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APPROACHES AND METHODS TO ENSURE SAFETY OF INTERNATIONAL TRANSPORT OF RUSSIAN RESEARCH REACTOR SNF

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ABSTRACT

International Russian Research Reactor Fuel Return (RRRFR) Program is a part of the program to reduce research reactor nuclear fuel enrichment and closely associated with it. Removal and delivery of HEU SNF from reactor pools to the RF reprocessing facility under the RRRFR program revealed new opportunities for delivery of fresh LEU fuel and extension of the research programs.

On the other hand, implementation of the RRRFR Program raised many regulatory, legal and administrative issues and catalyzed resolution of many practical issues raised during transportation of nuclear materials.

The report presents the related experience of the Russian organizations participated in this program. The basic technical solutions aimed at enhancement of nuclear material transportation safety are provided. It is shown that these technical solutions result in enhancement of the efficiency and quality of the transportations.

1. Introduction

Safety-related issues are the key ones for each operation with SNF. SNF transportation requires more attention to safety since it attributes to the larger number of dangerous situations and risks. In this report the term "SNF transportation" covers both nuclear fuel transport and preparation for transport including planning, certification, preparation of conveyances and accessories, creation of support equipment, designing of SNF loading technology. Such a definition allows comprehensively demonstrate the approaches and methods to ensure safety, used during implementation of the RRRFR Program.

RRRFR Program involves a lot of Russian organizations. One of them is Research & Development Company "Sosny", which performs SFA characterization at research reactors,

designs equipment for SFA loading into casks, modifies transport means to ship SFA packages, prepares justifying documents that are included into the Unified Project, participates in creation of equipment to operate non-Russian casks on the territory of the Russian Federation, arranges nuclear material transportations.

Below there are examples of activity of R&D Company "Sosny". A lot of these decisions are unique and aimed at ensuring transport safety at all stages of the project implementation: beginning with SNF repackaging up to its reprocessing. Safety is of primary importance for the International Transport of Russian Research Reactor SNF.

2. Preparation of Unified Project to import RR

Import of RR SNF into the Russian Federation is bound to development of the Unified Project. The Unified Project (UP) comprises the documents related to ecological aspects of SNF import and reprocessing as well as to a number of legal, economical, technical and administrative issues. Documents of the UP need to pass state ecological expertise review in the Federal Service for Ecological, Technological and Atomic Supervision (Rostechnadzor). Only if the Rostechnadzor commission issues the positive outcome of the state ecological expertise review, it is possible to implement the provisions of the Foreign Trade Contract (FTC).

R&D Company "Sosny" is committed to perform the following tasks being important for preparation of the documents of the UP.

Develop Transport and Technological Scheme for SNF Shipment including selection of the route, loading/unloading points, mating the transport means, selection of the specific conveyances, casks, loading/unloading equipment, legal justification of the necessity and feasibility for transportation, determination of the executors, distribution of responsibilities, cost estimation, development of the schedule for work implementation.

The most important final goal and at the same time condition for development of the Transport and Technological Scheme (TTS) is to ensure transport safety. Finally, the TTS is the project concept and technically, economically and legally justified optimum plan for SNF transport beginning with setting the task and getting acquainted with the transport subject, finishing with SNF reprocessing and determining the fate of the radioactive wastes (RAW). TTS is developed for each project of RR SNF import into the Russian Federation. Thus, for nowadays the Russian specialists arranged a lot of multimodal RR SNF transport by road, rail, sea and air (fig. 1, 2).

Fig. 1. ISO-containers with SNF are ready to be transported by road in Hungary

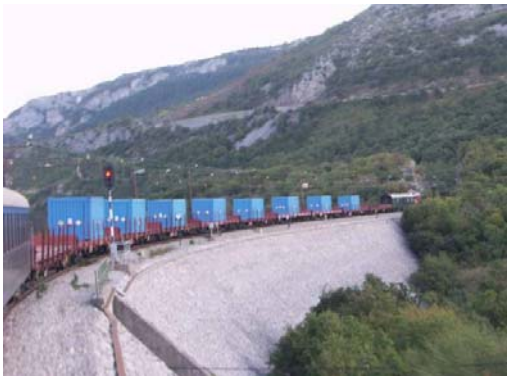


Fig. 2. The train of ISO-containers with SNF goes through Slovenia

Justify ecological safety during implementation of the UP. Russian legislation imposes very restrictive requirements on SNF import. In particular, regulatory documents require that after SNF import and reprocessing ecological situation in the region, where the reprocessing facility is located, not become worse, but even due to implementation of the ecological programs become safer. Proofs for ecological safety of the project as well as technical and administrative actions to ensure radiation, nuclear, fire and industrial safety at all stages of SFA and reprocessing product management are specified in the documents jointly prepared by specialists from the reprocessing facility, regional administration, ecologists and experts form R&D Company "Sosny". In the region of "Mayak" radiochemical plant, where RR SNF is reprocessed, rehabilitation activities are being performed on the contaminated sites of the Techa River; contaminated areas are being re-cultivated, special nets of "PA "Mayak" radiochemical plant are being created to reprocess wastes accumulated during implementation of the defense programs.

Develop methods for determination of conditions for RAW return. During preparation of the Foreign Trade Contract (FTC) for handling SFA the serious issue is a concurrence of the conditions for RAW return to the SFA supplier. In the FTC it is necessary to specify the inventory, composition, physical form, amount, type of the packaging for the reprocessing products to be returned. It is required that the amount of the returned products be determined in accordance with the approved methods proceeding from the condition of equivalency of the activity of the imported SFA and activity of the reprocessing products. Therefore the SFA supplier and the consignee (radiochemical plant) need to agree on the criteria for equivalency of the activity of the imported SFA and RAW to be returned. R&D Company "Sosny" proposed its own original method to determine conditions for the activity equivalency: the amount of the RAW to be returned needs to be calculated proceeding from the conditions of equality of the total dose equivalent of the activity of radionuclides in the returning RAW and in the supplying SNF batch at the moment of the reprocessing product return. At present this method is approved by Rostechnadzor and State Corporation "Rosatom". It is possible to adapt it for RR SNF import from all countries, to which RAW needs to be returned after RR SNF reprocessing.

3. Certification of RR nuclear fuel

The key documents that ensure safety of package design and transport of nuclear materials are certificates. Due to variety of nuclear fuel inventory and conditions for transport it is impossible to develop and approve a universal certificate for all transports. Therefore safety is justified for each transport.

Requirements to the certificates include the necessity for calculation and experimental justifications of nuclear and radiation safety, thermal regimes, strength. Performance of such calculations require acquisition and analysis of a number of data related to the parameters of the casks, inventory and physical conditions of SFA, its nuclear and radiation properties, character and the route for transport, conveyances, quality assurance, analysis of the potential accidents. This work is performed by R&D Company “Sosny” together with the leading Russian institutes and regulatory agencies.

The examples of uncommon tasks being resolved during certification of RR SNF transportation could be the cases of preparation of the certificates for SNF transport by air and transportation of RR SNF in untight canisters (the specifics will be provided below). It is necessary to underline reasonable position and professionalism of Russian specialists and first of all the representatives of the State Corporation “Rosatom” in resolving these issues. Comprehensive understanding of the importance and responsibility in arranging of RR SNF import by all involved parties allows resolving the issues being unique not only in the RF but for the whole world.

At present the inventory of transport packages certified for RR SNF transport in the RF comprise TUK-19, SKODA VPVR/M and TUK-128. TUK-19 was certified for transport by all possible transport modes: road, rail, sea, air. It became possible due to creation of a transport overpack.

4. Designing of transport overpacks for multimodal shipments

The most efficient solution of the issue of multimodal transportations is unification of transport means, in particular, usage of standard transport overpacks. The example can be fabrication, testing and certification of 20-feet ISO-containers for transportation of TUK-19 casks with SNF. The transport overpack for TUK-19 casks (fig.3) is based on the specialized 20-feet freight container that complies with the requirements of ISO standards, international conventions and industrial regulations for dangerous cargo transportation by different transport modes. The ISO-container is equipped with a set of tie-downs for TUK-19. The design of the TUK-19 package in the overpack passed expertise on compliance with Russian and international requirements for transportation of radioactive materials and all related certificates were issued. The new transport overpack significantly extends the possibilities to handle and transport TUK-19 casks. Transportation of TUK-19 does not require special railcars, special tie-downs, etc. All tie-downs of the ISO-container are standard; it can be installed in the aircraft (fig.4), in the hold of the vessel, on the typical rail platform or on the trailer. The ISO-containers are loaded by standard loading equipment that is available in any cargo terminal.

Fig. 3. Transport overpack for ISO-container to transport TUK-19

Fig. 4. Transport overpacks loaded into the cargo section of AN-124-100 aircraft

Similar transport overpack exists for another cask to transport RR SNF. SKODA VPVR/M casks are installed in a standard 20-feet ISO-container in the same way (fig.5) and such the overpacks are easily arranged in the conveyance (fig.6).

Fig. 5. SKODA VPVR/M cask is installed into ISO-container

Fig. 6. Transport overpacks are loaded into the hold of "MCL-Trader" vessel

5. Extension of conveyance fleet and routes for RR SNF shipment

Preparation of international transit agreements to transport RR SNF by rail is the time consuming process. It is possible to avoid transit-related difficulties by transporting RR SNF by sea and air. Both ways of SNF transport in the RF used to be exotic up to the recent time. However, in 2008-2009 under RRRFR Program RR SNF transport was certified and the pilot RR SNF shipments by air and sea were performed. Such shipments became possible due to making a number of new technical decisions including designs that were mentioned, fabrication and certification of equipment for shipment of TUK-19 casks with SNF by air.

Another group of issues that have to be resolved by R&D Company "Sosny" is modification of the transport means for RR SNF transport. The example is alteration of the vessel for general use into the vessel for SNF shipment. The design for the re-equipment of the Russian motorvessel "MCL-Trader" (home port is St. Petersburg) was developed and then alteration of this vessel was performed under supervision of international classification organization. All required vessel

documents were modified, the vessel personnel was specially trained and certified. The vessel obtained international certificate of INF-class and made the first shipments of RR SNF in September 2009 (fig.7). It should be emphasized that the vessel has sufficient water displacement, possibility to load packages by the vessel cranes; she is adjusted for trips in northern seas and consequently it is of higher safety level. The vessel is planned to be widely used in the RRRFR Program.

As for air transport the main obstacle for RR SNF transport was safety justification. However this task was also resolved. In accordance with IAEA safety regulations for certification of TUK-19 as "B(U) " package for SNF transport by air, additional justification of subcriticality was performed for the enhanced tests: puncture tests, thermal tests and crash tests. All additional requirements to resist enhanced impact of external temperatures, internal and external pressures, acceleration and vibration were met. The pilot air transport of RR SNF to Russia under RRRFR Program was in July 2009, the second is planned for November 2009. In both cases AN-124-100 aircraft "Ruslan" is used (fig. 8).

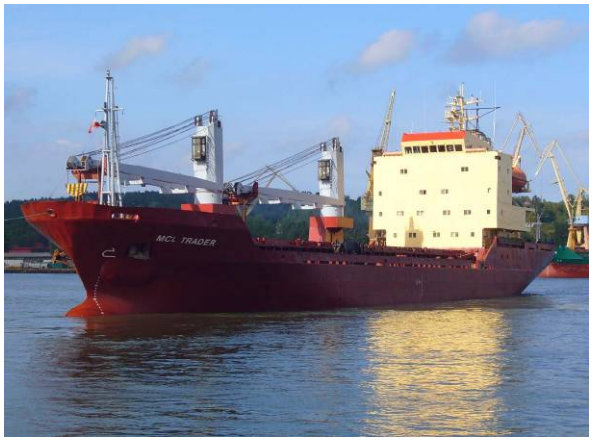


Fig. 7. Russian vessel of INF-class "MCL Trader"

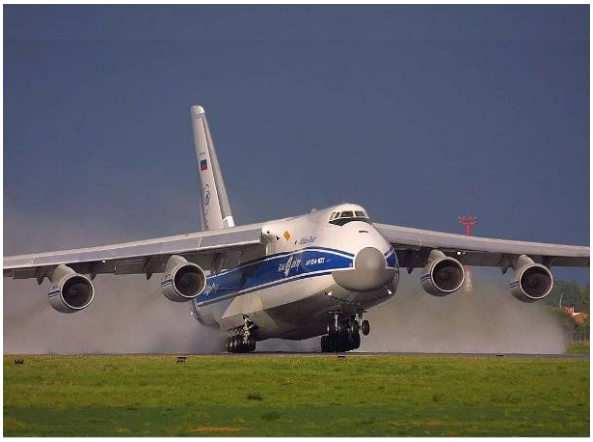


Fig. 8. AN-124-100 aircraft "Ruslan"

Thereby at present the fleet of Russian carriers of RR SNF includes all possible transport modes: road, rail, sea and air (fig.9, 10).

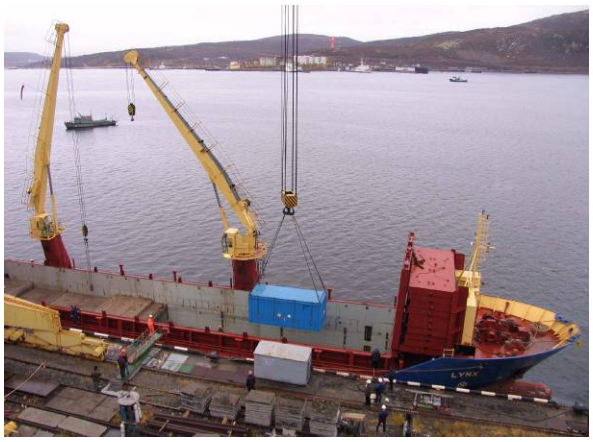


Fig. 9. Unloading SNF packages in the sea port of Murmansk (Russia)

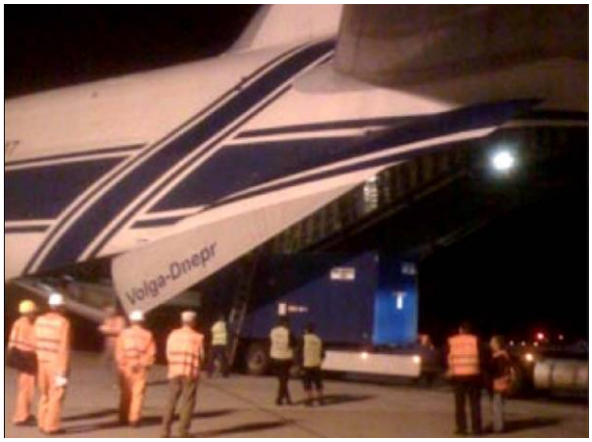


Fig. 10. Loading SNF packages in Otopeni airport (Romania)

6. Designing equipment to accept non-Russian casks in Russia

In the world there is a significant number of casks to transport RR SNF. However, their use worldwide is limited by the requirements of national legislation and technical capacities of the facilities that accept casks and reprocess SNF. For instance, PA "Mayak" is the basic Russian facility that reprocesses RR SNF. Traditionally PA "Mayak" accepts Russian casks. All necessary equipment is available in the acceptance area and storage. However, under international programs not only Russian casks are used but non-Russian as well. Therefore it became necessary to adapt Russian technologies to accept non-Russian casks.

There are two tasks in resolving this issue. The first task is to design and commission the equipment to handle non-Russian casks at Russian facilities. The second is to issue technical passports, manuals, certificates in compliance with the legislation. Both tasks are successfully being resolved with participation of specialists of R&D Company "Sosny". The example could be Czech SKODA VPVR/M cask that is widely used in the RRRFR Program. All necessary devises were designed and fabricated to operate it in Russia in compliance with all requirements of the fabricator (SKODA J.S a.s.) and the owner (NRI Řež). The equipment was assembled at PA "Mayak". All necessary technical documents were prepared and concurred with the fabricator and owner. Personnel of PA "Mayak" was specially trained. The design of SKODA VPVR/M was certified in Russia.

7. Development of technology and equipment to load SNF into casks

From the safety perspective handling to the RR SNF requires special attention especially when it is damaged and untight. R&D Company "Sosny" is a designer of a large variety of support equipment to load such non-standard SNF into casks. As an example numerous tools (fig. 11) were fabricated for repackaging untight SNF of RA reactor (Serbia). The specifics of this fuel will be described later.

Another example for designing support equipment is development of the technology for loading TUK-19 by the transfer cask. This task was resolved during transportation of RR SNF from

Romania. This task was raised due to restrictive safety requirements to this operation that were imposed by Romania regulatory agency. Specialists of R&D Company "Sosny" designed equipment and procedures for loading SFA into casks, trained the personnel, demonstrated equipment operation. The key and the most complicated component of the technology was the transfer cask (fig. 12), equipped with automatic grapple for loading and unloading of the baskets with SFA. The demonstration of the equipment and subsequent loading SFA proved safety at all stages of the technology both under normal and accident operation conditions. The whole procedure for loading SNF from the pool into TUK-19 took 1.3 hours. The maximum individual radiation dose after loading one TUK-19 does not exceed 0.05 mSv.

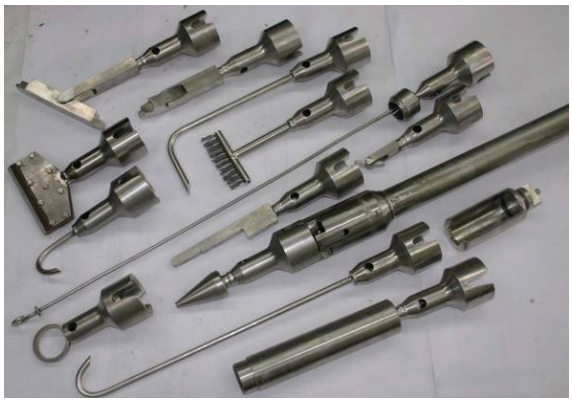


Fig. 11. Tools to repackage SNF of RA reactor

Fig. 12. Tests of the transfer cask for loading SFA into TUK-19

8. Designing ventilated canister and basket for interim storage and transportation of damaged SFA

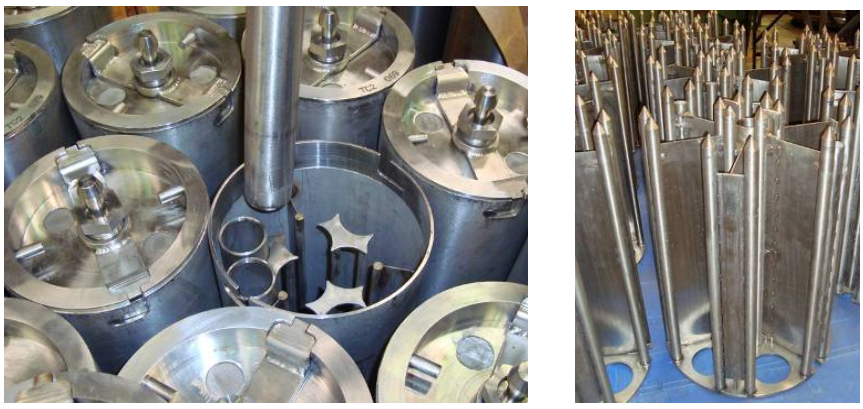
One more unique task of handling RR SNF, that was resolved in Russia, is preparation for transportation of significantly damaged RR SNF. The task was raised during implementation of the project for RA reactor SFA removal from Serbia to Russia under RRRFR Program.

The SFA have been stored for more than 20 years in the conditions favoring to the corrosion increase, therefore the significant part of SFA turned out to be leaky. Besides, in more than 80% of SFA fuel composition is metallic uranium that interacts with water and vapor. Therefore to ensure safety during transportation and interim storage of leaky SFA two issues had to be resolved: (1) exclude generation of dangerous concentrations of explosive mixture resulted from accumulation of hydrogen and (2) prevent leakage of radioactive materials from the fuel matrix into environment.

Two types of casks will be used to transport RA reactor SFA: Czech SKODA VPVR/M and Russian TUK-19. Unique canisters and baskets to provide enhanced capacity of the casks are required to arrange SNF into each of them. Thereby it was necessary to design two sets of canisters and baskets (for each cask), the design of which would provide the sufficient safety level.

The untight canisters were selected to ensure the sufficient level of fire and explosion safety. Such a design allows for the generated hydrogen to be freely released from the canister and enables to ventilate internal volume of the canister when placed in cask and change the gaseous medium. Carbon dioxide was introduced into the composition of the gaseous mixture inside the canister to suppress generation of pyrophoric uranium hydride. Periodicity for ventilation (change of gaseous medium) inside the cask was justified by calculations.

The technical decision was agreed with the operating organization ("Vinca" Institute), consignee (FSUE "PA "Mayak") and the Project customer (IAEA). By the present time all equipment for SNF repackaging was fabricated (fig.13) and delivered to RA reactor. Equipment for loading canisters with SNF into the casks will be supplied to the RA reactor at the end of this year. It is assumed that SNF repackaging into canisters will be started in November of 2009 and will be completed by mid 2010. After that the canisters with SNF will be loaded into the casks within 2 months. SNF transportation for reprocessing is planned for the end of 2010.



a *b*

Fig. 13. Canisters (a) and baskets (b) for interim storage and subsequent transportation of RA reactor SNF

Conclusions

The complexity and uniqueness of the RR SNF Removal Projects implemented under the RRRFR Program insistently require original logistical and engineering solutions. The experience gained by R&D Company "Sosny" demonstrates that the approaches and methods applied to the RR SNF handling do make international shipments safer. In addition, the harder the task was, the more attention was paid to safety issues. In the authors' opinion, the gained experience must be used as wide as possible in the international practice of SNF handling.