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The Use of Pb-208 as a Reflector of the NEPTUNE Reactor

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In previously conducted researches [1–4], it was reasoned that it is possible to obtain a neutron generation lifetime of 30 ns by adding highly enriched uranium (90%). However, to limit the proliferation of nuclear weapons, the International Atomic Energy Agency recommends using uranium enriched by no more than 20% in research reactors. To this effect, in this work, the authors propose the use of Pb-208 as a neutron reflector as an alternative to Ni. Increasing the neutron generation lifetime required to make the reactor more stable and safer. For this to be realized, the neutron generation lifetime must increase from 8 to 30 ns.

Table 1, shows the names of the various core options and the distribution of uranium rods added to the reactor core. Table 2 illustrates the effect of changing the reflector material from Ni+Be to Pb-208 on neutron generation lifetime, multiplication factor, and effective fraction of delayed neutrons.

Table 1. Distribution of uranium rods in the considered variants of the calculations

Variantion	Location of uranium rods containing uranium in the reactor core	Number of uranium rods added to the reactor core
V1	Reactor core without any additives	0
V2	In the reactor core, the **first row** next to the neutron moderator was replaced with rods containing "UN - 10% enrichment"	50
V3	In the reactor core, the **first row** next to the neutron moderator was replaced with rods containing "UN - 20% enrichment"	50
V4	In the reactor core, the **first row** next to the neutron moderator was replaced with rods containing "UN50+NpN50 - 10% enrichment"	50
V5	In the reactor core, the **first row** next to the neutron moderator was replaced with rods containing "UN50+NpN50 - 20% enrichment"	50
V6	In the reactor core, the **second row** next to the neutron moderator was replaced with rods containing "UN - 10% enrichment"	48
V7	In the reactor core, the **second row** next to the neutron moderator was replaced with rods containing "UN - 20% enrichment"	48

Variantion	Location of uranium rods containing uranium in the reactor core	Number of uranium rods added to the reactor core
V8	In the reactor core, the **second row** next to the neutron moderator was replaced with rods containing "UN50+NpN50 - 10% enrichment"	48
V9	In the reactor core, the **second row** next to the neutron moderator was replaced with rods containing "UN50+NpN50 - 20% enrichment"	48
V10	In the reactor core, **part of rods** in the second and third rows next to the neutron moderator were replaced with rods containing "UN - 10% enrichment"	44
V11	In the reactor core, replaced **part of rods** in the second and third rows next to the neutron moderator with rods containing "UN - 20% enrichment"	44
V12	In the reactor core, **part of rods** in the second and third rows next to the neutron moderator were replaced with rods containing "UN50+NpN50 - 10% enrichment"	44
V13	In the reactor core, **part of rods** in the second and third rows next to the neutron moderator were replaced with rods containing "UN50+NpN50 - 20% enrichment"	44
V14	In the reactor core, **part of rods** in the second and third rows next to the neutron moderator were replaced with rods containing "UN - 5% enrichment"	44
V15	In the reactor core, the **second row** next to the neutron moderator was replaced with rods containing "UN60+NpN40 - 10% enrichment"	48
V16	In the reactor core, the **second row** next to the neutron moderator was replaced with rods containing "UN40+NpN60 - 20% enrichment"	48

Table 2. Neutron generation lifetime, effective multiplication coefficient, and effective fraction of delayed neutrons for variations V1-V16 using a Pb-208 reflector

Variantion	Neutron generation lifetime, ns	K-eff	β-eff, e-3
V1	10.7	1.016	1.3433
V2	821.4	1.003	1.4309
V3	943.9	1.010	1.4693
V4	263.3	1.007	1.3693
V5	415.5	1.012	1.3987
V6	58.8	0.989	1.3984
V7	68.6	0.996	1.4618
V8	27.2	1.001	1.3703
V9	37.2	1.005	1.4145

Variantion	Neutron generation lifetime, ns	K-eff	β-eff, e-3
V10	33.3	0.984	1.4186
V11	34.3	0.992	1.4657
V12	18.0	0.997	1.3722
V13	22.3	1.002	1.3897
V14	27.23	0.980	1.3709
V15	30.31	0.998	1.3693
V16	30.87	1.007	1.3783

CONCLUSION

The results proved that it is possible to increase the neutron lifetime in the Neptune reactor by adding low-enriched uranium to the reactor core with the need to change the neutron reflector from beryllium-nickel to lead-208 without the need for a slow neutron filter.

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