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# MULTIMODAL SHIPMENTS UNDER PROGRAM ON RUSSIAN-ORIGIN RESEARCH REACTOR SNF RETURN TO THE RUSSIAN FEDERATION

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## ABSTRACT
The paper describes experience in preparation and organization of transportation of the nuclear material from research reactors under the Russian Research Reactor Fuel Return (RRRFR) Program. It also summarizes the evolution of transport equipment and routes including types of packages, their adaptation and certification, safety issues, peculiarities and prospective use of the packages and transport equipment.

## INTRODUCTION
The spent nuclear fuel (SNF) of the research reactors (RR), constructed with assistance of the USSR in some European, Asian and African countries, is returned to the Russian Federation under the International RRRFR Program. The main objective of the RRRFR Program is to minimize the risks of nuclear-weapons proliferation and international terrorism. The legal framework to implement the program is the U.S./Russia government-to-government cooperation agreement, signed in 2004. The terms and principles of highly enriched fuel return to the Russian Federation were approved by the 14 countries out of the 17 having Soviet-design reactors on their territories.
The RRRFR program allowed gaining a huge experience in RR SNF multimodal shipments. The international RRRFR Program is coming to its completion giving an opportunity to summarize lessons learned and preliminary results. At the time being the shipments of the Russian-designed SFAs from Uzbekistan, Latvia, Kazakhstan, the Czech Republic, Bulgaria, Hungary, Romania, Lybia, Ukraine, Poland, Serbia, Belarus, Vietnam are completed.

## EVOLUTION OF RR SNF TRANSPORT EQUIPMENT AND ROUTES
By the beginning of the the RRRFR program the fleet of Russian packagings for RR SNF shipments was represented mainly by the TUK-19, TUK-32, TUK-18, TUK-108, TUK-128 casks. In practice, it was possible to use the only type of casks - TUK-19 - due to its simplicity in handling, small mass (4.5 t), enough quantity of such casks available and, therefore, minimum arrangements necessary for its receipt and handling at the consignor's facility.
The first experience of shipments under the RRRFR program was gained during the RR SNF removal from Uzbekistan in 2006. The SFAs were transported to the radiochemical plant in the Russian TUK-19 casks by a traditional conveyance - by rail - within the TK-5 rail cars. The shipment from the research institute to the railroad station was carried out by road. Similar schemes were implemented when the RR SNF was removed from Latvia (in 2008) and Kazakhstan (in 2008–2009). In each of the cases the TUK-19 cask shipment by road required developing of special support equipment (Fig. 1), which was not general-purpose and excluded the possibility of its use in other projects.

a b

**Fig. 1. Installing the TUK-19 casks onto a truck (a) and into a TK-5 rail car (b)**

Using only one type of cask for such a large-scale program of the fuel return to the Russian Federation was obviously insufficient. The DOE devoted special funds for development and fabrication of sixteen SKODA VPVR/M casks within the framework of the program.

The Czech SKODA VPVR/M cask was initially more adapted for use in multimodal shipments, as it was installed within 20-foot freight ISO container (Fig. 2), the handling of which was unified for practically all conveyances.


**Fig. 2. The SKODA VPVR/M cask within the ISO container**

It was the first time a foreign cask was used in the RRRFR Program. The use of the Czech SKODA VPVR/M cask for RR SNF shipments to the Russian Federation required a certificate for the package design and shipment, as well as adaptation of Mayak PA procedure for its receipt and handling.

The Russian certificate of approval for the SKODA VPVR/M package design was prepared in two stages. Russian expert organizations VNIIEF and IPPE participated in the work. At the first stage, Russian experts revised the set of documents on the cask design safety justification, prepared by the Developer (SKODA JS a.s.), for its completeness and compliance with the requirements of Russian standards. Based on the Russian experts' comments, the Developer presented additional materials to justify radiation and nuclear safety of the package, as well as its strength (eliminating brittle failure under accident conditions at ambient temperature below zero, justification of the assigned lifetime, etc.)

At the second stage, an application for the Russian certificate of approval for the SKODA VPVR/M package design was developed and then submitted to a Russian competent authority of Rosatom State Corporation. The VNIIEF and IPPE experts completed a comprehensive assessment to justify the cask design safety under normal and accident conditions of transport. The results of the assessment verified that the Developer's justifications were correct.

Upon getting all necessary concurrences, on January 23, 2006, Rosatom approved Certificate RUS/3065/B(U)F-96 for the SKODA VPVR/M cask design for the shipment of research reactor SFAs, which was valid for three years. This certificate endorsed Czech Certificate of Approval CZ/048/B(U)F-96 (Rev.1). In 2009, the period of validity of the certificate was prolonged till July 1, 2011, and then - till October 31, 2016.

To prepare Mayak PA for receipt of the SKODA VPVR/M cask, additional equipment was designed and fabricated or purchased, all necessary technological documents were prepared, the personnel received training, the transport and technological scheme of the radiochemical plant was checked. Regarding the results of testing, it was concluded that Mayak PA was ready to handle the SKODA VPVR/M cask in full compliance with the requirements of the Fabricator (SKODA J.S a.s.) and the Owner of the cask (UJV Rez).

The Czech SKODA VPVR/M casks were used to remove the SNF from the the Nuclear Research Institute Rez, the Czech Republic, in 2007. The SFAs were shipped within the SKODA VPVR/M casks, placed in ISO containers, by road to the railroad station and then delivered to the radiochemical plant in Russia by rail, transiting Slovakia and Ukraine. Similar scheme was implemented when the RR SNF was shipped from Ukraine and Belarus.

a b

**Fig. 3. Shipment of the ISO containers containing the SKODA VPVR/M casks by road (a) and by rail (b)**

The first experience of the Czech SKODA VPVR/M cask shipment by inland waterways was gained during the SNF removal from Bulgaria in 2008. The waterway part of the route ran across the Danube River. A barge of a sea-and-river type was used for this part of the route (Fig. 4). The SKODA VPVR/M casks were shipped from the research institute to the river port of Kozloduy by road, where they were reloaded onto the barge. Then the casks were delivered along the Danube River to the Ukrainian river port of Izmail, from where they were shipped by rail to the reprocessing plant.

**Fig. 4. Loading the ISO containers with the SKODA VPVR/M casks onto the barge of a sea-and-river type**

In 2008, the Czech SKODA VPVR/M casks were used to remove the RR SNF from the Institute of Nuclear Research of the Hungarian Academy of Sciences. It was the first time a sea shipment was carried out within the framework of the RRRFR program. In some projects, a sea shipment of SNF is the only possible way due to transit-associated complications.

**Fig. 5. The Danish LYNX vessel used to remove the RR SNF from Hungary**

The Danish LYNX vessel (Fig. 5), class INF-2, equipped in accordance with the requirements of the International Code for the Safe Carriage of Packaged Irradiated Nuclear Fuel, Plutonium and High-Level Radioactive Wastes on Board Ships (INF Code), was used to cover the sea part of the route. ASPOL Baltic Corporation, a Russian sea carrier with the corresponding experience, supervised the observance of these requirements. As most of the shipment route by sea was outside the Russian territorial waters, the Russian certificate of approval included a condition whereby international accident maps had to be used in accordance with the requirements of the International Maritime Dangerous Goods Code. Particular attention was paid to the aspect of when the responsibility for physical protection would be handed over. A corresponding procedure was developed and approved for that purpose.

The SFAs were shipped within the SKODA VPVR/M casks, placed in ISO containers, by road from the research institute to the railroad station in Hungary, where they were transferred onto the rail transporters (Fig. 6). Then the ISO containers were taken by rail to the seaport of Koper, Slovenia (Fig. 7). The sea part of the route ran around Europe to the Russian port of Murmansk, from where the ISO containers were delivered by rail to the radiochemical plant.


a

b

**Fig. 6. Shipment of the ISO containers with the SKODA VPVR/M casks inside by road (a) and their transfer onto the rail transporters (b)**

a


b

**Fig. 7. Shipment of the ISO containers with the SKODA VPVR/M casks inside by rail across Slovenia (a) and their transfer onto the LYNX vessel (b)**

Within the framework of the Romanian VVR-S reactor spent fuel repatriation project, unification of the transport and handling operations with the TUK-19 casks was finally achieved by incorporating them into an overpack.

The overpack for shipment of the TUK-19 casks (Fig. 8) was based on a special freight large-capacity 20-foot container (special ISO container) satisfying ISO standards, international conventions and industry-specific regulations for transport of dangerous goods by various conveyances. The special ISO container was equipped with a set of equipment for fastening the TUK-19 casks in it. Over the year of 2008, the prototype container was fabricated and tested, and the Russian Maritime Register issued a certificate. The TUK-19 cask design as part of the overpack was subject to VNIIEF expert assessment for compliance with Russian and international regulations for transport of radioactive materials. The new transport overpack has significantly extended possibilities of handling and transportation of the TUK-19 casks by different conveyances, including sea and air.

The overpack was used to transport the SFAs of the Romanian VVR-S reactor by air. To certify the TUK-19 cask for RR SNF air shipment VNIIEF experts made calculations of dynamic deformation and a strength analysis of the TUK-19 cask under impacts simulating normal and accident transport conditions including an air crash. In addition the calculations to justify that an individual package remained subcritical after a series of enhanced tests were performed.

**Fig. 8. An overpack made on the basis of the freight ISO container for transport of the TUK-19**

The RR SNF was removed from Romania in June, 2009. The TUK-19 casks, loaded with SFAs and packaged into the ISO containers, were delivered by road to a Romanian airport. The Volga-Dnepr Airlines' AN-124-100 aircraft was used for this air shipment (Fig. 9). The flight route lied over the Black Sea to exclude crossing the airspace of third countries; when it lied over the land, it passed around large populated localities and hazardous industrial facilities. After an interim refueling stop in Ulyanovsk, the aircraft successfully landed at the Koltsovo airport, from where the consignment was delivered to Mayak PA by road.

A similar scheme of shipment, with air transport involved, was used for transportation of the RR SNF from Libya (December, 2009), Uzbekistan (August, October, 2012).

a b

**Fig. 9. The AN-124-100 Ruslan aircraft (a) and the overpacks with the TUK-19 casks inside, loaded into the cargo hold**

Not to involve the Russian sea transport into such a large-scale program of the fuel return would have been unreasonable. To arrange such a shipment, in January 2008, the Krylov Shipbuilding Research Institute, together with Sosny R&D Company, started the design effort to re-fit the MCL-Trader vessel (Fig. 10) of ASPOL Baltic Corporation.


a b

**Fig. 10. The Russian-design MCL-Trader vessel, INF-class, (a) and its hold before re-fitting (b)**

After development and approval of the design the vessel was re-fitted at the Estonian Netaman Oy shipyard under the supervision of the local representatives of the Russian Maritime Register and certified as the one of INF-2 class. Many efforts were made to develop and approve all necessary vessel documents; the crew received appropriate training and permits for work. The vessel was refitted in compliance with all standards, has a big displacement, allows for loading packages with deck cranes, fitted for navigating in arctic seas and, consequently, has a higher safety level. The MCL-Trader vessel was first used in September 2009 for an RRRFR shipment to transport the SNF from the Ewa and Maria reactors, Poland (Fig. 11).

**Fig. 11. Loading the ISO containers with the SKODA VPVR/M casks inside into the hold of the MCL-Trader vessel**

It took a total of six trips to move all the SFAs from the Polish reactors. The SKODA VPVR/M and TUK-19 casks placed inside the ISO containers were used for it. The route comprised a section from the research institute to a railroad station by road, then a section across the territory of Poland to the Polish port of Gdynia by rail, then a section across Scandinavia to the Russian port of Murmansk by sea and a section across the territory of Russia to the radiochemical plant by rail.

The Puma vessel was used to remove the RR SNF from Serbia, whereas the vessel Mikhail Dudin was used to remove the SNF from Poland (2012) and the Czech Republic (2013). .

Therefore, until 2008, SFAs shipments within the framework of the RRRFR program were carried out by road and rail only. Since 2008, sea shipments of SFAs began, whereas in 2009 air shipments were first used.

## PROSPECTS

In 2009 work started to develop a type C package on the basis of the SKODA VPVR/M overpack, suitable for shipment by air. Unlike the type B packages, certified for air shipment, type C packages do not have any additional activity level limitations imposed, and there are no requirements for the SFAs to be loaded into leak-tight canisters, but the package shall meet the requirements of structural strength and leak-tightness after extensive testing. According to the information we have, currently in the world there are no RR SNF casks, certified for compliance with the safety requirements of type C packages, except for the Russian TUK-145/C (Fig. 12).

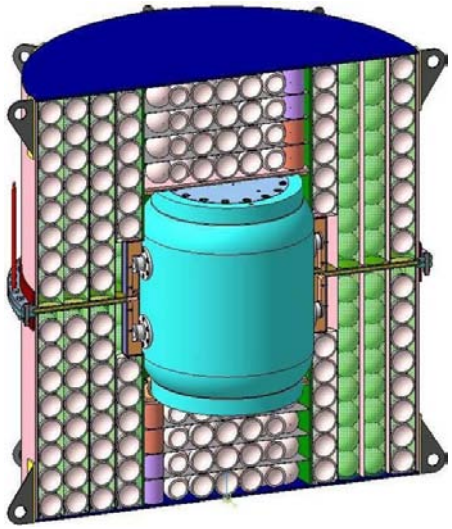

**Fig. 12. General view of the TUK-145/C**

In July, 2013, the TUK-145/C package was used to complete the RR SNF return from Vietnam. At the time being the work on preparation for the return of the RR SNF from Hungary and for the liquid RR SNF from Uzbekistan in TUK-145/C is in progress.

## CONCLUSIONS

The RRRFR program has become a catalyst for enhancement of the fleet of containers, development of the SFA loading equipment, use of new transport equipment and routes.

The available experience of multimodal shipments and the developed technical solutions have vastly expanded the capabilities of the SNF transport and are currently successfully being used for further implementation of the RRRFR program. This experience is of practical significance not only for the RRRFR program; it is versatile and can be used for other projects associated with the management of research reactors spent fuel.