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Calculation of Cesium Radioisotopes (^{134}Cs and ^{137}Cs) Generated from Ceramic fuel (UO_2) in nuclear Power Station, (PWR) Type

Wefaa S. Sugab[1], Dr. Ali K. Hasan[2], Dr. Najim A. Askouri[3]

[1, 2, 3]Department of Physics, Faculty of Education for Girls, University of Kufa, Najaf- Iraq

Abstract: ***The pressurized water reactors, One of the reactors used for power production of electricity. The nominal thermal power output of this hypothetical reactor (3000 MW).The process of fission by thermal neutrons leads to the formation of radioactive products. Calculations were performed using a special program conducted in "MATLAB" language. The calculation included the effect of neutron flux and thermal power on the production ratio of the isotopes emitting gamma radiation. It has been found that increase of the parameters led to increased production of gamma-ray sources ratio.***

Keywords: Calculation of Cesium Radioisotopes (134Cs and 137Cs)

1. Introduction

Following the discovery of the neutron, detailed measurements of the effect of bombarding elements with neutrons were carried out, notably by Enrico Fermi and his collaborators in Rome. Among the large number of elements investigated was the heaviest naturally occurring element, uranium. As with many of the other elements, the bombardment of uranium led to the production of induced β activity. At least four different β-active isotopes, of different half-lives and disintegration energies, were detected [1]. In the fission process, a neutron interacts with the target nucleus creating a compound nucleus that is unstable and splits into smaller nuclei releasing two or more neutrons and energy [2].after the discovery of nuclear fission process in 1939 continued his studies in detail it has been developed of scientific theories on the basis of the evolution of the structure of the nucleus. Researcher 'Tsuruta' studied the measurement of the ratio of fission products gamma activities from ^{239}Pu and ^{235}U fissions [3].'Handa' has conducted research with his group studies of ceramic fuels with use of fission gas release loop [4].Researcher 'Lewis' studied fission products release from defected nuclear reactor fuel elements. [5],In the present research we studied isotope Cesium released from the fission products as a Beta- gamma rays emitter

2. Theoretical part

The nuclei which are most easily used as fuel in fission reactors are the three even-odd nuclei ^{233}U, ^{235}U and ^{239}Pu which fission rapidly by thermal neutron capture [6].As it is (UO_2)ceramicfuels of low enrichment which is used in pressurized water type nuclear power reactor (PWR). "A thermal reactor uses light water as the reactor coolant and moderator" [7].Zircaloy-4 tubes is filled with UO_2pelletsand sealed to form a fuel rod About 200 of the fuel pins are grouped in a bundle called a fuel element and about 180 elements are assembled in an approximately cylindrical array to form the reactor core. a shield of concrete surrounds the pressure vessel and other equipment to provide protection against neutrons and gamma rays from the nuclear reactions. The shield also serves as an additional barrier to the release of radioactive materials [8]

3. Calculations and Results

3.1 Production of Radioisotopes

1- Effect of Thermal Power (P): The fission rate represents the number of fissions that occurs in nuclear fuel inside the reactor where about (3.1×10^{10} fission/sec) when thermal power (1watt) .When the thermal power of the reactor changes, the fission rate changes according to the form (3-1). Thus, the fission rate affects the production rate of radioactive isotopes by the following relationships [9]:

$$C = 3.1 \times 10^{10} \times P \quad (1)$$

$$Q = C \times Y \times t \quad (2)$$

Q radioisotope production rate, **Y** yield per fission accumulated during and t period of the reactor operating

2- Effect of Neutron Flux (∅): If certain material pounded with neutrons it generates radioactive isotopes by constant amount with time is calculated from the following relationship [10]

$$Q = NV.\sigma_c.\emptyset.Y.t \quad (3)$$

$\boldsymbol{NV}$Number of nuclei offissile nuclear fuel, $\boldsymbol{\sigma_c}$ fission Cross-Section and ∅ neutron flux.

3.2 Active Isotope Radiation

The previous calculations were based on the expense ratio of the production of the accumulated radioactive isotopes that are generated during the operation of the reactor, as it is well known that the fission products will begin to unravel after a period of operation of the reactor. The calculation can change the rate of radioactive isotopes atoms $\boldsymbol{N}$ after a period of operation of the reactor at the certain Neutron Flux from the following relationship [11]:

$$N = \frac{NV.\sigma_c.\emptyset.Y}{\lambda}\left(1 - e^{-\lambda t}\right) \quad (4)$$

Where $\boldsymbol{\lambda}$ is decay constant

Table 1: Half-life of radioactive isotopes and the yield of fission products accumulated from nuclei fission of ^{235}U [12]

Nuclide	Half-life (year)	Cumulative fission yields (%)
Cs-134	2.063	0.0000121
Cs-137	30	6.221

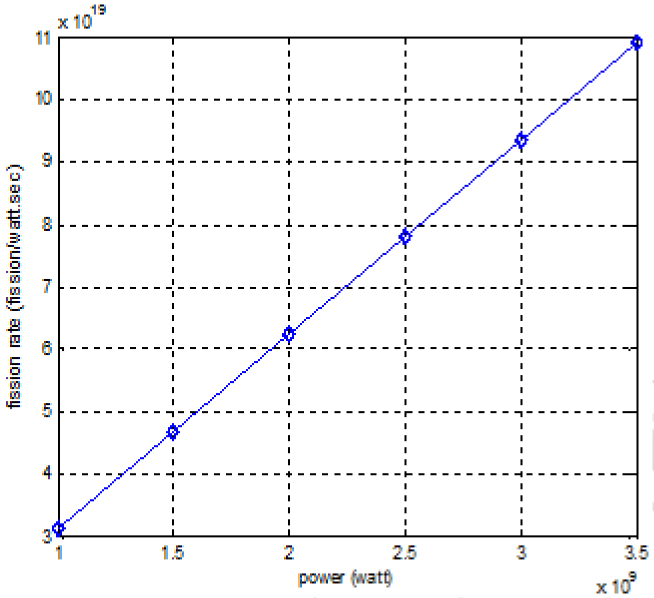

Figure 1: Relationship between the fission rate and thermal power of the reactor.

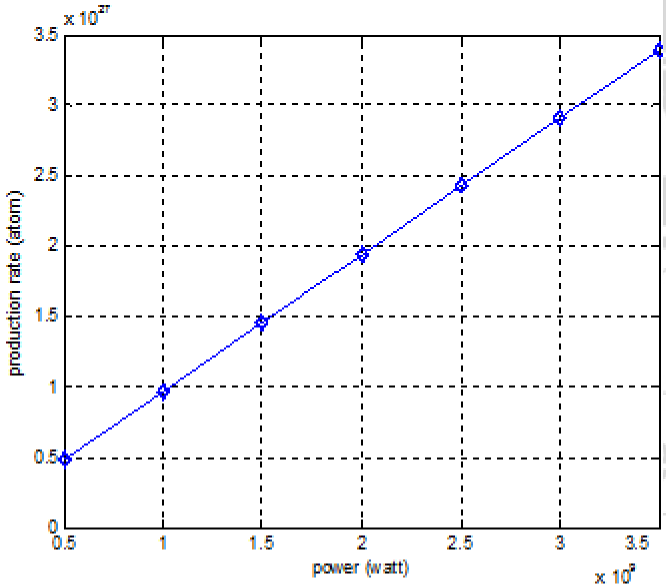

Figure 2: Effect of thermal power of the reactor on the total production rate of radioisotopes.

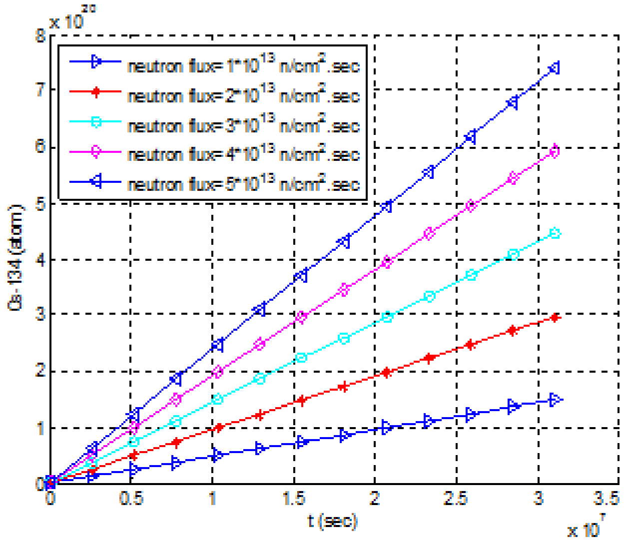

Figure 3: The production of (Cs-134) at different values of neutron flux.

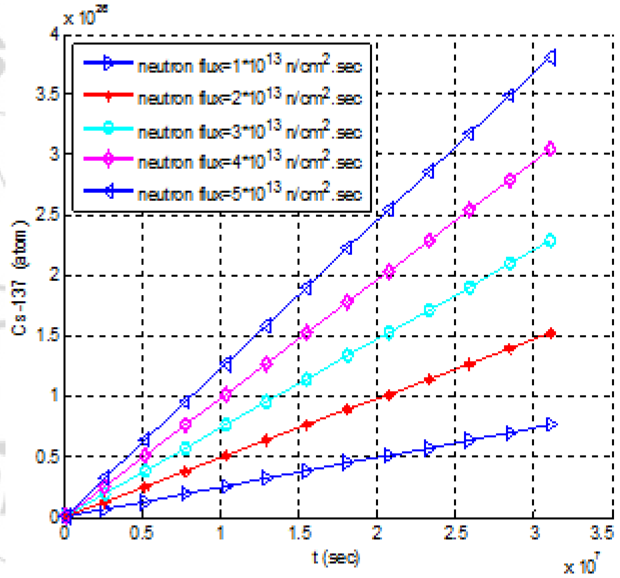

Figure 4: The production of (Cs-137)at different values of neutron flux

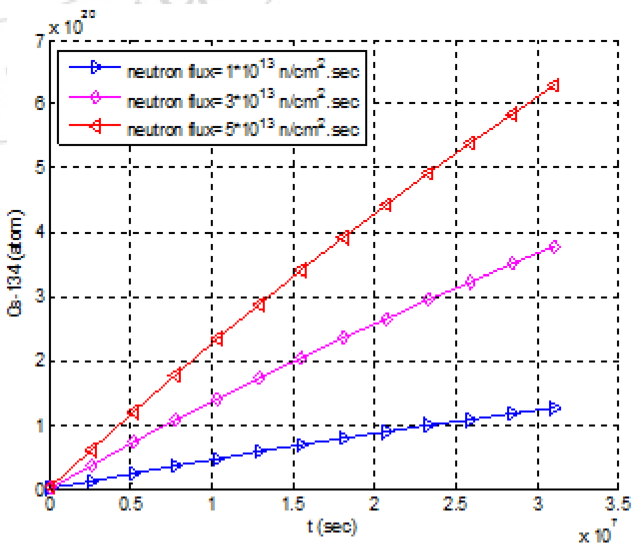

Figure 5: The accumulated number of (Cs-134)atoms inside the reactor because of the decay process

4. Discussion

Figure (1) shows the fission rate increase with the increase in thermal power. This leads to increased production rate of radioactive isotopes emitting gamma radiation and as shown in figure (2). At the normal thermal power of the reactor has a total percentage of production (2.91133440000000E+18) atom. Figures (3) and (4) describe the production rate increase with the increase in neutron flux. during the years of operation of the reactor. The of neutron flux (1~5 × E+13) $n/cm^2.sec$ increasing the production rate of (Cs-134)from (1.48E+20) to (5.56E+20) and (Cs-137) from (7.62E+25) to (2.86E+26). The different production ratios of these isotopes is related to the different fission yields Finally, the change of (Cs-134) atoms because of the decay process shown in figure (5) noting that the rate of production starts downward after a period of operation of the reactor. (Cs-137) decay is not evident because its long half-life which is much longer than the reactor operating time.

5. Conclusions

1) Our findings through the use of theoretical equations for calculating gamma radiation Quantities emitted from nuclear fission products in ceramic fuel of PWR-reactor demonstrates the success of the software used in the preparation of this research.
2) Radioisotope production rate is directly proportional to the period of operation reactor, neutron flux and the thermal power of the reactor.
3) The number of atoms of radioactive isotopes slightly changes during the period of operation of the reactor because of the decay process.

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