Development of a MELCOR Input for ThAI HM Tests

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1. Introduction

The combustible gas control in containment is one of the important items for plant safety, but there are still large uncertainties in analyzing the hydrogen behavior in the containment for the regulatory review of new plants. Moreover since the Shin Kori 1&2 and Shin Wolsong 1&2 plants – named Optimized Power Reactor 1000 (OPR1000) – are under licensing process now, so it is important for KINS (Korea Institute of Nuclear Safety) to have a reliable analysis methodology for the assessment of hydrogen risk. An integral severe accident code MELCOR which has been widely used was intensively verified against experiments, but we should always be careful about the capability of a code. As part of our efforts to establish a confident analysis environment we are going to simulate experimental data using MELCOR code. Our purpose is first to verify the code against experiments and second to establish a better analysis methodology.

For the verification of MELCOR code, OECD-ThAI (Thermal hydraulics, Hydrogen, Aerosols, Iodine) project was selected as the benchmark problem. ThAI is a downscaled containment test facility located at Eschborn, Germany. ThAI had been utilized in step 2 of the International Standard Problem ISP-47 on Containment Thermal-Hydraulics [1]. ThAI is a very well-designed test facility for the purpose of this study.

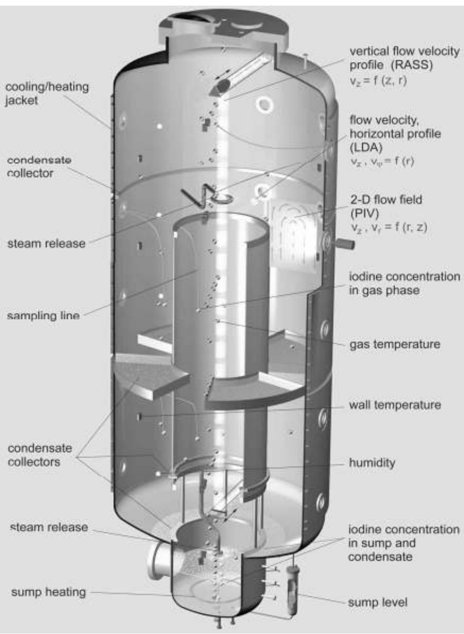


Fig. 1. ThAI test vessel configuration.

ThAI HM tests therefore will be referred for the MELCOR code verification. This paper describes the result of the first step of the work, that is, the development of steady-state input for MELCOR.

2. Development of MELCOR Code Input

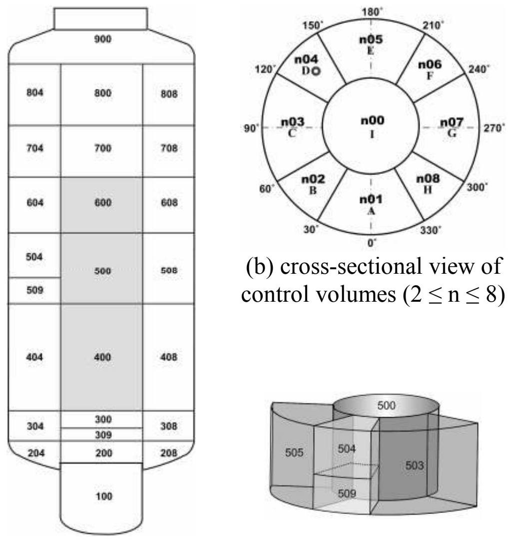
2.1 ThAI HM Tests

The test vessel is a 9.2 m-high cylindrical one made of stainless steel with total free volume of about 60 m^3. Various experimental program such as hydrogen-helium material scaling (HM) test, hydrogen deflagration (HD) test, hydrogen recombiner (HR) test, iodine deposits wash-down (IW) test and so forth, have been planned with the facility.

For HM tests conducted in 2007, the inner multi-compartment structure was generated by installation of an inner cylinder and condensate storage trays in the annulus as shown in Fig. 1 [1]. The tests consist of two phases. In phase 1, helium or hydrogen is released upward up to 4,200 sec from the vertical pipe installed at 4.8 m from the bottom of the vessel in the annular region. During the phase 2, steam is then released from 4,320 sec to 6,820 sec, from the vertical nozzle located at 1.8 m on the centerline of the vessel.

2.2 Modeling for MELCOR Code

MELCOR 1.8.5 was used for the analysis of ThAI HM tests [2]. The geometry of test facility was modeled



(a) control volumes (b) cross-sectional view of control volumes ($2 \le n \le 8$) (c) H_2 injection node (504)

Fig. 2. MELCOR modeling of ThAI facility.

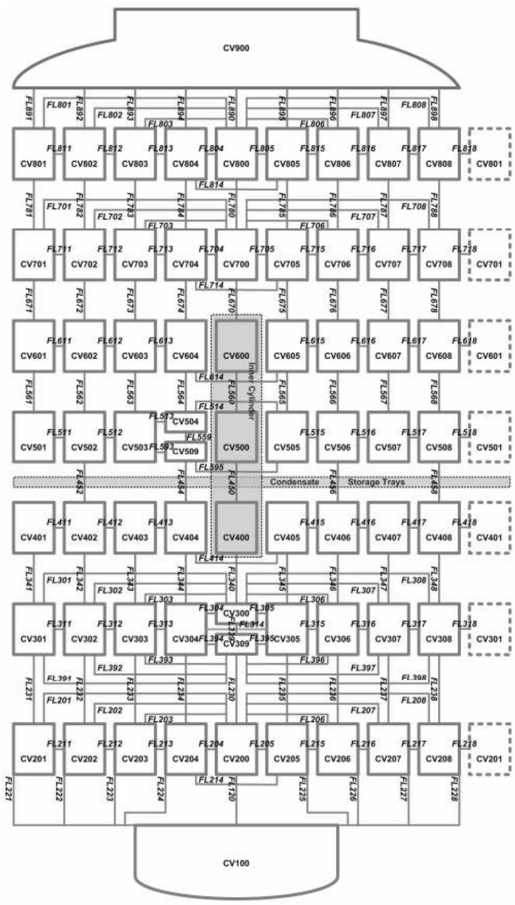


Fig. 3. Nodalization.

with 67 control volumes. Fig. 2 shows the conceptual diagram for the structure of CVs in this work. Test vessel was divided into 9 levels by elevation. In order to consider the effect of the condensate storage trays and the asymmetry of gas flow during phase 1, the annular region was modeled with 8 control volumes as illustrated in Fig. 2(b). The upper dome region (CV900) and the sump (CV100) were individually modeled with one control volume. Gas injection nodes for hydrogen/helium (CV504) and steam (CV300) were vertically divided into two control volumes (Fig. 2(c)) in accordance with the results obtained from sensitivity studies in which the calculation results were compared with the HM-2 test results for phase 1 [3]. Since the MELCOR code cannot simulate the jet injection of the experiment, such a division of a CV could be an effective method leading the light gas to go upward.

The open boundaries of each CV were modeled with 168 flow paths to the adjacent CVs while the closed boundaries (walls) were modeled by means of 91 heat structures. Fig. 3 shows the MELCOR nodalization for ThAI HM tests.

Initial relative humidity in the vessel was assumed as 50% according to the partial steam pressure measured in experiment [4]. Atmospheric temperature in test vessel was set to 20.7 ℃ as was specified in the test report. Initial wall temperatures measured in the HM-2 test for each level were taken for the initial gas temperatures at various measuring points to follow the experiment. Nonequilibrium option was used for the control volume thermal hydraulics. Special wall function or turbulence model was not used.

2.3 Simulation of initial steady-state condition

Using the developed MELCOR inputs, we have simulated the initial steady-state condition of HM-2 test to check the feasibility of the inputs. Fig. 4 is the result of steady-state calculation. The minimum and the maximum time step used are 0.001 sec and 0.3 sec, respectively. It is found that a steady-state has been achieved at 5,000 seconds successfully predicting the measured vessel pressure (1.008 bar) and local atmospheric temperatures.

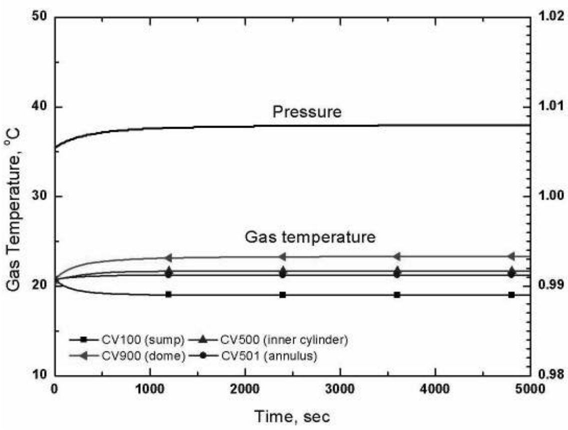


Fig. 4. Steady-state calculation results for pressure and gas temperatures in test vessel.

3. Conclusion

A MELCOR code input for ThAI test facility was developed. By simulating a steady-state condition of the experiment, we could check that the developed input works well. Further study will be to simulate the various ThAI experiments, thus to assess the capability of the MELCOR code in analyzing the hydrogen distribution in the containment and also to establish a better analysis methodology. The established methodology will be finally applied to the regulatory assessment of the combustible gas control for OPR1000 plant.

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