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Analysis for Condition of Corium Discharge from Reactor Vessel using MELCOR

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1. Introduction

Even though a reactor vessel is failed, containment is a final physical barrier to prevent the release of radioactive materials to the environment. To analyze the ex-vessel phenomena, the initial conditions must be identified clearly for the accurate analysis. The corium coolability on a reactor cavity is dependent on the condition of corium discharge from a reactor vessel.

The purpose of this paper is to find a representative condition of corium discharge from a reactor vessel for OPR1000, Korean representative operating PWR.

2. Method

The MELCOR code was used to analyze the progress of accidents [1]. The initiating events include SBO, TLOFW, SGTR, SBLOCA and LBLOCA. In each initiating event, the accident progress which resulted in the earliest failure of the reactor vessel was adopted based on the results of the level 2 PSA [2, 3]. In the selected accident sequences, the reactor trip was set. However, all the ESFs were assumed to be failed for operation. PSVs and MSSVs were open and shut. After the entry of SAMG, the mitigation for the depressurization of reactor coolant system was performed by opening safety depressurization valves. For the SBO sequence, one sequence with the highest frequency was added. It was a SBO-T4 sequence. In the SBO-T4 sequence, two turbine-driven auxiliary feedwater pumps (TDAFPs) were operated for four hours.

3. Results

3.1 Diameter of Corium Jet from Reactor Vessel

The diameter of corium jet from a reactor vessel is initially equal to the equivalent diameter of the broken hole on a reactor vessel. In the input model, the lower plenum of a reactor vessel was divided into one circle and five ring nodes. In one node, the total areas of penetration tubes were calculated and inputted. For the area in one node, the equivalent diameter could be calculated under the assumption it was regarded as one circle. For the additional case, only one penetration tube was modeled for each node. It implies that one tube plays a role for the very fast depressurization when a reactor vessel is broken. Fig. 1 shows the corium release mass flux and the failure diameter. In the MELCOR code, the failure diameter increased continuously by the Plich's model. The decrease of the corium release mass flux means that the failure diameter on the reactor vessel is not equal to the diameter of the melt jet discharged from the reactor vessel. Therefore, the maximum diameter of the melt jet was about 30 cm.

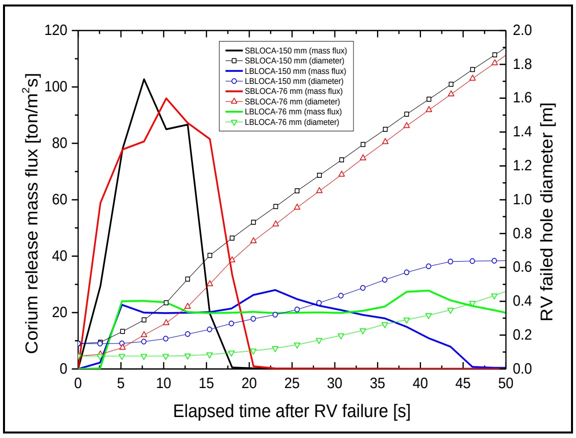

Fig. 1. Corium Mass Flux and Equivalent Diameter from Reactor Vessel Failure

3.2 Composition and Mass of Corium

Total corium mass ejected through reactor vessel breach was about 130 tons as shown in Fig. 2. It was about 80 % of whole core mass.

Fig. 3 shows the composition percentage in lower vessel head at the time of reactor vessel failure. In the case of SBO-T4 scenario, feedwater was supplied to a steam generator. Therefore, core can be cooled by the natural circulation in a primary loop due to the cooling in the steam generators. After the failures of TDAFPs, there was longer time by the failure of the reactor vessel. Therefore, more Zirconium was oxidized. For the other scenarios, the degree of oxidization was low due to the early failure of a reactor vessel.

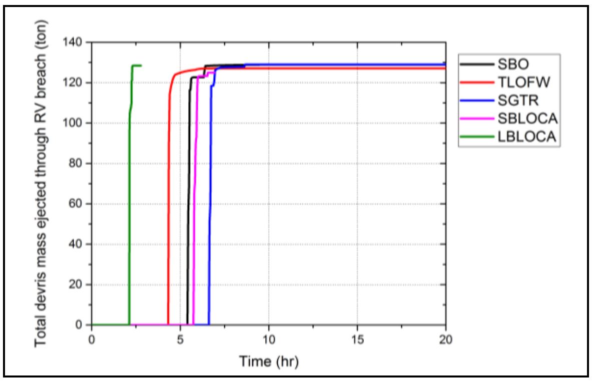

Fig. 2. Total Corium Mass Discharged from Reactor Vessel

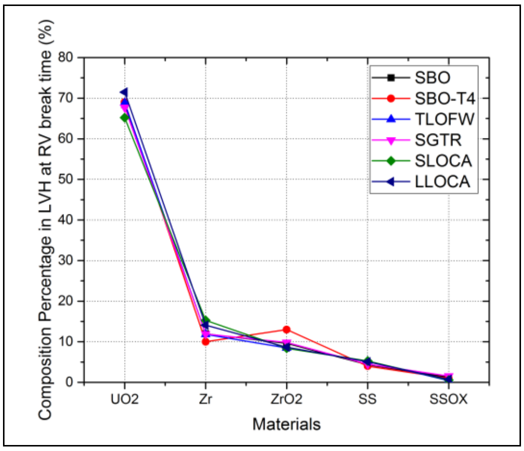

Fig. 3. Composition Ratio of Corium.

3.3 Temperature of Corium

The corium was accumulated in the lower plenum as a formation of molten pool or debris bed. Therefore, the temperature at each location had a wide range. Fig. 4 shows the temperature of corium in each accident sequence when a reactor vessel was failed. The point means the average temperature for the corium. The upper error bar means the maximum temperature of molten oxide pool. The lower error bar means the temperature of particulate debris at the failed penetration tube.

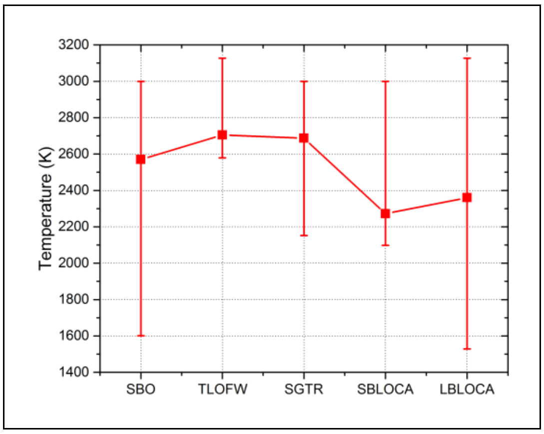

Fig. 4. Temperature of Corium.

3.4 Discharge Velocity of Corium

The corium velocity discharged from a reactor vessel to a reactor cavity is calculated by the pressure difference between lower plenum and reactor cavity and debris and molten pool height. Fig. 5 shows the discharge velocity of corium when a reactor vessel is failed. As shown in Fig. 1, the corium jet diameter became smaller than the broken diameter on the lower plenum after about ten seconds of the reactor vessel failure. After that time, the corium discharge velocity decreased due to the decreases of the pressure difference and pool height.

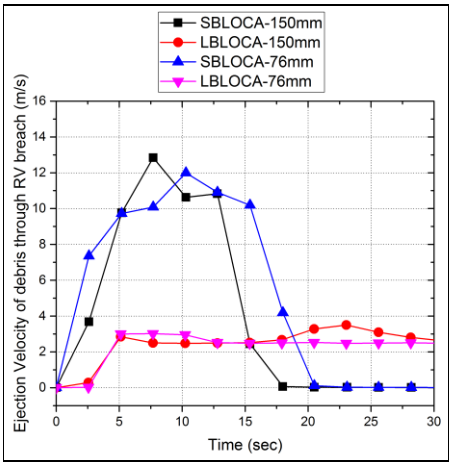

Fig. 5. Discharge Velocity of Corium.

4. Conclusions

To estimate the condition of the corium discharge from a reactor vessel, main severe accident sequences were simulated using the MELCOR code. The sequences resulting in the early failure of a reactor vessel were selected from a decay heat point of view. The decay heat is a key variable for debris coolability on a reactor cavity. Main results were calculated with a range of a variable due to the wide range of the conditions and the sequences.

The results can be used for the ex-vessel analysis in a severe accident of OPR1000.

Acknowledgement

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