Study on MELCOR Modeling for Plant-level SFP Severe Accident Analysis

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1. Introduction

A long-term loss of cooling in Spent Fuel Pool (SFP) has been importantly issued post the Fukushima accident, which causes a large-sized hydrogen explosion and leakage of radionuclide materials. The present study was carried out in attempt to show the effect of Plant-level SFP MELCOR models for OPR1000 NPP. It will be the development of a basic framework to support a risk management for SFP severe accident.

2. Analysis Methods

In order to model the SFP, Hanul 3&4 units Final Safety Analysis Report (FSAR)[1] and design documents were referred to. The spent fuel pool is a stainless-lined concrete pool that is an integral part of the fuel building. The storage capacity is provided for up to 1,498 spent fuel assemblies. Figure 1 shows the three-dimensional structure of SFP.

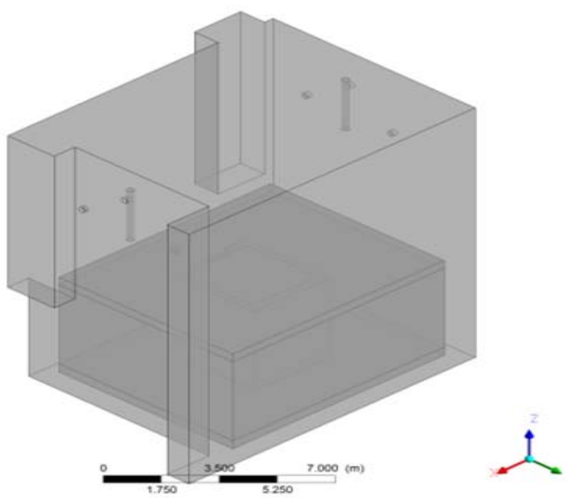

Figure 1. View of OPR1000 SFP Structure

2.1 Calculation of SFP Heat Load

A total heat load in SFP was estimated to be 18.71 MBtu/hr (5.5 MW) by incorporating a withdrawal history. The withdrawal history is summarized in Table 1, and Fig.2 shows the time-history heat load curve and the maximum heat load.

Table 1. Spent Fuel Withdrawal History

Period		Passing time after reactor trip	Number of FA
Previous	1	28.5 yr	68 FAs
	2	27 yr	68 FAs
	3	25.5 yr	68 FAs
	…	…	…
	17	4.5 yr	68 FAs
	18	3 yr	68 FAs
	19	1.5 yr	68 FAs
New	1	100 hr	68 FAs
Total			1,360 FAs

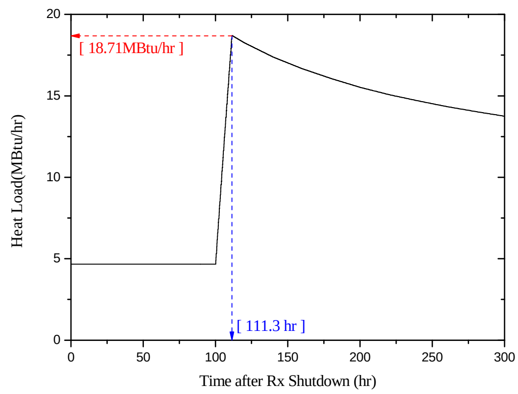

Figure 2. Maximum Heat Load in SFP

2.2 SFP MELCOR Modeling

The Plant-level SFP MELCOR modeling of OPR1000 was generated by using the following packages[3, 4].

- Spent fuel : Core (COR) Package
- Rack base : COR Package
- Between Rack and Pool wall : Control Volume Hydrodynamics (CVH) Package
- Rack upper pool : CVH Package
- Building : CVH Package
- Storage rack : Heat Structure (HS) Package
- Openings : Flow Path (FL) Package

The SFP MELCOR model(C-1) consists of 9 rings and 17 axial nodes in core model, 88 control volumes, 96 flow paths, and 89 heat structures as shown in Fig.3.

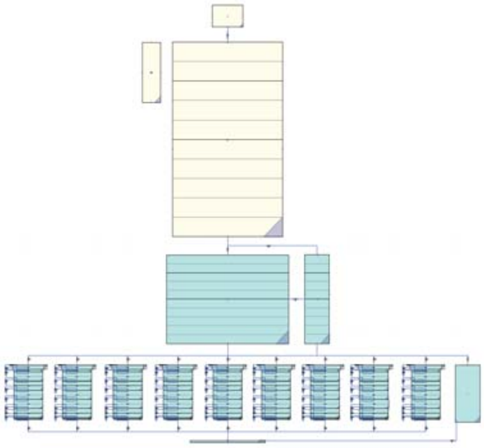

Figure 3. SFP Plant-level Modeling Nodalization (C-1)

The SFP MELCOR model(C-2) consists of 1 ring and 17 axial nodes in core model, 16 control volumes, 16 flow paths, and 17 heat structures as shown in Fig.4.

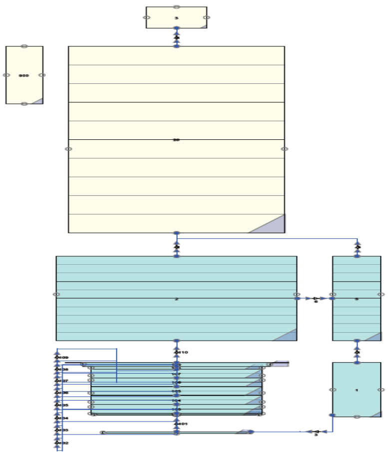

Figure 4. SFP Plant-level Modeling Nodalization (C-2)

The SFP MELCOR model(C-3) consists of 9 rings and 17 axial nodes in core model, 16 control volumes, 24 flow paths, and 17 heat structures as shown in Fig.5.

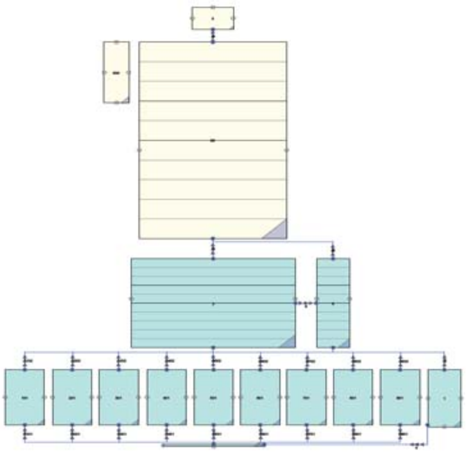

Figure 5. SFP Plant-level Modeling Nodalization (C-3)

3. Preliminary Analysis

A preliminary analysis for the SFP plant-level model was performed with respect to the modeling cases as summarized in Table 2.

Table 2. Modeling Cases for Plant-level SFP Analysis

Case	# of rings (EA)	# of CVHs (EA)	Heat load (MW)
C-1	9	81	5.5
C-2	1	9	5.5
C-3	9	9	5.5

Figure 6 through 8 shows the trend of the SFP water level decrease for the three cases due to pool boiling. In the case of C-1, the spent fuel storage rack was begun to be uncovered at about 90 hours after the loss of SFP cooling, resulting in about 125 hours of a dry-out time. In the case of C-2, the spent fuel storage rack was started to be uncovered at about 90 hours after the loss of SFP cooling, resulting in about 140 hours of a dry-out time. In the case of C-3, the spent fuel storage rack was started to be uncovered at about 79 hours after the loss of SFP cooling, resulting in about 130 hours of a dry-out time.

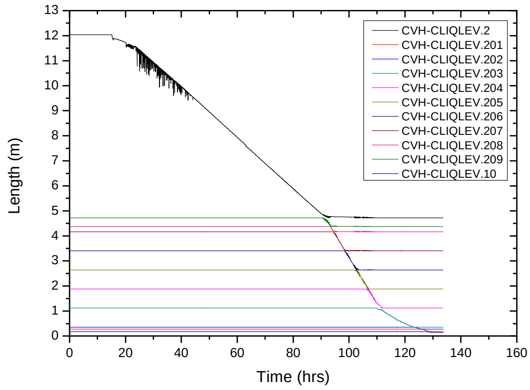

Figure 6. Trend of SFP water level (C-1)

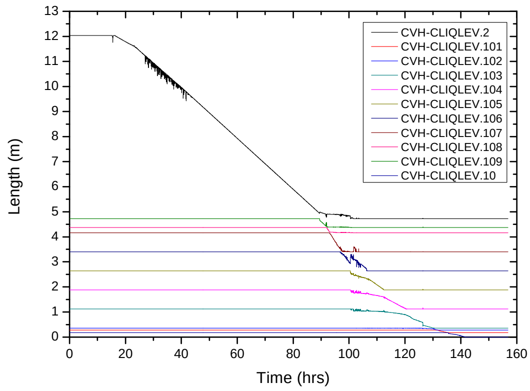

Figure 7. Trend of SFP water level (C-2)

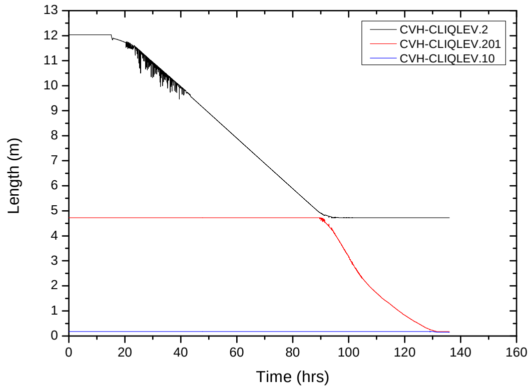

Figure 8. Trend of SFP water level (C-3)

Figure 9 through 11 show cladding temperatures in the cases of C-1, C-2, and C-3, respectively. Each case represented the following three modes of temperature changes.

- First mode : gradual temperature increase up to saturation temperature
- Second mode : constant temperature region during pool boiling period
- Third mode : sharp temperature increase at the uncovering time of each node

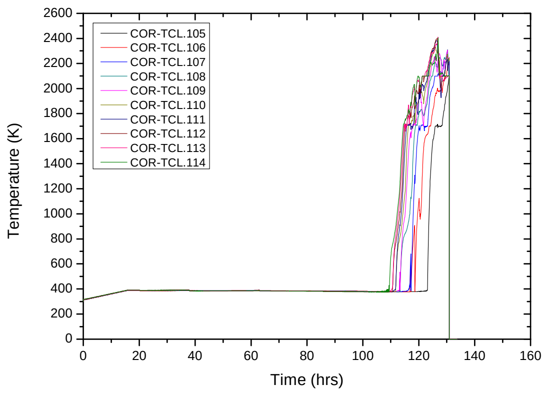

Figure 9. Cladding Temperature Variation (C-1)

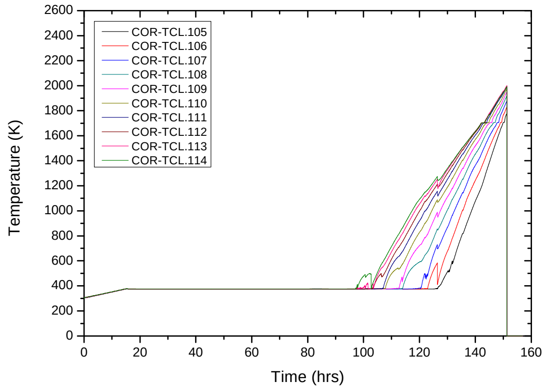

Figure 10. Cladding Temperature Variation (C-2)

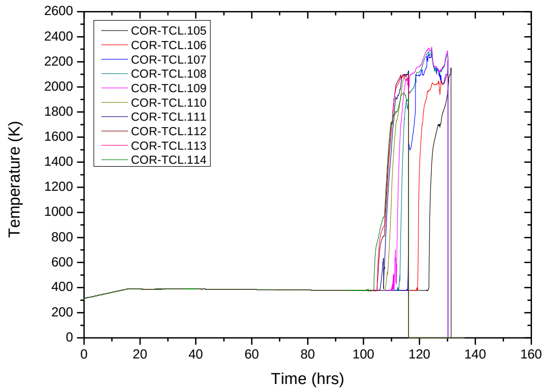

Figure 11. Cladding Temperature Variation (C-3)

Figure 12 through 14 shows accumulative hydrogen mass generated from metal-water reaction in the cases of C-1, C-2, and C-3, respectively. In terms of hydrogen generation, the most number of core node and CVH node produced the greatest amount of hydrogen among all cases, resulting in 100 kg.

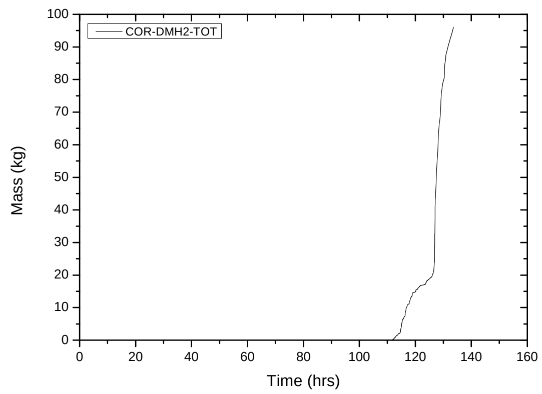

Figure 12. Accumulative Hydrogen Mass (C-1)

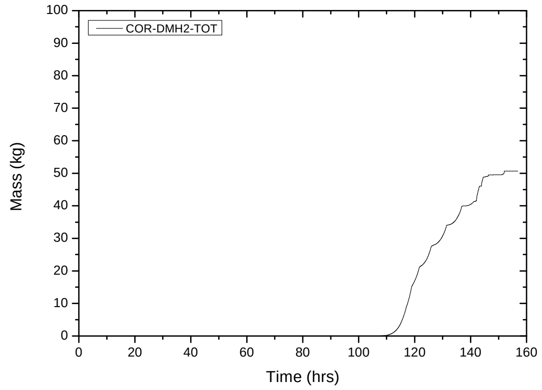

Figure 13. Accumulative Hydrogen Mass (C-2)

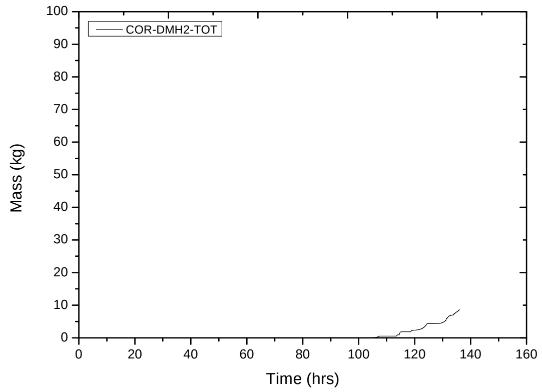

Figure 14. Accumulative Hydrogen Mass (C-3)

In Table 3, the analysis results are summarized for the three cases. Those results gave inconsistent trend in terms of the uncovering time, dryout time, ignition time, and hydrogen generation.

Table 3. Summary of Analysis Results

Case	Uncover time (hr)	Dryout time (hr)	Ignition time (hr)	Amount of hydrogen mass (kg)
C-1	90	125	110	100
C-2	90	141	100	50
C-3	79	130	105	9

4. Conclusions

In the present study, it was found that the different Core and CVH models for the same heat load and the same amount of water in SFP produced different results. Therefore, acceptable model should be selected by considering the actual accident sequence.

ACKNOWLEDGEMENT

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REFERENCES

[1] Hanul 3&4 Final Safety Analysis Report
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