SECTION 2

THERMAL REACTOR MATERIALS

UDC 621.039.4

CONVERSION OF HIGHLY ENRICHED FUEL OF RESEARCH REACTOR IN THE FRAMES OF INTERNATIONAL INITIATIVE

I. Vyshnevskiy[1], V. Slysenko[1], V. Bodnar[1], I. Bolshynskyi[2], J. Dewes[2], N. Mazina[1], V. Makarovskiy[1]
[1]Nuclear Research Institute of the National Academy of Sciences of Ukraine;
[2]National Nuclear Security Administration of the Department of Energy USA
E-mail: slisenko@kinr.kiev.ua

U.S. Department of Energyand the NationalNuclear Security Administrationlaunched an initiativeto reducethe risk of theftand illegal use ofnuclear and radioactive materials. In the framework of this initiativein the performanceof the Russian fuelreturn programfrom the research reactors(RRRFR) the staffand expertsmade the restitutionof highly enriched fuelto Russiaand performedthe conversionof the INRNAS of Ukraineresearch reactor to the fuel withlow-enriched uranium(LEU<20% U-235). The works were alsocarried out onthe systems modernization which are importantto the safe operationof the reactor.Ukraine has fulfilledits international obligationsand released the territoryfrom the highly enriched uranium in time.

In the international practice, there are three variants of handling spent nuclear fuel, such as the variant with *deferred decision* (that is, the variant with temporary storage of spent fuel until the decision on the further utilization of the spent fuel is taken), the variant with spent fuel *reprocessing*, and the variant with spent fuel *disposal*. The results of analysis of costs associated with the second and third variants demonstrate that the difference in expenses for handling spent fuel according to these variants relative to the total expenses for a nuclear fuel cycle is insignificant, and that in determining procedures required for implementing the nuclear fuel cycle, it is important to consider such factors as the national policy in the area of nuclear-power engineering, impact of the nuclear fuel cycle on the environment, and public acceptance. In Ukraine, as in many other countries, the first variant of handling spent fuel, that is, the variant with *deferred decision* is accepted. According to this variant, there is a need to have depositories for the long-term storage of spent fuel in Ukraine. While such depositories are designed, constructed, and operated for nuclear power plants, spent fuel of research reactors is stored in cooling ponds, which are not designed for long-term storage of spent fuel. Additionally, in research reactors, highly-enriched fuel is used (with the content of uranium U-235 more than 20 %), so there is a potential threat to the world community.

In 2004, the Department of Energy and the National Nuclear Security Administration put forward an initiative to reduce risks of theft and illegal use of nuclear and radioactive materials, and to ensure reliable storage of such materials. This initiative is known as the Global Treat Reduction Initiative (GTRI). One of the elements of the GTRI is the program for return of highly-enriched nuclear fuel of research reactors and highly-enriched nuclear materials to the country in which such nuclear fuel and materials were produced. The Russian Federation supported this initiative and on May 27, 2004, in Moscow, the agreement between the managements of the Russian Federation and the United Sates of America was concluded for the return of highly-enriched nuclear fuel, which was produced in the Russian Federation, from research reactors to the Russian Federation. This program is known as the Program for Return of Russian Fuel from Research Reactors (RRRFR). After a year, Presidents of Russian Federation and the United Sates of America confirmed the relevance and need of performing activities according to the GTRI.

In Ukraine, the work under the program for return of highly-enriched nuclear fuel to the Russian Federation has been commenced in May 2006. According to this program, it was planned to modify the Research Reactor of the Nuclear Research Institute of the National Academy of Sciences of Ukraine for the possibility to operate with low-enriched uranium (LEU) with the content of U-235 less than 20 %, obtain an experimental batch of LEU fuel, and, if the LEU fuel from the experimental batch can be used, to obtain such nuclear fuel in the amount that is equivalent to the highly-enriched uranium (HEU) to be returned, prepare and approve the required documents, perform preparatory engineering work for exporting the HEU, and export it.

The last export of spent fuel from the Nuclear Research Institute to the production association "Maiak" in the Russian Federation was in 1988. For this reason, at the start of the RRRFR program, there were more than 700 spent fuel assemblies, in terms of unitary spent fuel assemblies, that had been accumulated at the Research Reactor. These spent fuel assemblies were represented by WWR-M2 fuel assemblies, with 36-percent enrichment relative to uranium 235, and WWR-M5 (M7) fuel assemblies with 90-percent enrichment relative to uranium 235.

The spent fuel assemblies were stored in the storage facility which was put into service in 1960, simultaneously with the start of operation of the Research Reactor. Considering the high rate of filling the storage facility and its limited capacity, the decision was taken on the construction of a new storage facility for the spent fuel. At first, it was planned to construct an additional cooling pond (BV-2), which was intended for the temporary storage of all spent fuel available at the Research Reactor, and which could be adapted for use of TUK-19 containers of Russian origin, which were designed for disposal of spent fuel outside of the Research Reactor. The capacity of a TUK-19 container is 4 triple or 16 unitary WWR-M2 spent fuel assemblies. When VPVR/M casks (manufactured by "Shkoda", Czechia) were implemented, the decision was taken to use such casks for shipment of spent fuel assemblies. The capacity of a VPVR cask is 36 triple or 108 unitary spent fuel assemblies of the same type.

Considering the differences in the overall dimensions and weight of the containers, as well as the different in technology of loading of spent fuel assemblies into the casks, it was required to revise the design documentation for the spent fuel storage tank, the cover providing upper biological protection of the storage tank (see Photo Illustration 1), the hoisting mechanism (see Photo Illustration 2), the premises for the BV-2 cooling pond (see Photo Illustration 3), and the line for transporting spent fuel assemblies from the BV-1 cooling pond, as the preceding depository of spent fuel, to the BV-2 cooling pond (see Photo Illustration 4).

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

The changes were completed and coordinated with regulatory authorities. The premise for the BV-2 cooling pond was built and put into service. The financial support for this work was given by the US Department of Energy,

In order to ensure safety and create normal conditions for spent fuel assemblies handling the following work was performed:

1. A railtrack was constructed, and an electrically-driven carriage was manufactured for the transportation of the internal transport container (see Photo Illustration 5) from the reactor hall to the premise of BV-2, and for the transportation of VPVR/M casks to the special site.

2. The floor in the area of transloading operations and in the railtrack area was covered with special material for the possibility to provide effective and qualitative deactivation of the floor in emergency situations.

3. An additional system for video monitoring, digital data recording, and information storage, as well as a system for controlling TV cameras were installed.

4. An additional radiation control system was installed (for performing monitoring and warning functions in connection with a self-sustaining chain reaction, intensity of equivalent gamma-radiation dose, volumetric activity of beta-aerosols, contamination of

tools, work clothes, and bodies of employees, and individual radiation doses of employees).

5. The physical protection system and the fire-alarm system of the Research Reactor were modified as required.

6. The access roads to the premise of the BV-2 were partially reconstructed.

Thus, in December 2009, in a technical sense, the Nuclear Research Institute of the National Academy of Sciences of Ukraine was ready to carry out shipment of spent fuel assemblies.

In April 2010, at the Washington Summit for Nuclear Security, President of Ukraine declared the intention of Ukraine to completely dispense with highly-enriched uranium before the next Summit, which was planned to be in Seoul on March 26, 2012. This decision allowed the next stage of the RRRFR program to be performed, that is, to obtain all required permits and to effect shipment of spent fuel assemblies.

For the possibility to ship spent fuel assemblies with highly-enriched uranium of Russian origin, the following licenses and permits of regulatory authorities in Ukraine were obtained: the Permit of the Cabinet of Ministers of Ukraine for export of spent fuel assemblies; the Permit of the State Sanitation-and-Epidemiological Service of the Ministry of Public Health of Ukraine for performing work with ionizing radiation sources; the License of the State Nuclear Regulatory Committee of Ukraine for transportation of nuclear materials and performing activities in connection with preparation, loading, and shipment of cargoes and packages with spent nuclear fuel.

In order to obtain the license, the procedures for assuring quality in performing all the basic transportation works, the quality assurance program, the radiation control program, and the plan of emergency measures were developed, and the report on the results of safety analysis in activities associated with the transportation of radioactive materials was drawn up.

Additionally, the route for the transportation of the dangerous cargo with spent fuel assemblies was developed and agreed with regulating authorities, the quality certificate for the design of the package was approved by the regulatory authorities, the statement of compliance with the nuclear and radiation safety regulations when exporting radioactive materials, as well as the permit for performing international transportation of radioactive materials were issued by the State Nuclear Regulatory Committee of Ukraine, the permit of the State Export Control Service of Ukraine for the transfer of spent fuel assemblies to the Russian Federation was obtained, conclusions of the Ecological Expertise of the Environmental Administration of Ukraine were obtained; and documents were prepared and custom procedures were performed for the importation of transport containers to Ukraine and the shipment of the cargo with spent fuel assemblies to the Russian Federation.

Fig. 6

Fig. 7

Fig. 8

Fig. 9

Fig. 10

The spent fuel assemblies were loaded into transport containers by the personnel of the WWR-M Research Reactor, with the participation of representatives of Czech Nuclear Research Institute. The spent fuel assemblies from the BV-1 cooling pond were loaded into the internal transport container. The internal transport container was installed onto the electrically-driven carriage and transported from the reactor hall to the premise for the BV-2. By a bridge crane, the container was installed in a special area of the BV-2 for the following unloading of the spent fuel assemblies (see Photo Illustration 6). Then, the spent fuel

assemblies were loaded into transport VPVR/M casks in the presence of representatives of the IAEA, the National Nuclear Security Administration of the US Department of Energy, and the production association "Mayak". The spent fuel assemblies in the VPVR/M casks were dried, vacuum-processed, and filled with helium (see Photo Illustration 7). Then, the transport casks were tested for tightness, radiation control was performed, and, if required, the containers were deactivated. After the protocol of radiometric measurements was signed and the transport casks were sealed by the representative of the IAEA in the presence of the Russian representatives, the casks were loaded onto an electrically-driven carriage and were transported to the special area, where the casks were loaded into ISO containers (see Photo Illustration 8).

The ISO containers with the charged VPVR/M casks were closed in the presence of the representatives of all the involved parties and were sealed by the representatives of the Production Association "Maiak", which should accompany the cargo with the spent fuel assemblies during the rail shipment within the territories of Ukraine and Russian Federation. After all the ISO containers had been loaded, they were loaded onto truck trailers and transported by special trucks (see Photo Illustration 9) to the railroad station for forming a special train (see Photo Illustration 10) for the transportation of the containers to Russian Federation. At the boundary of Ukraine with Russian Federation the cargo was delivered to representatives of the production association "Mayak". At all the stages of shipment of the spent fuel assemblies, from loading at the site of the Research Reactor to the unloading at the site of the production association "Mayak", physical protection of the containers was ensured.

The first batch of 748 spent fuel assemblies was shipped to the Production Association “Mayak” in May 2010. The second batch of 218 spent fuel assemblies was shipped in March 2012 (see Table. 1). When shipping the first batch, all the cells of the VPVR/M transport casks were loaded, as the spent fuel assemblies before the loading into the casks have been stored in the cooling pond for a long time, so the total activity of the spent fuel assemblies in the container did not exceed 3930TBq, and the total residual heat power did not exceed 450 W. When shipping the second batch, it was necessary to determine which spent fuel assemblies and in which number should be loaded into transport containers in order not to exceed the specified values of the aforesaid parameters, as these spent fuel assemblies were removed from the reactor core in December 2010 in connection with the complete modification of the Research Reactor for the operation with low-enriched nuclear fuel. As is shown in the Table 1, in the first case, 7 completely loaded transport containers were used. In the second case, only 4 partially loaded containers were used. Due to these measures, the requirements for the safe transportation of the spent fuel assemblies were fulfilled.

Table 1

Types of fuel assembly	BBR-M2	VVR-M5(M7)	VVR-M2
	May 2010		March 2012
Initial enrichment (%)	36 (20)	90	36
Number of unitary fuel assemblies	101	15(5)	38
Number of triple fuel assemblies	193(6)	(5)	60
Number of transport containers	7		4
Total activity of fuel assemblies in a container (TBq)	2,053		2,790
Total residual heat power (W)	209.8		217.1
Number of fuel assemblies in terms of unitary assemblies	748		218
Total weight of U-235 (kg)	11.864		5.146
Total weight of uranium (kg)	55.780		19.354

It was already stated that the purpose of performing the program was the conversion of the Research Reactor for operation with LEU fuel. In Ukraine, these works were commenced in 2005. Together with the specialists of the Argonne National Laboratory of the US Department of Energy, the specialists of the Nuclear Research Institute had demonstrated the possibility to modify the Research Reactor for operation with LEU fuel without structural changes in the reactor core. The reduction of power flux density was insignificant, so the Research Reactor allowed the specified research works to be continued. The developed technical-and-economic justification and the concept design about the use of LEU fuel (either together with HEU fuel and as exclusive fuel) were agreed with the regulatory authorities in 2006.

In October 2008, the TVEL Company (Russian Federation) supplied 33 fuel assemblies with low-enriched uranium (see Fig. 11), which were produced by the Novosibirsk Plant of Chemical Concentrates. The comparative characteristics of these fuel assemblies are specified in Table 2. In December 2009 these fuel assemblies were loaded into the reactor core of the Research Reactor and were in service instead of fuel assemblies with highly-enriched uranium. 184 fuel assemblies with low-enriched uranium were supplied in December 2010, and 200 fuel assemblies with low-enriched uranium were supplied in February 2012.

Fig. 11

Table 2

Parameter	Number of units in a fuel assembly			
	1	2	3	4
Enrichment, %	19.7		36	
Number of fuel elements in a fuel assembly	3	9	3	9
Mass of uranium U-235 in a fuel assembly, g	41.7	125.1	37.5	112.5
Height of the core of a fuel assembly, mm	500			
Thickness of coating, mm	< 0.5min			
Thickness of the tubes of a fuel element, mm	2.5			

In connection with the international obligations of Ukraine to remove all highly-enriched uranium from the territory of Ukraine to December 2010, all the fuel assemblies with highly-enriched uranium were removed from the core of Research Reactor. The cartogram of the reactor core loaded with 205 fuel assemblies with highly-enriched uranium is shown in Fig. 12. The reactor core was loaded with fuel assemblies with low-enriched uranium. The total number of the fuel assemblies with low-enriched uranium was 88. The cartogram of the reactor core loaded with fuel assemblies with law-enriched uranium is shown in Figure 2.

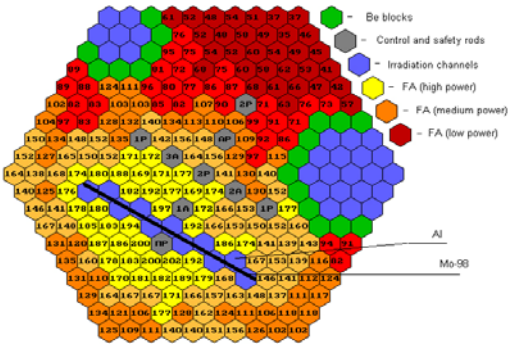

Fig. 12

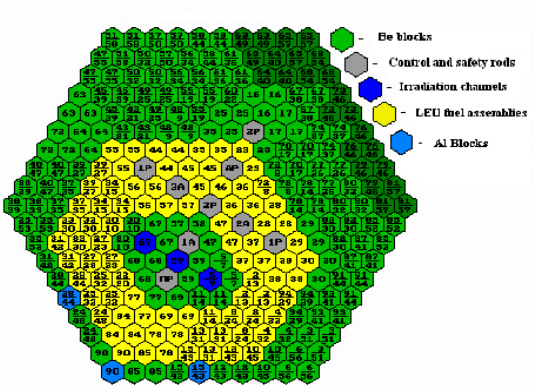

Fig. 13

Fig. 14

Fig. 15

This number of fuel assemblies with low-enriched uranium did not allow the nominal reactor power of 10MW to be achieved. It is supposed that the nominal reactor power will be ensured by removing the beryllium reflectors from core (indicated with green color in Fig. 13) and filling the free space with fuel assemblies with low-enriched uranium.

In December 2010, about 10kg of non-irradiated HEU fuel and special fissile materials of Russia origin were shipped from the Nuclear Research Institute to the Russian Federation. These materials included plutonium

disks, HEU pellets and rods with 90 percent of U-235 (see Fig. 12), and fuel assemblies with HEU.

The HEU fuel and special fissile materials were packed in special casks (see Fig,15) and loaded into transport containers under the supervision of IAEA representatives, transported by special trucks to airport, and exported by air to Russian Federation. So, the result of the six-year activity of the Institute for Nuclear Research under the RRRFR program, as a part of the GTRI, is that some systems, which are important for ensuring the safe operation of the Research Reactor, have been updated, the Reactor has been modified for operation with LEU fuel, and 17kg of uranium U-235 in highly-enriched spent fuel and 10kg of HEU fuel and fissile materials have been exported from Ukraine. Taking into account the fact that simultaneously with the export of HEU fuel and fissile materials from the Institute for Nuclear Research, highly-enriched uranium has also been transported from other institutions of Ukraine; it is evident that Ukraine has fulfilled its international obligations before the Seoul Summit and completely removed highly-enriched uranium from its territory.

Main materials of this work were presented at Scientific and Technical Seminar – Meeting "Development of Atomic Energy Industry in Russia and Ukraine – is a factor of sustainable interstate cooperation" that was held in Sochi, September 10 -12 2012.

Article received 18.06.2013

КОНВЕРСИЯ ВЫСОКООБОГАЩЕННОГО ТОПЛИВА ИССЛЕДОВАТЕЛЬСКОГО РЕАКТОРА В РАМКАХ МЕЖДУНАРОДНОЙ ИНИЦИАТИВЫ

И. Вишневский, В. Слисенко, В. Боднар, И. Большинский, Дж. Дьюес, Н. Мазина, В. Макаровский

Министерство энергетики США и Национальная администрация по ядерной безопасности выступили с инициативой по снижению риска хищения и незаконного использования ядерных и радиоактивных материалов. В рамках этой инициативы при выполнении программы возврата российского топлива с исследовательских реакторов (RRRFR) обслуживающий персонал и специалисты осуществили возврат высокообогащенного топлива в РФ и выполнили конверсию исследовательского реактора ИЯИ НАН Украины на топливо с низкообогащенным ураном (НОУ< 20% U-235). Были также выполнены работы по модернизации систем, важных для безопасной эксплуатации реактора. Украина выполнила свои международные обязательства и в срок освободила свою территорию от высокообогащенного урана.

КОНВЕРСІЯ ВИСОКОЗБАГАЧЕНОГО ПАЛИВА ДОСЛІДНИЦЬКОГО РЕАКТОРА В РАМКАХ МІЖНАРОДНОЇ ІНІЦІАТИВИ

І. Вишневський, В. Слісенко, В. Боднар, І. Большинський, Дж. Дьюес, Н. Мазіна, В. Макаровський

Міністерство енергетики США та Національна адміністрація з ядерної безпеки виступили з ініціативою щодо зниження ризику викрадення та незаконного використання ядерних та радіоактивних матеріалів. У рамках цієї ініціативи при виконанні програми повернення російського палива з дослідницьких реакторів (RRRFR) обслуговуючий персонал та спеціалісти здійснили повернення високозбагаченого палива до РФ і виконали конверсію дослідницького реактора ІЯД НАН України на паливо з низькозбагаченим ураном (НЗУ< 20% U-235). Було також виконано роботи з модернізації систем, важливих для безпечної експлуатації реактора. Україна виконала свої міжнародні зобов'язання і в термін звільниласвою територію від високозбагаченого урану.