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MELCOR 1.8.5 Sensitivity Study of Molten Core Concrete Interaction Experiment, SWICCS-1, 2 and 3

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I. Introduction

In a postulated core melt accident, if the molten core is not retained in-vessel despite taking severe accident mitigation actions, the core debris will relocate in the reactor cavity region. There, it will interact with structural concrete and could potentially result in basemat failure (through erosion or overpressurization) and consequent fission product release to the environment. Although a methodology of cooling the molten core by adding water on its top is selected as a severe accident management strategy in case molten core is released outside a reactor vessel, the possibility of a long-term cooling is still unresolved. In the OECD/MCCI project scheduled for 4 years from 2002. 1 to 2005. 12, a series of tests are being performed to secure the data for cooling the molten core spread out at the reactor cavity and for the long-term CCI (Core Concrete Interaction).

In this study, SWICCS-1, 2 and 3, of the SWICCS tests of OECD/MCCI project, was assessed using MELCOR1.8.5 and the sensitivity parameters' selection of CAV package were investigated in SWICCS-1 and the same options were applied to another experiments SWICCS-2 and -3.

II. Experimental Background

The SSWICS series of tests is considered complete. Parametric variations of the completed tests are summarized in table 1. The SSWICS reaction vessel (RV) has been designed to hold up to 100 kg of melt at an initial temperature of 2500°C. The RV lower plenum consists of a 67.3 cm long, 45.7 cm (18") outer diameter carbon steel pipe (figure 1).

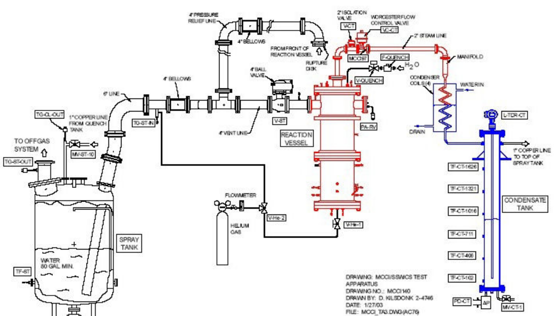

Figure 1. SWICCS Experiment Facility Diagram

The pipe is insulated from the melt by a 6.4 cm thick layer of cast MgO liner. Figure 1 is a schematic that provides an overview of the entire SSWICS melt-quench facility. SWICCS test series are listed in Table 1 and 2. Each tests is characterized by corium composition and injected water amount/time[1].

III. Experimental Procedure and Modeling

There are total seven control volumes in the simulation. Water is injected at 13 liter/min from 108s to 303s and total injected water is 40 liters.Water injection was initiated at 140, 140 and 113s at a flow rate of about 4.0, 4.0 and 12.0 l/min, lasting for 665, 760 and 183 s (ending at 805, 900 and 296 s) and resulting in an integrated flow of approximately 33, 39 and 34 liters, respectively. Once all the water had been injected, the control valve VC-CT was switched to automatic mode so that it could begin regulating system pressure. The valve immediately began to close, which caused the pressure to rise towards the set point of 1, 1 and 4 bar. The pressure oscillations had a period ranging from roughly three to five minutes.

Table 1. SWICCS Test Series Specifications

Parameter	1	2	3	4	5	6	7
Melt comp. (UO_2/ZrO_2/Cr/conc)	**61/25/6/8**	**61/25/6/8**	**61/25/6/8**	61/25/6/8	56/23/7/14	56/23/7/14	64/26/6/4
Concrete type	**LCS**	**SIL**	**LCS**	LCS	LCS	SIL	LCS
Melt mass (kg)	**75**	**75**	**75**	60	68	68	80
Init. melt T (°K)	**~2300**	**~2100**	**~2100**	~2100	~2100	~1950	~2100

Table 2. SWICCS Test Procedures

Event	SWICCS Experiment Time and Condition						
	1	2	3	4	5	6	7
Melt Charge	**N/A**	**N/A**	**N/A**	N/A	N/A	N/A	N/A
Ignition Start (seconds)	**0**	**0**	**0**	0	0	0	0
Water Inj. Start (sec)	**140**	**140**	**113**	108	104	120	102
Water Inj. End (sec)	**805**	**900**	**296**	303	726	335	296
Water Inj. Duration(sec)	**665**	**760**	**183**	195	622	215	194
Water Inj. flow (liter/sec)	**0.666**	**0.666**	**0.2**	0.216	0.1	0.2333	0.216
Water Injected (liters)	**33**	**39**	**34**	40	61	47	40
Test Pressure (bar)	**1**	**1**	**4**	4	4	1	4

For the MELCOR simulation, it is necessary to set up an appropriate scaling methodology, since geometrical differences exist between the SWICCS tests and the MELCOR simulations. The initial temperature of melt was obtained from the OECD/MCCI test results.

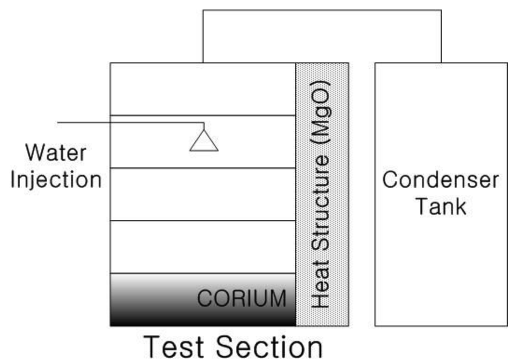

Figure 2. MELCOR Nodalization Diagram

IV. Results and Discussion

The MELCOR base calculation for SWICCS-1 test was performed using defaults input options. In Figure 3, the calculation results for defaults option case and optimal option case were shown. Initially, Corium ignition started and temperature of corium increased rapidly in experiment. In calculation, initial corium temperature set to the experiment and heat transfer to the surround structure/air made corium temperature decrease slowly. As the temperature decrease, crust is formed at corium outside surfaces and temperature decreasing rate reduce. At 140 seconds, water injection start and corium temperature abruptly decreased due to the quench process. After crust formed, the heat transfer rate decreased and boiling heat transfer in surfaces and conduction/convection heat transfer was occurred in test section. The water cooling makes corium temperature decrease gradually.

In MELCOR base calculation (use default values in CAV package), the initial rapid temperature decrease was predicted well, but after the end of initial temperature decreasing behavior, temperature change rate is smaller than that of experiment. In previous studies [2, 3], MELCOR CAV package three options, Emissivity of the oxide and metal phase (EMISS.OX, EMISS.MET) and MIXING option were changed. Through sensitivity study, the values were set to be 1.6 for each emissivity of oxide and metal phase and mixing option was set to be 1 which means that MELCOR CAV package calculate mixing and separation rates from correlations. As shown in the optimal option case of figure 4, the MELCOR predict the experimental temperature results very well.

With same option, SWICCS-2 and 3 tests were 6ssessed and the results were shown in figure 5, and 6. With these options, MELCOR results were almost exactly tracking the experiments. The strange behaviors in SWICCS tests in figure 4 and 5 means the malfunction of temperature sensors.

As a future works, all SWICCS tests will be assessed using new version of MELCOR and the optimum option values were studied. Also, the application to nuclear power plant will be performed.

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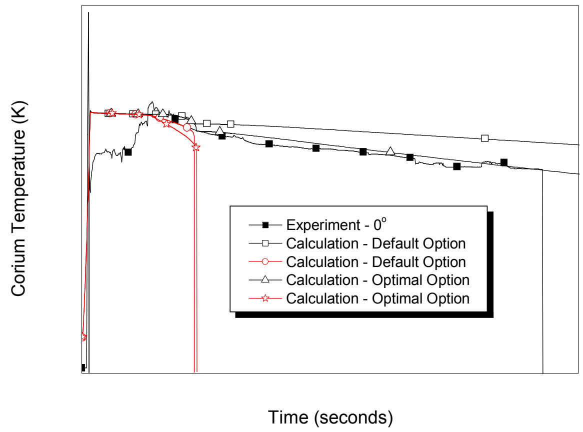

Figure 3. Corium Average Temperatures of Base and Sensitivity Cases for SWICCS-1

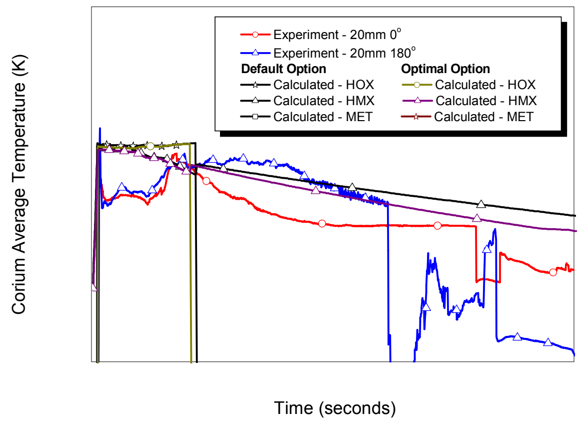

Figure 4. Corium Average Temperatures of SWICCS-2

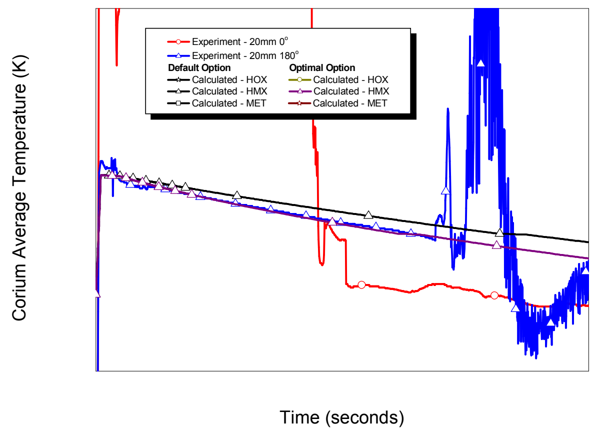

Figure 5. Corium Average Temperatures of SWICCS-3