Extending Vitrified Waste Canisters (CSD-V) Interim Storage Facility: Improving Durability by New Elements of Design – 11497

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ABSTRACT

Interim storage is an important facility for managing High Level Waste (HLW), especially prior to transportation and final geological disposal. AREVA is developing a new interim storage facility that will technically and economically improve recycling services.

Interim storage facilities in France have been developed in different locations for managing vitrified waste, before to be disposed or returned to owners. AREVA developed in La Hague the most significant interim storage facilities. Such a development relies on continuous improvements to deal with technical progress, economic optimization, sustainable development, and changes in regulations or societal requirements.

Hence, AREVA is now building a fifth interim storage facility for vitrified waste universal canisters (UC-V) in La Hague, by extending the existing E/EV/SE facility. At the moment, facilities in operation offer a capacity of 12420 canisters.

The main objective is to extend the facility's durability, compactness, and sustainability, by optimizing concrete formulation, global design, and minimizing environmental impact. It will ensure long-term canister stability, in terms of the physicochemical evolution for both glass and steel. It will also take greater advantage of the standardized UC-V design, potentially allowing for storage of compacted waste (UC-C).

The new E/EV/LH storage building has been designed to be operated over 100 years with respect to new building codes such as EUROCODE. Thanks to the E/EV/SE facilities' operational feed-back, the new design uses up-to-date technologies and features within the best economic scheme.

A "design-to-cost" project management method has been used, leading to a 20% cut in investments and operating costs, while still ensuring a high level of safety.

The paper describes the new E/EV/LH interim storage facilities' characteristics and related capacities. It is designed for 4212 universal canisters and cover a surface of 600 m2 - a reduction of 30% when compared to the surface needed to store the same number of canisters in the previous storage facilities.

The development of this new facility demonstrates AREVA's twenty years of experience in developing interim storage facilities thus building confidence in future facilities and public acceptance of the closed nuclear fuel cycle.

INTRODUCTION

France has a long-standing energy policy based on nuclear power. It derives more than 75 % of its electricity from nuclear energy thanks to an active development in nuclear technologies and processes.

The last national energy policy act (July 2005) reinforced that policy, especially driven by the CO2-free nuclear energy concept. Despite nuclear's attractiveness regarding limitation of CO2 production, it produces different kinds and levels of radioactive waste. Consistently the national policy also focuses, for many years, on reducing radioactive waste and providing a management solution. The focus is mainly on high level and long lived waste.

Within that context, over the years, AREVA developed the reprocessing of used fuel so as to recover uranium and plutonium for re-use thus reducing high-level waste volumes for disposal. Reprocessing allows more energy to be extracted from the used fuel and leads to a large reduction in the wastes for disposal.

On the other hand, the method of long-term disposal of these wastes had to be defined. The national 28 June 2006 Planning Act, concerning the sustainable radioactive materials and waste management, selected geological deep disposal as the reference solution for the long-term -that solution being actively prepared to be implemented after 2016.

Figure 1: Areva La Hague plant, including interim storage facilities on right side

Since the geological disposal is in preparation while used fuel from the French reactors and from other countries is processed at AREVA La Hague plant, high level waste from reprocessing (3 to 4 % of the used fuel material) has to be stored in the mean time in interim storage facilities, for later disposal or return to foreign owners.

In addition, geological repository design is strongly driven by waste's thermal behavior. In the French case, all fuels treated and vitrified produce waste with high thermal power. Interim storage is needed in order to achieve the thermal power limit for the geological repository.

Interim storage is a key facility for managing High Level Waste (HLW), especially before transportation and final geological disposal. AREVA is therefore operating specific storage facilities for HLW in La Hague.

Since June 15th 2009, AREVA has been building a new interim storage facility, the extension of the existing facility called EEVSE. This new building has been designed to join a previous interim storage facility to form a single global facility.

Even if vitrified waste interim storage facilities in France have been historically developed in other locations, AREVA - La Hague is the most significant interim storage site. It relies on continuous improvements to deal with technical progress, economic optimization, sustainable development, and changes in regulations or societal requirements.

The paper describes the new E/EV/LH interim storage facility's characteristics and related capacities. It will technically and economically improve recycling services and disposal architectures.

CURRENT FACILITIES, CAPACITIES, AND SERVICES

Vitrified canisters are produced in La Hague at an average rate of 1000/year as a result of reprocessing services for customers.

These services include, as said before, an interim storage before the shipment of canisters to owners.

The first step for improving interim storage was to achieve canister standardization. Current processes produce HLW in a Universal Canister-Vitrified (UC-V).

The UC-V is a steel canister 43 cm (17 inches) in diameter and 1,4 m (55 inches) in height.. The total volume is about 180 liters (47.5 US gallons) and is filled with about 400 kg (882 pounds) of glass containing 65 kg (143 pounds) of fission products and minor actinides (about 15% to 17% in weight of FP and actinides) calcinated, melted, and incorporated in borosilicate glass matrix

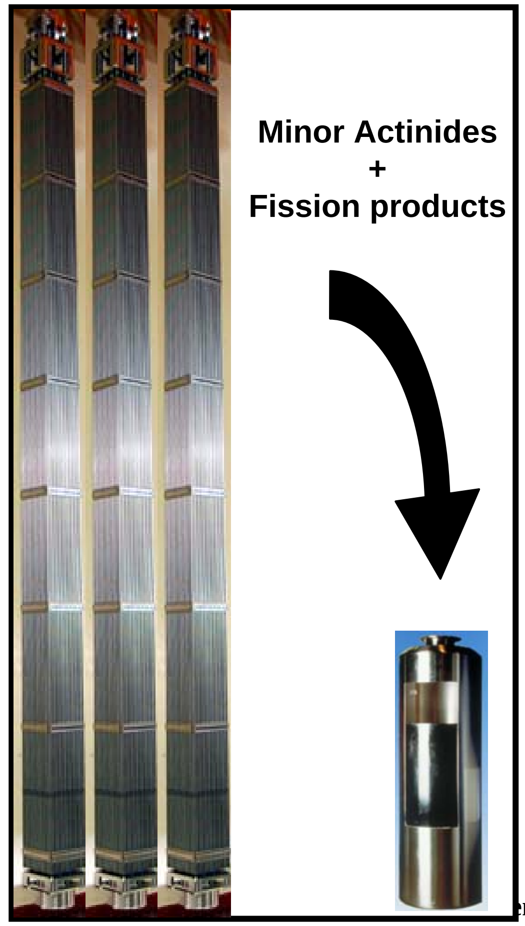
Figure 2: Universal Canister-Vitrified (UC-V)

Major actinides (U, Pu) are separated and preserved to be re-used.

One UC-V contains the fission products and actinides of about 3 spent nuclear fuels (SNF - mean value evaluated with a burn-up of 45 GWd/tU and 500 kg of heavy metal per assembly).

Metallic residues (structural components) are compacted; the standard waste form for compacted ends and hulls is called UC-C (same shape, filled with compacted ends and hulls).

These UC-V canisters are stored in the production facilities R7 and T7 since 1989 and in the interim storage facility E/EV/SE since 1995. At the moment these facilities offer the capacity for 12420 canisters within 3 buildings (4 modules with a hundred wells).



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R7 and T7 facilities are part of the production processes. R7's interim storage capacity is 4500 canisters in five modules of a hundred wells; each well contains nine canisters. T7's design is very close to that of R7: four modules of a hundred wells, each well offering a storage capacity for nine canisters. These facilities may therefore store up to 8100 canisters.

These two facilities are dedicated to the first cooling stage of UC-Vs just after vitrification when the initial thermal power is possibly over 2 kW. These facilities contain French as well as foreign UC-V. R7 and T7 interim storage facilities are cooled by a forced ventilation system.

The E/EV/SE interim storage facility has been designed to be used in a second phase after some years of thermal power decay in R7 or T7. It is a 4320 canisters facility divided into two modules of 180 wells containing 12 canisters each. It is dedicated for glass with thermal power less than 2 kW while waiting to reach the 500W thermal power limit (limit given for French geological deep disposal) or being returned to owners.

The EE/V/SE ventilation system design has been modified to be fully passive using natural air circulation in a metallic sleeve enclosing each well (double skin structure). Thus cooling air is not in contact with the containers and can be discharged by the chimney without high level filtration. E/EV/SE was designed for a provisional duration of 50 years.

E/EV/SE also offers improved storage compactness, an increase capacity from 10 to 30 t eq HM/ m² (ton of equivalent heavy metal per square meter) in comparison to R7 and T7.

From a technical point of view, E/EV/SE was initially designed to be extended step by step, by adding identical modules of 180 wells, depending on canister management needs.

At the beginning of 2010, the La Hague plant had produced about 15000 UC-V – the French portion being about 2/3 of the total production. More than 80% of foreign vitrified wastes have been returned to their owners (about 4500 canisters); however, the French portion has to be managed on-site for the time being.

Decision was taken in early 2007 to launch an expansion step, including additional improvements and optimizations.

Beyond the management of French high level waste, AREVA interim storage design is also proposed at an international level. AREVA built for the Netherlands Central Organization for Radioactive Waste (COVRA) the Habog facility (1999-2003 at Borsele).

The Dutch government management policy for high level radioactive waste relates to storage on surface facility for the next 50- 100 years. The Habog facility has therefore been built to last over such a period. It has been designed for resisting gas explosions, airplanes crashes, earthquakes and flooding, according to similar optimization processes than E/EV/SE – with passive air cooling system for instance.

It took advantage of feedback and know-how from E/EV/SE and from the standardization of UV-C canisters. It allows to store the Dutch canisters from both fuel reprocessed at Sellafield or at La Hague.

Gaining from feed-back, past experience, optimizing concept and design in interim storage is then also considered by AREVA as a potential competitive advantage for international services.

TECHNICAL ITEMS, FEED-BACK, AND SOLUTIONS FOR THE NEW E/EV/LH

Safety, still regarded as the main topic, was taken into account for designing facility operations. Design and planning has been consequently approved by French Safety Authority. For example, the building is designed to withstand a 5.8 magnitude earthquake (Richter scale, at 15 km from the source).

Otherwise, objectives for improving durability and compactness were among the more important goals of the project, such as optimizing concrete formulation or minimizing environmental impact.

Figure 4: View of the E/EV/SE installation and of COVRA Habog facility

Durability includes long term canister stability, in terms physicochemical evolution of both glass and steel. The way to take greater advantage of UC-V design standardization has been investigated. For instance, standardization potentially allows for the storage of compacted waste, that is, canisters with different waste content but designed within the same standard.

The new E/EV/LH storage building has been designed to be operated up to 100 years with respect to new building codes such as EUROCODE. Thanks to E/EV/SE facilities operational feed-back, the new design uses up-to-date technologies and features within the best economic scheme.

Finally, this new facility is more compact (+30% of canisters per m²) than the previous one, takes advantage of more than 20 years of interim storage, manufacturing, and operating experience, respects sustainable development aspects, and guaranties safety.

A second extension will be considered later, in 2020, according to the same principles. The global optimization of such extensions is related to the fact that there is no need to rebuild the handling zone facility; new buildings will be connected to existing buildings.

The new extension program consists of larger modules with 324 wells:

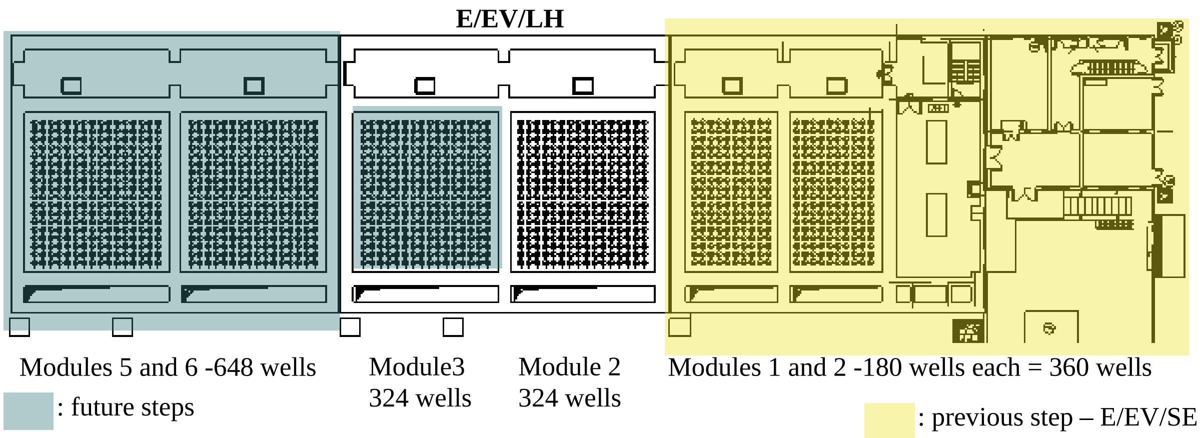

Figure 5: Revisited extension program

New facility characteristic and, technical evolutions

La Hague's new interim storage extension program is shown in Figure 5. The facility under construction is divided into 2 different areas, a storage zone (modules and wells) and a handling zone containing technical supplies and controls shared with the existing E/EV/SE facility

The new E/EV/LH facility will be joined to the existing one, to become only one facility at the end of construction. Only the first E/EV/LH module (Module 2 on figure 5) is competed by wells. The second module (Module 3 on figure 5) will be completed later during the next step of construction.

Compactness:

The new facilities cover a surface of 600 m2 - reduced by 30% compared to E/EV/SE compactness. The improvement of capacity has been achieved by optimizing the use of well volume, allowing the addtition of a 13th canister in every well, and by enlarging the size of new modules (compare Modules 2 and 3 to Modules 1 and 2 on figure 5), increasing the space devoted to storage in comparison to the space for walls and structure.

Durability: preventing corrosion effects

Due to thermal dilatation, metallic vertical wells of previous storages include a dilatation joint at the bottom of every well. That joint allows the accommodation of thermal effects without adding constraints which could damage the well structures.

The joint has been located, up to now, in the lower zone of wells, where the temperature is lower and condensation may appears if any.

Even though such condensation has never been observed, this specific location has been considered as a potential corrosion zone. In order to improve the durability of the facility by limiting corrosion, all the dilatation joints were relocated.

Durability: formulating long standing materials

With the objective to increase the use of the module over 100 years, concrete and metallic structures were specifically designed. Concrete formulations were fitted to local soils and air chemistry, which usually lead to carbonation and /or chlorination. Consequentially, these types of damage are expected to be very low for years.

Well materials, especially the double skin for the flow of cooling air, were also designed to ensure higher resistance to corrosion.

Temperature measurement and air temperature modeling

Managing the existing E/EV/SE has provided significant feed-back and experience in terms of temperature measurement and modeling in the storage modules. This shows the critical locations for temperature measurements as well as locations that are not actually useful for modeling. For the storage extension design, different points of temperature measurement have been defined, increasing acquisition where useful and reducing it where is not.

The temperature path will be better known thanks to the experience gained by modeling, while, at the same time, the costs for measurement equipment are reduced. In practice, temperature measurement devices are located on the foundation raft, intermediary floor, and at different levels on walls. Thermocouples have also been located in specific wells within the module.

An experimental pit

E/EV/LH will be therefore complete with an experimental well designed to let air come in contact with its content. Specific samples of metal and concrete within that well will be exposed to local conditions throughout the operation of the facility. The goal is to check that radiological resistance of materials is as expected. Samples may be used to study the long-term evolution of metal and concrete in a radiological environment for other applications such as the design of a geological repository, for example.

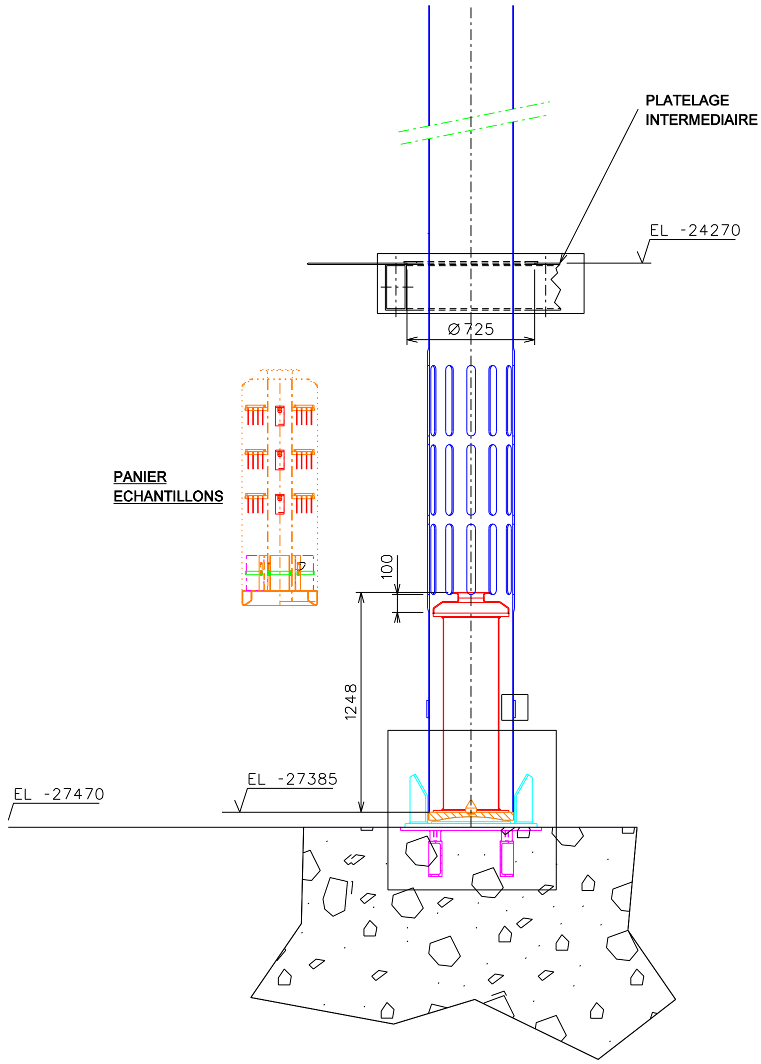

Figure 6: Experimental pit

Ventilation

The shape of the chimney's air inlet has been modified to improve protection against icing-over and snow effects and therefore reduces corrosion risks due to the humidity inside the building.

In addition, the need for the electrostatic air filtering system has not been retained since it has been observed in the previous storage facilities that only a very low influx of particles really exists. This brings benefits by reducing the maintenance operations for the filtering system, including lowering costs and reduction of the radiological exposure of staff.

The filtering system has obviously been maintained for the outlet flow of the chimney. It is protected from moisture by using a condensation system at the inlet.

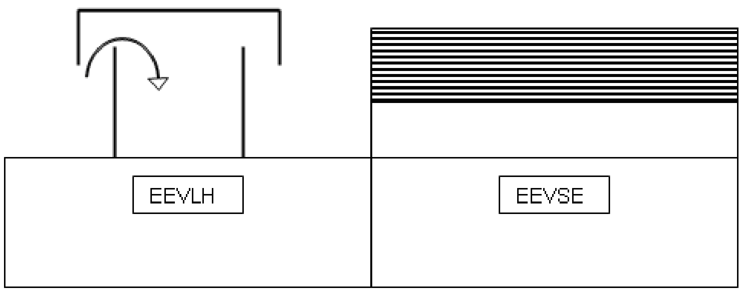

Figure 7: Chimney inlet design change

Radiological protection

Radiological protection is another way for improvement in the new design. Radiological flux outside the facility is already very low for all the existing interim storages. It has been also dramatically reduced inside the facility. This has been achieved by modifying the geometry of the air inlet plenum (U shaped) and by adding concrete shielding all around the chimney outlet.

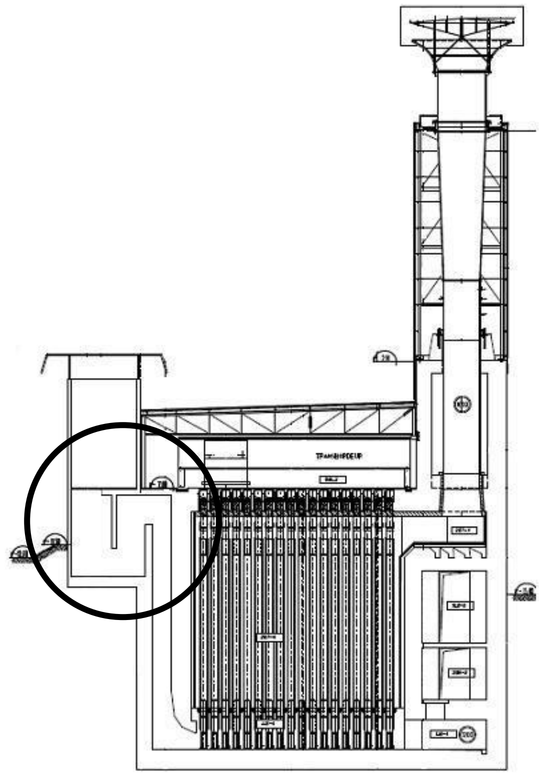

Figure 8: Air inlet plenum new design

PROJECT MANAGEMENT, A DESIGN TO COST METHODOLOGY

An innovative “design-to-cost” project management method has been used, leading to a 20% cut in investments and operating costs, while still ensuring a higher level of safety.

This methodology has effected investments as well as operational costs. Some of the design changes have been directly obtained trough this methodology, such as the reduction in well distances or the increase in module size, as explained above. On the other hand, the optimization of civil works has also provided additional cost reductions.

Optimization by using parts of pre-existing facilities

The first cost optimization was achieved by designing the new facility as an extension of E/EV/SE, by planning to use pre-existing equipment, especially for operations. Offices, main networks (energy, commodities…), and bridge cranes, for instance, were planned to be connected to or to be the same as the ones in E/EV/SE.

However, when building such an extension, drawbacks and additional costs may occur for the operation of the existing E/EV/SE facility, which has to be kept in operation during the construction of the extension. This has been managed by keeping the construction site completely independent and by planning for the final phase works involving the connection to existing facilities.

Optimization of civil works and concrete

In the previous E/EV/SE facility, wells hang within the upper module cover. Due to their weight, the upper floor was designed to support that heavy load. For the new facility, wells are standing directly on the bottom floor, reducing the global structure dimensioning in terms of volume of concrete and steel support structures.

In addition, it can be seen that because the dilatation joint has been moved to the upper part of the well, the bottom floor can be less deep than in the E/EV/LH design. As a consequence, side walls are smaller and require even less concrete and iron structures than in the E/EV/SE design.

Optimization of engineering studies

As said above, part of the cost optimization comes from the use of operational equipment already in use for the existing E/EV/SE. In addition, the design to cost methodology also pointed out that cost optimization may be achieved in using, for example, parts of previous engineering studies.

The wells' size and canister position, for example, has been kept identical (except for the shock absorber at the bottom of every well which has been reinforced to support a 13^{th} canister). It allows the use of the existing mechanical behavior evaluation study (performed for existing facilities), when analyzing safety cases, such as the falling down of a canister within wells.

Cumulative costs

Using the above methods, project costs have been cut by 20%, by comparison to initial expected costs without having effected safety, for instance, there was even an increase in radiological protection.

By comparison to the previous facility E/EV/SE, a global cost reduction by 20% per stored canister has been achieved

Sustainable development, Safety management, and "eco-conception" method

Another innovative aspect of this project management method is sustainable development integration taking into account industrial waste management and construction site environmental impact.

Soil and removed materials have been re-used on site or moved to a very close location, reducing transportation and cost. By comparison to a standard approach, it has been estimated that greenhouse gas and CO2 emissions have been reduced by 55% to 60 %.

The construction site was also isolated from other sites in La Hague in order to develop a specific safety management and a "0 accident policy".

"Eco-conception" for "ecological conception" covers either respect of endemic wild species or reducing CO2 impact by choice of judicious materials and limitation of quantities used (as we saw previously by improving compactness, for example). As said above, soil has been moved close to the initial location in a specific ecosystem with a detailed survey of domestic wild life.

The ventilation system based on natural convection drastically limits operational costs on one hand and environmental impact on the other hand.

As a result of different technological choices, global CO2 emissions will have been reduced by 40% compared to the initial project (a "brother building" of E/EV/SE). Also, the visual impact has also been re-evaluated to make the new building as aesthetic as possible.

FEED-BACK AND FUTURE OPTIMIZATION

The development of the project provides some feed-back for existing facilities and opens means for future optimization.

Feed-back optimization

The possibility to house 13 canisters per well instead of 12 has been studied for the new facility, but it has also been considered for the existing E/EV/SE. As project feed-back, it will allow the increase of E/EV/SE capacity. The application of this optimization to all of the extension programs, when fully built, will provide interim storage for about 30,000 universal canisters.

Management optimization

Increasing capacity by adding a 13th canister brings constraints for the thermal power of that additional canister. The effective use of that capacity is therefore related to the availability of the appropriate canisters at the right time – including minimizing operating costs.

This emphasizes that managing canister production is an important way for optimizing the effective capacity of interim storage. In practice, managing vitrified waste interim storage needs to select spent fuel to be treated (depending on its radiological characteristics) consistently with the storage availability where the new canister will be successively stored (consistently too with its thermal power evolution).

On the other hand, to optimize waste transport, it's even necessary to anticipate how and when wells are cleared out when canisters are removed from storage to be sent back to owners or to final geological disposal.

Management of spent fuel and vitrified canister processing chronicles will therefore stay a current item for the future optimal use of interim storage capacities.

One may also focus on the fact that it is also an element for the reversibility of geological disposal, or for designing the geological disposal project. For example, the size, location, and flexibility in managing interim storages may change the need for local interim storage on a geological disposal site.

Future optimization, from an eco-conception point of view, may also concern heat transfer and recycling. The fact is that a full module of the E/EV/LH may have a heat load up to 6 MW which is given off from the module in the current design. It could be an interesting option to recycle part of it as an energy source for the plant, saving part of the energy needed within the different industrial processes.

Full studies have been launched for two options either by using a heat exchange system within the chimney or by diverting a part of the air flow for thermal exchange outside de facility. The first system does not provide enough energy savings. The second option may produce several hundred KW but generates a decrease of the air flow within the module to a level considered to be too low for the required safety standards.

This potential improvement needs more investigations and efficiency proofs prior to implementation.

CONCLUSION

Within the frame of its recycling activities and services, AREVA designed standardized universal canisters to manage high level vitrified waste. As a result of used fuel treatment, they present great advantages in term of volume, radiotoxicity, and standardization when compared to initial used fuel.

The management of these canisters, before sending them back to their owner or while waiting for a final geological disposal, is also provided by AREVA using specific interim storage facilities in La Hague.

AREVA has twenty years of experience in developing such interim storage facilities, thus building confidence in safety and step by step optimization of designs. Since June 2009, AREVA is building a new facility in La Hague.

This interim storage has been designed in order to increase safety, capacity, compactness, durability, and radiological protection. Eco conception has been used, lowering environmental impact and CO_2 emissions during construction. The project has been prepared using a “design to cost” methodology, finally leading to a global cost reduction by 20%, even when accounting for feed-back improvements from experience acquired on previous interim storages.

Such a development allows AREVA to provide improved services at the best cost and to contribute to the global high-level waste management in France.