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STATIONARY TVSA FUEL CYCLES AT KOZLODUY NPP WWER-1000 REACTORS

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ABSTRACT

The old designed Russian fuel assemblies TVS-M have been under operation for many years at Kozloduy NPP WWER-1000 reactors. A lot of experience was gained with TVS-M assemblies operation and a distortion tendency was found out. To avoid this problem a decision for a gradually substitution of TVS-M fuel assemblies with advanced ones (TVSA) has been taken.

Two different stationary fuel cycles with 42 and 48 fresh TVSA fuel assemblies are presented and discussed in this paper.

The KASKAD computer code system is used for development of the fuel loading patterns of Units 5&6 at Kozloduy NPP.

1. INTRODUCTION

The subject of this paper is to present two different stationary fuel cycles with 42 and 48 fresh TVSA fuel assemblies developed at Kozloduy NPP and to consider their advantages or disadvantages.

The Russian code system KASKAD [1,2] has been used for neutron-physics calculations of the WWER-440/1000 reactors at Kozloduy NPP since 2002. In the code system KASKAD are included the three-dimensional nodal diffusion code BIPR-7A [1] and the two-dimensional pin-by-pin diffusion code PERMAK-A [2].

The main considered stationary fuel cycle is arranged with 42 fresh TVSA fuel assemblies, but the fuel cycle length, achievable in this case is about 290fpd (without power reactivity effect) or about 302fpd (including power reactivity effect).

It is now decided that WWER-440 Units 3 and 4 of Kozloduy NPP will be shutdown before their design lifetime at the end of 2006 and there will be a necessity of efficient energy production. Therefore, the development of fuel cycles longer than 320fpd will be one of the main tasks for the nearest future.

2. STATIONARY FUEL CYCLE WITH 42 FRESH TVSA ASSEMBLIES

The main advantage of the TVSA fuel assemblies is their much stronger construction in comparison with TVS-M, as long as their neutron-physics and thermo-hydraulic characteristics remain almost the same.

The stationary fuel cycle with 42 fresh assemblies is based on two types of TVSA fuel assemblies – 6 nonprofiled 3.98wt% (Fig.1) and 36 profiled 4.30wt% (Fig.2).

In Table 1 are presented some important from neutron-physics point of view TVSA characteristics.

Using 42 fresh fuel assemblies can be achieved about 290fpd for the stationary fuel cycle without power reactivity effect. A cycle length of almost 302fpd can be provided in case power reactivity effect is used.

The assembly averaged burnup (**Bu**) distribution and assembly power peaking factor (**Kq**) distribution are presented in Fig. 3.

The main advantage of this stationary fuel cycle is that the maximum values of the power peaking factors remain practically the same regardless of using power reactivity effect or not.

The fresh fuel part of the total costs (FFPTC) has been estimated using the following formula:

$$FFPTC = \frac{FFC}{Power * FCL * Efficiency}, \left[\frac{rel.units}{kWh} \right]$$

where:

FFC – fresh fuel costs, rel. units

Power – current thermal power, kW

FCL – fuel cycle length, h

Efficiency = 0.32

For the fuel cycle with 42 fresh fuel assemblies without power reactivity effect FFPTC=0.003143 [rel.units/kWh].

If the power reactivity effect is taken into account the fresh fuel part of the total costs is lower: FFPTC=0.003064 [rel.units/kWh].

3. STATIONARY FUEL CYCLE WITH 48 FRESH TVSA ASSEMBLIES

Due to the technical requirements the next two cycles are planned to be relatively short (about 260-270fpd). It is expected that at the end of 2008 all modernization procedures at WWER-1000 units 5 and 6 will be completely finalized.

At this time WWER-440 units 3 and 4 will have been stopped. Therefore, the development of fuel cycles longer than 320fpd will be a question of present interest. There are two ways of achieving longer cycles:

- the first one is to use 48 fresh fuel assemblies, with the same characteristics as described in Table 1;

- the second one is to use 42 fresh fuel assemblies with higher enrichment, mass of UO_2, fuel column height or fuel pellet without a hole.

In the paper is presented the first way only. Using 48 fresh fuel assemblies can be achieved about 320fpd for the stationary fuel cycle without power reactivity effect. A cycle length of almost 335fpd can be provided in case power reactivity effect is used.

The assembly averaged burnup (**Bu**) distribution and assembly power peaking factor (**Kq**) distribution are presented in Fig. 4.

For the fuel cycle with 48 fresh fuel assemblies without power reactivity effect FFPTC=0.003255 [rel.units/kWh].

If the power reactivity effect is taken into account the fresh fuel part of the total costs is lower: FFPTC=0.003152 [rel.units/kWh].

In Table 2 are compared some of the most important neutron-physics characteristics of the two considered fuel cycles. It is beyond doubt that, among the suggested stationary fuel cycles, these with 42 fresh fuel assemblies are more economical than those with 48 fresh fuel assemblies. Especially when the power reactivity effect is used – the average burnup of unloaded FA is higher (reach to 50MWd/kgU) and the fresh fuel costs are lower.

4. CONCLUSIONS

Two different stationary fuel cycles with 42 and 48 fresh TVSA fuel assemblies are presented and discussed in this paper.

In general, it could be pointed out, that with 42 (6*3.98wt%+36*4.30wt%) fresh fuel assemblies and power reactivity effect can be provided stationary cycles at about 302fpd.

In case of necessity of cycles longer than 310fpd the reactor core can be refueled either with 48 fresh fuel assemblies, or with 42 fresh fuel assemblies of new generation with higher enrichment, mass of UO_2, fuel column height or fuel pellet without a hole. It is definitely more economical than using 48 fresh fuel assemblies.

5. REFERENCES

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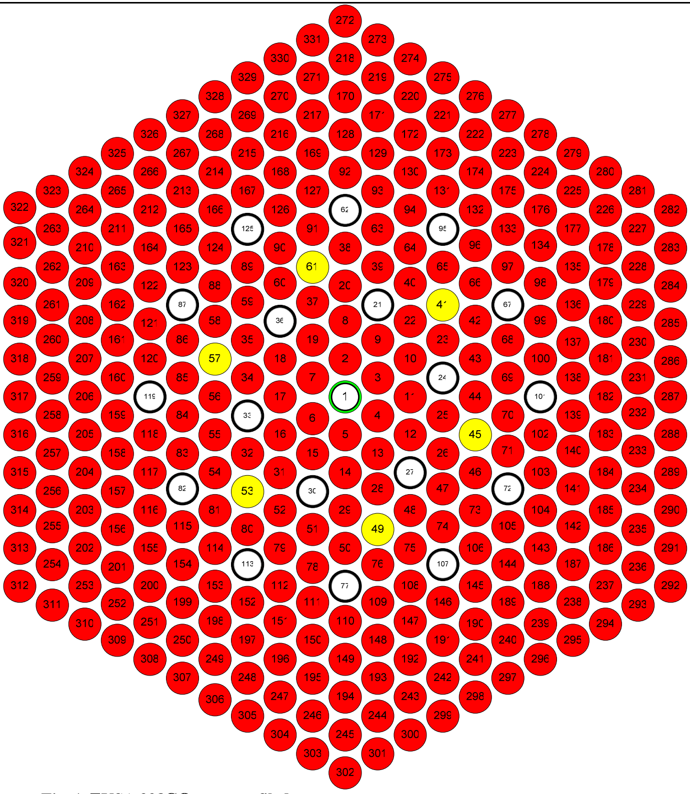

Fig. 1. TVSA 398GO - nonprofiled

306 rods – 4.0wt% — Central tube

6 Gd rods – 3.3wt% — Guide tube

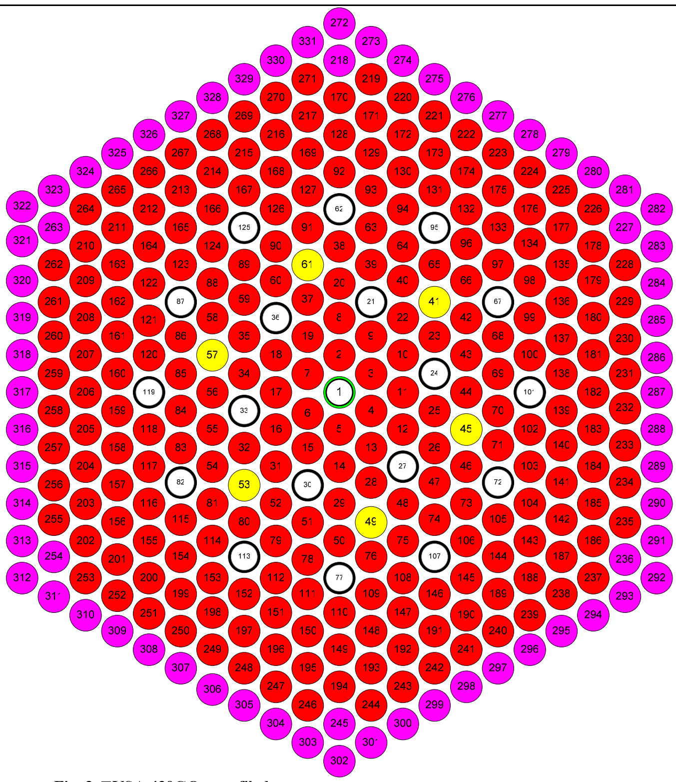

Fig. 2. TVSA 430GO - profiled

240 rods – 4.4wt% — Central tube

66 rods – 4.0wt% — Guide tube

6 Gd rods – 3.6wt%

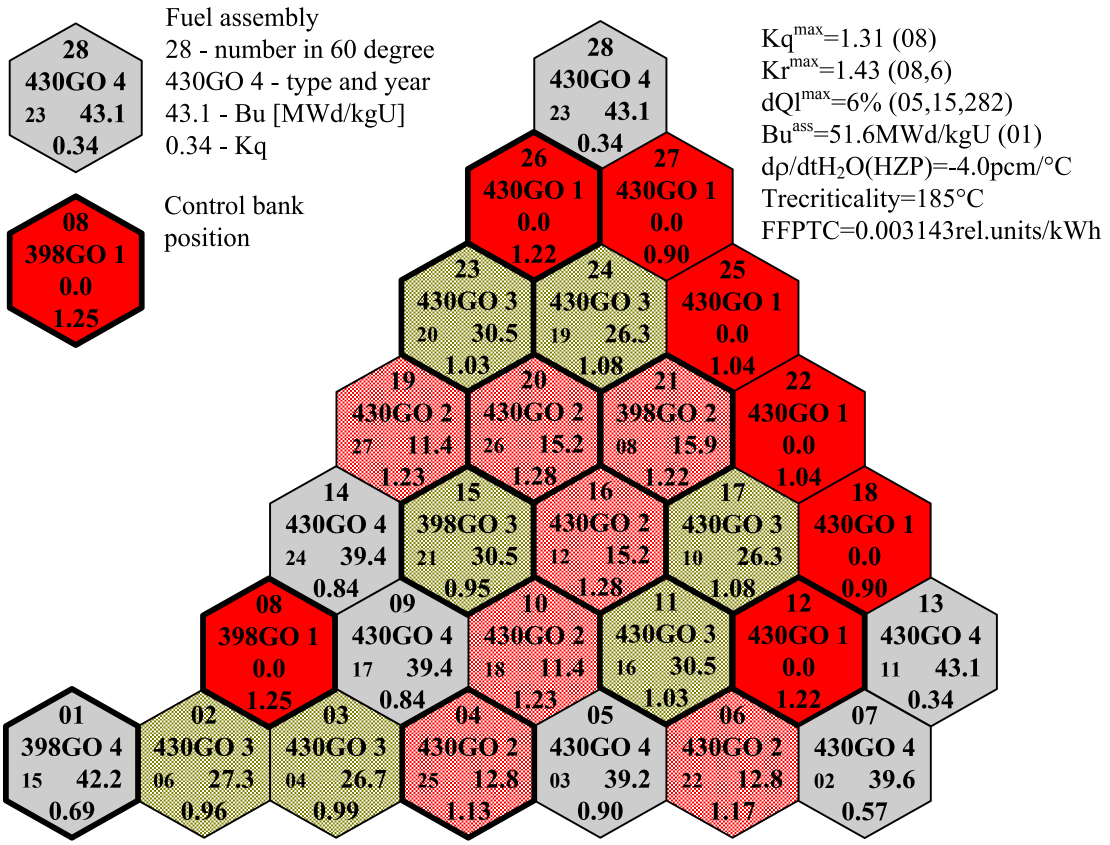

Fig. 3. WWER-1000 stationary fuel cycle – 42 TVSA FA – T=290fpd

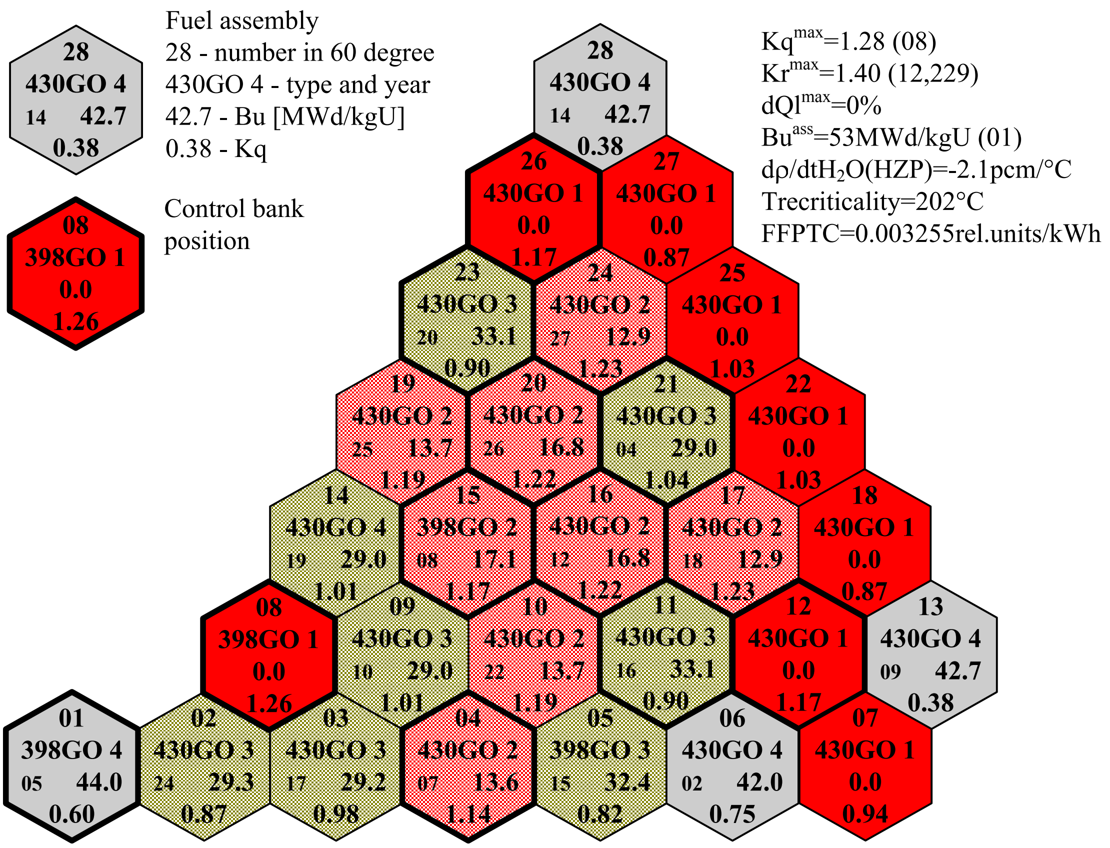

Fig. 4. WWER-1000 stationary fuel cycle – 48 TVSA FA – T=320fpd

Number of fuel rods	312
Assembly lattice pitch, cm	23.6
Size by fuel alignment plate, cm	23.4
Mass of UO_2, kg	491.4
Fuel column height, cm	353
Rod lattice pitch, cm	1.275
Cladding outer diameter, cm	0.91
Cladding inner diameter, cm	0.773
Fuel pellet outer diameter, cm	0.757
Hole diameter, cm	0.15

Table. 1. TVSA fuel assembly characteristics

	42 fresh FA		48 fresh FA	
	without power reactivity effect	with power reactivity effect	without power reactivity effect	with power reactivity effect
Fuel cycle length, fpd	290	272 + 30	320	305 + 30
Average burnup of unloaded FA, MWd/kgU	48.2	50.0	46.6	47.6
Maximal burnup of unloaded FA, MWd/kgU	51.7	53.4	53.1	54.0
$\mathbf{Kq}^{max}$ – Assembly power peaking factor, rel.	1.31	1.31	1.28	1.28
$\mathbf{Kr}^{max}$ – Pin-wise power peaking factor, rel.	1.43	1.43	1.40	1.42
$\mathbf{Ql}^{max}$ – Linear power density, W/cm	327	339	330	338
Moderator temperature reactivity coeff., pcm/°C	-4.0	-5.9	-2.1	-3.8
Recriticality temperature, °C	185	188	202	204
Fresh fuel part of the total costs, rel.units/kWh	0.003143	0.003064	0.003255	0.003152

Table. 2. Stationary TVSA fuel cycles – characteristics