Development of Basic MELCOR Models to Analyze Severe Accidents in SFP

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1. Introduction

A risk assessment and management of Spent Fuel Pool (SFP) has been raised as an emerging issue after Fukushima accident. One of the essential processes for this is to define potential accident scenarios leading to severe accident in SFP and in turn to evaluate their impact on the severe accident risk. However, little studies have been made related to this matter, mainly due to a lack of the pertinent tools and models with which a reasonable level of accident analysis is possible. In recent times, several new models to analyze severe accidents expected in SFP have been added to the MELCOR 1.8.6 COR package.

This paper provides MELCOR 1.8.6 modeling and analysis results performed for two different fuel assembly configurations of the OPR1000 SFP: one is a single fuel assembly and the other is a 1x4 fuel assembly.

2. Formulation of MELCOR SFP Models

To evaluate cladding oxidation behavior, two models were prepared assuming no water around spent fuel assembly.

2.1 MELCOR Modeling for Fuel Assemblies

The following major features in COR package were made to MELCOR 1.8.6 to facilitate the analysis SFP accident scenarios [1]:

- A new rack component permitting modeling of a SFP racks, and
- An enhanced air oxidation kinetics model.

2.2 SFP MELCOR Modeling

2.2.1 Single Assembly Model

A single fuel assembly (FA) MELCOR model was made to predict axial ignition characterization. The single FA model consists of core, heated channel volume, air circulation volume, and environment as shown in Fig.1. Figure 2 shows the time-history temperature changes along the axial direction. Ignition was started to take place from the most upper cladding.

2.2.2 1x4 Assembly Model

A 1x4 fuel assembly (FA) MELCOR model was developed by using the single FA model to focus on radial ignition characterization as shown in Fig.3.

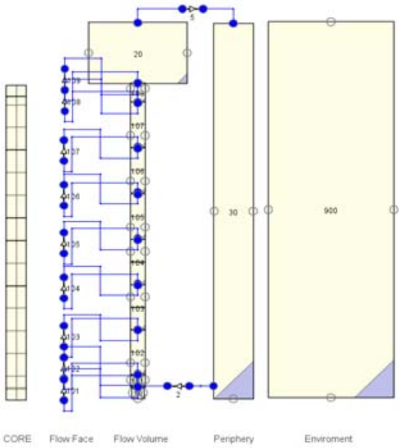

Figure 1. Nodalization of the single FA model

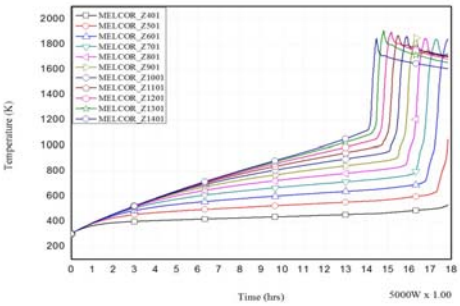

Figure 2. Temperature changes in cladding for the single FA model

The only center FA was heated so that heat and/or fire could be investigated. Figure 4 shows the time-history temperatures for the center FA and periphery FA along the axial direction. It was found that the temperature of the periphery FAs increased due to thermal effect transported from the center FA.

3. Preliminary Analysis for Accident Scenarios

3.1 SFP Severe Accident Scenario

The enhanced MELCOR program is capable of the following types of SFP evaluation:

- normal operating conditions,
- partial loss-of-coolant inventory accident, and
- a complete loss-of-coolant inventory accident.

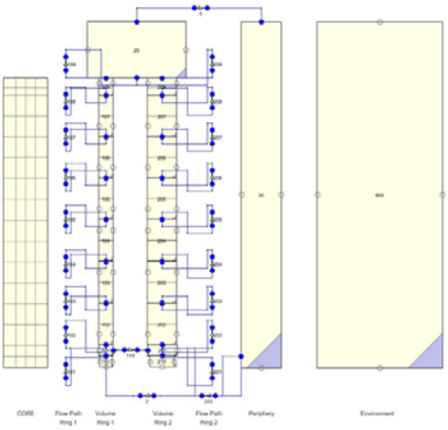

Figure 3. Nodalization of the 1x4 FA model

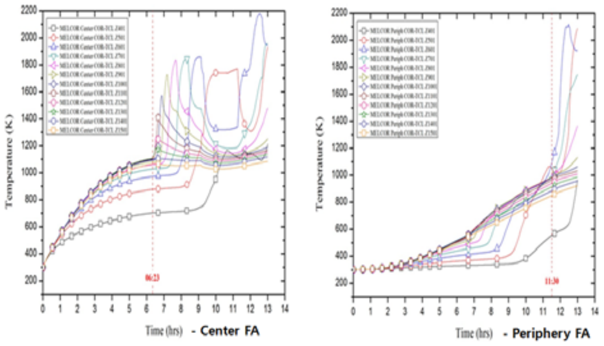

Figure 4. Temperature changes in cladding for the 1x4 FA model

Figure 5 shows the MELCOR modeling for each OPR1000 SFP severe accident scenarios. Initial conditions for the scenarios are given as shown in Table 1.

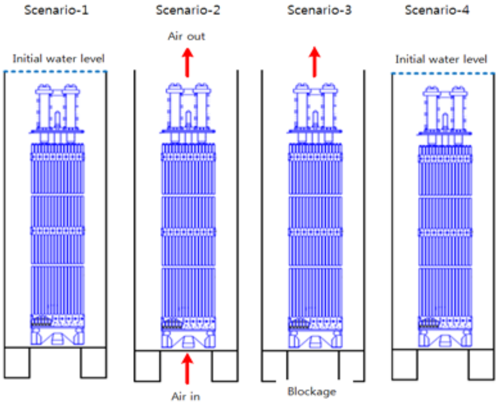

Figure 5. MELCOR modeling for basic scenarios

Table 1. Initial conditions for the scenarios

	Wet/Dry	Thermal Power(kW)	Remarks
Scenario 1	Wet	5	Water-filled condition
Scenario 2	Dry	5	Bottom open
Scenario 3	Dry	5	Bottom closed
Scenario 4	Wet	24	Water-filled condition

3.2 Evaluation of SFP Scenario

The basic MELCOR input model was built by using a OPR1000 NPP [2]. Cladding temperatures at the top of the active fuel cell were compared as shown in Fig.6. Among the scenarios having the same thermal power, only scenario-2 generated ignition by the oxygen-Zr reaction. Due to the ignition, scenario-2 yielded the biggest cladding oxidation thickness as shown in Fig.7. In terms of oxidation thickness that indicates the amount of oxidation reaction, the continuous air injection under air condition was found to produce more oxygen-Zr reaction.

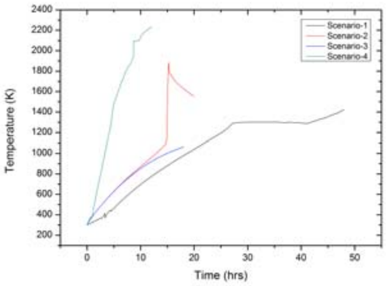

Figure 6. Cladding temperatures at the top of the active fuel cell

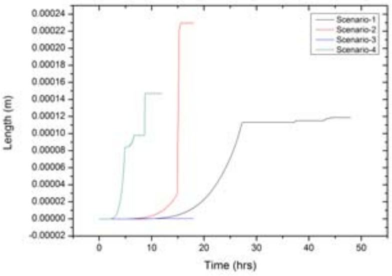

Figure 7. Cladding oxidation thickness at the top of the active fuel cell

4. Conclusions

Comparing the results of scenario analyses, it was found that the totally dry-out condition resulted in more severe damage in cladding. The MELCOR SFP models will be expanded to a plant-level MELCOR SFP model considering realistic scenarios. The SFP risk assessment technology will also be a basis to accomplish the future SFP risk management technology and framework.

ACKNOWLEDGEMENT

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