Sensitivity Analysis of TMI-2 Benchmark Problem Using MAAP4 Code

Jae S. Yoo[a], Kune Y. Suh[a,b*]
[a]*Department of Energy Systrems Engineering, Seoul National University*
599 Gwanak-Ro, Gwanak-Gu, Seoul, 151-744, Korea
[b]*PHILOSOPHIA, Inc.*
599 Gwanak-Ro, Gwanak-Gu, Seoul, 151-744, Korea
[*]*Corresponding author: kysuh@snu.ac.kr*

1. Introduction

Quite a few computer codes have been developed to analyze severe accident conditions in a light water reactor (LWR) nuclear power plant (NPP). Oxidation of the fuel cladding is one of the key phenomena during the severe accident. The experimental database on core degradation and melt relocation and their consequences on hydrogen production and vessel rupture is limited to small scale experiments which are only partly representative of what could occur in a reactor. As a consequence, there is uncertainty in the capability of codes to predict the core degradation in postulated severe accident transients of NPPs. The current version of MAAP4 is equipped with the Baker-Just model as default, and the MATPRO model as an alternative for calculating kinetics of oxidation [1]. This correlation is to be seen as the most important available correlations and well justified up to now for the licensing purpose. As a conservative approach, it may not be suitable for the best-estimate calculations. Recently developed models have a potential to account for progression of fuel degradation. The literature survey has suggested adopting the Urbanic-Heidrick model in MAAP4 [2,3]. The core degradation physical parameters used in the standard calculation with MAAP4 are compared against the alternative physical parameters for Urbanic-Heidrick model. The Three Mile Island Unit 2 (TMI-2) scenario was selected as the case to analyze since it concerns the only full scale LWR to have experienced core degradation. Data from the code calculations were compared to the TMI-2 end state to determine the code's predictive capability.

2. Plant Description and Transient

A proper definition of boundary conditions and plant characteristics is essential for the accurate prediction of the TMI-2 transient. However, some of these data are either unknown or difficult to estimate. Although these data do not bring any improvement in the understanding of severe accident processes, they have required important efforts from code users who have tried to estimate them. An alternative scenario was proposed based on standard scenario to avoid such problems [4]. Fig. 1 shows the plant description and alternative scenario. The objective is to make the calculations on a well-defined plant and with prescribed boundary conditions so as to avoid additional and unwanted sources of discrepancies between code predictions [5]. The standard TMI-2 plant is modeled with the complete primary loops A and B, and a simplified secondary loop. The geometry of the circuits is provided in the following section. The initial state corresponds to the standard TMI-2 sequence.

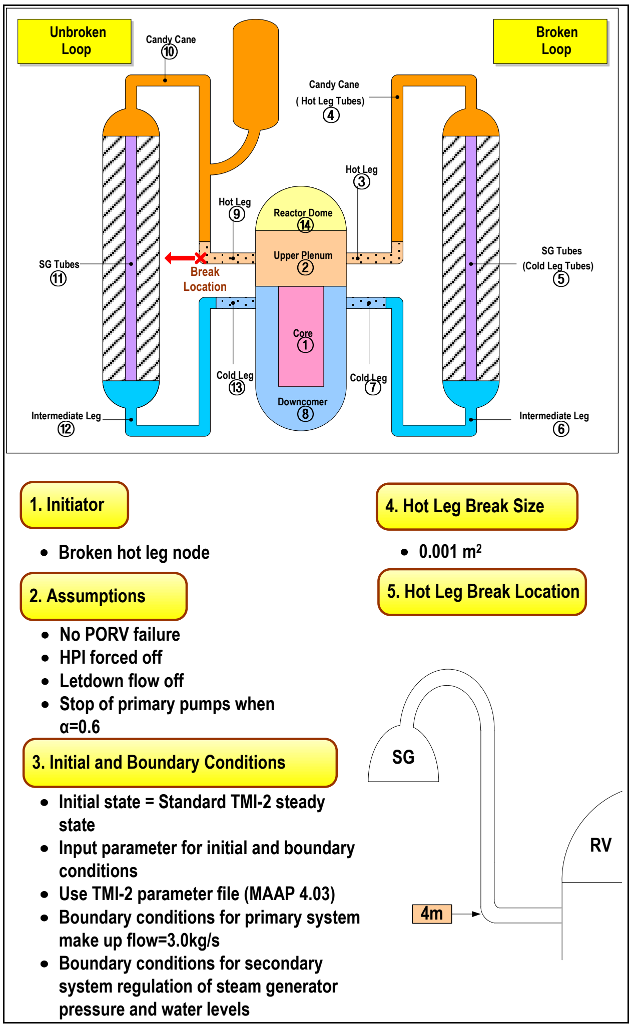

Fig. 1. Plant description and alternative scenario.

3. Sensitivity Analysis

The cladding oxidation in core begins at 6251 s. The maximum core temperature exceeds 2499 K by 7638 s in the standard calculation. In the sensitivity calculation, on the other hand, the maximum core temperature exceeds 2499 K at 7528 s. It is followed after few seconds by clad failure and first melt relocation. The first clad collapse occurs a bit earlier at 7775 s with the Urbanic-Heidrick correlation and at 7794 s with the Baker-Just correlation. The melt relocation is calculated later on at 7775 s in the sensitivity calculation due to high pressure injection. Fig. 2 shows the ZrO2 mass according to each oxidation model.

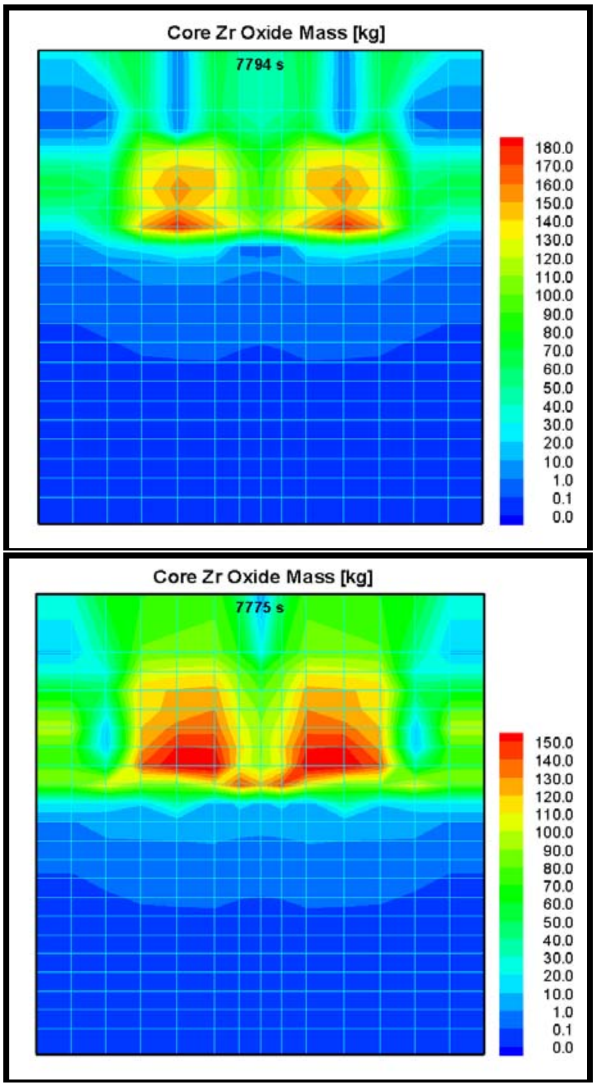

Fig. 2. Oxidation at the end of calculation.

4. Results

The core degradation physical parameters used in the standard calculation with MAAP4 are compared against alternative physical parameters for the Urbanic-Heidrick model. This model correlation seems to be a best option at high temperature. The Urbanic-Heidrick model is deemed to most accurately predict the zirconium oxidation at high temperature resorting to precise experiments.

Acknowledgments

This works was performed under the auspices of the Brain Korea 21 Energy and Resources Engineering Program funded by the Korean Ministry of Education, Science & Technology.

REFERENCES

[1] "Hydrogen Generation during Severe Core Damage Sequence," Final Report for IDCOR Task 12.1, Fauske & Associates, Inc. & Argonne National Laboratory, Argonne, IL, USA1983.
[2] V.F. Urbanic and T.R. Heidrick, High Temperature Oxidation of Zircaloy-2 and Zircaloy-4 in Steam, Journal of Nuclear Materials, Vol.75, pp.251–261, 1978.
[3] S. Leistikow, G. Schanz, H.V. Berg, and A.E. Aly, Comprehensive Presentation of Extended Zircaloy -4/Steam Oxidation Results (600-1600°C), Proc. IAEA IWGFPT/16, 188-199, Risø Nat. Lab., Denmark, May 16-20, 1983.
[4] J.S. Yoo, K.Y. Suh, Analysis of TMI-2 Benchmark Problem Using MAAP4.03 Code, Nuclear Engineering Technology, Vol.41, pp.945-952, 2009.
[5] S. Weber, H. Austregesilo, F. Fichot, O. Marchand, G. Bandini, M. Barnak, P. Matejovic, S. Paci, K.Y. Suh, M. Buck, and L. Humphries, A Benchmark Exercise on an Alternative TMI-2 Accident Scenario, N13P1403, Proc. NURETH-13, Kanazawa City, Ishikawa Prefecture, Japan, September 27-October 2, 2009.