COMPARATIVE ANALYSIS OF METHODS FOR MEASURING BURNUP OF SPENT FUEL ASSEMBLIES BETI

M.A.Ruziyeva[1], **M.M.Najmiddinov** [2], **K.S.Sobirov** [2]
[1]Bukhara Engineering Technological institute - 15, K.Murtazoev ave., Bukhara, 200117, Uzbekistan
[2]Bukhara Institute of Natural Resources Management of the National Research University of TIIAME - 32, Gazli shokh ave., Bukhara, 105009, Uzbekistan
e-mail: mavlyuda.ruziyeva@mail.ru

ABSTRACT

This article describes about the comparison of the methods made it possible to evaluate their advantages and disadvantages, and to develop recommendations for their use. The performed methodological developments can also find application for control measurements of fuel assemblies of other reactors using highly enriched fuel.

Keywords: *Beta radiation, relativistic speeds, radioactive nuclei, electron, positron, neutron, proton, a nuclear reactor, kinetic energy, alpha particle, relativistic energy, phase velocity, Cherenkov radiation, spectrum, active neutron method, passive neutron method, passive neutron method.*

АННОТАЦИЯ

В данной статье рассказывается о сравнении методов, что позволило оценить их преимущества и недостатки, а также разработать рекомендации по их использованию. Выполненные методические разработки могут найти применение и для контрольных измерений ТВС других реакторов, использующих высокообогащенное топливо.

Ключевые слова: *Бета-излучение, релятивистские скорости, радиоактивные ядра, электрон, позитрон, нейтрон, протон, ядерный реактор, кинетическая энергия, альфа-частица, релятивистская энергия, фазовая скорость, черенковское излучение, спектр, метод активных нейтронов, метод пассивных нейтронов, пассивный нейтрон. метод.*

INTRODUCTION

Beta radiation consists of free electrons or positrons at relativistic speeds. These particles are known as beta particles. Beta particles are high-energy, high-speed electrons or positrons emitted by certain fission fragments or certain primordial radioactive nuclei such as potassium-40. The beta particles are a form of ionizing radiation, also known as beta rays. The production of beta particles is termed beta decay**.**

A nuclear reactor occurs especially the β− decay because the common feature of the fission products is an excess of neutrons (see Nuclear Stability). An unstable fission fragment with the excess of neutrons undergoes β− decay, where the neutron is converted into a proton, an electron, and an electron antineutrino.

MATERIAL AND METHODS

Characteristics of Beta Radiation Key characteristics of beta radiation are summarized in the following points:

- Beta particles are energetic electrons. They are relatively light and carry a single negative charge**.**
- Their mass is equal to the mass of the orbital electrons with which they are interacting. A much larger fraction of its kinetic energy can be lost in a single interaction than the alpha particle.
- Their path is not so straightforward. The beta particles follow a very zig-zag path through absorbing material. This resulting path of the particle is longer than the linear penetration (range) into the material.
- Since they have very low mass, beta particles reach mostly relativistic energies.
- Beta particles differ from other heavy charged particles in the fraction of energy lost by the radiative process known as the bremsstrahlung**.** Therefore for high energy, beta radiation shielding dense materials are inappropriate.
- When the beta particle moves faster than the speed of light (phase velocity) in the material, it generates a shock wave of electromagnetic radiation known as the Cherenkov radiation**.**
- The beta emission has a continuous spectrum.
- A 1 MeV beta particle can travel approximately 3.5 meters in the air.
- Due to the presence of the bremsstrahlung, low atomic number (Z) materials are appropriate as beta particle shields.

RESULTS

Determination of fuel burnup in nuclear reactors is of great importance for their efficient and safe operation. Fuel burnup is one of the main indicators that determine the economic efficiency of a reactor. Measurement of the burnup depth of spent fuel assemblies with acceptable accuracy is a rather difficult task.

IRT fuel assemblies are stored for a long time in the storage pools, which can lead to the loss or inaccuracy of passport data. Over the course of several years, several methods have been developed for determining the burnup depth of IRT SFAs. In this paper, the following methods are considered:

- Active neutron method;
- Passive neutron method;
- Method for measuring burnup by gamma radiation of fission product Cs^{137};
- Re-irradiation method.

Figure 1 – Sectional view of eight-tube IRT-3M fuel assembly

DISCUSSION

Based on the research results, the following conclusions were made:

1. Despite the fact that the "Passive neutron method" is the fastest and cheapest, it has a number of significant disadvantages. First, a set of spent fuel assemblies with known burnup is required for the calibration behavior. Second, the size of UO_2 microparticles in the Al matrix has been found to significantly affect the generation of neutrons. In this work author is not provide for the introduction of a correction for current method.

2. "The method of measuring the burnup by gamma radiation of the fission product Cs^{137}" is rather laborious, it requires the introduction of a large number of calculated corrections and calibration spent fuel assemblies with a known burnup. Its main advantage is the ability to obtain a large amount of information about the measured spent fuel assemblies: the distribution of burnup along the length of the fuel assembly, average and maximum burnup with an error of about 5-8%.

3. The most accurate is the "Method for determining the residual content of fissile isotopes in spent fuel assemblies using repeated irradiation". It makes it possible to obtain the burnup distribution along the length of the fuel assembly, the average and maximum burnup with an error of less than 3%. For calibration, a fresh fuel assembly is used with the manufacturer's passport data on the mass of U^{235}. The main difficulty of the method is the need to re-irradiate spent fuel assemblies. This requires a working reactor. Despite the high labor intensity of this method, it can be recommended to be used to check the calculated data and programs, as well as for the certification of SFAs.

4. The most promising method for determining burnup for performing fast control measurements with a sufficiently high accuracy (5%) is the "Active Neutron Method". This method has a number of advantages: a fairly simple apparatus is used for neutron measurements, no spent fuel assemblies with known burnup are required to calibrate the measuring system, no data on the history of SFA irradiation are required, the number of calculated corrections is minimal, measurements can be carried out 2-3 months after extraction spent fuel assemblies from the reactor.

CONCLUSION

The comparison of the methods made it possible to evaluate their advantages and disadvantages, and to develop recommendations for their use. The performed methodological developments can also find application for control measurements of fuel assemblies of other reactors using highly enriched fuel.

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