Molten Corium-Concrete Interaction Behavior Analyses for Severe Accident Management in CANDU Reactor

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1. Introduction

After the last few severe accidents, the importance of accident management in nuclear power plants has increased. Many countries, including the United States (US) and Canada, have focused on understanding severe accidents in order to identify ways to further improve the safety of nuclear plants. It has been recognized that severe accident analyses of nuclear power plants will be beneficial in understanding plant-specific vulnerabilities during severe accidents [1]. The objectives of this paper are to describe the molten corium behavior to identify a plant response with various concrete specific components.

2. Methods and Results

In this section some of the techniques used to model station blackout (SBO) are described. SBO scenario major results-MCCI impact analyses for concrete composition (11 mass fraction such as SIO2,CAO, CO2, ..) are summarized in Table. 1. Four cases selected for analyses are defined as follows.
.S1SBO (Default Concrete with Spray & PAR)
.S2SBO (New Concrete Mass Fraction, Spray & PAR)
.M1SBO (Default Concrete, No Spray & No PAR)
.M2SBO (New Concrete Mass Fraction, No Spray & No PAR)

2.1 MCCI Model

The molten corium pool is usually surrounded on all sides by crust in the case of severe accident conditions. If the critical heat flux at the calandria vessel wall/reactor vault interface is exceeded at a certain limit, the solid crust will be melted and the molten corium inside the calandria vessel will make contact with the reactor vault to bring about a corium-concrete interaction. The results of this paper are to develop and implement severe accident management guidance. Therefore the corium will be maintained inside the calandria vessel by this in-vessel retention strategy.

Though molten corium-concrete interaction (MCCI) is a slow process, it can cause a containment failure if the corium is not cooled at the reactor cavity or the basement in the PWRs. However, the basemat melt-through in CANDU is not considered because molten debris reaches the containment basement floor after several days into the accident, exceeding the three day mission time. Through this study, mitigating effects for containment integrity have been effectively tested and studied through a set of SBOs whose elements were a plant's specific status, scenarios, and parameters.

2.2 MCCI Mitigating Analyses

If the concrete mass fraction is changed for an SBO, slow progress of MCCI with a new MCCI mass fraction delays the concrete ablation to the reactor vault (RV) failure with a time difference of 7.4 hours. In addition, oxidation of zircaloy and core materials generates hydrogen, and MCCI also generates hydrogen and carbon monoxide, which are combustible. The combustion of these gases at once can threaten the integrity of the containment.

Table 1: Mitigating Analyses SBO Scenario Major Results

	1 SG Dry	1 Pr Tube Rupture	NO WATER PRESENT IN CTK	CONTAINMENT FAILED	CTK VESSEL FAILED	> CONCRETE MELT TEMP.	CORIUM FAILURE OPENS AT FLOOR
S1SBO-A1	1,379	4,555	30,230	25,393	139,757	139,762	408,094
S2SBO-A1	1,379	4,555	30,230	25,393	139,757	139,762	495,357
M1SBO-A1	1,446	4,714	29,256	19,613	136,045	136,050	381,342
M2SBO-A1	1,446	4,714	29,256	19,613	136,045	136,050	456,562

2.3 Concrete Ablation Model

For these analysis, Fig.1 shows that difference of concrete ablation thickness between two cases and time difference of reactor vault bottom failure is about 75220 Sec. (21Hrs)

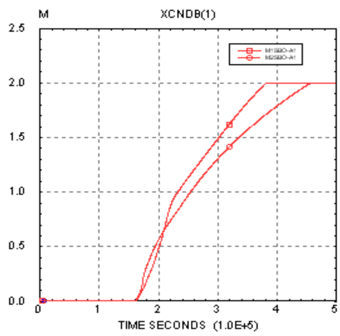

Fig. 1. Thickness of Concrete Ablation from Concrete Default value & New Concrete value from concrete (MCCI).

2.4 MCCI H2 Model

To limit the accumulation of these combustible gases, hydrogen igniters are usually adopted for both PWRs and CANDU plants. The H2 mass decreases about 700Kg with the new MCCI mass fraction. If the containment spray system fails for an SBO, slow progress of the MCCI delays the reactor vault (RV) failure with a time difference of 2.7 hours as Fig. 2. Once the PHTS has voided a boil-off, further gradual pressurization of the containment building will occur from the generation of steam in the calandria tank and in the calandria vault for CANDU plants. Non-condensable gases generated from the interaction of molten corium with the concrete of the calandria vault for CANDU plants and with the concrete of reactor cavity floor for PWRs contribute to the pressure build up in the containment.

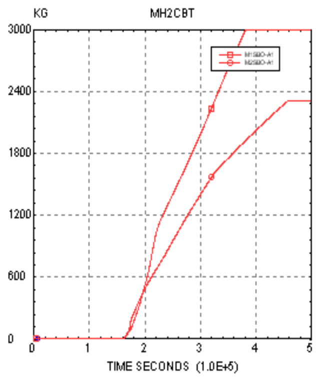

Fig. 2. H2 mass Comparison in REACTOR VAULT: Between Concrete Default value (M1SBO) & New Concrete value (M2SBO) : MCORB(2).

2.5 MCCI CO Model

The CO mass of ISSAC with the used input (M1SBO) is much more (about 40Kg) than that of ISSAC with the suggested input (M2SBO-New concrete mass fraction value) as Fig. 3. This pressurization process could last from hours to several days, depending upon the effectiveness of engineered safety features. As a result, the mitigating effect analyses showed how much various accident statuses (concrete composition & Spray) evidently affect an accident progression.

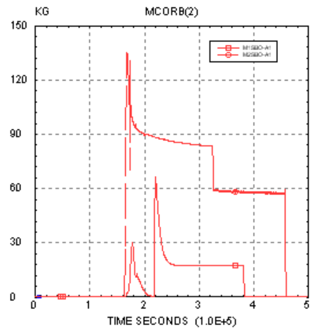

Fig. 3. CO mass Comparison in REACTOR VAULT : Between Concrete Default value (M1SBO) & New Concrete value (M2SBO)

3. Conclusions

Accident analyses techniques using ISSAC can be useful tools for MCCI behavior in severe accident mitigation. Thus far these results of this paper are to develop and implement severe accident management guidance.

REFERENCES

[1] KAERI, Severe Accident Management Guidance for Pressurized Heavy Water Reactors, KAERI/TR-3280/2006, 2006.
[2] USNRC, Individual Plant Examination: Submittal Guidance, NUREG-1335, August 1989.