

Fluid (Air/Water) Cushion Transportation Technology for Emplacing Heavy Canisters into Horizontal Disposal Drifts – 8094

Jean-Michel Bosgiraud, Wolf K. Seidler, Louis Londe
ANDRA, Parc de la Croix Blanche, 1-7, rue Jean Monnet
92298 Châtenay-Malabry, CEDEX, France

Erik Thurner, Stig Pettersson
Swedish Nuclear Fuel and Waste Management Co (SKB)
Box 250, SE-101 24 Stockholm Sweden

ABSTRACT

The disposal of certain types of radioactive waste canisters in a deep repository involves handling and emplacement of very heavy loads. The weight of these particular canisters can be in the order of 20 to 50 metric tons. They generally have to be handled underground in openings that are not much larger than the canisters themselves as it is time consuming and expensive to excavate and backfill large openings in a repository. This therefore calls for the development of special technology that can meet the requirements for safe operation at an industrial scale in restrained operating spaces. Air/water cushion lifting systems are used world wide in the industry for moving heavy loads. However, until now the technology needed for emplacing heavy cylindrical radioactive waste packages in bored drifts (with narrow annular gaps) has not been previously developed or demonstrated.

This paper describes the related R&D work carried out by ANDRA (for air cushion technology) and by SKB and Posiva (for water cushion technology) respectively, mainly within the framework of the European Commission (EC) funded Integrated Project called ESDRED (6th European Framework Programme).

The background for both the air and the water cushion applications is presented. The specific characteristics of the two different emplacement concepts are also elaborated. Then the various phases of the Test Programmes (including the Prototype phases) are detailed and illustrated for the two lifting media.

Conclusions are drawn for each system developed and evaluated. Finally, based on the R&D experience, improvements deemed necessary for an industrial application are listed.

The tests performed so far have shown that the emplacement equipment developed is operating efficiently. However further tests are required to verify the availability and the reliability of the equipment over longer periods of time and to identify the modifications that would be needed for an industrial application in a nuclear and mining environment.

INTRODUCTION AND BACKGROUND

In industry, air and water cushion systems for lifting and handling heavy loads (up to several hundred tons) are being used world wide. The application of such a technology is however generally limited to situations where the air or water cushions are acting on flat and smooth “sliding” surfaces. Applications where the air/water cushions act on cylindrical surfaces (i.e. either on the surface of the load to be moved or on the surface on which the cushions “slide”) are not so common.

The specific applications considered within the scope of the ESDRED work [1] are most likely without precedent, since the emplacement concepts relate to moving and placing cylindrical waste canisters inside horizontally bored disposal drifts (cells) whose cylindrical walls have a rough surface. At the same time the annular gap between the outside diameter (OD) of the canister and the inside diameter (ID) of the disposal drift wall is limited to a few cm. Working underground with radioprotection constraints, requiring remote control (i.e. no direct access or vision of the moving load) adds a further level of complexity. The two emplacement concepts that were developed and tested are presented below.

Water Cushion Application

SKB (Sweden) and Posiva (Finland) have, since 2001, a joint project called the KBS-3H disposal concept. The main components in the system are shown in Fig. 1. The Super Container (SC) to be emplaced consists of a copper canister (containing Spent Fuel), a buffer annulus (made of bentonite rings) and an outer perforated steel cylinder equipped with short feet. The weight of the SC is in the order of 46 tons, with an OD diameter of 1.77 m and a length of 5.57 m. It is emplaced inside a 300 m long horizontal disposal drift excavated in granite by using a water cushion deposition machine.

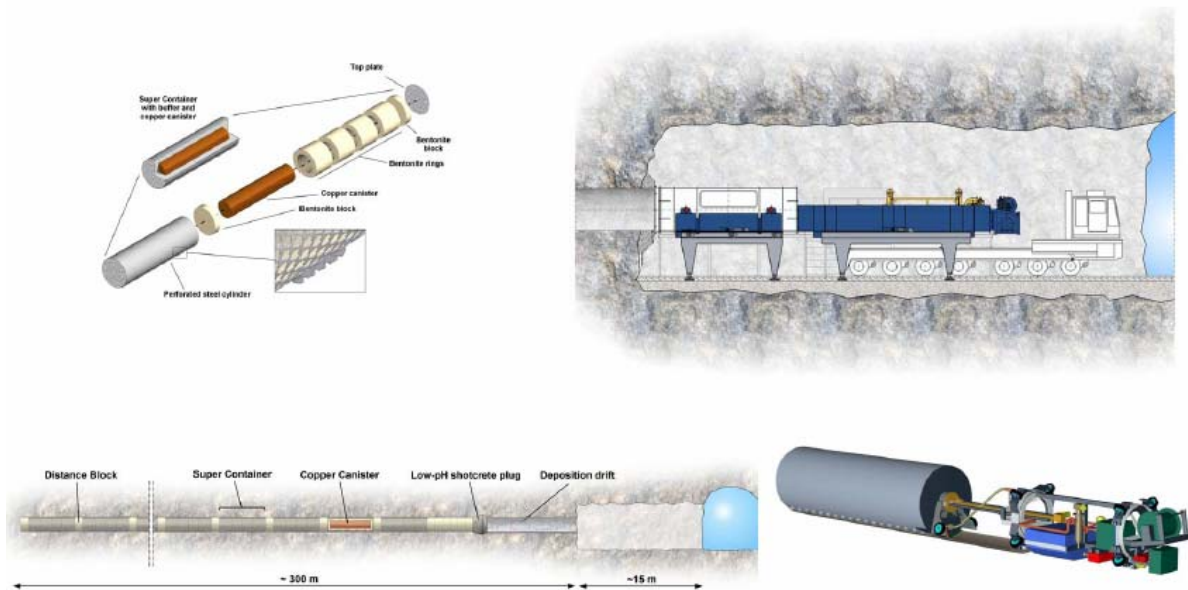


Fig. 1 Main components of the KBS-3H emplacement concept (SKB & Posiva)

The deposition equipment for the KBS-3H concept has become part of the ESDRED Project and has been partly financed by EC within the 6th Framework Programme since February 2004. However, between 2001 and 2004, SKB and Posiva had already carried out prototype testing using both air and water cushions in order to prove the feasibility of this technology for cylindrical objects and surfaces. Water was selected as the appropriate lifting medium for two main reasons: i) it is a fluid compatible with the host formation (granite), ii) it avoids the important pressure loss that would be experienced over a 300 m long air umbilical. Alternately, an air compressor with a 75 to 100 kW electrical motor mounted on the mobile emplacement system would have created too much heat and also increased the size and weight of the emplacement machine. Unlike air, water can be continuously recycled through a small water tank mounted on the deposition machine. In this case, a 7 kW electrical pump is sufficient to provide the necessary water pressure and flow.

Air Cushion Application

ANDRA in France has selected the air cushion technology for emplacement of SF (Spent Fuel) canisters as well as for the transport and placement of sets of buffer rings. In the ANDRA case (unlike the KBS-3H concept described above), the sets of buffer rings and the SF canisters are handled separately and not as one package. The ANDRA system has also been developed within the framework of the ESDRED Project. The main components in the ANDRA disposal system for emplacement of SF canister are shown in Fig. 2.

The buffer (bentonite/sand) rings are assembled in sets of four (4). Each set of rings has a weight of 17 tons, with an OD of 2.25 m and a length of 2 m. The weight of the SF canister is 43 tons and it has an OD 1.25 m and a length of 5.39 m. The disposal cell excavated in clay has a length of approximately 40 m. Only the emplacement of the SF canisters is described in this paper.

Air was selected as the appropriate lifting medium for two main reasons: i) it is a medium compatible with the host formation (clay), ii) the pressure loss experienced over a 40 m long umbilical is compatible with the proper functioning of the air cushions.

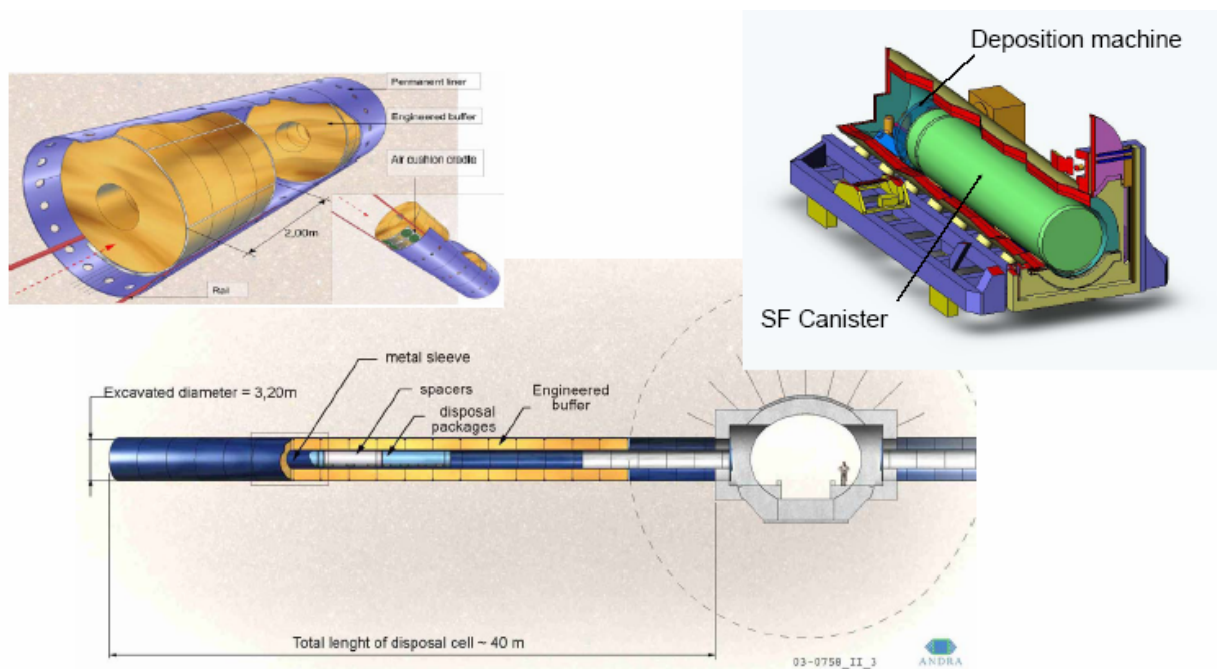


Fig. 2. Main components of ANDRA's emplacement concept for a SF canister disposal cell.

DEVELOPMENT OF THE DEMONSTRATORS

Testing Initial Prototypes

The main objective of the original test campaigns was to investigate if standard cushions (i.e. "off the shelf" components) could be efficiently used for cylindrical objects/surfaces with a limited diameter. As these cushions are designed to operate on flat surfaces, their structure has to be curved to the appropriate radius. A successful trial was a pre-requisite to the further development of a full size demonstrator. A

second objective was to determine the appropriate operating parameters for a good performance of the future full scale emplacement system. The cushions are fixed onto a pallet which supports the pay load. This pallet lifts when the cushions are activated. The actual lifting height of the pallet depends on the fluid flow, the pressure at cushion inlet and the design of the cushion.

In the case of SKB and Posiva, the test bench used for the prototype had the same diameter as the KBS-3H disposal drift but the length and the weight of the mock-up canister was reduced to ¼ scale. The load during the tests was thus limited to approximately 12,250 kg (1/4 of the real load) and only eight (8) pairs of cushions were installed instead of 32 for the full load. As the inclination tolerance for the real disposal drift is 2 degrees (°) ±1°, an inclination of 3° was therefore simulated on the prototype test rig. Preliminary prototype tests were performed successfully at the SOLVING facility in Jakobstad, Finland. The two first tests were performed with air in April and July 2003, and the third test was performed with water in March 2004.

In the ANDRA concept, the use of air cushion technology as an emplacement means for the SF canister had not been tested prior to the ESDRED Project. The feasibility tests carried out by SKB for the KBS-3H Super Container (before the start-up of the ESDRED Project) could not be considered as a solid enough basis for confirming the feasibility of ANDRA's specific application. This was primarily due to the fact that ANDRA's canister and disposal cell have a smaller diameter than the equivalent SKB components and because ANDRA's SF canister has a higher linear weight. Therefore, ANDRA decided that it too needed to perform preliminary prototype testing, similar to that of SKB, with an air cushion supplier (BERTIN), in France. These tests were successfully carried out from July 2004 to January 2005 and later repeated by BERTIN, on behalf of MECACHIMIE, who had been selected by ANDRA as the final supplier for the full scale deposition equipment. These tests [2] were carried out using a dummy canister with a 1:1 scale outer diameter of 1.25 m, a 1:3 scale length of 1.93 m and a 1:3 scale weight of 13.74 tons (instead of 43 tons) as compared to the real canister. The number of air cushions used was six (6) instead of 18 for the real case. This preliminary prototype testing confirmed that the air cushions (as modified) were working effectively and could subsequently be used even for a heavy cylindrical object with an outer diameter of only 1.25 m. The main operating parameters were also determined for this specific application.

Selection of Contractors

After the prototype testing was completed, it was decided to proceed with the next step of the R&D programme by implementing the full scale demonstrator phase for each of the two emplacement systems being considered.

In a first step, SKB/Posiva and ANDRA set out to prepare and launch a joint request for proposal (RFP) to tentatively select a common contractor for the design, manufacture and testing of the two emplacement systems. In the end, however, two separate but very similar RFP documents, with provisions for bidding to both parties, were sent to a common bidders list. The subsequent bid and tender process took place between mid 2004 and mid 2005. In the end, this coordinated and competitive bid process did not produce the expected results i.e. a joint purchase to a common supplier. Instead two separate contracts were awarded respectively to CNIM (France) by SKB/Posiva and to MECACHIMIE (France) by ANDRA. The kick off meetings took place immediately after execution of the contracts.

The work programme in the two cases started with preliminary and detailed studies, followed by the manufacturing and erection of the equipment. The systems then underwent the testing campaign per se. These activities were carried out in line with the main milestones posted in the initial schedule of work.

The present paper focuses on the test campaigns and the related results, taking for granted that the engineering, supply and manufacturing is of limited interest to the reader [3].

Definitions

The definitions given below are intended to facilitate the reader's understanding of the word "**Demonstration**" and of the "**FAT**" & "**SAT**" acronyms used in the rest of the paper. This will also help him/her to differentiate the specific ANDRA and SKB case stories concerning the approach and methodology of testing their respective emplacement (deposition) system. For SKB, the following three (3) steps were conducted: the **F**actory **A**cceptance **T**ests (**FAT**), the **S**ite **A**cceptance **T**ests (**SAT**) and the **Demonstration**, whereas ANDRA only conducted the **FAT** and the **SAT**.

The **FAT** included all the Commissioning Operations [4,5] and were carried out in the Contractor's factory (Workshop) at the end of the Fabrication and Erection process, to check the basic functioning of the main parts of the system developed, i.e. to confirm that the main components were effectively working in accordance with the technical specifications. These commissioning operations were intended to confirm the main operating specifications assigned to the system and also looked at trouble shooting the main defaults identified at the time, if they were detrimental to an efficient operation of the equipment. In the case of SKB, those **FAT** were carried out mainly in CNIM's facilities at La Seyne-sur-Mer (France) and then completed on site at the Äspö HRL (Sweden). They were followed by the **SAT**.

The **SAT** included all the Commissioning Operations and were carried out **in situ**, i.e. in the Äspö **H**ard **R**ock **L**aboratory (**HRL**) in Sweden. They were implemented in the real underground environment, i.e. inside a chamber and a 90 m long deposition drift excavated in the host rock (granite). At this location, the emplacement system was complete with all its components in a fully operational configuration. The check-up was consequently more thorough than for the **FAT** and the trouble-shooting was applied to all the relevant components of the system. Once the performances obtained were evaluated and deemed acceptable, by comparison with those specified in the Contract, the Contractor was released (Contract sign-off) and SKB's staff took over to carry out the **Demonstration** phase per se.

The **Demonstration** phase of the test campaign covered, among other things, the "endurance testing" (long term) part of the trials. It focused on the reliability of the system and was a way of identifying weak components that needed to be re-engineered, retrofitted or substituted by more rugged replacement parts. It was also a way to assess the ultimate performance of the system (after the "learning curve" period) and to evaluate what could be the industrial efficiency of a real machine (i.e. re-engineered for nuclear applications).

For ANDRA, the approach was a bit different. Since ANDRA had no available underground facility to test its emplacement devices in, it was planned from the very beginning to carry out the entire test campaign in the same venue, i.e. the selected Contractor's workshop. This happened to be MECACHIMIE - SGN premises in Beaumont- Hague (a special facility called HRB) in France. Subsequently, the **FAT** and the **SAT** were combined into one full testing programme per configuration: i.e. one for the Bentonite Rings emplacement system and one for the SF Canister emplacement (the only one presented in the pages to come). For time schedule and budget reasons, it was decided not to run any endurance (long term) trials similar to what is called the **Demonstration** phase in the SKB case.

Full Scale Demonstrator by SKB/Posiva

For SKB/Posiva the FAT were carried out at the CNIM factory, at La Seyne-sur-Mer, in France, in February 2006, before delivery of the equipment to the Äspö HRL in Sweden. However, during the FAT, all the planned tests could not be performed. Once the equipment was installed in the real underground conditions and during the initial start-up of the SAT in May 2006 it was discovered that the SC could not be properly balanced to the point that derauling of the water cushion pallet would at times occur during the testing. Preventive actions had to be taken. The deposition machine was therefore retrofitted with a guidance system intended to prevent the uncontrolled rotation of the SC. At the same time a fork was attached to the electrical cart radioprotection shield to improve the alignment of the load vis-à-vis the water cushion pallet. Following this retrofitting, the SAT at the HRL could effectively start.

An overview of the set-up of the equipment at the Äspö HRL test site is shown in Fig. 3 below. The picture is taken from the rear of the chamber in which the emplacement equipment was pre-positioned in front of the mouth of the disposal drift.



Fig. 3. Set-up of equipment at the Äspö HRL (level -220 m) test site. The SC is inside the transport tube with the shielding gamma gates open (the control room is on the left side of this photo).

Two (2) SCs (built with SF copper canister and buffer material mock-ups) and two (2) Distance Blocks (spacers with dimensions similar to the canister mockup) were manufactured for the purpose. The mock-ups were representative of the real payloads, with the correct physical dimensions and weights.

To ensure that the guidance system functioned properly, it soon became evident that the lifting height of the water cushions had to be reduced. It was therefore decided to replace the original water cushions with a different brand of cushions that had a reduced lifting height and that also had less sensitivity to load variations. The pallet was also equipped with four (4) lift sensors for indicating the lifting height.

The SAT were carried out in accordance with a detailed SAT Programme [6] and included the following check operations detailed in Table I.

Table I: Testing Sequence for the KBS-3H

Test designation
Checking of the HMI (Human-Machine Interface) and Control System with power on
Checking of the machine moving parts using the portable controls
Checking of the machine moving parts from the control room
Checking of the water cushion pallet hydraulic circuit
Deposition machine tests without load
<ul style="list-style-type: none"> • Forward drive: manual mode
<ul style="list-style-type: none"> • Locking in stop position
<ul style="list-style-type: none"> • Backward drive: manual mode
<ul style="list-style-type: none"> • Recovery of the machine using the emergency winch
Deposition machine tests with load
<ul style="list-style-type: none"> • Docking of the Super Container
<ul style="list-style-type: none"> • Lifting pallet test
<ul style="list-style-type: none"> • Recovery of the Super Container
<ul style="list-style-type: none"> • Deposition of the Super Container
<ul style="list-style-type: none"> • Deposition of Distance Blocks
<ul style="list-style-type: none"> • Recovery of Distance Blocks

All tests from the **SAT** were recorded [7]. A summary of the main observations and results is provided below in Table II. An overview of the performance data with reference to the main contractual functional requirements is also provided in the same Table II.

Table II: Main Performance Data

Cycle	SAT	Tests after modifications to valves
Lifting of container	35 s	28 s
Container transport	19 s	19 s
Lowering of container	35 s	16 s
Machine transport	11 s	11 s
Total Cycle Time	100 s	74 s
Travel Distance	1487 mm	1487 mm
Average Transport Speed	14,9 mm/s	20,1 mm/s

The first tests with the machine showed that there was a high risk that the rotation of the container about the long axis could increase cumulatively each time the container was moved due to the gap between the guides on the pallet and the slide plate. This gap is 5 mm, which allows the container to rotate approximately +/- 0.2 – 0.3° at each stroke of the system which advances in 1 m increments. As soon as a

rotation of the canister is detected by the sensors, a compensating system (ballast system) is activated to offset the rotation phenomena.

Another important observation was that if the container, together with the pallet and the slide plate, was rotated more than $3.5 - 4^\circ$, then this movement could create problems for the proper functioning of the water cushions (due to the uneven load distribution resulting from such a configuration). As reported previously, the water cushions are sensitive to load variations (the problem that can occur with a too important rotation is that some of the cushions, which get more loaded than normal, are not able anymore to lift the container). After considerable effort, the conclusion was that it is impossible to properly handle an unbalanced SC with the presently developed water cushion system.

During the tests it was observed that the system is sensitive to the alignment between the emplacement equipment and the drift so that having the best possible initial alignment of the whole set up is of paramount importance.

All the other functional requirements outlined in the Contract were fulfilled. The cycle times (in seconds) measured for the transport and deposition of the SC are shown in Table II.

The **Demonstration** test period started immediately after the completion of the **SAT**. During this test phase, the SC was repeatedly transported to the far end of the deposition test drift (only 95 m instead of 300 m for a real application) and recovered. According to this endurance demonstration test programme, the goal was to make one deposition and subsequent recovery per day. The cumulative travel distance of the deposition equipment to September 2007 was approximately 12,000 m. The transportation of the SC was performed in both manual and automatic modes.

The performance requirement for an average deposition speed of 20 mm per second (mm/s) was reached after making some minor adjustments to the water cushion control valves. However, there continues to be a problem with the water cushion pressure relief valves. They have a tendency to jam after a period of operation, resulting in high cushion pressures that can damage the cushions, which may result in an uneven lowering of the SC (the uneven lowering will result in a rotation of the SC, which the ballast system cannot compensate for). The function and reliability of these relief valves is presently being reviewed.

Besides the problem with the water cushion valves and some initial problems while running the machine in automatic mode (due to damaged laser sensors on the slide plate), the tests have been performed without any major problems.

The tests have also shown that there is no problem controlling the container rotation if the set-up is well aligned from the very start-up of operations. However, the system is more sensitive when moving forward than when reversing. This is due to the rotational flexing of the deposition machine, which seems to be more pronounced when pushing than when pulling back the load (SC).

Full Scale Demonstrator by ANDRA

The test campaign related to the emplacement of the CU1 (SF) canister took place from May 2006 to September 2006. This campaign started with the erection of a complete test bench in the configuration shown below in Fig. 4.

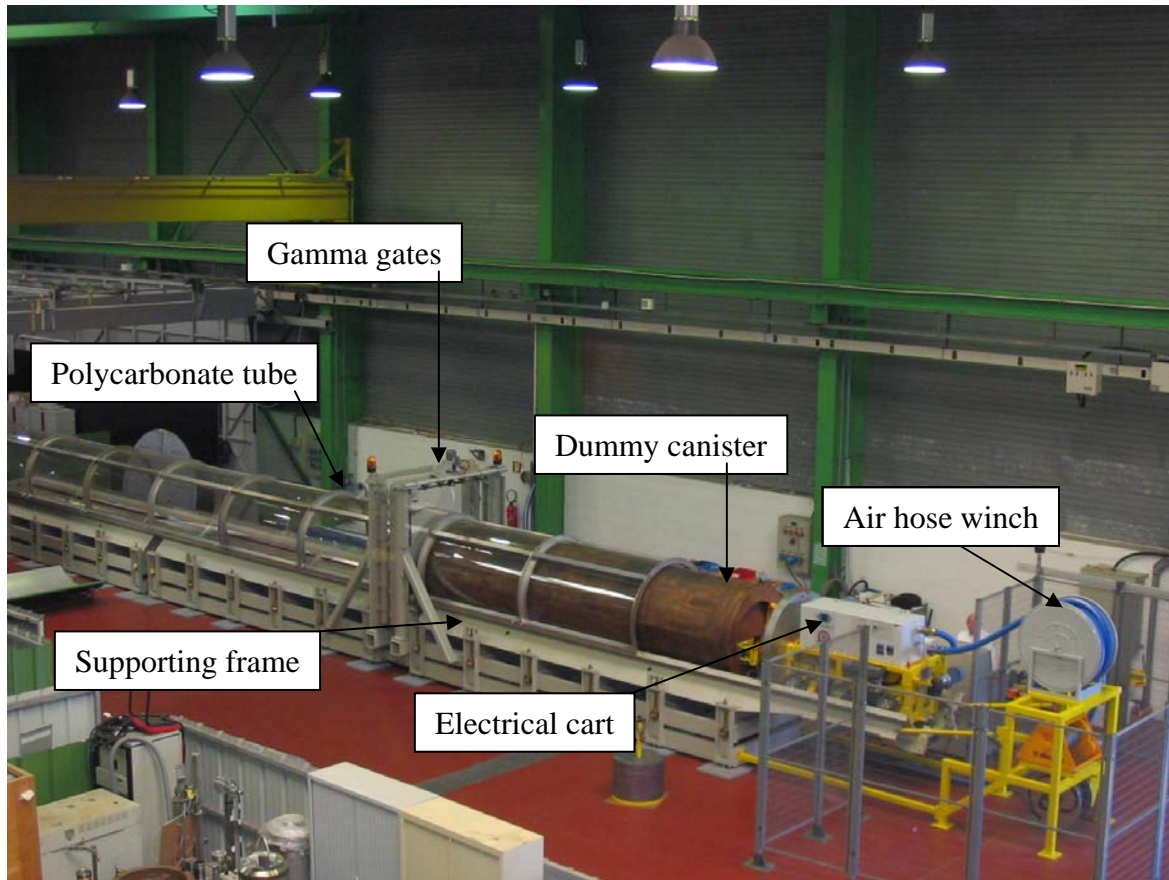


Fig. 4. ANDRA - Set-up of the CU1 emplacement system at the HRB test site (SGN-Mécachimie's premises in Beaumont-Hague).

The complete test bench was composed of the following main parts:

- A supporting frame equipped with adjustable feet for simulating the geometrical defaults likely to be encountered in a real disposal cell underground or/and the steps/misalignment between the docked shielding cask and the disposal cell mouth.
- A polycarbonate tube (for viewing during demonstrations) with stainless steel sliding track sections fixed to the full length of its invert. These sections have two (2) guide rails welded to the upper surface of the sliding track. When the SC canister is set down onto the rails, there is enough clearance between the bottom of the canister and the top of the sliding track so that once the air cushions are deflated the slide plate attached to the electrical cart can be advanced, i.e. the pallet and sliding plate can be moved separately from the SC. The rails also act as a guide for the slide plate and air cushion pallet, which follow the path of the SC to its final destination. The ID of the polycarbonate tube is similar to the diameter of the inner steel sleeve in a real disposal cell.
- Two (2) gamma gates: one attached to the cell mouth and one attached to the shielding cask. The shielding cask gate is motorized and it moves the passive cell mouth gate.
- An electrical cart (the deposition machine) equipped with a radioprotection shield and an electrical pushing jack for advancing the SC in 1 m increments (see Fig. 5),
- A slide plate attached to the body of the electrical cart,
- An air cushion pallet attached to the pushing jack,

- A control & monitoring console (see Fig. 5),
- A 43 ton dummy canister (5.4 m long) whose centre of gravity could be adjusted longitudinally and radially.

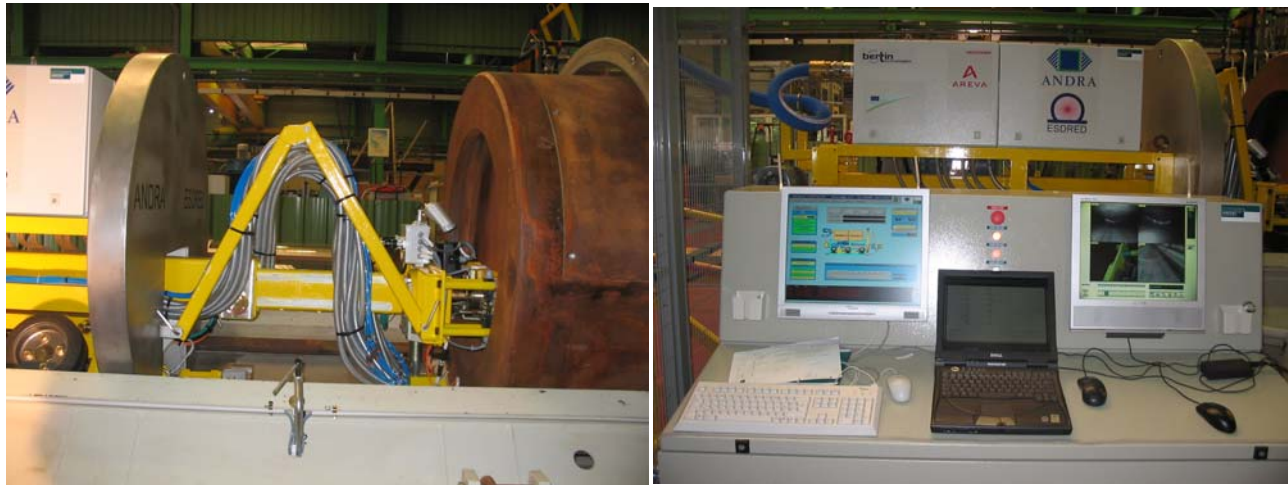


Fig. 5. Details of electrical pushing jack connected to the SF canister (left) and Control & Monitoring Console (right).

The primary objectives and challenges in this test programme [8] were as follows:

- To show that the emplacement equipment could meet or exceed all the specified technical performances, including the successive emplacement (and subsequent retrieval) of the dummy canister in automatic mode, inside the polycarbonate/steel tube, the automatic closing and opening of the gamma gates and finally the specified average travel speed over a complete emplacement cycle.
- To demonstrate that the emplacement equipment could pass over obstacles such as the recesses in the door frames created by the shielding gates or over the discontinuities between two (2) consecutive sections of guide rails. For this purpose, the use of a sliding plate could not be avoided.
- To evaluate the sensitivity of the system to the various construction defaults (steps, misalignments, etc) likely to be encountered underground and to any off-centre (radial or longitudinal) location of the centre of gravity of the dummy canister.
- To identify the weak points of the system likely to require some re-engineering and/or retrofitting in the real industrial application.
- To identify some potential improvements (mainly in terms of ruggedness and performance).

All tests executed during the **FAT & SAT** were recorded in a test report [9]. What follows is a condensed overview of the results with reference to the main functional requirements as well as other observations noted during the tests.

The commissioning of the emplacement system took place during the months of May and June 2006. PLC programming was a large part of the work during that period. The main difficulties encountered during this commissioning period (and their solutions) are listed below:

- The friction coefficient between the lower face of the slide plate and the steel invert (sliding track) of the polycarbonate tube turned out to be bigger than anticipated. Consequently, the pushing force, which had to be exerted by the electrical cart's pushing jack, exceeded the capacity of that jack. This problem was solved by attaching a Teflon sheet onto the lower face of the slide plate.
- At the end of each 1 m stroke of the pushing jack (moving the air cushion pallet over the slide plate), the air cushions had to be deflated to lower and sit the canister on the sliding track rails. Subsequently, the sliding plate was advanced by another 1 m. The time needed for deflating and purging the air from the air cushion system turned out to be too long. Consequently, the cycle time specified could not be achieved. This problem was solved by the installation of a quick relief (purge) valve.
- The compressed air feeding the air cushions carried considerable moisture. This resulted in the formation of condensation within the air cushions following the quick pressure drop. As a result, the rubber part of the air cushion tended to want to separate from its steel supporting plate. Replacement cushions were glued with a water resistant compound and the problem was solved.
- The presence of moisture in the air also impacted the operation of the flow control system. A regular purging of the electro-valves turned out to be necessary on a regular basis, i.e. at the end of every emplacement cycle.
- As originally designed, the air cushions could raise the air cushion pallet higher than the top of the guide rails inducing a tendency for derailing the system. This problem was solved by increasing the height of the guide rails by adding a 5 mm band spacer underneath the rail,
- The air cushions also turned out to be quite sensitive to individual load variation. This phenomenon appeared mainly when simulating the longitudinal imbalance of the SF canister. In the most critical simulation tested (combination of longitudinal imbalance together with a change of inclination of a tube section), the canister could not be moved.

Despite the issues noted above, the test programme turned out to be a complete success. The specified emplacement performances were exceeded as the average emplacement speed over one complete cycle was found to be 1.8 m per minute (m/min) versus the 1.2 m/min specified. In addition, the SF canister emplacement process turned out to be very smooth, without shocks. The stability of the canister on the pallet was maintained even in the case of radial load unbalance or of geometrical defaults in the polycarbonate/steel sleeve.

Issues not fully solved within the framework of the test programme, but that should be addressed in a future version of this equipment, are listed below:

- Since the air cushions are sensitive to load variation, a more accurate air flow control is needed, such that fine tuning of each air cushion is possible.
- In order to avoid derailing of the air cushion pallet, the air cushion lifting height must not only be monitored, but also controlled (see previous point).
- Since the air cushions are sensitive to moisture content in the air, the compressor should be equipped with a dessicator.
- The air feed inlet should be modified so that the air cushions can be activated and deactivated more quickly thus resulting in a reduced the overall cycle time.
- In automatic mode, the winding and unwinding of the air hose umbilical attached to the back of the electric cart was not perfect and “needed a hand” from time to time. This was due, at least in part, to the friction coefficient of the hose on the invert slide track, which created a parasitic (drag) force. A different hose material might reduce the friction coefficient (and also the wear on the hose) and consequently reduce the drag force exerted on the electrical trolley. Finally, a

spooler mounted on the hose winch would improve the winding / unwinding of the hose on the winch drum.

- Alternately a more powerful electrical motor mounted on the electrical cart could compensate for the friction force (drag) exerted by the hose,
- The very heavy weight (43 ton) of the SF canister induced some inertia efforts, which were a real strain on the electrical pushing jack frame, which occasionally emitted some “cracking noise”. A stiffer jack frame would reduce the stresses and the bending effects on the jack.
- Finally a slide plate made of composite material (carbon fibre or similar) instead of stainless steel would help to reduce the friction between the bottom of the slide plate and the top of the slide track fixed to the invert of the polycarbonate tube.

CONCLUSIONS

The series of industrial scale tests carried out from May-June 2006 to September 2007 by SKB/Posiva and by ANDRA on their respective emplacement equipment helped to validate the use of fluid cushion technology for placing heavy loads in very confined spaces. This work also identified some of the limitations of the equipment as well as the necessary refinements/modifications that should be implemented prior to a full scale industrial application in a future deep geological repository in clay or granite.

Conclusions Related to the Testing of the Water Cushion System (SKB/Posiva)

The tests performed have shown that the emplacement equipment designed and fabricated within the scope of the ESDRED Project can operate effectively for the transport and deposition of Super Containers with a weight of 45t in horizontal drifts excavated in hard rock. Further tests are however required to verify the availability and the reliability of this equipment over longer time periods.

It has also been observed that the water cushion technique used by SKB/Posiva is sensitive to load variations. This means that the Super Container to be transported must be well balanced. This requirement implies that all fuel positions in the canister must be completely filled with fuel elements or fuel dummies. Finally, the system is also sensitive to the set-up alignment between the transport tube for the Super Container, the deposition drift and the start tube for the deposition machine.

Conclusions Related to the Tests of the Air Cushion System (ANDRA)

The tests performed have shown that the emplacement equipment designed and fabricated within the scope of the ESDRED Project can be operated effectively for the transport and emplacement of Spent Fuel Containers with a weight of 43t in mock ups of horizontal disposal cells. Further tests will also need to be conducted in real underground conditions and over a longer period of time to assess the availability and the reliability of this equipment.

It has also been observed that the air cushion technique used by ANDRA is sensitive to load variations. This means that the air cushions must be individually monitored and controlled. Finally, an efficient spooling system is considered necessary for a proper functioning of the air hose winch.

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