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Preliminary Analysis of TMI-2 Severe Accident Scenario using CSPACE

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1. Introduction

As a part of the integrated severe accident computer code development project in Korea, KAERI (Korea Atomic Energy Research Institute) has been developing a stand-alone severe accident analysis code, the COMPASS (COre Meltdown Progression Accident Simulation Software), which simulates the in-vessel severe accident phenomena including the core heat up, material melting and relocation, corium behavior in the lower plenum, and vessel failure. In addition, CSPACE computer code is developing for simulation from initiating events to a reactor vessel failure in PWR (Pressurized Water Reactor). The CSPACE is the result of merging the COMPASS and SPACE (Safety and Performance Analysis CodE for nuclear power plants) models, which is designed to calculate the severe accident situations of an overall RCS thermal-hydraulic response in SPACE modules and a core damage progression in COMPASS modules. For the purpose of CSPACE validation, the Three Mile Island Unit 2 (TMI-2) accident has been analyzed in this study. This analysis has been performed to estimate the efficiency of the CSPACE computer code and the predictive qualities of its models from an initiating event to a severe accident. Preliminary CSPACE results are compared with TMI-2 data, such as, a pressurizer pressure.

2. TMI-2 Severe Accident Scenario

On March 28, 1979, the TMI-2 pressurized water reactor underwent a prolonged, a total loss of feed water with a small break loss of coolant accident (SBLOCA) that resulted in a partial melting of the core, significant cladding oxidation, and a significant release of fission products from the fuel. The progression of the TMI-2 accident was mitigated by an injection of the emergency cooling water.

The TMI-2 accident scenario [1] can be divided into four phases, beginning with a reactor scram, as follows:

- Phase 1: From 0 to 100 minutes. This represents the part of the accident where some or all of the main coolant pumps were operating, forcing convective two phase coolant through the core.
- Phase 2: From 100 to 174 minutes. During this time span, all the main pumps were shut down, and a boiling off of the water in the reactor vessel resulted in a progressive uncovering of the core, causing major and very severe core damage.
- Phase 3: From 174 to 224 minutes. This represents the first recovering and major quenching of the core by a short operation of the main coolant pump at 174 minutes and a continued core heatup and damage, even when the core is recovered again by an operation of the high pressure safety injection system after 200 minutes.

3. TMI-2 Plant Description and CSPACE Input Model

TMI-2 was designed and manufactured by Babcock & Wilcox, Inc. The core contained 177 fuel assemblies. The reactor coolant system (RCS) consisted of the reactor vessel, two vertical one-through steam generators, four reactor coolant pumps, an electrically heated pressurizer, and interconnecting piping. The system was arranged with two heat transport loops, each with two RCPs and one steam generator. Fig. 1 shows an input nodalization of CSPACE computer code. All primary and main secondary systems are modeled including the pressurizer, PORV (Pilot-Operated Relief Valve), and safety injections. In core input model, 3 radial and 5 axial nodes are used. Fuel and control rod are connected to the fluid volumes in the core.

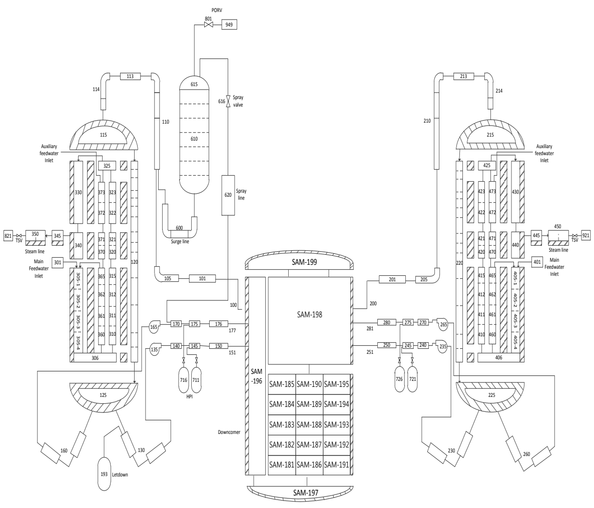
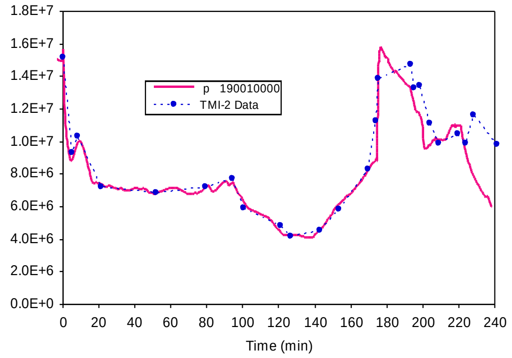


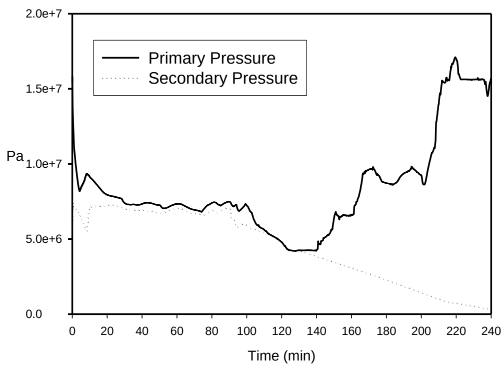
Fig. 1. CSPACE nodalization for TMI-2

3. CSPACE Results and Discussion

Fig. 2 shows the preliminary CSPACE results for the pressurizer pressure with a comparison of TMI-2 data. A reduction feed water to the steam generator caused the coolant to expand and initially increased the RCS pressure. The pressurizer PORV opened when the pressure reached 15.7 MPa. The PORV failed to close as the RCS pressure decreased, initiating a small break loss of coolant accident. Emergency core cooling was reduced by operators who thought that the pressurizer liquid level indicated a nearly full RCS, while coolant continued to be lost from the PORV. After an initial decrease in the RCS pressure, the pressurizer pressure remained at approximately 7 MPa. After a pump termination at 100 minutes, the liquid level in the reactor vessel decreased, which resulted in a core uncovery. Continued core degradation with a coolant boiling caused the pressurizer pressure to increase. The CSPACE results are very similar to the TMI-2 data in general, with the exception of a rapid increase in the pressure at approximately 170 minutes, which is a result from deficiency of CSPACE model on a melted fuel relocation and quenching process. Fig. 3 shows the preliminary CSPACE results for a water level in the pressurizer, the maximum fuel cladding temperature, and fuel cladding mass in the core. The preliminary CSPACE results are similar to the TMI-2 data before fuel melting and relocation.

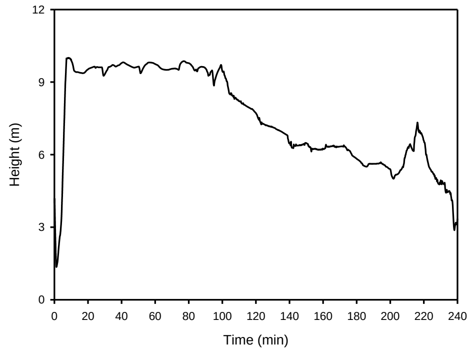


(TMI-2 data and SCDAP/RELAP5 results)

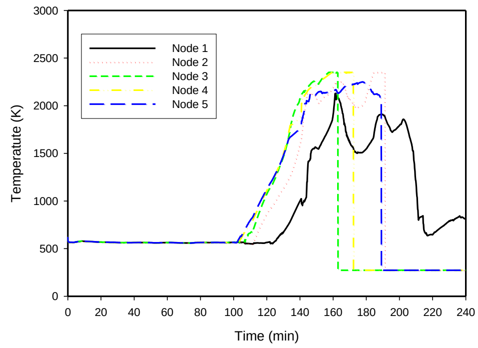


(CSPACE results)

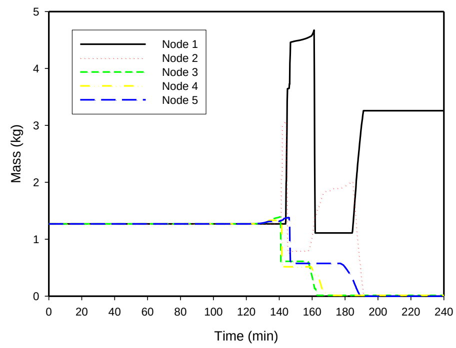
Fig. 2 Pressure history in TMI-2 accident



(Water level in the Pressurizer)



(Fuel Cladding Temperature)



(Fuel Cladding Mass)

Fig. 3 Preliminary CSPACE results on TMI-2 accident

3. Conclusions

The preliminary CSPACE results are very similar to the TMI-2 data in general with the exception of melt relocation and quenching. More CSPACE model development and analysis for a melted fuel relocation and quenching process in the core and lower plenum are necessary to simulate the TMI-2 data.

ACKNOWLEDGEMENT

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[1] J.M. Broughton, P. Kuan, D.A. Petti, E.L. Tolman, et al., A Scenario of the Three Mile Island Unit 2 Accident, Nuclear Technology, Vol. 87, p. 34, 1989.