	6206
Dousing tank depleted for spray	7460	-	5520
CTK rupture valve open	7421	7413	7282
SAMG entry condition	**7422**	**7414**	**7283**
Pressure tube rupture (loop 2)	7421	7414	7282
Pressure tube rupture (loop 1)	7629	7613	7483
Corium relocation start (loop 1)	13784	13875	13621
Corium relocation start (loop 2)	13784	13872	13621
Core collapsed (loop 1)	26320	26600	27979
Core collapsed (loop 2)	26320	26600	27979
No water in CTK	29062	29366	30116
Calandria vessel failed	132351	132601	141631
R/B failure	**-**	**-**	**141718**
Calandria Vault Breached	**445199**	**456004**	**455920**
End of calculation	576000	576000	576000

*Note : Case 1 : LAC & spray operating
Case 2 : LAC operating. No spray
Case 3 : No LAC. Spray operating

Table 1. The important plant parameters for Wolsong plant

Plant Parameter		Value
Power (MWth)		2,140
Water Inventory (10^3 kg)	Steam Generator	151
	PHTS	120
	ECC Tank	214
	Dousing Tank (Spray) (ECC)	2162 (1551) (611)
	Calandria	216
	Calandria Vault	370
Core Material (10^3 kg)	UO_2	99
	Zircaloy	43
Containment Failure Pressure (kPa(g))		417

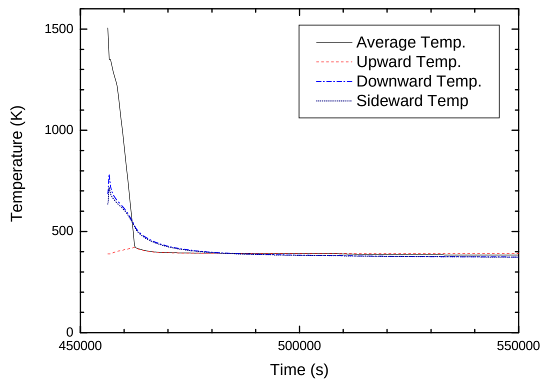

Fig. 1. Various temperature of corium in the basement.

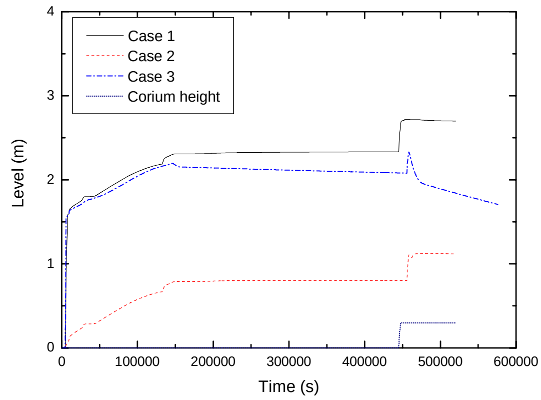

Fig. 2. Water level and corium height in the basement.