EXPERIENCE IN ORGANIZATION OF IRREGULAR SHIPMENTS OF RADIOACTIVE MATERIAL

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ABSTRACT

The International Program on Russian Research Reactor Fuel Return (RRRFR) is coming to its completion giving an opportunity to summarize lessons learned and preliminary results. The Program has completed NM shipments from nuclear facilities of 14 countries. This required solving a wide range of various tasks associated with preparation and transportation of different fuels of different health in conditions of undeveloped infrastructure involving all transport modes to minimize transiting through third countries. No doubt, the unique engineering solutions developed under these conditions are useful for future NM transportation projects including Russian ones.
The paper describes some of the engineering solutions developed under the RRRFR program, in particular, design of the Type C package for air shipment of research reactor SNF.

1. Introduction

The International Program on Russian Research Reactor Fuel Return (RRRFR) is coming to its completion giving an opportunity to summarize lessons learned and preliminary results.
During 1999-2002, specialists commissioned by the IAEA, Russia and the United States undertook major efforts to prepare various research reactors for participation in the RRRFR programme. On 28 May 2004, Russia and the United States signed an agreement to cover cooperation between the two countries in shipping Russian-origin research reactor nuclear fuel back to the Russian Federation, providing the legal framework for programme implementation. The RRRFR program has involved 14 countries out of 17 having Russian-design reactors.
Numerous Russian organisations have since taken part in the RRRFR programme. All projects have been performed under Rosatom management and Rostekhnadzor supervision.
It would be logical to apply the experience obtained under the RRRFR program to the Russian nuclear facilities operated on HEU fuel. A “pilot” shipment of RR SNF from the SSC “RF-IPPE” is an illustration of such an application.

2. Return of RR nuclear fuel under RRRFR program

A U.S./Russia cooperation agreement was signed in 2004. By now, almost all non-irradiated fuel has been removed. These shipments were performed by air. This resolves several

transit-related problems; in particular, logistic and customs procedures became simpler and physical protection became easier.
Return of the research reactor SFA to the Russian Federation under the RRRFR program involves much more serious tasks – economical, technical and organizational. This requires close cooperation of all organizations involved in the project.
The RRRFR program has become a catalyst for enhancement of the fleet of containers, development of the SFA loading equipment, development and use of new transport equipment and routes. The equipment and technologies developed for these projects have already been used for domestic shipments.

3. Preparation and removal of damaged SFA from Serbia

The project on removal of damaged Russian-origin SNF from Serbia was completed in late 2010.
One of the peculiarities of the Serbian project was a big quantity of severely damaged fuel. The fact that the fuel at the Serbian facility was damaged caused no doubts, since the activity of the water had been constantly increasing; however, it was almost impossible to experimentally check the health of the fuel, the degree of its damage and the state of aluminum tubes containing the fuel. So, in selecting a fuel handling technology and making safety analysis, we had to develop conservative theoretical models and follow the predictions. The big quantity of the spent fuel and its fast-worsening state required that the fuel be removed as a single run and in the shortest possible time. A long route, several transit countries and transport modes, two types of casks, new European regulations and many other nuances made the Serbian campaign one of the most complicated in terms of getting licenses.
Non-tight canisters were used to transport the Serbian fuel (Fig. 1). It was quite a trick, since the damaged fuel is usually transported in a tight packaging.

Fig. 1. Non-tight canister for damaged spent fuel shipment

Sosny and VNIIEF experts analyzed and justified all safety aspects of handling the new canisters. The major issue was fire and explosion safety. The oxidized surface has a big quantity of associated water, and its removal was unfeasible in the infrastructure of the Vinca Institute. Once confined, the damaged SNF may generate an explosive hydrogen-oxygen concentration within several months. To avoid this, a non-tight design of the canister was selected allowing for regular blowing of the spent fuel inside the cask and preventing a hazardous hydrogen-oxygen concentration. Thus, it was demonstrated that a tight canister for the damaged fuel is not always a sound option and each particular situation requires a thorough analysis to come out with the best decision.

An important thing that had a positive effect on the Serbian project was a centralized coordination of the RRRFR shipments. This facilitates advantageous interactions between the projects and allows using experience, ideas, equipment and engineering solutions developed under other projects. So, the SNF was loaded with a transfer cask and transported in ISO containers for TUK-19 casks developed for the removal of the spent fuel from Romania, as well as SKODA casks fabricated for the removal of the spent fuel from the Czech Republic. Proven routes were used to deliver empty casks (by road and air); a sea route used for the removal of the spent fuel from Hungary for the first time was selected. In their turn, some Serbian solutions will be used in other projects. For instance, the Vietnamese project has adopted the “Serbian” idea and design of the equipment to transfer the SKODA VPVR/M cask by forklift.

Thus, the projects benefit from a unified program in terms of safety, schedule and cost.

The spent fuel started from Vinca Institute on the night of the $18^{th}/19^{th}$ November, 2010 (Fig. 2). It was a very important event for Serbia that had been waiting for it for almost 26 years. Serbian president Boris Tadic who had come in person to see off the vehicle convoy emphasized this fact in his address to the organizers of the shipment. The removal of the spent fuel from Vinca Institute got a wide response and appraisal of the international community and became a good example of international cooperation in enhancing safety of the nuclear industry.

Fig.2. The international team of the Vinca project at the port of Koper, Slovenia

3. Removal of LEU SNF from Romania

After the breakup of the Soviet Union, the import of the RR SNF has almost stopped due to the complexity of organizing international shipments. For the past ten years, foreign research reactors have had a chance to ship the HEU SNF for reprocessing only under the RRRFR Program.

The first shipments after a long break were made in 2012. The 153 EK-10 SFAs stored at IFIN-HH (Magurele, Romania) were transported in three shipments. The shipments were paid by the Romanian side under the RF/Romania Government-to-Government Agreement.

From the beginning of the project preparation, it was decided to use to a maximum extent possible the infrastructure and experience created already under the RRRFR Program for the HEU SNF repatriation as the most efficient way to achieve the project tasks in a minimum period of time and with minimum efforts.

The EK-10 spent fuel assemblies were loaded into TUK-19 casks using the transfer cask earlier developed by SOSNY R&D Company and fabricated in Romania. Then, the fuel was transported in ISO-containers by road from the IFIN-HH site to Otopeni (Bucharest) airport, after that by Volga-Dnepr Airlines’ aircraft AN-124-100 to Koltsovo airport (Yekaterinburg) and again by road to Mayak PA site (Ozersk). Due to the use of air transport, the necessity to

negotiate with transit countries was eliminated and the duration of the shipments by air was significantly reduced, thus enhancing the physical protection level.
To remove LEU SNF from Romania, a new route was used allowing shipment of Class 7 Cargo across the Black sea via the port of Caucasus. The plan included:
– Delivery of ISO containers with TUK-19 casks and ancillary equipment from Mayak PA to the port of Caucasus by rail,
– Transportation by the *Slavyanin* ferry (Fig.3) across the Black sea to the ferry terminal in Varna, Bulgaria,
– Reloading of the ISO containers from the railcars onto trucks at the ferry terminal in Varna,
– Shipment by trucks from the ferry terminal in Varna to IFIN-HH, Romania across the Bulgarian-Romanian border.

Fig.3. The *Slavyanin* ferry used for the shipment of empty TUK-19 casks

The new route can be useful for further shipments of radioactive material (not only RRRFR shipments) between the Russian Federation and European countries, since the port of Murmansk usually used for such shipments is located far away from European (mostly, Mediterranean) ports and the period of transportation can exceed one month (like in the Serbian project). The route through the port of Caucasus significantly decreases the period of transportation, which is a positive factor from the viewpoint of physical protection.

4. Development of TUK-145/C packaging (Type C)

In September, 2009, Sosny started development of the first Type C packaging by order of the U.S. Department of Energy under the RRRFR program. At the initial stage, a concept decision was taken to develop a dismountable energy absorption container accommodating a SKODA VPVR/M cask (Fig.4).
In June 2010, after the feasibility to develop a Type C packaging for air shipments was validated, Sosny got a Technical Assignment for development of the Type C packaging approved by the Department of Nuclear and Radiation Safety of Rosatom State Corporation and concurred by all concerned entities. The packaging was assigned identification number TUK-145/C.

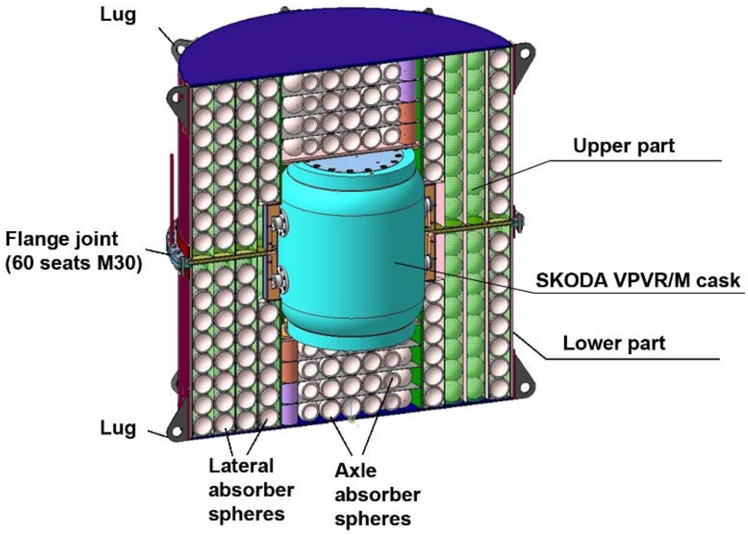

Fig. 4. Design of the TUK-145/C package

Since field tests for impact onto a solid target at a velocity of 90 m/s is a mandatory requirement, Sosny experts designed a mockup packaging TUK-145/C, which was a scaled-down replica. The 1:2.5 scale mockup was fabricated in April, 2011. By that time, a program of tests had been developed and approved by Rostatom State Corporation.

By order of Rosatom a Test Commission was assigned to include representatives of different Russian enterprises. The mockup packaging TUK-145/C was tested in May, 2011 on a rocket sled at VNIIEF. After the tests it was visually examined and analyzed (Fig.5).

Fig. 5. Successful completion of the tests on the rocket sled

A certificate of approval of the package design was obtained in April, 2012. The energy absorption container (EAC) was fabricated in June, 2012.

To try out the procedure for reloading the TUK-145/C package from the truck in the aircraft (Volga-Dnepr aircraft AN-124-100), a dry run was carried out at Ulyanovsk-Vostochny airport in June 2012 (Fig.6).

Fig. 6. TUK-145/C and its developers

A certificate of approval for the shipment of SFAs from DNRR research reactor of Dalat Nuclear Research Institute, Vietnam in TUK-145/C has been obtained. The Russian certificate for the TUK-145/C package design has been submitted to the Vietnamese and Hungarian regulatory bodies for endorsement. International projects involving the TUK-145 packaging for air shipments of high-activity radioactive material are being discussed.
It is worth mentioning that organization of air shipments was started in 2005 after Russian regulations NP-053-04 were put into effect. Over the past years, considerable progress has been made in this field, i.e. equipment has been prepared and several SNF shipments by air have been certified and completed. In the authors' opinion, in view of development of international cooperation in the nuclear field the transport of the spent fuel by air is relevant for discussion regarding the experience gained, new proposals and the legal framework.
In the course of the RRRFR program, considerable experience in organizing various shipments of radioactive material has been gained. Despite the fact that the international regulatory method based on TS-R-1 has been widely used in all countries, administrative procedures for licensing transportation of radioactive material differ. This is due to a different scope of procedures to go through at competent authorities in each particular country. For the purpose of strengthening the international cooperation in safety and security of radioactive material, it is necessary to focus on harmonization of national regulations and development of emergency response regulation procedures during international shipments of radioactive material.

5. Development of a technology of "top loading" of the SKODA VPVR/M cask

A new technology and equipment for reloading SFAs into the SKODA VPVR/M cask by means of a transfer cask (top loading) were developed in the frame of the project on removal of RR SNF from Dalat Nuclear Research Institute (Dalat, Vietnam).
A support plate is installed on the SKODA VPVR/M cask to protect personnel from ionizing radiation and an adapter to position the transfer cask with SFAs above the cells of the SKODA VPVR/M cask basket (Fig.7). The transfer cask with SFAs is installed on the adapter and then the SFA is unloaded from the transfer cask and is placed into the cell of the SKODA VPVR/M cask basket. This loading method might be used at research reactor facilities, where there is no possibility for standard bottom loading of the SKODA VPVR/M cask.

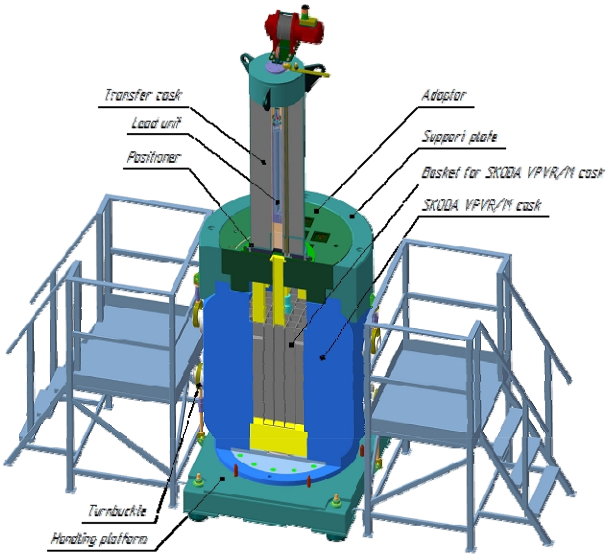

Fig. 7. Loading of SFAs into the SKODA VPVR/M cask by means of the transfer cask

6. Pilot SNF shipment from IPPE

In a logical continuation of the RRRFR program it was extended to also cover the Russian nuclear installations that use highly-enriched fuel in line with the objectives of the Global Threat Reduction Initiative. Perspectives of such international cooperation are being currently discussed.

In 2008, the Federal Targeted Program for Ensuring Nuclear and Radiation Safety started preparation of the spent fuel for shipment from IPPE. The Institute has accumulated significant stocks of the fuel from research reactors and critical assemblies tested in hot cells. So, the major part of the fuel is leaky / damaged.

To prepare the SFAs for the shipment, several types of equipment and systems were developed and commissioned including:

– air-tight canisters for loading deformed and non-deformed VM SFAs in TUK-19 casks and fuel rods from VM SFAs in TUK-108/1 casks;

– a set of equipment for the hot cell for handling standard baskets, unloading the SNF from the baskets, cutting the upper end parts of the VM SFAs, loading the VM SFAs in the canisters, and air-tightening the canisters with the lid (Fig. 8).

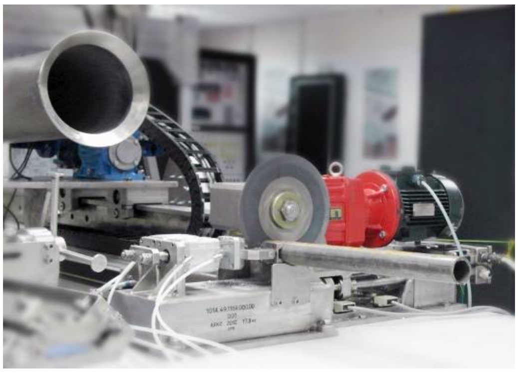

Fig. 8. Basket tilter and VM SFAs cutter

Preparation of the spent fuel for transportation from IPPE was started in 2009. First, the SNF inventory was defined to be accepted and reprocessed at Mayak PA with no changes to the standard technology. The TUK-19 cask handling procedure was modified.

Out of all the spent fuel stored in the storage facility, the VM SFAs and all EK-10 SFAs were selected for the first shipment. The end parts of the VM SFAs were cut off to fit in the air-tight

canisters. All necessary shipping and licensing documents were prepared, and a procedure for TUK-19 leak tests was developed.
After all the preparation operations were completed, the EK-10 SFAs and canisters with the VM SFAs were loaded into 16 TUK-9 casks, which in their turn were put into special freight large-capacity containers. The containers were delivered to the reloading ground by trucks and reloaded on rail flatcars. Then, a special train was made up and sent to Mayak PA.
We can conclude that the pilot removal of the RR SNF from IPPE was a transfer of the RRRFR experience on Russian sites.
The major problem affecting big-scope shipments of the spent fuel from IPPE is the bad rail road connecting Obninskoye station with the Institute site. The rail road has not been operated for many years and got almost destructed. At present, reconstruction of the rail road is being prepared.
The use of large-capacity TUK-108/1 casks will speed up the process increasing the rate of removal up to 1-2tU/year. The complete removal of the RR SNF from IPPE will allow decommissioning of the research reactors and the spent fuel storage facility on the site.
It is noteworthy that Russia has more than a dozen of organizations with significant stocks of the spent fuel from research reactors and critical assemblies (more than 100 facilities in total). Organization of the fuel removal and reprocessing requires coordination of the operators' activities, since it is desirable to use a unified system of project management, unified equipment and transport plans and unified licensing documents to optimize the budget and the overall schedule of the Russian RR SNF consolidation and reprocessing.

7. Conclusions

The Russian-Origin Fuel Return Program predetermined active development of technologies, transport means and logistics of RR nuclear shipments.
The RRRFR program is coming to an end but research reactors continue their operation.
Rich experience of Sosny R&D Company might help in solving the problem of SNF removal from research reactor facilities.