Actinides Burnup in a Sodium Fast Reactor

J. Ramón Ramírez S., Raúl Pineda A., E. Martínez Caballero, Gustavo Alonso
Instituto Nacional de Investigaciones Nucleares
Carretera Mexico-Toluca S/N, La Marquesa, Ocoyoacac, C.P. 52750, Mexico

Abstract

The burnup of actinides in a nuclear reactor is been proposed as part of an advanced nuclear fuel cycle, this process would close the fuel cycle recycling some of the radioactive material produced in the open nuclear fuel cycle. These actinides are found in the spent nuclear fuel from nuclear power reactors at the end of their burnup in the reactor. Previous studies of actinides recycling in thermal reactors show that would be possible reduce the amounts of actinides at least in 50% of the recycled amounts. in this work, the amounts of actinides that can be burned in a fast reactor is calculated, very interesting results surge from the calculations, first, the amounts of actinides generated by the fuel is higher than for thermal fuel and the composition of the actinides vector is different as in fuel for thermal reactor the main isotope is the ^{237}Np in the fuel for fast reactor the main isotope is the ^{241}Am, finally it is concluded that the fast reactor, also generates important amounts of waste.

1. INTRODUCTION

Since the beginning of the nuclear era, the reprocessing of nuclear fuel technology has been part of plutonium recovery, which main use was the nuclear weapons production. After that, the plutonium has been used in the manufacture of mixed oxides fuel named MOX[1], which has permitted to obtain additional energy from the plutonium fission in thermal and fast reactors
In recent years, in addition of reprocessing, that permits the separation of plutonium, uranium and fission products, a process named partitioning has been developed, which permits the separation of minor actinides from fission products

In recent years the idea of actinides recycling surged as the advanced nuclear fuel cycle for the generation IV nuclear reactors requires a nuclear fuel cycle closed, so, the recycling of plutonium and minor actinides is necessary to close the nuclear fuel cycle.

Previous studies[2] shown that: the amounts of minor actinides generated into a BWR fuel at a burnup of 47500 MWd/THM was around of 135 grams per Assembly of material with a concentration of main isotopes, as given in Table I.

Table I Actinides vector generated in thermal reactor

Isotope	237Np	241Am	244Cm
Weight %	79.8045	8.3830	11.8125

2. SODIUM FAST REACTOR CONCEPT

It is necessary to have a design of sodium fast reactor to perform the calculations and evaluate the inventories of material at the end of the irradiation step, so, a concept of sodium fast reactor was developed which here is named SFR-AT 300 or (Sodium Fast Reactor-Actinide Transmutation 300 MWt).

The SFR-AT 300 is a Concept of 300MWth fast reactor conceived to calculate the actinides transmutation under fast neutron flux, it consist of one core with two concentric regions of different plutonium concentration, each as MOX fuel and is cooled by liquid sodium.

The first description of their components starts here with the more basic component: The fuel rod.

As shown in Figure 1, the fuel consists of a stainless steel tube containing the MOX fuel of 21.5% Pu reactor grade in a matrix of depleted uranium with 0.25% ^{235}U from enrichment tails.[3]

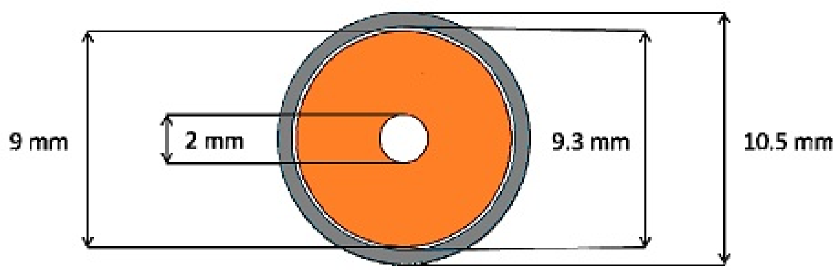

Figure 1 MOX Fuel Rod Diagram

With the basic component, the fuel assembly is constructed, as shown in Figure 2, a total of 127 fuel rods using triangular array into a hexagonal channel is the fuel used for the whole core, al parameters are given in the table II.

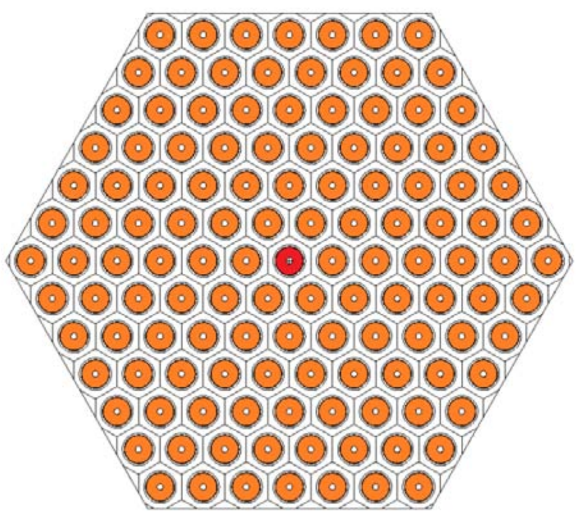

Figure 2 MOX Fuel assembly for SFR-AT 300 Reactor

Reactor SFR-AT 300 (Power)	300 MWth
Fuel Assemby design	Hexagonal
Number of pins	127
Active Length	80 cm
Pin pitch	14 mm
Pin outer diameter	10.5 mm
Pellet outer diameter	9 mm
Pellet inner hole Diameter	2 mm
Gap	0.75 mm
Cladding thickness	0.5 mm
Cladding Material	SS-316L
Fuel Material	MOX, Reactor Grade Pu
Pu concentration	18.7 %
Fissile Uranium Concentration	2.5 % from uranium tails
Fuel density	9.7 g/cm^3
Hexagonal Channel Thickness	2 mm

Table II Fuel Assembly Parameters

The core of the reactor is a compound of one core with two regions, one of them consisting of four fuel rings in a hexagonal mesh, this core has an average concentration of reactor grade Pu of 21.5 %, a number of fuel assemblies in this region is 54.

The second region consists of three concentric rings of fuel with a total of 96 fuel assemblies of lower concentration of Pu. Surrounding the core, exist a ring of a reflector made of natural uranium oxide and finally, an external ring that shields the whole core, this shielding is made of stainless steel. The power of the core is controlled by ten control assemblies and three safety assemblies for secure shutdown placed in the inner core.

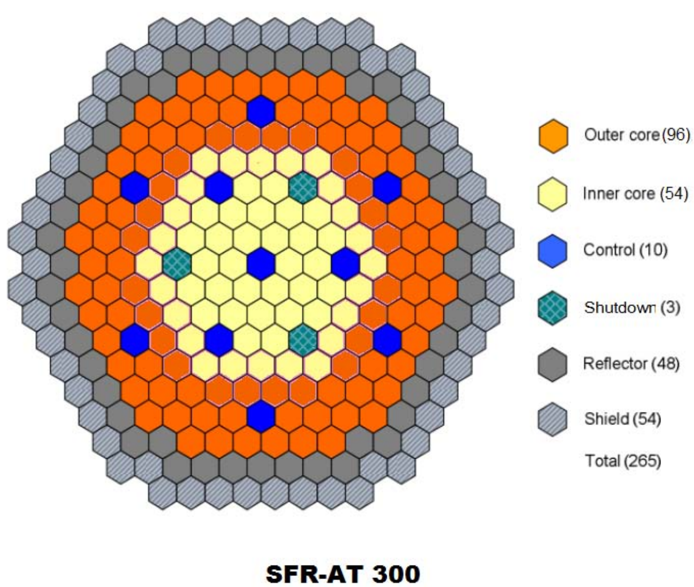

Figure 3 Layout of the SFR-AT 300 Fast Reactor Core

3. RESULTS FOR A FUEL ASSEMBLY

The results obtained for the fuel proposed are as follows: First, the amounts of actinides generated in this fuel at a burnup of 55 000 MWd/tHM is of 100.74 g of actinide, this amount is generated for a fuel assembly that contains 57.9 kg of heavy metal, in comparison the fuel for thermal reactor generates 135 g in a mass of 180 Kg of heavy metal, so, if a mass relation is applied: 180/57.9 = 3.1, the equivalent amount of actinides would be of 312.3 g for the fast reactor fuel. Here is important to mention that the main product in thermal fuel is Neptunium-237 while for fast reactor fuel is Americium-241 as it is shown in the Tables I and III.

Table III Actinides concentrations Vector

Isotope	^{237}Np	^{241}Am	^{244}Cm
Weight %	7.44	90.03	2.52

The procedure was, first, calculate the inventory with fresh fuel free of actinides to obtain a reference to the normal production of actinides in fuel for fast reactors using MOX. Later the actinides were integrated into the fresh fuel considering to put in there, the same concentration used in calculations with thermal reactor fuel, that was 6% of actinides with the composition given in Table 1, all this calculation were made with the code MCNPX[4].

The results obtained are shown in Table IV, where can be observed some interesting amounts.

Table IV Actinides inventory For Fresh Fuel and Fuel W/Ac 6%

Results: Fuel SFR-AT 300					
	Reference 48400 MWd/THM		Test With/Ac 48000 MWd/tHM		
Isotope	Initial grams	Final grams	Initial grams	Final grams	Difference
92235	104.7	11.91	95.19	73.61	-21.58
92238	41770.0	40200.0	37980.0	36670.0	-1310
93237	0.0	9.16	3030.0	2460.0	-570
94238	208.9	170.1	208.9	600.0	391.1
94239	8382.0	7496.0	8382.0	7484.0	-898
94240	3411.0	3495.0	3411.0	3489.0	78
94241	1225.0	929.1	1225.0	937.0	-288
94242	696.2	693.1	696.2	699.0	2.8
95241	0.0	110.8	318.3	364.8	46.5
96244	0.0	3.1	448.6	360.9	-87.7
SumaAc	0.0	123.06	3796.9	3185.7	610

The main result shown in the Table 3 is a net reduction in the initial and final amounts of actinides (610 g) for the case of actinides incorporated into the fresh fuel, a reduction of the 237Np (570 g) with respect to the initial amount introduced in the fuel, a reduction of 244Cm (87.7 g), and an increment of 241Am (46.5 g). The reduction of actinides with respect to the original amount is around 16%.

4. CONCLUSIONS

First it is concluded that the fuel for SFR generates up to three times the amount of actinides than the fuel for a thermal reactor, this is mainly due to the high concentrations of plutonium handled in the MOX fuel. In agreement with the calculations done in both fuels, it is important to point out that the isotopes are different between them, in the thermal spectra, the main product is ^{237}Np and in the fast spectra the main product is ^{241}Am.

ACKNOWLEDGMENTS

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