State of the Art for Stacking and Emplacing B Type Waste Packages into Large Horizontal Disposal Caverns in a Clay Host Formation - 11005

J. M. Bosgiraud, J. J. Guénin, T. Labalette, G. Ouzounian, J. P. Rigal
Andra, 1/7 rue Jean-Monnet, 92 298 Châtenay-Malabry Cedex, France

ABSTRACT

The research and development work required for manufacturing and testing a full scale demonstrator for remote emplacement of B type waste packages into large horizontal caverns was initialized by Andra in 2007. The technical work is presently implemented in close cooperation with COMEX Nucléaire (an industrial integrator). The case story is twofold.

The first part is related to the initial development of a system used for remote emplacing of a pile of three B type waste containers (each container has a box-type shape, with a 2.6-m length, a 1.5-m width, a 1.9-m height, and a 20-t weight) into 300-m long concrete lined horizontal disposal drifts (also called disposal vaults) with an inside diameter of approximately 10-m (those vaults are excavated in the Callovo-Oxfordian clay host formation at a 550 to 600-m depth). The fully automatized emplacing system is remotely controlled and monitored by a Wi-Fi type transmission, partly embarked on a trolley mounted cart transporting the pile of containers (their design being developed by Andra separately). The concrete containers are preliminary stacked (in a hot cell) in a pile of 3, using an overhead travelling crane.

The second part is related to a system which is being manufactured (for further test and assembly): the application has been re-engineered for remote emplacing of two concrete containers only at a time, in a 400-m long cavern with an 8-m internal diameter (the containers are now preliminarily stacked in a pile of 2, inside a hot cell, using a ground travelling gantry crane). The re-engineering process is justified. The planning of the test campaign (scheduled in 2011) is within the broader planning initialized by Andra to demonstrate its technical capacity to operate reliable and rugged technologies for the future building and operation of a deep nuclear waste geological repository. The qualification test campaign of the Wi-Fi transmission system has already been carried out over a 500-m length, in a realistic underground environment.

The successful completion of the technical trials is mandatory to confirm the mechanical feasibility of remotely emplacing B type concrete containers into large horizontal disposal vaults over long distances, with only a minimal clearance between the piles of containers and the disposal drift walls, while also checking to a certain extent the retrievability capacity of the system. The developed technology is deemed simple and robust. Additional improvements are likely to be incorporated into the design of the future real industrial repository.

The capacity to satisfactorily operate the emplacement system in compliance with its performance assignments and later display the complete machinery at work in Andra's showroom will be instrumental for the confidence building process Andra is engaged in with the various stakeholders during the public enquiry period (circa mid-2013) preceding the deep geological repository license application (planned circa 2014-2015).

INTRODUCTION

The present paper describes the initial B type waste emplacement concept envisaged by Andra and the final mechanical system now being developed, following a re-engineering phase.

BACKGROUND

The background of the work carried out is embedded in Andra's Dossier 2005 [1] which served as a reference document for the passing of the December 28th, 2006 law now governing Andra's activities and in Andra's Dossier 2009 [2], which is an update of the previous document and the last one preceding the licensing file.

The B Type Waste and Its Conditioning in Concrete Containers

The B type waste to be emplaced is a Medium Level and Long Lived waste with a vast array of radionuclides from different industrial origins. The primary packages are conditioned in various ways (drums, boxes) and come with a diversified content (e.g. bitumen matrix, concrete matrix, compacted hulls and endings), usually in large quantities (total volume of primary waste is around 70 000-m^3). Each primary package of B type waste is placed (depending on its mass, geometry, activity and chemical content) in group of 1 to 9 packages inside a high performance concrete box. The mass of the standard disposal package thus created (also called B type disposal container) varies from around 6 to 20 metric tonnes. The estimated volume of B type disposal containers to be stored is around 240 000 m^3.

The typical B disposal package is composed of a concrete box (with 1 to 9 lodgings for housing the primary waste canisters) and a concrete lid. The concrete box with its rebar system is cast in a steel mould and left for a 4 week curing period before commissioning. Its handling is enabled via 2 lateral steel inserts. The compressive strength of the self-compacted concrete (a specially developed formulation) is above 70 MPa and its durability is deemed exceeding 100 years (which is the time period specified to enable some retrievability). Figure 1 shows such a B type disposal package for the "B.3.1.2" container with 2 bitumen primary canisters.

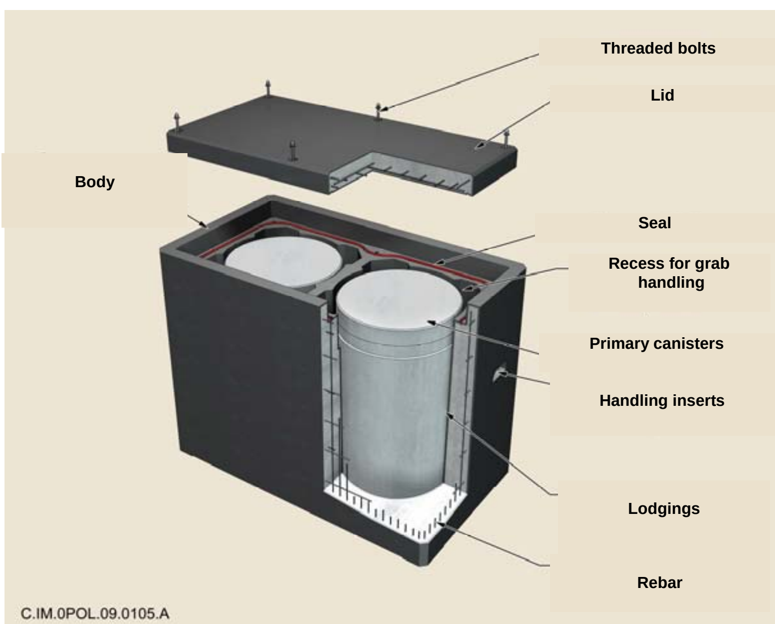

Fig. 1. Disposal Container (B3.1.2 type) Concept [2].

Disposal Concept Design for B Type Package Storage Vaults

The B type waste package disposal facilities and the transfer and emplacement processes are designed with the aim of facilitating any waste package retrieval operations which may be decided in the future, using, if possible, similar means to the ones used for emplacement. As a result, some mechanical clearances for handling purposes (that must be durably maintained) are provided between the pile of packages and the drift walls (or between 2 package piles). A gap of a few decimetres (5 to 20-cm) is now adopted. This value is deemed compatible with the handling of the waste containers during the formation of the pile or later during its transport and deposition in the vault using a battery motorized travelling cart. Figure 2 shows the mechanical clearances considered in the design of a disposal vault for various container sizes and various pile configurations.

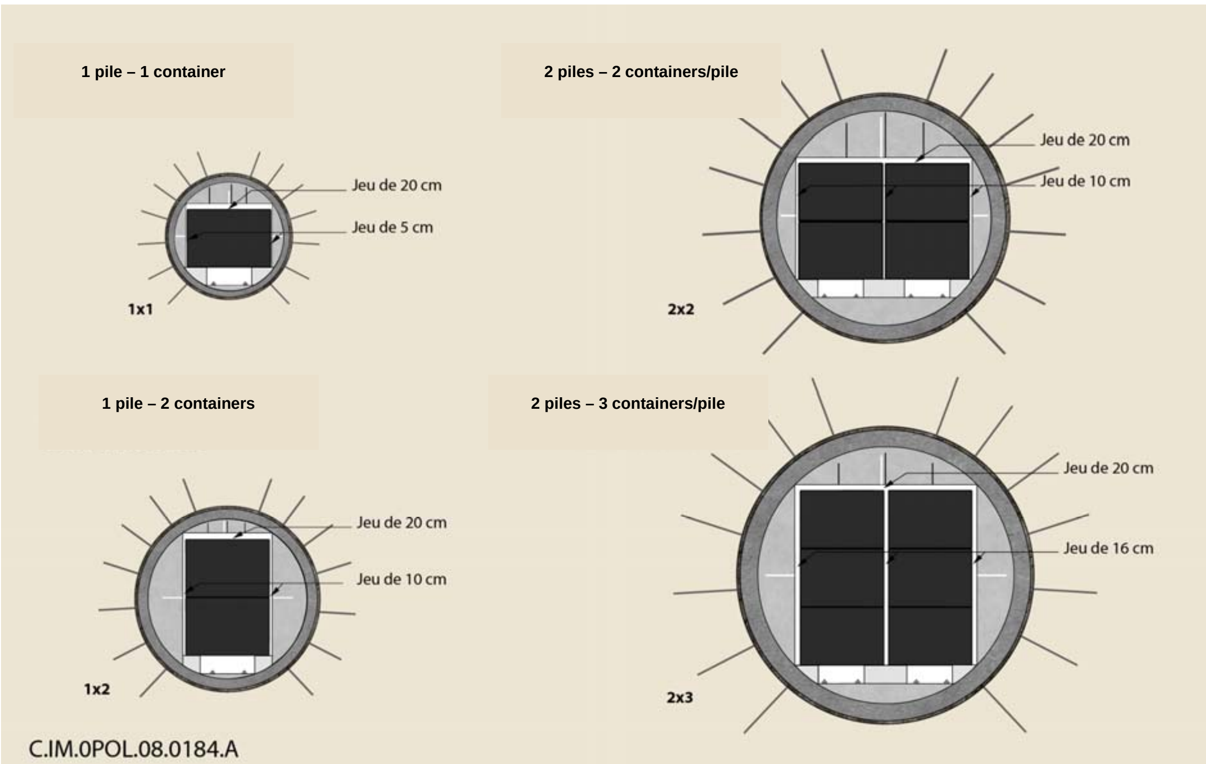

Fig. 2. Cross section of disposal drifts showing the associated clearances [2].

The B type waste disposal drifts are dead-end, horizontal, vaults with an excavated diameter (varying with the number of packages assembled per pile and with the individual size of the container) not exceeding 10-m. At this stage, their length has been limited to around 400-m (useful section) in the reference disposal concept. The drift may be equipped with a ventilation system at both ends for some type of primary waste (bitumen matrix in particular). On closure, the storage drift is sealed by a swelling clay (bentonite) barrier located between two concrete retaining plugs. Figure 3 shows a disposal vault layout in operating mode with its hot cell, while Figure 4 shows a B type waste storage area (panel) in closure phase (with concrete plugs and bentonite sealing).

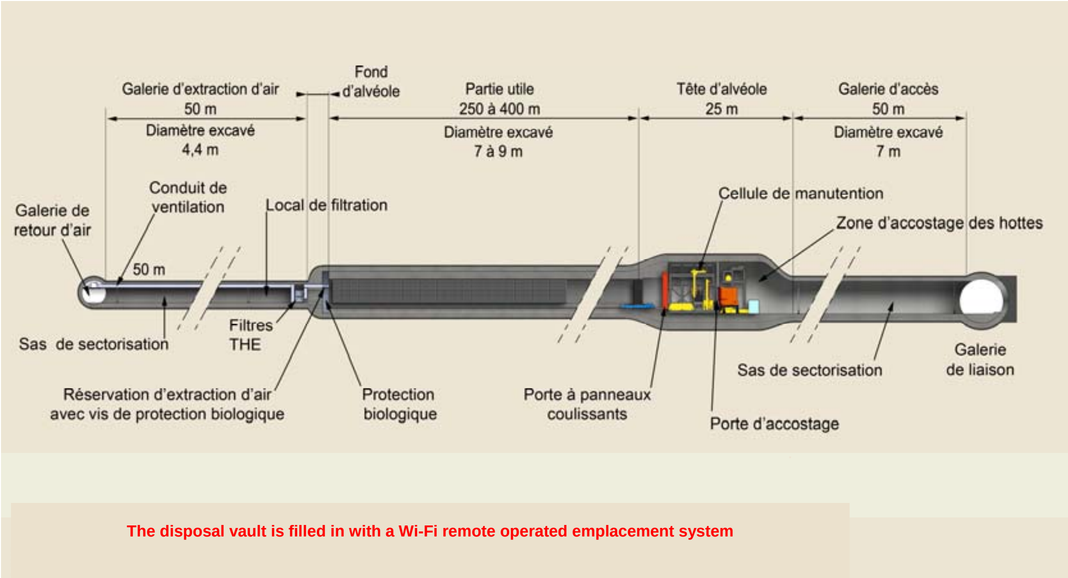

Fig. 3. Disposal vault in operation stage [2].

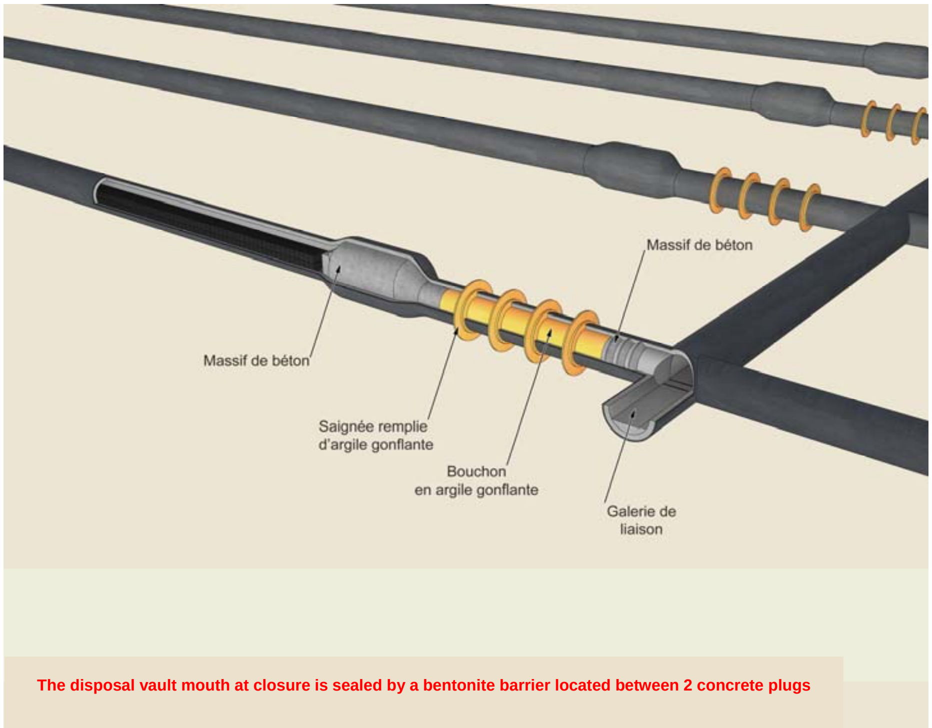

Fig. 4. B type waste disposal panel in closure stage [2].

The B Type Container Transfer from the Surface Facility to the Underground Disposal Drift Mouth

The B type package transfer process in the deep geological repository may be split into two phases:

- The transfer from surface facilities to underground infrastructures (approx.550-m deep). The related technical issues are not discussed, but simply presented hereafter.

- The emplacement per se of the waste into the disposal drifts. For that second phase Andra has successively developed two handling solutions which are detailed hereafter.

The repository layout in Andra's Dossier 2009 [2] significantly differs from that initially presented in the Dossier 2005 [1]. For siting reasons, negotiating of land with owners and with local political stakeholders has led to a new implantation scenario. The surface facilities are now split in two parts: the nuclear zone, which is no longer directly above the underground infrastructures, and the mining zone.

Thus, the various access means are not limited to vertical shafts but include also two access ramps with a 10 to 12% dip. Figure 5 displays the new configuration.

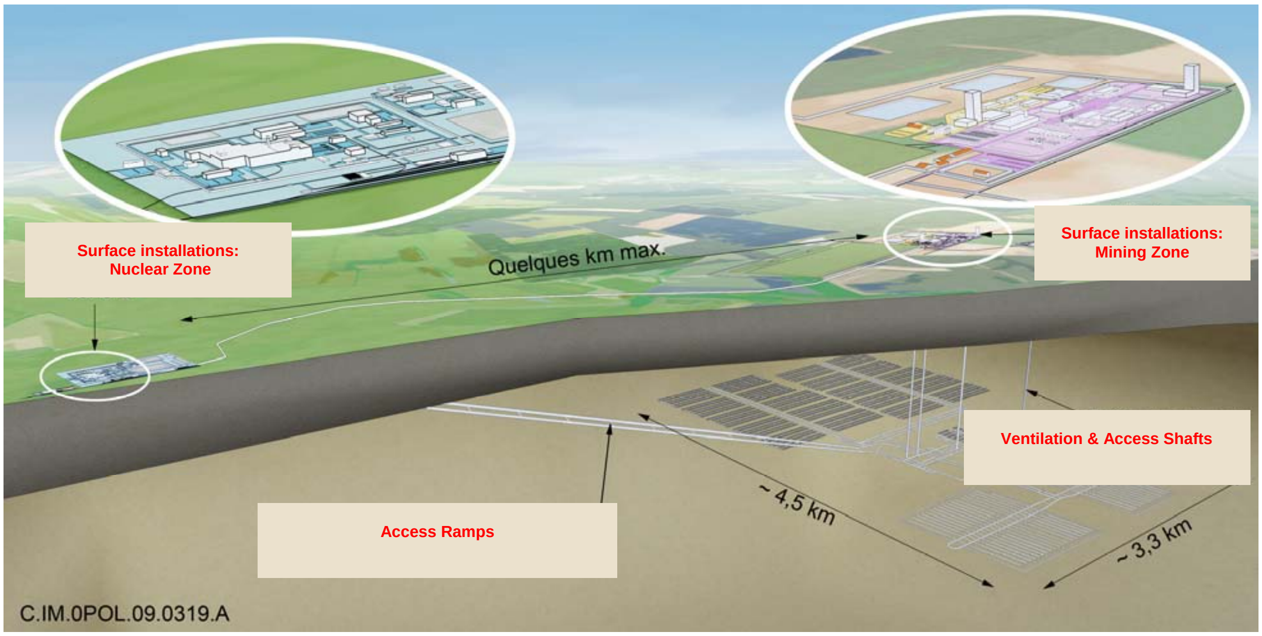

Fig. 5. General view of Andra's Deep Geological Repository [2].

The B type container is planned to be manufactured and subsequently loaded with the primary waste canisters in the surface nuclear zone, hence the use of an access by ramps for this type of payload. The B type container transfer starts from a surface buffer interim storage facility where the containers are sorted per category and left for awhile for additional concrete curing.

After a certain period of time (the storage campaign for a given category of B waste is scheduled depending on the availability of the corresponding disposal vault), the transfer is initialized (most likely in fully automatic mode) by introducing the canister inside the transport shielded cask. The equivalent residual dose rate of disposal packages does not allow workers to handle them without radiological protection. In the repository, all the disposal packages are conveyed from surface to underground inside shielded transfer casks that are designed to limit operators' exposure below the corporate annual dose requirements (5mSv/year) specified by Andra.

Then the shielded cask loaded on the transfer shuttle starts its descent down the ramp until it reaches, after a 5 to 6-km trip, the underground infrastructures. Figure 6 (via a synoptic) illustrates the related steps. The present surface to underground ramp transfer description refers to the use of an electrically powered truck as a transport shuttle. An alternative development scenario could lead to the selection of a cable car system (funicular railway system), deemed more performing from an operational safety point of view.

Once inside the repository underground infrastructures, the casks are conveyed to the disposal cells on a dedicated vehicle called the "Docking Shuttle". Specific equipment is designed to reload the cask at the crossroad to the access drift and to convey it in front of a disposal cell mouth to which it will be docked.

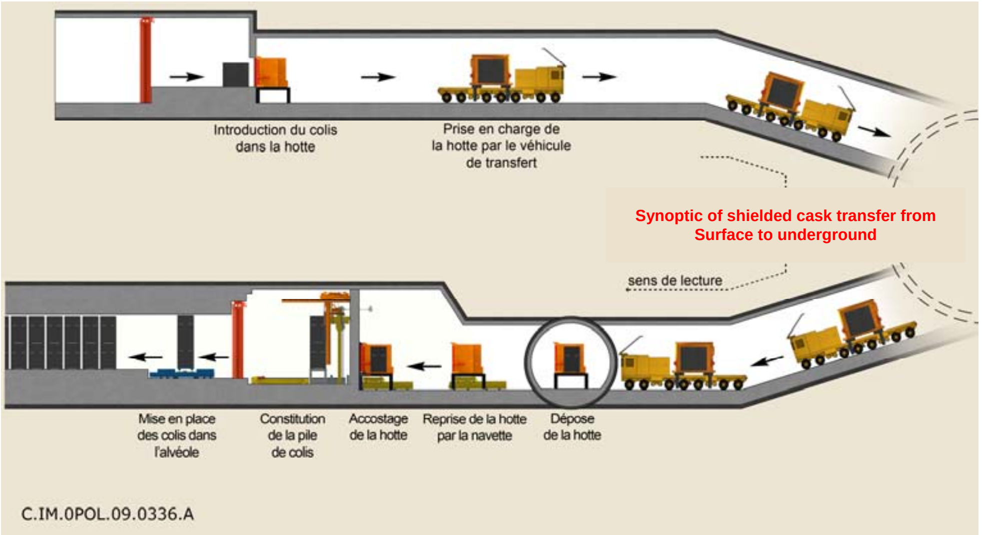

Fig. 6. Synoptic of Shielded Cask Transfer from Surface to Underground [2].

This "cask switch" from transfer shuttle to docking shuttle and the final cask docking onto the disposal vault hot cell wall is illustrated as a synoptic in Figure 7.

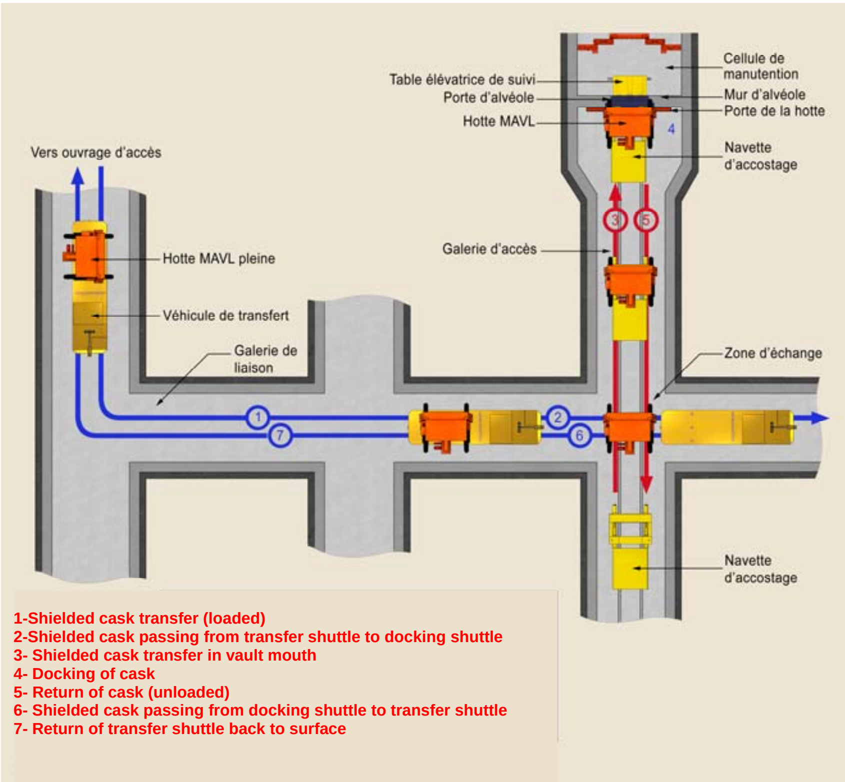

Fig. 7. Synoptic of "cask switch" between transport shuttle and docking shuttle [2].

A sketch of the electrically powered railway mounted docking shuttle conveying the shielded cask to the vault hot cell partition vault is available in Figure 8. Once the docking operation is completed, the B type container disposal sequence can be implemented.

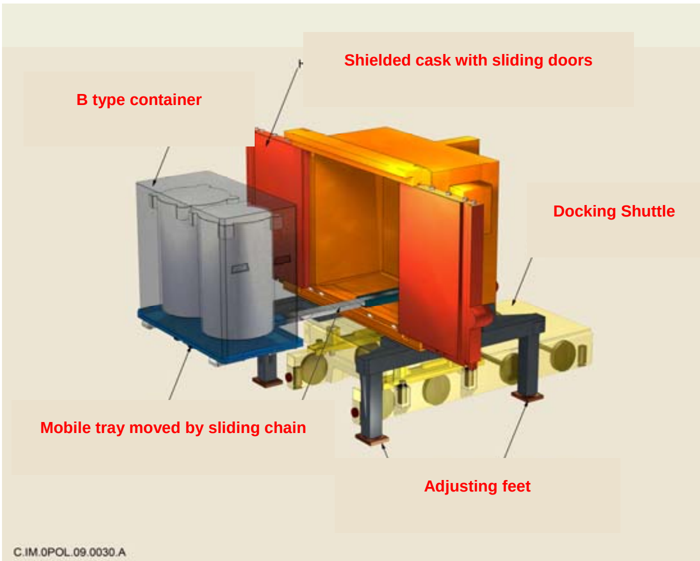

Fig. 8. Sketch of Docking Shuttle with Shielded Cask and B type Container [2].

THE INITIAL B TYPE PACKAGE EMPLACEMENT PROCESS

The hot cell (a metallic structure erected or dismantled in concurrent operations) is installed at the vault mouth to enable the pile formation and the loading of the pile on the transport cart travelling inside the useful disposal vault section. Its main mechanical components are visible on Figure 9.

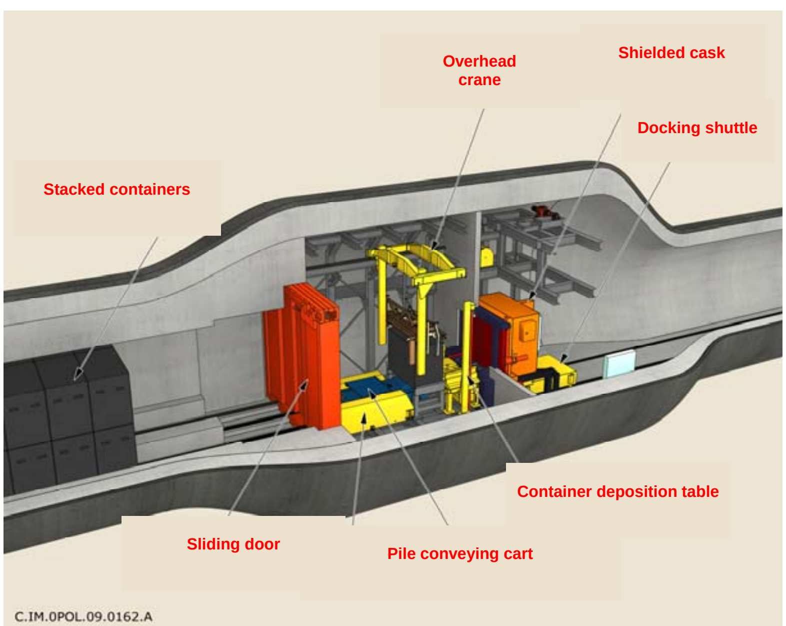

Fig. 9. Artist’s view of hot cell and its main mechanical components [2].

The container emplacement sequence starting with its extraction from the shielding cask and finishing when it reaches its final position inside the disposal vault is summarized in an 8-step synoptic as shown in Figure 10.

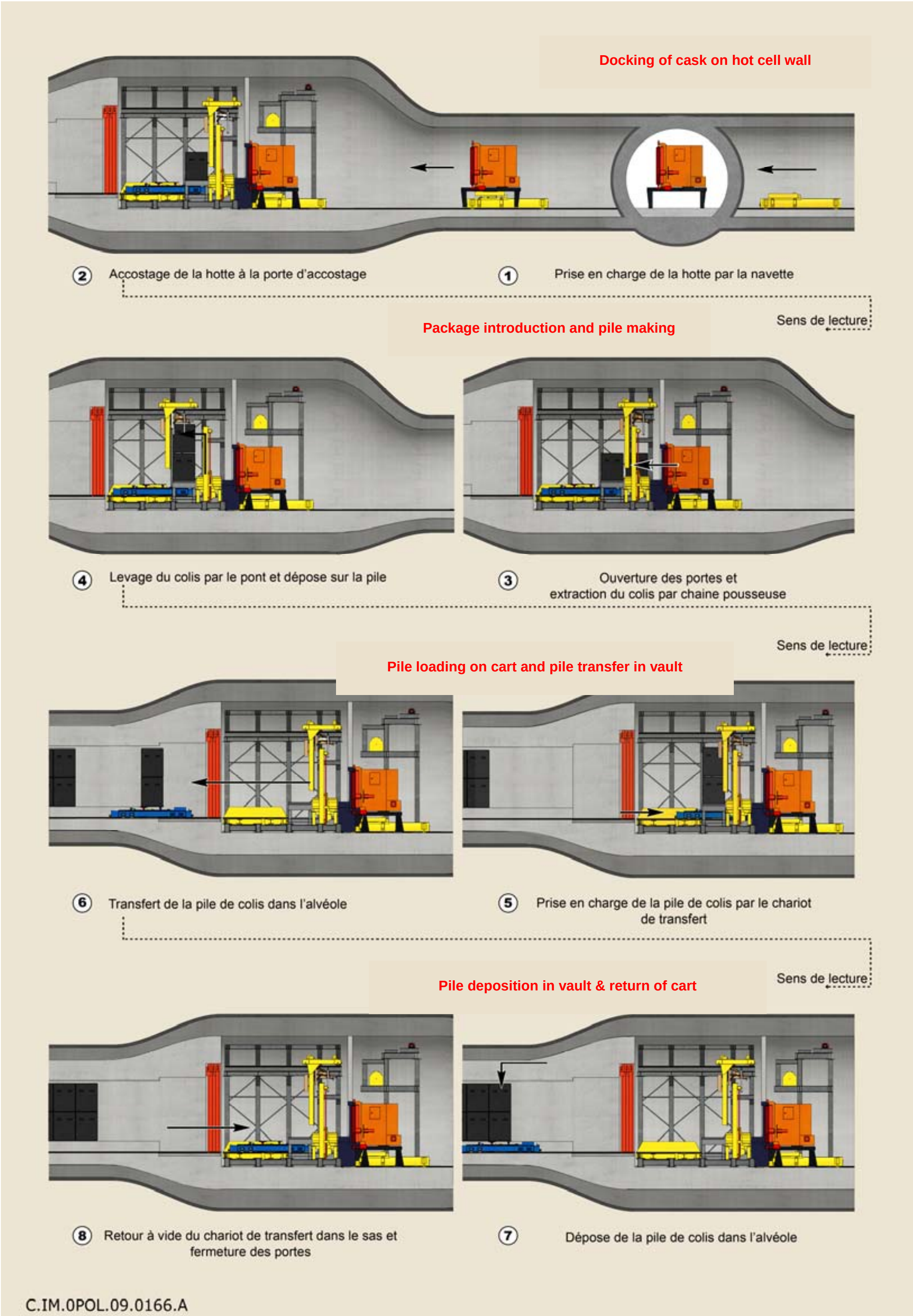

Fig. 10. Synoptic of B Type Package Emplacement [2].

The Initial Design Development and Its Stoppage

The design development of the emplacement system included all the associated equipment needed to build and test a full scale industrial prototype, working as per the emplacement sequence presented above, starting with a loaded shielded cask arriving (on a docking shuttle) to the vault mouth, followed by a docking of the cask gates onto the hot cell shielding gates and finishing with the deposition of a package pile inside the vault. This development took place between mid-2007 and mid-2009.

The full-scale design of the emplacement system comprised the following main components, which are detailed in Andra's Dossier 2009 [2].

- A simplified transport unit (docking shuttle),
- A shielded transfer cask, providing appropriate radio-protection at all times during the transport and emplacement process,
- A hot cell structure with a docking wall at rear and a sliding door at front,
- A travelling overhead crane for package lifting and piling, c/w a 4 leg lifting beam,
- A deposition table for the pile making, and
- A battery driven cart (mounted on rails) to introduce and transfer to its final position the package pile along one of the two disposal lines.

The emplacement system included a fully automatic and a manual mode, with remote control and monitoring of all operations inside the hot cell or inside the disposal section. It also included some special devices (infrared video camera and laser scanner) to detect physical obstacles and prevent any collision (most likely associated with a package fall).

The system developed was an application for emplacing a pile of three "B.3.1.2" type waste containers (each container has a box-type shape, with a 2.6-m length, a 1.5-m width, a 1.9-m height, and a 20-t weight) into 300-m long concrete lined horizontal vaults with an inside diameter of approximately 10-m. This application case was considered as the most dimensioning one.

The design development was partly stopped at mid-2009 because of two major events which affected the whole project:

- Andra decided to limit for a time the vault maximum internal diameter to 8-m instead of 10-m initially. This decision was taken because of the relative uncertainty still existing on the host rock behaviour (short and long term geo-mechanics) and also on the deferred effects induced on the vault concrete linings. As a result, the maximum pile height for the biggest packages could not exceed that of two packages, at least within the scope of the present research work.
- Andra was otherwise faced with a technical problem related to the concrete box development. Following the concrete mould-casting, some cracks appeared around the steel handling inserts located at mid-height on the package lateral faces. It was decided to reposition the package handling interface at its four bottom corners. As a result, the lifting beam shape had to be re-dimensioned (with an extension of the lifting legs).

This situation led to a re-engineering of the disposal concept and of the emplacement process in order to benefit (and not default) from the new technical challenges. The outcome of this new approach and the subsequent technical choices selected are discussed in the next chapter.

THE NEW B TYPE PACKAGE EMPLACEMENT PROCESS FOLLOWING REENGINEERING

The critical analysis of the initial concept and the subsequent re-engineering created a stoppage of the design studies for about a year (re-started in June 2010 and now scheduled for completion in March 2011). First of all, in the case of the B.3.1.2 type concrete container and in order to keep a similar storage capacity and a similar excavated volume, the vault diameter reduction (from 10-m to 8-m) was compensated by a vault disposal length extension from 300-m to 400-m (this decision implied a confirmation that the Wi-Fi transmission capacity could be also demonstrated on the new length defined).

The main advantage of the overhead crane is its excellent positioning capacity (by pendulum effect) when making a pile of three packages, but this advantage is not so obvious when the pile is reduced to two packages. Besides, a drawback associated to the overhead crane is the space requested for its installation, since a bigger diameter (implying an additional volume of excavated material) is needed at cell mouth level by comparison with the standard diameter considered in the useful part of the vault.

This extra-volume caused extra-cost and was of technical concern (cf. the new maximum excavated diameter cited above). It was thus deemed of great interest to focus on an alternative lifting means which would allow keeping a similar geometry (the same excavated diameter) in all sections of the vault. The solution selected is a railway mounted travelling gantry. Figure 11 illustrates this new device and shows that the vault excavated diameter now stays flush regardless of the vault section considered. An additional improvement is that the hot cell steel structure is now less important (hence easier to erect or dismantle), which is an asset for logistics (transport and lifting of structural beams underground). The general package emplacement synoptic stays otherwise the same as presented in Figure 10.

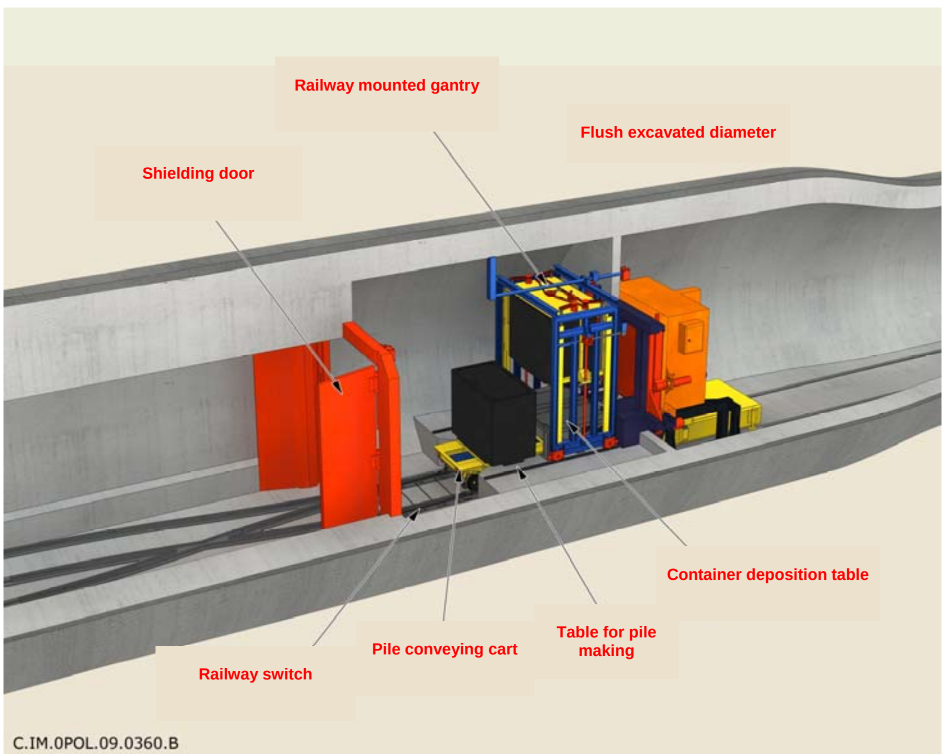

Fig. 11. Artist’s view of hot cell and its main mechanical components (new concept).

In parallel to this re-engineering phase, the design and fabrication process alterations concerning the concrete boxes have turned out positively. The programme focus is now to define in detail the test campaign and the related mechanical system qualification schedule.

One of the most challenging tests to be carried out is what is called the “collision test” in which the colliding of a pile (during its transfer inside the vault while transported by the cart) with an obstacle is simulated. The purpose is to check: (i) the relative displacement between two packages after a shock (and to compare the measured values with the numerical results obtained by simulation), (ii) more generally the efficiency of the safety devices incorporated in the transport cart, and (iii) the general capacity of the mechanical system developed to remove the pile (after collision) back to the hot cell and then to evacuate individually the two packages inside the shielded cask (this is in a way an anticipation of a retrievability situation).

Figure 12 illustrates one of the collision test situations anticipated (the collision structure has an adjustable beam to enable the creation of a shock in different positions on the pile). The situation presented is deemed the most critical collision on the upper part of the pile which could be caused in a real industrial case by a contact with a vault ceiling block, following a non detected local ceiling subsidence.

The safety devices integrated in the cart include some devices for detection of obstacles, and also some sensors detecting a propelling effort anomaly at cart wheel level (e.g. current peak intensity). Those safety devices are programmed to (i) warn the operator, (ii) stop the emplacement process, and (iii) switch the system control from “automatic” to “manual”.

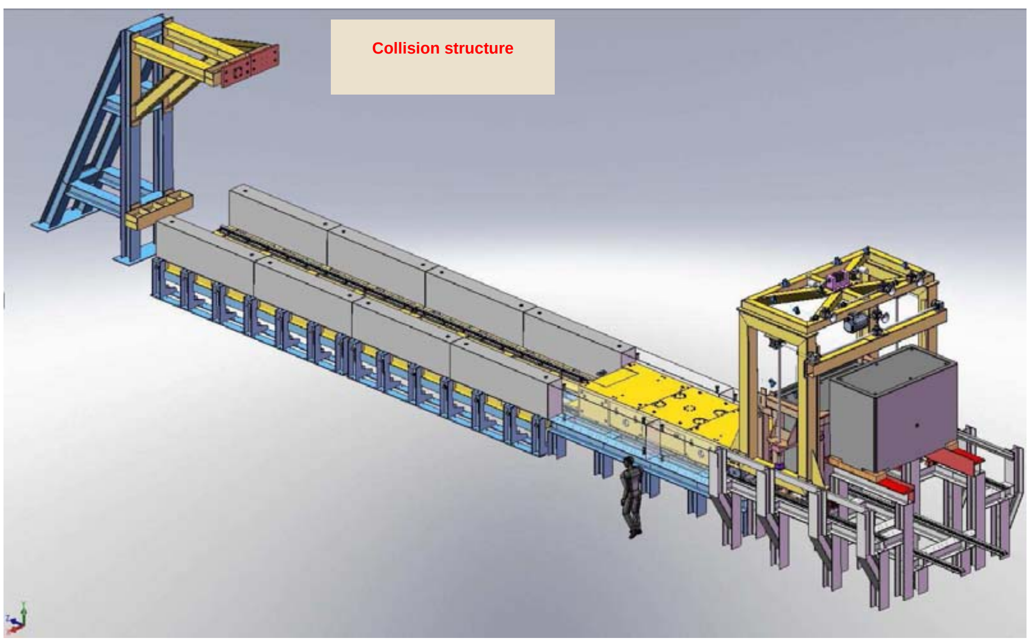

Fig. 12. Test bench view with collision trial scenario.

THE FIRST RESULTS OBTAINED WITH WI-FI TRANSMISSION

The only category of tests implemented so far is the Wi-Fi transmission tests with the video and detection devices which are positioned on the electrical cart. It was considered very important to check that a remote control of the emplacement system and of the cart, in particular, was possible by Wi-Fi over a long distance, in the absence of any relay antenna.

This emitting/receiving capacity was satisfactorily demonstrated underground over a 500-m distance, i.e. with a 100-m safety margin relative to the 400-m long reference vault. The detection system was also tested (scanner laser and infrared video camera) with positive results. Those tests could be planned ahead of the general test programme schedule, since the components or equipment involved were dissociable from the mechanical pieces constituting the electrical cart or the hot cell.

The Underground Laboratory selected for the Wi-Fi transmission tests was the LSBB (Low Magnetic Noise Underground Lab) situated in the southern French Alps, where a similar overburden (500-m) and a similar type of drift lining (cast concrete with no recesses) to those at the candidate repository location in the Meuse/Haute-Marne districts could be found.

CONCLUSION AND OUTLOOK

The successful completion of the Wi-Fi transmission test campaign was a good and early demonstration of the capacity to remotely control the electrical cart during the pile emplacement phase, over a vault length of 400-m. The suitability of the technology was confirmed.

The simplification in design obtained (at the end of the re-engineering phase) for the emplacement mechanical system as a whole is also promising. This new solution, which is planned to be manufactured and tested at full scale in 2011, before installation at Andra’s show-room in 2012, is combining two advantages:

- An optimisation of future logistic operations, thanks to a reduction of the hot cell structure,
- A reduction of the drift excavated diameter (a potentially significant economic saving).

A successful completion of the newly planned test campaign will be instrumental to demonstrate Andra’s capacity to build and operate such an emplacement system in the future deep geological repository. Its installation at the Andra’s show-room will be a positive communication tool and a complement to the Industrial Demonstrator (called the “Pushing Robot”) already displayed for the emplacement of vitrified waste packages.

ACKNOWLEDGMENTS

The authors want to thank the various contractors (engineering companies, industrial integrators) who are cooperating in the development programme presented above and who stayed very positive despite the difficulties encountered during its re-engineering phase.

REFERENCES

1. A. ROULET, D. DE WINTER, J. J. GUENIN et al., “Architecture and Operation of a Deep Geological Repository, Dossier 2005”, Andra (2005). www.andra.fr.
2. J.J. GUENIN, J.P. RIGAL, M. GUARISO et al., “Architecture and Operation of a Deep Geological Repository, Dossier 2009”, Andra (2009). www.andra.fr.