Characteristics of Modular Fast Reactor SVBR-100 Using Thorium-Uranium (233) Fuel

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INTRODUCTION

1. **Thorium resources in the earth's crust are several times as much as those of uranium (essentially increased raw basis for nuclear power).**
2. **Technical grounds to use the thorium fuel cycle:**
   - **thorium-232 is better "raw" isotope compared with uranium-238**
   - **Thorium dioxide is more chemically and radiation resistant**
   - **Its thermo-physical properties (heat conductivity, linear expansion coefficient) are better**
   - **less number of plutonium isotopes and long-lived minor actinides is built**

Nuclide	SVBR mean spectrum values			
	σ_c, b	σ_f, b	$\alpha=\sigma_c/\sigma_f$	ν_f
^{232}Th	0.30	0.01	29.5	2.01
^{233}U	0.22	2.46	0.09	2.52
^{235}U	0.43	1.69	0.26	2.47
^{238}U	0.26	0.04	6.03	2.44
^{239}Pu	0.38	1.68	0.23	2.95

   - **inherent supporting of nuclear materials non-proliferation (hard gamma rays emitters bismuth-212, thallium-208)**
   - **the thorium fuel cycle is preferable for weapon plutonium utilization**
3. **SVBR RF allows use of various nuclear fuels based on UO2, MOX, UN, (Pu-U)N** and others

BASIC TECHNICAL CHARACTERISTICS OF RI SVBR-100

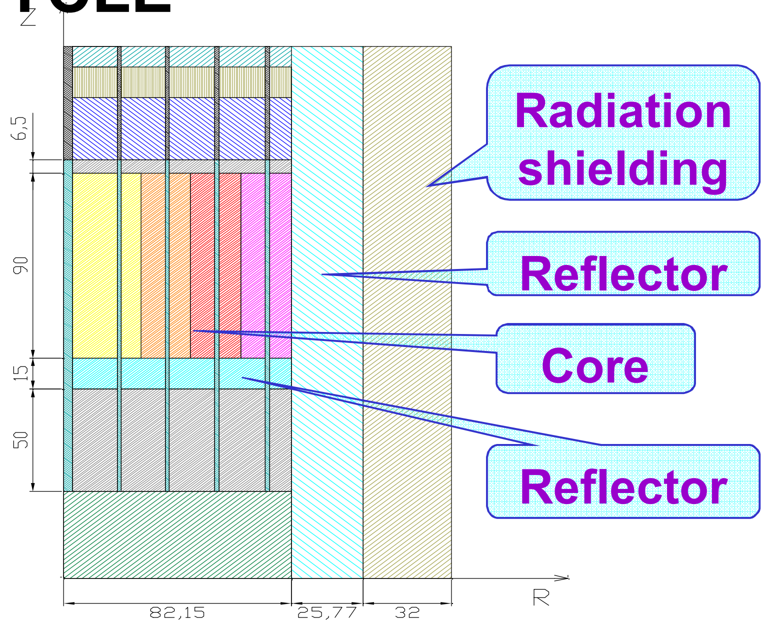
1. **Fast reactor core with chemically inert lead-bismuth coolant (LBC).**
2. **A monoblock (integral) design of a pool type is used for the primary circuit equipment.**
3. **A two-circuit scheme of heat removal is used.**
4. **The levels of coolants' natural circulation in the heat-removal circuits are sufficient to ensure reactor's heat decay removal without over-heating of the core.**

Parameter	Value
RF thermal power, MW	280
RF electric power (gross load), MW	101.5
Fuel: type load of U-235, kg average enrichment in U-235, %	UO_2 ~1470 ~16.5
Time between refuelings, years	7-8
Reactor monoblock dimensions (diameter/height), m	4.5/7.5

CHARACTERISTICS OF U-TH FUEL CYCLE

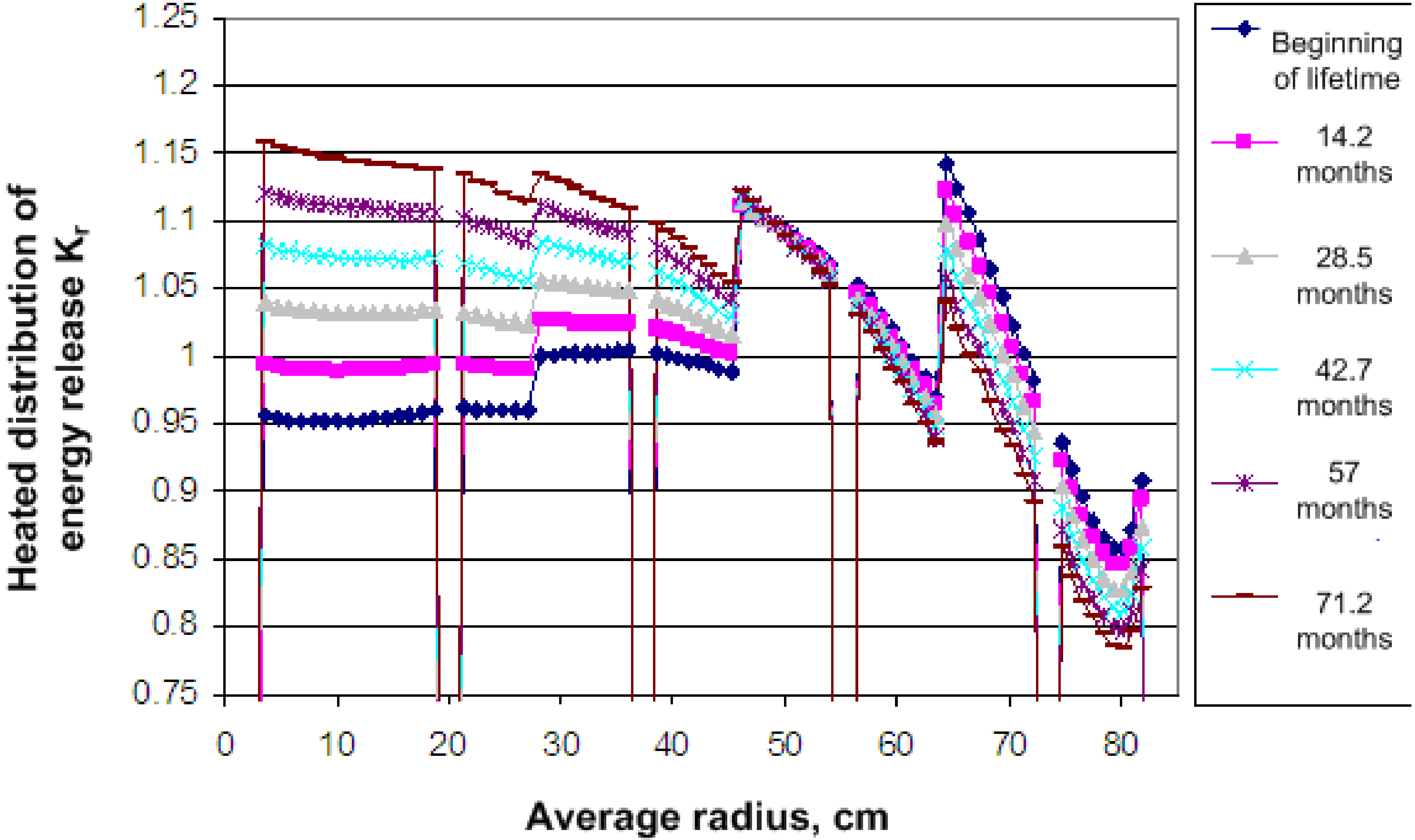
1. Numerical Model

2. Types of fuel: $\left({}^{233}U + {}^{232}Th\right)O_2$, $\left({}^{233}U + {}^{232}Th\right)N$, $\left({}^{233}U + {}^{232}Th\right)_{metal}$



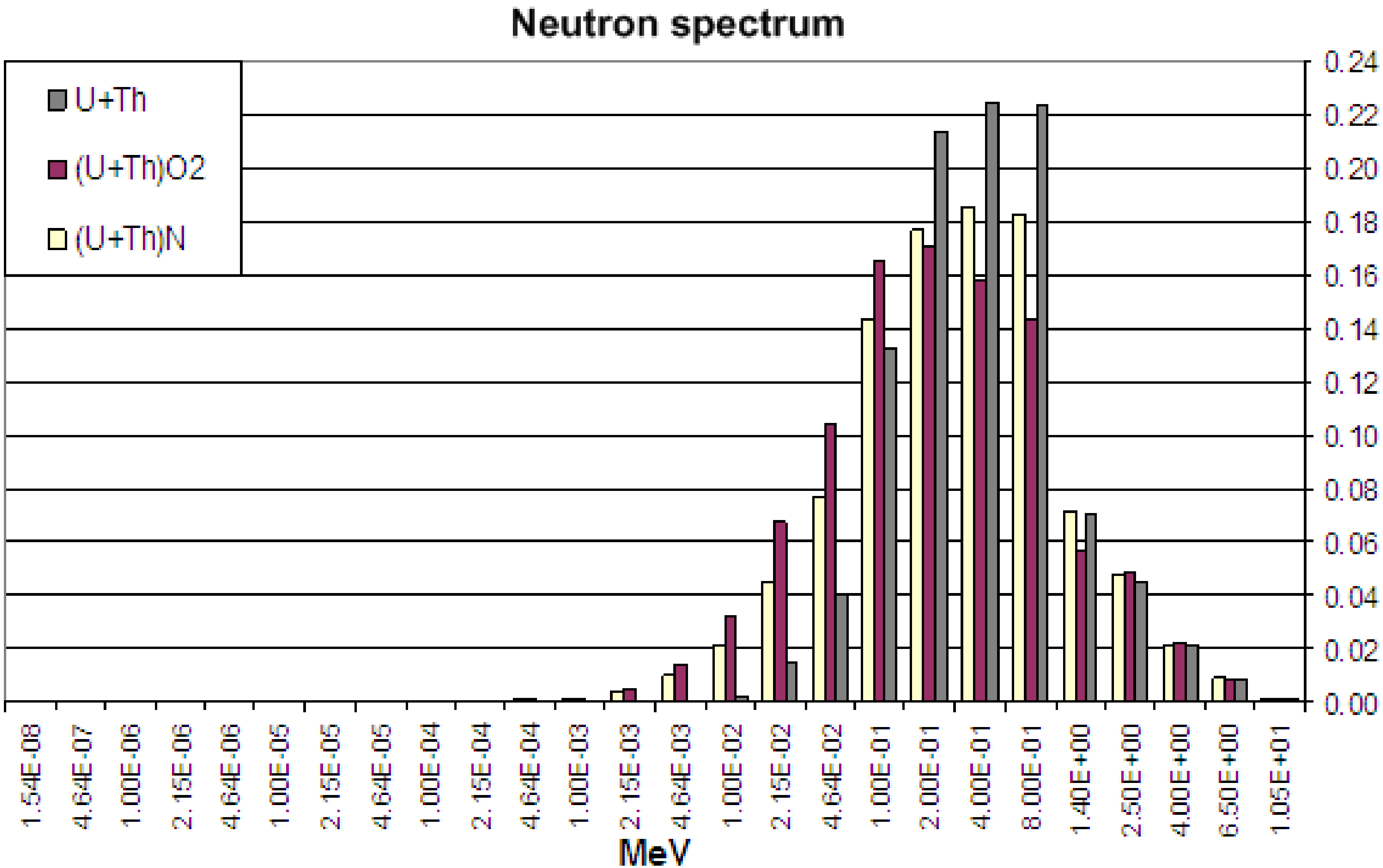
Profiling zone number	(U+Th)	$(U+Th)O_2$	(U+TH)N
	Enrichment in uranium-233, %		
1	9	10.4	9.3
2	9.6	11.0	9.7
3	10.8	12.4	11.0
4	13.6	15.6	13.2

CHARACTERISTICS OF U-TH FUEL CYCLE (2)



Distribution along the core radius for non-uniformity coefficient of (heated) energy release distribution for nitride fuel (U+Th)N

CHARACTERISTICS OF U-TH FUEL CYCLE (3)

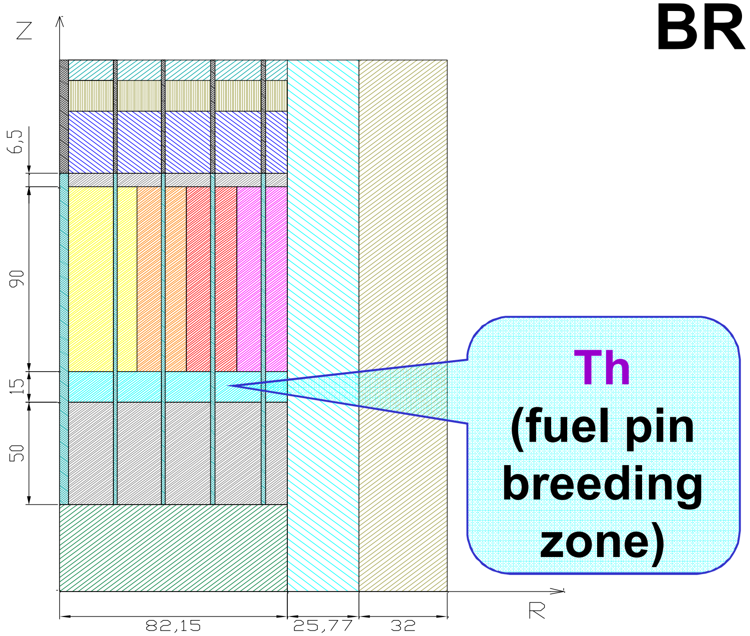


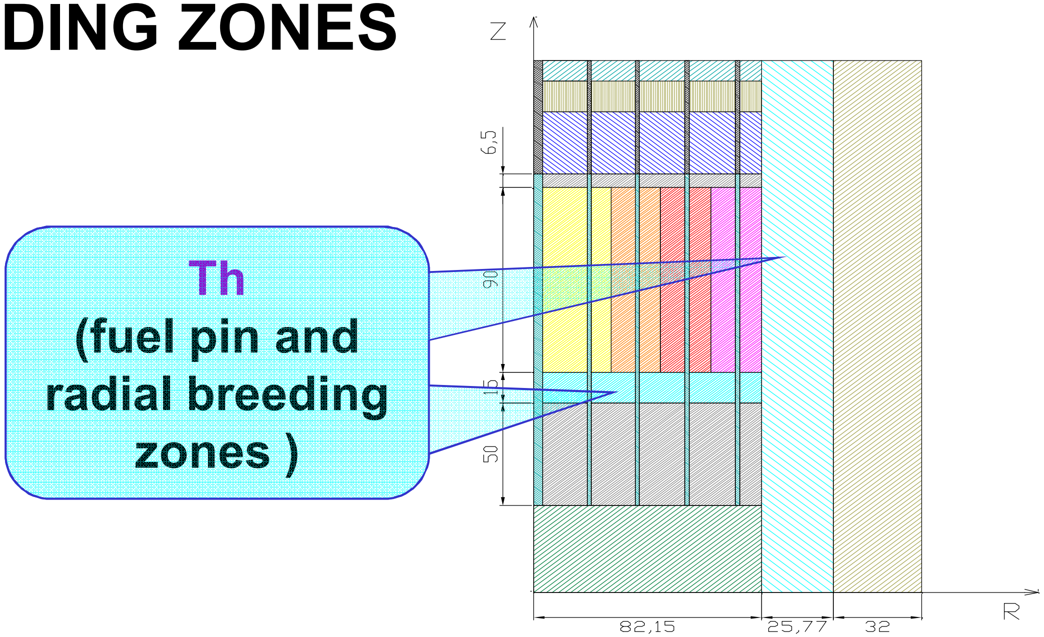
Neutron spectra in the core for 3 kinds of fuel

CHARACTERISTICS OF U-TH FUEL CYCLE (4)

Parameter, dimensionality	Fuel type		
	Metal (U+Th)	Oxide $(U+Th)O_2$	Nitride (U+Th)N
Effective fuel density, g/cm^3	10.5	9.6	12.5
Average enrichment in uranium-233, %	11.5	13.2	11.5
Uranium-233 load G_3, t	~1,3	~1,2	~1,4
Total load of uranium and thorium $G_{т.а.}$, t	~11,1	~9,0	~12,5
Reactivity change over the lifetime, %	8.7	9.1	6.0
U-233 breeding ratio	0.85	0.85	0.9

SENSITIVITY STUDIES OF URANIUM-233 BREEDING RATIO. BREEDING ZONES





Parameter, dimensionality	Core design		
	(U+Th)N	+ fuel pin breeding zone	+ fuel pin and radial breeding zones
U-233 enrichment, %	11,5	11,6	12,0
Uranium-233 load G_3, t	1,4	1,4	1,5
Total load of U and Th, t	12,5	14,7	21,6
Reactivity change, %	6,0	6,2	6,1
U-233 breeding ratio	0,9	0,92	0,97

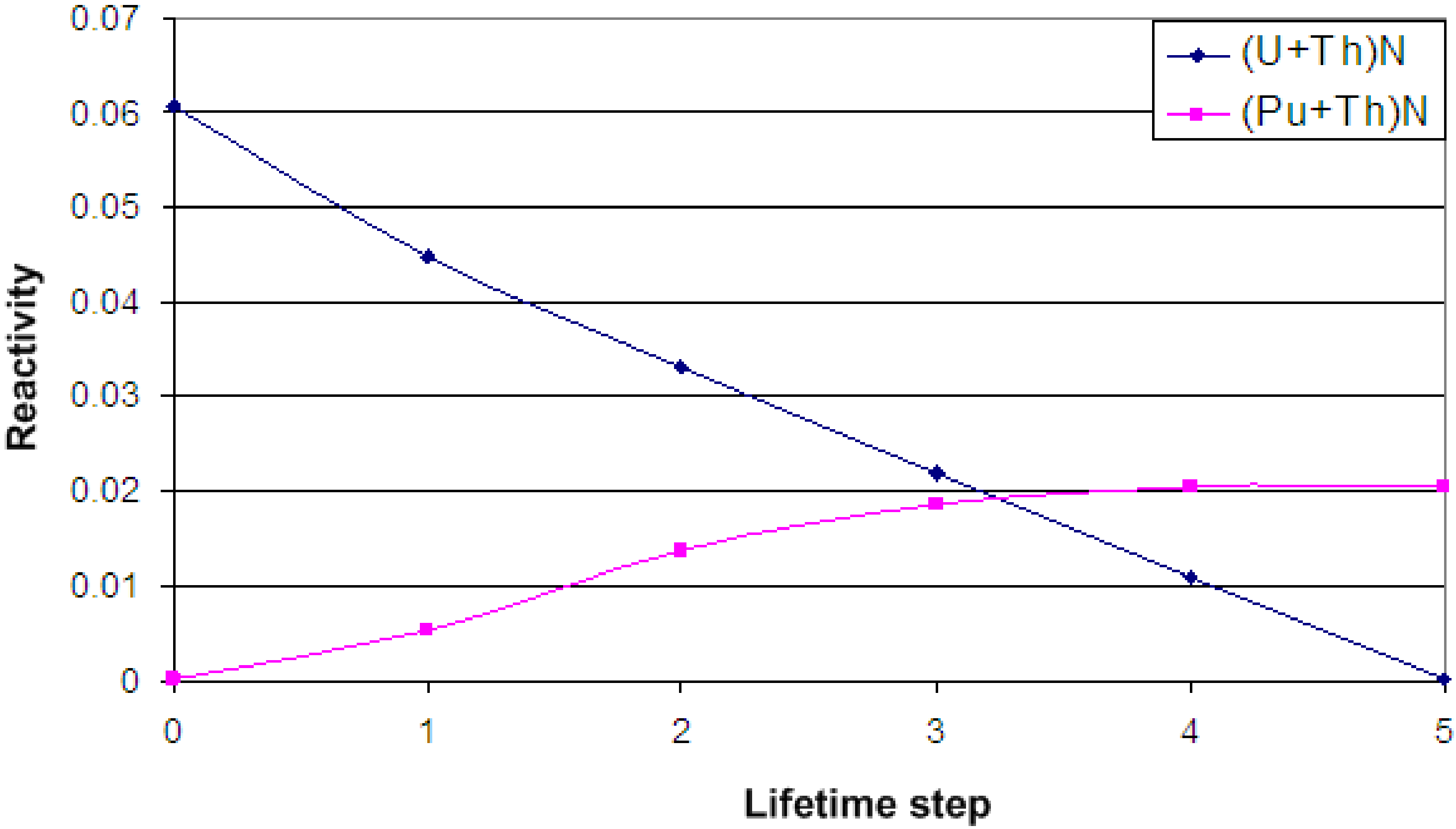
SENSITIVITY STUDIES OF URANIUM-233 BREEDING RATIO. CORE DIMENSIONS

Parameter, dimensionality	Core design		
	(U+Th)N	Core Height is increased by 10 cm	Core Height is increased by 20 cm, Core diameter is increased by ~ 7 cm
Average fuel enrichment in uranium-233, %	11,5	10,8	9,7
Uranium-233 load G_3, t	1,4	1,5	1,7
Total load of uranium and thorium, t	12,5	13,7	16,6
Reactivity change over the lifetime, %	6,0	4,8	3,2
U-233 breeding ratio	0,9	0,94	0,96

CHARACTERISTICS OF U-Th-Pu FUEL CYCLE

1. **Nitride fuel composition (Th+Pu)N .**
2. **Isotopic content of Pu corresponds to the spent nuclear fuel of reactor WWER.**

Isotope	Content, %
Pu-238	1.7
Pu-239	65.3
Pu-240	23.9
Pu-241	3.6
Pu-242	5.6



Reactivity dependences on the lifetime moment

CHARACTERISTICS OF U-Th-Pu FUEL CYCLE (2)

Parameter, dimensionality	Fuel type	
	(U+Th)N	(Th+Pu)N
Average fuel enrichment in uranium-233 or Pu, %	11,5	14,6
Load of uranium-233 or Pu, t	1,4	2,0
Total load of the core, t	12,5	12,5
Reactivity change over the lifetime, %	-6,0	+2,0
Breeding ratio	0,9	0,98

CONCLUSIONS

- **The performed computations for three different types of fuel (oxide , nitride and metallic), have revealed that maximum of uranium-233 breeding ratio, which equals to 0.9, is achieved when nitride type of fuel is used**
- **Adding breeding zones or increasing of the core dimensions result in increasing uranium-233 breeding ratio (up to BR = 0,97 or BR = 0,96 respectively).**
- **There is opportunity of using plutonium as initial fissile isotope to implement U-Th-Pu fuel cycle. Breeding ratio is assessed by 0,98 if nitride fuel composition (Th+Pu)N with effective density of 12.5 is used.**
- **The obtained data have demonstrated that both for U-Th FC and U-Th-Pu FC there is an opportunity to achieve a value of U-233 BR to be over unity when using the breeding zones and slightly increased the core dimensions.**