Lessons learnt from DIADEM
medium-level waste interim storage’s construction

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Abstract

As part of its decommissioning policy, the nuclear energy division of CEA has identified material whose high enough radioactive features neither authorize an interim storage in existing facilities nor an evacuation to a French operational disposal. Pending availability of definitive solutions, it has been decided to explore the opportunities to store such material in new facilities, which constitutes the main subject of DIADEM project and the need for a strategic new interim storages construction Program.

The methodology on demonstrating the robustness of stored waste containers has been one key point in safety assessment. Such qualification process conducted together with LGM and LIGERON companies leads to ensure the containment of radioactive material in any situation. The facility is planned to receive 3 types of cylindrical stainless steel containers, with identical diameters and increasing heights. The sides' thickness enables the containers to resist handling hazards such as falls, and means higher corrosion resistance. Both drop tests and corrosion measurement’s qualification are under development. Non-destructive corrosion detectors will be installed in the hot cell and will monitor the characteristics of acoustic emission in stainless steel containers during the corrosion process.

The lids will be screwed onto the containers in the waste-producer’s facilities, and then welded in DIADEM’s hot cell before storage. The decontamination process in the hot cell and the lid welding will guarantee a low contamination level for periods of several decades. For waste involving radiolysis phenomena, the lids will also be equipped with metal filters allowing gases to escape. These special filters are designed to only give gaseous pressure release, while blocking all particles. To avoid corrosion issue on the filters due, a study was made to selecting a filtering media according to requirements of nuclear standards and DIADEM’s operation. A test plan was built to ensure the characteristics of filtering media, including accelerated aging studies, hydrogen diffusion rate, filter efficiency and pressure versus flow curves. A specific housing has also been designed to adapt the filter to the lid and to protect the media. One filter can meet all requirements for one container, each container is equipped with 4 filters. Finally, filters must be removable so that they can be replaced during the storage, therefore remote handle tools come with the filter.

This summary is reporting the lessons learnt since the construction started in 2013.
1. Introduction

As part of its decommissioning policy, the nuclear energy division of CEA has identified material whose high enough radioactive features neither authorize an interim storage in existing facilities nor an evacuation to a French operational disposal [1]. The need was first identified on Marcoule’s site, especially to accommodate future waste dismantling of PHENIX reactor. Pending availability of definitive solutions, it has been decided to explore the opportunities to store such material in new facilities, which is the main subject of DIADEM project and the need for a strategic new interim storages construction Program.

As a state-own R&D and D&D agency, CEA has developed a recognized expertise both in safety and management of highly active waste [2]. The choice of the most relevant waste treatment schemes is first an assessment of the main radioactive features of the waste:

- Activities in CEDRA and EIP existing facilities containers are respectively less than 185 GBq and 6 TBq, where DIADEM containers activity will be up to 176 TBq,
- Containers dose is limited by the safety assessment : 10 Gy/h in CEDRA, about 1 Gy/h in EIP, and almost 700 Gy/h in DIADEM,
- Fissile materials in waste are limited under 10 g in CEDRA, DIADEM will accept containers with less than 200 g,
- The strategic new interim storages construction Program will also take into account intermediate level of doses and activities and small producers with higher density of fissile materials, activities and dose, for the design of the facilities to build.

The DIADEM project started in 2006 [3]. First, the CEA carried out a feasibility study and formed the basis for launching a consultation and call for tenders. The prime contractor was appointed in 2008, and the design studies were completed in early 2013. It is planned to commission the facility at the end of 2020.

![Figure 1: Pictures of existing facilities CEDRA and EIP and the DIADEM Project](image)

As other existing facilities (Fig. 1), DIADEM’s role is to safely store containers of highly irradiating and/or high α content waste. The facility has been designed for a lifetime of at least fifty years.

During these fifty years of storage, the facility shall have to ensure that the containers are kept in a state of preservation which will enable their retrieval at any time with current means of operation. It shall also keep records of each container’s characteristics, including its origin, nature and radiological content.
2. Methodology on demonstrating the robustness of containers

The safety requirement on containers in the DIADEM installation (Fig. 2) relates to the qualification of containers for falling, stacking and handling during normal and accidental operating phases. This qualification leads to ensure the confinement of the radioactive material in any situation. To do this, the container must remain tight, so it needs to be sufficiently robust to avoid important distortions causing the container breaking.

For that purpose, the mechanical strength of the container is checked under the following three conditions:

- **Handling:** The mechanical strength of the container body and of the gripping interface during the handling phases, taking into account the vertical and horizontal dynamic coefficient of amplification according to the FEM. In the event of an earthquake, the handled container must not fall down.
- **Stacking in Storage Cell:** The containers are stored in vertical guides. This means that the container at the bottom of the pile supports a maximum weight of 7 tons. The mechanical strength of the containers is checked during normal operations as well as during accidental situations, such as an earthquake or a loss of ventilation and air conditioning, resulting in an increase in the temperature of the containers to 100°C.
- **Falling:** The containers of the DIADEM installation are qualified at a drop of 7 m on unalterable slab and a drop of 14 m on shock absorber. A container, stacked on a shock absorber in the storage cells, must be robust enough to deal with another container drop of 14m. After a fall, containers should be sufficiently robust to avoid important distortions in order to allow an evacuation from storage cell by handling system.

For this purpose CEA has carried out studies using FEM and fast dynamic calculations in order to validate the design of the containers. Prototypes of containers and shock absorbers have been constructed to perform representative fall, stacking and handling tests. Calculation notes, resulting from the studies, as well as tests were reported in the safety assessment for validation.
Fall and handling tests have taken 5 steps:

- Step 1: prototype construction in order to approve the manufacturing processes,
- Step 2: lid welding qualification to obtain welds representative of what will be produced in the DIADEM installation,
- Step 3: manufacturing of about 20 containers to perform the test: the 3 types of containers have been manufactured, some containers we left empty and others were filled with representative weight to simulate waste. Some lids were only screwed, others both screwed and welded.
- Step 4: Optimization of the containers’ manufacturing process and costs best estimate,
- Step 5: Drop tests and then fall recoverability test from storage to the hot cell.

3. Hot Cell

The shielded cell allows remoting operations on containers:
- before storage: welding of the lid and decontamination of the container’s external surfaces,
- during the storage period: monitoring such as acoustic measures for corrosion detection inside the containers.

This shielded cell is divided into two tight sub-cells physically separated by a steel wall in order to avoid contaminating the entire shielded cell in case of a contamination issue on containers.

The cell (Fig. 3) is equipped with:
- three posts equipped with Master-Slave Manipulator, to allow remote operations
- two travelling cranes to handle containers inside the cell
- two tippers to allow a horizontally move of the container across the wall between the two sub-cells
- a remote welding station to weld the lid of containers
- a decontamination station to check all external areas of containers. If contamination is detected, the station is able to decontaminate by dry friction on all external areas of containers.
- a detection system of corrosion by the emission and reception of ultrasound to check corrosion inside the container.
- a storage rack able to store up to two containers in the cell.

Figure 3: Containers prototypes, construction of the hot cell and welding station’s project.
4. Filters

Then, to avoid corrosion issues on the filters due to HCl, a study started to enable selecting a filtering media according to the requirements of nuclear standards and DIADEM’s exploitation. To ensure characteristic of filtering media regarding containers with radiolysables waste, a test plan was designed, that including accelerated aging studies, hydrogen diffusion rate, filter efficiency and pressure vs flow curves. A specific housing was also designed to adapt the filter to the lid and to protect the media. One filter can complete all requirements for one container, each container is equipped with 4 filters. Finally filters must be removable in order to change them during the storage, and therefore remote handle tools come with the filter.

At the beginning, sintering stainless steel filters are chosen to allow a way for H₂ gas. The problem is that waste also contains chlorinated substances, conducting to hydrochloric acid by a recombination of H and Cl ions. HCl, going through the filter, damages stainless steel filter. Because of the aggression of stainless steel by HCl, a corroded product clogs the medium.

![Image](image-url)

**Figure 4:** Stainless steel medium before exposition during 14 days to a high HCl concentration and preliminary design of removable filters

Therefore, studies are launched to identify a new medium, and to integrate it to the design of the container (Fig. 4). These studies are conducted according to the requirements of nuclear standards and DIADEM’s operation.

To prevent any risk of clogging, it was also decided to allow changing the filter during storage. This option modifies the integration of filter, as the first solution was a not removable filter welded to the lid of the container. Now we need to develop a removable filter, with a new medium, and also removable tooling in order to operate it in a hot cell. Selections of different mediums more or less corresponding to the need are submitted to a test plan. A test protocol has been designed to qualify medium before, during and after the test plan. The test plan was designed to stress medium with a dynamic flow of air charging in HCl by a 2 molar HCl aqueous solution under the medium. Qualification of medium is done by measuring the hydrogen diffusion rate, the filter efficiency and pressure vs flow curves.

A medium in ceramic fiber was identified for the application on DIADEM. Now the subject is to complete characterization of filters and to develop tools for the change of filter during DIADEM’s operation.
5. Design and construction management for the facility – lessons learnt

Since 2009 INGEROP and ATR are providing full-scope design and construction supervision for the project. The construction works started after a thorough design phase in 2014. Nowadays, the civil works progress is about 70%, with an expected end of works in late 2019. More than 10000 cubic meters of concrete will be poured for the building, which dimensions are 51 m width x 57 m length x 24 m height.

![Figure 5: Overall view of the base mat construction](image)

Foundations, heavy base mat, perimeter walls and hot cell rooms are completed (Fig. 5); the completion of the storage hall is the next real challenge. The hall features a 145 cm-thick concrete slab, weighing more than 1000 tons, featuring 252 holes interfacing with tall vertical racks creating the channels for housing the cylindrical containers (Fig. 6). The interface between the racks, slab and lower/upper connections are really delicate and will involve fine tailored reinforcements and pouring schemes: several methods have been tested on real-scale mockups to perfect the set-up. The last step will be the creation of the massive concrete roof of the storage hall that has been redesigned to improve the overall erection program.

![Figure 6: Racks handling operations](image)
The major lessons learned during the civil works of Diadem – which are all in all similar to those of other major nuclear construction projects – are the following:

- configuration and interface management, assisted by 3D models, is crucial for main metal inserts – heavy supports and embedded parts in the concrete – up to the smallest detail during the execution drawings,
- tolerances requirements versus reality, design versus construction: concrete’s and embedded parts’ tolerances need to be aligned between different trades, phases and suppliers, so the use of preinstalled anchors should be limited,
- concrete composition and stability thereof before and all along long pouring sessions call for constant monitoring,
- pouring activities usually take one day per zone, while reinforcements can take up to 2 months to be put in place. This kind of variations in the rhythm of operations is difficult to manage for a civil works contractor and its supply chain,
- high reinforcement complexity and density (up to 200kg of steel/m³), together with coactivity, always affect scheduling more than expected, becoming the driver of the schedule itself during civil works.
- synchronization of competitive design activities by different suppliers gets even harder to manage during construction, due to approaching deadlines.

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References

