Design of Compact Beam Shutter for Biological Shielding on IRT-T Reactor for BNCT Applications

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Introduction

Currently, interest in BNCT in Russia is steadily growing. On base of operating research reactors, as well as operating and developing accelerators, installations for performing clinical and preclinical BNCT studies are being created. This paper is devoted to the problem of reconstruction of the horizontal channel GEK-1 shutter of IRT-T reactor to improve characteristics of the ionizing radiation beam for BNCT.

Materials and Methods

The IRT-T reactor is a 6 MW pool type research reactor. As a result of performed studies of determination more suitable base for BNCT implementation, the horizontal channel HEC-1 was selected.

One of the ways for improving parameters of a neutron beam is reducing distance between reactor core and site of therapy. To reduce the length of the horizontal channel HEC-1, it is possible to replace the existing shutter with a more compact one. The existing shutter is a structure consisting of 5 cylindrical sections made of paraffin, steel and boron carbide with a total length of 1.85 m.

According to the legislation in force in the Russian Federation, the maximum dose rate behind the shutter in the closed state should not exceed 2.7 nSv/h. Thus, in framework of this work, materials of the compact shutter, their location and thickness were chosen in such way that the total dose rate from neutrons and photons does not exceed the value determined by law.

Due performing neutronic calculations, codes based on the Monte Carlo method were used. For the initial calculation of the neutron and photon fields distribution MCU-PTR code was used. The energy and angular characteristics of ionizing radiation beam, obtained at first stage of calculations, were used as initial data for calculations in PHITS code, which has significant capabilities for visualizing interaction of ionizing radiation with a matter.

Results

As a result of this research, parameters of the ionizing radiation beam were significantly increased. In the process of performing multivariance calculations, the optimal composition of the shutter materials was determined, allowing to ensure the required dose rate values behind the closed gate. The optimal combination is B_4C (11 cm) – Bi (14 cm) – CH_2+Li (20 cm) – Pb (10 cm) – CH_2+Li (15 cm) – Pb (10 cm)

With a decrease in the shutter length from 1.85 m to 0.95 m, the thermal neutron flux increased from 8.41E+08 n/cm^2/s to 5.01E+09 n/cm^2/s. The fast neutrons component increased slightly from

2.59E-12 Gy·cm^2 to 2.82E-12 Gy·cm^2 per thermal neutron. The photons component also increased slightly from 1.98E-11 Gy·cm^2 to 2.09E-11 Gy·cm^2 per thermal neutron.

Conclusion

By reducing length and changing the material composition of shutter, it is possible to ensure appropriate radiation safety conditions. Reducing distance between the reactor core and the location of irradiation allows to increase thermal neutrons flux by more than 6 times with slightly increasing dose rates from photons and fast neutrons components.

Significantly increased absolute values of neutron flux of all energies with installation of appropriate BSA will allow to achieve parameters of the ionizing radiation beam suitable for conducting preclinical BNCT studies.