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Investigate the Possibility of Alternative U_3Si_2-Al fuel for the Tehran Research Reactor Compared to the Neutron Multiplication Factor

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ABSTRACT

Considering that uranium enrichment is one of the major costs in a nuclear reactor, we can reduce amount of necessary richness with using and replace to another uranium compounds and alloys with higher density. In this study, we have replaced a new fuel to the previous fuels and we have computed the neutron multiplication factor alternative fuels in the core of reactor and the previous fuels are compared with the new fuels and finally, the possibility of replacing the new fuel are examined in the Tehran Research Reactor.The use of high enriched uranium also effects on rising costs of a reactor and the amount of reactor safety and by reducing the fuel enrichment can be achieved more nuclear safety and reduce the cost of the reactor Significantly.In this paper, we have used of the MTR-PC software with the data of needle fuel model cell by blade geometry and condense energy perseus method for solving the transport equation. and by comparing the multiplication coefficients of infinite and effective in U_3Si_2-Al fuel with different densities have been concluded that U_3SI_2-AL fuel with the density 4.8 (gr U/cm^3) and 10% enriched (or even less) can be suitable alternative for the currently fuel in Tehran reactor and it can be used in research reactors.

KEYWORDS: neutron multiplication, uranium, enrichment, Tehran Research Reactor, U_3Si_2-Al fuel

1.INTRODUCTION

1.1.Nuclear research reactors

These nuclear reactors are considered as a major step towards nuclear activities. These reactors are the first manifestation of the nuclear technology and these have been basic growth of other nuclear technologies and non-nuclear such as testing materials and industrial processes. The value of this object When it is determined that we understand all the uses of nuclear energy except electricity generation directly begin from research nuclear reactors. (Osuli, 2007)

1.2.Introducing the Tehran Research Reactor

Tehran University suggested the construction of a nuclear reactor in 1958 and the government approved it. The construction operation of the Tehran University reactor started in 1963 and it was prepared in November 1967 and was exploitation.

The reactor had a capacity of 5 MW and worked with 5/584 kilograms of 93 percent highly enriched uranium fuel which was supplied by America until 1978. (Documents center and diplomatic history.2007)

At first, this reactor was under the Medical Sciences of Tehran University and then in 1974 was transferred to the organization of the Atomic Energy Organization of Iran. Reactor control system was converted into lamps to transistor by GA U.S company in 1977. In late 1981, some reactor of the elements observed in the pool water and it seemed that the reactor fuel had been damaged or its life is finished, So negotiated with various countries for buy a new fuels that can be substituted for the fuels prior negotiations and finally a contract was signed with Argentine INVAP company for new design and construction in 1989. Eventually, the design of core with the new arrangement was performed and reactor fuel delivered and was placed in the core in 1993. The Argentine reactor with fresh fuel fabrication startup in late 1993 and up to now has been exploitation. (Hemati Asia Baraki , 2012)

The reactor is kind of a heterogeneous and pool reactor, which has the following characteristics:

Table 1. Reactor Specifications of the Tehran Research Reactor(TRR)

factor	quantity
Thermal power	5 MW
Fuel	Low enriched U-235,MTR type, Al Clad
Ave. Thermal Neutron Flux at 5 MW	3.1×10^{13} n/cm^2.sec
Number of plates per fuel element	19 for SFE 14 for CFE
Core dimensions (First Operation Core)	40.5×38.54×89.7 cm
Moderator	Light Water
Shielding	Water, Lead, Barytes Concrete and regular Concrete
Coolant	Light Water

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The fuels of this reactor consist of elements of uranium, oxygen, and aluminum that the percentages of them listed in the table below.

Table 2. The weight percentage of fuel contained elements U3O8-Al

Elements	U-235	U-238	AL-27	O-16
weight percentage	12.45	49.78	26.59	11.18

1.3.Conversion the reactor from highly enriched uranium fuel to low enriched fuel

Reactor Conversion to low-enriched fuel is a major change which will affect on the economic aspects and the reactor operations. The conversion program should include review of current and future uses of the reactor, so that the reactor core with the new low enriched fuels could be ready for the reactor mission. New reactor core size, geometry, density, and arrangement of reactor core can be optimized for improve the economy and reactor efficiency.

2.Propose

Considering that uranium enrichment is one of the major costs in a nuclear reactor, we can reduce amount of necessary richness with using and replace to another uranium compounds and alloys with higher density.

3.Methodology

In this study, we used of MTR-PC software that investigated infinite and effective multiplication factors in U_3Si_2-Al fuel with different densities in the Tehran Research Reactor and we have used of following method for solving problem:

A) To determine the cell type we have considered needle fuel model with energy condense in order to obtain all the desired energy groups.

B) Using a blade geometry that has been divided to 16 parts, calculations of spectrum and shielding resonance has been performed.

C) It is used the Perseus method for solving the transport equation.

D) Transport equation is solved in five energy groups.

According to calculations was done and extraction of required information from the output of the Excel and MTR-PC reactor simulation software, diagrams of reactor multiplication factor is drawn for U_3SI_2-AL fuel with the different density and richness of uranium and the U_3O_8-AL current fuel that compared together.

4.Analysis

Here calculations for five different density of U3Si2-Al fuel ((gU/cm3) 3 to (gU/cm3) 6) are performed with the following layout and then they have been compared with fuels that is used in the Tehran Research Reactor.

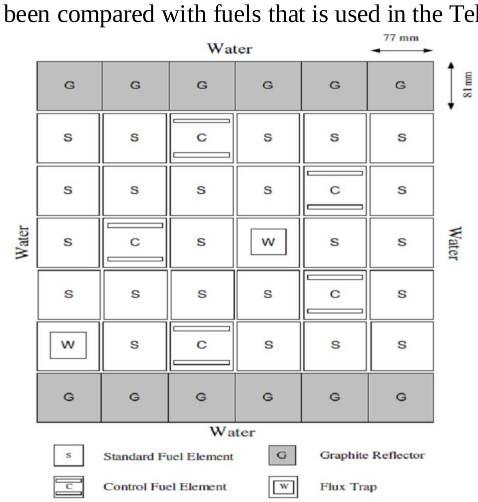

Fig .1. The current arrangement of the Tehran Research Reactor

It is important to note that the results of calculations performed for the core in the fresh fuel situation and this result is also true for the burn up fuel.

Table 3. comparison of the reactor multiplication factor in current fuel (U_3O_8-AL) to U3Si2-AL fuel with different densities of uranium

Uranium density in fuel	effective multiplication factor	Infinite multiplication factor
3	0.9803979	1.547014
3.5	1.0118849	1.576539
4.8	1.0681157	1.621606
5.5	1.0888693	1.634574
6	1.1010721	1.641739
trr	1.0688456	1.616863

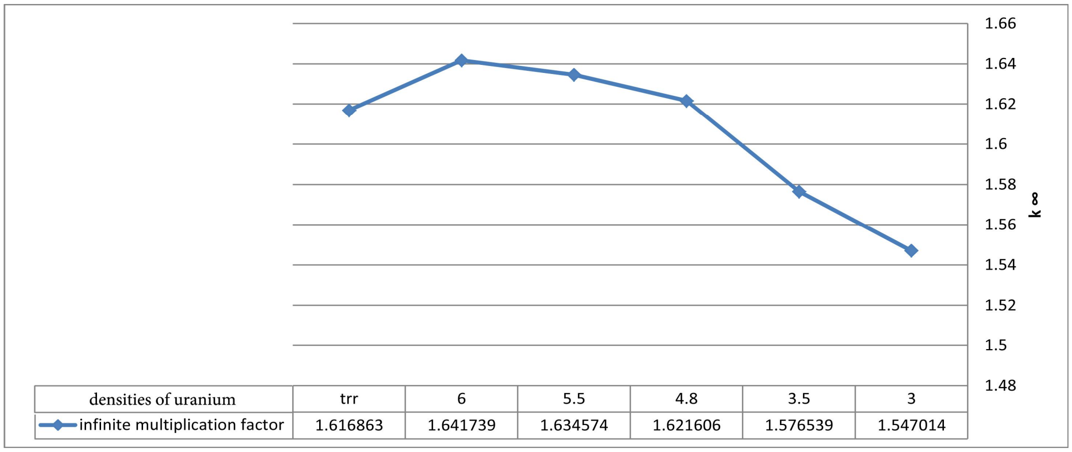

Diagram 1. comparison of the reactor infinite multiplication factor in current fuel (U_3O_8-AL) to U3Si2-AL fuel with different densities of uranium

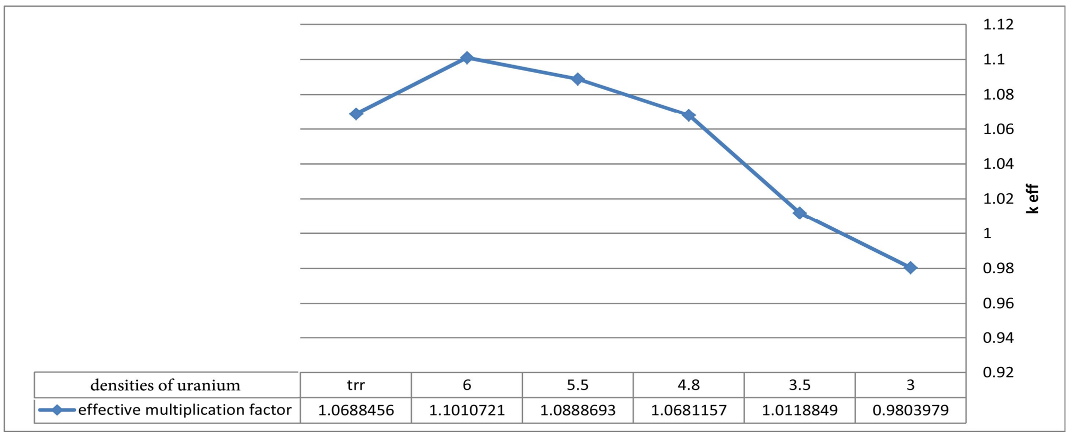

Diagram 2. comparison of the reactor effective multiplication factor in current fuel (U_3O_8-AL) to U3Si2-AL fuel with different densities of uranium

By analyzing graphs and table above, we reach to this conclusion that the increase in uranium density in the fuel U_3Si_2-Al increases neutron Multiplication factor. Of course this increase for the high-density 4.8 (grU/cm3) is higher than amount of multiplication factor of current reactor fuel (U3O8-Al) and the possibility of using this fuel is more emphasis in the Tehran research reactor.

Using the materials above and that the U_3SI_2-AL fuel with 4.8 (grU/cm3) density can be a good alternative to current fuels; we have investigated this fuel with lower enriched fuel.

Table 4. comparison of the reactor multiplication factor in current fuel (U_3O_8-AL) to U3Si2-AL fuel with different enriched of uranium

Enrich fuel	effective multiplication factor	Infinite multiplication factor
10	1.0977125	1.569689
15	1.1540635	1.624102
19.5	1.1847919	1.651687
trr	1.0688456	1.616863

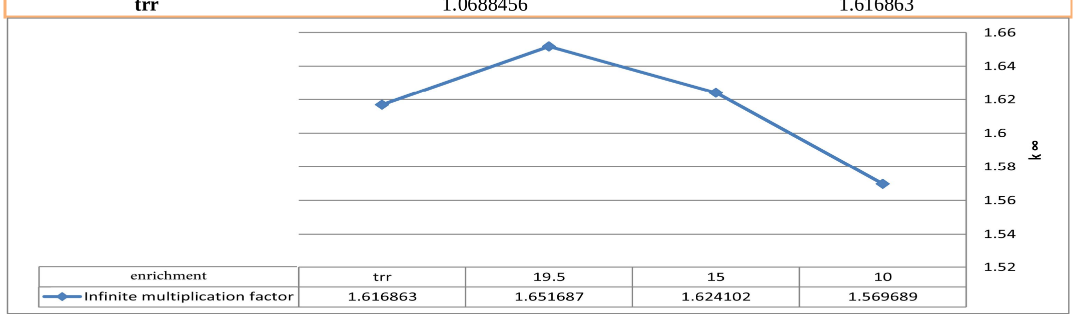

Diagram 3. comparison of the reactor infinite multiplication factor in current fuel (U_3O_8-AL) to U3Si2-AL fuel with different enriched of uranium

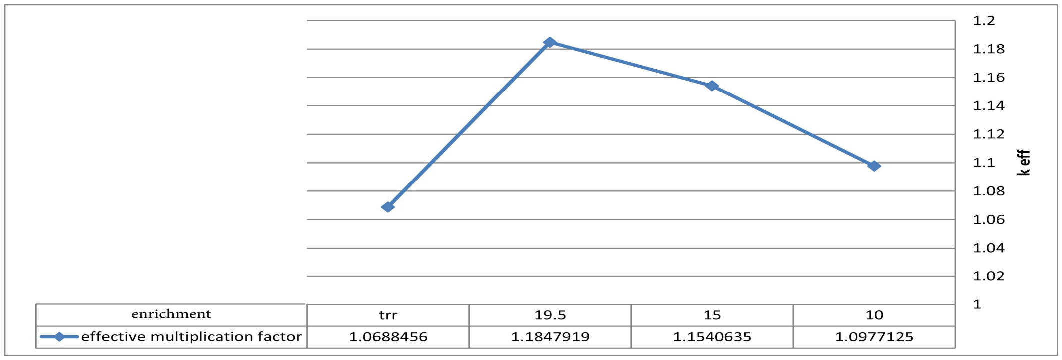

Diagram 4. comparison of the reactor effective multiplication factor in current fuel (U_3O_8-AL) to U3Si2-AL fuel with different enriched of uranium

The obtained result of table and diagrams above show that the Multiplication factor of U_3SI_2-AL fuel with 4.8 (grU/cm3) density is almost identical with multiplication factor of current fuel (U3O8-AL) in the Tehran Research Reactor and this means that U3SI2-AL fuel with 4.8 (grU/cm3) density and the enrichment of 10% will be critical and can be use in the Tehran Research Reactor.

Table 5. Specifications of U_3SI_2 fuel

factor	quantity
Fuel	LEU
Type of meat	U3Si2 -Al
Number of fuel plates	23
Plate thickness	0,135cm
Meat thickness	0.061cm
Cladding thickness	0.0381cm
Meat width	1.51 cm
Average water channel	0.245 Cm
Total plate width	6.5 Cm
FE dimensions	8.01×7.71×89.7cm
Active fuel length	61.5cm
U-235 enrichment	19.7 %
U-235 per fuel plate	225 Gr
Uranium per fuel plate	1142.14 Gr
Meat density	4.8 Gr/CC
U density	6.11 Gr/CC
Uranium density in the meat	0.9456 Gr/CC
U-235 Weight percentage	2.228%
U-238 Weight percentage	90.54%
AL-27 Weight percentage	32.519%
Void fraction in the meat	13.3%
Grid array	6X9 fuel

Table 6. Physical characteristics of the fuel

Fuel	density (grU/cm^3)	density (gr/cm^3)	Melting point (c)	Thermal Expansion Coefficients (1/C)	Thermal conductivity (W/m-K)
U_3si_2	4.8	12.2	1665	$15.5*10^{-6}$	49.8

5.Conclusion

According to the results obtained K_{eff} is acceptable and U3SI2-AL fuel with the density 4.8 (gr U/cm3) and 10% enriched (or even less) can be suitable alternative for the currently fuel in Tehran reactor and it can be used in research reactors.

Also suggested considering the capabilities of this fuel and possibility of enrichment reducing it and reduce of the related cost, this fuel be examined in terms of safety, thermo-hydraulic and etc.

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