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REMOVAL OF SPENT NUCLEAR FUEL FROM SERBIA. ISSUES, SOLVING, LESSONS LEARNED

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ABSTRACT

The removal of SNF from RA reactor site (PC NFS, Serbia) is the most time-consuming and technically complicated operation under RRRFR Program. The project was organized by IAEA. The most efficient techniques and lessons learned from other projects of the RRRFR Program as well as new unique technical decisions were used.

Two big challenges were resolved during implementation of Serbian Project: (1) preparation of damaged fuel located in the packages unsuitable for transport, taking into account insufficient infrastructure of RA reactor site and (2) removal of large amount of fuel in one multimodal shipment through several transit countries. The main attention was paid to safety justification of all activities. All approvals were obtained in Russia, Serbia and transit countries.

Special canisters were designed for transportation of specific RA reactor fuel (of small dimensions, unidentifiable, damaged due to corrosion). The canister design was selected to be untight – it was the most expedient decision for that case from safety perspective.

The technology and a set of equipment were designed for remote removal of the fuel from the existing package (aluminum barrels and reactor channels) and placing of the fuel into the new canisters. After fabrication and assembling of the equipment theoretical and practical training of the personnel was performed. Fuel repackaging took about 5 months. SNF was transported in TUK-19 and SKODA VPVR/M casks. The baskets of large capacity were designed and fabricated for SKODA VPVR/M casks. Special requirements to drying the packages and composition of gaseous medium inside were justified to ensure fire and explosion safety.

Due to the tight schedule of RRRFR Program as well as geographical peculiarities of RA reactor site location all types of transport means were used in this transportation: empty casks were delivered by road and air, SNF was transported by road, rail and sea.

This paper contains main stages of project realization, describes accepted technical and organizational decisions.

In 1950s, a heavy-water research RA reactor was built to the soviet design on the site of the Vinca Institute of Nuclear Sciences situated near Belgrade, the capital of Serbia. The reactor was shut down in the mid 80s; and since the Serbian government did not intend to operate it any more, it was decided to decommission it. But, on the way to the “green lawn” there arose one of the most complicated challenges, i.e. removal of the spent fuel.

Fig. 1. RA reactor

Over 13 000 fuel assemblies of the TVR-S type were supplied from the Soviet Union for the RA reactor. The TVR-S assemblies are small cylindrical blocks in aluminum claddings. Initially, the reactor consumed low-enriched fuel, but later on it was converted to highly enriched one. All the fuel that had been accumulated for 25 years of the reactor operation was stored on the site, and no shipments had ever been made.

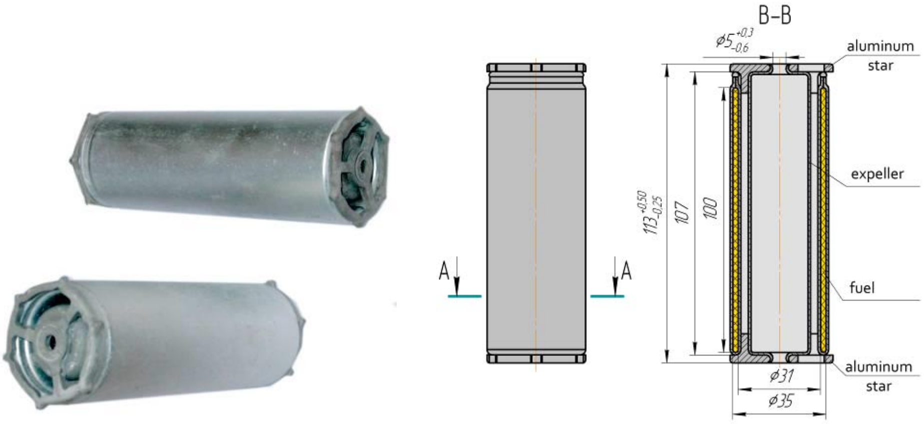

Fig. 2. Fuel assemblies of the TVR-S type

The spent nuclear fuel (SNF) was stored in the standard way loaded in stainless steel channels (SSCH) in the reactor channels pool. The stainless steel channels were suspended on special metal frames.

But at one point, all standard storage locations were found fully occupied, and the Serbian engineers had to provide a more compact arrangement of the fuel in the storage pool. They developed and fabricated unique aluminum barrels that accommodated the major part of the oldest fuel.

The fuel storage is an annex to the reactor building containing four basins of water. A transport channel connects the basins with the reactor reloading chamber. By the end of the reactor operation, almost all the standard storage locations had been occupied by the reactor channels containing the spent fuel, and a few vacant locations at the bottom had been taken up by the aluminum barrels.

a) b)

Fig. 3. Aluminum barrels (a) and reactor channels (b)

The fuel was stored in tap water that was never subject to any treatment. The high percentage of chloride and sulfate ions and a high hydraulic conductivity caused corrosion of the spent fuel. Moreover, some fuel assemblies had already been damaged during the reactor defueling after some incidents during the reactor operation. So, the activity of the water had been growing year by year. Having escaped from the damaged fuel, the high-level fission products in the water were a hazard to the personnel, and a potential hazard to the environment. Day by day, the situation grew even worse, so the top priority was to remove the fuel.

Fig. 4. Cooling pool water and damaged SFAs.

Serbia joined the Fuel Repatriation Program to return it to the country of origin, Russia. The Serbian government had neither funds, nor experience in projects of that kind, so the IAEA accumulating donor funds acted as the Customer and called for a tender. The U.S. Department of Energy, European Union, Russia and the Czech Republic provided the major funds to implement the project.

The tender was won by a consortium of Russian companies including Sosny R&D Company (a company specializing in organization of the fuel shipments and having experience in its preparation), FSUE Mayak PA (the consignee and the only facility in Russia capable of reprocessing the spent nuclear fuel), and TENEX (at that moment the only enterprise authorized by the Government to sign spent fuel import contracts).

At the end of 2006, the IAEA signed a contract with the Russian consortium. The basic conditions of the contract stated that:

- the fuel should be removed as a single shipment,
- the shipment should be completed by the end of the year,
- all on-site operations should be performed by the Serbian personnel,
- all Serbian, Russian and international standards, regulations and laws should be complied with.

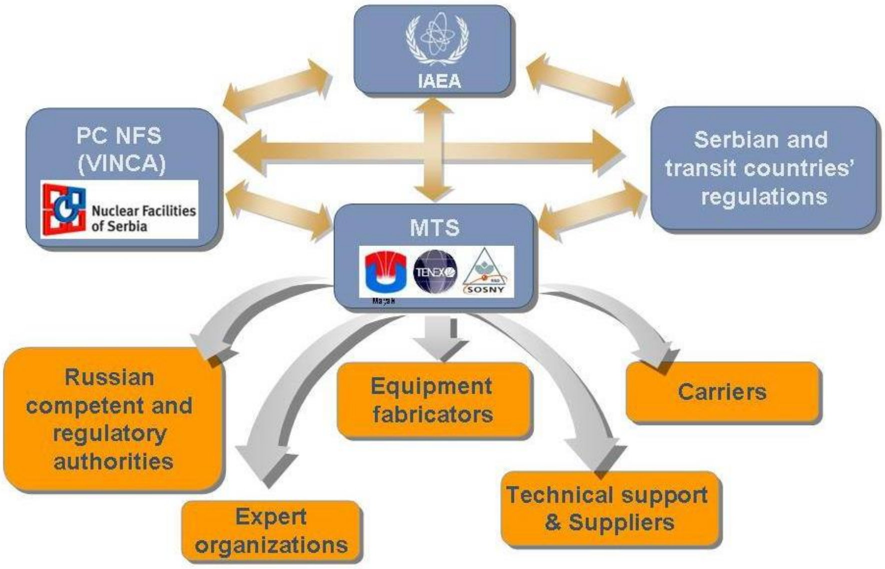

Fig. 5. Diagram of interaction between the participants in the project

An analysis of the shipping casks available demonstrated that TUK-19 and SKODA VPVR/M were the best choice. It took 16 casks of each type to ship all the fuel at a time.

It was obvious that the existing packaging, i.e. the reactor channels and aluminum barrels, was not appropriate for the shipment of the spent fuel to Russia both from the viewpoint of transportation, and requirements of the reprocessing plant. So, a new high-capacity packaging was developed and fabricated. That was the TS-1 canister for the TUK-19 cask and the TS-2 canister and TS-3 basket for the SKODA VPVR/M cask. The TS-1 and TS-2 canisters are similar in design, but differ in length; this fact enabled using the same handling equipment for all the canisters.

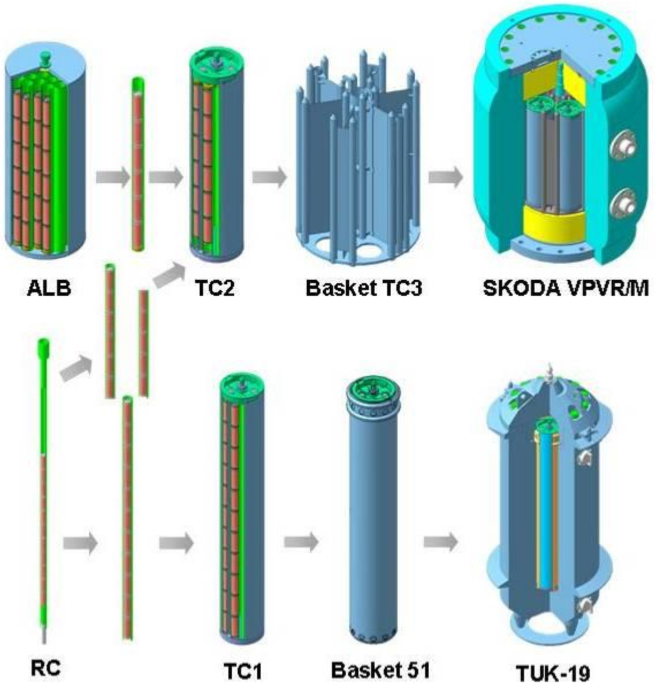

Fig. 6. Cutting and loading of TVR-S from aluminum barrels and reactor channels

Sosny specialists and contracted experts reviewed and justified all safety aspects in handling the new canisters. The major challenge was assuring explosion and fire safety. The oxidized surface of the spent fuel contains a plentiful of bound water which is impossible to remove. When enclosed, the spent fuel can generate an explosive concentration of hydrogen and oxygen within several months. To avoid this, an untight design was selected for the canisters and special requirements were justified for packages dry-up and gaseous medium inside them.

Such a design enabled regular purging of the spent fuel in the cask and preventing a dangerous concentration of hydrogen and oxygen. When stored in the reactor basin or in the storage pool at Mayak PA, the untight canisters release radioactive substances into the water. To ensure radiation safety, a water chemistry control system was developed by Savanna River National Laboratory and installed in the Serbian basin.

The main area, where almost all the fuel repackaging operations were carried out, was the neck of basin 4 in which a working frame tower was installed. The water in the basin ensured protection of the personnel. The working frame tower has three tiers. The underwater tier accommodated different tools and equipment: an aluminum barrel tilter, canister seats, and vessels for solid radioactive waste. The second tier was the main working ground for the operators. Here, there are seats for long-length tools and video monitors. The third tier is designed for handling operations with the long-length tools.

The reactor channels were too long to be removed from the baskets in the cooling pool; so this operation, as well as cutting of their upper parts, which did not contain the fuel, were performed in a shielded room in the reactor vessel. The thick concrete walls shielded the personnel from radiation. The operations performed in the shielded room were completely automated; the operator controlled and operated the equipment remotely.

The fuel-containing canisters were put onto special racks under water in basins 1 through 4.

The process could be observed from a specially equipped operators' room with video surveillance and communication systems, a control panel for the water chemistry control system and control units for the radiation monitoring system. It also was a place of making accounting records of the radioactive material.

Fig. 7. Working frame tower and operator's room

For repackaging and loading the spent fuel into casks, more than 150 kinds of unique equipment ranging from simple long-length tools to sophisticated large-size equipment with electric and pneumatic units were developed and fabricated.

The lower fragments of the reactor channels were cut off with a tube cutter and a winch driven by a stepper motor ensuring precise positioning of the channels. Then, the reactor channels were cut on the working frame tower with a tube cutter of a different design.

The aluminum barrels were opened on the working frame tower with a driller and a tilter. The principle of the procedure is sequential concentric drilling of the bottom to remove the fuel-containing tubes.

A set of long-length tools was designed to transfer the tubes and separate spent fuel assemblies and to handle the canisters, i.e. to transfer them in the pool and to install their covers.

Fig. 8. Equipment and tools for SNF repackaging

The fuel-containing canisters were put into the cask baskets underwater; in the process the casks were installed on a special frame above the basin. Loading the spent fuel through the bottom is the standard procedure for the SKODA VPVR/M casks, but the canisters with the Serbian fuel were rather heavy. So, a special self-balancing tool was developed.

A special transfer cask was used to load the fuel into the TUK-19 casks, since they can be loaded only through the top. The transfer cask was developed under the Romanian Fuel Return project and then adapted for the Serbian campaign. The spent fuel was loaded into the transfer cask above the basin in the same way as into the SKODA VPVR/M casks; then, the transfer cask was installed on a TUK-19 to put the fuel inside.

a) b)

Fig. 9. Loading SKODA VPVR/M cask over the basin (a)
Equipment check before loading the TUK-19 cask through the transfer cask (b)

Handling the casks on the grounds at the reactor facility required special engineering solutions, too. A rail system was mounted in front of the reactor building to transfer the casks between the reactor hall, the storage room and the outside ground. The crane in the storage room has low lifting capacity, so it was decided to use a forklift to transfer the casks there. Since it was necessary to simultaneously install a big number of casks in the reactor hall, the load on the floor was calculated to ensure their safe arrangement.

Fig. 10. Arrangement of casks in the reactor hall.
A forklift and a transport trolley for the casks

The equipment fabricated by Sosny R&D Company was delivered to the reactor facility and mounted. A joint Russian-Serbian team adjusted the equipment and carried out dry-run tests.

Training the Serbian operators to implement the procedure and work with the equipment was an integral part of safety issues during the repackaging operations. Empty reactor channels, aluminum barrels and casks were used for the training which was conducted before each new stage of the work: fuel repackaging from aluminum barrels and reactor channels, loading and handling of SKODA VPVR/M and TUK-19 casks.

With the participation of Russian experts, Serbian and Sosny specialists prepared Safety Analysis Reports. Independent assessments by the IAEA experts and the Slovenian regulatory authority verified the calculations and conclusions that the proposed procedure was safe. That was the basis for the Serbian regulatory authority to authorize the work.

The fuel repackaging and cask loading operations were carried out by the Vinca personnel with the technical support and continuous supervision by the Sosny specialists. It took a year and half to mount the equipment and conduct training and all operations with the spent fuel. Over that period, no incidents happened to cause the personnel overdose or a radioactive release into the environment. The actual radiation doses received by the personnel were many factors of ten lower than the values allowed by Russian and Serbian standards and regulations.

Preparation for the transport of the spent fuel to Russia included analysis of different routes in terms of their feasibility, safety and cost-effectiveness. For different reasons, many options were denied in favor of the most appropriate one through Hungary and Slovenia to a Slovenian port in the Adriatic See, and then by sea to the Russian port of Murmansk followed by an overland shipment across Russia to Mayak PA. By that time, the route had been tried during the RR SNF shipment from Hungary.

The selected route was supported by all necessary authorizations, i.e. Russian certificates for the package design and transportation endorsed in Serbia, Hungary and Slovenia and licenses for transit through Hungary and Slovenia.

By November 2010, everything had been prepared for the shipment, the fuel in casks was residing on the Serbian site, and all authorizations were in hand…

Fig. 11. Transport scheme of SNF shipment from Serbia

Special ISO containers were used for the multi-modal shipment of the SKODA VPVR/M and TUK-19 casks. They were developed under the RRRFR Program to ship the spent fuel by different transport.

In November 2010, fourteen ISO containers with the spent fuel were loaded onto trucks on the RA reactor site and transported in the vehicle convoy to the Serbian-Hungarian border. At the border railway station the ISO containers were reloaded on the train. Having passed through Hungary and Slovenia, the fuel arrived at the Slovenian port of Koper. There, the ISO containers were reloaded onto the sea vessel licensed for the transport of spent nuclear fuel and delivered to the Russian port of Murmansk through the Mediterranean Sea, the Atlantic and Arctic Oceans. In Murmansk, the Serbian and Russian parties signed a Spent Nuclear Fuel Transfer Statement. The final reloading,…. and the Serbian fuel is heading to the Urals by rail, to Mayak PA site.

Fig. 12. Reloading the ISO containers in the Slovenian port of Koper. Project leaders with Boris Tadic, the president of Serbia

Thus, in December 2010, the large project on removal of almost 2.5 tons of significantly degraded fuel was completed (more than 8 000 SFAs). This event evoked a wide response and appraisal of the international community and became a good example of international cooperation for safety in nuclear industry.

Removal of the spent fuel from the RA reactor is the most time-consuming and technically complicated of all RRRFR campaigns; it is the largest IAEA project of this kind in the history of technical cooperation. The Serbian campaign has become a success due to the high competence and effective cooperation of many local and international organizations. The gained experience is useful and can be applied in other projects on fuel removal and nuclear decommissioning.