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Analysis of the TMI-2 Accident by using MARS/SCDAP

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1. Introduction

As part of a benchmark analysis, the Three Mile Island Unit 2 (TMI-2) accident has been analyzed by using the MARS/SCDAP computer code. This analysis has been performed to estimate the efficiency of the MARS/SCDAP computer code and the predictive qualities of its models from an initiating event to a severe accident. The MARS/SCDAP computer code, which is the result of merging the MARS and severe core damage analysis package (SCDAP) models, is designed to calculate the severe accident situations of an overall RCS thermal-hydraulic response and a core damage progression.

2. TMI-2 Accident Scenario

On March 28, 1979, the TMI-2 pressurized water reactor underwent a prolonged, 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 I: From 0 to 6,000 seconds. 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 6,000 to 10,440 seconds. 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 10,440 to 13,440 seconds. This represents the first recovering and major quenching of the core by a short operation of the main coolant pump at 10,440 seconds 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 12,000 seconds.

Phase 4: From 13,440 to 18,000 seconds. During this time period, the core geometry changed to a coolable configuration, initiated by a major relocation of the core material into the lower head of the reactor vessel.

3. TMI-2 Plant Description

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.

4. MARS/SCDAP Input Model

The input model for the MARS/SCDAP calculation of the TMI-2 was a combination of the MARS, SCDAP, and COUPLE input models. Heat structures for the fuel rods and the lower part of the reactor vessel in the MARS input model were replaced by the SCDAP and COUPLE input models, respectively. Figs. 1 to 3 show the MARS input model for the THI-2.

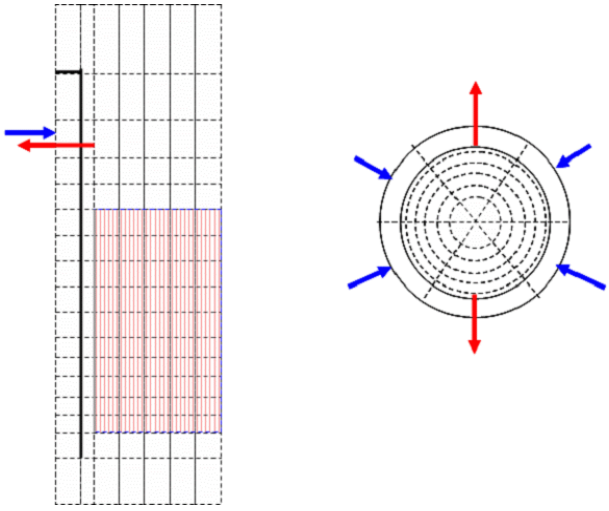

Figure 1. MARS-3D input model for the reactor vessel of the TMI-2.

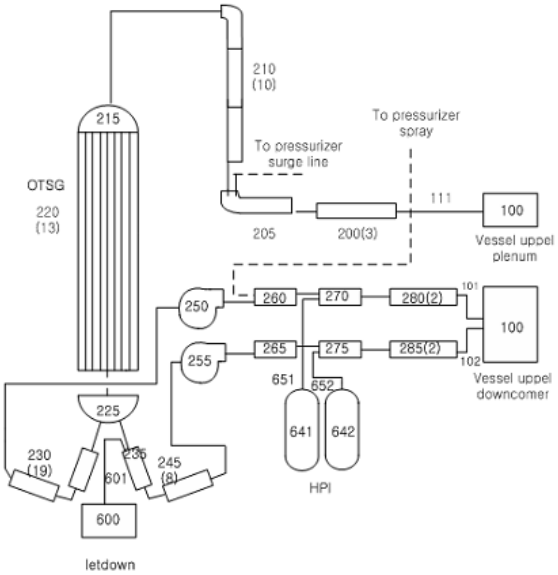

Figure 2. MARS input model for the RCS of the TMI-2.

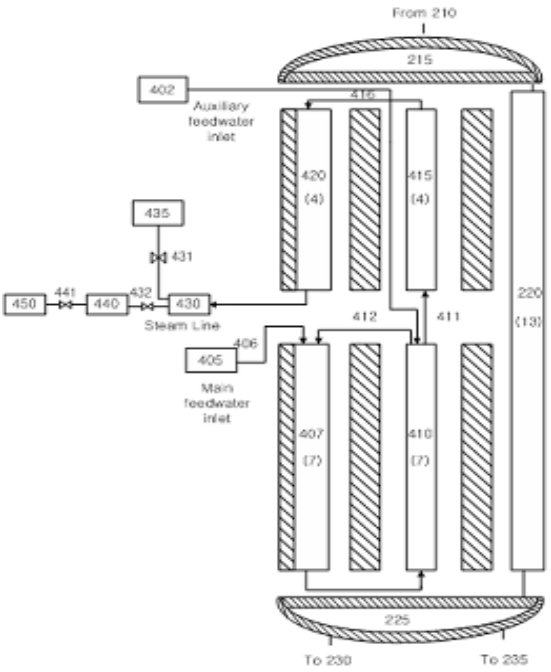

Figure 3. MARS input model for the steam generator of the TMI-2.

4. MARS/SCDAP Results and Discussion

Figure 4 shows the MARS/SCDAP results for the pressurizer pressure. In the Fig. 4, SCDAP/RELAP5 is the SCDAP/RELAP5 results of the TMI-2 data[2]. MARS-1D/SCDAP is the one-dimensional modeling case of the TMI-2 reactor vessel in the MARS input. MARS-3D-N10/SCDAP and MARS-3D-N20/SCDAP are the three-dimensional modeling case of the TMI-2 reactor vessel in the MARS input with an axial node number of 10 and 20, respectively.

A reduction feed water to the steam generator caused the coolant to expand and initially increased the RCS pressure. The pilot-operated relief valve (PORV) opened when the pressure reached 15.7 MPa, with a reactor scram occurring when the pressure reached 16.3 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 6,000 seconds, 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. MARS/SCDAP calculation for TMI-2 accident was terminated by an execution error at 95,000 seconds.

As shown in Fig. 4, MARS/SCDAP results for the pressurizer pressure are very similar to the SCDAP/RELAP5 results of the TMI-2 data.

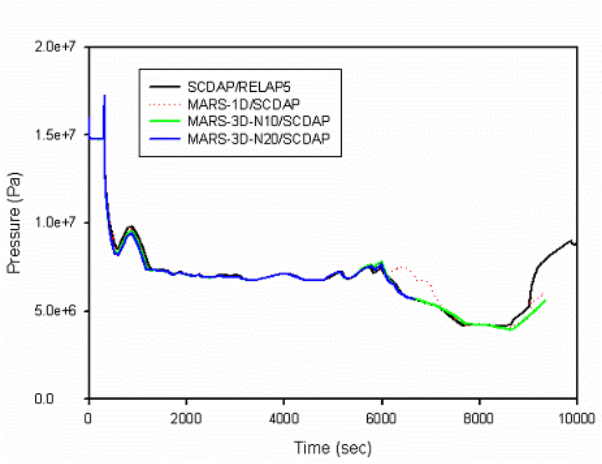

Figure 4. MARS/SCDAP results for the pressurizer pressure.

Figure 5 shows the MARS/SCDAP results for the maximum fuel cladding surface temperature. MARS/SCDAP results are very similar to the TMI-2 data of the SCDAP/RELAP5 results. MARS-3D-N20/SCDAP results during the core heat-up phase are a little different from the SCDAP/RELAP5 results. More detailed analysis for the TMI-2 accident is necessary to verify the MARS/SCDAP model.

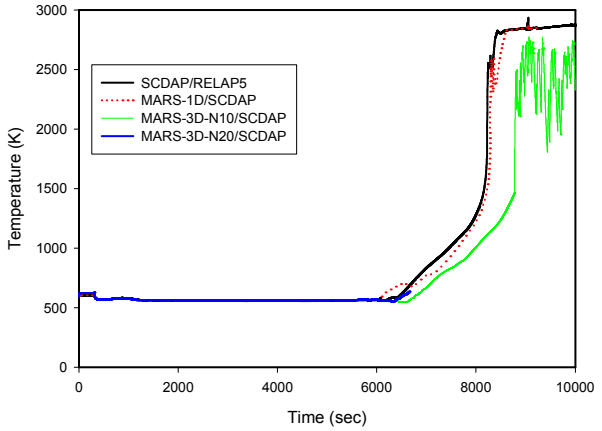

Figure 5. MARS/SCDAP results for the maximum fuel cladding surface temperature.

ACKNOWLEDGMENTS

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REFERENCES

1. Broughton, J. M., Kuan, P., Petti, D. A., Tolman, E. L., et al., A Scenario of the Three Mile Island Unit 2 Accident, Nuclear Technology, Vol. 87, pp. 34-53, 1989.
2. Siefken, L. J., SCDAP/RELAP5 Code Manual Vol. V: Developmental Assessment, NUREG/CR-6150, INEL-96/0422, January 2001.