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Analysis of a Hypothetical Station Blackout in Kori Nuclear Unit 1 Using the MARS and CUPID codes

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1. Introduction

The primary objective of this study is to analyze multi-dimensional two-phase flow in the reactor coolant circuit during a station black out (SBO) accident. Kori nuclear unit 1(KNU-1) was selected to perform this study since an SBO accident occurred at KNU-1 during the preventive maintenance period in February 2012. It lasted 12 min. The accident led to a loss of residual heat removal (RHR) during the SBO period and subsequent 7 min, resulting in the increase of the hot leg temperature up to 58.3 ^{o}C from 36.9 ^{o}C. In this work, a hypothetical prolonged SBO was analyzed to investigate its potential danger using the MARS and CUPID codes.

2. Modeling the Plant

2.1 Initial and boundary conditions

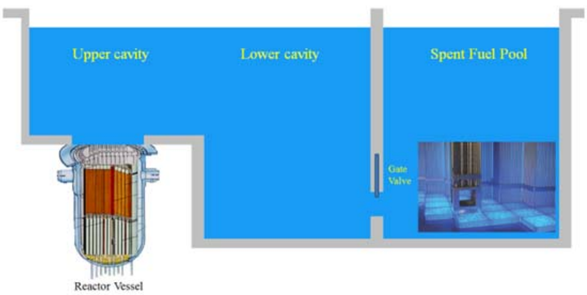

Fig. 1 The KNU 1 plant layout during the preventive maintenance period

Fig. 1 presents the configuration of the plant during the maintenance period; the reactor vessel head was open to the containment atmosphere and the reactor cavities were filled with borated water. The lower reactor cavity was connected to the spent fuel pool (SFP) via the fuel transfer channel. In this analysis, the SFP was not considered because the coolant in the pool seems to have very small effects on the plant behavior. The water level in the upper cavity was about 7m height above the hot legs.

Initially, the decay heat of 6.34 MWth was being removed by the RHR system. The coolant temperatures at the cold and hot legs were 25.4 ^{o}C and 36.9 ^{o}C, respectively.

2.2 The Code Input Models

2.2.1 MARS code input model

Fig 2 shows the MARS input model for the plant, including the reactor and the reactor cavities. The 1D module is used for the reactor vessel region, which consists of 45 volumes and 50 junctions.

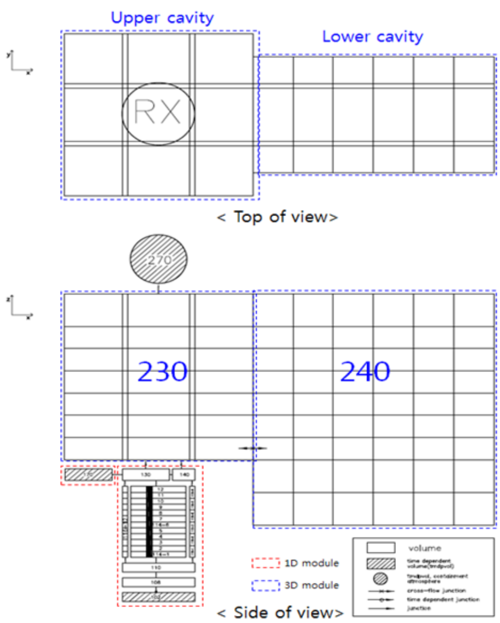

Fig. 2 Top, side of view for the MARS input model

The 3D module is adopted for the reactor cavities. The upper cavity is connected to the outlet of the reactor vessel. It is divided by 5, 5, 7 volumes for x, y, z-direction, respectively, consisting of 175 volumes and 430 junctions. The lower cavity is divided by 6, 5, 9 volumes for x, y, z-direction, respectively, resulting in 270 volumes and 681 junctions.

On the “top” volumes of the reactor cavities, a static quality of 0.0005 is set to represent the air layer above the free surface in the cavities.

2.2.2 The CUPID code input model

21,632 hexahedral meshes (total) are used for the CUPID code analysis. The schematic is shown in Fig. 3. The upper and lower cavities are filled with borated water to a height of 7.26m from the reactor vessel. A cavity, which has a height of 3m from surface of cooling water, is considered as air-layer, quality of which is approximately 0.999. A baffle wall is inserted between core section and bypass section. It is considered as wall condition.

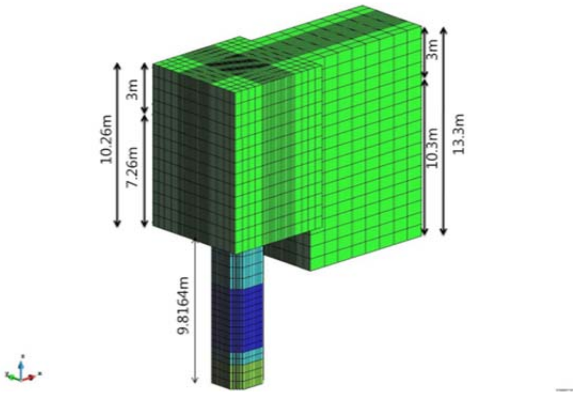

Fig. 3 Side view of generated mesh for the CUPID code analysis

3. The Results of Calculations

3.1 Results of the MARS code

A steady state was obtained by running a null transient and then, a SBO was assumed to occur at 2,000 sec, resulting in a loss of RHR system.

Because of the loss of RHR system, the reactor coolant temperatures increased at a constant rate as shown in Fig. 4. At about 40,000 s, the core exit temperature near the top of the hottest fuel assembly reaches 120.90 ^{o}C. However, this does not evoke a boiling at the core because of the hydrostatic head and instead, a flashing occurs near the free surface as the hot water flows upward by buoyancy.

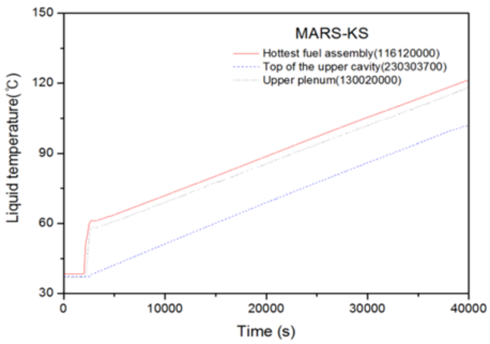

Fig. 4 Coolant temperature behaviors of MARS analysis (at 40,000sec after SBO accident)

The hot leg temperature was compared with the measured value from the data of KNU 1. The results, 58.27 ^{o}C at 19 min after the SBO occurs, from MARS showed fairly good agreement with that of the data (58.3 ^{o}C).

3.2 Results of the CUPID code

At 19 min after the SBO accident in the CUPID code analysis, the coolant temperature near the hot leg was 47 ^{o}C, which is about 10 ^{o}C lower than measured value. This result may be caused by inaccurate friction factor. The friction factor in this analysis seems somewhat lower than the actual one. This leads to greater natural circulation flow. Consequently, the calculated temperature of the CUPID analysis is lower than the measured one. The temperature behaviors, however, are similar to those of the MARS results, as shown in Fig.5. The flow in the reactor vessel was strongly multi-dimensional, especially, in the upper plenum and the upper part of the reactor core.

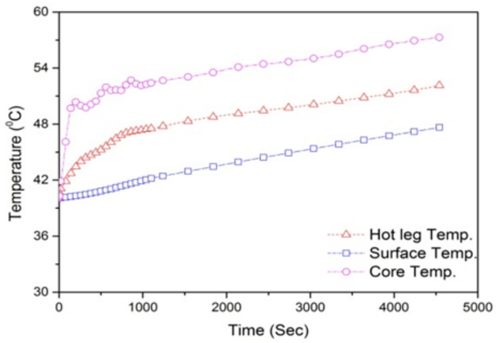

Fig. 5 Coolant temperature behaviors of CUPID analysis (at 4,540sec after SBO accident)

4. Conclusion

Using the MARS and CUPID codes, a hypothetical prolonged SBO at the KNU-1 was analyzed to investigate its potential danger.

The coolant temperatures in the reactor increased continuously after the SBO accident. However, a boiling in the coolant core did not occur until about 40,000 s. Thereafter, flashing occurs near the free surface above the top of the reactor core. The coolant temperature in the CUPID code analysis was lower than the measured one at 19 min and that of the MARS 3D calculation. It is because of smaller friction factors. However, in general, the results of the two codes were consistent with each other.

REFERENCES

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