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September 6, 2001

Mr. Gary M. Holahan
Director
Division of Systems Safety and Analysis
U.S. Nuclear Regulatory Commission
OWFN, Mail Stop O-10-A-1
11555 Rockville Pike
Rockville, MD 20852-2738

Subject: Pebble Bed Modular Reactor: Thermal Hydraulics Analysis

Dear Mr. Holahan:

During our meeting on August 28, 2001, I said that I would pass on to you a draft ISL report on how TRAC-M can model the PBMR. It is enclosed. It shows the potential for TRAC-M being a good assessment tool for gas-cooled reactors.

If you have any questions regarding this initial modeling, please call me (301-255-2269).

We appreciated the opportunity to meet with you and look forward to working with you in the future.

Sincerely,

James F. Meyer
Manager
Nuclear Systems Analysis Division

Enclosure: Draft Report: "Summary of ISL's TRAC-M Code Model

Cc: R. Youngblood, ISL, Inc.

File: 2001-3 BD

PEBBLE BED MODULAR REACTOR

Summary of ISL's TRAC-M Code Model

by

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August 2001

1. INTRODUCTION

A Pebble Bed Modular Reactor (PBMR) is a high temperature helium cooled reactor using a Brayton cycle with a gas turbine to generate electricity. The TRAC-M code solves the mass, momentum and energy conservation equations for both 3-D and 1-D components including pumps, valves, turbines and heat exchangers. Helium is also not a problem since it is one of the fluids available in the TRAC-M code. Having pebbles instead of rods in the core region is a feature that requires new models. The fuel spheres are about the size of tennis balls. The spheres contact each other and also radiate energy to each other.

Recently Los Alamos Laboratory added additional features to the TRAC-M code for ATW and PBMR applications which make modeling of the PBMR more accurate. The new features are:

1. spherical conduction,
2. generalized surface-to-surface thermal radiation
3. contact conduction
4. correlations for pressure losses in a pebble bed
5. correlations for convective heat transfer in a pebble bed

2. TRAC-M Vessel Model of PBMR

ISL built a TRAC-M model of a PBMR vessel which used the spherical conduction feature. (The other four new features listed above were not available at that time). Figure 1 shows helium entering the vessel at two locations (at the top and side). The vessel schematic is split down the middle to show the hardware on the left and the TRAC noding on the right. The model uses four radial hydraulic rings to provide the necessary four vertical flow paths. The major helium flow

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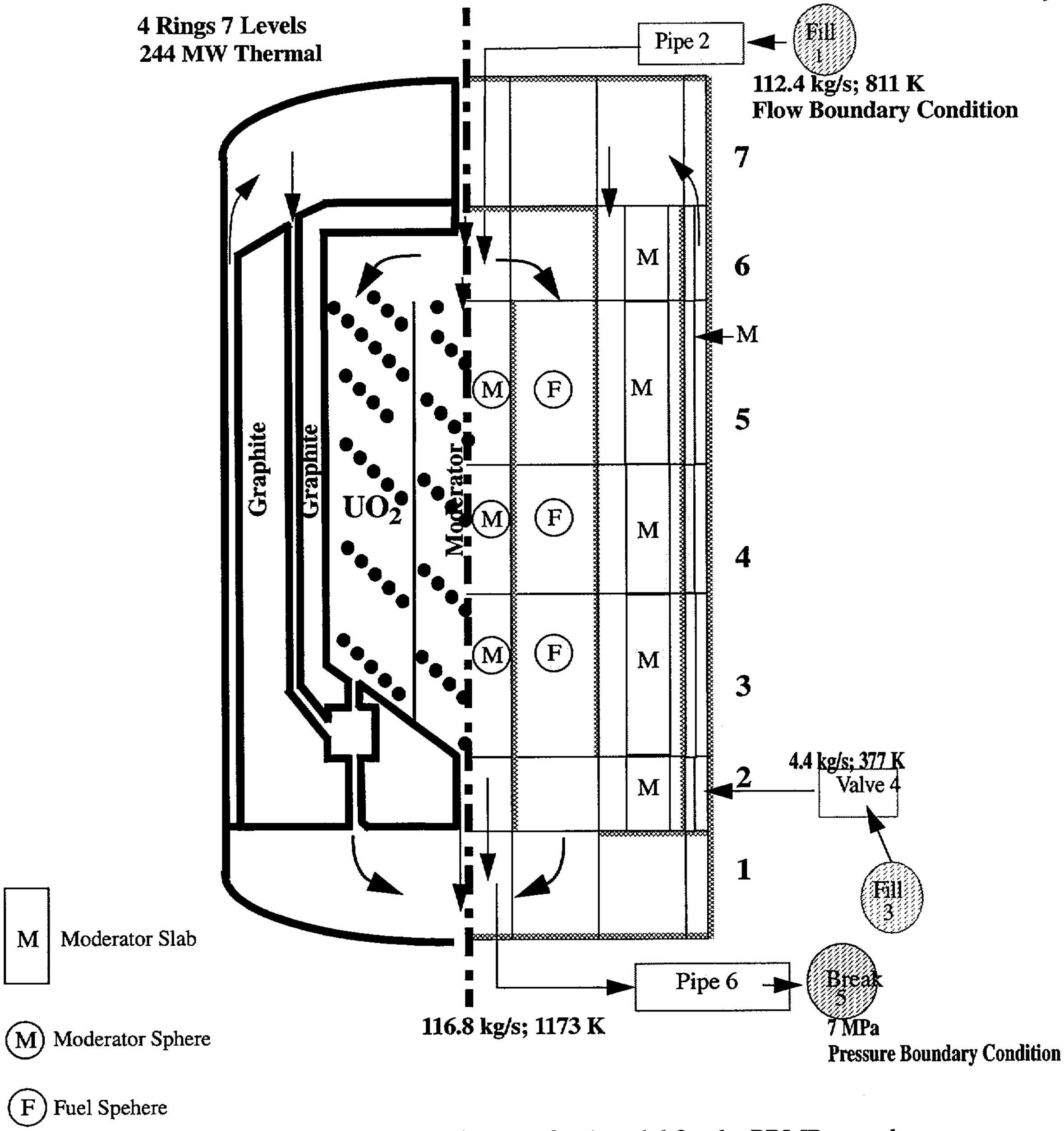

Figure 1. Schematic of the TRAC-M model for the PBMR vessel

enters the top of the core with a flow rate of 112.4 ks/s and a helium gas temperature of 811 K. The central ring is filled with spheres containing only graphite moderator. Ring two contains fueled spheres. A small flow enters the side of the vessel and flows to the top of the vessel in ring four and back down in ring 3 to cool the graphite in the vessel periphery. Seven axial hydraulic levels were used.

Figure 1 also shows the ex-vessel components of the TRAC-M model. FILL and BREAK components were used to set the boundary conditions.

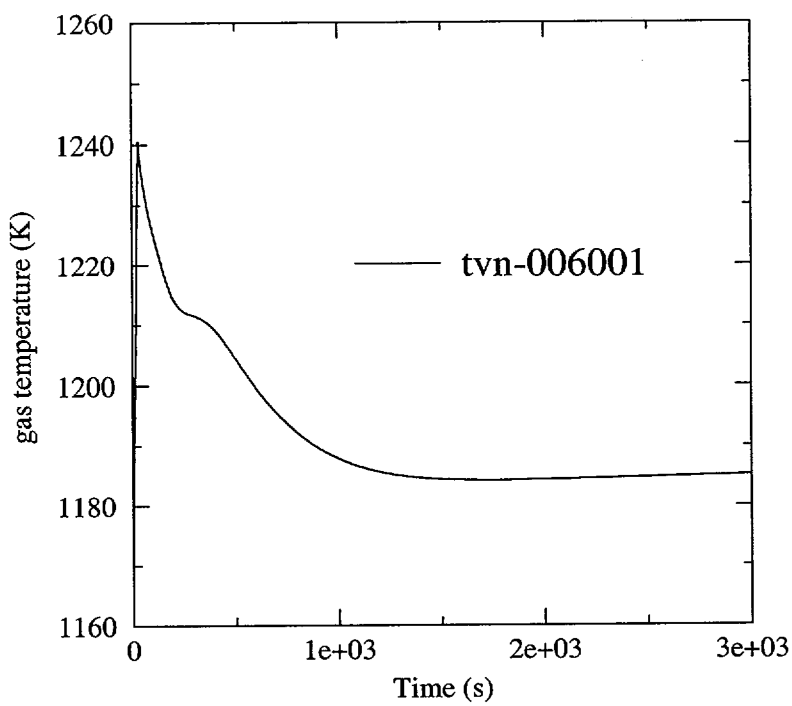

Figure 2. Predicted helium temperature at vessel exit.

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The model was exercised by running a 3000 second transient with fixed boundary conditions to obtain steady state conditions. The results of the preliminary exercise with this model were compared to the data published at the vendor's web site (www.eskom.co.za/nuclear/pebble_bed/pebble_bed.html). The web site reports an exit temperature of 1173 K and TRAC-M predicts about 1185 K (see Figure 2). The difference is small and may be caused by differences in helium specific heats used in the two calculations.

The important feature of the TRAC-M code is that it can predict the transient behavior of the reactor for various types of assumed transients. The predicted temperature profile of a fuel sphere for this steady state calculation is shown in Figure 3. A layer of graphite with a higher conductivity than fuel causes the flattening of the profile near the outer edge.

3. TRAC-M Loop Model of PBMR

FILL and BREAK components, which specified boundary conditions, were removed and replaced with PIPEs, a PUMP and a TURBINE component. In the PBMR loop, the helium coolant goes through three turbine stages. The helium exits the turbine at a temperature, which is above the saturation temperature of water at the same pressure, then flows through a recuperator, where it reheats the helium returning to the reactor. Unfortunately, the closed loop test revealed that the current TURBINE component was designed for use only with steam-water fluid mixture, and that this component assumed that the temperature of the downstream fluid was always at the

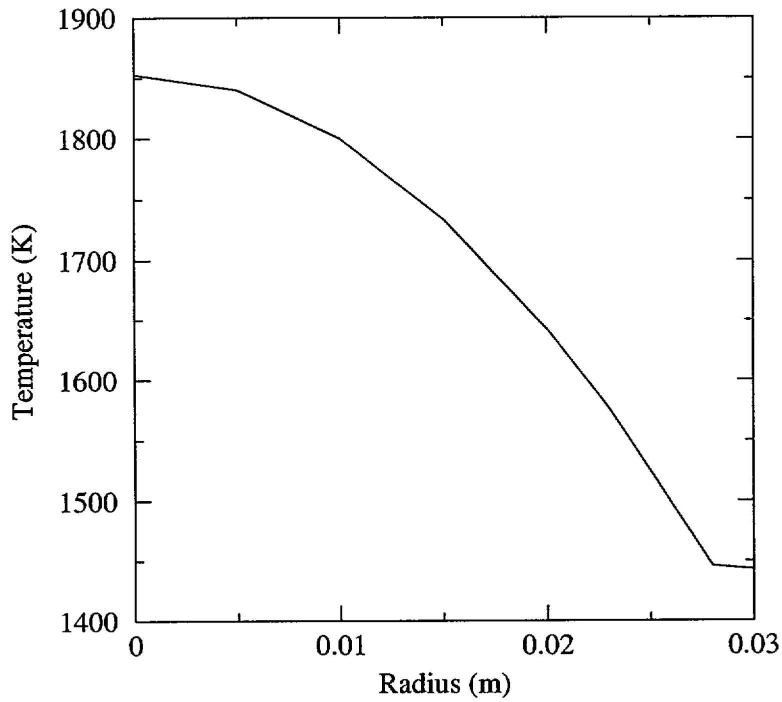

Figure 3. Fuel sphere temperature at the bottom of core

saturation temperature of water corresponding to its exit pressure. Due to the current turbine model's inability to predict the temperatures for the helium at the turbine exit, TRAC-M could not simulate the closed PBMR loop properly.

4. Future Development

A gas turbine model must be developed for TRAC-M. The RELAP5 turbine component can be tested in a helium environment to determine if it has the same shortcoming as the TRAC-M turbine. If not, the RELAP5 model can be ported to TRAC-M.

PBMR has two turbines which turn shafts to drive helium gas compressors in order to bring the helium pressure back up to 7 MPa. A third turbine drives an electric generator. The RELAP5 code has what is called a SHAFT component to couple turbines to other energy consuming components. The RELAP5 SHAFT component concept can also be developed in TRAC-M.

Although the porous media models of pressure drop and heat transfer coefficients are now available, assessment calculations must be performed to make sure they are functioning properly. This also applies to the surface-to-surface thermal radiation model.

The number of vessel cells in the existing TRAC-M PBMR model will need to be increased to capture the natural convection flow paths for 'Loss-of-Flow' accidents. Buoyancy effects could result in flow stagnation in some regions of the core. Increasing the number of cells is a relatively easy task.

A recent NRC report titled “Comparison of GRSAC and TRAC Modeling Capabilities as a Foundation for a PBMR Accident Simulation Code” reports that graphite oxidation and annealing models are also needed.

5. Conclusion

TRAC-M shows good potential for use in predicting the fuel and graphite moderator temperature transients in the PBMR vessel. A new gas turbine model needs to be developed for the TRAC-M code to further its PBMR predictive capability. Assessment calculations need to be performed.

Jim Meyer
ISL

Gary Holahan