FIRST EXPERIENCE IN DEVELOPING THE PROCEDURE FOR LIQUID SPENT FUEL TRANSPORT AND REPROCESSING

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ABSTRACT

Notwithstanding the fact that solution reactors with liquid nuclear fuel are operated both in Russia and abroad, no handling procedure has existed until now considering irradiated liquid fuel preparation for transport and reprocessing.

The paper presents peculiarities of preparation for removal of liquid SNF of IIN-3M reactor of Foton JSC (Tashkent, Uzbekistan) to the Russian Federation.

Particular attention was paid to safety of work with liquid SNF.

INTRODUCTION

The Radiation and Technological Complex (RTC) has been operated by Foton JSC since 1975 on a site that is located in Tashkent, the capital of the Republic of Uzbekistan. The complex consists of two gamma irradiation facilities containing Co-60 sources and an IIN-3M research reactor (RR) using the liquid nuclear fuel in the form of uranyl sulphate solution enriched to 90% in uranium-235.

In order to enhance the nuclear and radiation safety of the Tashkent public and to reduce the proliferation threat, the Government of the Republic of Uzbekistan made a decision to decommission the RTC.

According to the Contract among IAEA, Foton JSC and Consortium comprised of the Institute of Nuclear Physics of Academy of Sciences of the Republic of Uzbekistan and Sosny R&D Company concerning the decommissioning of the RTC of Foton JSC, any on-site operations relating to the IIN-3M reactor decommissioning can be started only when all nuclear fuel and other radiation sources are removed from the site.

The HEU fuel removal is a part of the Russian Research Reactor Fuel Return (RRRFR) program initiated by the U.S. Department of Energy, the IAEA and the Russian Federation. The RRRFR program successfully completed several dozens of shipments of fresh and spent fuel from different countries using Russian origin research reactors to the country of origin for reprocessing and further use in nuclear industry.

Uzbekistan is one of the participants of the RRRFR program. In 2004 the non-irradiated HEU-fuel of WWR-SM reactor was removed from the Institute of Nuclear Physics of the Republic of Uzbekistan. In 2006 the first, so called "pilot shipment" of the irradiated fuel from the WWR-SM reactor was accomplished under the RRRFR program. Then in 2012 two air shipments of the RR SNF from Uzbekistan were performed using TUK-19 casks.

Russian-origin homogeneous reactors using UO_2SO_4 uranyl sulphate solution are listed in Table 1. All these reactors use uranyl sulphate solution enriched to 90% in ^{235}U. At present the conversion of the ARGUS reactor in Kurchatov Institute to use the low-enriched uranium is in process.

Table 1. Russian-origin solution reactors

RR Owner	Facility Name	Volume of solution, l	Status
Kurchatov Institute	GIDRA (HYDRA)	22.8	operational
Kurchatov Institute	ARGUS	22	operational
JSC Foton	IIN-3M	23	operational
NIIP	IIN-3M	22.4	decommissioned
VNIITF	IGRIC	54	operational
VNIIEF	VIR-2M	104.6	operational

In addition, there are reactors that use other solutions:

- VNIITF has a YAGUAR reactor facility that uses $UO_2SO_4 + H_2O + CdSO_4$ solution;
- The ROMASHKA reactor in the Kurchatov Institute that used the $UC_2 + H_2O$ solution was decommissioned; all fuel was discharged and loaded into capsules.

In spite of the fact that there are some reactors in the RF that use the liquid nuclear fuel, no technology of liquid spent nuclear fuel (LSNF) shipment existed. Moreover such a fuel was not included in the inventory of the fuel that can be reprocessed at Mayak PA. That's why the Uzbek Government imposed very strict requirements for the safe work relating to the fuel discharge from the reactor, temporary storage and loading into transport cask.

Sosny R&D Company faced some complicated problems: it was necessary to design the special equipment for LSNF discharge from the reactor into temporary storage canisters, and to design the equipment for LSNF loading into transport canisters and for loading the canisters into the SKODA VPVR/M cask. Also the special equipment was designed for handling the LSNF-containing canisters at Mayak PA. It was necessary to develop the technology and to justify the safe LSNF discharge from the reactor and reprocessing at Mayak PA.

Since the liquid irradiated nuclear fuel had never been shipped to the RF before, a new Gov-to-Gov Agreement was concluded between Uzbekistan and Russia. This agreement established the legal and regulatory framework necessary for import of LSNF of the IIN-3M reactor to the Russian Federation. It also states that the irradiated nuclear fuel will be returned from the Republic of Uzbekistan to the Russian Federation in accordance with the procedure and the requirements to the import of the foreign research reactor spent fuel assemblies (SFAs) to the RF for the temporary storage and reprocessing without return of the secondary waste to the originating country stipulated by the Russian laws.

Preparation of the IIN-3M liquid spent fuel for the removal to the RF for reprocessing included the following activities:

- design, fabricate and test the equipment for LSNF discharge from the reactor into temporary storage canisters;
- discharge the LSNF from the reactor into temporary storage canisters and inspect the SNF;
- design, fabricate and test the equipment for LSNF loading into transport canisters;
- design, fabricate and perform a dry run of the equipment for loading the transport canisters into the SKODA VPVR/M cask at UJV Rez, the Czech Republic, and the IIN-3M reactor site;
- design, fabricate and test the equipment for LSNF receipt at Mayak PA;
- perform the research activities concerning the determination and improvement of the reprocessing processes; prepare and issue a safety analysis report and obtain the licenses authorizing the LSNF receipt and reprocessing at Mayak PA.

The particular attention was paid to the safe LSNF handling at each stage of this project.

1. Equipment for LSNF discharge and temporary storage

After the reactor shutdown all liquid spent fuel remained inside the reactor vessel (about 23 l), and some containers with the liquid spent fuel were stored in the safe box in the isotope storage room (about 1 l).

Special equipment was designed and fabricated for discharge and temporary storage of uranyl sulphate solution, such as:

- equipment for fuel batching discharge from the reactor vessel and loading into six temporary storage canisters ensuring the simultaneous measurement of the liquid volume;
- equipment for fuel temporary storage before its shipment for reprocessing; and
- equipment for fuel batching loading from the temporary storage canisters into transport canisters.

All equipment above ensures nuclear safety and protects the personnel from the ionizing radiation. It also prevents any unauthorized access to the uranyl sulphate solution arranged for temporary storage.

The equipment design process included several safety analyses, such as nuclear, radiation, fire and explosion (hydrogen accumulation) safety analyses, and an analysis of possible accidents. The nuclear safety expert assessment report issued by the IPPE and the expert assessment report issued by the State Inspectorate Sanoatgeokontechnazorat, the Uzbek regulating authority, have confirmed the compliance of all safety documentation with the applicable Uzbek rules and regulations.

Equipment for LSNF discharge and temporary storage is designed to be installed in the reactor hall of the main building of the Foton IIN-3M reactor (Fig. 1). The equipment was tested at the production site of Sosny R&D Company, delivered to JSC Foton in October 2013, mounted and commissioned in January 2014 on completion of the personnel training.

Fig. 1. Half-mounted equipment for LSNF discharge and temporary storage in the reactor hall

2. LSNF discharge from reactor and fuel inspection

On completion of mutual tests of the equipment and the personnel training, the uranyl sulphate solution was discharged from the reactor core in September 2014 using the equipment for LSNF discharge and temporary storage and the special developed procedure. The volume of the discharged fuel was measured. The fuel was loaded into the temporary storage canisters (Fig. 2).

Fig. 2. IIN-3M reactor. Readings on the control monitor during the LSNF discharge from the reactor

The personnel exposure during these operations was significantly less than the admissible limits.

Also during the inspection a volume of fresh and irradiated fuel located in the isotope storage room was measured using the measuring cylinder (Fig. 3).

Fig. 3. Measuring the volume of the fuel samples taken in the isotope storage room

The results of the fuel inspection were recorded in the report and used to conclude a Foreign Trade Contract on the LSNF removal from the Republic of Uzbekistan to the Russian Federation.

3. Equipment for LSNF loading into SKODA VPVR/M cask and for air shipment

The transport and handling plan for the liquid spent fuel shipment from Uzbekistan to the RF was prepared basing the multi-modal principle:

- load the LSNF-containing canisters into the SKODA VPVR/M cask on the IIN-3M site; load the SKODA VPVR/M package into the ISO container; install the ISO container with the SKODA VPVR/M package on the truck and transport it to the Tashkent airport by road;
- build up the TUK-145/C package (SKODA VPVR/M cask + energy absorbing container) (special truck is a property of Mayak PA and will be delivered to the Tashkent airport by air beforehand, as well as the energy absorbing container); load the TUK-145/C package installed on the truck on board the aircraft and transport it to the Russian Federation;
- unload the TUK-145/C package installed on the truck from the aircraft in the Ekaterinburg airport; transport the TUK-145/C package to Ozersk by road and receipt the TUK-145/C package containing the liquid spent fuel at Mayak PA.

Fig. 4. Loading TUK-145/C package installed on a truck into AN-124-100 Ruslan aircraft

Two certificates of approval for the package shipment were prepared: Certificate of Approval for SKODA VPVR/M Package Design and Shipment№ RUS/3205/B(U)F-96T authorizing its transportation by road within the territory of Uzbekistan and Certificate of Approval for TUK-145/C Package Design and Shipment № RUS/3197/B(U)F-96T(Rev.1) authorizing its transportation by air and road within the territory of the Russian Federation.

A special canister was designed to ensure safe transportation of the liquid spent fuel in the transport packaging. The canister consists of a body and a cap (Fig. 5). The canister body is a tight cylindrical welded assembly. A lead shield plug seals the internal space of the canister from the top. It ensures the personnel protection from the ionizing radiation from the liquid spent fuel in the vertical direction during the canister cap installation and removal, the canister connection to the systems for pouring the LSNF in/out of the canister and during the leak testing. There are two connectors in the canister neck: one for fuel and one for gas. The gas connector is intended for vacuuming the canister while filling it with the liquid spent fuel, for replacement of the gas medium and for weld leak testing after the canister filling with the LSNF. The gas connector is a quick pipe fitting with a shutoff valve installed in the gas branch pipe. The branch pipe in the lead plug connects the gas connector with the inner cavity of the canister.

The calculations of the state of the canister loaded with liquid SNF under accident mechanical impact resulted from vertical axial fall of the canister by the bottom on the solid target from the elevation of 1.7 m (maximum possible elevation of the canister fall when they are in the cask) allowed making the conclusion that the integrity and tightness of the canister are maintained that excludes release of liquid SNF from the canister.

For transportation of canisters with liquid SNF it was decided to use TUK-145/C that had previously been used to transport RR SNF from Vietnam and Hungary by air. The system of special polyethylene energy absorber of four types (Fig. 6) was added into the cask for this shipment. They were installed into the free cells of SKODA VPVR/M cask as well as on the top and bottom of each canister providing additional dynamic absorption of dangerous radioactive content of the package.

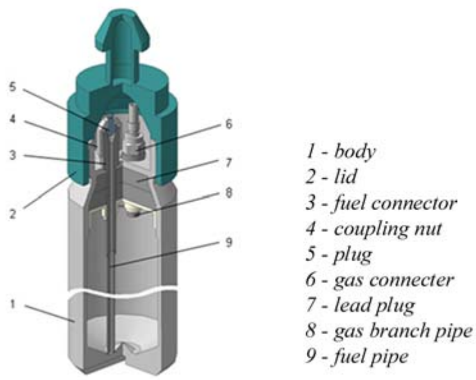

Fig. 5. Transport canister

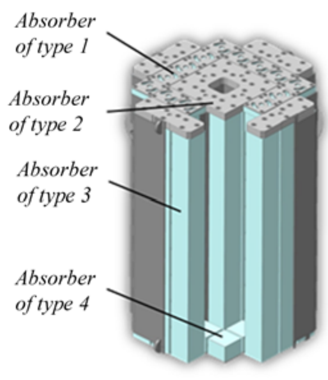

Fig.6. SKODA VPVR/M basket

Impact of the TUK-145/C cask loaded with canisters with liquid SNF onto a solid target at a velocity of 90 m/s was calculated to support the selected design. It was determined that in all considered cases of impact (axial, side and angle) canisters with liquid SNF inside SKODA VPVR/M cask maintain their integrity and tightness that excludes release of liquid SNF from canisters and its appearance inside SKODA VPVR/M cask in case of air crash.

Nuclear safety of package design and shipment is justified by IPPI export assessment reports No.14-033 and No.13-152, respectively.

The technology was developed for loading liquid SNF of IIN-3M RR into casks that provides for the following:

- portion loading of uranyl sulphate solution from temporary storage canisters into transport canisters;
- performance of leakage tests of transport canisters and verification of their mass;
- loading of canisters with liquid SNF into SKODA VPVR/M by the transfer cask.

Equipment previously used for loading SFA at Dalat Research Reactor Institute in Vietnam, for example, handling platform, support plate with an adapter and guide pins, was partially applied to implement the technology. The part of the equipment was specially designed for this shipment including transport canisters, transfer cask, grapples, shock absorbers.

In October 2014 in the Czech Republic at UJV Rez the equipment was tested for compatibility with SKODA VPVR/M cask and equipment used during removal of SFA from Vietnam (Fig. 7).

Fig. 7. Dry Run of equipment to verify its compatibility with SKODA VPVR/M cask

After the Dry Run the equipment was transported to Uzbekistan. At the same time the second batch of the equipment designed by Sosny Company containing ramps, pallet truck, leak test station, buffer tank, weighting module and transport canisters was also transported there. After assembling the equipment in the reactor room the reactor personnel was trained and related certificates were issued. In March 2015 after the related Dry Runs the equipment was commissioned.

Fig.8. Dry Runs of equipment on site of IIN-3M reactor

Safety of the equipment for loading liquid SNF into the transport cask and its compliance with the existing rules and regulations of Uzbekistan were confirmed by the related analysis and expert assessments.

4. Equipment for receipt of LSNF at Mayak PA

In 2013 Transport and Technological Scheme of acceptance, temporary storage and reprocessing of LSNF was developed, U extraction parameters were optimized, measures to compensate the effect of the corrosive solution on the equipment were developed and parameters of radioactive waste resulted from LSNF reprocessing and handling procedure were refined for Mayak PA to accept a new type of SNF.

Special equipment was designed to implement this scheme: the grapple and fixation for unloading LSNF from transport canister and the line for discharge of LSNF into technological reprocessing apparatus. Within the frame of safety assessment of the designed equipment the strength, fire and explosion safety, radiation and nuclear safety were calculated. Nuclear safety was validated by technical expert assessment report No.14-036 made up by Nuclear Safety Department of FSUE “SSC-IPPE”. After developing technological procedures and instructions for Mayak PA as well as performance of the expertise by specialists of Scientific and Engineering Center for Nuclear and Radiation Safety the License of Rostechnadzor for acceptance, temporary storage of packages and reprocessing of IIN-3M RR LSNF of Foton at Mayak PA was issued.

During 2014 equipment for acceptance, temporary storage and handling of LSNF at Mayak PA was fabricated in compliance with the design documents prepared by Sosny Company. Fabricated and assembled equipment was commissioned after fabrication tests.

CONCLUSIONS

In September 2015 the canisters were loaded into the transport cask on the site of IIN-3M reactor (Tashkent). The first batch of LSNF was transported by air to the radiochemical plant of Mayak PA for reprocessing.

Technologies developed for preparation for shipment and reprocessing of LSNF of Uzbekistan can be used for handling SNF of Russian solution reactors. Besides, the technologies can be applied for shipments of other highly-radioactive uranium liquids for reprocessing at Mayak PA.