AIP | Conference Proceedings

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Citation: AIP Conf. Proc. **1351**, 397 (2011); doi: 10.1063/1.3608995
View online: http://dx.doi.org/10.1063/1.3608995
View Table of Contents: http://proceedings.aip.org/dbt/dbt.jsp?KEY=APCPCS&Volume=1351&Issue=1
Published by the American Institute of Physics.

Burn-up and Operation Time of Fuel Elements Produced in IPEN

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Abstract The aim of this paper is to present the developed work along the operational and reliability tests of fuel elements produced in the Institute of Energetic and Nuclear Research, IPEN–CNEN/SP, from the l980´s. The study analyzed the U-235 burn evolution and the element remain in the research reactor IEA-R1. The fuel elements are of the type MTR (Material Testing Reactor), the standard with 18 plates and a 12-plate control, with a nominal mean enrichment of 20%.

Keywords: nuclear fuel elements, burn up, research reactor, IEA-R1 reactor
PACS: 28.50.Dr

INTRODUCTION

IPEN started the production of fuel elements for the IEA-R1 reactor in 1985. The first prototype number 128, with two fuel plates, started to be irradiated on October 07, 1985, in the position 15 of the matrix plate (Fig. 1). One month later, on November 18, the second prototype number 129 was placed on the matrix plate. In these positions, the burn is very low or insignificant. Since corrosion or leaking problems did not occur, the elements were transferred to the reactor core. On March 10, 1988, the element 129 was place in the position 33: this date, the burn calculation of fuel elements, produced in IPEN, starts.

The first complete fuel element, with 18 plates [1], was number 130, which entered the core on September 5, 1988, starting a regular supply that has continued to date. Seventy-five elements were produced until the end of 2006, 65 of them of the standard type and 10, control.

The element 138, with 12 plates, was the first control fuel element to enter the core, on November 26, 1991.

Since the beginning of these elements, a burn up control of U-235 and U-Total, Plutonium production and location, i.e., where the fuel element is stored or in use, has been done. These data are filed in computer and printed forms, constituting a data basis, which are updated monthly.

All this control process has the goal of verifying the fuel elements, developed in IPEN, performance and, also, meeting the nuclear material safeguard requirements by the Comissão Nacional de Energia Nuclear (CNEN) [2] and International Atomic Energy Agency (IAEA) [3].

XXXIII Brazilian Workshop on Nuclear Physics
AIP Conf. Proc. 1351, 397-400 (2011); doi: 10.1063/1.3608995

In the beginning of these fuel elements supplies, the operation schedule was 2 MW, Monday through Friday, from 8:00 a.m to 5:00 p.m, with a shutdown every 15 days, on Mondays, for preventive and corrective maintenance. With this operation and potency, a core comprising 30 fuel elements was used, 26 standard and 4 control (Fig.01)

From November 1995 on, the reactor had its operation system altered for uninterrupted 64h per week, to supply the growing national radioisotope production, mainly, for medical use.

Therefore, to unite the Facility with the most recent safety improvements, better measures of safety were implemented, with the addition of new procedures and rebuilding/upgrade of the existent systems, aiming a feasible continuous reactor operation in the potency of 5 MW [2].

On September 09, 1997, the reactor started to operate, only, with fuel elements produced in IPEN, with the potency of 3.5 MW and a single core, formed by 24 fuel elements, of which 20 standard and 4, control (Fig. 02).

U-235 Burn Up Calculation

For each day of reactor operation, the operation time, dissipated energy (E_d) are registered. A written control is kept every month. After one month or when necessary, the energy dissipated accumulated is used for the correspondent U-235 burn calculation. Using the computer codes “HAMMER” and “CITATION”, the cellular calculation and the thermal neutrons flux, in each position in the core, were obtained. These values allow to obtain the factor $\frac{Q_i}{Q_m}$, where $\mathbf{Q_i}$ is the thermal flux in the position **i** and $\mathbf{Q_m}$ is the average flux in the core.

For each position in the core, a second factor is determined, $\frac{M_i}{M_t}$, which provides the existent relation between the U-235 mass, in the position i ($\mathbf{M}_i$) and the total U-235 mass of the core ($\mathbf{M_t}$). With these two factors, the burn factor (FQ) is expressed:

$$FQ = \frac{M_i}{M_t} x \frac{Q_i}{Q_m}$$

Normalizing this factor, the normalized burn factor is obtained:

$$\sum_{i=1}^{n} FQN = 1 \qquad \text{where} \quad n = \text{number of fuel elements}$$

Then, the burned U-235 amount is obtained, for the **i** position or for each fuel element, in grams, i.e.:

QTDQ = FQN * E * 1.24,

where: 1.24 is the U-235 burned mass in grams, for each MWh of energy dissipated by the reactor [4].

Data Analysis

Figures 1 and 2 present the IEA-R1 reactor core configurations and their change to make the core more compact and allow the operation in a potency of 5MW.

In figures 3 and 4, an increase in the burn up and reduction in the remaining time, in the core of the fuel elements fabricated in IPEN, are observed. The gradual progression of these elements utilization shows the care in the security test and evaluation observed in the production of these elements.

Nowadays, the reactor operates at 3.5MW, a potency that allows the production of the radioisotopes requested and a safe operation, due to the modernization and acquisition of new control systems.

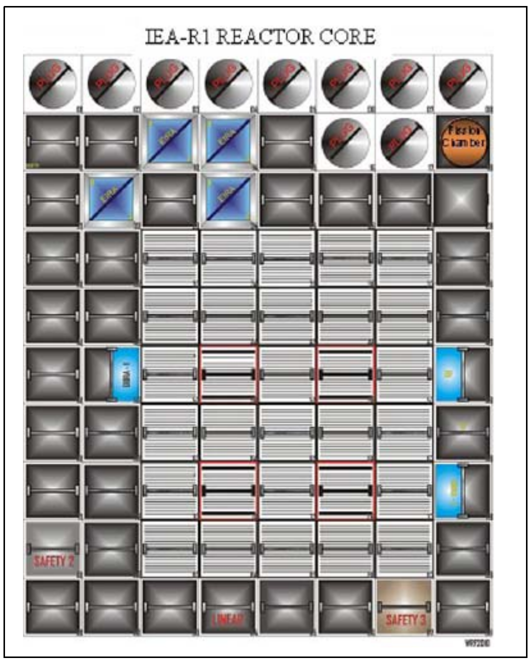

FIGURE 1 –Basic Configuration for Operation in 2 MW

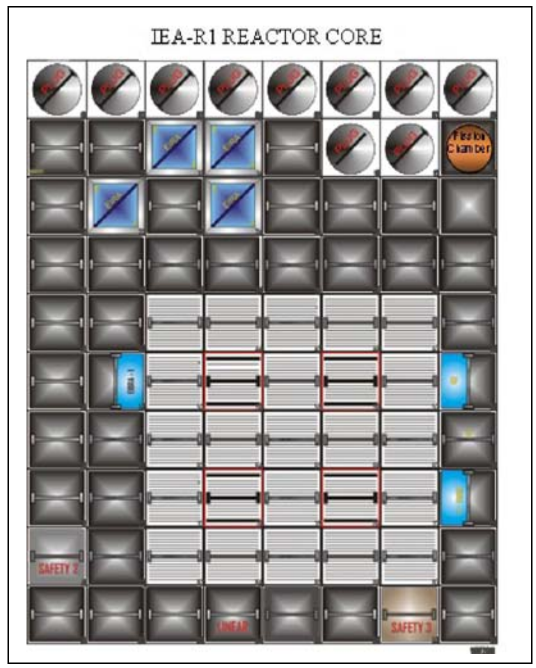

FIGURE 2 –Basic Configuration for Operation in 5 MW

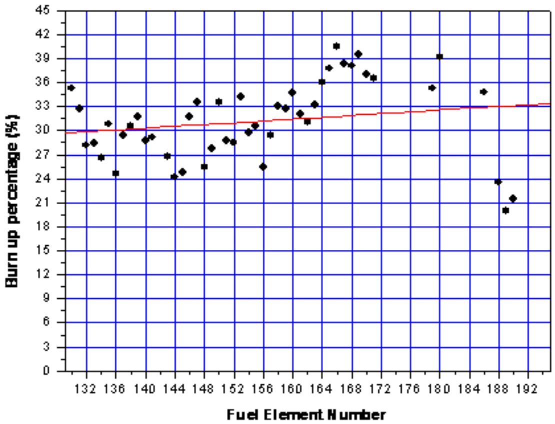

FIGURE 3 – Final Burn of Fuel Elements

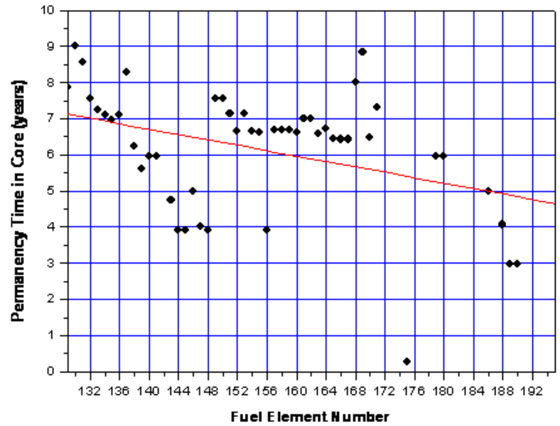

FIGURE 4 – Total Remaining Time of the Fuel Elements in the Core

Conclusion

After more than twenty years using the fuel elements produced in IPEN, a gradual increase in their burn percentage was verified. This increase generated from the reliability acquired over the operation years. Their remaining time in the core has been diminishing as a consequence of the potency increase and, consequently, the burn increase.

With the perspective of increase in the operation potency for 5MW and the operation weekly schedule for 120 hours, the remaining time of the elements in the core should continue to diminish and the burn percentage should increase to reach the limit of 50%.

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