Industrial Program of Waste Management - Cigéo Project - 13033

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ABSTRACT

The French Planning Act of 28 June 2006 prescribed that a reversible repository in a deep geological formation be chosen as the reference solution for the long-term management of high-level and intermediate-level long-lived radioactive waste. It also entrusted the responsibility of further studies and design of the repository (named Cigéo) upon the French Radioactive Waste Management Agency (Andra), in order for the review of the creation-license application to start in 2015 and, subject to its approval, the commissioning of the repository to take place in 2025.

Andra is responsible for siting, designing, implementing, operating the future geological repository, including operational and long term safety and waste acceptance. Nuclear operators (Electricité de France (EDF) , AREVA NC, and the French Commission in charge of Atomic Energy and Alternative Energies (CEA) are technically and financially responsible for the waste they generate, with no limit in time. They provide Andra, on one hand, with waste packages related input data, and on the other hand with their long term industrial experiences of high and intermediate-level long-lived radwaste management and nuclear operation. Andra, EDF, AREVA and CEA established a cooperation agreement for strengthening their collaborations in these fields.

Within this agreement Andra and the nuclear operators have defined an industrial program for waste management. This program includes the waste inventory to be taken into account for the design of the Cigéo project and the structural hypothesis underlying its phased development. It schedules the delivery of the different categories of waste and defines associated flows..

INTRODUCTION

A reversible repository in a deep geological formation has be chosen as the reference solution for the long-term management of high-level (HLW) and intermediate-level long-lived radioactive waste (ILW-LL) by the French Planning Act of 28 June 2006. This Planning Act also entrusted the responsibility of further studies and design of the repository upon the French Radioactive Waste Management Agency (Andra), in order for the review of the creation-license application to start in 2015 and, subject to its approval, the commissioning of the repository to take place in 2025 [1].

Andra is responsible for siting, designing, implementing, operating the future geological repository, including waste acceptance, operational and long term safety. Nuclear operators Electricité de France (EDF), AREVA NC, and the French Commission in charge of Atomic Energy and Alternative Energies (CEA) are technically and financially responsible for the waste they generate, with no limit in time. They provide Andra, on the one hand, with waste packages related input data, and on the other hand with their long term industrial experience of high and intermediate-level long-lived radwaste management and nuclear operation.

The development of the repository shall be achieved over a long period, around one century. This leads to develop the project in successive phases. Hence the designer will acquire additional experience at every new development phase of the project, notably during Phase 1, which he may reuse during the following phases in order to optimize the project and its cost.

The knowledge of the radioactive waste (radwaste) inventories is crucial [2],[3]. The preparation of the first phase of construction and of the subsequent phases requires planning of the delivery of various waste packages.

The diversity of waste packages to accommodate must be taken into account when specifying the repository components that will be used throughout each operational period, including surface-to repository zones connecting ramps and shafts.

THE INDUSTRIAL PROGRAM OF WASTE MANAGEMENT AS A BASIS FOR THE DESIGN AND IMPLEMENTATION OF THE CIGÉO PROJECT

Andra has launched in 2012 the basic design of the Cigéo project [4]. This study has needed to stabilize the input data particularly those concerning the waste inventory and waste packages delivery modality within an agreement between Andra and the nuclear operators EDF, AREVA, and CEA.

The Industrial Program of Waste Management (PIGD) provides the link between Andra and waste producers to plan and implement coherent industrial resources. In this context Andra, EDF, AREVA and CEA established a cooperation agreement for strengthening their collaborations in these fields. The PIGD describes the waste inventory. It schedules the delivery of the different categories of waste and defines associated flows. It identifies the existing industrial facilities which will be used on nuclear operator sites to manage the waste packages prior to their shipment. It also points out the needs for additional facilities to be implemented by nuclear operators (waste packaging, interim storage, shipment facilities). It also addresses the waste transportation system from production/storage sites to Cigéo. This program is aimed at being periodically revised in accordance with the successive design phases of the Cigéo project.

INDUSTRIAL BASELINE

The main activities contributing to the production of HLW and ILW are the electro-nuclear industry (EDF nuclear power plant reactors, AREVA fuel recycling plants at La Hague and Melox) and research and national defence activities (CEA centres). Along with used fuel reprocessing residues waste produced by operation and maintenance in recycling and nuclear power plants must be taken into account.

Successive generations of nuclear reactors have been developed in France:

- First generation mainly consisted in 9 Natural Uranium Gas Graphite reactors built during the years 1950th to 1960th.

- Second generation is constituted by 58 pressurised water reactors currently in operation in France.
- Third generation, with the European Pressurized water Reactor (EPR^{TM}recator) under construction in Flammanville (in western France).

Used fuels unloaded from the EDF reactors are reprocessed in AREVA plant at La Hague. The aim of reprocessing is to separate the uranium and plutonium, themselves considered as valuable materials, from the waste itself: fission products, activation products, minor actinides packaged into a stabilized and safe form in La Hague plant. Added to these high-level residues are essentially metallic materials from fuel assemblies and intermediate-level operating and maintenance waste from reprocessing plant (liquid effluents, etc.).

The ILW-LL produced by sectors other than electro-nuclear industry (research, defence) is usually intermediate-level technological waste: replaced or obsolete parts contaminated by processed materials and radioactive waste, etc.

The waste inventory defined to design Cigéo includes both the waste already produced, that is stored in conditioned and unconditioned form on the production sites and the waste that will be produced in the future by the current french nuclear power plants, recycling plants and nuclear research activities including waste coming from dismantling operations.

This inventory assumes an average operating time of fifty years for all existing PWRs as well as for the EPR^{TM}recator under construction. Future net electricity production taken into account is about 430 terawatt hours per year (TWh/y) (+ 13 TWh provided by the EPR^{TM}recator). The estimated cumulative production in 2066 is about 21,000 TWh. The cumulative tonnage of heavy metal (hmT) discharged in 2066 is about 64,150 tonnes (hmT) including 58,000 hmT of uranium oxide (UOX) fuels, 2,150 tons of (ERU) Re-enriched Uranium fuels and 4,000 tons of mixed oxide (MOX) fuels. All these used fuels are considered to be reprocessed and the relating reprocessing wastes are included in the Cigéo waste inventory.

This inventory is based on the continuation of nuclear power generation in the future and especially on the reuse, after recycling of the Pu content into MOX fuels. The waste to be produced by the future reactor fleet is not considered.

CIGÉO WASTE INVENTORY

Cigéo is designed to accommodate both intermediate level long-lived waste and high level waste.

Intermediate-Level, Long-Lived Waste

ILW-LL include a large variety of items such as structural elements from fuel assemblies (cladding from the fuel rods called "hulls", end pieces called "end caps" and assembly spacer grids, etc.), sludge from effluent treatment, miscellaneous equipment (filters, pumps, etc.). Most ILW (except solidified sludges) are basically metallic but organic and inorganic components such as plastics and cellulose may also be included.

These wastes are divided in 77 waste package families and represent a volume of about 70,000 m^3. Examples of ILW waste packages are given in figure 1 (a) solid maintenance waste in fiber reinforced concrete containers (CBFC'2) with a volume of 1,18 m^3, (b) bitumineous waste package from effluent treatment (volume of 222 liters), and (c) compacted waste packages CSD-C (volume of 180 liters).

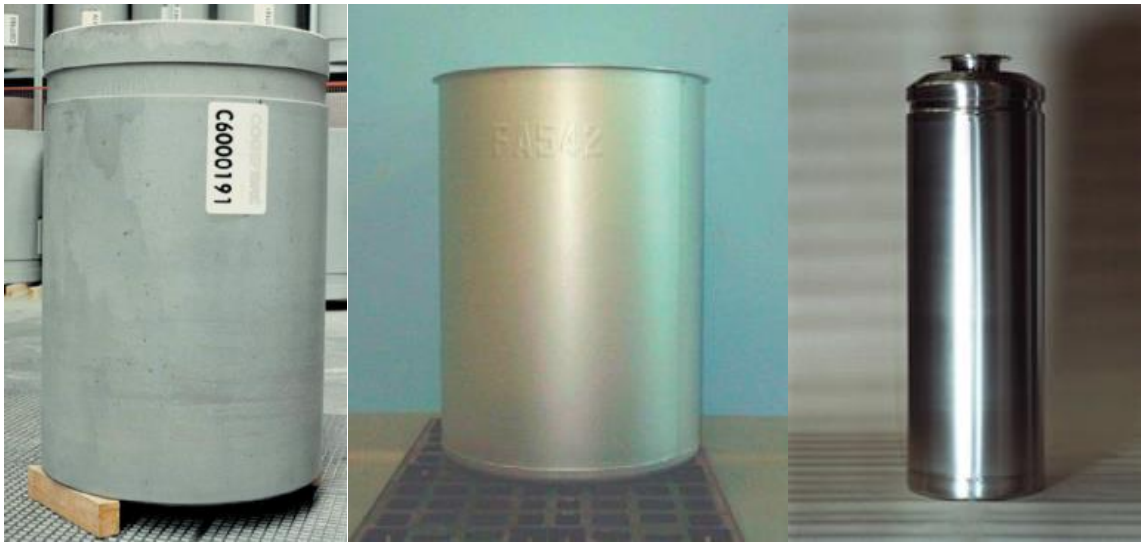

Fig. 1. Example of intermediate level waste packages (a) solid maintenance waste in fiber reinforced concrete containers (CBFC'2), (b) bitumineous waste package from effluent treatment, and (c) compacted waste packages CSD-C).

High-Level Waste

HLW mainly consist in unrecoverable material contained in used fuel pellets: fission products, minor actinides, activation products. Its high beta-gamma level generates considerable heat which decreases over time, mainly with the radioactive decay of cesium 137 and strontium 90. It is incorporated into a borosilicate glass matrix R7/T7 glass with a particularly proven and high and long-lasting containment capacity under favourable physico-chemical environment conditions. The radionuclides are thus spread uniformly in the glass matrix. This vitrified waste is poured into standard stainless steel drums which a volume of 180 liters (figure 2) .

HLW are divided in 17 waste package families and represent a volume of about 10,000 m^3.

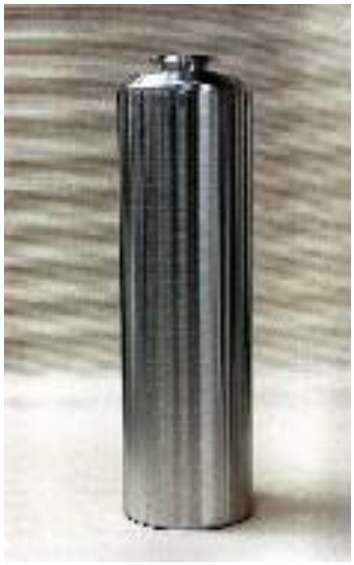

Fig. 2. Example of vitrified fission products and minor actinides waste package CSD-V.

WASTE DELIVERY PROCESS

A major issue of the industrial program of waste management is a preliminary time schedule of waste delivery. It aims to take into account the industrial needs of waste producers with regard to waste package flows and logistical means from storage to disposal. The guiding principles are the following :

- Disposal of ILW between 2025 and 2085;
- A gradual rise over the period 2025 – 2030;
- Reception at Cigéo until 2050 of waste produced to date;
- Smoothing the flow of waste packages to be transferred from the surface to the underground disposal cells;
- Disposal of highly exothermic HLW from 2075, to benefit from significant heat decrease;
- Simultaneous disposal of ILW and HLW between 2075 and 2085; and
- The possibility of operating Cigéo until 2140 (receipt of packages and closing).

Transportation

The development of the transportation system of conditioned waste from the production sites to Cigéo is the responsibility of waste producers. The main production sites (La Hague and Marcoule) have infrastructures for road and rail transport. EDF Bugey site is connected to the rail network.

Transport Casks

The diversity of waste leads, as forecasted now, to a diversity of transport casks type which could be standardized in the future. Most casks to be used to transport waste from La Hague already exist. An example of the TN28 which is used for transportation of CSD-V is shown in figures 3 .

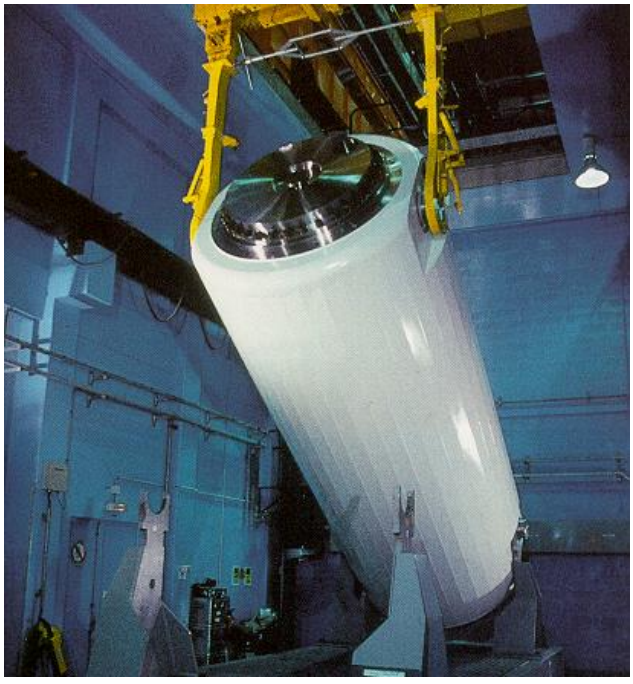

Fig. 3. TN 28 Transport cask for 28 CSD-V.

Storage Facilities

All waste produced by 2025 will be stored on the production or conditioning sites prior to be shipped to Cigéo for disposal. Table I identifies main storage facilities in France for various waste families. The forecast operating lifetime of these stores is generally 50 years. This leads to estimated shutdown dates between 2040 and 2060.

TABLE I: Main Storage Facilities in France for ILW and HLW Families

Site	Storage	Waste Families
La Hague	R7, T7, E-EV-SE (figure 4)	− Vitrified fission products and minor actinides CSD-V − Molybdic vitrified solutions (CSD-U) − Intermediate level vitrified effluents (CSD-B)
	ECC*	Compacted waste packages CSD-C (hulls, end caps, maintenance waste)
	EDS**	Hulls and end caps in concrete matrix
		Solid maintenance waste in concrete matrix (CAC)
		Solid maintenance waste in fiber reinforced concrete containers (CBFC'2)
		Powdered waste cemented steel containers called (ECE)
	Buildings S & ES	Bitumineous waste from effluent treatment STE3
		Bitumineous waste from STE2
		STE2 sludges dried, compacted and packaged in steel drums
		Maintenance waste contaminated with alpha emitters
Marcoule	APM (Atelier Pilote de Marcoule) (Building 213)	Pilot vitrified waste PIVER
	AVM (Atelier de Vitrification de Marcoule)	− Vitrified fission products and minor actinides AVM − Maintenance waste produced by the operation in the AVM Facility (Marcoule vitrification workshop) − IL vitrified effluents
	Casemate 14	Waste conditioned in bitumineous matrix
	EIP (figure 5) (Entreposage Intermédiaire Polyvalent)	Waste conditioned in bitumineous matrix
	Diadem	*Highly irradiating waste (in design phase)*
Cadarache	CEDRA FI *** (buildings 374 and 375)	Sludges cemented in concrete containers (500 litres {L})
		Cemented maintenance waste (870 L)
	CEDRA MI*** (building 376)	Cemented maintenance waste (500 L)
Bugey	*ICEDA*****	*NPP activated waste – maintenance and dismantling (under construction)*

*ECC : Entreposage des Coques Compactées

**EDS : Entrepôts de Déchets Solides

***CEDRA FI and MI : Conditionnement et Entreposage de Déchets Radioactifs

****ICEDA : Installation de Conditionnement et d'Entreposage des Déchets Radioactifs

Fig. 4. E-EV-SE Storage (AREVA La Hague).

Fig. 5. EIP Storage (CEA – Marcoule).

Industrial Issues on the Cigéo Site

Reception of Transport Casks and Buffer Storage

Waste package flows and delivery schedule determine the design of the reception facilities in the basic design of Cigéo.

Transportation casks will be unloaded in dedicated workshops installed in Cigéo's nuclear surface facilities. No significant storage capacity is considered on the Cigéo site. The required buffer capacity will be progressively defined with regard to an industrial optimization of Cigéo operation.

Overpacking

The nuclear surface facilities will allow the overpacking of waste packages in disposal containers prior to underground transfer for disposal.

Control of the Waste Packages

The waste management programme includes a number of waste controls to be implemented at various stages:

- Permanent controls carried out under the responsibility of the waste producers all along of the production process; record files are transmitted to Andra;
- On line controls carried out under the responsibility of Andra to check compliance with Cigéo safety requirements; and
- Second level controls for quality control within the waste acceptance process.

Part of these controls will be carried out in Cigéo's nuclear surface facilities.

Underground Transfer and Waste Emplacement

Special shielded casks will be used to protect operators from irradiation during waste transfer between surface facilities and underground disposal cells. These casks are unloaded at the entrance of the disposal cells before waste emplacement. Waste emplacement requires remotely controlled handling equipement.

SUMMARY AND CONCLUSIONS

In this paper we have described the waste inventory of ILW and HW to be taken into account in the Cigéo Project and the structural hypothesis underlying its passed development. We have also described the waste delivery process.

These data are an essential input of the basic design of the Cigéo project. These data have been compiled in the PIGD document. This document has been evaluated by the French regulator.
This inventory has been prepared by the three main waste producers AREVA, CEA EDF and by Andra in the frame of a cooperation agreement which has allowed a reinforcement of the collaboration between them.

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