Retrieval of High Level Waste for the Cigéo Project - A Practical Retrieval Test Story - 16085

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ABSTRACT

Since the passing of the June 28, 2006 Act, Andra has incorporated in its step-wise design development of the French high level waste (HLW) and intermediate level long lived waste (IL-LLW) deep geological repository (DGR, aka Cigéo) various requirements linked to “reversibility” at different stages of the repository life cycle (from its construction phase to its final closure).

Reversibility is based on a number of practical dispositions including the progressivity of the development and deployment of the facility, the flexibility of the nature of operations being carried out, the adaptability of the facility to future modifications and the possible retrieval of waste. The capacity to retrieve waste from Cigéo, also called “retrievability”, bears specific requirements. On a shorter term, one must demonstrate that the waste container retrieval operations are technically safe and feasible over at least 100 years.

The current paper starts with two acceptations: retrievability and reversibility. It details how those two notions are defined and interlinked. The “Retrievability Scale” as proposed by OECD/NEA (and adopted by Andra) is also reminded. The needs for demonstration of retrieval operations are also exposed for the two categories of waste containers disposed of in Cigéo (IL-LLW and HLW) within the context of their respective emplacement configurations (in disposal horizontal vaults and micro-tunnels) at different stages of the repository life cycle.

The technical part of the paper is then focused on a practical case story: a technological test campaign (still running) of HLW container retrieval out of a steel cased disposal micro-tunnel. On a test bench built on surface to simulate (create) the environmental conditions that may prevail inside a HLW micro-tunnel at time of retrieval, it was possible to check whether the mechanical means developed for the purpose were adequate and sufficient.

The test case story is exposed, c/w the problems and challenges encountered (high temperature impairing the retrieval robot’s proper functioning, presence of corrosion products…). The trouble-shooting solutions implemented and the results are commented.

This article concludes with a critical analysis of the methods and equipment used, the results obtained and provides some perspectives of improvement. The positive outcomes of this technical test campaign pave the way for planning the in situ retrieval tests to be programmed in the “industrial pilot phase” of Cigéo (to be implemented over the ten first years of operations, including the active and inactive test period and the first years of disposal activities): the industrial pilot phase is presently scheduled around 2026-2036 (provided the Cigéo construction is authorized

in 2021, following the licensing request filing scheduled in 2018).

The issues of IL-LLW containers retrieval (for which specific solutions are also studied and technical demonstrations engaged or planned) are also briefly presented.

BACKGROUND

Concerning the evolution of Retrievability and Reversibility issues within the legal context in France, a few milestones are first reminded:

- In December 30, 1991, the first Nuclear Waste Management Research Act was voted by the French Parliament. This law provided for the study of a DGR where reversibility was accounted for in parallel with a design option where irreversibility was the reference;
- In December 1998, the French Government decided that in effect the studies on the DGR would be conducted with respect to the “logic of reversibility” only;
- In June 28, 2006, a new Nuclear Waste Management Act was passed, stating that a deep reversible repository becomes the reference solution for HLW/IL-LLW waste disposal and that the DGR licensing can only be granted after passing a new law establishing the “reversibility conditions” (the period of reversibility of the disposal cannot be less than 100 years).

This legal context has defined an innovation regime for Andra, which demands a permanent mediation work between technical, social and political realms. The ethical demand for reversibility is linked with the long time scale implied by the management of HLW and IL-LLW, in particular the operational period of Cigéo that will last over a century (its final closure is estimated around 2150).

Andra’s current perception of stakeholders’ expectations concerning reversibility is summarized as follows:

- One must keep open alternative waste management solutions;
- One must facilitate the decision of the future generations;
- Future scientific and technical developments will have to be progressively introduced in the project;
- Stakeholders (and the Parliament) must keep a tight control of the disposal process and deployment progress, including DGR closure operations;
- Retrieval of waste is a technical feature that facilitates possible decisions like reconditioning of waste, valorization of the substances in the waste, reorientation of the waste disposed of towards alternative waste management solutions.

At the same time, the Regulators and the external reviewers have stressed that technical provisions for reversibility and retrievability must not jeopardize operational and long term safety.

DEFINITION OF REVERSIBILITY AND RETRIEVABILITY

During the period 2008-2011, a “Reversibility and Retrievability” project was run under the aegis of OECD/NEA (see Ref. 1). At the end, a definition was adopted for each of these 2 terms:

- Retrievability is the ability to retrieve (remove) emplaced waste or entire waste packages, at different stages of the DGR life cycle. The "Retrievability Sale" presented in Figure 1 implies that the capacity to retrieve the packages becomes more complex as the progressive closure of individual disposal cells, disposal panels, connecting drifts, shafts and ramps is carried out. As a counterpart, passive (long term) safety progressively prevails.

- Reversibility has a broader meaning. It refers to the decision-making process adopted during the project implementation: it involves ensuring that pursuing, modification or reversal of one or a series of previous decisions may be possible if needed, without excessive effort. It implies that the options illustrated in Figure 2 stay open and that retrievability may be reassessed on a regular basis. Reversibility is defined as the capacity to offer to the next generation different choices in terms of long term radioactive waste management.

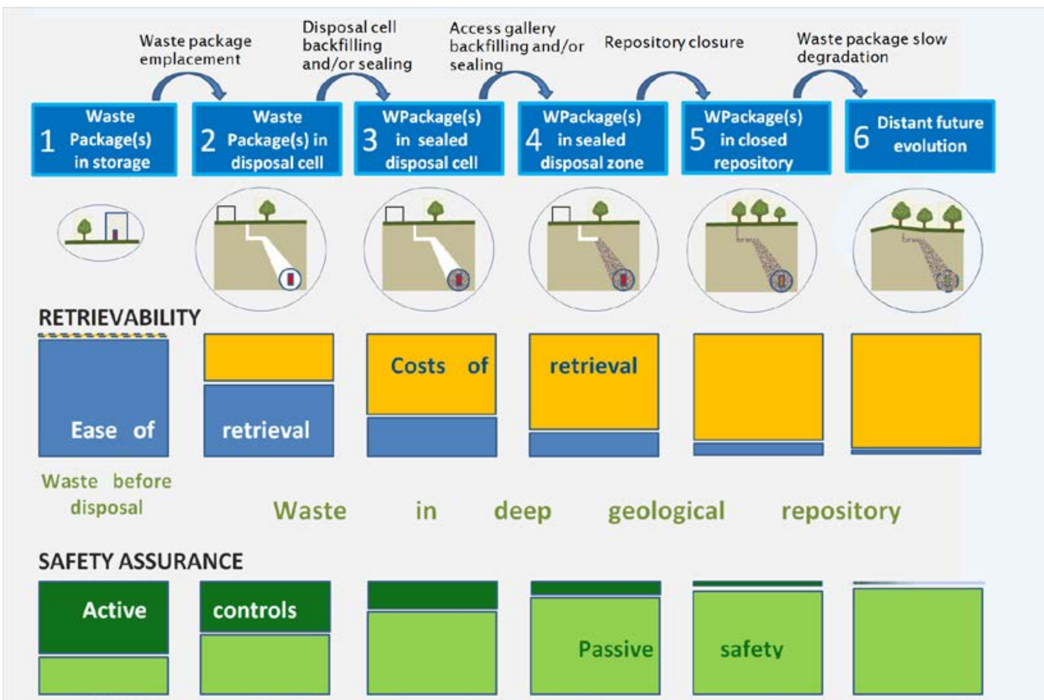

Figure 1 – Retrievability scale as per OECD/NEA

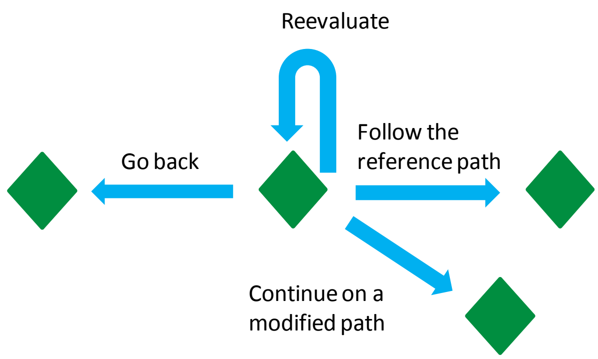

Figure 2 – Reversibility options during the DGR life cycle

DESIGN FEATURES LINKED WITH RETRIEVABILITY

Practically speaking, to address the evaluators and stakeholders' expectations, specific retrievability design features must be integrated to the DGR engineering approach. The following key issues have been taken into account:

- Durability of disposal packages: the steel (for LLW) or concrete (for IL-LLW) storage containers (in which the primary waste canisters are lodged) must stay structurally intact over the retrievability period (at least 100years) to maintain their handling capacity. This integrity over that lapse of time must be justified (for that purpose, the phenomenology is described and phenomena such as "corrosion of steel" are dealt with);
- Durability of disposal cell: the steel casing (for LLW) or concrete liner (for IL-LLW) must also stay structurally intact over the period. This integrity has also to be demonstrated (e.g. evaluation of host rock creeping effects on the underground structures is apprehended);
- Handling capability: there is a need for an accurate package positioning inside the disposal cell coming with a sufficient handling clearance to enhance retrievability (should the disposal cell walls converge with time). This is proved by the construction and test of mechanical emplacement prototypes;
- The mechanical capacity to safely retrieve waste packages must be demonstrated for each type of cell;
- At a later stage, real in situ retrieval operations (for a limited amount of waste packages) must be planned and will be implemented at regular intervals of the Cigéo storage life (independently of the political decision to remove the waste or not, and the ways and means this decision can be taken);
- In the general DGR layout, a capability to transport and to store the removed waste packages must be provisioned (even if a specific installation is not built in advance of hypothetical retrieval operations).

A PRACTICAL RETRIEVAL TEST STORY FOR HLW PACKAGE

Waiting for its final closure (sealing), the HLW disposal cell is totally filled with the waste packages and closed with a radioprotection plug. In this situation the water produced by the disposal cell is either in a liquid or a vapor phase and can be collected (or dissipated by ventilation) in the access drift, while the cell inside is subject to a progressive temperature build-up (due to the thermal activity of the waste).

The HL-LLW package is composed of a primary canister (containing a vitrified waste matrix issued from spent fuel reprocessing) encapsulated inside a steel overpack (some 60mm thick). Its mass varies between 2 and 3 metric tons, for a length of 1.5m to 2.2m and an OD of some 60cm. Its body is equipped with 4 ceramic sliding runners, aimed at reducing the friction effort (during its introduction inside the disposal cell steel casing) and at preventing a progressive “corrosion sticking” (since the host formation water is coming with time inside the cell) which could jeopardize retrieval operations. Its lid (welded to the body, by the electron beam welding technology) is equipped with a machined circular inner groove to allow for traction effort at time of retrieval. Figure 3 illustrates a typical HL-LLW package.

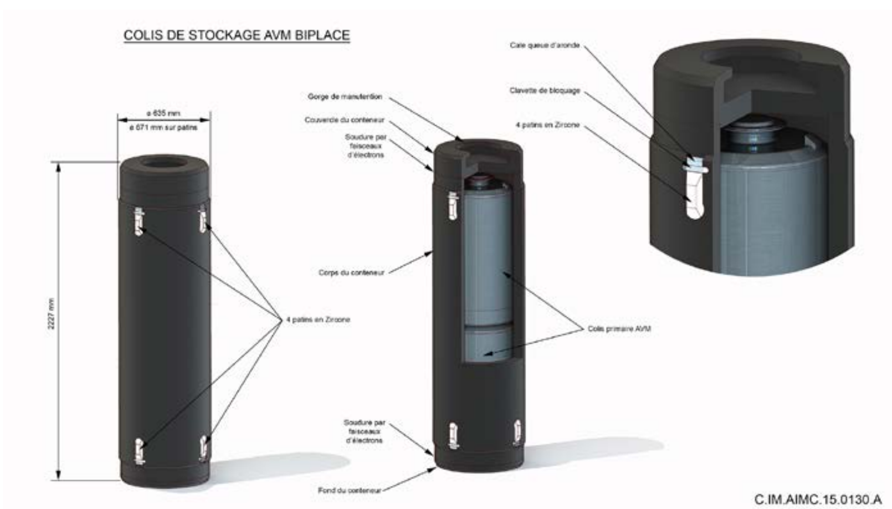

Figure 3 – HLW Waste Package concept

The disposal cell in which the HL-LLW packages are emplaced consists of an 80m to 100m long horizontal borehole (drilling diameter is about 90cm), cased with a steel liner (some 2.5cm thick, with an OD of about 75cm). A disposal cell contains some 30 to 50 HLW packages.

The HLW disposal layout (before its final closure) is illustrated in Figure 4.

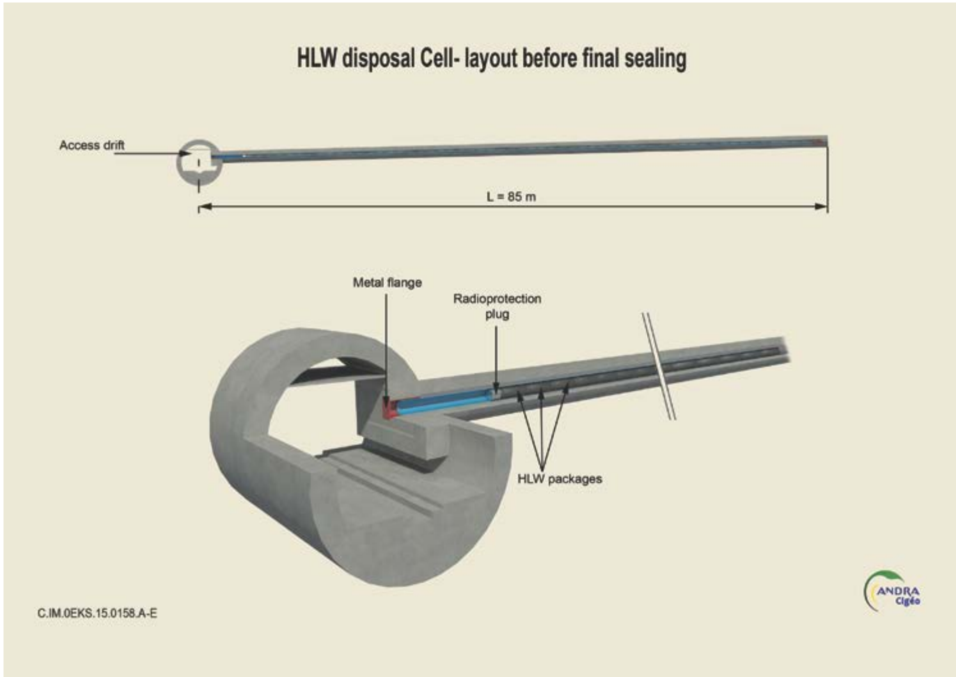

Figure 4 – HLW Disposal Cell layout with radioprotection plug at end

To demonstrate the capacity to remove a HLW package, Andra launched in early 2014 a test campaign where the anticipated evolution with time of the disposal cell (and that of the package) in Cigéo environmental conditions has been simulated. The HLW package retrieval robot concept is illustrated in Figure 5.

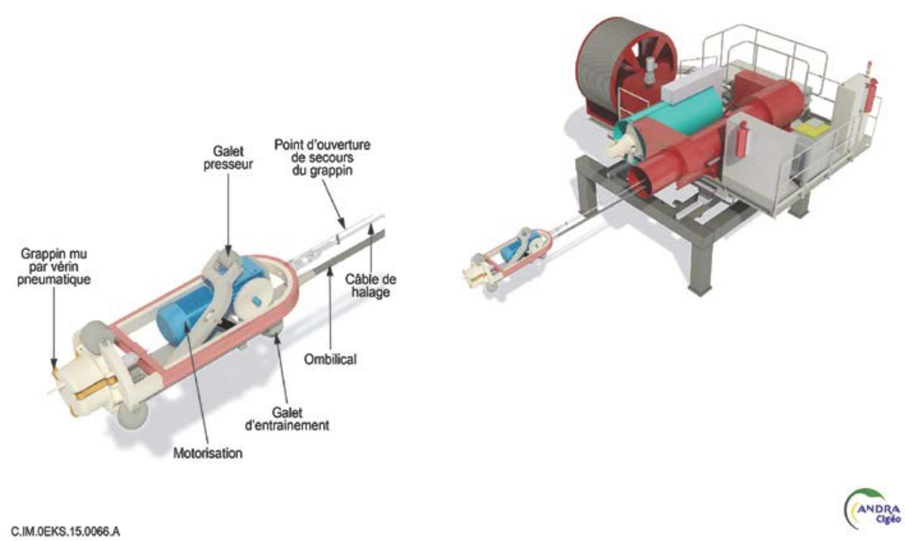

Figure 5 – HLW Disposal retrieval robot concept

The test bench created for this test campaign incorporated special devices to provide heat (up to 90°C) inside the steel liner as well as a salt spray (generating a flow of condensed water running on the liner bottom intrados). These conditions were considered as a penalizing situation, since in the real underground environment the thermal peak should be reached after some 10 years, while the water inlet peak may be somehow deferred in time and with a significantly reduced flux by comparison to the one created on the test bench.

Indeed, during the test campaign, the corrosion phenomenon was very active and some rust was quickly produced in significant quantities. More than 1.5mm of steel was “consumed” by corrosion, either on the steel lining intrados or on the steel package extrados, was measured after a few cycles of “heat and spray combined”. The corrosion created was also considered as representative of what could be measured in the real in situ conditions prevailing after 100 years, thus the saline spray was stopped and only the heat effect was maintained in the liner. The rust was produced in pluri-centimetric flakes, with an important “bulk effect”: 1.5mm of steel “consumption” created flakes of rust some 5mm thick.

The robot built for remote retrieval had to face stringent ambient working conditions:

- The effect of temperature led to change the cameras embarked on the air propelled robot on two occasions and also to modify the actuators (installation of mechanical relays instead of electrical ones);
- Conversely, the presence of water and vapor had no impact on the robot functioning, since its water tightness was satisfactory;
- The effects of corrosion were the most delicate point to handle. Even if the friction effort measured when pulling the package on a much rusted liner intrados did not show any significant difference by comparison with that measured for a package sliding on an “intact” intrados, the robot and the package had a tendency to “plough” and scrape the rust, generating more flakes. Finally, some rust powder and flakes build-up was observed at the cell end. This situation was considered as a potential hazard, since the presence of solids in the radioprotection door rabbet is likely to jam or prevent cell opening and closure operations. Figure 6 shows the liner intrados corrosion and the rust accumulation at the cell entrance (radioprotection door) as observed during the test campaign.
- A decision was taken in mid-2015 to develop and test in 2016 a new robot dedicated to the brushing and vacuum cleaning of rust flakes and powder. This robot will be alternately used with the pulling robot, in due proportion of the needs for rust evacuation (and as preliminarily observed by the cameras embarked on the pulling robot). In Cigéo, this robot could also be used at the early stage of cell loading operations, to minimize the rust inside the liner.

In short, the pulling robot, as tested and optimized after trouble shooting, is capable to move backward the HLW package and retrieve it in severe thermal and humidity ambient conditions. However, it is not a sufficient tool, since sooner or later the rust build-up will generate radioprotection hazards. The rust cleaning system described above is at the time the most adapted complementary device to fully satisfy the retrieval needs.

It is inferred that HLW retrieval operations once the cell is sealed by a bentonite plug positioned inside the liner (i.e. at Level 3 of Retrievability) should also be reasonably straightforward, after the bentonite plug will have been excavated and the remaining bentonite debris will have been swept or vacuum cleaned by a dedicated robot (it is assumed that any H_2 likely to appear inside the cell will have anteriorly been purged).

Figure 6 – Rust production inside the liner (left) and build-up at package contact (right)

TECHNICAL CHALLENGES FOR RETRIEVABILITY OF IL-LLW PACKAGES

The IL-LLW packages are concrete cubic containers (weighing up to 15-16 metric tons) installed inside a 500m long and 10m ID cavern (vault). In 2014-2015, Andra successfully tested a mechanical prototype aimed at retrieving IL-LLW packages from a disposal cavern. This test campaign was run inside a cavern mock-up and showed that a package could be removed even if the initial handling tolerances between the package faces and the cavern walls were downgraded. However, the tests corresponded to a situation in which the cavern was closed and safe from a radioprotection point of view, but not sealed yet.

When the IL-LLW cavern is closed by a seal at both ends (Figure 7 shows a conceptual view of a sealed cavern), there is a significant evolution of ambient conditions. The water coming into the cell or the gases produced are not collected (or dissipated by ventilation) anymore in the access drift (or the ventilation drift). A gas build-up is developing (H_2 in particular), likely to create by concentration an explosive atmosphere (since the seals are progressively becoming water and gas tight, when bentonite is saturated).

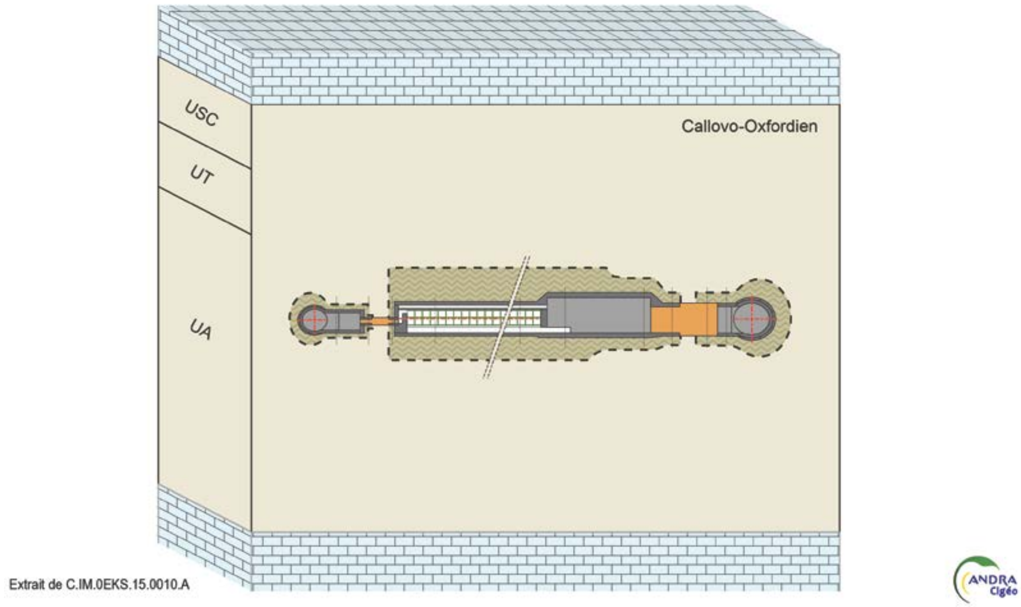

Figure 7 –Conceptual view of a Sealed IL-LLW Disposal Cavern, at Level 3 of Retrievability

In such a situation, in order to remove the packages from the vault, one must first reopen the cavern endings (each seal is composed of a bentonite swelling core contained by 2 low pH concrete plugs) and reposition the package handling equipment. The "cross through" ventilation must first be reactivated to eliminate the explosive atmosphere. These operations create 2 technical challenges:

- Finding a way to drill through the concrete plugs and the bentonite core without inducing any "blow-out". This may be implemented by adapting an oil industry technology, where "blow out preventers" are commonly used. A special study and specific tests are required;
- Dismantling the concrete containment plugs without damaging the structural concrete liner forming the vault wall. A first "deconstruction test" was carried-out in mid-2015, at the end of the "Full Scale Seal Experiment" (Ref.2). It consisted in wire-sawing (thanks to a diamond powder impregnated steel cable) the containment low pH concrete plugs. This was achieved in a reasonable amount of time, without significant difficulties (see Figure 8).

Figure 8 –Low pH SCC containment plug (left) and its wire sawing (right)

It is inferred that the deconstruction of seals at both ends of an IL-LLW disposal cell is possible, but that all the steps of dismantling must be thoroughly explored, in particular the ways the cell atmosphere is purged and the cell ventilation recreated.

SUMMARY AND CONCLUSIONS

From a social point of view, reversibility corresponds to the expectation of an increasing part of the many types of stakeholders involved in the global decision-making process. It has also to deal with democracy (confidence build-up and public acceptance) and with the caution principle.

Now reversibility of decisions and retrievability of waste are two connected notions. If the retrievability capacity is not somehow demonstrated at early stages of the Cigéo Project and later checked in situ at regular intervals, the confidence might be altered and the law.

It is Andra's intent to pursue its dialogue with the concerned parties to prepare the legal and technical contents of this law and at the same time to further explore the practical conditions of retrievability and to develop the adequate handling systems likely to remove the waste.

So far, the various tests of the mechanical prototypes developed to check the capacity to remove the waste packages are satisfactory, but there remain various technical challenges like the preliminary purge of the cell atmosphere and its monitoring: Andra will continue its series of retrieval operations tests in the years to come.

REFERENCES

1- “Reversibility of Decisions and Retrievability of Radioactive Waste- Considerations for National Geological Disposal Programmes” (OECD/NEA, 2012).

2 -“Outcomes of the Full Scale Seal Experiment: A Seal Industrial Prototype for the Cigéo Project” (Bosgiraud et al. – Paper 15207 - WM2015 Conference, March 15 – 19, 2015, Phoenix, Arizona, USA).