Comparison of MAAP5-CANDU and MAAP4-ISAAC MCCI Analysis for CANDU

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1. Introduction

The severe accident phenomena analysis for domestic CANDU type NPPs (nuclear power plants) has been performed using the MAAP4[1)]-ISAAC code developed by KAERI and FAI (Fauske & Associates LLC.), which has been utilized as the only and effective tool up to date. On the other hand, the overseas countries holding the CANDU type NPPs have used MAAP-CANDU code developed by FAI with EPRI (Electric Power Research Institute) and COG (CANDU Owners Group).

Recently, the possibilities for periodic upgrade and maintenance of MAAP4-ISAAC code is becoming uncertain for various reasons. So, KHNP decided that the severe accident analysis code should be changed from MAAP4-ISAAC to MAAP5-CANDU and developed the base input model (parameter file) for domestic CANDU type NPPs. Even though the MAAP4-ISAAC and MAAP5-CANDU have the similar structures, the previous severe accident results produced by MAAP4-ISAAC cannot be replaced by those from MAAP5-CANDU right now in practical aspects. At this stage, it is needed that the comparison of the analysis results produced by those two codes and the identification of the appropriateness for model parameters should be performed.

MCCI (Molten Core Concrete Interaction) phenomena has been one of the unresolved issues for the severe accident analysis of NPPs. In this analysis, we compare the major results produced by MAAP5-CANDU and MAAP4-ISAAC for the same accident conditions. The major purpose of this work is to find the insight for the difference of code characteristics and the major factors that affect the major calculation results. Based on such efforts, we can get the another insights for severe accident analyses of CANDU type NPPs and change the analysis frame for CANDU from MAAP4-ISAAC to MAAP5-CANDU in the near future.

2. Methods and Results

2.1 Accident Sequence and conditions

KHNP had been completed the detailed MCCI analysis for domestic CANDU type NPPs with the accident sequences giving high contribution rates to the PDS (plant damage status) frequency resulted from the PSA (Probabilistic Safety Analysis)[1]. Among these sequences, the most conservative sequence used in this analysis is as below;

1) Initiating Event
   : Loss of end-shield cooling due to earthquake
2) Accident Conditions
   : Failure of SI and Secondary Injection
   : Local Air Cooler Success

Also, we could find the most conservative combination of parameters through the sensitivity analysis that could maximize the downward ablation due to MCCI for CANDU type NPPs. So, this combination is used for this analysis.

The analysis time is 72 hours and it is assumed that the CVWM (Calandria Vault Water Makeup) using external emergency cooling water injection is initiated at 24 hours after the calandria tank failure.

The MCCI analyses with two codes are performed for the same accident sequence and conditions described above. The detailed code versions are MAAP5-CANDU version 5.0A and MAAP4-ISAAC version 4.03.

2.2 Analysis Results

The figure 1 shows the change of PHTS (Primary Heat Transfer System) water mass.

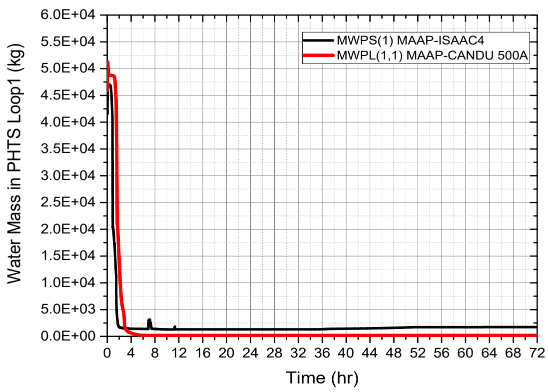

Figure 1. PHTS LOOP1 Water Mass

1) MAAP is an Electric Power Research Institute (EPRI) software program that performs severe accident analysis for nuclear power plants including assessment of core damage and radiological transport. A valid license to MAAP4 and/or MAAP5 from EPRI is required.

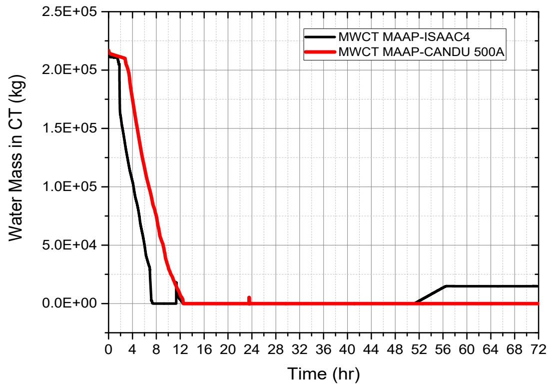

Figure 2. Calandria Tank Water Mass

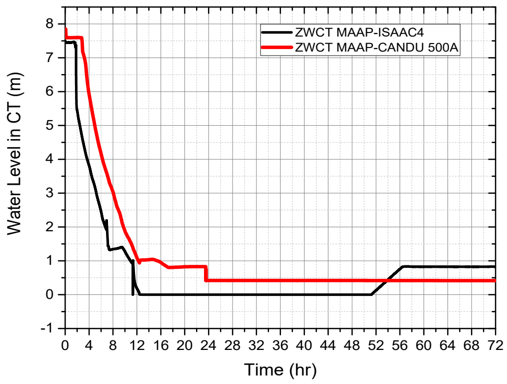

Figure 3. Calandria Tank Water Level

The reduction rate is somewhat slower for the case of MAAP5-CANDU. So, as shown in figure 2 and 3, the change of calandria tank water lever and mass is also somewhat slower for the case of MAAP5-CANDU.

From figure 2, while the calandria tank water mass is reduced to 0 kg, the water level shown in figure 3 is not reduced to 0 m since the water level calculated in MAAP code generally include the height of debris remained in the calandria tank. However, after the tank failure, the water level calculated by MAAP4-ISAAC is reduced to 0 m, but the water level calculated by MAAP5-CANDU do not reduced to 0 m. That is to say, MAAP5-CANDU calculate that some part of corium is still remained in the calandria tank even after the calandria tank failure [2]. In the case of MAAP4-ISAAC, the whole corium is moved to containment vault [3]. So, the corium mass participated in MCCI given by MAAP4-ISAAC is somewhat larger than that by MAAP5-CANDU. As a result, it is expected that the ablation depth calculated by MAAP4-ISAAC is larger than that of MAAP5-CANDU.

After 52 hours, the calandria tank water level is calculated to be increased again in MAAP4-ISAAC. The reason is thought that the coolant injected into vault flows into the calandria tank reversely through the failure part.

However, the general features related with PHTS behavior except the corium mass moved to the containment vault do not shows the meaningful differences for the both cases, MAAP5-CANDU and MAAP4-ISAAC.

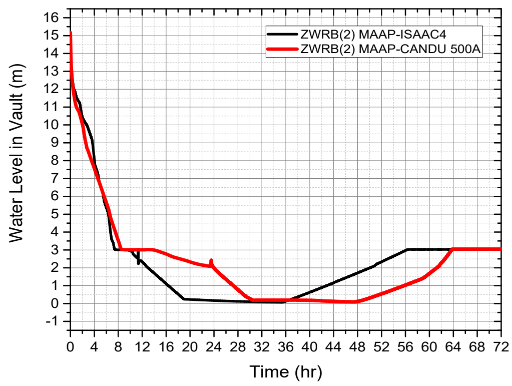

Figure 4. Calandria Vault Water Level

From the figure 4, it is known that the reduction trend of calandria vault water level is similar for the both case until 12 hours after the accident initiation that is the calandria tank failure time for MAAP4-ISAAC. In the case of MAAP5-CANDU, the calandria tank failure time is about 24 hours after the accident initiation. So, there is a 12 hours difference for the water makeup time of the containment vault due to CVWM injection.

It seems that the difference in the calandria tank failure time comes from the difference in the core damage model used in the MAAP5-CANDU and MAAP4-ISAAC.

The figure 5 & 6 shows the progress of ablation due to MCCI. In the case of MAAP5-CANDU, the ablation is started at the time of calandria tank failure and progressed during 1 hours. After that, the ablation is stopped for about 10 hours. Then the ablation restarts and progresses until 48 hours. However, in the case of MAAP4-ISAAC, the temporary halt of reaction does not appear during the ablation progression. The main reason for such temporary discontinuation in MAAP5-CNADU is thought as that the corium is cooled by the remaining coolant in the containment vault even though the ablation is initiated and progressed by the hot corium during 1 hour right after the calandria tank failure. However, as the coolant in the containment vault is dried out, the corium temperature gets increased again up to 1600K, then the ablation is restarted. Finally, the CVWM initiation begins at 48 hours, and then the ablation is stopped because the MCCI is terminated by effective cooling by injected water. The general behavior described above can be also explained by the "Vault Corium Pool Temperature", "Vault Water Level" and "CVWM Flow Rate" profile shown in the figure 7

The final ablation depth calculated by MAAP4-ISAAC is 1.95 m, and it is somewhat larger than that calculated by MAAP5-CANDU, 0.71 m. The main reason for this difference can be explained as that the 12