AVAILABLE REPROCESSING AND RECYCLING SERVICES FOR RESEARCH REACTOR SPENT NUCLEAR FUEL (INTRODUCTION OF A NEW IAEA REPORT)

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ABSTRACT

International activities in the back-end of the research reactor (RR) fuel cycle have so far been dominated by the programmes of acceptance of highly-enriched uranium (HEU) spent nuclear fuel (SNF) by the country where it was originally enriched. These programmes will soon have achieved their goals and the SNF take-back programmes will cease. However, the needs of the nuclear community dictate that the majority of the research reactors continue to operate using low enriched uranium (LEU) fuel in order to meet the varied mission objectives. As a result, inventories of LEU SNF will continue to be created and the back-end solution of RR SNF remains a critical issue. In view of this fact, the IAEA, based on the experience gained during the decade of international cooperation in supporting the objectives of the HEU take-back programmes, will draw up a report presenting available reprocessing and recycling services for research reactor spent nuclear fuel. This paper gives an overview of the guiding document which will address all aspects of Reprocessing and Recycling Services for RR SNF, including an overview of solutions, decision making support, service suppliers, conditions (prerequisites, options, etc.), services offered by the managerial and logistics support providers with a focus on available transport packages and applicable transport modes.

1. Introduction

The international activities in the back-end management of RR nuclear fuel cycle have been dominated by the programmes of acceptance of RR SNF by the country where it was originally enriched. Two programmes were created under the Global Treat Reduction Initiative (GTRI) umbrella, for US-origin and Russian-origin fuel, and they had the major goal to eliminate the inventories of HEU fresh and spent nuclear fuel stored at the RR sites worldwide. However, these programmes will soon have achieved their goals. When there are no more HEU inventories at RRs and no commerce in HEU for RRs, the primary driver for the take-back programmes will cease resulting in their phase out.

The needs of the nuclear community dictate that the majority of the RRs continue to operate using LEU fuel in order to meet the various mission objectives, including science and research, education, isotope production, etc. As a result, inventories of LEU SNF will continue to be created during the RRs lifetime with no obvious path to its disposal. Countries

operating one or more RRs, especially those with no nuclear power programme, may have to choose either to create a national final disposition route for relatively small amounts of RR SNF or to permanently shut down their RRs before the termination of the HEU take-back programmes. Finding appropriate, sustainable and cost effective solutions for the back-end management of the fuel cycle is critical to the continued use of RRs in these countries.

Developing a geological repository for SNF and high level waste (HLW) is not an easy task. Only in a few advanced countries, great progress has been made towards its implementation, including Finland, the USA, Sweden, and France. The technology and costs involved for development and maintenance of a geological repository for hundreds of years make it difficult to afford for most countries, especially for countries with one or two RRs and no nuclear power programme. IAEA, NEA and OECD continue to support the nuclear community in developing geological repositories and their efforts are reflected in a wide range of available publications, including specific safety requirements, international conferences proceedings, joint research reports, guidelines etc.

The IAEA publication presented here [1] will address the available mature options for the management of the back-end RR fuel cycle. Thus emphasis is made on reprocessing and recycling, including regulatory framework, overview of solutions, decision making support, service suppliers' conditions (prerequisites, options, etc.), services offered by the managerial and logistics support providers, with a focus on available transport packages and applicable transport modes.

Industrial entities in two countries, France and Russia, offer international SNF management services on a commercial basis. These services can provide the basis for viable RR SNF management options, depending upon their scope, technical compatibility, applicable regulatory framework, sustainability criteria, cost and accessibility.

This paper summarizes the collection of information that will be included in the IAEA publication on available reprocessing and recycling services for RR SNF.

2. RR SNF Management in France

2.1. Reprocessing and Recycling

The reprocessing process as performed at the AREVA La Hague facility [2] is summarized in Fig 1. The RR fuel reprocessing technology of the La Hague facility includes the following steps:
A - The reception and cooling step: once the fuel is received at La Hague facility, it is placed in interim storage pools for cooling. This cooling or deactivation substantially decreases the radioactivity of the fission products.
B - The dissolution step: the fuel is introduced into the existing dissolver through a pit specially designed for RR spent fuel. The dissolution is realized in a hot nitric acid solution. At this step, the process is limited by the aluminium concentration to 35-40g aluminium/L, to manage the risk of precipitation into aluminium nitrate. The resulting solution is then blended with the solution coming from the dissolution of the UOx fuel (power reactor fuel).
C - The extraction step: Uranium and plutonium are extracted from the solution by a liquid-liquid extraction process. Several extraction cycles in pulsed columns, mixer-settler banks, or

centrifugal extractors are necessary to meet the end-product specifications. At the end of these cycles, the following solutions are generated:

- a solution specifically containing the uranium;
- a solution specifically containing the plutonium;
- a solution containing the fission products and the minor actinides.

This last solution is then “vitrified”, i.e. conditioned into a stable, homogeneous and durable glass matrix, and encased in a standard canister, “Vitrified Universal Canister” (UC-V)[1]. The UC-Vs are then stored in a specific storage facility at La Hague site for cooling.

D - Following a cooling storage period, the UC-Vs are returned to the customer country for interim storage prior to final disposal.

In order to comply with the customer country’s regulations and technical constraints, the waste can also be conditioned by other means.

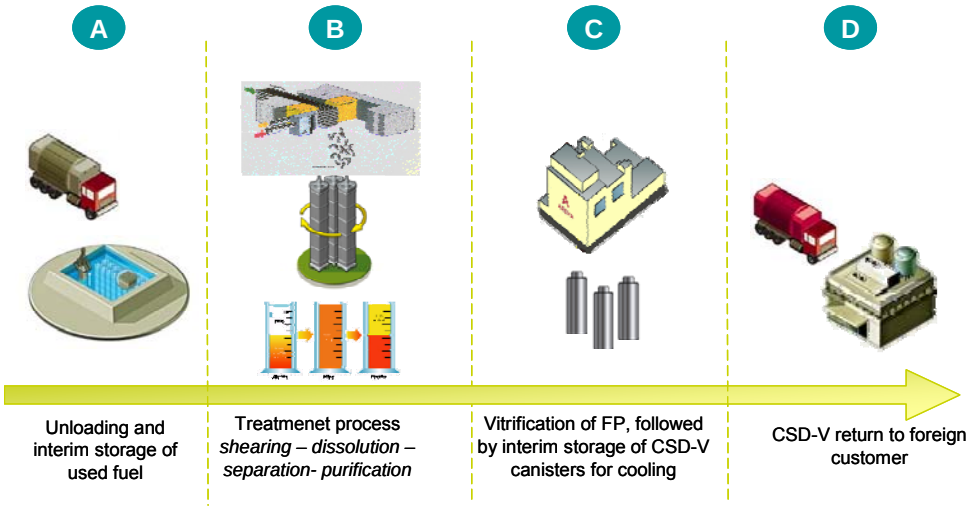

Fig 1. Schematic view of the research reactor fuel treatment process

2.2. Packages and Transport Modes

AREVA TN International, part of AREVA Logistics Business Unit, owns and operates a fleet of four TN™MTR casks (Fig. 2) whose design is based on IAEA regulations. Specific baskets have been developed for international shipments. Each cask can transport up to 68, 52 or 44 MTR radioactive elements, depending on the basket used and the SNF parameters. AREVA TN International can also propose several other types of casks which satisfy TS-R-1 IAEA 96 requirements (TN™MTR-RHF, TN-LC). A summary of the available packages and transport modes is presented in Table 1.

Package	Road	Railway	Water	Air
TN™MTR-68	Yes	Yes	Yes	No
TN™MTR-52, 52S, 52SV2	Yes	Yes	Yes	No
TN™MTR-44	Yes	Yes	Yes	No
TN™MTR- RHF	Yes	Yes	Yes	No
TN-LC	Yes	Yes	Yes	No

Tab 1: Packages and transport modes

[1] Conteneur Standard de Déchets Vitrifiés (CSD-V)

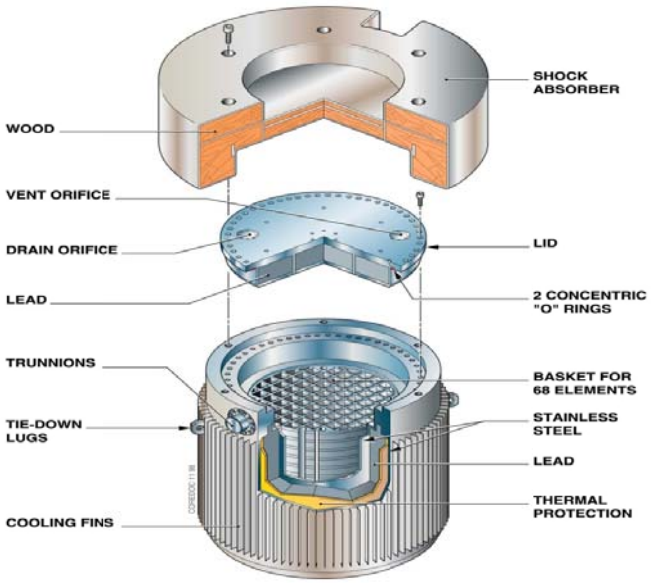

Fig 2. Artistic view of the TN™MTR Cask

Other packages, such as TN™-106 or TN™-17, can also be used depending on the customers' requirements and site constraints (e.g. existing lifting capacity, floor load limitation, special constraints etc.).

2.3. International Agreements and Licensing Summary

With the usual customer-supplier commercial and industrial relationship, the inter-governmental exchanges are to be very well considered in the whole project time frame. Except for the transportation and treatment authorization to be obtained after application to Safety Authorities, discussions for Intergovernmental Agreements (IGA) between the Governments of France and the corresponding country are to be set up. The Fig 3 bellow shows the typical schedule and main steps to be followed from first discussions and exchanges about a RR SNF management up to the effective contract signature.

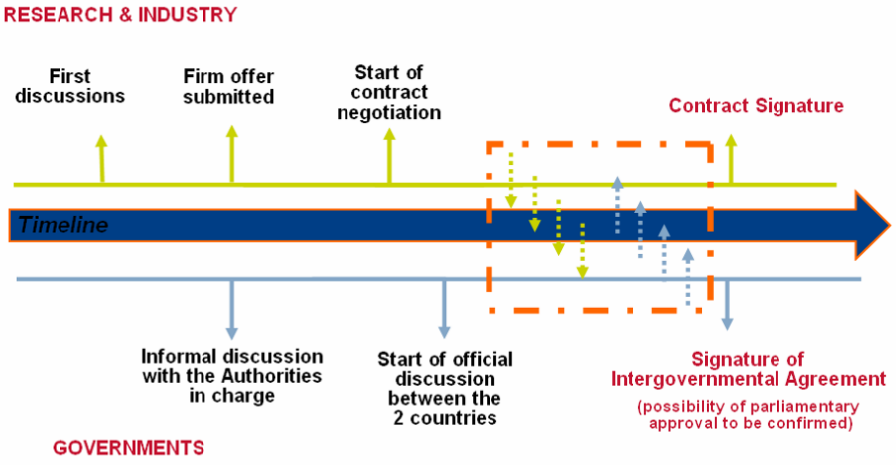

Fig 3. Typical schedule for a new RR used fuel recycling contract

This standard schedule is to be followed since 2006 French law on foreign radioactive waste management has been issued.

The IGA application is to feature three main types of information. Each of these steps is to be clearly developed in the final agreement:

- Project description: information on the material owner or related contractor (if different from the material owner), introduction of the main stakes for the owner or related contractor, location of the nuclear material, legal status and origin of the material, , the planned contractual structure for material treatment and recycling, the planned scope of collaboration between the parties;
- Acceptability of treatment: type and characteristics of material to be treated (design, total mass, mass of oxide and heavy metals, burn-up rate, cooling, initial enrichment, etc.), the material transportation (cask and transportation procedures to be realized);
- Schedule: quantities to be treated and timing, period of delivery of SNF from the customer to AREVA La Hague facility, periods of treatment, period of waste return, use/reuse of the recycled material, deadline for last return of waste.

The French approval certificates of AREVA transportation casks are regularly renewed in order for this equipment to be available for all RR SNF removal projects. Agreement extensions have to be obtained for each type of RR SNF to be transported in these casks. When needed, specific baskets can be designed and manufactured for RR SNF transportation.

Two main authorizations issued by the French Nuclear Safety Authority (ASN) are necessary in order to implement a reprocessing solution in France: transportation authorization and reception-reprocessing authorization at La Hague plant.

The AREVA reprocessing plant of La Hague has reception and reprocessing authorization for a wide range of known RR SNF. An extension of this authorization shall be obtained if the plant plans to receive new types of RR SNF. In addition, based on the past activities and experience in reprocessing various type of research and fast reactor spent fuel, AREVA has decided to launch the project of a new Polyvalent Fuel Treatment Facility (TCP[2]) at La Hague site. TCP will address various fuel specificities at the shearing and dissolution steps in order to answer varied customers' needs without hampering current La Hague reprocessing plant capacity. The new facility will substantially expand the reprocessing spectrum services of the La Hague plant.

3. RR SNF Management in Russia

3.1. Reprocessing and Recycling

At present, in Russia functions only one reprocessing facility – Mayak PA reprocessing plant RT-1, situated in Ozersk of the Chelyabinsk Region. The main distinctive feature of the plant RT-1 is a wide range of reprocessed fuel. SNF of power reactors (VVER-440 and BN-600), naval propulsion reactors, commercial-scale reactors and research reactors is reprocessed here. The distinctive features of the plant RT-1 technology are:

- Three multipurpose process lines allow not only reprocessing different fuel types on each of them, but implementing joint reprocessing of different SFAs.

[2] Traitement des Combustibles Particuliers

- Extraction of neptunium during SNF reprocessing is aimed at its separated storage and fabrication of radioisotopic products.
- Commercial output of regenerated uranium with targeted ^{235}U enrichment by means of mixing the uranium resulted from reprocessing different SNF.
- Separation of different elements from residual SNF solutions for fabrication of radioisotopic products (caesium, strontium, promethium, krypton, etc.).

The SNF, delivered to the plant, is placed into a cooling pool, where more than three meters of water above the fuel make a reliable biological shielding. The duration of RR fuel interim storage is up to 2 years before reprocessing. Safety of the SNF interim storage is ensured by highly efficient pool water purification system and radiation monitoring systems. The first stage of SNF reprocessing is to cut the SFAs into 60 mm pieces, load them into a batch-type dissolver, where the fuel is dissolved in nitric acid solution. Nitric-acid solution of fuel composition is clarified by filtering and then is reprocessed by the PUREX process. The PUREX process allows to extract and separate the valuable elements (uranium, plutonium, neptunium). The targeted products of SNF reprocessing are:

- uranyl nitrate melt, obtained from evaporation of nitric-acid solution of uranium;
- triuranium octoxide, obtained from precipitation by ammonia and subsequent roasting of the precipitate;
- plutonium dioxide, obtained from precipitation by oxalate and subsequent roasting of the precipitate.

Beside the mentioned targeted products, the plant process flow may provide full-scale extraction of neptunium and radioactive iodine. The needs of radioisotopic production require krypton (^{85}Kr), strontium (^{90}Sr), caesium (^{137}Cs), americium (^{241}Am), promethium (^{147}Pr) and other radionuclides to be separated from the spent fuel.

The safe management of radioactive waste is an important aspect of the plant RT-1 operation (Fig 4). The vitrification plant has been in operation since 1987. The principal objective of the vitrification plant is to include HLW and, partially, intermediary level waste (ILW), into the matrix of sodium aluminophosphate glass.

Fig 4. HLW treatment at Mayak PA

3.2. Packages and Transport Modes

The RR SNF can be shipped to the Russian Federation in certified transport packages. TUK-19, SKODA VPVR/M, TUK -145/C, Castor MTR2, TUK-128, TUK-135, TUK-32 (or TUK-18 cask similar to the latter) transport packages for RR SNF shipment operations have certificates in the Russian Federation (Table 2).

Package	Road	Railway	Water	Air
TUK-19	Yes	Yes	Yes	Yes
TUK-145/C[3]	Yes	Yes	Yes	Yes
SKODA VPVR/M	Yes	Yes	Yes	No
Castor MTR2	Yes	Yes	Yes	No
TUK-128	Yes	Yes	No	No
TUK-32 (or TUK-18)	Yes	No	No	No

Tab 2: Packages and transport modes

Over the past five years several air shipments of RR SNF to Russia were carried out due to the following advantages: the air shipment may help reaching difficult access places, improve the shipments schedule in big programs or when a limited fleet of transport packages can be used, assure better security in the cases of long routes and avoid dangerous goods transiting in the close proximity of communities or environmental protected zones [3]. For air transport of RR SNF TUK-19 casks have been certified as Type B(U) package and TUK-145/C as Type C package (Fig 5) [4].

a b c

Fig 5. a. TUK-19 casks in ISO container. b. Loading of ISO container on the board of AN-124-100 airplane. c. Loading of TUK-145/C cask on the board of AN-124-100 airplane.

3.3. International Agreements and Licensing Summary

The Federal Law No. 7-FL “On Environmental Protection” d/d January 10, 2002 extended the possibility for the Russian organizations to cooperate in the back-end nuclear fuel cycle services. The terms of SNF import are stipulated as follows:

- The SNF import is permitted for interim storage and/or reprocessing.
- The project shall undergo a state ecological expertise during which a general decrease of the radiation effects and enhancement of environmental safety, resulted from implementation of the project shall be justified.

[3] The TUK-145/C package represents a package-in-package design solution: the TUK-145/C accommodates the SKODA VPVR/M package converting with this the Type “B” package to Type “C”

- The basis for the import are international contracts of the Russian Federation.
- It is worth mentioning that the Law gives preference to the option of returning the radioactive waste resulting from reprocessing to the country of origin of the RR SNF.

The following project preparation procedure has been formed:

(1) Conclusion of an international contract on co-operation in SNF import (both of Russian and foreign origin) into the Russian Federation, which has the form of a government-to-government agreement with the foreign country. Two options are possible: radioactive waste (RW) return to the export country, or permanent disposition in the Russian Federation. To initiate an international contract, the authorized body of the export country has to send a corresponding letter to the State Atomic Energy Corporation Rosatom.

(2) Elaboration of the documentation for a Unified Project of SNF import. The Unified Project documentation is prepared in relation to the prospective conclusion of a Foreign Trade Contract (FTC) for operations with spent fuel assemblies subject to the state ecological expertise. These documents are elaborated and approved in compliance with the established requirements, including:

- FTC draft (containing the resulting finances for the Project implementation, and the expenses for the management of spent fuel assemblies and of products resulted from reprocessing, approved in the established order);
- special ecological programs, implemented out of the funds incoming from foreign trade operations with spent fuel assemblies;
- materials to justify general decrease of the risks of radiation impact and enhancement of environmental safety as result of the Unified Project implementation, as well as the timeframe of interim technological storage of spent fuel assemblies and reprocessing products, stipulated by the FTC;
- other materials to be submitted to the state ecological expertise assessment in compliance with the requirements of the Russian Federation legislation, including the conclusion of the Russian Federal Service for Environmental, Technological and Nuclear Supervision and the Ministry of Public Health of the Russian Federation.

Federal Centre for Nuclear and Radiation Safety (FCNRS) is authorized by the Government of the Russian Federation to sign FTCs for SNF imports.

The licensing procedure can be divided in three main steps:

- Package design approval;
- Shipment approval;
- Import/export license for nuclear commodities and technologies.

FCNRS prepares applications and obtains import licenses for SNF.

The certificate of approval for the package design and certificate of approval for shipment can be combined into one certificate of approval which can also contain the conditions for shipment of empty packages.

State Atomic Energy Corporation Rosatom, Department of Nuclear and Radiation Safety, Organization of Licensing and Approval Activities is responsible for issuing certificates of approval for package design and shipment.

4. Engineering Support, Management and Logistics Service Providers

Experience shown that engineering support is required during SNF preparation and shipment different stages:

(1) Decision preparatory phase: preparation of feasibility studies, selection of route, transport modes and packages, support in forming RR coalitions for cost and schedule optimization, development and licensing of new packages and transport means etc.
(2) Contracting: allows implementation of turnkey solutions providing project management of subcontractors, interface with authorities, schedule control, work implementation coordination etc.
(3) Licensing: according to [4] SNF is transported in Type B(U)F or C packages (for fissile materials) that require multilateral approval of certificates for package design and shipment, therefore engineering support is provided during licensing in the country of the Consignor, Consignee as well as in transit countries.
(4) RR Facility support in the shipment preparatory phase: during SNF inspection and acceptance by the reprocessing facility, development of spent fuel assemblies' loading technology in transport packages, Consignor's facility modifications for allowing the transport package handling, failed fuel repackaging etc.
(5) SNF shipment: carriers licensing, contracting and coordination, SNF loading in transport packages, preparation of shipment documents, technical escort of the shipment, interface between the Consignor, Consignee, carriers and different authorities during shipment etc.
(6) Post shipment activities: support during preparation, licensing and shipment of the HLW resulted from reprocessing back to the SNF originator country.

During many years of international cooperation lead by IAEA [5], US and Russian Governments for the implementation of the HEU take-back programmes, as well as of RR SNF commercial reprocessing and recycling services provided by France and Russia, worldwide service providers have worked together and developed experience in all above mentioned stages of SNF preparation and shipment.

AREVA TN has several decades of experience in the international transport of spent fuel by road, rail and sea, can rely on the collaboration of companies in the AREVA group and can offer efficient, reliable and safe solutions. AREVA TN's main activity is to design, manufacture and deploy packaging systems for nuclear material for both nuclear power plants and research reactors. AREVA TN has extensive experience under the U.S. Foreign Research Reactor Fuel Return Program with the transport of irradiated research reactor fuel elements (TRIGA, MTR, DIDO, etc.) to the Idaho National Lab and Savannah River Site in the USA from Japan, Denmark, Austria, Netherlands, Portugal, Taiwan, and Indonesia, shipments of LEU and HEU from the DOE/NNSA Y-12 site in Oak Ridge to France, and of fresh MTR and TRIGA fuel elements and radioisotope production targets from France to numerous countries, including the USA, Australia, Indonesia, The Netherlands, Sweden, Norway, Japan and South Africa. AREVA TN also transported nuclear fuel to AREVA's La Hague reprocessing plant from Australia, France, and Belgium. AREVA TN also has significant experience transporting irradiated targets, irradiated fuel pins, and irradiated hardware to hot cells and other research facilitates using the smaller TN-106 cask.
Beside its reprocessing and recycling activities, AREVA also provides comprehensive solutions for SNF management such as engineering work in developing waste storage and disposal equipment and facilities.

Sosny R&D Company's main activities are focused on research and development in the field of nuclear energy. Initially the company specialized in deliveries of irradiated SNF assemblies from Russian NPPs to Scientific Research Institute of Atomic Reactors - RIAR (Dimitrovgrad) for post-irradiation examinations, development of research equipment, SNF research and further analysis of the results. Later on Sosny R&D Company took part in the Russian Research Reactor Fuel Return (RRRFR) programme aimed to return research reactor fresh and irradiated fuel of Russian origin to the Russian Federation, participating in projects from Belarus, Bulgaria, Czech Republic, Germany, Hungary, Kazakhstan, Latvia, Libya, Poland, Romania, Serbia, Ukraine, Uzbekistan and Vietnam. Today Sosny R&D Company offers the following licensed services: development and supply of equipment for NPPs, RRs, subcritical assemblies, nuclear fuel cycle facilities and RW management facilities, destined for the production, reprocessing and transport of nuclear fuel and radioactive materials, research and engineering service provider to operators of facilities involving handling of nuclear materials and radioactive substances, transportation of nuclear materials and radioactive substances, development and certification of conveyances and packages (including foreign) in the Russian Federation, and those of Russian origin in other countries.

Different other contractors have proven international experience in different stages of SNF preparation and shipment: ÚJV Řež, a. s. (SKODA VPVR/M package services), SKODA a.s. (package development) and DMS s.r.o. (Class 7 dangerous goods shipment on public road) - Czech Republic, DAHER – NCS (package and shipment services) – Germany, J/S ASPOL-Baltic Corporation (SNF sea shipments) and Volga-Dnepr Airlines (fresh and spent nuclear fuel air shipments) – Russian Federation.

5. Conclusions

The upcoming IAEA Technical Report "Available Reprocessing and Recycling Options for Research Reactor Spent Nuclear Fuel" will contain a full set of guiding information on mature technologies and services for the back-end management of RR SNF that will help the RR community in finding and implementing available solutions, and so allowing the continued and safe operation of RRs in many countries.

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