

# INVESTIGATION OF TRITIUM AND $^{233}\text{U}$ BREEDING IN A FISSION-FUSION HYBRID REACTOR FUELLING WITH $\text{ThO}_2$

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## INTRODUCTION

In the world, thorium reserves are three times more than natural Uranium reserves. It is planned in the near future that nuclear reactors will use thorium as a fuel. Thorium is not a fissile isotope because it doesn't make fission with thermal neutrons so it could be converted to  $^{233}\text{U}$  isotope which has very high quality fission cross-section with thermal neutrons.  $^{233}\text{U}$  isotope can be used in present LWRs as an enrichment fuel.

In the fusion reactors, tritium is the most important fusil fuel. Because tritium is not natural isotope, it has to be produced in the reactor. The purpose of this work is to investigate the tritium and  $^{233}\text{U}$  breeding in a fission-fusion hybrid reactor fuelling with  $\text{ThO}_2$  for  $\Delta t=10$  days during a reactor operation period in five years.

## PROBLEM DESCRIPTION

The neutronic analysis is performed on an experimental hybrid blanket geometry shown in figure 1, which has been presented to the international scientific community on different occasions [1-5].

In the center of the hybrid blanket, there is a line neutron source in a cylindrical cavity, which simulates the fusion plasma chamber where high energy neutrons (14.1

MeV) are produced. The conventional fusion reaction delivers the external neutron source for blankets following,



A first wall made of stainless steel, type SS-304, surrounds the fusion plasma chamber. Surrounding the first wall is the fuel zone made up of natural-ThO<sub>2</sub> fuel and it is cooled with different coolants. In this work, five different moderator materials, which are Li<sub>2</sub>BeF<sub>4</sub>, LiF-NaF-BeF<sub>2</sub>, Li<sub>20</sub>Sn<sub>80</sub>, natural Lithium and Li<sub>17</sub>Pb<sub>83</sub>, are used as coolants. The volumetric ratio of coolant-to-fuel to is selected as 2:1. The cladding of the fuel rods is made of stainless steel, type SS-304, as the first wall. The radial reflector, called tritium breeding zones, is made of different Lithium compounds and graphite in sandwich structure. This structure of the radial reflector reduces the neutron leakage drastically and leads to a better neutron economy [1,2]. In the work, eight different Lithium compounds were used as tritium breeders in the tritium breeding zones, which are Li<sub>3</sub>N, Li<sub>2</sub>O, Li<sub>2</sub>O<sub>2</sub>, Li<sub>2</sub>TiO<sub>3</sub>, Li<sub>4</sub>SiO<sub>3</sub>, Li<sub>2</sub>ZrO<sub>3</sub>, LiBr and LiH.

Neutron transport calculations are conducted in spherical geometry with the help of SCALE4.4A SYSTEM [6] by solving the Boltzmann transport equation with code CSAS[7] and XSDRNPM [8], under consideration of unresolved and resolved resonances, in S<sub>8</sub>-P<sub>3</sub> approximation with Gaussian quadratures using the 238 groups library, derived from ENDF/B-V [9].

The numerical outputs of the transport calculations have further been processed with the help of the auxiliary code ERDEMLI [10] to evaluate specific information for this work.

## **CALCULATIONAL RESULTS**

### **• Tritium Breeding Rate (TBR)**

In the tritium breeding zone of the fission-fusion hybrid reactor, tritium breeding reactions are as :

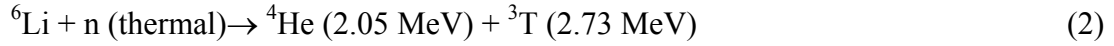


Table I shows TBR as integral neutronic data in the tritium breeding zones in the fission-fusion hybrid reactor for different coolants and tritium breeding materials both at the beginning of the reactor period (BOL) and at the end of the reactor period (EOL).

For a self-sustained fusion fuel supply, a tritium breeding rate (TBR) > 1.05 is required. It is shown in table I that at the BOL and at the EOL,  $\text{Li}_{17}\text{Pb}_{83}$  moderated blanket has well results compared to other moderators for TBR. According to Lithium compounds used tritium breeding zone, at the BOL and at the EOL,  $\text{LiH}$ ,  $\text{Li}_3\text{N}$ ,  $\text{Li}_2\text{O}$ ,  $\text{Li}_2\text{O}_2$  and  $\text{Li}_4\text{SiO}_4$  have well results.

- **${}^{233}\text{U}$  Breeding Rate (UBR)**

In the fuel zone of the fission-fusion hybrid reactor,  ${}^{233}\text{U}$  isotopes are produced with  ${}^{232}\text{Th}(n,\gamma){}^{233}\text{U}$  reactions.

Table II shows UBR as integral neutronic data in the fuel zone in the fission-fusion hybrid reactor for different coolants and tritium breeding materials both at the beginning of the reactor period (BOL) and at the end of the reactor period (EOL). It is shown in table II that at the BOL and at the EOL,  $\text{Li}_{17}\text{Pb}_{83}$  moderated and  $\text{Li}_2\text{ZrO}_3$  tritium breeder blanket has well results compared to other moderators and tritium breeders for UBR.

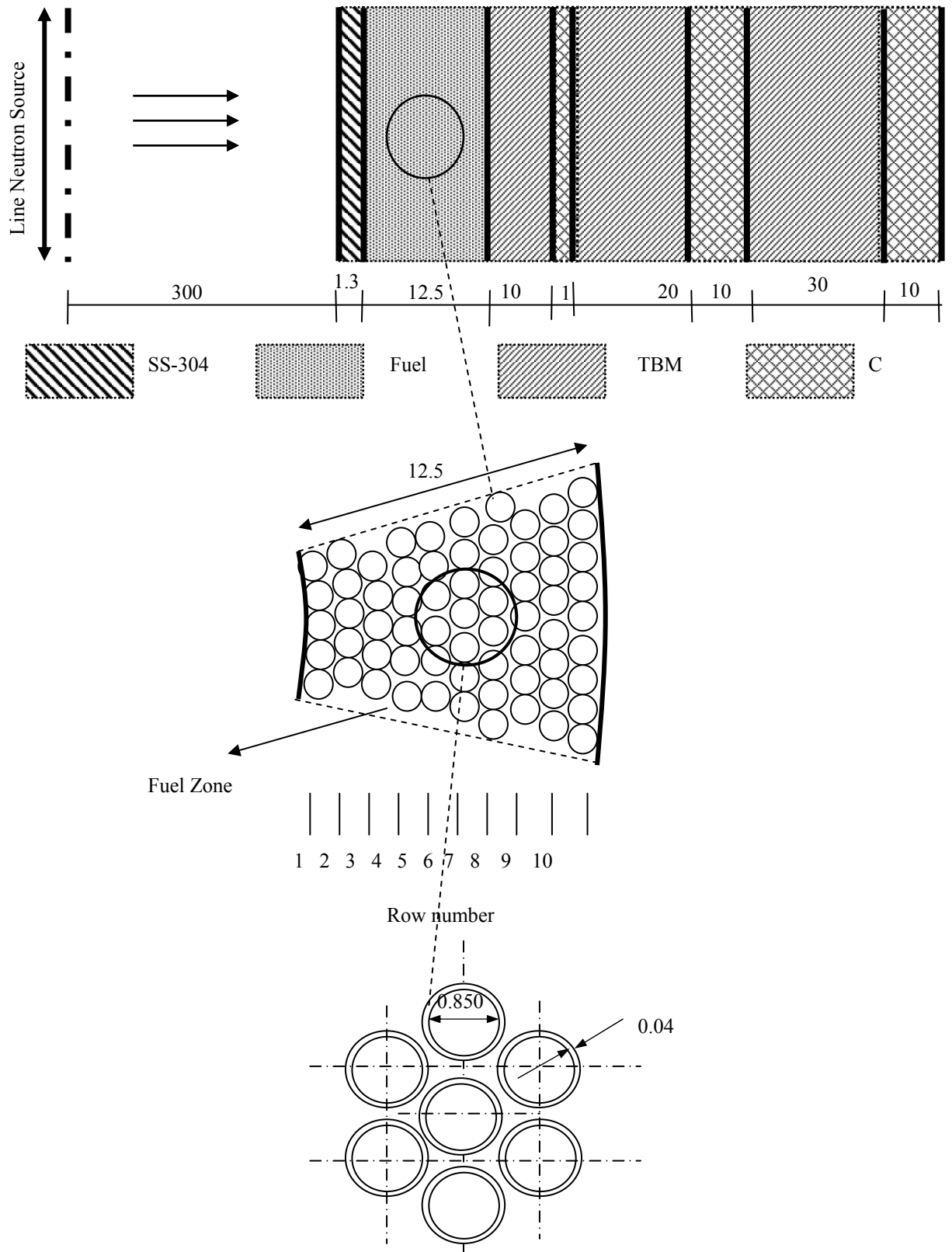


Figure 1. Cross-sectional view of the investigated blanket  
(dimensions are given in centimeters)

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Table I. TBR as integral neutronic data in the fission-fusion hybrid reactor for different coolants and tritium breeding materials.\*

Coolant Materials	Reactor Period	Tritium Breeding Materials							
		Li <sub>3</sub> N	Li <sub>2</sub> O	Li <sub>2</sub> O <sub>2</sub>	Li <sub>2</sub> TiO <sub>3</sub>	Li <sub>4</sub> SiO <sub>4</sub>	Li <sub>2</sub> ZrO <sub>3</sub>	LiBr	LiH
Li <sub>2</sub> BeF <sub>4</sub>	BOL**	0,79591	0,78678	0,72263	0,60501	0,69497	0,58029	0,62662	0,92617
	EOL**	1,00965	1,0173	0,96409	0,86345	0,93909	0,81784	0,87512	1,07433
LiF-NaF-BeF <sub>2</sub>	BOL	0,84761	0,84021	0,7765	0,66752	0,74842	0,63438	0,14576	0,97039
	EOL	1,11062	1,12654	1,08171	1,00616	1,05893	0,94492	0,17508	1,15337
Li <sub>20</sub> Sn <sub>80</sub>	BOL	0,90194	0,88428	0,8271	0,72293	0,80131	0,66704	0,15564	1,02171
	EOL	1,05499	1,0629	1,02414	0,94537	1,00409	0,87674	0,17627	1,12497
Natural Lithium	BOL	0,95578	0,92668	0,84136	0,71899	0,80151	0,67576	0,18284	1,09773
	EOL	1,05338	1,04135	0,96345	0,85354	0,92565	0,80698	0,19752	1,14735
Li <sub>17</sub> Pb <sub>83</sub>	BOL	1,17021	1,15602	1,0905	0,96015	1,0597	0,89115	0,99447	<b>1,30774</b>
	EOL	1,44189	<b>1,47728</b>	1,44953	1,37629	1,43115	1,27928	1,33877	1,47516

\* : Normalization is made for one 14.1 MeV incident neutron into the blanket, TBR= <sup>6</sup>Li(n,α)T rate+ <sup>7</sup>Li(n,αn')T rate

\*\* : BOL : beginnig of reactor periyod      EOL : end of reactor periyod

Table II. UBR as integral neutronic data in the fission-fusion hybrid reactor for different coolants and tritium breeding materials.\*

Coolant Materials	Reactor Period	Tritium Breeding Materials							
		Li <sub>3</sub> N	Li <sub>2</sub> O	Li <sub>2</sub> O <sub>2</sub>	Li <sub>2</sub> TiO <sub>3</sub>	Li <sub>4</sub> SiO <sub>4</sub>	Li <sub>2</sub> ZrO <sub>3</sub>	LiBr	LiH
Li <sub>2</sub> BeF <sub>4</sub>	BOL**	0,26060	0,27111	0,28423	0,31989	0,289	0,31997	0,31719	0,1845
	EOL**	0,26033	0,27517	0,2938	0,34572	0,30104	0,34354	0,33631	0,17416
LiF-NaF-BeF <sub>2</sub>	BOL	0,28219	0,29422	0,31031	0,35102	0,3161	0,35343	0,25787	0,19637
	EOL	0,28362	0,30226	0,32542	0,38736	0,33451	0,38842	0,24935	0,1852
Li <sub>20</sub> Sn <sub>80</sub>	BOL	0,20152	0,21989	0,23697	0,26881	0,24342	0,27714	0,17041	0,12946
	EOL	0,18939	0,21119	0,23063	0,26682	0,23864	0,27766	0,15733	0,11816
Natural Lithium	BOL	0,15815	0,17465	0,18534	0,2082	0,19006	0,21949	0,14026	0,08722
	EOL	0,14623	0,16429	0,17643	0,20082	0,18171	0,21365	0,12687	0,07841
Li <sub>17</sub> Pb <sub>83</sub>	BOL	0,27812	0,30528	0,33211	0,38654	0,34216	<b>0,39383</b>	0,34696	0,171
	EOL	0,26003	0,29238	0,32266	0,38505	0,33499	<b>0,39468</b>	0,33244	0,15532

\* : Normalization is made for one 14.1 MeV incident neutron into the blanket, UBR= <sup>232</sup>Th(n,γ) <sup>233</sup>U rate

\*\* : BOL : beginnig of reactor periyod      EOL : end of reactor periyod