The Universal Canister strategy in spent fuel reprocessing: UC-C a real industrial improvement

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ABSTRACT

In commercial nuclear activities, spent fuel back end management is a key issue for nuclear countries as spent fuel represent most of national civil nuclear waste legacy. Ensuring public safety and protection of the environment, now and in the future has been and still remains a major commitment, it is still the subject of thorough development efforts and active public debates. Considerable benefits can be obtained from the Universal Canister strategy as implemented in France in spent fuel treatment and waste conditioning based on reprocessing.

COGEMA developed sophisticated waste conditioning processes to simplify High Level and Long Lived Intermediate Level Waste storage and final disposal. Main benefits are:

- Waste stabilization by immobilization and encapsulation;
- Ultimate waste toxicity reduction;
- Drastic ultimate waste volume reduction;
- Ultimate waste packages standardization.

The most up-to-date treatment-conditioning at La Hague reprocessing plant results in only one type of residue, the Universal Canister: (i) Fission products are being conditioned for many years as residues in borosilicate glass, into Universal Canister for vitrified waste, the UC-V.(ii) Fuel structure - hulls and end-fittings - is now conditioned as residues in Universal Canister for compacted waste, the UC-C. This standardization into one single package geometry facilitates handling, transportation and simplifies final disposal requirements.

The Universal Canister strategy benefits are now completely available and operational with the industrial scale production of UC-Cs at the ACC facility of La Hague. Facility description and production records are presented here. Such benefits are available to nuclear power plants (NPP) operators and to radioactive waste management agencies world-wide.

When implemented on an exclusive basis at the country scale, the spent fuel treatment-conditioning option greatly simplifies the design of the geological repository and maximizes its industrial implementation.

In other countries where direct disposal is the chosen route, the spent fuel treatment-conditioning option can also be considered as an interesting way to decrease the size and optimize the costs of the geological repository.

INTRODUCTION

Commercial nuclear activities, i.e. nuclear power plants and facilities of the nuclear fuel cycle are producing three types of radioactive waste as per the IAEA classification: LLW, ILW and HLW. Whilst the final management of the large volumes of LLW is solved thanks to the accepted technique of shallow land repositories (repositories have been and are successfully implemented in several countries for LLW), the final management of the comparatively very small volumes of HLW and long lived ILW is still the subject of thorough development efforts and active public debates. Consequently, spent fuel management remains a key issue for nuclear countries as spent fuel represent most of national civil nuclear HLW legacy.
This paper intends to show how considerable benefits can be obtained from the Universal Canister strategy as implemented in France in spent fuel treatment and waste conditioning based on reprocessing. We will at first recall the main advantages of spent fuel treatment-conditioning and those of the vitrification process industrially implemented for decades. We will then discuss the recent industrial achievements of the compaction process used to condition fuel structural parts, which make waste drastic volume reduction an industrial reality.

SPENT FUEL DIRECT DISPOSAL AND/OR TREATMENT-CONDITIONING

Spent fuel direct disposal
Spent fuel direct disposal operation is getting closer in a few countries where repository site(s) is designated, studied etc. Starting actual spent fuel reception and disposing it into repository is still, in any case, at least about one decade away.

In the USA, the Yucca Mountain site was designated in July 2002 as the site for the geological repository for spent fuel from the US NPP. The USA will be the first country to have a geological repository. As considered in the proposed action in the final EIS (1) its capacity for commercial spent fuel assemblies is 63000 metric tonne heavy metal (MTHM). It is also designed for the disposal of other types of HLW such as vitrified waste, US DOE spent nuclear fuel and US Navy spent fuel. However, the existing backlog of US commercial spent fuel as of to-date is about 50000 MTHM and the total discharged US commercial spent fuel is expected to reach the site present capacity by around 2011.

The direct disposal strategy is also followed in Sweden where three sites are being considered for one repository which should open in 2015 and in Finland. The Olkiluoto site which should be operational in 2020.

In other countries favouring at present the direct disposal option, it is progressing very slowly because of technical, economical and public acceptance issues.

Spent fuel treatment-conditioning is a decades long industrial reality
France is following a long ago defined reprocessing and conditioning strategy. Spent fuel from French commercial NPP is routinely reprocessed and ultimate waste are separated and conditioned per category. LLW are sent to the French radioactive waste agency (ANDRA) Soulaines repository. Thanks to their small volume and the quality of their conditioning, HLW are easily interim-stored at the reprocessing site pending availability of the French final disposal facility.

Therefore, COGEMA has devoted considerable efforts at simplifying HLW and Long Lived ILW storage and final disposal, by developing sophisticated waste separation, sorting and conditioning processes. The most up-to-date treatment-conditioning at La Hague reprocessing plant results in only one type of waste package: the Universal Canister.

Main benefits are:
- Waste stabilization by immobilization and encapsulation;
- Ultimate waste toxicity reduction;
- Drastic ultimate waste volume reduction;
- Ultimate waste package standardization.

MAIN ADVANTAGES OF THE SPENT FUEL REPROCESSING OPTION

Spent fuel reprocessing option is to be considered under two main aspects:

Separation
The La Hague plant achieves a very high recovery rate of the fissile and energy-rich material still contained in spent fuel. About 99.9% of uranium and plutonium are recovered and can be recycled into
fresh fuel. Thus, the content of alpha emitters in the resulting waste is reduced to the lowest possible level.

**Waste conditioning**
Fission products which account for 99% of the spent fuel beta-gamma activity are conditioned as residues in borosilicate glass, poured into the Universal Canister for vitrified waste (UC-V). The vitrification process and canister technology are decades long industrially proven activities at COGEMA Marcoule and La Hague plants.

Hulls and end-fittings as well as technological waste are conditioned as residues in Universal Canister for compacted waste: the UC-C.

**Consequently**
Separation and waste sorting enable to put strong efforts on what in spent fuel is actually waste. The ultimate waste to be conditioned are actually the non recoverable part of the fuel (non recovered fissile material, fission products, structural parts…) and the technological waste. They are all conditioned into a small volume of stable, easy to handle and easy to store residues.

**More than four times ultimate waste volume reduction**
The total volume of the above residues is less than 0.5 m$^3$/metric tonne heavy metal or initial uranium (MTHM or mtU). This is to be compared with the direct disposal of the spent fuel, where the volume to be stored is more than 2 m$^3$/MTHM (Fig. 1.).

![Fig. 1. Total volume of HLW/ILW residues versus direct disposal](image-url)
Residue package standardization

An additional asset of the waste management strategy offered by COGEMA lies in the use of one unique canister geometry for all types of residues to be disposed of, i.e. for both vitrified waste (UC-V) and for compacted waste (UC-C). This standardization of residue package allows to considerably simplify all subsequent stages (handling, intermediate storage, transport and final repository).

UC-V and UC-C have the same outline and outside dimensions (Fig. 2.). They also have an identical vertical handling head which is a considerable advantage for a type of package which will have – at any stage - to be remotely handled.

The volume of one UC is 0.18 m\(^3\) per piece. Dimensions, weights, typical dose rate, activity contents and decay heat are recapped in Table 1.

UC–V: A DE FACTO INTERNATIONAL STANDARD

Immobilization of fission products and actinides at the atom level in borosilicate glass enables COGEMA to manufacture residues of great stability and quality, respectful of the sustainable development approach.

Constitution, structure and benefits of the Universal Canister for vitrified waste are well known and have already largely been documented in previous publications such as (2) (3) (4). Main characteristics of UC-V are recalled in Table 1.

An international consensus (France, Japan, UK, USA, Germany, Belgium, Russia, Switzerland, the Netherlands, Italy, etc) exists on the choice of borosilicate glass as being the matrix for immobilization at the atom level of fission products and long lived actinides.
As of today vitrified residues are the only HLW form the specification of which is licensed by so many regulatory bodies. They are approved by the French Safety Authority, and also by the Authorities of all reprocessing customers’ countries (for vitrified residues: Japan, Germany, Belgium, the Netherlands, Switzerland, the United Kingdom and Australia). They have been manufactured for over ten years in R7/T7 facilities of La Hague.

In France, ANDRA uses R7/T7 vitrified residues as the reference for the underground repository design. In the other countries similar thinking processes are underway. Residue specifications describe the packages and are established on the basis of the residue stability, its resistance to radiation and lixiviation. All these criteria are governed by sustainable development considerations.

Consequently, the universal canister of vitrified residues is not only a de facto international standard, it is actually a real cost saving input data for the repository designers all over these reprocessing customers countries.

**UC–C: A REAL INDUSTRIAL IMPROVEMENT**

The Universal Canister strategy benefits are now completely available and operational on the industrial scale. The hulls and end-pieces compaction facility - the La Hague ACC facility - is successfully operating since beginning of 2002 and fully operational since May 2002. Its super-compactor enables to condition hulls and end pieces or technological waste. Facility description and production records are presented here.

**Hulls and end-fittings supercompaction: the ACC facility**

The ACC facility is designed to receive, process and condition structural waste (hulls and end-fittings) originating from spent fuel and technological waste which are not suitable for surface disposal.

The process – essentially mechanical – takes six main steps (Fig. 3.):

**Step 1**
- Reception and radiological characterization of hulls and end-fittings drums produced in the shearing-dissolution facilities, R1 and T1,
- and reception of the technological waste from the entire La Hague site.

**Step 2**
- Separation of hulls and end-fittings in a dosing separator and filling of 80 litre cans to be compacted. Dosing of hulls and end-fittings per can enables to optimize compaction.
- Filling of cans with technological waste. Larger technological waste are priorily laser or mechanically cut.

**Step 3**
Cans drying with hot inert gas. Drying is aimed at avoiding residual water and associated hazards.

**Step 4**
Cans are compacted at 200 MPa into disks in one of the two 2500 tons press lines. Compaction at an optimized 200 MPa enables to maximize volume reduction. Each compacted disk overall density is hence more than 60 % of the density of its components.

**Step 5**
UC-C canister filling with about 7 disks and outer lid welding.
Fig. 3. Simplified Process Diagram of The ACC Facility
Step 6
Radiolocal characterization of cans (outside contamination monitoring using smear test, and nuclear measurements). If necessary outside surface decontamination with high-pressure water jets can be performed before transfer to on-site interim storage. Nuclear measurements enable to detect residual fissile material trace contents ($^{235}\text{U}$ and $^{239}\text{Pu}$) and to check compliance of produced canisters with package acceptance specifications as of alpha and beta activities as well as thermal power.

Active liquid waste generated by ACC operation is recycled and treated in the La Hague overall process.

Fig. 4. the ACC process cell
picture taken before active commissioning

The UC-C: a package designed for long term storage and final disposal

UC-C is part of COGEMA general commitment to reduce ultimate waste volume. It offers COGEMA customers a unique strategy for storing long lived ILW and HLW in Universal Canisters in order to optimize total costs of the fuel cycle back-end.
UC-C is replacing the former process of hulls and end-fittings embedding in cement grout with two main aims:
- Reduce the volume of stored waste by an average factor of 5,
- Optimize handling, transport and storage of ultimate waste until final disposal with canisters of one same geometry.

Table 1. UC-C nominal mean values (UC-V nominal mean values are given for comparison)

<table>
<thead>
<tr>
<th></th>
<th>UC-C</th>
<th>UC-V</th>
</tr>
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<tbody>
<tr>
<td>Total mass</td>
<td>700kg</td>
<td>500kg</td>
</tr>
<tr>
<td>Overall height</td>
<td>1338 mm</td>
<td></td>
</tr>
<tr>
<td>Overall diameter</td>
<td>430 mm</td>
<td></td>
</tr>
<tr>
<td>β activity of fission products</td>
<td>67 TBq</td>
<td>22500 TBq</td>
</tr>
<tr>
<td>β activity of activation products</td>
<td>160 TBq</td>
<td>NA</td>
</tr>
<tr>
<td>α activity of actinides</td>
<td>1 TBq</td>
<td>140 TBq</td>
</tr>
<tr>
<td>Decay heat</td>
<td>40 W</td>
<td>1750 W</td>
</tr>
<tr>
<td>γ Dose rate at 0 m (contact)</td>
<td>65 Gy/h</td>
<td>14000 Gy/h</td>
</tr>
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UC-C specification nominal mean values
UC-V specification nominal mean values

**UC-C design features:**
- UC-C mechanical design is robust and simple
  - material is low carbon stainless steel with additives to enhance corrosion resistance,
  - containment and handling possibility are preserved in case of dropping (qualified through safety drop tests).
- UC-C design complies with basic process and long term storage safety requirements
  - good behaviour of the package against Zr fines ignition hazard was proven by tests at temperatures up to 500°C,
  - it is considered that hulls compaction prevents oxygen diffusion and improves thermal diffusion,
  - the lid of the canister is fitted with a sintered SS filter to vent radiolysis gas.

**The ACC facility: industrial production records in 2002**

ACC facility active operation started mid December 2001 after successful completion of inactive testing (Table 2.).
- Active qualification period
  Before industrial operation an active qualification period was carried out until April 2002. 18 underwater stored hulls and end-fittings drums and some technological waste were treated to validate the process and nuclear measurements for active waste with selected PWR and BWR fuels on a wide range of burn-ups, cooling times and initial enrichments.
- Industrial operation
  As for any industrial activity, actual operation is gradually increased through a ramp-up period. Present results show very good manufacturing achievements both in terms of throughput and produced product quality.
Table 2. ACC facility: industrial production records

<table>
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<tr>
<th></th>
<th>Active Qualification</th>
<th>Industrial Production</th>
<th>Total Production</th>
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<tr>
<td>processed drums</td>
<td>18</td>
<td>166</td>
<td>41</td>
</tr>
<tr>
<td>compacted cans</td>
<td>223</td>
<td>1945</td>
<td>494</td>
</tr>
<tr>
<td>produced UC-C</td>
<td>32</td>
<td>260</td>
<td>69</td>
</tr>
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</table>

CONCLUSION

After a successful commissioning and about one year of satisfactory industrial operation of the La Hague ACC facility, the COGEMA Universal Canister strategy has become a fully implemented industrial reality.

Its benefits are available to NPP operators and to radioactive waste management agencies world-wide
→ in terms of industrial optimization:
  o Drastic ultimate waste volume reduction,
  o Ultimate waste packages standardization,
→ as part of their sustainable development policy:
  o Ultimate waste stabilization separation and immobilization,
  o Ultimate waste toxicity reduction.

When implemented on an exclusive basis at the country scale, the spent fuel treatment-conditioning option considerably simplifies the design of the final geological repository and maximizes its industrial optimization.

In other countries where direct disposal is to be implemented, the spent fuel treatment-conditioning option can also be considered as an interesting way to decrease the size and optimize the costs of the final geological repository.

References:
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