Assessment of Core Status of TEPCO's Fukushima Daiichi Nuclear Power Plants
(106) Improvements of SAMPSON debris to lower head wall heat transfer models

*Alexandre Ezzidi[1], Chiaki Kino[1] and Masao Chaki[1]
[1]Institute of Applied Energy (IAE)

Since the RPV is considered as the most important barrier to prevent large fission product releases to the environment, the US-NRC, following TMI-2 accident, had initiated two research projects: Vessel Investigation Project (VIP) with Benchmark of Vessel Margin to Failure [1], dedicated to the behavior of the RPV, this is despite that TMI-2 RPV did not fail. Therefore, investigation of the phenomena which resulted in Fukushima RPV failures is crucial. In the present work, a preliminary stand-alone analysis is performed by SAMPSON code for Fukushima RPV taking into account gap cooling effects observed in SONATA experiment. Three CHF correlations have been tested for the boiling in the gap, all showed very different results. However, even that an existing correlation with a correction factor seems to be promising with better agreement with test data in the code, further investigations would be desirable for the correlation to accurately predict the failure times of Fukushima RPVs.

Keywords: Fukushima, Severe Accident, In-Vessel Retention, Gap Cooling, Lower Head Failure, Molten Core Relocation, SAMPSON

1. Introduction

Simulation result of SONATA-IV experiment by SAMPSON/DCA code [2] had shown that the heat transfer from molten debris to lower head wall was highly underestimated in comparison to experiment data. Furthermore, an effective gap cooling model was missing in the code. Therefore, the present study aims at investigating ways to improve debris to lower head wall heat transfer models in order to correctly predict the wall temperature and hence, RPV failure time.

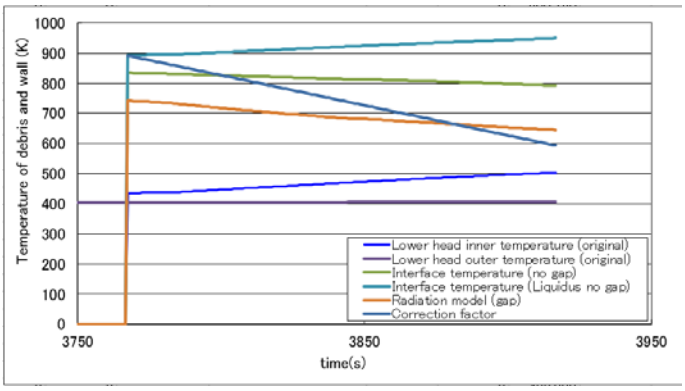
2. Analytical Method

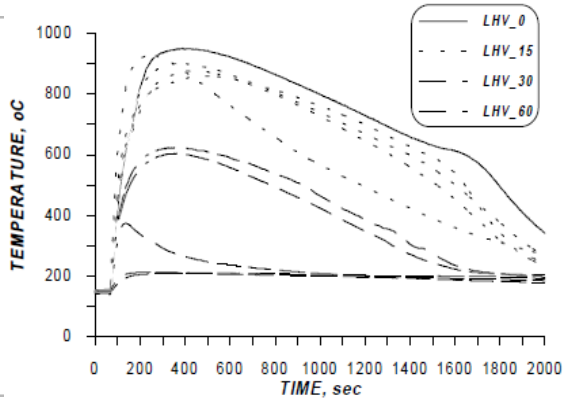
In the absence of a gap between debris bed and lower head wall, as a first order approximation, an interface temperature is estimated based on debris and wall material properties and their initial temperatures. Figure below shows the calculated wall temperatures: green curve (/) using debris melting temperature and light blue curve (/) using a bulk debris temperature. Assuming the presence of water in lower head, the estimated interface temperature is then used in the calculation of heat transfer to the wall through the gap taking into account the heat removal by boiling. Several existing CHF correlations are tested for the heat removal in the gap, including Fauske correlation [2], but all of them showed unrealistic results. A correction factor is then considered.

3. Results and Future Work

The result of lower head wall maximum inner and outer temperatures by the original model, blue curve (/) and purple curve (/) respectively, are presented in Figure below. Using one of above CHF correlations with a correction factor, debris to wall net heat transfer is calculated and the results of wall maximum temperature are compared to Lava-3 test data of SONATA-IV shown on right-side Figure below. The calculated new wall temperatures, considering heat removal in gap, are presented in Figure below as follows: orange curve (/) assumes only radiation from debris to wall while dark blue curve (/) assumes both radiation and conduction through the gap. This result shows only that wall temperature decrease is within the range of the test data as direct comparison with temperatures at different locations of the test is not possible because of different debris configurations between the calculation and the test.

Even though notable improvement is obtained, the present model, however, is still not completed as the evaluation does not take into account several other phenomena such as crust formation and a variable gap size. Therefore, many improvements including several new models, such as two-layer and three-layer debris models, and benchmark against real RPV lower head data of Fukushima which could be evaluated through an extensive investigation of Fukushima RPVs, as what was done for the RPV of TMI-2 [1]. This knowledge will be used for the discussions regarding 1F estimations of debris and FP and may help to clear some of the open items regarding Fukushima accident.





References

[1] NUREG/CR-6197, “TMI-2 Vessel Investigation Project”, US-NRC, 1994.

[2] Ezzidi, A. Kino, C., Chaki, M., Naitoh, M., “(97) Assessment of SAMPSON/DCA Heat Transfer Models between relocated molten core and RPV lower head wall,” Fall Meeting of AESJ, September 13-15, 2017.

[3] Fauske, H. K., “Operation of Reflux Condensation and Flooding Limitations”, FAI Process Safety News, Spring 2002, Volume 9, Number 1, 2002.

—Acknowledgement—
This work has been financially supported by the Japanese government’s Ministry of Economy, Trade and Industry.