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Research Reactor Back-End Operations: Growing needs and available services

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ABSTRACT

In terms of back-end, research reactors are facing today two major challenges:
- Identifying sustainable spent fuel and waste management solutions
- Defining and implementing the best fitted dismantling strategy.

Reprocessing of UAl and USi spent fuel at La Hague and all related activities have been performed since decades by Orano on behalf of international operators. Range of spent fuels that can be reprocessed has been extended; new types of casks are being developed; a new facility is to be implemented in the existing plant, thus opening additional reprocessing capacities for research reactor spent fuels.

Regarding decommissioning programs, Orano brings research reactors its strong experience in establishing efficient and cost-effective strategies for several types of nuclear facilities. In addition, Orano 40 years' nuclear operating experience and continuous R&D efforts allow providing operators with integrated waste management solutions.

Hence, Orano keeps supporting research reactors in their Back-End operations through robust and valuable solutions.

1. Sustainable used fuel management

Identification of sustainable spent fuel management solutions is a major challenge faced today by research reactor operators. In terms of Research Reactor Spent Fuel (RRSF) management up to disposal, two strategies are available (see Fig. 1):

- RRSF conditioning followed by disposal of spent fuel
- RRSF reprocessing and final waste conditioning followed by disposal of non-fissile waste.

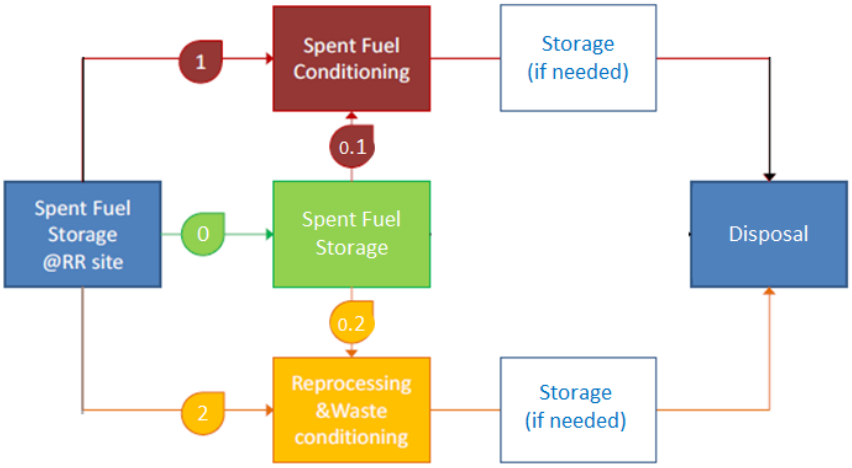


Fig. 1: Two available RRSF management strategies

Whereas technologies for conditioning of RRSF are currently under development, reprocessing of RRSF is today a mature technology implemented since years by several research reactor operators with Orano support. In reprocessing their RRSF the nuclear operators benefit from:

- Reduced volume and radiotoxicity of final waste as compared with unprocessed used fuel
- Waste packaged in form designed for stability for thousands of years
- Final waste exempted of IAEA safeguards.

These combined advantages lead to clear predictability on the RRSF management cost, to reductions of risks with regard to long-term management of nuclear materials and to optimized disposal in terms of design and operations.
Having built a strong industrial experience with RRSF handling, Orano is able to continuously develop its capabilities in order to meet with the RRSF management market expanding needs.

Transportation of RRSF

Since early 1990's, around 150 MTR-type RRSF transportation casks have been transported to the Orano 'La Hague' used fuel reprocessing plant.
As of today, the 'TN®MTR' cask (see Fig. 2) is used for transport of MTR used fuel, especially for transportation to La Hague site as well as to the US DOE Savannah River Site. Its main features are as follows:

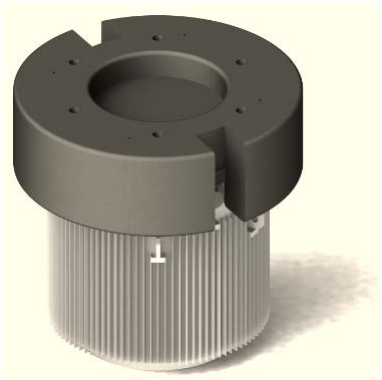


Fig. 2: TN®MTR cask

- Several types of basket, generic or specialized according to the RRSF design
- The highest RRSF transportation capacity worldwide, with a 68-positions basket
- Wet or dry loading at reactor site
- Licensed in the USA, Australia, Belgium, France, Indonesia, Portugal, the UK.

A new package, the 'TN®LC' cask (see Fig. 3), is also proposed for transportation of used fuel from research reactors, full-length commercial irradiated fuel assemblies, irradiated pins, with following main features:

- Designed for handling of NRU/NRX, TRIGA fuel elements, MTR fuel elements and more
- Loading or unloading in vertical or horizontal position
- Operation in wet or dry conditions
- Licensed in the USA, several foreign validations underway.

Fig. 3: TN®LC cask

In 2017, the RRSF transportation service offer was extended: transport (for reprocessing purpose) of non-intact aluminium-cladded fuel is now authorized by the Belgian and French Safety Authorities, based on the use of aluminium cans designed by SCK•CEN [1] with Orano support.

RRSF reprocessing operations

Through conditioning of final waste under strongly optimized and stable form, reprocessing of RRSF allows to:

- Obtain clear predictability on the RRSF management cost,
- Reduce the risks with regard to long-term management of nuclear materials and
- In the end move to an optimized disposal in terms of design and operations.

Starting at 'Marcoule' reprocessing plant and up to the 90's, 18 tons of UAl-type RRSF from 21 reactors in 11 countries have been reprocessed by Orano.
Since 2005 and as of mid-2018, more than 10 additional tons of UAl-type RRSF have been reprocessed at industrial scale at the Orano La Hague plant which has been initially designed for reprocessing of LWR used fuel (over 30,000 tHM reprocessed since end of the 70's).
The reprocessing operations on La Hague site [2] are summarized in Fig. 4.

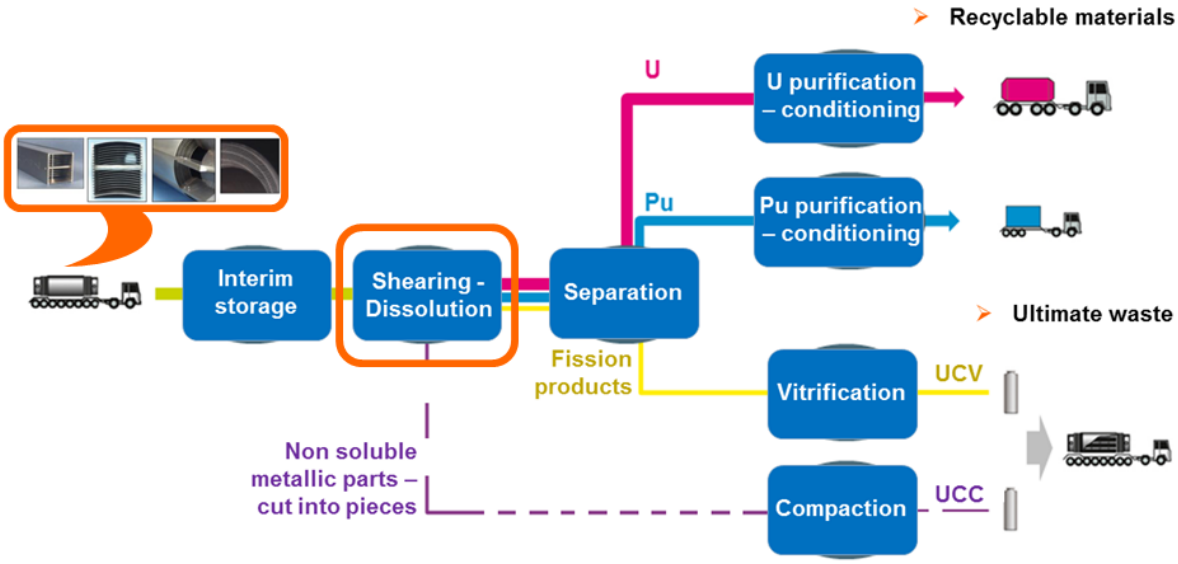


Fig. 4: Process diagram for RRSF reprocessing on La Hague site

The U-Al RRSF specific reprocessing operations mainly take place at the dissolution step.

From wet storage pool to the dissolution facility, the RRSF is transferred with a shuttle basket with operations performed by operators with dedicated cranes and tele-manipulators. The RRSF are then loaded in the dissolution pit one by one by directly dropping them in the boiling nitric acid. The dissolution process is controlled thanks to a dedicated camera placed on the top of the dissolution pit.
Once the RRSF batch is completely dissolved, the solution is mixed with LWR dissolution solution coming from the other dissolution lines.

The first industrial Silicide fuel reprocessing campaign was performed at La Hague plant in 2017 [3]. The process is the same as for U-Al RRSF except for one additional operation performed prior to the mix with the LWR dissolution solution: separation of Silicon from the dissolution solution.

In 2017 also, reprocessing of non-intact aluminium-cladded fuel was authorized and performed based on the use of aluminium cans designed by SCK•CEN with Orano support.

In order to meet with expanding needs in terms of RRSF management, a new Special Fuel Treatment facility is to be implemented in the existing La Hague reprocessing plant opening thus additional reprocessing capacities for special fuel like RRSF and allowing also to extend even more the range of special fuel which can be reprocessed. This future facility, called 'TCP' (see Fig. 5), will benefit from Orano's industrial spent fuel reprocessing feedback while taking part in the next steps towards a fast reactor fuel cycle development using innovative treatment solutions.

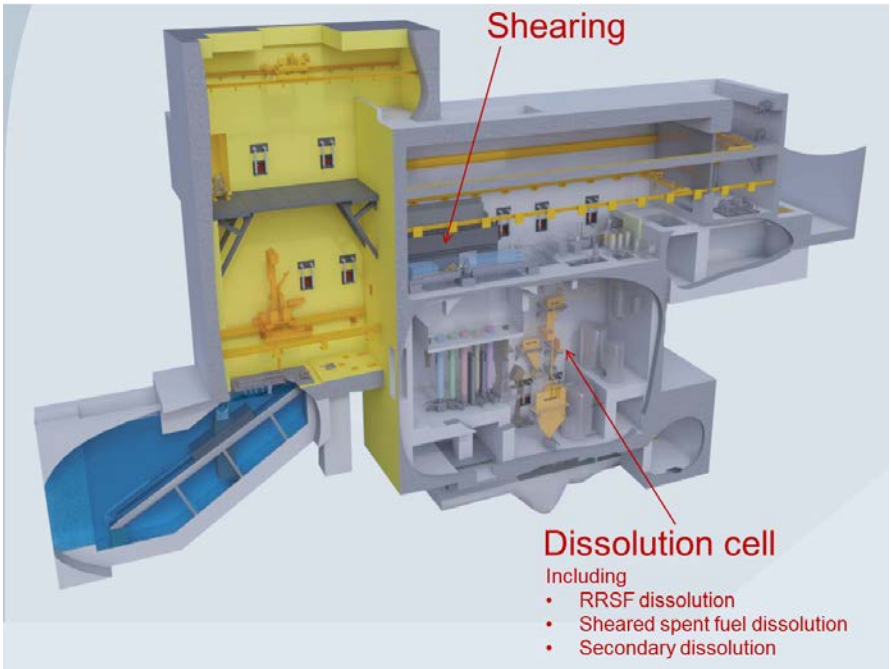


Fig. 5: Overview of main TCP facility operations

Management of final waste produced from reprocessing

As per French law [4], any introduction of spent fuel or radioactive waste from abroad onto the French territory shall only be authorized pursuant to intergovernmental agreements and provided that no residual radioactive waste resulting from the processing of such substances shall be stored in France beyond the term prescribed by such agreements.
At Orano La Hague plant, the waste accountancy system determining the amount of waste to be returned to the country of origin is compliant with the French law.
The equivalence is determined with two units being the residue activity unit (UAR) based on neodymium content (in dg, because it is a representative indicator that can be effectively measured), and the residue mass unit (UMR) based on weight of non-soluble metallic structural components of the spent

fuel (in kg). UAR and UMR are sent out of France under the form of Universal vitrified residues Canister and Universal compacted residues Canister respectively (see Fig. 6):

- Vitrified residues. The fission products and minors actinides are vitrified in a homogeneous glass matrix and conditioned in Universal Canister (high activity UC-V or intermediate activity UC-U). This type of conditioning is very stable and ensures containment over thousands of years.
- Compacted residues. Structural waste coming from non-soluble-cladded fuels are compacted and conditioned in Universal Canister (UC-C) with the same external geometry as UC-V/U.

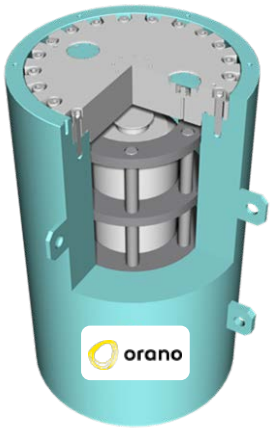
Fig. 6: UC-V (or U) and UC-C with height 1.3 m / 4.3 feet

Conditioning of final waste into Universal Canisters leads to multiple benefits:

- Simplified transport and on-site handling conditions thanks to standardization,
- Volume saving in storage/disposal facilities,
- High stability of the residues demonstrated for the very long term,
- Exemption of IAEA safeguards and
- Rationalization of the ultimate waste policy through standardized type of waste.

UCs are managed today in Australia, Belgium, France, Germany, Japan, the Netherlands, Switzerland and the UK [5]. Casks for large quantities of UCs (up to 28 UCs, vitrified type or up to 20 UCs, compacted type) are operated today on routine basis:

- The TN®28 cask (transport) licensed in Belgium, France, Japan, the Netherlands and the UK,
- The TN®81 cask (transport and storage), licensed in Australia, France, Spain, Switzerland, and the UK.



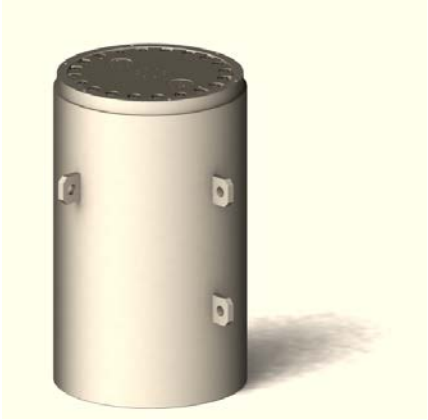
The hereabove casks may not be adapted to the return or storage of small quantities of radioactive residues.
The 'TN®MW' cask design having been licensed by the French and Belgian Safety Authorities for transport of nuclear waste, an adaptation of this cask for accommodating one UC is being developed (see Fig. 7).

< Fig. 7: Concept of TN®MW cask for one UC

RRSF dry storage

Decision can be made for putting in place an intermediary step before implementation of one or the other available RRSF management strategies. In such a case, research reactor operators may need modular dry storage solutions.
Orano will be able to propose in the near future a cask for transport and storage of radioactive material with fissile content such as RRSF (see Fig. 8). This concept is based on existing TN®MW cask design [6]:

- it has been licensed in 2017 by the French and Belgian Safety Authorities for transport of material resulting from production of Molybdenum 99
- two first units have been successfully delivered and loaded on client's site in the following months and two others are about to be delivered to same operator.



Such solution presents following advantages in terms of support to reactor operations:

- Modularity
- Flexibility keeping door open to both RRSF management strategies
- Support to management of spent fuel storage pool capacity.

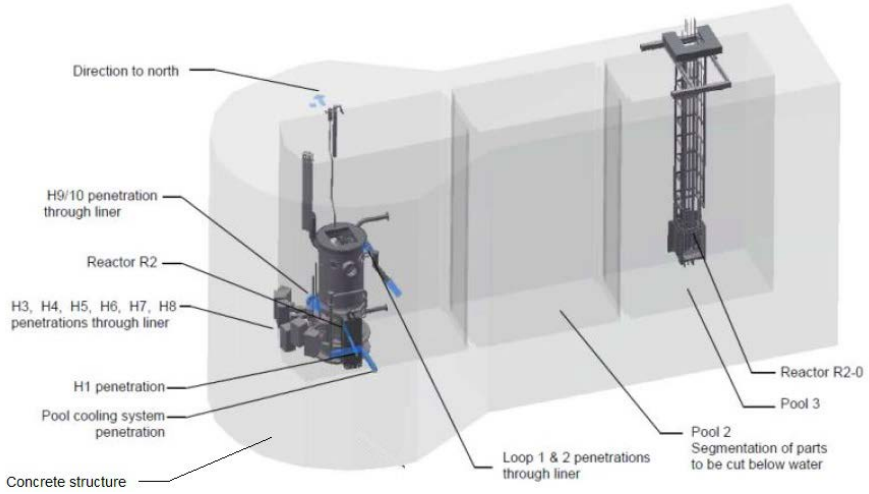
< Fig. 8: Concept of TN®MW cask for transport and storage of RRSF

2. D&D & waste management

When approaching the research reactor's end of life, the challenge faced by operators resides in conducting a safe and efficient plant rundown to reduce the radiological inventory and prepare the reactor for future works, while at the same time establishing the most adapted and economically viable decommissioning and waste management program. Operators also have to manage major issues such as budgeting and financing, relations with regulatory authorities and defining a resource management strategy.

As an owner-operator and service provider, Orano has accumulated extensive experience in D&D of nuclear facilities over the last decades. Orano is indeed in charge of the decommissioning of its own facilities such as UP2-400 treatment facility on La Hague site or the GB1 enrichment plant, and is involved in several major decommissioning programs in France, the United Kingdom, Japan, and in the United States.

Furthermore, Orano is managing full reactor decommissioning programs in France, and in the United States with the North Star alliance. It has also delivered several research reactors decommissioning projects such as SVAFO in Sweden (see Fig. 9), Phebus in Cadarache, Phenix in Marcoule, Ulysse in Saclay, as well as TRITON, EL3, PEGASE, MELUSINE, SCARABE.



< Fig. 9: SVAFO reactors dismantling scope of work

D&D planning and operations

Sufficient planning and preparation are central in the success of a decommissioning project. Orano is using all experiences of its D&D projects worldwide to provide optimized and comprehensive D&D services to support operators during the transition period from operations to the decommissioning project, and during operations.
The objectives of the decommissioning planning are to:

- Establish a robust hazard reduction, waste driven technical scenario
- Organize the resource transition from Operations to decommissioning
- Develop a stakeholder/regulator engagement process to secure the deployment of the scenario
- Establish a baseline cost and schedule to secure funding and endorsement by funding and regulatory authorities

The decommissioning plan is defined and implemented taking into account the human and financial resources as well as the local regulatory and safety requirements, with the objective to define the best fitted strategy in terms of costs, planning and technologies. Orano is present in all disciplines of the D&D, from planning (studies, concepts development, engineering and licensing) to the realization of the D&D (sampling, characterization, decontamination and components dismantling.)

The final plant rundown and the first 3 years after final shutdown are also critical transition periods that can create opportunities or risks for the future of the decommissioning program.

Waste management

Waste management is the backbone of the decommissioning program and the identification and implementation of the best fitted management strategy is known to be the crucial point to manage the total cost of dismantling. Based on its 40 years' experience in waste management, Orano proposes a unique integrated range of management solutions for legacy, operational and dismantling waste.

Characterization is the first step towards a rigorous strategy definition therefore Orano has been developing innovative waste characterization tools such as Nanopix (developed in collaboration with the CEA [7]), CartoOnline, Collecte, Riana™ and Manuela™ to provide operators with standard, simple and adaptable tools. Once thoroughly characterized, the waste can be oriented in the best stream in terms of costs, disposal approach and future environmental protection.

As regards to waste conditioning, the objective is to safely and durably stabilize the waste into a solid waste form. Orano operates more than 80% of the waste conditioning units in France and is bringing its expertise in radiolysis, corrosion, lixiviation and long-term behavior to managing waste routes in a sustainable, innovative and cost effective manner. Having conditioned and transported ~300,000+ m^3 of VLL-SL-LL French radioactive waste, Orano is also able to support research reactors with their own Safety Authorities in regards to packaging acceptance.

Orano global approach aims to minimize the costs, the volume and toxicity of the final waste as well as the incremental investments, while achieving environmental, safety, political and legal requirements.

3. Conclusion

Considering the evolution of international and national regulations, and their request for clarification of used fuel and radioactive waste management, the identification of a used fuel management sustainable strategy is one of the major challenges research reactor operators are facing today.
Upon entering end of life phase of the reactor, the operators face additional challenge relating to definition and implementation of best fitted dismantling strategy.
Based on its long-term and international experience on RRSF management in addition to successful implementation of decommissioning programs on its own and other operators' facilities, Orano is able to offer the research reactor operators up-to-date and adapted back-end services. Continuously meeting the evolving market needs, Orano is ready to set up sustainable partnerships with its research reactors customers in order to robustly manage their back-end operations.

4. Acronyms

D&D	Decommissioning and Dismantling
LL	Long Lived (waste)
LWR	Light Water power Reactor
MTR	Material Testing Reactor
RRSF	Research Reactor Spent Fuel
SL	Short lived (waste)
TRIGA	"Training, Research, Isotopes, General Atomics" research reactor type
UAR	Residue Activity Unit
UC (-V/U/C)	Universal Canister (high activity vitrified residues/intermediate activity vitrified residues/compacted residues)
UMR	Residue Mass Unit
VLL	Very Low Level (waste)

5. References

[1] https://www.sckcen.be/en

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[4] Act No.2006-739, dated 28 June 2006, on the Sustainable Management of Radioactive Materials and Waste and Decree 2008-209, dated 3 March 2008

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[7] http://www.cea.fr/english