Status of the GAMMA-FR code validation - TES pipe rupture accident of HCCR TBS

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1. Introduction

The GAMMA-FR (Gas Multicomponent Mixture Transient Analysis for Fusion Reactors) code is an in-house system analysis code to predict the thermal hydraulic and chemical reaction phenomena expected to occur during the thermo-fluid transients in a nuclear fusion system. [1] A safety analysis of the Korea TBS (Test Blanket System) for ITER (International Thermonuclear Experimental Reactor) is underway using this code. This paper describes validation strategy of GAMMA-FR and current status of the validation study with respect to 'TES pipe rupture accident of ITER TBM'.

2. GAMMA-FR code Validation

For developing the design scheme and system codes of the ITER TBM program in Korea, the developed system codes (the GAMMA+ code) were modified to accommodate the fusion application. GAMMA-FR is a breach of the GAMMA+ code, therefore the general thermal hydraulic validation of the mother code is directly inherited to GAMMA-FR. In the early days of the ITER program (prior to 1995), the MELCOR 1.8.2 code was chosen as one of several codes to be used to perform ITER safety analyses. Korea fusion reactor system code development is underway to achieve a reliable safety analysis code, replacing MELCOR for the HCCR TBM analysis. GAMMA-FR validation has two methods, i.e., fusion system related experimental validation and code to code validation using MELCOR.

3. Description of the accident

The first TBS accident that was selected to compare GAMMA-FR and MELCOR is an air ingress accident in the TBM's tritium extraction system (TES) [2].

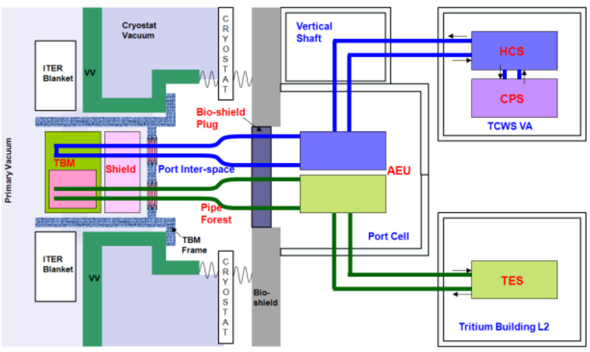

Fig. 1 HCCR-TBS Schematic diagram

This accident is initiated by purge pipe rupture at upstream position of the TES circulator inside Port Cell. Due to suction pressure, air ingress with moisture discharges to TBM BZ followed by reaction with beryllium and graphite. However, in this analysis, only graphite with air reaction is taken into account since moisture contents in the Port Cell is considered to be very limited. [2]

2.1 MELCOR modeling

An initial MELCOR model was developed for this TES single pipe break accident based on a GAMMA-FR input model.

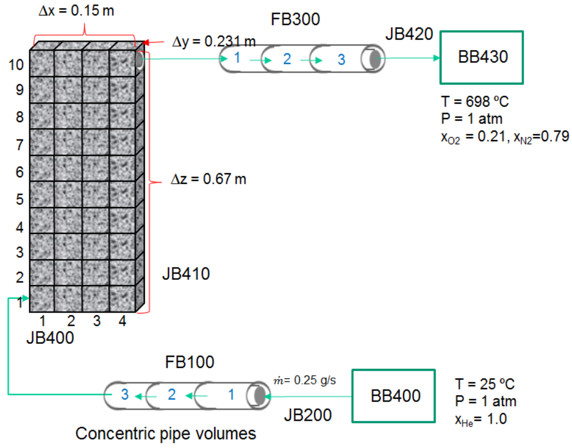

Fig. 2 MELCOR nodalization of TES pipe rupture accident

Two models of the reflector have been developed. The first model contained 4 axial pebble bed zones, designated as the 1x4 model. The second contained 4 radial and 10 axial pebble bed zones, designated as the 4x10 model. In addition to changes in reflector modeling, it was decided that the MELCOR code needed to be modified to use the time dependent gas composition during an accident when predicting the effective pebble bed thermal conductivities. The gas thermal conductivity is a significant contribution for pebble bed heat conduction. During the accident the pebble gas changes from helium, which has a high gas thermal conductivity, to an air/carbon dioxide mixture, which has a lower gas thermal conductivity. As a result, a user function was added to the MELCOR code that predicts the effective bed thermal conductivity with the Zehner/Schlünder (ZS) model. [3]

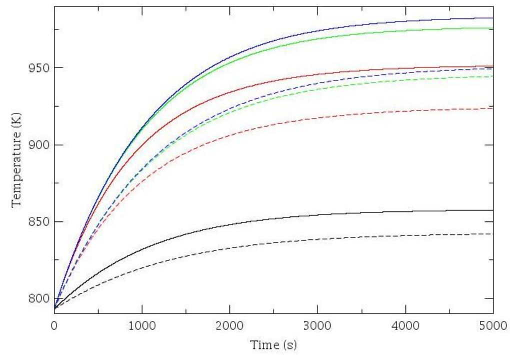

Fig. 3 MELCOR (dash lines) and GAMMA-FR (solid lines) predictions of graphite pebble bed temperature temperatures from 1x4 models at axial elevations of 0.0838 (black), 0.2513 (red), 0.4188 (green), and 0.5863 (blue) m, respectively

A comparison for the MELCOR and GAMMA-FR 1x4 model results for pebble bed temperatures are shown in Figure 3. This calculation allows radial conduction to fixed boundary temperatures of 693 K on the left and 722 K on the right, axial conduction within the bed but adiabatic on the top and bottom bed faces, and neglects conduction in the toroidal direction. A helium sweep gas flowing at $2.5x10^{-4}$ g/s is applied and the effective thermal conductivities are based on the Zehner/Schlünder (ZS) model with a graphite thermal conductivity for the pebbles of 120 W/m-K. Reasonable agreement was obtained, with the GAMMA-FR temperatures at z=0.0838 m being ~10 K higher and at z=0.5863 m ~35 K higher that the MELCOR model. A parametric case was run with these same two input models where the helium gas flow rate was set to zero. In this zero flow case the transient temperatures at all four elevations are identical, with the GAMMA-FR model predicting a final temperature of 984 K with an effective pebble bed thermal conductivity of 5.6 W/m-s compare to the MELCOR model predicting 950 K and 5.1 W/m-K. The applied power to the pebble bed zones were checked and found to be consistent. Therefore this does not explain the temperature differences. It is interesting that the temperature difference in the parametric case between these codes is approximately the same as that for the base case (~35 K) at z=0.5863 m. Perhaps there is a near wall effect on the effective thermal conductivity for GAMMA-FR which has not been included in the MELCOR model that is the difference, but this will have to be resolved. [3]

3. Conclusion

GAMMA-FR code to code validation is conducted and it shows reasonable agreement, however, near wall effect on the effective thermal conductivity needs to be investigated for better results. The GAMMA-FR code was scheduled for validation during the next two years under UCLA-NFRI collaboration. Through this research, GAMMA-FR will be validated with representative fusion experiments and reference accident cases.

4. Acknowledgement

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References

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