THE SHIPMENT OF RUSSIAN-ORIGIN HIGHLY ENRICHED URANIUM SPENT AND FRESH NUCLEAR FUEL FROM BELARUS AND DELIVERY OF FRESH LOW ENRICHED URANIUM NUCLEAR FUEL TO BELARUS

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Abstract
In October-November 2010, under the Global Threat Reduction Initiative, the Joint Institute for Power and Nuclear Research – “Sosny” of the National Academy of Sciences of Belarus completed a shipment that returned of Russian-origin highly enriched uranium (HEU) spent and fresh nuclear fuel to the Russian Federation. The spent and fresh fuel was legacy material, discharged from the two decommissioned mobile Pamir-630D reactors and the IRT-M research reactor. This shipment marked the complete removal of all HEU spent nuclear fuel from Belarus. The HEU fresh fuel of Pamir-630D mobile reactor has been fulfilled simultaneously with delivery of new low enriched uranium (LEU) fresh fuel for “Giacint” critical facility in uranium-235 equivalent amount.

1. INTRODUCTION
In the 2010 under the Global Threat Reduction Initiative, the Joint Institute for Power and Nuclear Research – “Sosny” (JIPNR-Sosny) of the National Academy of Sciences of Belarus repatriated highly enriched uranium (HEU) fresh and spent nuclear fuel to the Russian Federation. The fresh and the spent nuclear fuel were from the decommissioned Pamir-630D mobile reactor and IRT-M research reactor. These fuel shipments marked the complete removal of all HEU spent nuclear fuel (SNF) from Belarus. The HEU fresh fuel of Pamir-630D mobile reactor has been replaced with new low enriched uranium (LEU) fresh fuel. LEU fresh fuel was design and produced for “Giacint” critical facility under Belarus-Russian—American cooperation on conversion nuclear fuel of research reactors.
This paper discusses the Pamir-630D mobile reactor, the Pamir-630D HEU fuel, the fresh LEU fuel for “Giacint” critical facility and the various aspects of the shipment including: the planning, preparations, and coordination required for completing this international shipment successfully.

2. HEU SPENT AND FRESH NUCLEAR FUEL OF PAMIR-630D REACTOR

In 70-80 years of last century JIPNR-Sosny (early - Institute of Nuclear Power of the National Academy of Sciences of Belarus) developed the mobile nuclear power plant "Pamir-630D" [1-3]. Appointment of NPP Pamir was maintenance with the electric power of the mobile and stationary objects located in remote and hard-to-reach regions.

The mobile NPP had an electrical power output of 630 kW (thermal power of the reactor is 5000 kW; reactor campaign is 10000 hours) and included five basic modules: a reactor; a turbine generator set; two modules of system for control and protection; and an auxiliary module. The modules were installed on semi-trailers that could be transported by trucks. A picture (see Figure 1) of the reactor module on its semi-trailer is provided below.

![Fig. 1. Reactor module of NPP “Pamir-630D.”](image)

The coolant of reactor was nitrogen dioxides with nitric oxide additives ($N_2O_4 \leftrightarrow 2NO_2 \leftrightarrow 2NO + O_2$). The moderator and reflector neutrons of core was the zirconium hydride $ZrH_{1.9}$. The reactor core consisted of 106 fuel assemblies, surrounded with 45 reflector assemblies (see Figure 2).

Flattering of power distribution as to the radius and the height of the core was reached with decreasing of moderator's content in a central region of the core as well as by placing of burning out absorber (boron enriched to 85% boron-10) into a part of FA which simultaneously served for compensation of excess reactivity of the reactor for a campaign. Three types of fuel assemblies were used in the active core placed with the pinch of 45 mm. 12 sealed ampoules of rod’s drive of the control system are founded into the bottom of the reactor. The material of neutron absorber was europium dioxide $Eu_2O_3$.

Each fuel assembly (see Figure 3.) included seven fuel rods. The fuel elements (see Figure 4) were made from $UO_2$ particles enriched to 45% $^{235}U$ in a nickel / chromium matrix ($UO_2$-Ni-Cr) and clad in stainless steel. Diameter of fuel rod - 6, 2 mm, length - 650 mm. Thickness of clad - 0, 4 mm. Volume content of $UO_2$ in the fuel composition was near 60%. Fuel rod was composed from 5.2 mm diameter pellets. The pellets consist of specified spherical particles with build-up cover from stainless steel. The height of fuel core was 500mm.
Fig. 2. Cartogram of the “Pamir-630D” reactor loading.

Fig. 3. Fuel assembly of NPP “Pamir-630D.”
1 – bottom nozzle; 2 – bottom tube plate; 3 – clad; 4 – casing tube; 5 – fuel rod; 6 – zirconium hydride block; 7 – top tube plate; 8 – top nozzle
The first one reactor of NPP Pamir-630D was put into operation in 1985 and testing was halted in 1986. During tests the reactor was deduced on various levels of power. Average energy-producing for the period of tests is estimated by $6.9 \times 10^6$ kW-hour. The fuel was discharged in 1991 with an average burn up of 0.78% uranium atoms. All 106 spent fuel assemblies were stored in the spent fuel pool (one no hermetic Pamir assembly was failed and was placed in a sealed canister). Except for Pamir fuel the spent nuclear fuel which was tested in IRT-M reactor were stored in pool. It was five sealed canister with experimental ball fuel rods and fuel rods type EK-10. The burn up of this fuel is estimated from 7 to 20%.

The spent fuel pools of the Spent Fuel Storage Facility are located in the same building where the pilot reactor was tested. The critical parameters of the water in the pool are checked out once a week. The water in the pool is checked for specific activity of fission-produced isotopes of Cs-134 and Cs-137 and corrosion-produced Co-60 isotopes.

The second reactor of Pamir-630D NPP was not tested. The 114 fresh fuel assemblies and 53 specimen fuel Pamir rods were stored in the Fresh Fuel Storage Facility. Before the beginning of shipment the fuel assemblies have been disassembled and from them fuel rods are taken. Summary there was prepared 851 fresh fuel Pamir rods for shipment on exchange program of HEU/LEU uranium fuel.

3. SHIPMENT OF SPENT AND FRESH NUCLEAR FUEL

Planning, preparations, coordination of the HEU repatriation and of the LEU delivery include facility preparations, safety arrangements, casks management and train/plane shipping/delivery logistics. Safety arrangements considered the radiation exposure and the steps for unloading and loading the fuels. Calculations and analyses have been performed to validate the developed procedure for transporting the fuels and the amount loaded per cask/train and plane.

SCODA VPVR/M casks (see Figure 5) for transportation of HEU spent nuclear fuel have been selected. This casks with spent fuel in ISO-containers was been transported from the JIPNR - Sosny to the railway station by trucks and further to Russian Federation by railway.
In Russia, the SKODA VPVR/M cask certificate for design and transportation was issued by the Rosatom State Nuclear Energy Corporation on June 11, 2010. In Belarus, the certificate validation was issued by Gosatomnadzor on September 3, 2010.

For the fresh nuclear shipment TK-S16 casks (see Figure 5) was selected. This cask has the certificate for design and air transportation the fresh nuclear fuel both Russia and Belarus.

Both for shipment of spent nuclear fuel in SKODA VPVR/M cask and for shipment of fresh nuclear fuel in TK-S16 cask calculations on nuclear and radiating safety have been lead in Russia (VNIEF, Russia) and Belarus (JIPNR-Sosny, NAS Belarus). Loading of casks by nuclear fuel completely corresponded to national requirements on nuclear and radiating safety.

Authorization to import the spent nuclear fuel into Russia was received using the procedure mandated by Russian decree. A Unified Project (UP) was developed and approved after a positive conclusion by the State Ecological Expertise Review Board. The UP is a collection of analyses and documents that look at: Justifying the safety and assessing the environmental impact of import; implementation of special ecological programs; anti-terrorist measures; cask licenses; emergency response; and the Foreign Trade Contract (FTC). The FTC was the main contract between FCNRS and JIPNR-Sosny to import the spent nuclear fuel. The FTC includes transportation, reprocessing, storage and disposal. Once the UP was approved, a governmental decree was issued along with the import license.

In Belarus, transportation permission of SNF was supported by documents looking at: physical protection; emergency response; cask licensing; facility license; and environmental and health concerns. The transportation permission of SNF was issued by the State Industrial Supervisory Authority, Gospromnadzor. The export license was issued by State Military-industrial Committee of Belarus.

In accordance with GTGA between Republic of Belarus and the Russian Federation from October 8, 2010 the shipment of HEU fresh nuclear fuel to Russian Federation realize under the condition of the delivery of LEU fresh nuclear fuel to Belarus with uranium-235 equivalent amount. For performance of this condition FSUE “SRI SIA “LUCH” produced LEU nuclear fuel in advance according to the order of ROSATOM Corporation. Uranium fuel has been taken for this purpose from the State reserve of the Russian Federation. IAEA and DOE of USA through their subcontractors provided financing producing of LEU fuel and an HEU/LEU fuel exchange.
Uniqueness of operation on exchange of fuel consist that on the airport in period of several hours simultaneously there was unloading LEU nuclear fuel and loading HEU nuclear fuel aboard the plane. At first of all TK-S16 containers with fresh HEU nuclear fuel have been transported from the JIPNR - Sosny to the airport by truck. Simultaneously TK-S16 containers with LEU fresh nuclear fuel have arrived from Russian Federation to the airport Minsk(Belarus). At the airport TK-S16 containers with LEU fresh fuel have exchanged TK-S16 containers with fresh HEU fuel. Then TK-S16 containers with fresh LEU nuclear fuel have been transported by truck from the airport to the JIPNR – Sosny. TK-S16 containers with fresh HEU nuclear fuel have been transported by plane to the Russian Federation.

Inspectors of IAEA provided the full control of loading HEU nuclear fuel in JIPNR-Sosny of the National Academy of Sciences of Belarus.

4. LEU FRESH NUCLEAR FUEL FOR “GIACINT” CRITICAL FACILITY

Critical facility “Giacint” of the JIPNR-Sosny of NAS Belarus (see Figure 7) is destined for basic research on the physics and safety of neutron-multiplying systems and applied research in a substantiation of development of new generation of different nuclear energy sources. It provides the experimental base for the development of fundamental and applied nuclear power engineering, including research in a substantiation of development of new generation of reactor facilities of different destination.

![Fig. 7. The critical facility “Giacint”: control board, critical assemblies with liquid and solid hydrogenous moderator.](Image)

The LEU fuel replacement will be created for research purposes at the critical facility “Giacint” on development of perspective cores for research and power nuclear reactors [3]. This fuel has been developed by FSUE “SRI SIA “LUCH” and JIPNR-Sosny. The fuel assembly for “Giacint” critical facility consists from seven LEU fuel rods (see Figure 8). The fuel assembly does not have the clad.

The LEU fuel consists of uranium-zirconium carbon nitride $U_{0.9}Zr_{0.1}C_xN_{1-x}$ with 19.75% enrichment by U-235. Density of a fuel composition is not less than 12 g/sm$^3$, porosity - less than 12%, density of uranium - more than 10.5 g/sm$^3$, diameter of a pellet – 10.7 mm. Length of the fuel core - 500 mm, diameter of the fuel rod (see Figure 9) -12 mm, length of the fuel rod - 620 mm. Thickness of clad is 0.6 mm. The clad material is stainless steel or niobium. This fuel will be used for developing new reactor configurations at low power cooled by gas or water. In particular, this nuclear fuel can be used at conversion HEU on LEU nuclear fuel in research reactors. Critical assemblies have been developed for performance of this purpose with/ without water moderator.
At the critical facility “Giacint” benchmark experiments on following critical assemblies with use new LEU fuel are planed:

— With water moderator and reflector;
— Without moderator and with beryllium-steel reflector
— Following parameters of this critical assemblies will be measured:
— Critical loading;
— Efficiency of control and safety rod;
— Reactivity margin;
— Distribution of neutron flux density on radius and height of a core.

5. CONCLUSION

The shipment of highly enriched uranium nuclear fuel from the Joint Institute for Power and Nuclear Research – “Sosny” marked the end of a successful project that removed all of the spent HEU from Belarus. LEU fresh fuel was design and produced for “Giacint” critical facility under Belarus-Russian–American cooperation on conversion nuclear fuel of research reactors. Exchange of HEU/LEU nuclear fuel was realized with uranium-235 equivalent amount in frame of international projects between the organizations of Belarus, Russian Federation, United States of America and IAEA.

REFERENCES

