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Document Title

Recalculation of the First Criticality of the HTTR

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INTRODUCTION

- The discrepancy between measurement and the former FZJ diffusion calculation amounted to $\Delta k = 0.0287$ at the first criticality, presented at the 2.RCM of the IAEA CRP-5.
- Possible reasons for this circumstance were studied using simplified (1-d and 2-d) models of a thin annular core with 18 fuel columns:
  1. improved modelling of the fuel and burnable poison (BP) unit cells,
  2. use of many(26) group homogenized cross sections in the whole core diffusion calculation, in order to describe the core/reflector coupling accurately,
  3. consideration of the actual boron impurity in some dummy fuel blocks and of air in graphite pores,
  4. taking into account the **exact position** of the BP-sticks in the fuel blocks in the whole core diffusion calculation with 24 horizontal meshes per fuel block.
- Some results of these studies are listed in Table 1:
  - increase of k_{eff} by increasing energy group numbers by about Δk=0.036 - 0.056
  - decrease of k_{eff} by the use of new unit cell models and the consideration of the detailed structure of the fuel block by about Δk=0.064 - 0.042

These results were the reason to repeat the detailed whole core calculations taking into account the above mentioned four items.

COMPUTATIONAL METHODS AND NUCLEAR DATA

- The code system and the basic nuclear data used in the criticality calculations were the same as those in the previous calculations, presented in detail at the 1.RCM of the IAEA CRP-5.
- The following computational methods remained unchanged:
  - the calculation of the Dancoff factors,
  - the treatment of the axial heterogeneity of the BP by B-10 adjustment,
  - and the treatment of the neutron streaming by anisotropic diffusion coefficients on the basis of the Benoist method.

New Fuel-,BP-, and Graphite-Unit Cells

In order to consider the detailed structure of the HTTR fuel block, each fuel block is divided into 3 different regions:

- one fuel region, corresponding to 18/24 of the whole block,
- two BP regions, each corresponding to 2/24 of the whole block,
- one „empty BP" region, according to 2/24 of the whole block.

WHOLE REACTOR CALCULATIONS

- Using the 26-group cross sections from the cell calculations the whole HTTR reactor was modelled with the CITATION diffusion code in a 3-dimensional triangular-z model with 4 vertical and 24 horizontal meshes per block.
- When taking into account:
  - the neutron streaming correction,
  - the neutron axial self-shielding in the BP,
  - the reactivity of the CR insertion (-0.0040)

the first criticality will be achieved at 18 fuel columns in the core with an excess reactivity of $\Delta k/k=0.84$ %.

- Due to the consideration of
  - the detailed structure of the HTTR fuel block in the whole core calculation,
  - air in the graphite pores and the actual boron impurity,
  - the detailed energy-dependence of the neutron flux by a fine energy group structure,

the number of fuel columns to achieve first criticality increases by about 2 fuel columns in comparison to the results presented at the 1.RCM (see Fig.1).

- Remaining discrepancy between measurement and FZJ diffusion calculation: $\Delta k=0.0113$ at the first criticality (i.g. at 19 fuel columns).
- Possible reasons:
  1. a not yet adequate treatment of the BP absorber regions,
  2. a too small streaming effect.
- to point 1:
  - In the recalculation the consideration of the axial heterogeneity of the BP remained unchanged. This means: The axial self-shielding in the BP was taken into account by a reduction of the B-10 concentration.
  - Now, we considered the axial heterogeneity by another method: it was provided that in the BP-region of the whole core diffusion calculation the absorption was the same as in the more accurate 2-d DORTcalculation for this region. The result was: The B-10 adjustment overestimated the efficiency of the BP compared to the use of group constants obtained in a 2-d DORT-cell calculation (see Table 2 and Fig. 2).
  - Thus, the discrepancy between experiment and calculation will increase when taking into account the axial self-shielding of the BP by a more accurate method.
- to point 2:
  - When comparing the streaming effect calculated by the deterministic diffusion code CITATION with the streaming effect calculated by the JAERI-HTTR Monte Carlo code MVP it is noticed that the influence of the neutron streaming in the diffusion calculation is about 26% smaller than the effect calculated by theMonte Carlo code, in the case of 18 fuel columns in the core (see Table 3). Thus, our present neutron streaming correction, basing on the theory of Benoist, should be assessed in a further investigation.

CONCLUSION

- Better approach to the experimental results by the following treatments seems to be necessary:
  1. detailed heterogeneity of the BP- and fuel-region in the whole core calculation,
  2. use of fine group constants or accurate leakage iteration in the diffusion calculations of the whole core in order to describe the core/reflector coupling accurately.
- When applying these treatments and regarding the actual boron impurity in some dummy fuel blocks together with air in the graphite pores the first criticality was achieved at 18 fuel columns in the case of fuel loading from the core periphery.
- Furthermore, it turned out:
  - A 26 energy group structure seemed to be sufficient to get reliable results.
  - But, the discrepancy between experiment and calculation will increase when considering the axial self-shielding in the BP by using group constants obtained in a 2-d transport calculation.

APPENDIX: TABLES AND FIGURES

	k_{eff}		Δk
	Old Unit Cells 6 Mesh Hom. Model	New Unit Cells 24 Mesh Het. Model	between New-Old Model
4 Groups	1.0484	0.9857	-0.0637
26 Groups	1.0840	1.0419	-0.0421
Δk 26-4 Groups	+0.0355	+0.0563	–
52 Groups	1.0842	1.0430	-0.0412
Δk 52-26 Groups	+0.0004	+0.0011	–

Table 1: Effective Multiplication Constants and Δk Values for a Simplified 3-d, Triangular-z HTTR Core Model (18 Fuel Columns) Using Different Unit Cell Models

No Streaming Correction and BP Adjustment
Helium in Graphite Pores and Old Boron Impurity

Groups	k_{eff}			Δk
	Homog.	heterogeneous		2-d-DORT-cell calculation - B-10 Adj.
	BP	by B-10 Adj.	by 2-d DORT-cell calculation	
4	0.9857	1.0099	1.0138	+0.0040
26	1.0419	1.0647	1.0735	+0.0088
52	1.0430	1.0657	1.0746	+0.0090

Table 2: Effective Multiplication Constants and Δk Values for a Simplified 3-d, Triangular-z HTTR Core Model (18 Fuel Columns) Using Different Treatments of the BP

No Streaming Correction, 24 Horiz. Meshes/Block
Helium in Graphite Pores and Old Boron Impurity

No. of Fuel Columns	Streaming Effect [%Δk/k]	
	CR Guide Columns Upper and Lower Reflector Blocks	CR Guide Columns and Irrad. Columns by MVP[a]
18	1.69	2.30
24	1.38	-
30	1.18	1.30

Table 3: Streaming Effects
[a] Results of JAERI-HTTR presented at the 1.RCM

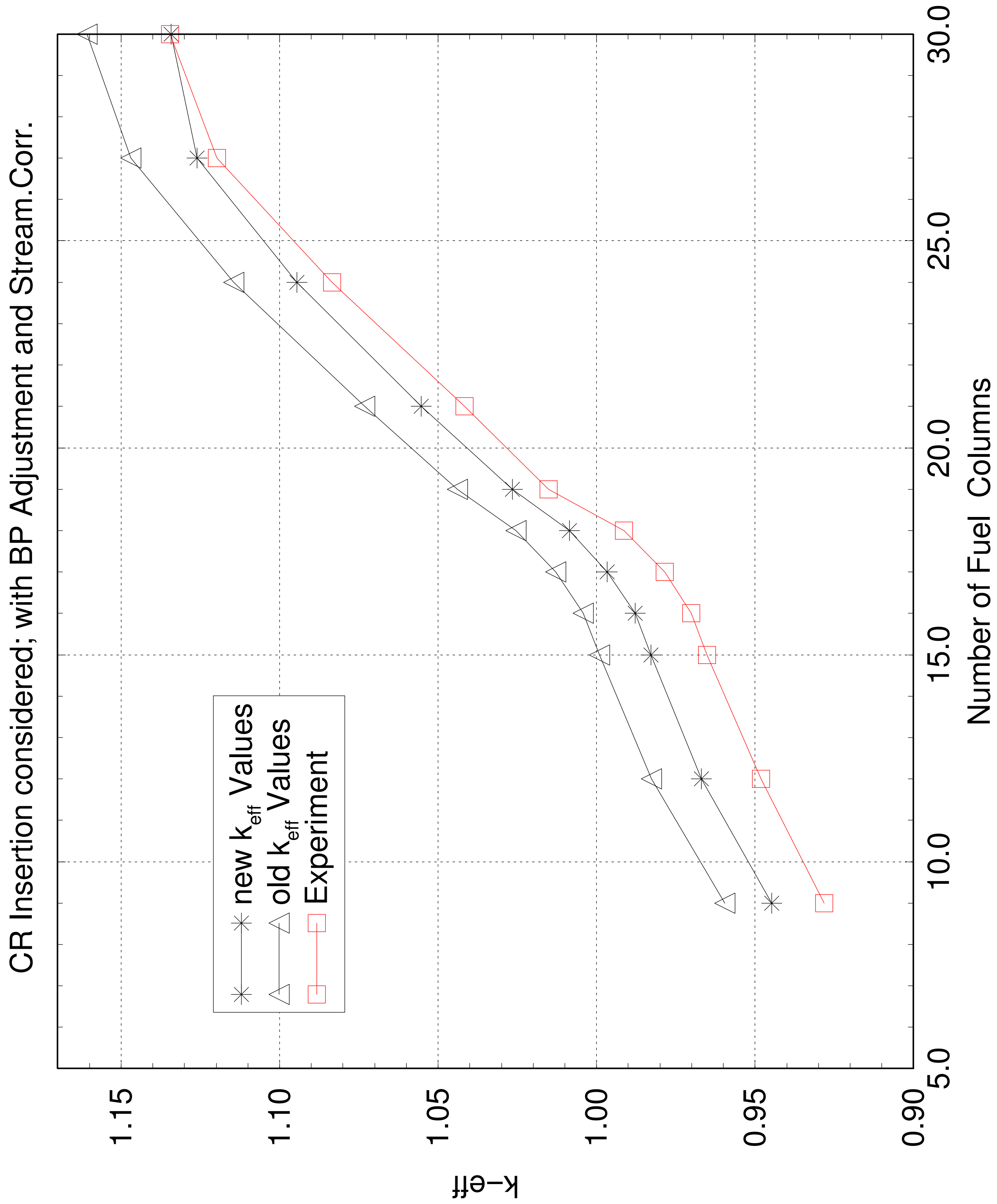

Fig. 1: Effective Multiplication Factor as a Function of the Number of Fuel Columns in the Core

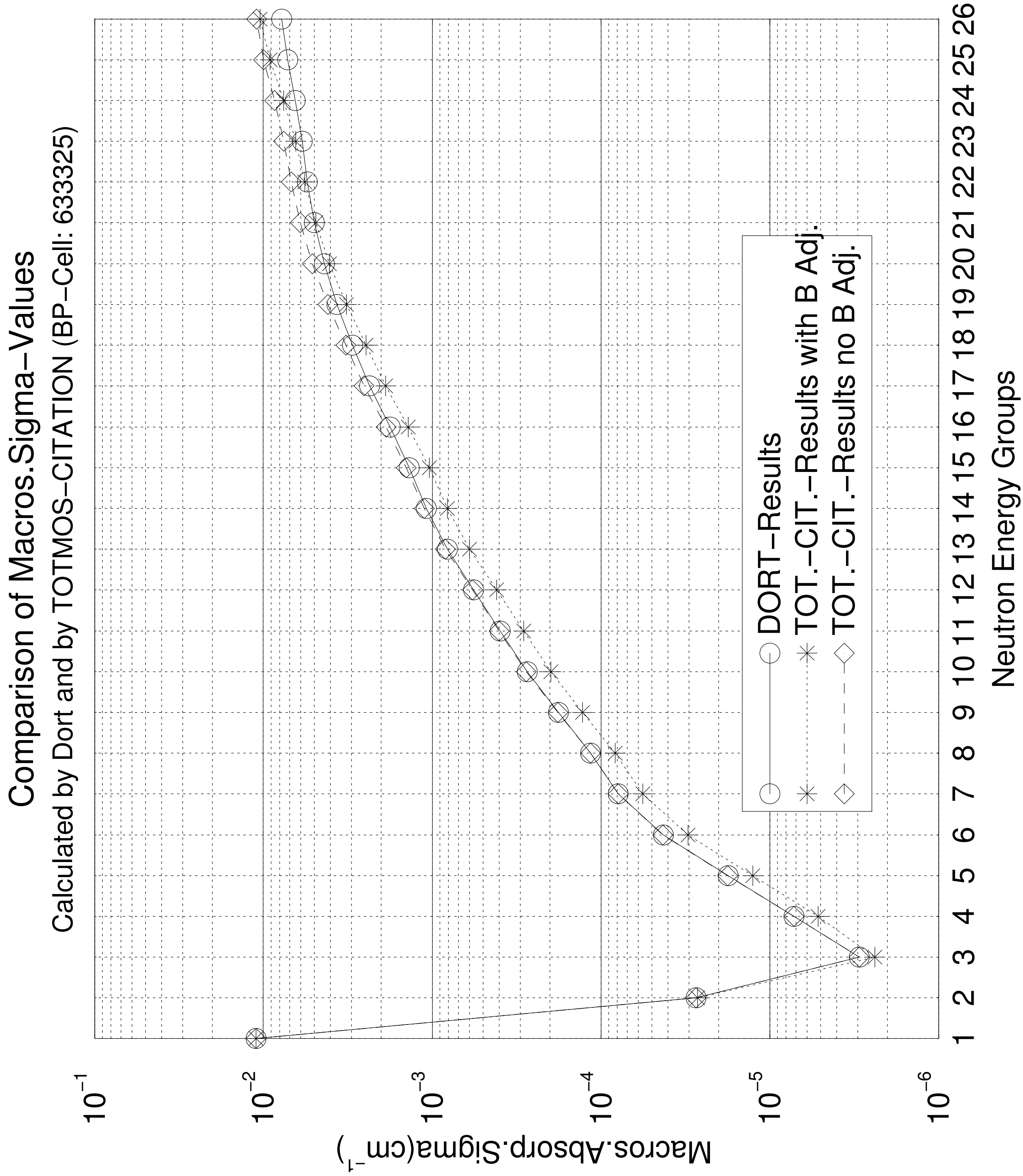

Fig. 2: Different Macroscopic Sigma-Values Calculated by DORT and by TOTMOS-CITATION