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Analysis of HTTR Startup Core Physics Test by Monte Carlo Method

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1. Introduction

The Very High Temperature Reactor (VHTR) has been studies as one of the candidate of the Generation-IV (Gen-IV) reactor. The Japan's High Temperature Engineering Test Reactor (HTTR) is a graphite-moderated and helium gas cooled reactor with an outlet temperature of 950℃ and thermal output of 30 MW [1].

In this study, the McCARD model has been established for a benchmark analysis of the HTTR start-up core physics test. The McCARD [2] code adopts the Monte Carlo method and the cross section library is ENDF-B/VII.0.

2. HTTR Core Model

Fig.1 shows the radial core arrangement, and the HTTR core specifications are represented in Table I. The HTTR core is a form of the annular type. In the startup core physics experiment stage, three different types of cores were formed; thin and thick annular core were achieved at 18 and 24 fuel column loaded core, and full core with 30 fuel columns. The reactor core component is arranged in the reactor pressure vessel which has 13.2 m height and 5.5 m diameter. The core is consists of 30 fuel columns and 7 control rod guide columns with active core height of 290 cm and 230 cm effective diameter. An additional 9 control rod columns are located in the outer reflector region. The replaceable reflector region adjacent to the active core consists of 9 control rod columns, 12 replaceable reflector columns, and 3 irradiation columns. There are 2 top reflector blocks, 5 fuel blocks, and 2 bottom reflector blocks in each fuel column.

3. Results and Discussion

There are 12 different fuel types in HTTR fuel. In this study, the fuel is modeled by the reactivity-equivalent transform method (RPT) [3] as shown in Fig. 2. Also, a 31-pin and 33-pin fuel assembly is modeled with two different burnable poison concentrations.

Through the double heterogeneity and RPT calculations, the RPT radius was determined within 90 pcm of the k-effective difference. The calculations were performed for 12 fuel enrichments, and the results are represented in Table II. It can be seen that the RPT radius is not sensitive to the fuel enrichment.

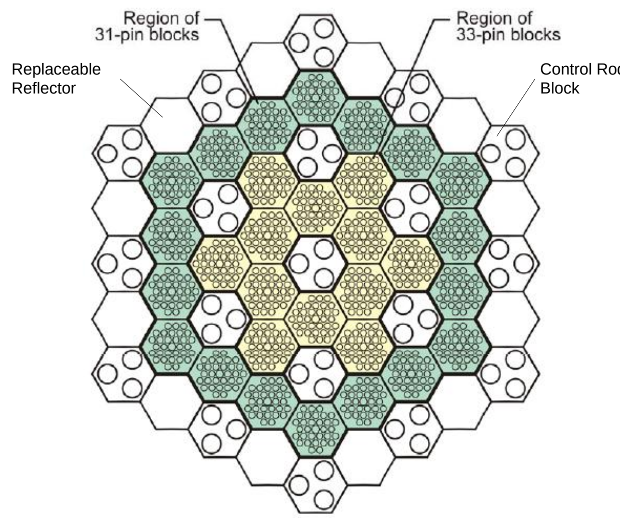

Fig.1 HTTR Core Fuel Block Arrangement

Table I: Specification of the HTTR

Parameter	Value
Thermal power	30 MW
Outlet coolant temperature	950℃
Inlet coolant temperature	395℃
Equivalent core diameter	230 cm
Effective core height	290 cm
Uranium enrichment	3 to 10 wt%
Fuel type	Pin-in-block
Number of fuel blocks	150
Number of fuel columns	30
Number of control rod block	
In core	7
In reflector	9

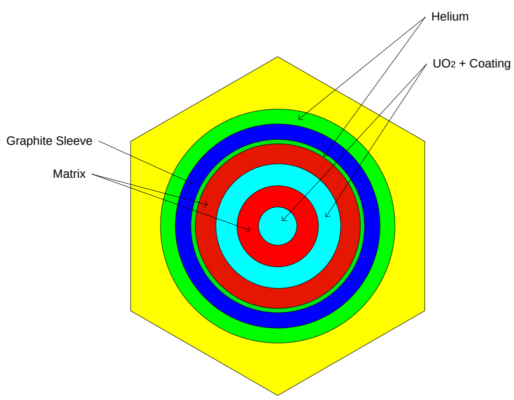

Fig.2 RPT Cell Model

Table II: RPT Radius with Fuel Enrichment

Enrichment (wt%)	RPT Radius (cm)
3.4	1.2240
3.9	1.2359
4.3	1.2358
4.8	1.2368
5.2	1.2367
5.9	1.2356
6.3	1.2236
6.7	1.2249
7.2	1.2235
7.9	1.2234
9.4	1.2229
9.9	1.2230

Before the fuel loading, the fuel region is filled with graphite dummy blocks. The fuel loading is carried out by replacing the dummy blocks by the fuel blocks. The loading order is shown in Fig. 3.

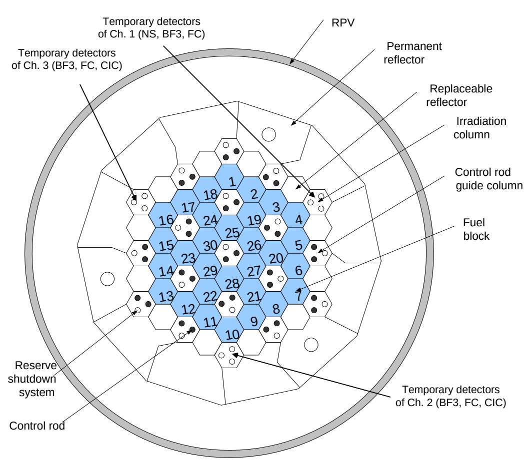

Fig. 3 Fuel Loading Order

The effective multiplication factors with different number of fuel columns are compared in Table III. In the experiment [4], the first critical was achieved with 19 fuel columns while the calculation gives the first critical with 18 columns. The difference in excess reactivity at 18 fuel columns is 0.0284 Δk/k. For all the cases the calculation gives higher excess reactivity of range between 0.0126 and 0.0294 Δk/k. The difference becomes smaller with increase of the fuel columns.

Table III: Comparison of multiplication factor

No. of Fuel Columns	K_{eff} Calc.	K_{eff} Exper.	Δk/k
18	1.02028	0.99130	0.0284
19	1.03904	1.01520	0.0294
24	1.11119	1.08420	0.0243
30	1.15079	1.13630	0.0126

4. Summary

From the results, it is known that the McCARD gives a little higher excess reactivity with fuel column. These discrepancies are thought to be caused by the ENDF-B/VII.0 library and the impurities represented by the equivalent boron concentration. It is expected that the results are to be improved with the ENDF-B/VII.1 library in future.

REFERENCES

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