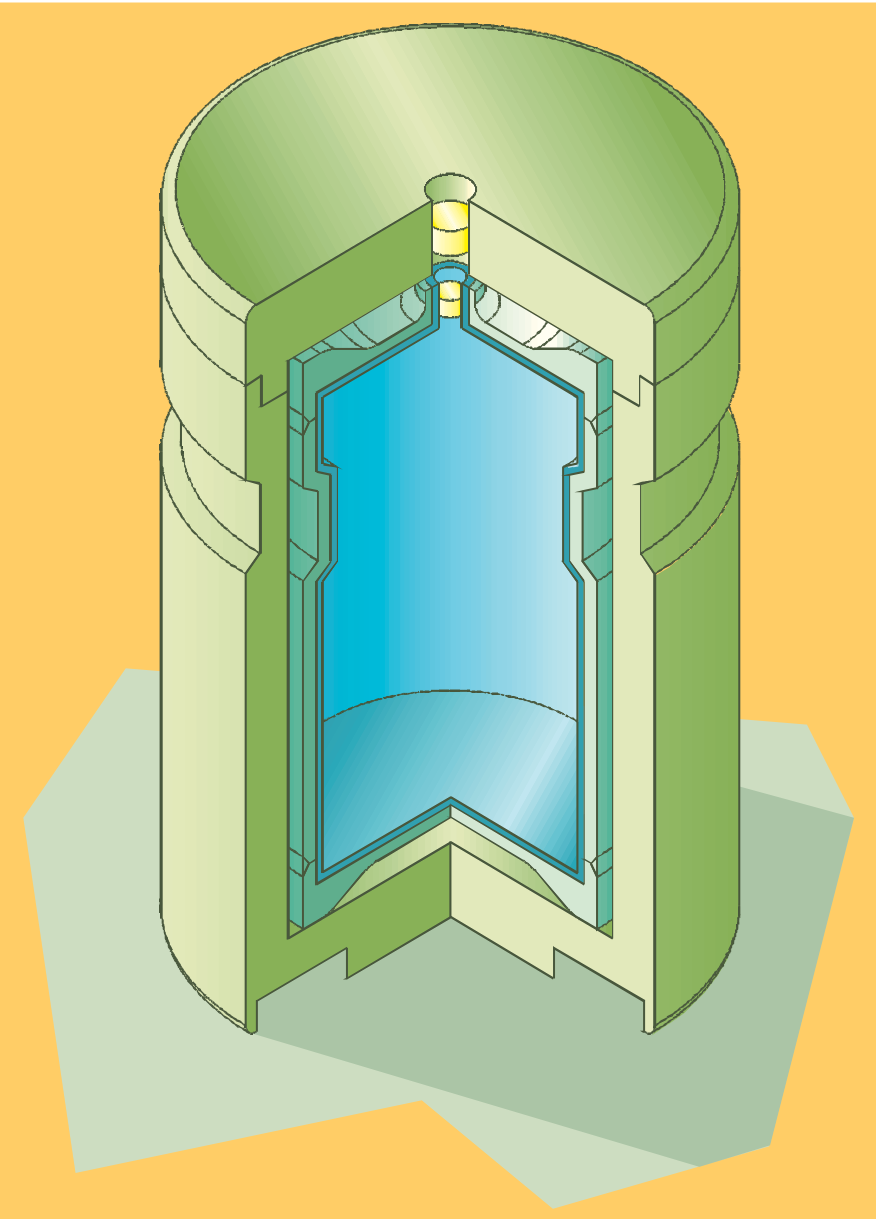
WORKING TOWARDS A UNIVERSAL CONTAINER FOR CATEGORY B WASTE

Long-lived, intermediate-level waste, known as category B waste, accounts for most long-lived waste (> 90%), although it only accounts for a very small fraction of radiotoxicity (< 10%). It comes in a wide variety of forms. The first step to be taken is to classify it into a few families and define a standard management mode for each one. Research teams are therefore seeking to propose a range of universal containers for existing packages and waste still to be conditioned.



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CEA is currently developing a range of universal containers for category B waste, designed both for waste to be conditioned, with extremely varied physical and chemical properties, and waste that has already been conditioned. The aim is to reduce the number of types of package and rationalize the various existing systems.

Restricting the diversity of packages

Category B waste, which does not give off heat, is characterized by a wide variety of physical and chemical properties (see box A, ***What is radioactive waste?***). About half of it is now **conditioned** in a safe and lasting manner in many different types of **packages** (see box G, ***Conditioning, a vital phase***). Over the years, the diversity of waste has led to the design and manufacture of a wide range of **containments**, each adapted to a specific waste category. In spite of this, CEA and other producers still have some 30,000 m^3 of category B waste that is undifferentiated or waiting to be reconditioned. Continuing to adopt the current approach of developing specific conditioning for each type of waste would considerably increase the number of package types. CEA is therefore conducting studies to develop conditioning processes for all waste for which there are no known outlets, and complementing existing methods by rationalizing them to optimize waste management costs.

Study for a new cementation concept

The most commonly used process for category B waste is cementation, which entails incorporating waste in a hydraulic binder-based material composed of calcium aluminates and silicates. The exact composition of the material depends on the degree of solidity and leaktightness required. The cement **matrix** offers many advantages that explain its wide use: it is a familiar material offering good mechanical strength, it is easy to use and relatively inexpensive. Furthermore, additives can be used to adapt its chemical properties to the waste to be conditioned. However, its resistance to water-induced damage does not exceed a few thousand years.

These observations have led to the definition of a mineral-matrix concept where ceramic particles are themselves immobilized in cement. These particles are made up of elements resulting from hydrothermal stabilization of the soluble waste components in an NZP[(1)]-type containment structure, and insoluble products from **radionuclides**. The scientific feasibility of the concept has been proven on simple simulated elements and is now being demonstrated for complex simulated waste. Until 2002, this work has focused on the **formulation** and manufacture of suitable stabilization products. At the same time, alteration studies are being conducted on these NZP particles to identify and quantify deterioration mechanisms. If results are positive, and industrial implementation is possible at a reasonable cost, by 2006 researchers will arrive at a cement- and ceramic-based conditioning process improving the containment capabilities and **durability** of cementation alone by a factor of 100.

(1) Zirconium and sodium phosphate, formula $NaZr_2P_3O_{12}$.

Combining incineration and vitrification techniques

Cementation-based processes offer one possible solution, but leave greater volumes of waste to be disposed of. In addition, the matrix and process must be individually adapted to the chemical properties of the waste to be conditioned. This justifies the search for an "omnivorous" process covering all categories of waste and containing them in a matrix offering high performance levels in terms of final waste reduction.

To meet this objective, CEA is developing an incineration–vitrification process (see *Waste vitrification: more than one string to its bow*). Incineration meets the need to process waste with varying chemical properties, and leads to significantly reduced volumes. Glass matrices offer outstanding containment performance and do, in fact, constitute the reference for high-level waste. The incineration–vitrification process is widely used for processing domestic waste and its solidity in this area has been demonstrated.

The solution that research workers are aiming for combines two techniques already well developed at CEA: a plasma torch for incineration, and a cold crucible for vitrification. By 2002 they will know whether this combination is technically and economically viable. Category B waste includes a very wide range of chemical species. CEA researchers are working to define a small number of glass formulations – less than 5 – to cover all of this category. They will go on to explore the long-term behavior of each matrix and, at the same time, investigate the behavior of radionuclides that are emitted as a gaseous phase and must be captured. In this process, all the radioelements included in the waste must be found in the vitreous matrix, meaning that all the gas released during incineration must be trapped and incorporated into the glass.

The incineration–vitrification process is applicable to evaporation concentrates, sludge from effluent treatment stations, various types of waste in powder form, and possibly, the

Plasma-torch incineration-vitrification facility at CEA/Cadarache. The waste to be processed is fed into the furnace along with glass frit, and incinerated with a plasma torch. Studies conducted with this facility, which uses non-radioactive elements, aim to demonstrate the feasibility of processing various waste, and check that the chemical elements are contained in the glass formed, or trapped during gas treatment. This phase entails defining tests to be performed using radioelements on the MAP (plasma waste-vitrification model) facility.

Emmanuel Joly/CEA

recovery of old waste packages requiring reconditioning. Implementation of such a process on an industrial scale could be contemplated as of 2006.

Developing a range of universal containers

The **canister**, which is the outer envelope of the package, is a key part of any **storage** or **disposal** concept. It is the first part of the package that can be handled, and acts (alone or in conjunction with another part) as the first containment barrier.

Continuing its initiative to rationalize different conditioning processes, CEA has begun to develop a range of universal containers known as CUBE containers (universal category B waste container), designed to accommodate conditioned waste, and undifferentiated waste with varying chemical properties (figure). Research workers are adopting a dual-**envelope** approach. The first function of the outer envelope is to allow the package to be handled and, therefore, recovered. In some cases, it can also help to improve the containment capability of the package. This aspect is at the heart of the initiative to standardize the CUBE in terms of geometry and choice of material. The inner envelope can be an existing package, requiring some "over-conditioning" to optimize handling, guarantee its recovery, or make it suitable for long-term storage or geological disposal. In the case of undifferentiated waste, it can be a specifically designed cartridge within which the waste is blocked. Both these envelopes act as the first containment barrier over time.

Optimizing geometry

The geometry adopted is a cylinder optimizing the final volume of the package after "over-packaging", as most existing packages are cylindrical. Furthermore, this configuration contributes to good mechanical behavior of the materials. Package dimensions will have to be optimized according to the type of waste to be containerized, permissible storage limits, mechanical strength of the container, and monitoring degrees over time. The maximum values chosen are 3 m for the height and 3 m for the diameter.


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View of the incineration-gas treatment system in the furnace of the MAP plasma waste-vitrification model. This model is set up in the Chicade facility at CEA/Cadarache, and designed for the study of beta-gamma radionuclide distribution between the vitrified product and gas emissions, when waste is processed by plasma melting under conditions representative of real industrial conditions.

Selecting the best-suited materials

Researchers have compared three basic materials for the outer envelope: carbon steel, stainless steel, and hydraulic binders. Carbon steel is commonly used and its behavior is well known. However, its use is not recommended in large volumes in deep disposal sites because of the hydrogen induced by corrosion. Stainless steel does not offer long-term guarantees against corrosion. Hydraulic binders (cements) represent the best compromise and have therefore been selected by research teams for the outer envelope.

The inner envelope is only proposed for unsorted, undifferentiated waste. Its purpose is to eliminate any chemical reaction between the waste to be conditioned and the outer envelope. Materials being studied are solid ceramic, enameled steel and high-density polymers.

From functional demonstrator to container

Research and development programs are focusing principally on the aging and durability of materials, and assessing their resistance to **alpha** and **gamma** radiation. As a result of these programs, several functional demonstrators will be developed in 2002 to carry out specific bench tests on particular manufacturing methods concerning critical functions over the long term. These programs have several objectives. The first is to guarantee the behavior of containers over time by implementing behavioral characterization tests studied elsewhere. The tests will be performed on objects with representative size under real conditions. They will mainly be concerned with the behavior of selected materials, interfaces (closures) and gas-management methods. The second is to validate the integration of all package parts and operating functions under long-term storage and geological disposal conditions (filling, handling, opening/closing, drop resistance, monitoring criteria). The last is to check the industrial feasibility of the manufacturing and conditioning processes of the various materials considered.

Taking the results of these functional demonstrators, CEA will produce complete containers by 2004 to qualify all functional features.

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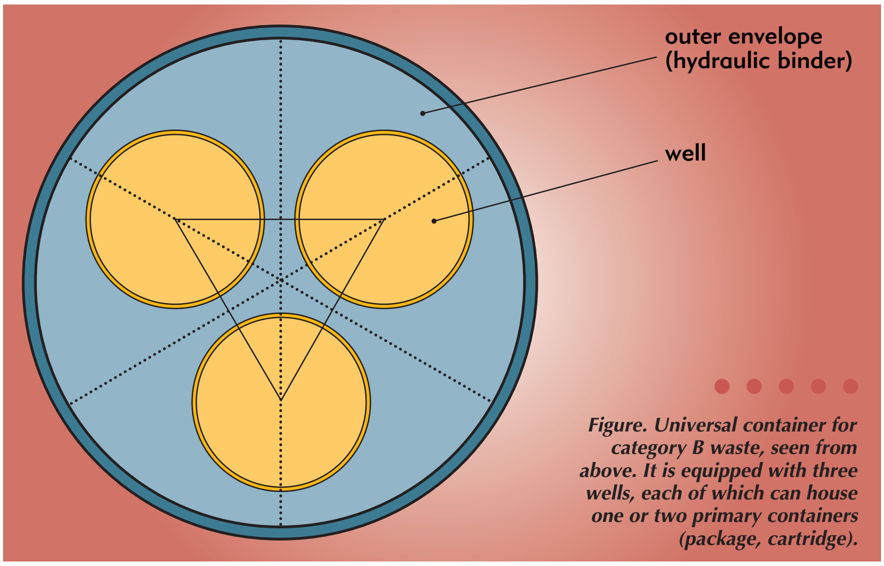

Figure. Universal container for category B waste, seen from above. It is equipped with three wells, each of which can house one or two primary containers (package, cartridge).