

Modernization of the VVR-TS reactor core for the increasing of the radionuclides production

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Abstract. We have studied the possibility of increasing the ⁹⁹Mo and ¹³¹I production through modernization of the VVR-TS reactor core. It has been found in particular that the introducing of beryllium reflector on the core periphery can significantly increase the starting reactivity margin. This, in turn, give us possibility to create an additional channel for increasing their production.

1. Introduction

The development of nuclear medicine, primarily associated with the diagnosis and treatment of cancer and are increasingly used in cardiac, neurological, endocrine and other diseases. In this regard, it is becoming increasingly important question of obtaining on nuclear power plant special isotopes. The need for such isotopes is increasing worldwide. The procedure for obtaining isotopes is very specific and time-consuming. It depends on many factors that require knowledge of the nuclear reactor features and neutron-physical processes occurring in the reactor core and target. In this case the main problem is to ensure the most efficient of use of reactor channels. From this depends directly on how the nomenclature of manufactured products, as well as production costs and, consequently, its availability to the end user.

The effectiveness of the production depends significantly on two main factors. Firstly is the operating conditions of a reactor. At any time the optimal conditions can be implemented in various experimental channels. Firstly the precise model of the reactor VVR-Ts was created to allow a high degree of accuracy to estimate the neutron-physical parameters of various channels, depending on the power and position of control rods and, thus, build the strategy to find the optimal location of the targets in the experimental channels of the reactor. Second, the effectiveness of production largely depend on the characteristics of the target and means of its placement in the experimental channels. Therefore, an important part of the research of the various special conditions that can be created for target, which may also allow to increase the yield of a particular nuclide.

The ¹³¹I and ⁹⁹Mo production when targets irradiated by neutrons in the reactor core essentially depends on the duration of exposure, and its location [8,9]. Therefore, for good prediction of its production in the reactor is necessary to create an adequate model for the reactor campaign calculation. However, up to now neutron calculations for VVR-Ts reactor were carried out using engineering codes (HEXA code for VVR-Ts). The main objective of these codes is to ensure the proper operating of the reactor facility, rather than radionuclides production estimation [1,2]. To



achieve this objective significantly more accurate calculation model was created, which allowed to solve this problem.

2. Modeling

The paper presents the results of calculations of neutron-physical characteristics of VVR-Ts reactor using the developed model of the reactor core and the results are compared with experimental data. As an example, Fig. 1 shows a comparison of the calculated reactivity margin during reactor campaign with real measurement.

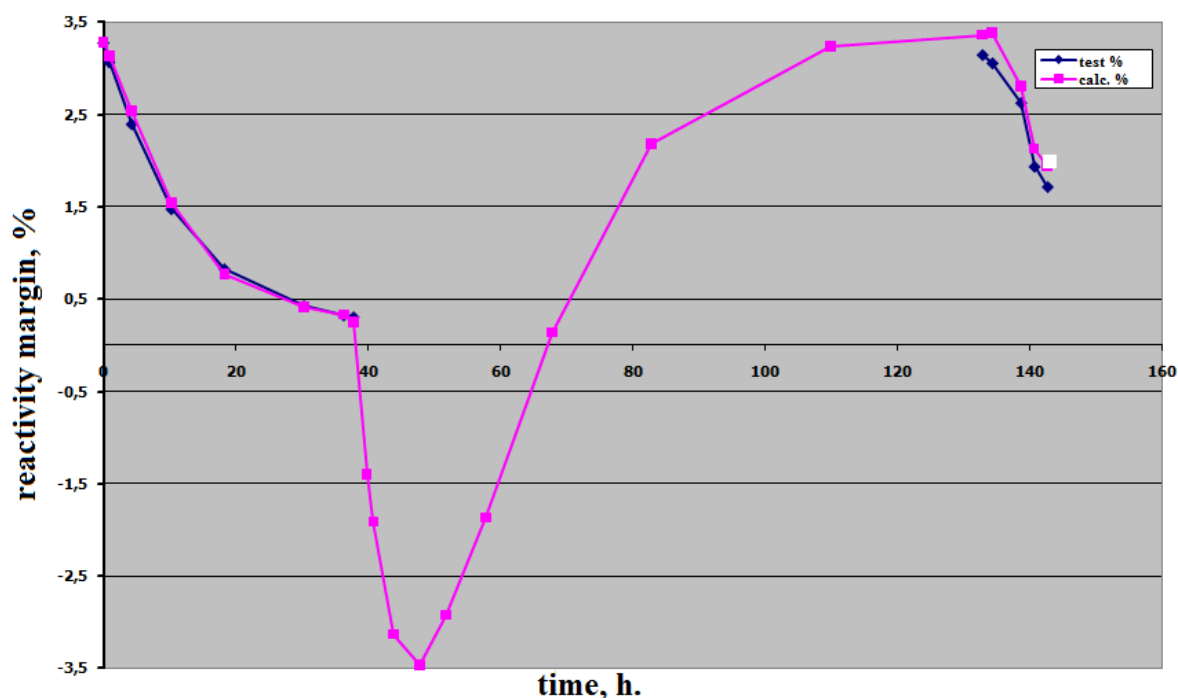


Figure 1. Comparison of the calculated reactivity margin with experiment.

The results of computational studies of the possibility of using beryllium reflectors to improve the neutron-physical characteristics of the VVR-Ts reactor, which is used at the Karpov Research Institute of Physical Chemistry to produce radionuclides, are presented. The calculations showed that in principle beryllium can be used by substituting it for some number of standard fuel assemblies. This made it possible to decrease the number of fuel assemblies from 70 in the standard core to 69 in a modified core and to increase the time between fuel overloads up to 14 days. The calculations also indicate that the neutron flux density in the experimental channels can be increased significantly, which is important for increasing the production of radionuclides [3].

The paper discusses also the possibility of increasing the ^{131}I and ^{99}Mo production for the uranium-containing and tellurium targets by placing beryllium blocks in the reactor core of the VVR-Ts reactor.[4,5] It was found that there was a reserve increase of these isotopes production. It can be obtained through increasing the neutron flux in the experimental channel and by mitigating the neutron spectrum.

The comparison of the ^{131}I and ^{99}Mo production for standard and modified targets was done for the standard core and for the core with a beryllium reflector. The calculations were performed for different variants of the beryllium reflector locations in the core. We considered four options:

- core without beryllium blocks (standard);
- two beryllium blocks are located on the perimeter of the core near the experimental channel;

- beryllium blocks are located around the perimeter of the core;
- beryllium blocks surround the experimental channel.

As an example, Fig. 2 shows all options mentioned above.

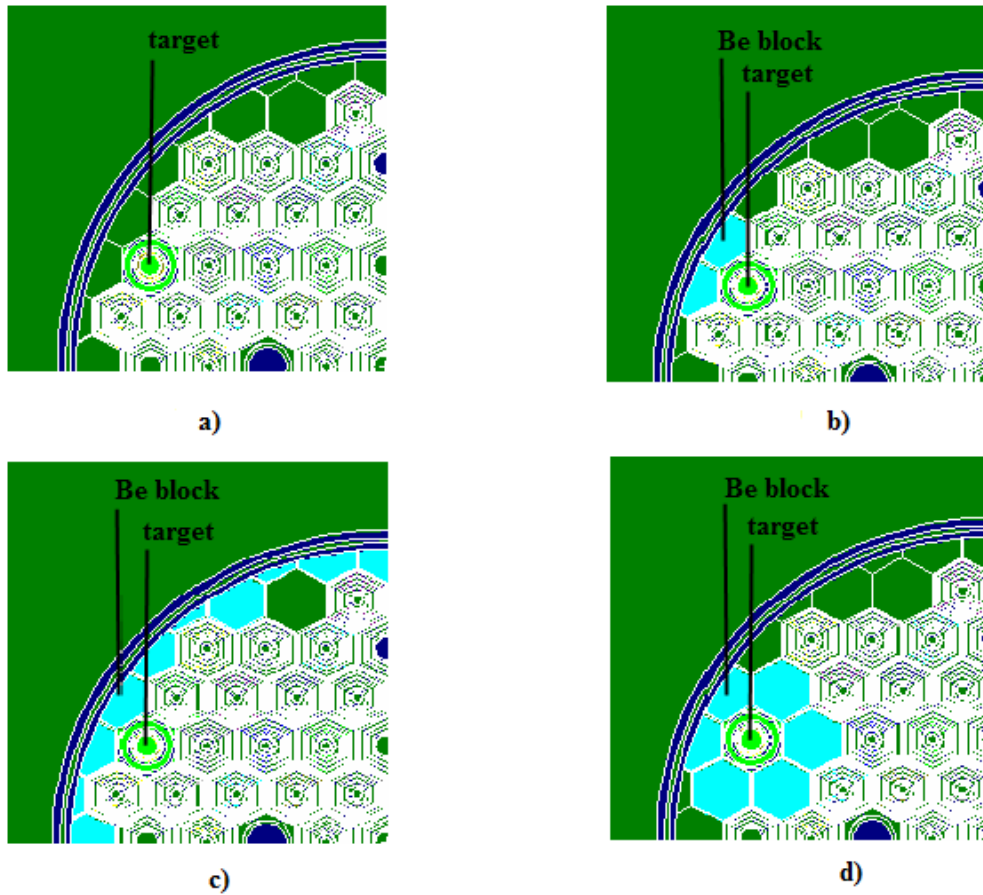


Figure 2. VVR-Ts core: a - core without beryllium blocks (standard); b - two beryllium blocks are located on the perimeter of the core near the experimental channel; c - beryllium blocks are located around the perimeter of the core; d - beryllium blocks surround the experimental channel.

The calculation results show that the use of beryllium inserts can significantly increase production ^{99}Mo . For example, option d, this increase was 7.5% for the initial target and more than 9% - for the modernized [7, 10]. Similar results were obtained for ^{131}I .

Changing the initial reactivity margin for the options discussed above is shown in Table 1.

Table 1. The change of the reactivity of the reactor core at the modernization of the VVR-Ts (variants a to d).

Option	a	b	c	d
Change of the reactivity, $\beta_{\phi\phi}$	0	-0.3	-1.2	3.2

Thus, the option with the core surrounded by the beryllium reflector allowing us significantly increase initial reactivity margin. This result was the basis of proposals for the modernization of the core, which is scheduled for 2017-2018 years [6].

Also we investigated the possibility of using low-enriched uranium fuel in the reactor VVR-Ts. It was found that for steady state overload, number of overloaded low-enriched fuel assemblies are equal to 2-3 instead of 1-2 for highly enriched fuel. In this case neutron flux density in both cases were very similar by increasing the fuel load using new fuel assemblies. The duration of each campaign increased on average by 50%.

3. Conclusions

As a result of our studies, it was found that:

- the use of beryllium as a reflector in the reactor core allows us significantly improve its neutron-physical characteristics;
- when the low-enriched fuel is using in the reactor core, number of overloaded fuel assemblies are equal to 2-3 instead of 1-2 for high-enriched fuel and not leads to a considerable reduction in neutron flux density.

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