A Study on the External Calandria Vessel Cooling for PHWR SAMG

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1. Introduction

Severe accident management guidance(SAMG) for the Wolsong heavy water reactor is being developed at KAERI. And seven individual accident management strategies are included in this SAMG. One of the key strategies is to maintain the cooling water of the calandria vault to retain the relocated corium within the calandria vessel through an external vessel cooling during severe accident scenarios, which is so-called an in-vessel retention for the light water reactor. This study focuses on the feasibility of the in-vessel retention strategy in the Wolsong heavy water reactor.

2. Analysis and Results

Several limiting factors can be considered in studying the in-vessel retention for a light water reactor. These factors include the choking limit for a steam venting due to the insulation structure of the reactor cavity, the critical heat flux for a downward facing boiling on the vessel outer surface[1], the focusing effect by a thin metal layer on the top of the molten corium in the lower plenum of the reactor vessel, and the two-phase flow instabilities in the natural circulation loop within the flooded cavity due to the thermal insulation structure around the reactor vessel[2].

2.1 Limiting Factors of the Chocking andthe two phase flow instability

In the typical light water reactor design, there is a bottleneck between the reactor vessel lower head and the insulation structure. When a high rate of vapor is generated on the vessel lower surfaces under severe accident conditions a choking can occur at the bottleneck, which may increase the vessel wall temperature and finally result in a vessel failure. Wolsong plants, however, have no thermal insulation structure around the calandria vessel. Hence the choking limit for a steam venting through the bottleneck or the two-phase flow instabilities in the natural circulation loop within the flooded calandria vault can not be limiting factors in the Wolsong plants.

2.2 Limiting Factor of the Focusing Effect

There is no considerable steel material in the core of the Wolsong plant, and as a result only a negligible metal layer can be formed on the corium of the calandria bottom. This means that we don't need take account of the limiting factor of the focusing effect from the metal layer in the Wolsong plants.

2.3 Limiting Factor of the Critical Heat Flux

The corium from this plant has a lower volumetric decay heat power compared with the same powered light water reactor. This results from the fact that the plant uses natural uranium and that a severe accident progression occurs slower than that of a light water reactor. Table 1 compares the accident progression of the Wolsong plant with that of a typical Korean standard nuclear power plant (KSNP) which is a 1000 MWe light water reactor. The selected scenario is a typical loss of coolant sequence without any recovery action. The ISAAC(Integrated Severe Accident Analysis Code for CANDU Plants) computer program[3] and MAAP[4] have been used in the calculation. Calculation results show that the time of corium relocation, calandria water depletion, and calandria vessel failure for the Wolsong plant is much later than the times for the KSNP.

Table 1. Comparison of the accident progression of the Wolsong plant with the KNGR

Key Events	Wolsong plant (hours)		KNGR (hours)
	Loop 1	Loop 2	
SG dryout	2.3	0.9	
LRV(PSV) open	1.5	1.8	
Core uncovery start	early	2.2	early
fuel channel rupture	2.3	3.1	
Core melt start			0.9
Corium relocation	2.3		1.5
Calandria (RV) dryout	9.0		1.6
Calandria (RV) fail	35.3		2.6

One of major different design features of the Wolsong plants from other light water reactors is a calandria vessel. The calandria is always submerged in water because the calandria vault is flooded during a normal operation. And the molten corium in the bottom of the calandria vessel has a very large heat transfer area to the outside water of the calandria vault through the vessel wall. As a result, the critical heat flux is not exceeded on the caldaria vessel wall's surface. Figure 1 shows the total heat transfer rate from the calandria vessel to the caldaria vault shield water for two maximum heat flux limits. When the maximum heat flux is limited artificially to 0.1 MW/m^2, the vessel wall fails at about 12 hours after the accident initiation. If the maximum heat flux is increased to 0.2 MW/m^2 , the vessel wall does not fail as long as the wall is submerged in water. The vessel failed only after the bottom wall was uncovered.

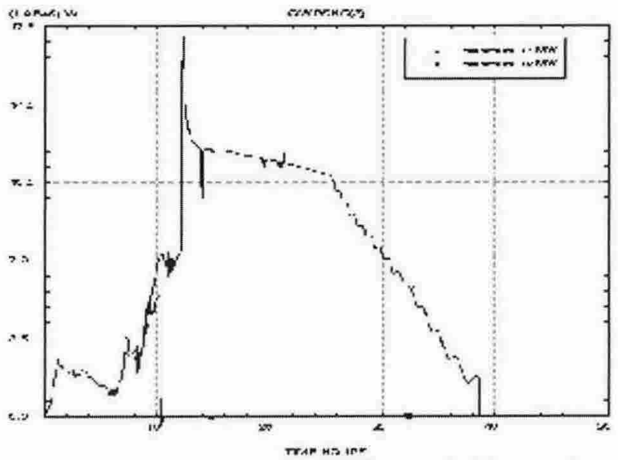

Figure 1. Total heat transfer rate from caladria vessel to calandria vault water

3. Conclusion

Wolsong plants have a greater advantage for an in-vessel retention during severe accidents. The choking limit for a steam venting and the two-phase flow instabilities in the natural circulation loop due to the insulation structure, and the focusing effect by a thin metal layer on the top of the molten corium are no longer limitations in the Wolsong plants. In addition, a low power & low decay heat, a large heat transfer area of the lower plenum, and an inherent flooding system of the calandria vault will also be an advantage for the critical heat flux limitation. Based on the above discussion, the in-vessel retention strategy seems to be very effective for the Wolsong plants.

Acknowledgements

This study has been carried out under the nuclear R&D program planned by the Korean Ministry of Science and Technology(MOST).

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