# Preliminary Neutronics Results for the OECD MHTGR-350 Benchmark

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## 1. Introduction

The OECD/NEA MHTGR-350 neutronics/thermal-fluids coupled benchmark problem was proposed to test the existing analysis methods for prismatic high temperature gas-cooled reactors (HTGRs) and to develop more accurate and efficient tools to analyze the neutronics and thermal-fluids (TF) behavior for the design and safety evaluations of prismatic HTGRs.[1] The benchmark problem is based on the MHTGR-350 reactor designed by General Atomics (GA). Phase I of the problem has three steady state exercises : Exercise 1 for neutronics stand alone with fixed cross-sections, Exercise 2 for thermal-fluids stand alone and Exercise 3 for coupled steady state. Phase II is defined for coupled transient cases. Phase III is defined to test the depletion capabilities of lattice physics codes. Phase III has two exercises : Exercise 1 for cold state and Exercise 2 for hot state.

In this paper, a preliminary results for Exercise 1 of Phase I obtained by using CAPP code[2] and the results for Phase III by McCARD code[3] are presented.

## 2. Methods and Results

### *2.1 Definitions of the Problems*

The actual core geometry is shown in Fig. 1 and the permanent reflectors were simplified by using hexagons as shown in Fig. 2. There are 22 fuel columns in the 1/3 core model and ten fuel blocks are loaded axially per fuel column. Control rod is partially inserted in column 33 shown in Fig. 2. The macroscopic cross-sections are given for the 220 fuel blocks, inner/outer reflectors, and the control rods with 26 neutron groups. Control rod cross-sections are provided for the two models respectively : hexagonal model and triangular model. The whole hexagon is homogenized in the hexagonal model even though the control rod is inserted in one of the six triangles while the triangle in which the control rod is inserted is homogenized separately from the other five triangles in the triangular model.

Figure 3 shows the super-cell model and the pin number for Phase III. The depleting doubly heterogeneous fresh central block is surrounded by non-depleting homogeneous burnt fuel blocks (purple) and reflector blocks (red). Each exercise of Phase III has two cases : no burnable poison (BP) cases (Ex.1a and Ex. 2a) and BP loaded cases (Ex.1b and Ex. 2b). BP compacts are loaded at the six corner pin positions (1, 8, 103, 114, and 209) in Fig. 3(b).

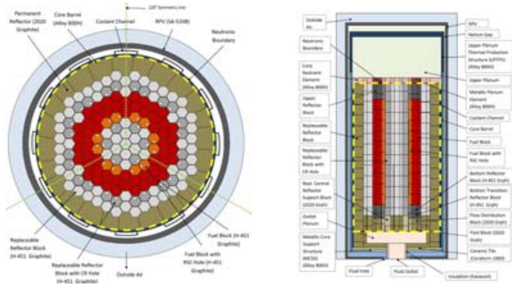
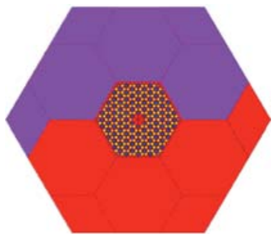
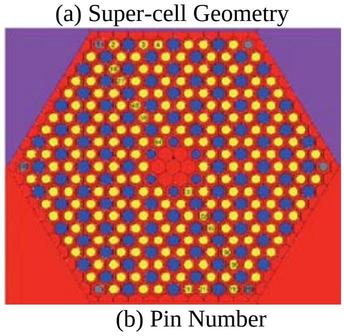


Fig. 1. MHTGR-350 Core Geometry.

Fig. 2. Simplified 1/6 Core Model for Phase I and II.



(a) Super-cell Geometry



(b) Pin Number

Fig. 3. Super-cell Geometry and Pin Number for Phase III.

### *2.4 Preliminary Results*

Table I shows some preliminary results with CAPP code for Phase I Exercise 1. The table also presents some preliminary results of Idaho National Laboratory (INL) calculated by PHYSICS code.[4] The two results show a good agreement with each other. Figure 3 and 4 show the relative power density distributions.

Table I: Preliminary Results for Phase I Exercise 1

| Model | Hexagonal CR | | Triangular CR | |
|---|---|---|---|---|
| Code | CAPP | PHYSICS | CAPP | PHYSICS |
| Keff | 1.06693 | 1.06688 | 1.06665 | 1.06631 |
| RW[1)] | 75.0 | 73.0 | 103.0 | 96.0 |
| AO[2)] | +0.1695 | - | +0.1563 | - |
| Pm[3)] | 23.08 | - | 23.00 | - |

1) Rod Worth in [pcm]  2) Axial Offset
3) Maximum Power Density in [W/cm$^3$]

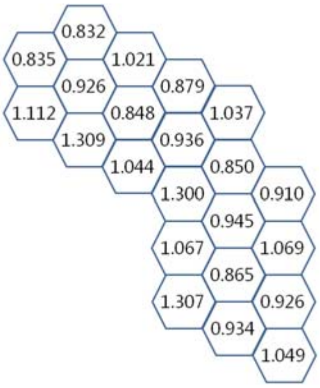



Fig. 3. Radial Relative Power Density Distribution for the Triangular Control Rod Model.

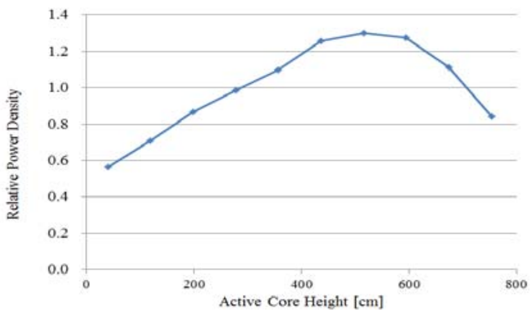



Fig. 4. Axial Relative Power Density Distribution for the Triangular Control Rod Model.

Figure 5 shows the infinitive multiplication factors of the hot cases (Exercise 2a and 2b) of Phase III calculated by McCARD code. Figure 6 shows $^{235}$U mass at pin 2 in Fig. 3(b) for the two cases. Figure 7 shows $^{239}$Pu mass at pin 2 in Fig. 3(b) for the two cases. We observe more production of $^{239}$Pu in BP loaded case (Exercise 2b), which is consistent with the fact that the neutron spectrum is harder in BP loaded case.

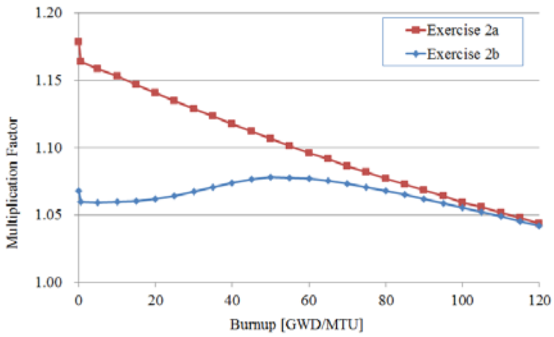



Fig. 5. Infinitive Multiplication Factors for the Four Cases of Phase III.

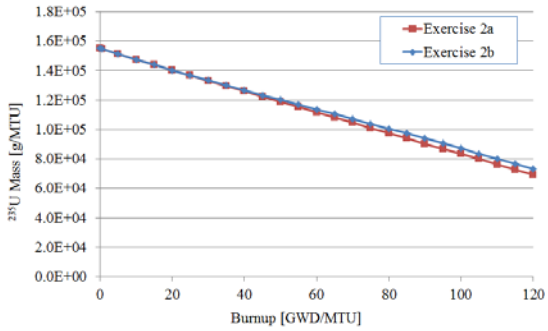



Fig. 6. $^{235}$U mass at Pin 2 for the two Cases of Phase III.

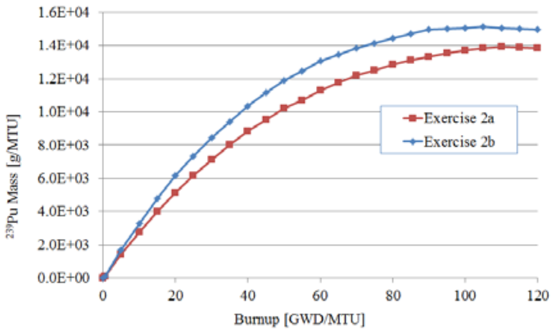



Fig. 7. $^{239}$Pu mass at Pin 2 for the two Cases of Phase III.

## 3. Conclusions

In this paper, some preliminary neutronics results for the OECD/NEA MHTGR-350 neutronics/thermal-fluids coupled benchmark problem were presented and some of the global parameters for Phase I Exercise 1 were compared with those presented by INL research group. They showed a good agreement with each other. The results for Phase III were also reasonable. The benchmark is ongoing and more comparisons with the results of other research groups will be made as soon as they are available.

## REFERENCES

[1] "Prismatic Coupled Neutronics/Thermal Fluids Transient Benchmark of the MHTGR-350 MW Core Design – Benchmark Definition," Draft date : 07/16/2013.
[2] Hyun Chul Lee, et al., Development of HELIOS/CAPP Code System for the Analysis of Block Type VHTR Cores, PHYSOR 2012, Knoxville, Tennessee, USA, April 15-20, 2012.
[3] Shim, H.J., Kim, C.H., 2002. Error propagation module implemented in the MC-CARD Monte Carlo code. Trans. Am. Nucl. Soc. 86, 325.
[4] Gerhard Strydom, PHYSICS-RELAP5 Phase I Results of the OECD/NEA MHTGR-350 MW Benchmark, NGNP Technical Review Meeting, Salt Lake City, Utah, May 24, 2012.