Reduction of fuel enrichment of the WWR-K research reactor (Kazakhstan)

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Introduction

The WWR-K research reactor (rated power up to 10 MW) was put in operation at the Institute of Nuclear Physics of Kazakh Academy of Sciences in November, 1967. Great number of the vertical experimental channels for material irradiation and radioisotope production disposed both in the reactor core and in the reactor tank, as well as five horizontal radial channels and the single tangent one, allowed to solve a lot of scientific or industrial tasks.

The reactor operated till October 1988; when, by decision of the regulatory body of the former USSR, the reactor was shut down from the necessity of performing a number of improvements to its safety because of high seismicity of the reactor site (more than 9 on the MK scale).

Beginning with 1989, the stuff of the Kazakhstan National Nuclear Center fulfilled the works on enhancement of the reactor safety at the conditions of high seismicity. Essential assistance in these activities has been provided by IAEA and International Scientific Technical Center.

As the result of these efforts (after estimation of the efficiency of the seismic safety up-grading reactor systems fulfilled by experts from Kazakhstan, Russia and IAEA), the decision permitting re-start of the reactor operation was taken by the regulatory body of the Kazakhstan – the Kazakhstan Atomic Energy Agency. It was stipulated reduction of the reactor power to 6 MW and creation more compact core configuration. The reactor was put in operation again in March 1998, and now at the reactor some research and irradiation works are being fulfilled.

Core and fuel assembly descriptions

The reactor core is disposed at the lower part of aluminium tank (diameter 2.3 m, height 5.7 m) under water (3.5 m deep). The core vessel (diameter 0.74 m, height 0.91 m) has a supporting grid (thickness 50 mm) with 85 holes for locating of the Fuel Assemblies (FA), control rod channels and experimental channels.

In the core of the WWR-K reactor the FA with tubular type fuel element (FE) are used. There are two types of the FA: the five-tube ones and three-tube ones (the WWR-TS type FA). Five-tubes FA consists of four coaxial hexagonal tubes and one – of round shape (Fig.1, right). In the central part of three-tube FA the channels of control rods are placed.

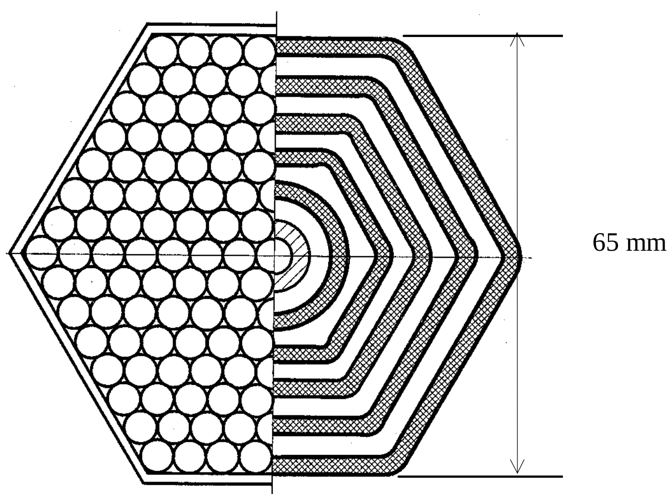

Fig.1.
Cross-section of the FA with pin-type FE (left) and tubular-type FE (right).

Each FE consists of three layers: the one (core) made of uranium-aluminium alloy (length – 600 mm, thickness 0.6 mm) and two covering layers (claddings) made of aluminium alloy (thickness – 0.65 mm). Total thickness of FE is 2.3 mm. The gap between the FE is 3 mm. The uranium enrichment in FE is 36%. Five-tube FA contains 109 grams of uranium-235.

Restarting the reactor was performed at core with 42 fresh FA: 36 five-tube type and 6 three-tube type. At present there are 44 FA in the core. With fuel burn-up, the number of the FA is to be increased. At the equilibrium core configuration the number of the FA is to be about 65 to70.

Investigations planned for choose of the WWR-K LEU conversion variant

The aim of the planned activities at the reactor is to reduce the risk of non-approved proliferation of high enriched uranium. This could be achieved by transition to application of fuel having enrichment less than 20%. The transition is to be fulfilled with keeping unchanged of the existing reactor core vessel. The task can be solved either via rising up the uranium concentration in the FE of the present tubular type or by creation of FE of a new type.

In the frame of the Russian program RERTR new kinds of uranium fuel are being developed. Surely, the results of these developments can allow to use the low enriched fuel for existing tubular FE. However, this way is restricted by complicated FE design compared to other types of FE (for example, of plate or pin type) and requires to change the technology of fabrication and reprocessing of the fuel. That is why, perhaps more achievable approach to transition to reactor operation with low enriched fuel is to develop a new, not so complicated FE design and, respectively, FA. This approach can allow to preserve the external dimensions and operational parameters of the existing FA. One of the possible FE design is the pin type (Fig.1, left). This design will allow to improve the technological and economical parameters of FE as well as FA manufacture and, finally, of the core in whole.

The cross-section of the FA with pin type and tubular type FE is shown on Fig.1.

To choose the most optimum way of reactor conversion to using the low enriched fuel, the implementation of following investigations are planned:

1. Calculations and assessment of possibility of the WWR-K reactor core conversion.

1.1. The standard equilibrium core configuration: 68 FA of the WWR-TS type, 36% enrichment (109 grams of uranium-235 in five-tube FA).

1.1.1. Development of the calculation model of the WWR-K reactor on a base of the Monte-Carlo and diffusion codes. Receipt of calculation results on the flux densities of the thermal ($E<0.625$ eV) and fast ($E>0.821$ MeV) neutrons in some of the experimental channels (measured in advance) in order to compare the fluxes during the transition to low enriched fuel.

1.1.2. Calculations by means of the Monte-Carlo and diffusion codes of the excess reactivity, the flux density of the thermal and fast neutrons of the specified places of the core, and the efficiency of the control rods.

1.1.3. Calculations by means of the diffusion codes of burn-up in the core with fuel of 36% enrichment in order to obtain the duration of the operational reactor cycle; the excess reactivity to the end of cycle; the average burn-up in unloaded FA; and the flux densities of the thermal/fast neutrons at specified points. The data are to serve as the standard ones for comparing with versions corresponding to the fuel of 19.75% enrichment.

1.2. The core configuration consisting of 68 FA of the WWR-TS type with fuel of 19.75% enrichment (108 grams in five-tube FA). Calculation of the reactor parameters by means of the diffusion codes.

1.3. The core configuration consisting of 68 FA of the WWR-TS type with fuel of 19.75% enrichment (119 grams in five-tube FA). Calculation of the reactor parameters by means of the diffusion codes.

1.4. The core configuration consisting of 68 FA of the WWR-TS type with fuel of 19.75% enrichment (130 grams in five-tube FA). Calculation of the reactor parameters by means of the diffusion codes.

1.5. The core configuration consisting of 68 FA with pin type FE with fuel of 19.75% enrichment (130 grams in FA). Calculation of the reactor parameters by means of the diffusion codes.

1.6. The core configuration consisting of 68 FA with pin type FE with fuel of 19.75% enrichment (140 grams in FA). Increase of uranium-235 content in a FA caused at the expense of using control rods of only one type. Calculation of the reactor parameters by means of the diffusion codes.

1.7. Safety analysis of the reactor with low enriched fuel.

2. Experiments.

2.1. Determination at the critical assembly of the critical load parameters with WWR-TS type FA in order to correct the calculation model.

2.2. Determination at the reactor of the critical load parameters with spent fuel WWR-TS type FA in order to correct the calculation model.

3. Development of the design and technology of fabrication of the pin type FE on a base of low enriched fuel in accordance with the WWR-K reactor requirements. Calculation validation of operational reliability of the pin type FE in WWR-K reactor core.