Long-Term Interim Storage Concepts with Conditioning Strategies Ensuring Compatibility with Subsequent Disposal or Reprocessing

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Abstract

The objective of the CEA studies carried out under research topic 3 (long-term interim storage) of the 1991 French radioactive waste management law is to demonstrate the industrial feasibility of a comprehensive, flexible interim storage facility by thoroughly evaluating and comparing all the basic components of various interim storage concepts. In this context, the CEA is considering reference solutions or concepts based on three primary components (the package, the interim storage facility and the site) suitable for determining the specifications of a very long-term solution. Some aspects are examined in greater detail, such as the implementation of long-term technologies, conditioning processes ensuring the absence of water and contamination in the facility, or allowance for radioactive decay of the packages. The results obtained are continually compiled in reports substantiating the design options. These studies should also lead to an overall economic assessment in terms of the capital and operating cost requirements, thereby providing an additional basis for selecting the design options. The comparison with existing industrial facilities highlights the technical and economic progress represented by the new generation of interim storage units.

Introduction

Many packages or primary waste materials of divers types and forms are currently stored locally in facilities corresponding a wide variety of technical options, material lifetimes and qualified storage periods. In the absence of a disposition route and schedule for these wasteforms, the need for rationalizing an interim solution has become increasingly clear in the major nuclear countries. Moreover, the characteristic development time of a nuclear power generating system is on the order of several decades, and that no final industrial disposition route has been specified or even decided to date for long-lived waste.

Hence the usefulness of a long-term interim storage facility, as opposed to a buffer storage unit (e.g. a storage pool in a spent fuel reprocessing plant) in which destination of the packages is known at the time they are placed in temporary storage. A facility of this type must meet several criteria:

- Interim storage of packages for several decades, unspecified at the outset; internationally, this unspecified duration is gradually taking the form of a century-long objective as a conservative measure considering the uncertainties facing the nuclear power industry.
- A conditioning strategy supplementing the existing industrial routes, capable of accommodating all types of waste while minimizing the number of different waste packages to simplify operations and provide flexibility with regard to the possible evolution of the nuclear power generating capacity.
- Propose this solution at a reasonable cost, comparable to that of existing industrial solutions for shorter-term interim storage facilities.

No existing industrial interim storage facility meets these criteria, notably with respect to long-term safety. Hence the need to design a new long-term interim storage facility, i.e. a unit capable of ensuring safe storage of nuclear waste for century-long periods. Extended interim storage units must be designed to meet specifications consistent with long-term safety: the facility must be designed considering that the duration of the interim storage period is unknown at the moment the packages are placed in the facility.

The package

All the radioactivity intended for conditioning to date arises from French nuclear power reactor fuel; most of this fuel is reprocessed and the resulting radioactive waste is conditioned in glass packages corresponding to an industrial standard. The *package* was designed for long-term containment, and provides a safe high-performance management solution for the back-end of the fuel cycle including interim storage and ultimate disposal. A standard package has not been defined for a number of other wasteforms. No reference interim storage packages are currently available in France for spent fuel or for certain categories of Type B waste.

The management of these wasteforms in long-term interim storage and ultimate disposal will depend on the development of a suitable conditioning strategy. The approach adopted to define the conditioning strategy based on the existing family of industrial waste packages, with the objective of minimizing the number of different packages by seeking to design a multipurpose package providing a high degree of flexibility and accommodating a very wide range of radioactive materials.

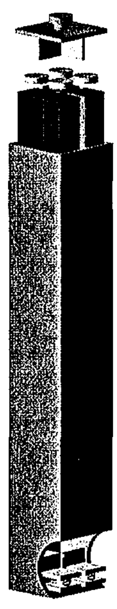
In this context, a multipurpose package must address four major issues:

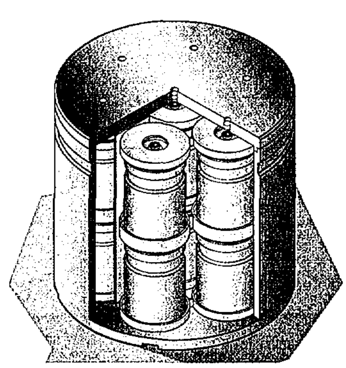
- Accept the comprehensive inventory of radioactive materials, i.e. all types of spent fuel, existing and future Type B and C waste.
- Provide a continuous management route for disposition (reprocessing or ultimate disposal) on removal from extended interim storage, while minimizing the need for subsequent treatment or repackaging.
- Qualify the conditioning processes as part of the demonstration of package durability.
- Allow safe retrieval of the packages after extended interim storage.

The performance of the waste package is enhanced by a double containment system:

- The waste or fuel holder, designed to minimize the number and variety of packages in interim storage, constitutes the primary barrier against dispersal of radioactive material. The holder is the basic object handled throughout the interim storage period, and must be compatible with the radioactive materials.
- The container constitutes the second barrier; it allows a number of waste or fuel holders to be handled collectively, and represents the interface with the interim storage facility.

Multipurpose spent fuel package





Multipurpose "type B" waste package

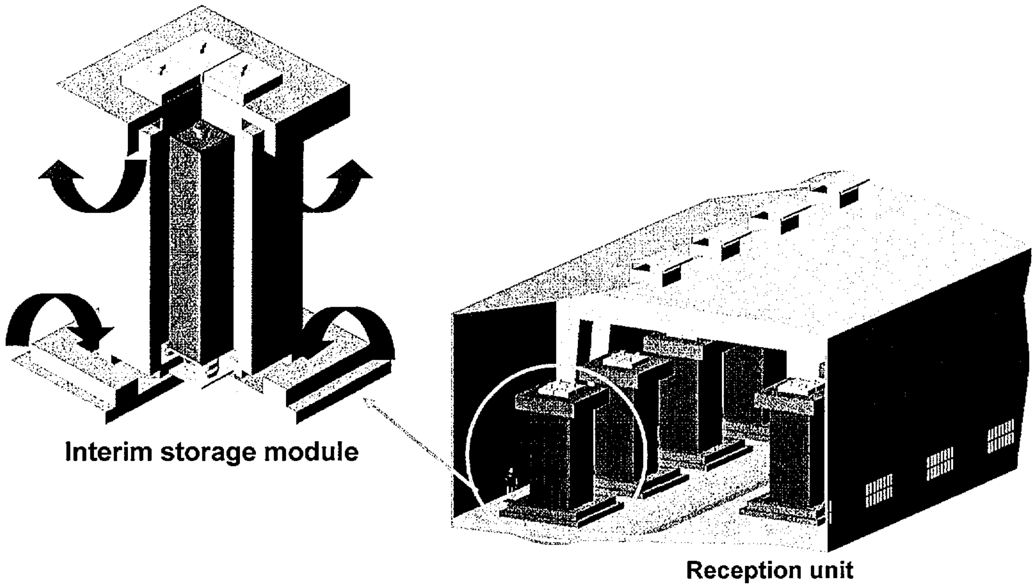
Examples of interim storage packages considered

The objective of this research and development program is to maximize the compatibility of the packages with the disposition routes. Considering the uncertain nature of the industrial decisions that will be made over the coming decades, the research objective is to minimize the burden on future generations by limiting the package reconditioning operations necessary on removal from interim storage. The issues of continuity between interim storage and disposal are addressed by two radically different solutions: one considers the case where the interim storage package is directly compatible with the disposal facility without requiring any repackaging at the moment it is retrieved from storage; the second extends the logic of optimizing the interim storage by postulating that the wasteform should be systematically repackaged on retrieval, while maintaining the waste or fuel holder as the basic unit.

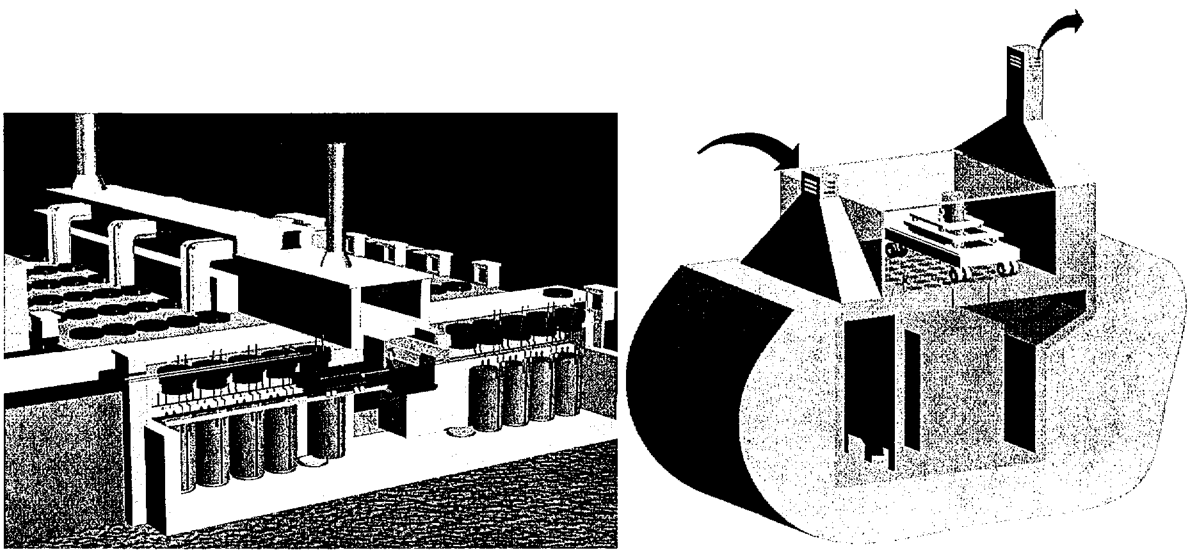
The interim storage facility

The assessment covers a broad spectrum of surface, semi-underground or subsurface interim storage facilities, which may be considered in four groups:

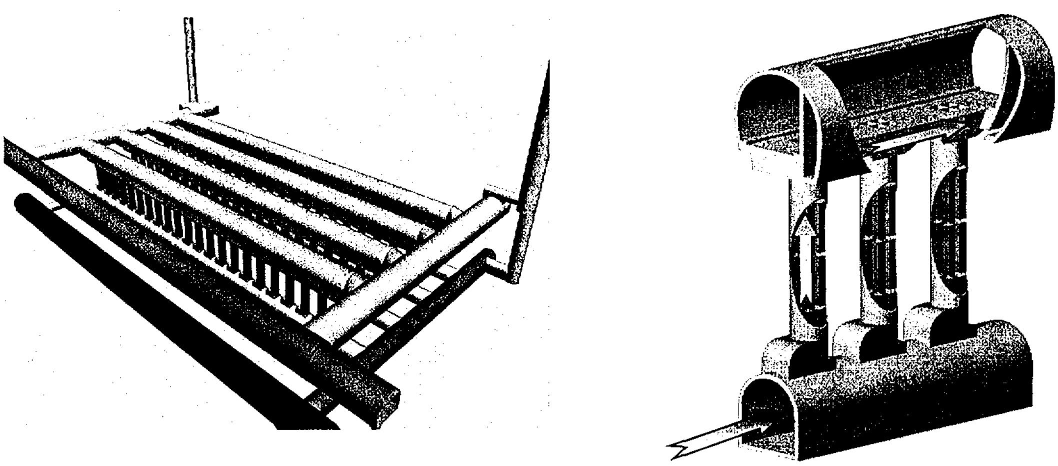
- *Regional spent fuel interim storage unit.* This modular interim storage concept is strictly a surface facility designed for very simple implementation at a cost competitive with existing industrial solutions. Individual interim storage modules with radiological protection accommodate the spent fuel packages, and provide a continuous management route with the disposition options selected on completion of the interim storage period.
- *High thermal density concrete bunker* (a centralized surface or semi-underground interim storage facility). The fuel holder is the basic handling unit in this innovative concept, with provisions for storing a large number of fuel holders in containers, which are considered permanent fixtures in the storage facility. A handling cell is provided for conditioning the fuel holders and for retrieving them for repackaging after storage. The high thermal density requires cooling provisions that will change over time. One option currently being considered provides for natural ventilation supplemented during the first few decades by a water cooling system.
- *Natural convection air-cooled concrete bunker.* This semi-underground concept optimizes a proven industrial solution for long-term performance. The interim storage unit is designed as a centralized nationwide facility providing a flexible solution for thermal and irradiating radioactive waste packages.
- *Subsurface interim storage facility.* This strictly subsurface, centralized interim storage facility comprises a network of underground storage galleries excavated in a massif above ground level, with horizontal access provisions. The host rock formation provides suitable physical protection of the facility—and therefore of the packages—against external agents. Hard rock formations are particularly favorable from the standpoint of their static and dynamic (earthquake) resistance, which could make it unnecessary to shore up the excavations. Exothermic packages (spent fuel and type C waste) would be stored in vertical shafts cooled by natural convection; the air intake and exhaust stacks would be underground. Type B waste would be stored directly in the galleries or in pits, depending on their dose rates.



Example of a surface interim storage concept



Example of surface or semi-underground interim storage concepts



Example of a subsurface interim storage concept