RESEARCH AND TEST REACTOR SPENT FUEL TREATMENTAND FINAL WASTE CONDITIONING

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INTRODUCTION

Many human activities raise the major issue of waste management. As for radioactive wastes, they arise from a number of activities other than nuclear powered electricity generation itself. Those activities include applications in various fields such as medicine, industry, education and research. Research and Test Reactors (RTRs) are one of the tools used in research applications. About 600 RTR have been built and commissioned worldwide. They concern developed as well as developing countries, nuclear and non-nuclear states. The beneficial effects of those activities are not to be questioned. However, they imply that a comprehensive management is necessary for induced waste, including appropriate treatment and conditioning for ultimate disposal.

One characteristic of these activities, compared to nuclear powered electricity generation, is that they are very dispersed : for instance, 60 countries[1] across every continent are or have been operating about 600 RTRs, whereas only about 25 countries[2] have significant commercial nuclear programs.

Roughly half of the RTRs are still in operation. For the shut down RTRs as well as for the operating ones, the spent fuel issue has to be tackled. Different options are available but treatment-conditioning through reprocessing constitutes the only comprehensive and durable management. Besides, this option offers two additional advantages. Firstly, it benefits from the long experience of existing flexible industrial facilities from countries like France. Secondly, it turns RTR spent fuel into stable residues readily suitable for final disposal. Indeed, a durable solution does exist for RTR fuel management.

Therefore the real management issue of waste arising from nuclear applications lies elsewhere, in all the heterogeneous waste streams: however small, they do justify a management scheme at each stage from production to disposal.

Nuclear applications other than power generation produce large quantities of various radioactive waste

Nuclear applications are steadily growing worldwide in developed as well as developing countries as most of them use radioisotopes in other activities than power generation (let us call them "other nuclear applications"). Among the various "other nuclear applications" the following can be quoted:

- Use of sealed sources or unsealed radioisotopes in medicine for diagnosis and therapeutic purposes,

- Multiple industrial applications such as gauges, detectors, sterilizers, radiographs…
- Research and educational applications: irradiators, reactors, targets, and calibration sources.

All of such applications generate radioactive wastes which have to be managed in a durable way.

Key criteria are commonly put forward when referring to the management of these nuclear wastes. They concern the quantities involved and waste potential hazards.

Quantities and management plan: quantities of wastes from "other nuclear applications" are often underestimated and their management plans uncomplete

A common idea is that wastes arising from nuclear powered electricity are notably more quantitative than these from "other nuclear applications". This assumption has to be mitigated, considering different specific examples.

In the Netherlands, low and intermediate level waste (LILW) arising from the operation of Borselle nuclear power plant amounts each year to about 100 m^3. High level waste (HLW) results essentially from fuel reprocessing and represents around 10 m^3 each year. In the same time, use of radioactive materials in healthcare centers, research centers and industry results in a variety of waste, either solid or liquid, as paper, plastics, metals and glass, but also biomedical waste, animal carcasses, instruments or laboratory equipment and sealed sources. Whatever their kind, these waste are treated and conditioned in COVRA's central facility. Once conditioned, they amount to 200 m^3 annually[3]. The Netherlands have chosen extended storage for all their radioactive waste. Nevertheless, this choice does not imply that waste are not safely treated and durably conditioned.

In Italy, where commercial nuclear activities are today stopped following the Chernobyl accident, 200 m^3 of waste are produced annually on the sites of reactor and research centers, whereas 1,000 m^3 arise from medical and industrial activities [3]. As for cumulated quantities, waste sources and categories stand as follows:

Source of radioactive waste		**Category and percentage**
Nuclear powered electricity	NPPs	ILW, 22%
	Fuel cycle facilities	LILW from reprocessing, 21% Non reprocessed fuel, 16% ; HLW, 0.3%
"other nuclear applications"	Industry and hospitals, biomedical applications	LILW, 21%
	Research and experimental centers	ILW and HLW, 20%

For most of the accumulated radioactive wastes, a final decision regarding treatments and conditioning is yet to be taken. A disposal site for LILW has yet to be found, wastes being in the meantime stored on the various production sites.

In Australia, where there is no nuclear powered electricity, radioactive wastes come from a range of medical, agricultural, industrial and research applications, including the Lucas Heights Research Laboratories of the Australian Nuclear Science and Technology Organization (ANSTO) with the HIgh Flux Australian Reactor (HIFAR), the only Australian research reactor presently in operation.

As a result of all such "other nuclear applications", Australia has accumulated about 3,700 m^3 of radioactive waste over 40 years[4]. They are currently stored at over 50 locations within Australia. The Government works steadily at establishing a unique disposal site for all the radioactive wastes.

On the opposite, countries that operate nuclear power stations like France produce comparatively larger quantities of radioactive wastes from commercial facilities. France has early set up a comprehensive radioactive waste management policy. It includes inventories, collection and appropriate treatment and conditioning facilities for every category of waste, either produced by commercial operators or the so-called "small producers", that is healthcare, industry and research centers.

With the French policy, waste issues are solved by stages:

- Short lived LILW are disposed of since 1969 in near surface disposal centers, formerly the Manche center (CSM) and currently the Aube center (CSA),
- Long lived ILW (LLILW) and HLW ultimate evacuation is the object of R&D axes in accordance with the 1991 waste law. In the meantime, they are stored on the production site.

Some worldwide performed inquiries have shown that in most cases no comprehensive management exists for waste arising from "other nuclear applications". This fact results in particular from origin diversities and numerous contributors. In consequence, through the production and application of radioisotopes, significant quantities of radioactive waste are being produced and inventories have built up. At the moment, such radioactive wastes are often stored in the production premises, which is not a durable answer to the waste issue whatever the quantities at stake: cumulated low volumes leads to stockpiles. This issue is such that the IAEA has been implementing a comprehensive program in order to assist Member States on all aspects of collection, treatment, storage and disposal of these wastes[5].

1. Waste hazards: the categories of ultimate residues from RTR spent fuel treated-conditioned by reprocessing do not differ from those arising from "other nuclear applications"

Another widely spread idea is that wastes arising from nuclear powered electricity and RTR are more hazardous than those from "other nuclear applications".

Actually, one must keep in mind that radioactivity may not be the only hazard linked to the waste arising from nuclear applications. This is especially the case for waste arising from biomedical applications: in many instances, potential hazards constituted by chemical, biological or physical properties add to risks linked to the presence of radionuclides.

The case of spent sealed sources led to the establishment of the IAEA's Spent Radiation Source Program in 1991. This Program originated from the need to assist Member States in their efforts to prevent unnecessary exposure and even accidents with spent sealed sources. One specific topic of this program dealt with spent radium sources, which were formerly used mostly by hospitals. The small size of the sources and their high apparent value – their outer casing including platinum or gold – increased theft risks and associated irradiation accidents. In addition, obsolete manufacturing standards could result in radioactive leakage. Moreover, the long period of radium made it necessary to condition spent sources appropriately for a long-term storage awaiting the availability of a final disposal liable to accept long-lived ILW and HLW.

Conversely, reprocessing of spent fuel from either NPPs or RTRs results in well mastered stable residues appropriate for final disposal.

2. The durable management of waste: a case by case approach

Neither the supposedly low volumes produced nor the less hazardous properties of waste arising from nuclear applications other than nuclear powered electricity allow to evade waste management issues. As underlined above, one important feature of these applications is that waste produced vary greatly in origin, producers, nature, tonnage, radioactive level and type of contained radioisotopes. There is no unique solution. A case by case approach is necessary.

For the case of RTR spent fuels a durable and comprehensive management is fully operational and available. Moreover, this scheme leads to low ultimate waste volumes, conditioned as residues under the most suitable forms and a unique standardized package. These fully stabilized residues are directly suitable for disposal and a fortiori for long interim storage. Moreover, their unique conditioning simplifies the disposal facilities design and operation.

They are easy to integrate in the appropriate management schemes – even small-scale ones – which are needed in order to ensure general public safety and environment protection at all stages from waste collection, including specific processing, conditioning, up to storage and disposal.

The management of spent fuel from Research Reactors : available options

Available options for RTR spent fuel management are theoretically the same as for commercial spent fuel, and include extended interim storage, direct disposal and reprocessing. In practice however, available options depend heavily on the very special nature of the fuel.

Long term interim storage of RTR spent fuel does not constitute a reliable solution at the present time since some operators have already experienced corrosion and material degradation problems during RTR operating lives. Extended storage for RTR fuels would obviously require important R&D programs as well as costly storage facilities specifically designed and operated for the long term. Finally, this option does not constitute a definitive solution.

As for the direct disposal option, it also faces several unsolved problems arising from neutronical as well as chemical properties of RTR spent fuel. As it has already been detailed in other instances[6], on the long term, neither nuclear safety is ensured due to uranium enrichment linked criticality risks nor repository mechanical stability due to hydrogen production through corrosion processes. Third, this option remains theoretical for the time being since no repository is currently available. Moreover, the RTR spent fuel instability would imperatively need significant treatment, stabilization and conditioning works, resulting in an unsatisfying option due to the large volume of conditioned residues it implies. Final, this option is not a sustainable one due to the amounts of uranium that would thus be eventually put in the final repository.

On the opposite, the RTR spent fuel treatment-conditioning based on reprocessing is a durable, operational and comprehensive answer:

- It is an industrial reality, demonstrated by the 30-year operating experience in commercial reprocessing at COGEMA-La Hague plants. HEU fuels are typically of UAl_x chemical form, particularly suitable for reprocessing. As it has already been detailed in other instances[7], COGEMA has long since acquired the know-how from its operating experience in RTR spent fuel reprocessing.

- It has an important impact regarding the reduction of the potential radiotoxicity of ultimate waste to be disposed of. Actually, the very high efficiency achieved at La Hague allows 99,9% of uranium and plutonium to be recovered from spent fuels thus minimising residues long-term radiotoxicity as shown in the table hereafter.

Period (years)	0 to 100	100 to 100,000	100,000 to 1,000,000
Main contributor to Radiotoxicity	Fission Products & Pu	Pu	Pu then U

- Any spent fuel and nuclear material at La Hague plant is submitted to EURATOM and IAEA safeguards.

- It results in separated products conditioned under stable matrices appropriate to the activity contained and guaranteeing a safe conditioning for long term storage and final disposal. This point is detailed further.

- RTR fuels being diluted into LWR spent fuels, reprocessing is then a non-proliferating and cost-effective option.

A COMPREHENSIVE MANAGEMENT VIA REPROCESSING

Flexible processes adaptable to RTR fuels

As it has already been explained in other instances [6], the high level of flexibility of COGEMA-La Hague plant makes it possible to smoothly process RTR spent fuel. Minor adaptations are performed on purpose, especially in the existing shearing and dissolution units. The RTR fuel quantities to be reprocessed (a few tons of spent fuel per year) are diluted into power reactors UO_2 spent fuels (nominal capacity 1600 tHM per year) to blend down the U-235 content to a maximum of 2%.

After dissolution, the current chemical operations, and especially the U/Pu/Fission products separation and the conditioning of separated wastes into residues, are basically performed following the reference process. Actually, residues returned to customers are, to a large extend, "tailor-made", thanks to the flexibility of chemical processes. Thus, minor adjustments may concern plutonium recovery rates or residues characteristics within the limits of existing specifications so as to meet customers' specific requirements.

1. Integrated conditioning of ultimate waste

Waste to be finally returned to customers consist of:

- Fission products and TRU are vitrified into a borosilicate matrix, which is recognized as an internationally agreed conditioning form. According to customers specific requirements as to vitrified waste characteristics, resulting quantities to be returned are determined following the established accountancy procedures in force between COGEMA's and its current customers.
- Technological wastes and structural parts of fuel elements that contain long-lived ILW (LLILW) are compacted. This technique has been selected in the framework of a continuous waste conditioning optimization process over the years.

These specific immobilization processes ensure that the residues have a high degree of safety, durability and quality most appropriate for an extended interim storage and subsequent final disposal. Actually, the residues thus manufactured are directly suitable for final disposal without the need of any additional conditioning.

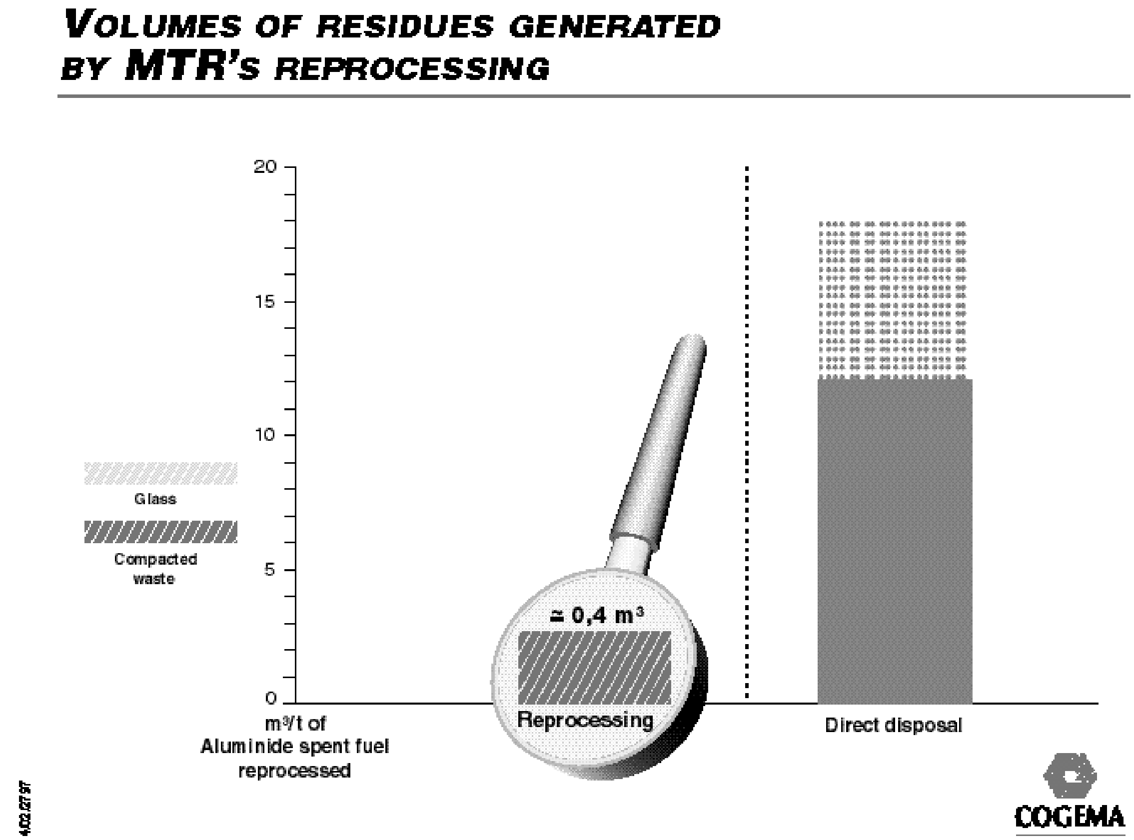
In addition, these integrated waste conditioning technologies conduct to a significant volume reduction of the residues to be disposed of :

- As regards commercial LWR, a volume reduction factor of 4 is achieved :

Reprocessed fuel residue	
Compacted + Vitrified residues	**0.5 m^3/tHM**
Direct Disposal waste	
UO_2 spent fuel	**2.0 m^3/tHM**

- As regards RTR, a volume reduction factor of 30 to 50 is achieved :

0.4 m^3 per ton of spent fuel, compared to the direct disposal option: 12 to 18 m^3 per ton of spent fuel, as shown on the following figure:

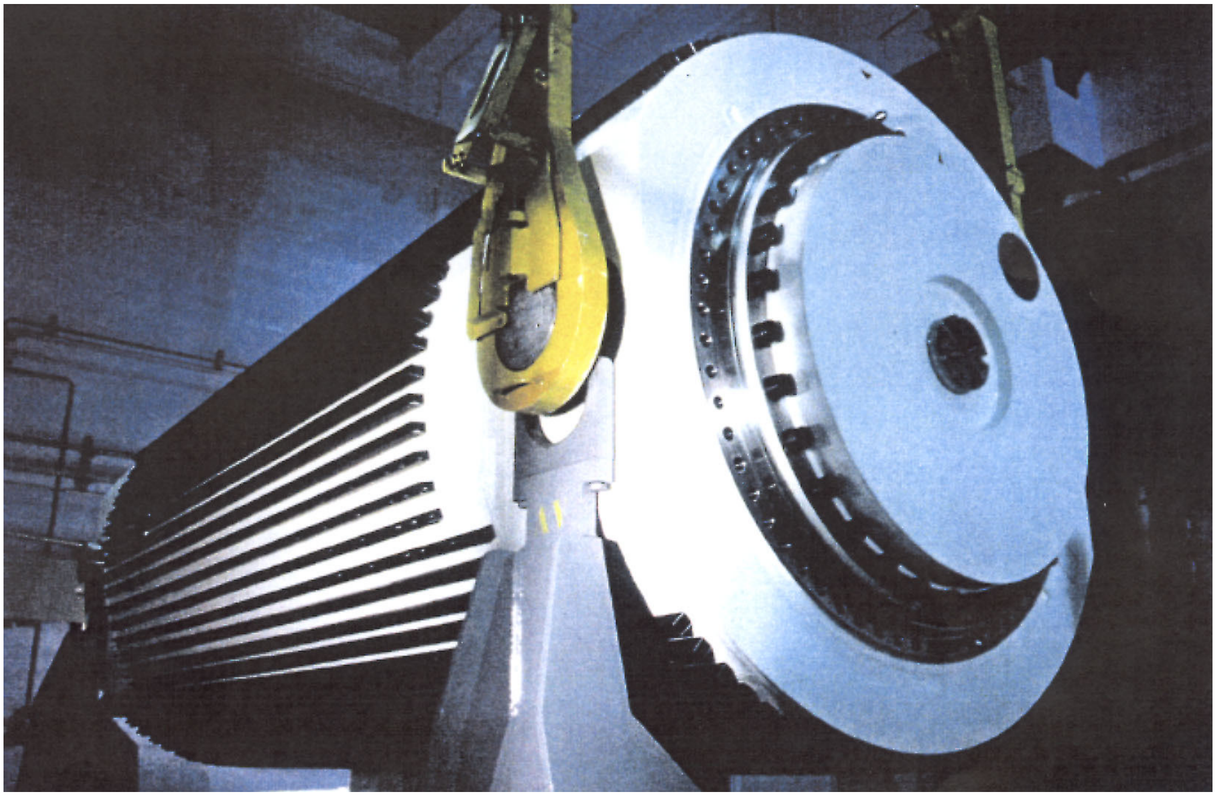


Universal Canister and dual-purpose Transport & Storage cask : a rationalized system

A major advantage of the whole waste conditioning process is the standardization of ultimate waste residues package, the so-called "Universal Canister", which comprises vitrified canisters and compacted canisters.

The Universal Canister constitutes a real benefit for the customers, as it gives them the ability to rationalize the ultimate waste management, including on-site handling, transport operations as well as waste interim storage and repositories policies.

Moreover, for the return shipment to the customer, the Universal Canisters may be loaded into dual-purpose Transport and Storage casks. Such dual purpose casks (similar to those already stored at Gorleben, Germany, as shown on the photograph here-below) constitute a significant advance since they can easily be stored in existing facilities without requiring any sophisticated infrastructure or any safeguards provision, and since no elaborate control or operating procedures are needed.



TS 28 Transport and Storage cask

CONCLUSIONS

Among the different wastes arising from nuclear applications other than nuclear powered electricity, RTR spent fuel is one for which a durable waste management option is proven and operational: the treatment-conditioning through reprocessing. One of the main advantages of this option is indeed to offer a complete RTR spent fuel management, since reprocessing operations include conditioning of ultimate waste under safe and durable matrices most appropriate to an extended interim storage and subsequent final repository, whenever operational. Actually, the residues thus manufactured are directly suitable for disposal without the need for any additional conditioning. The combination of the Universal Canister with the dual purpose cask offers an additional benefit to the customers, as it gives the ability to rationalize waste management and considerably simplifies any interim storage. Final, the reprocessing option allows a significant reduction in terms of volume and radiotoxicity of the ultimate waste when compared to direct disposal. The efficiency of such a solution is proven and some RTR operators have already entrusted COGEMA with the management of their aluminide spent fuel.

Wastes arising from "other nuclear applications", medicine, education, industry and research, lead to much larger cumulated volumes compared to residues resulting from reprocessed RTR spent fuel. They contain ILW and HLW and as such are no different from residues from reprocessed RTR spent fuel, apart from the fact that the latter are directly suitable for disposal. These other wastes are heterogeneous in terms of contaminants, degree of contamination, nature, tonnage, not to mention other potential hazards as for biomedical waste. They are not always well reported and characterized. Often, they are extendedly stored on production sites.

Consequently, this is where the real waste issue lies, justifying the different countries current efforts, even the so-called "non-nuclear" ones, in order to set up comprehensive waste policies, including the final disposal. Pending the adoption of whatever waste management policies, residues from reprocessed RTR spent fuel are simple ones to handle and constitute only one among the many waste fluxes to the chosen final destination whatever it is.

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