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HTR-N

HTR-N & N1
High-Temperature Reactor Physics and Fuel Cycle Studies
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Document Title

HTR-N1

Calculation of the Control Rods Worth for HTTR performed by UNIPI

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1	08-09-2003	Minor corrections	UNIPI	N/A	CEA	FZJ
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Chronology and history of revisions

Rev.	Date	Description
0	31-08-2003	First issue
1	08-09-2003	Minor corrections

Table of Contents

1. Introduction

Work Package 1 of the <<HTR-N1>> contract is concerned with[1]

- Isothermal temperature coefficient estimation on the fully loaded core configuration at hot zero power and with fixed control rod positions
- Evaluation of the control rod worth for different core configurations at hot hot zero condition. Scram reactivity of all the control rods and scram reactivity of the reflector control rods only
- Evaluation of the critical control rod depths related to different core power level (qualification of the thermal feedback models)

This work represents UNIPI contribution to the task N1/1.2[1] (Evaluation of the control rod worth for different core configurations).

2. Description of codes and libraries

To perform our transport calculations we used an improved version of WIMS-D/5B code[2] (namely WIMS-D/5B-P1[7]) for cell calculation and a new nuclear library (172 energy groups) based on JEF2.2 dataset developed by IAEA in the frame of Wims Library Update Project (WLUP)[3].
To perform diffusional calculations over the whole core, we used CITATION code[4] with 7 energy groups.

3. Geometry and Material Definition

To perform our transport calculation we used the fuel cell model described in figure 1[5]. The whole core model used in CITATION input is described in figure 2 and 3[5]. Figure 4[5] describes fuel and burnable poison zoning plan of the HTTR. General specifications of HTTR[6] and specifications of fuel blocks[6] are described in table 1 and 2.

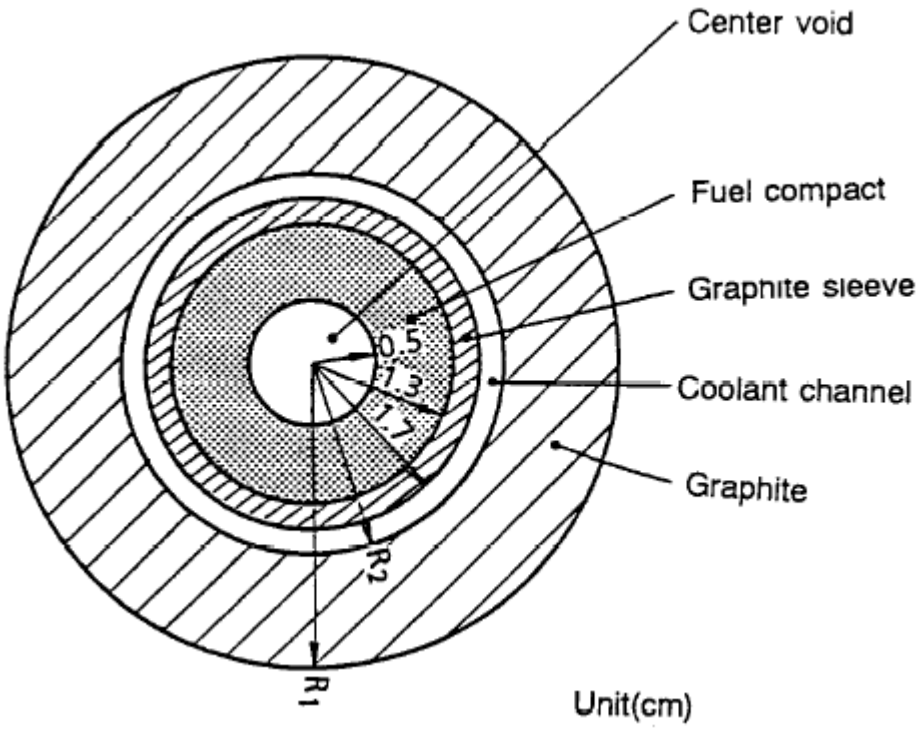


Figure 1 – One dimensional cylindrical fuel cell model (R_1 = 3.41 cm, R_2 = 2.09 cm)

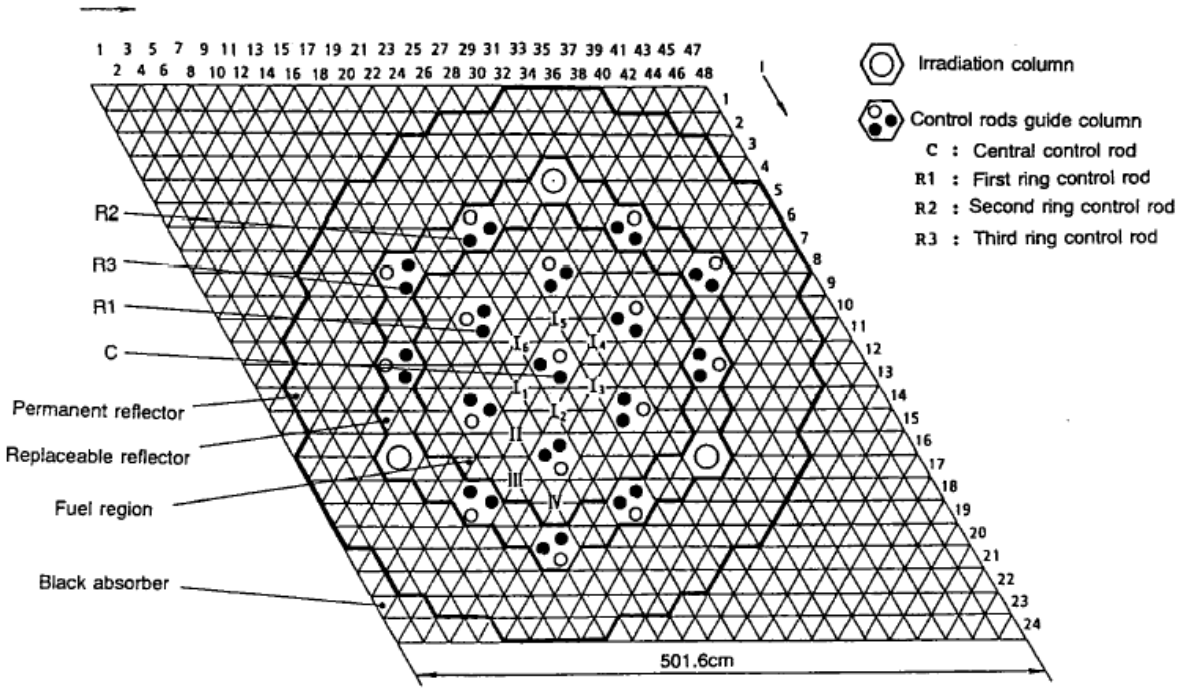


Figure 2 – Hexagonal plane of core calculation

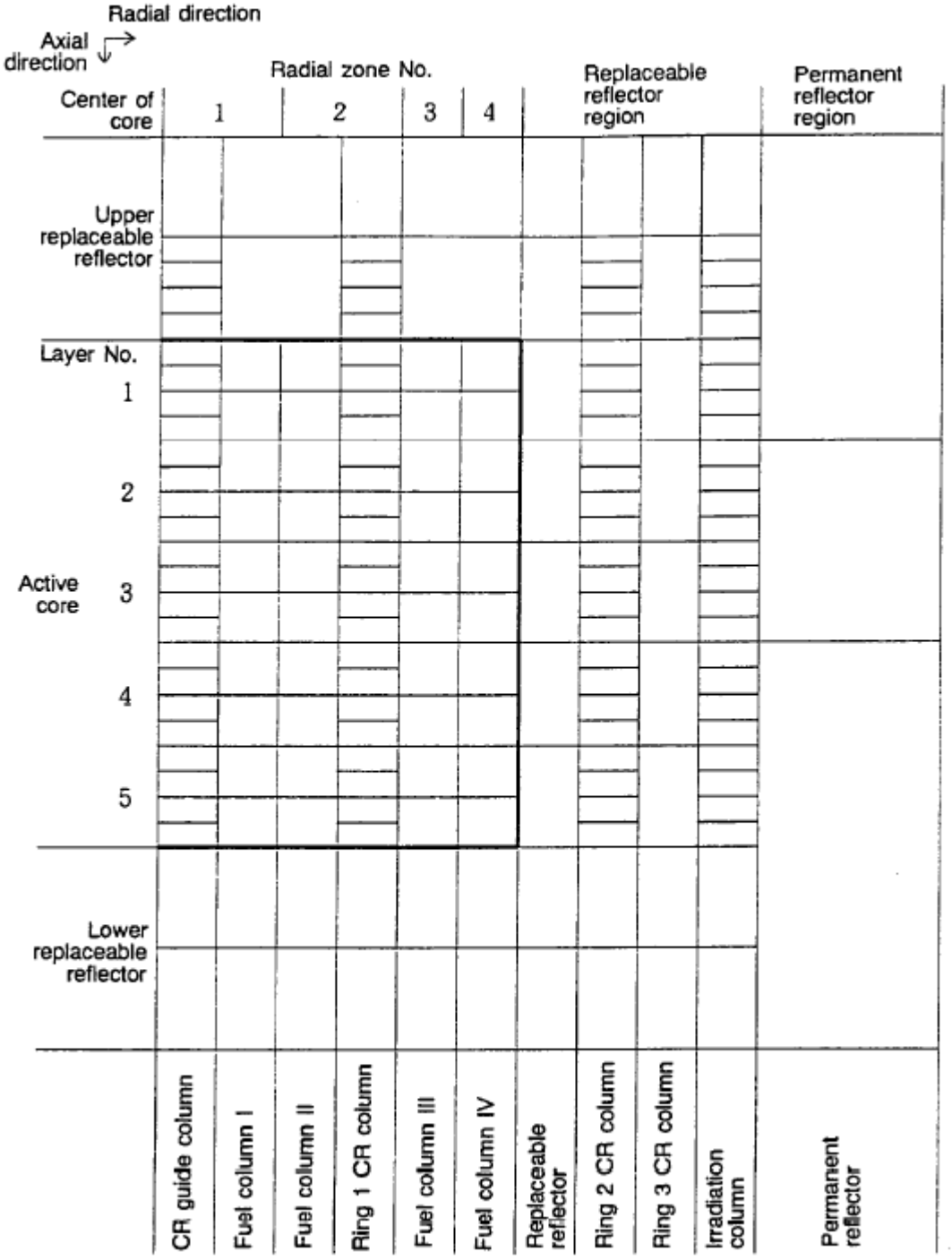
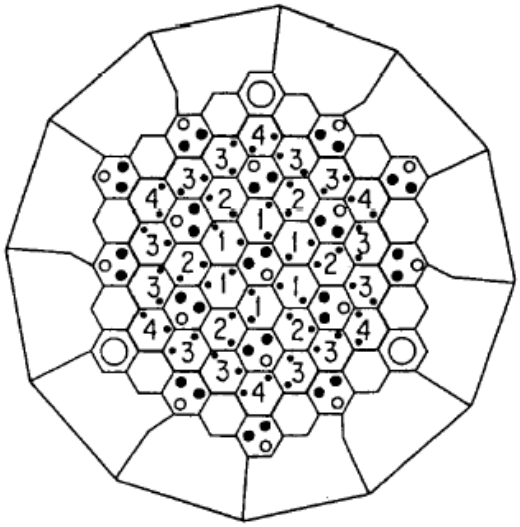


Figure 3 – Hexagonal plane of core calculation



Layer*3	Fuel zone number*1				BP*2
	1	2	3	4	
1	6.7	7.9	9.4	9.9	2.0
2	5.2	6.3	7.2	7.9	2.5
3	4.3	5.2	5.9	6.3	2.5
4	3.4	3.9	4.3	4.8	2.0
5	3.4	3.9	4.3	4.8	2.0

*1 ^{235}U enrichment(wt%)
*2 Natural boron concentration(wt%)
*3 The number indicates the layer number from the top fuel block.

: Fuel column
N : Zone number
• : Burnable poison
: Control rod guide column
• : Control rod
o : Reserve shut down system
: Replaceable reflector
: Irradiation column

Figure 4 – Fuel and BP zoning plan of the HTTR

Thermal power	30 MW
Outlet coolant temperature	950 °C
Inlet coolant temperature	395 °C
Primary coolant pressure	4 MPa
Core structure	Graphite
Equivalent core diameter	2.3 m
Effective core height	2.9 m
Average power density	2.5 w/cm^3
Fuel	UO_2
Uranium enrichment	3 to 10 wt%
Type of fuel	Pin-in-block
Burnup period	660 days
Coolant Material	Helium gas
Flow in core	Downward
Reflector thickness	
Top	1.16 m
Side	0.99 m
Bottom	1.16 m
Number of fuel blocks	150
Number of fuel columns	30
Number of pairs of CRs	
In core	7
In Reflector	9

Table 1 – Specification of the HTTR

Number of fuel rods in a fuel block		33/31
Graphite block		
	Material	IG-110
	Widths across flats	36 cm
	Height	
58 cm		
	Density	1.75 g/cm^3
Fuel rod		
	Outer diameter	3.4 cm
	Length	54.6 cm
	Number of fuel compacts	14
	Graphite sleeve	
	Material	IG-110
Fuel compact		
	Outer diameter	2.6 cm
	Inner diameter	1.0 cm
	Length	3.9 cm
	Packing fraction of CFPs	30 vol%
	Density of matrix	1.7 g/cm^3
Coated fuel particle(CFP)		
	Diameter	920 μm
Fuel kernel		
	Material	UO_2
	Diameter	600 μm
	Enrichment	3-10 wt%
	Density	10.41 g/cm^3

Coatings	Thickness	Density
Buffer	60 μm	1.10 g/cm^3
Inner PyC	30 μm	1.85 g/cm^3
SiC	25 μm	3.20 g/cm^3
Outer PyC	45 μm	1.85 g/cm^3

Burnable absorber rod	
Material	B_4C+C
Length (BA/Graphite disk/BA)	20/10/20 cm
Density	1.8/gcm^3
Natural boron density	2.24/2.77 wt.%

Table 2 – Specification of fuel blocks

4. Results

As a result of our calculation, we have obtained the following value:

Control Rods Position	K_{eff}
178.9 cm	**1.0031**
Scram of reflectors Control Rods	**0.86535**
Scram of all Control Rods	**0.67937**

These results are in good agreement with those obtained by the other partners.

REFERENCES

/1/ X. Rapsaet
"HTR-N1 (Kick-off). WP1 : METHOD VALIDATION FOR BLOCK TYPE FUEL CORES"
HTR-N1 project – 12 October 2001

/2/ ANSWERS Software Service
"WIMS-D/5: A Neutronics Code for Standard Lattice Physics Analysis" ed. A.E.A.
U.K. (Winfrith) 1995

/3/ F. Leszczynski, D. L. Aldama, A. Trkov
"WIMS-D Library Update**.** Final report of a co-ordinated research project"
IAEA – October 2002

/4/ T. B. Fowler, D. R. Vondy, G. W. Cunningham
"Nuclear Reactor Code Analysis Code: CITATION"
ORNL – July 1971

/5/ J.A.E.R.I.
"Design of High Temperature Engineering Test Reactor "
Japan – September 1994

/6/ J.A.E.R.I.
"Benchmark Problems of Start-up Core Physics of High Temperature Test Reactor (HTTR)"
Japan – 1998

/7/ G. Lomonaco, N. Cerullo
"WIMS-D/5B-P1: an improvement of WIMS-D/5B code using new neutron libraries obtained by WLUP project" – to be published