

COMPARATIVE CHARACTERISTICS OF REACTORS *KINI* AND *INP* AND THEIR USAGE IN THE MEDICAL PURPOSES

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The aim of this work is to provide neutron physics foundation and technical validation for the development of a neutron source having parameters satisfactory for Neutron Capture Therapy (NCT) in the treatment of human cancer tissues. Such treatment requires an epithermal neutron flux of not less than 10^9 neutron/cm²s and a fast to epithermal neutron ratio of less than 1:50. The best way to achieve such a source at an existing nuclear reactor is to transform a thermal column into an epithermal source with a neutron spectrum in the range of 1 eV - 10 keV. For this purpose the main material of the thermal column, graphite, has to be replaced by light materials such as aluminum, fluoride, lithium-7, and some others. In addition, special filters, reflectors, and converters may improve the parameters of the beam. Taking into account last year's international requirement of converting all research reactors to low enriched uranium (LEU) fuel, it is necessary to estimate the possibility of creating such boron NCT (BNCT) neutron source using both high-enriched uranium (HEU) and LEU fuel.

The first and most necessary stage of this work is the accurate physical calculations of all the parameters of such a source. This problem demands detailed and rather intricate computer calculations using the Monte Carlo method. The widely used MCNP computer package developed at Los Alamos National Laboratory, USA is available for such calculations in circumstances close to the real situation. Nevertheless, this work needs significant efforts of

highly qualified specialists, using up-to-date computer techniques with long time calculation times and a deep understanding of all the physical processes that take place in the area of the neutron beam, as well as in the reactor core. This is connected mainly with nuclear safety demands that have to be satisfied during all transformations needed for development of a new source.

The specialists of the INR Neutron Physics Department (NPD) have experience with MCNP for Kiev research reactor (KRR) calculations, up-to-date computer techniques, and acquaintance with the development of neutron sources, as evidenced by their participation in international BNCT conferences and meetings on this problem [1-4]. In NPD there also exists considerable experience and practice in the development of the neutron filter beam technique and associated experimental measurements that may be successfully used for testing some obtained intermediate results.

As it is well known, the large interaction cross section of thermal neutron with B-10 isotope leading to a splitting of B-10 nucleus onto He and Li together with absorbability of cancerous tumors to take up the boron atoms much more than healthy cells, are the basis of Boron Neutron Capture Therapy method. As ionization capability of He and Li ions is high, and their runs are short, then the cells, preferably enriched by boron, are killed and the healthy cells are damaged much less. However, as the penetrating capability of thermal neutrons is low, then to reach the cancerous tumors, localized into several centimeter depths, the epithermal neutrons are more suitable. In addition, the use of thermal neutrons carries attendant problems due to the magnitude of the skin dose. Epithermal neutrons have the lower neutron capture rate in hydrogen and it would result in reduction of a skin dose, and moderation of epithermal neutrons within the head would give rise to thermal neutron peak at the cancerous tumor site. The most suitable neutrons for BNCT are neutrons with energies from 1 eV to 10 keV, because their KERMA factor and hence, the direct tissue damage, is smaller than for thermal or fast neutrons.

Such neutron beams may be formed at nuclear research reactors. The concept of the source consists in transformation of the reactor radiation by means of neutron moderators and filters. For this purpose reconstruction of the reactor thermal column will be necessary to convert it into an epithermal neutron beam using specially selected moderators, filters, collimators and shielding. The spatial configuration of these source elements and material compositions will be selected to optimize the flux of epithermal neutrons with energies of 1eV - 10 keV, since such neutrons are the most suitable for treating tumors in inner organs, and to minimize the background of other energy neutrons and gamma rays. The Monte Carlo method neutron will determine the beam parameters and photon calculations taking into account both the peculiarities of the KRR and URR systems and nuclear properties of the source materials in the modified thermal column.

Several epithermal neutron beams for BNCT have been constructed in various countries, e.g., in the USA (Brookhaven National Laboratory, Massachusetts Institute of Technology); in Sweden (Studsvik); in the Netherlands (Petten); in Finland (Helsinki); in Japan (Tokaimura, Kumatori); in the Czech Republic (Rez); in Argentina (Bariloche). The neutron sources for all of these epithermal irradiation facilities are the reactor cores of the reactors. In order to obtain an epithermal neutron beam having parameters satisfactory for BNCT, the modification of these reactors have been carried out. Now most of these facilities have been or will soon be used for experimental BNCT treatments. Both in Ukraine and in Uzbekistan the epithermal irradiation facilities for BNCT are not yet created though demand for them is very big - concerning information from the medical cancer treatment institutions in Ukraine from the total number of all patients with first-identified cancer tissues about 5000 persons have the brain tissues, the most perspective method of their treatment is the BNCT. Both in Ukraine and in Uzbekistan this method can be advanced on existing research reactors.

Modifications of research reactors may be relatively straightforward and not prohibitive cost, especially in comparison with construction of new reactors specialized for BNCT. But any reactor modification should be forestalled the careful calculations taking into account of all

peculiarities of the specific reactor system. Using of the world experience in epithermal neutron beam development is very important to say, that the research reactor in Kiev and Tashkent may be reconstructed into epithermal irradiation facilities, to expedite selection of suitable materials for moderator, collimator, shielding, etc., but a KRR and URR modifications demand carrying out of calculations considering their peculiarities. Our preliminary MCNP calculations confirmed that the epithermal flux, required by BNCT, might be achieved at the KRR.

Now it is necessary to carry out the detailed calculations of all system (moderator, collimator, shielding, etc.) needed for transformation of existing thermal column into epithermal taking into account both the actual structural features of the KRR and URR, and all demands concerning parameters of epithermal beam, required by BNCT (intensity of epithermal neutron flux, specific fast neutron and photon doses, etc.). The main calculation results we plan to test by means of experimental measurements.

The results obtained for the development of epithermal neutron beams for BNCT at the KRR allow one to say that we can improve the beam parameters using some different from wide-used materials for collimators and filter (e.g. using of the nickel-60 filter) and our results may be used as in our future work on thermal column transformation at KRR and URR, as for beam improving at another reactor system.

The results of filter calculations and typical construction of thermal column is shown on Fig.1.

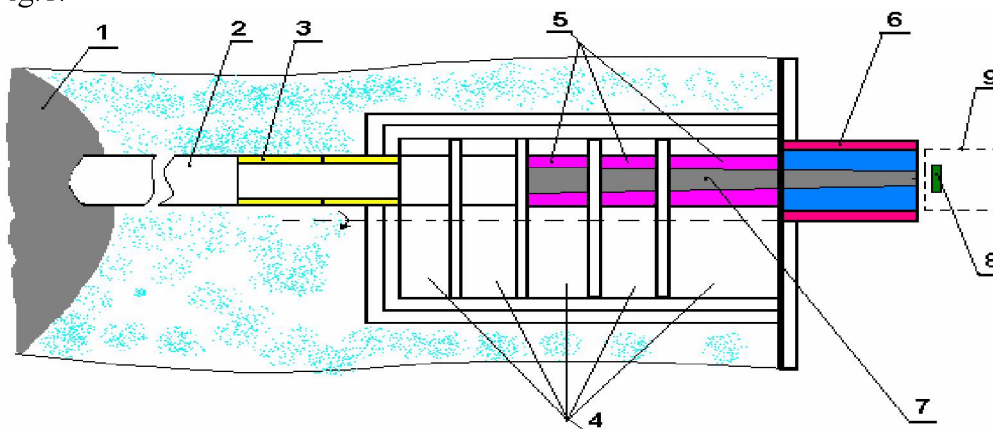


Fig.1. Construction of neutron filters of thermal column. 1- beryllium moderator; 2 - horizontal channel tube; 3 – preliminary collimator; 4 – beam shutter disk; 5 – filter-collimator assemblies; 6 – outside collimator; 7 – filter components; 8 – sample for activation; 9 – device for samples removing.

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