1.7 MCU calculation of spacing grid influence on fuel assembly axial power distribution

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ABSTRACT

Presence of spacing grid in fuel assembly noticeably decreases local energy release due to small local change of uranium-water ratio. Condition of total energy release conservation leads to some increase in maximum of axial power distribution. With MCU Monte Carlo code these increase/decrease were calculated for some VVER-440 and VVER-1000 FA's. Since geometry of spacing grid is very complicated, two different sensibly simplified models were proposed. Both gave close results. Local minimums turn out to be ~5% lower than average and local maximums increase slightly more than 1%.

Spacing grid is a part of fuel assembly, which ensures proper space positional relationship of tvels and guiding channels. Total volume of zirconium spacing grids is only a tiny part of VVER fuel assembly volume. Even their weight relative to weight of zirconium fuel cladding is small (5 - 6%). So at a glance it seems that since neutron absorption in spacing grids is small, their influence upon neutron transport must be negligible

But their presence in some places in the core slightly increases uranium-water ratio there. This effect turns out to be much more noticeable than weight or volume ratio predicts and leads to some decrease in power production in these places. With calculated total power production being normalized on given value, this will lead to increase, though somewhat lesser, in power production maximum.

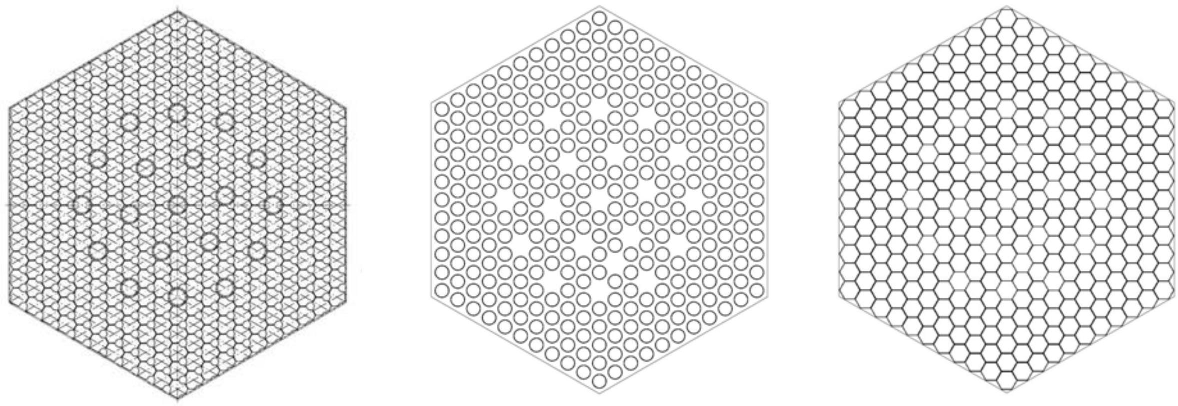
The influence of spacing grid on power distribution was detected in some measurement of gamma radiation along spent fuel tvels, but accuracy of these measurements was insufficient for reliable evaluation of this effect or its dependence on core parameters. Some information gave fine-mesh deterministic calculations, which for that case must be carried out with mesh axial step no more than 1 cm, i.e. be computer resource consuming. This together with difficulties of preparation of proper cell characteristics for cell axial segments containing parts of spacing grid also prohibited receiving of reliable information of spacing grid influence on power distribution.

We have made closest to reality approach with Monte Carlo modeling of neutron transport in infinite uniform core, composed of axially infinite VVER fuel assemblies. Without spacing grid this task can be reduced to two-dimensional one, but with spacing grids placed at proper distance apart it is definitely three-dimensional. Parameters of spacing grids considered are given in Table 1.

Table 1 – spacing grids parameters.

	VVER-440	VVER-1000
spacing grid weight, g	190	550
spacing grid height, cm	2	2
spacing grid axial pitch, cm	25	29

Real geometry of spacing grid is very complicated, as can be discerned possibly on Fig.1 A. So we decided to smear grid zirconium either by tvel coating surfaces (Fig.1 B), or by surfaces of tvel containing pin cells (Fig.1 C). Height and weight of spacing grid was conserved at this smearing. Similar simplifications were applied also in VVER-440 case.



A B C

Figure 1. Real (A) and two simplified(B,C) geometries of spacing grid of VVER-1000

In all cases fuel enrichment was about 3.7 - 4.95%, its temperature – 700^{o}C, that of water – 300^o C, pressure – 160 kg/cm^2, $\mathbf{C}_{\mathbf{H_3BO_3}}$ – either 0 or 6 g/kg. Axial fuel assembly segments with top/bottom mirror conditions were analysed. Fuel assemblies were divided into 0.25 cm thick horizontal layers. Power production in these layers was calculated with MCU code[1]. Some parameters of these calculations are given in Table 2.

Table 2 – Monte Carlo modeling parameters

	VVER-440	VVER-1000
Number of horizontal layers	50	58
Millions of histories/variant	300	1000
Power distributions stat. error	<0,030%	<0,025%

At first results for two simplified spacing grid geometries were compared for VVER-440 case with $\mathbf{C}_{\mathbf{H_3BO_3}}$ = 6 g/kg. From Figure 2 it is seen, that they are nearly indistinguishable. So in all subsequent calculations was used only B model of spacing grid as somewhat more convenient one. Main results of these calculations are presented in Table 3. Power distribution conduct and its dependence on boric acid concentration are illustrated by Fig.3.

Table 3 – Minimal and maximal deviation
of axial power distribution from height average one.

Deviation, %	VVER-440		VVER-1000	
	$\mathbf{C}_{\mathbf{H_3BO_3}}$ = 0 г/кг	$\mathbf{C}_{\mathbf{H_3BO_3}}$ = 6 г/кг	$\mathbf{C}_{\mathbf{H_3BO_3}}$ = 0 г/кг	$\mathbf{C}_{\mathbf{H_3BO_3}}$ = 6 г/кг
Max.	**1.32**	**1.14**	**1.04**	**0.98**
Min.	**-5.28**	**-4.88**	**-5.42**	**-5.04**

So the influence of spacing grid upon assembly axial power distribution was evaluated. Significance of this influence may depend on situation, but its scale is now specified. Similar approach can be used in more thorough studies of this effect burnup dependence or power distribution along different tvels.

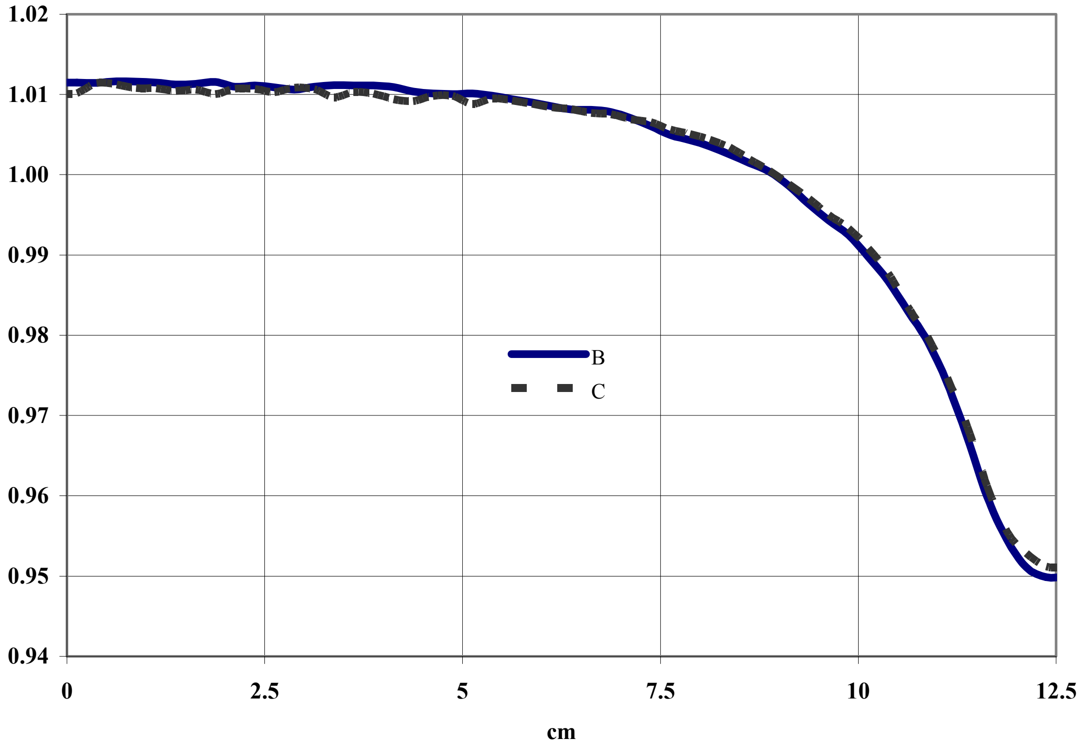


Figure 2. Normalized to average unity axial power distribution in VVER-440 fuel assembly for B and C simplified geometries of spacing grid.

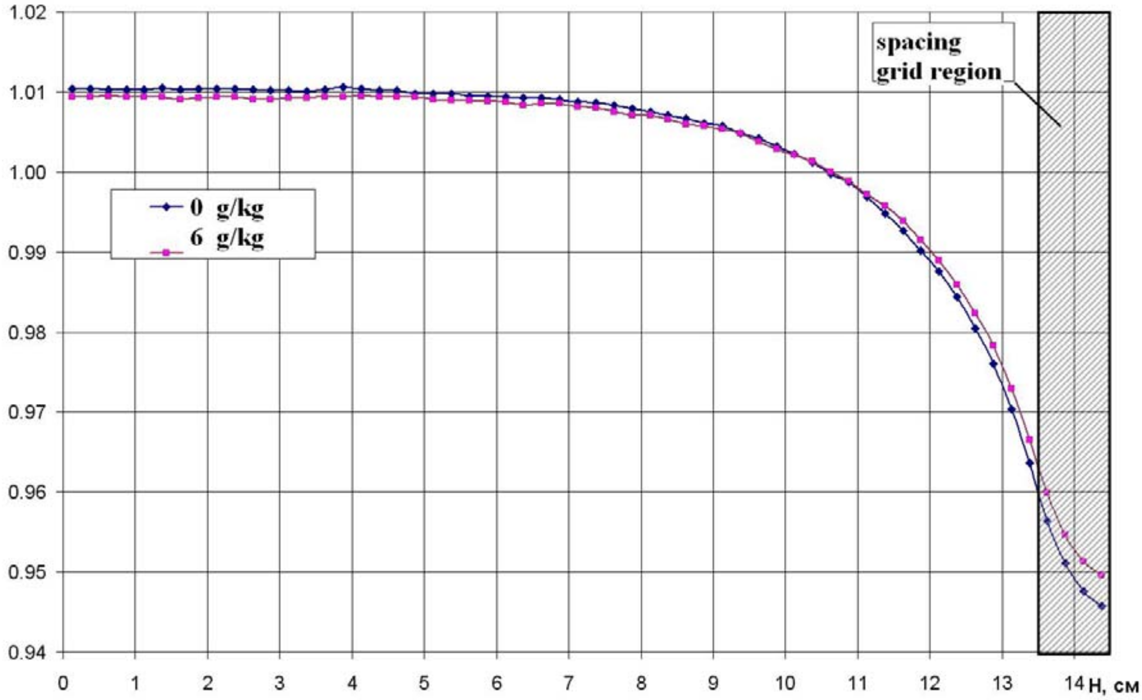


Figure 3. Normalized to average unity axial power distribution in VVER-1000 fuel assembly

REFERENCES

1. Gomin E.A., Majorov L.V. et al.. *Program MCU-RFFI/A with library of constants DLC/MCUDAT-1.0. Federal supervision of Russia on nuclear and radiating safety.* Registration number of the passport of certification 61 from 17.10.96.