EUROPEAN
COMMISSION

Community Research

ESDRED

(Contract Number: FI6W-CT-2003-508851)

DELIVERABLE 5 OF MODULE 3 – WP4
Report on Emplacement/Transportation Tests

Author(s):	Bo Halvarsson / Erik Thurner / Jean-Michel Bosgiraud	
Revision & Approval:	Stig Pettersson	
Validation:	W.K. Seidler	

Date of issue of this report: 21 August 2007

Start date of project: 01 February 2004 Duration: 60 Months

Project co-funded by the European Commission under the Euratom Research and Training Programme on Nuclear Energy within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	Yes
RE	Restricted to a group specified by the partners of the [ESDRED] project	No
CO	Confidential, only for partners of the [ESDRED] project	No

DISTRIBUTION LIST

Name	Number of copies	Comments
Christophe Davies	Uploaded on CIRCA	EC Project Officer
Stig Pettersson	1	SKB
Erik Thurner	1	SKB
Bo Halvarsson	1	Vattenfall Power Consultant AB
Timo Aikas	1	Posiva
Jukka Pekka Salo	1	Posiva
Jean-Michel Bosgiraud	1	ANDRA
Jean-Jacques Guénin	1	ANDRA
Wolf Seidler	1	IPC of ESDRED
ESDRED Files	1+1 CD Rom	Also on M, FTP site & Filenet

TABLE OF CONTENTS

TABLE OF FIGURES

EXECUTIVE SUMMARY

This report is **Deliverable WP4-D5 of Module 3** of the ESDRED project. The report presents the results of the **SAT (Site Acceptance Tests)** of the KBS-3H deposition system (**Part 1 of Module 3**) for SKB/Posiva. For ANDRA, the **FAT (Factory Acceptance Tests)** and the **SAT** of the heavy load emplacement equipment (**Parts 2 and 3 of Module 3**) are both presented. For SKB/Posiva the **SAT** were carried out in situ, i.e. at Äspö HRL (Sweden), while for ANDRA its emplacement equipment was tested in Mécachimie - SGN premises (i.e. in a surface workshop, called HRB) in Beaumont-Hague (France).

Note: *Since ANDRA has only performed factory tests of its equipment on surface and not in an Underground Research Laboratory, then the D5 contains for Parts 2 &3 of Module 3 the results of all the testing phases (i.e. SAT & FAT combined) which took place in the same venue, while for SKB's Part 1, the results of the SAT only are reported (since the FAT of Module 3/ Part 1, which took place in La Seyne-sur-Mer, have already been described in a separate document, Deliverable WP3-D4 of Module 3).*

The KBS-3H deposition equipment, for SKB, included as **Part 1 of Module 3**, is shown in **Figure 1** below.

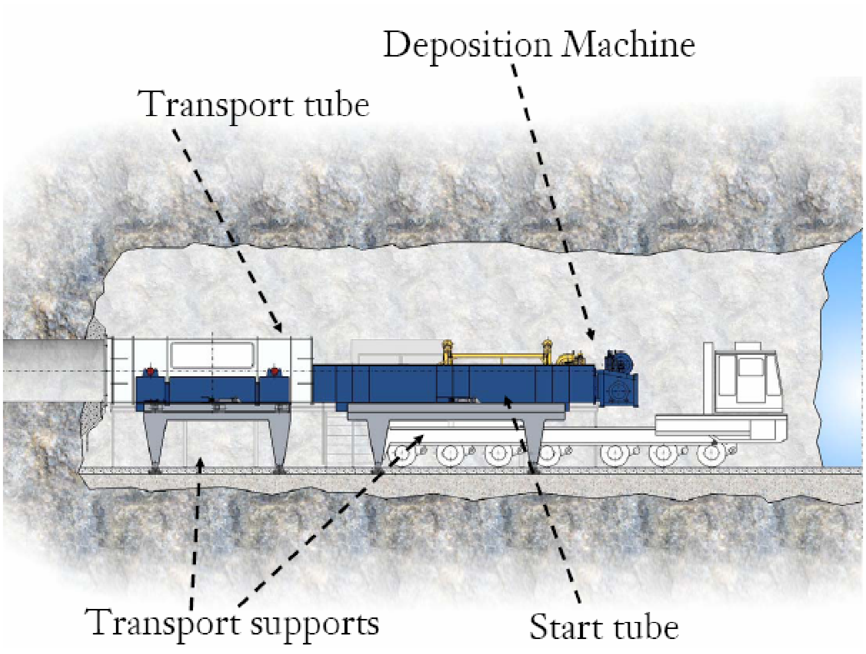

Figure 1 - SKB/Posiva - General Layout of the KBS-3H demonstration emplacement test (Part 1 of Module 3)

For ANDRA, **Part 2 of Module 3** deals with the transportation of sets (17t each) of 4 pre-compacted buffer rings with an air cushion pallet, while **Part 3 of Module 3** deals with transportation of a SF canister (43t), called CU1 package, also with an air cushion pallet.

The ANDRA demonstration concepts are similarly presented in the **Figure 2 & Figure 3** below.

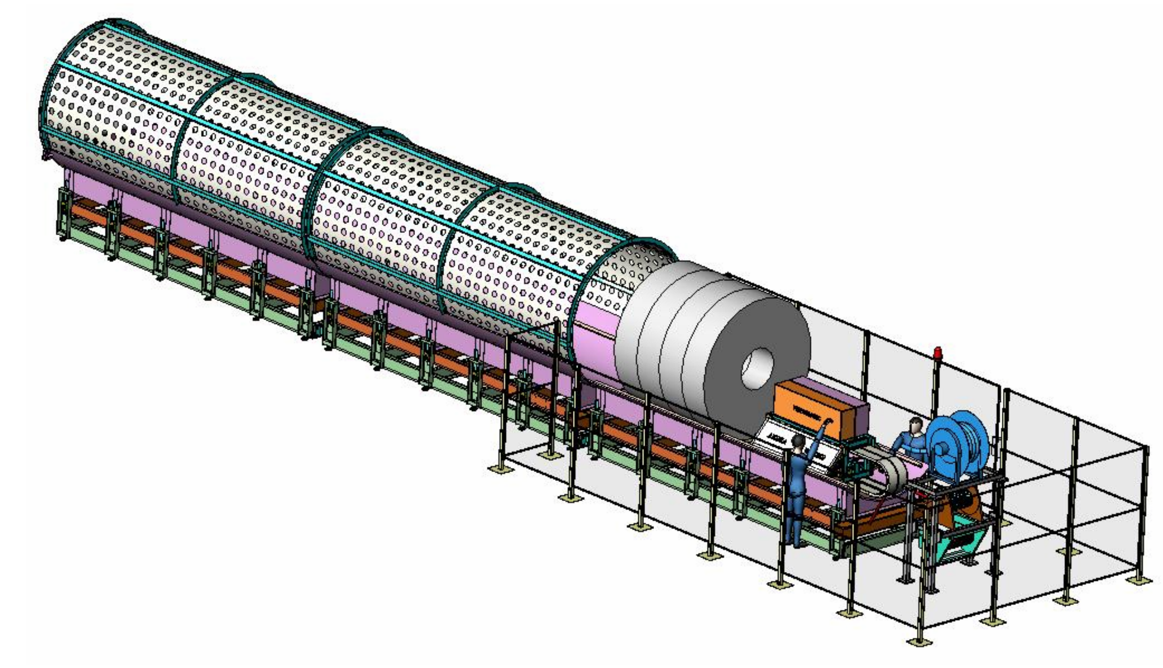

Figure 2 - ANDRA - General Layout of the Bentonite Rings demonstration emplacement test (Part 2 of Module 3)

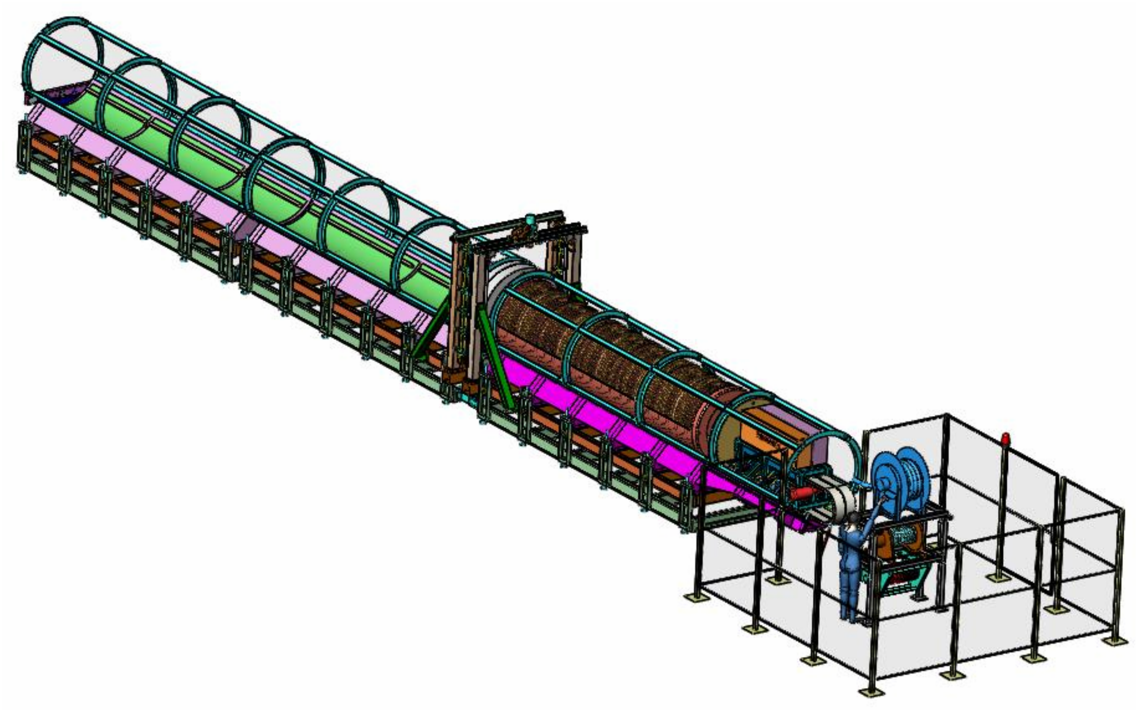

Figure 3 - ANDRA - General Layout of the CU1 demonstration emplacement test (Part 3 of Module 3)

1 - INTRODUCTION

1.1 General

In the framework of the studies carried out on various designs for the deep geological disposal of long-lived high-level radioactive waste, 13 waste management organisations from 9 European countries have launched a research and development programme supported by the European Commission. It is one of the new Integrated Projects within the European Commission 6th Framework Programme (FP 6). This Integrated Project is called ESDRED ("Engineering Studies and Demonstration of Repository Designs"). It is conducted with the purpose of building industrial scale demonstrators for the following 4 technical areas (hereinafter called "Technical Modules").

ESDRED contains four (4) Technical Modules as follows:

- Module 1: "Buffer construction technology",
- Module 2: "Waste canister transfer and emplacement technology",
- Module 3: "Heavy load emplacement technology",
- Module 4: "Temporary sealing technology".

ESDRED also contains 3 Functional Modules that are transversal to the 4 Technical Modules:

- Module 5: "Training and communication activities",
- Module 6: "Integration activities",
- Module 7: "Management".

All the Modules are divided into Work packages (WP) and come with Deliverables produced at the end of each Work Package.

The partners within Module 3 are SKB (Svensk Kärnbränslehantering AB) acting as Module 3 Leader, Posiva and ANDRA (Agence Nationale pour la Gestion des Déchets Radioactifs).

The purpose of this document is to present the Deliverable WP4-D5 of Module 3, entitled "Report on Emplacement/Transportation Tests".

1.2 Description of the three heavy load emplacement concepts within Module 3

Module 3 consists of three (3) different heavy load emplacement concepts (also called **Parts 1, 2 & 3 of Module 3**). These concepts are described below:

- **Part 1** (SKB/Posiva's concept) is related to a deposition machine complete with ancillary equipment for disposal of a Super Container with a weight of about 45 tonnes in horizontal drifts with a diameter of 1.85 m. This disposal concept for spent nuclear fuel is called KBS-3H in SKB's and Posiva's programmes. The main components in the KBS-3H concept are shown in **Figure 4**.

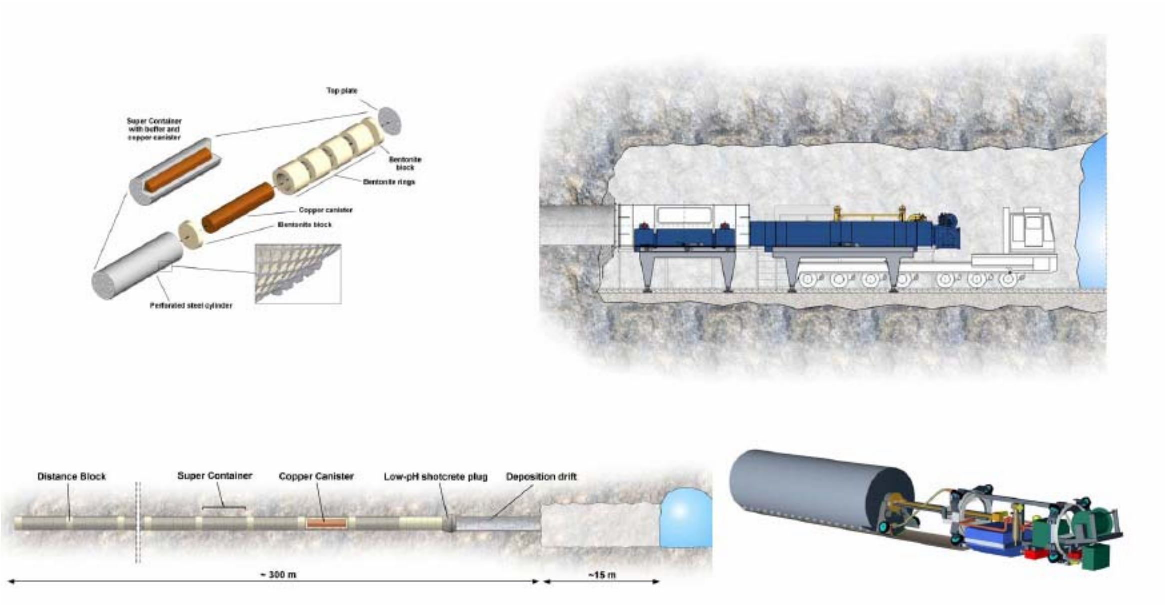

Figure 4 - Clockwise the main components in the KBS-3H concept: Super Container with canister and buffer; the deposition equipment; the deposition machine; the deposition drift.

- **Part 2** (ANDRA's concept) is related to a deposition machine with ancillary equipment for emplacement of sets of bentonite rings into the perforated liner of a disposal cell, used to build the engineered barrier system. The load is about 17 tonnes, with a length of about 2 m and a diameter of about 2.25 m.

- **Part 3** (ANDRA's concept) is related to a deposition machine with ancillary equipment for disposal of spent fuel canisters into the inner tubular metal sleeve of the disposal cell. The load is about 43 tonnes, with a length of about 5.39 m and a diameter of 1255 mm.

The main components in the ANDRA's concepts are shown in **Figure 5** below.

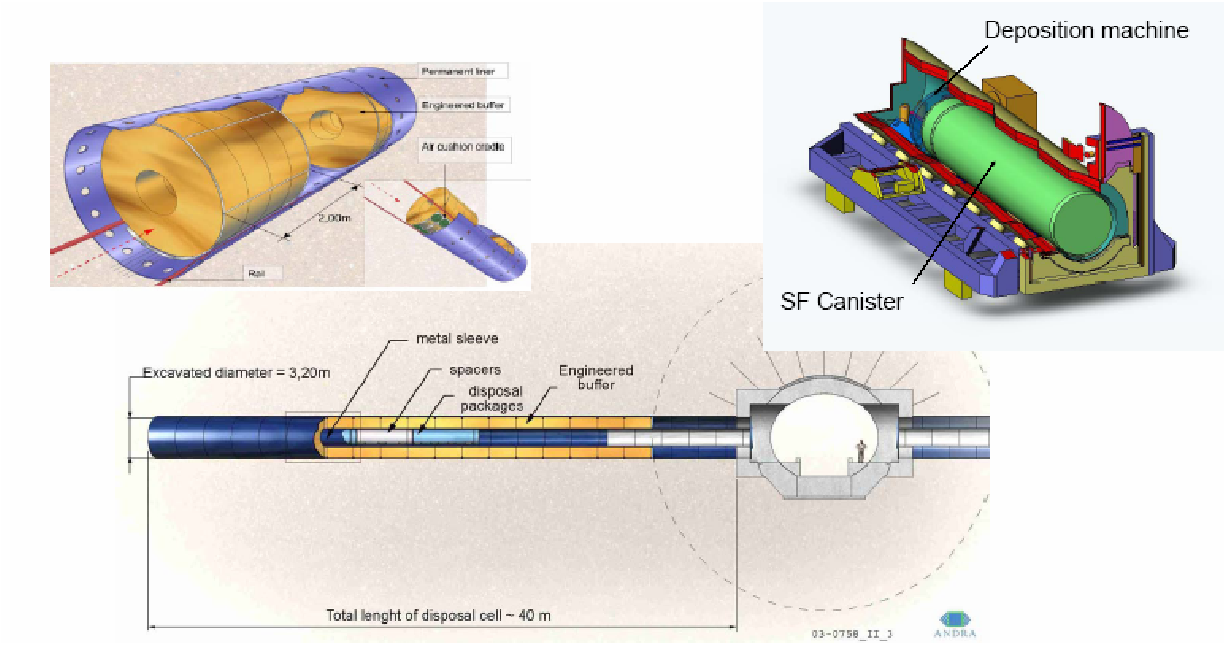

Figure 5 - Clockwise the main components in the ANDRA's concepts: emplacement of a set of 4 pre-assembled buffer rings (17tonnes) inside the perforated liner using an air cushion pallet; shielding cask & deposition machine using the same technology for emplacement of SF canister (43tonnes); overview of the disposal cell.

1.3 Definitions

The following definitions are given below to facilitate the reader's understanding of the word "**Demonstration**" and of the **FAT & SAT** acronyms. This will also help him / her differentiate the specific ANDRA and SKB case stories, concerning the approach and methodology of testing their respective emplacement (deposition) systems.

For SKB, 3 steps were considered:

- **FAT**: The **F**actory **A**cceptance **T**ests are all the Commissioning Operations which are 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. that the main components are effectively working in accordance with the technical specifications. These commissioning operations look at covering the main spectrum of performances allocated to the system and also at trouble shooting the main defaults identified at the time, if they are detrimental to an efficient functioning. In the case of SKB, those **FAT** were carried out mainly in CNIM's facilities at La Seyne-sur-Mer and completed on site at the Äspö HRL. They were followed by the **SAT**.

- **SAT**: The **S**ite **A**cceptance **T**ests are all the Commissioning Operations which are carried out **in situ**, i.e. in the Äspö HRL. They are implemented in the real underground environment, i.e. inside a chamber and a deposition drift excavated in the host rock (granite). The emplacement system is then complete with all its components in a fully operational configuration. The check-up is consequently more thorough than for the **FAT** and the trouble-shooting is applied to all the concerned pieces of equipment. Once the performances obtained are evaluated and deemed acceptable by comparison with those specified in the Contract, the Contractor is released (Contract sign-off) and SKB's staff takes over to carry out the **Demonstration** phase per se.

- **Demonstration**: This phase of the test campaign covers the "endurance testing" (long term) part of the trials. It focuses on the reliability of the system and is a way of identifying the weak components which must be re-engineered, retrofitted or substituted by more rugged spare parts. It's 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. reengineered for nuclear applications).

For ANDRA, the approach was different:

Since ANDRA had no underground facilities available to test its emplacement devices, it was planned to carry out the whole test campaign in the same venue, i.e. the selected Contractor's workshop. It happened to be Mécachimie - SGN premises in Beaumont-Hague (a workshop called HRB). Subsequently, the **FAT** and the **SAT** were combined in one full testing programme per configuration: one for the Bentonite Rings emplacement **(Part 2**) and one for CU1 Canister emplacement **(Part 3)**, while for time schedule and budget reasons, it was decided not to run any endurance (long term) trials similar to what is called **Demonstration** for SKB.

<u>Note:</u> Part 3 was run before Part 2, since the most technically challenging part was the one dealing with the heaviest load (the CU1 canister).

2 - COMMISSIONING AND EMPLACEMENT/TRANSPORTATION TESTS

2.1 Part 1 – SAT of the KBS-3H for SKB

2.1.1 General

The commissioning of the KBS-3H equipment was carried out in two steps:

- The first step, Factory Acceptance Test (**FAT**), was carried out in the Manufacturer's workshop (i.e. CNIM premises at La Seyne-sur-Mer / France) and completed in Aspö HRL (Sweden). This phase is described in Deliverable D4 of Module 3. It took place between January 2006 and February 2007,

- The second step, Site Acceptance Test (**SAT**), was carried out underground at the final test site i.e. Äspö HRL. It took place in February 2007 and will be prolonged by endurance testing throughout the year 2007.

The main purpose of the **SAT** test is to verify that delivered equipment described in Deliverable D4 of Module 3 ref. [4] ("Commissioning Report") fulfils the requirements which were outlined in Deliverable D1 of Module 3 ref. [1] ("Input Data & Functional Requirements"), i.e. that the KBS-3H concept with water cushion technology is technically suitable for emplacement of Super Containers and Distance Blocks in a horizontal disposal drift (excavated in granite) with small annular clearances.

More precisely, the purpose of the SAT is to verify the good functioning of all the equipment. They consist of:

- Pre-operational tests of all mechanical and electrical systems to assure proper operation on the Test Site,
- Verification that the deposition machine is functionally complete and capable of effective emplacement of Super Containers and Distance Blocks in a disposal drift,
- Verification that the deposition machine fulfils the requirements listed in the "Functional Requirements" listed in Deliverable D1 of Module 3.

Besides the **SAT**, SKB/Posiva also performed the following **Demonstration** tests, which are not a part of the ESDRED project per se:

- **Demonstration** of the KBS-3H deposition concept (as a whole),
- **Demonstration** of the Integrity of the Disposal Container and the Distance Block during the deposition process.

The main purpose of this last category of tests is to verify the availability and the reliability of the equipment for a longer period of time (evaluation through endurance testing). This is a continuation of the activities performed during the **SAT.**

2.1.2 Description of Site Acceptance Test for Super-Container Deposition

The Site Acceptance Test (**SAT**), which commenced on February 7, 2007, was finally approved on February 16, 2007 at SKB's HRL Äspö, Sweden. SKB/Posiva's **Demonstration** per se of the KBS-3H deposition concept as a whole started directly after that the **SAT** was approved. These tests will continue until December 2007.

2.1.2.1 Test set-up

An overview of the set-up of the equipment at the test Site is shown in **Figure 6.**

Figure 6 - Set-up of equipment at the test site at Äspö HRL, level -220m.

Two (2) Super Containers (built with SF copper canister and buffer material mock-ups) and two (2) Distance Blocks were manufactured for the purpose. The Super Containers and Distance Blocks are mock-ups of the real payloads, but with the correct physical dimensions and weights. These items are not part of the ESDRED Project and were subsequently designed and manufactured by SKB/Posiva outside of the Project.

As described in Deliverable D4, following the **FAT**, the deposition machine was retrofitted with a guiding system to prevent uncontrolled rotation of the Super Container (see **Figure 7**). The gap between the guides is approximately 5 mm.

At the same period, a fork was also attached to the electrical cart radioprotection shield to improve the alignment of the load vis-à-vis the palette. **Figure 8** is showing the radiation shield with the "forks" that are used for centring of the slide plate / pallet between the container feet.

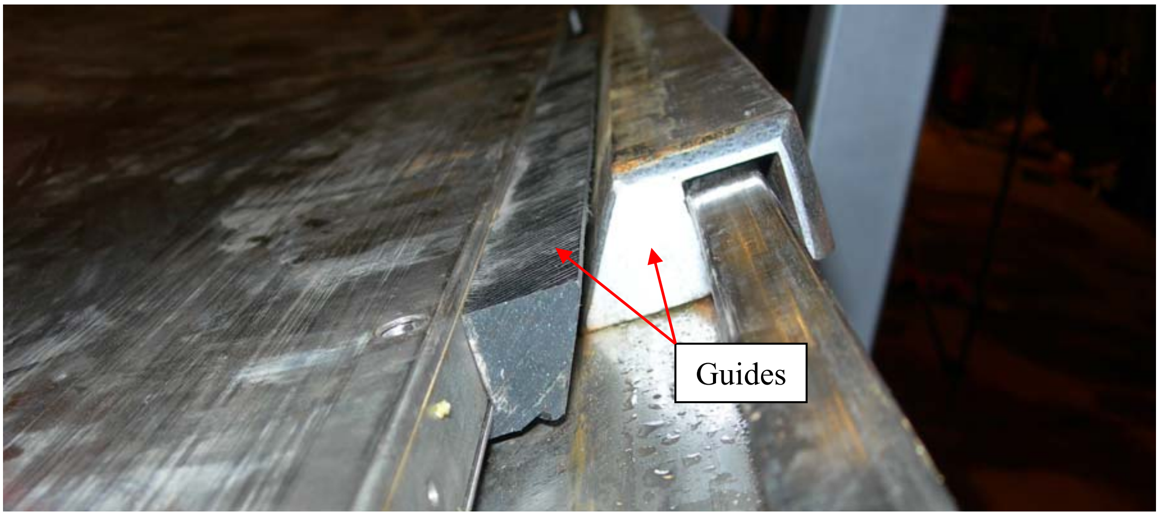

Figure 7 - Guides between the pallet and the slide plate.

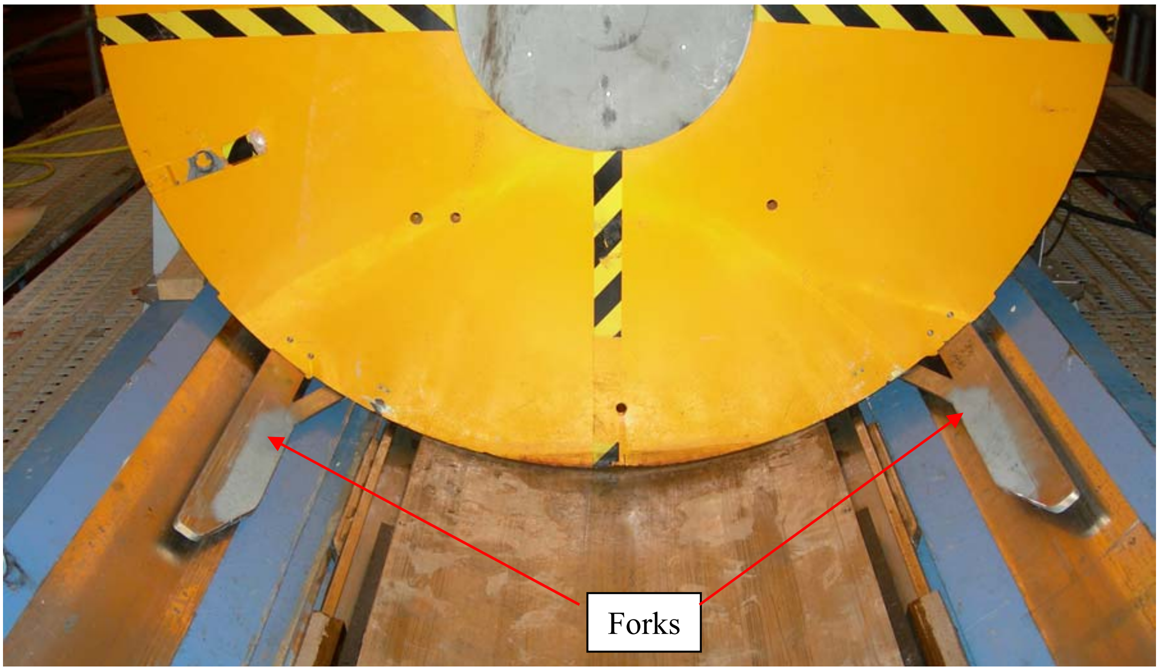

Figure 8 - "Forks" mounted on the radiation shield for centring of the container.

To ensure a proper function of the guides, it appeared that the lifting height must be limited. It was therefore also decided to change the original water cushions (original brand from "Bertin") to new water cushions (new brand from "Solving") with less lifting height and also with less sensitivity to load variations. The pallet, which is provided with 24 cushions in two longitudinal rows left/right, is shown in **Figure 9** below.

Figure 9 - Installation of new water cushions on the lifting pallet.

The water cushions are inter-connected in pairs along each side, except for cushions in rows 1, 4, 7 and 10, which are cross connected between the left and the right side to allow for cushion selection, in case of transport of distance blocks (whose weight is lower than that of the Super Container). The cross connected cushions in rows 4 and 10 are normally closed during transport of the Super Container, which means there are only 20 out of 24 cushions active at a time. This set-up has been chosen with regards to the cushion pressure/load behaviour. It appeared in the previous cushion tests that the cushion lifting height is sensitive to load and/or pressure changes. The sensitivity is however less at higher pressure. The set pressure is 2.7 bars with 20 cushions.

The pallet was also provided with four (4) lift sensors for indication of the lifting height, see **Figure 10**. The sensors are located between the cushions in row 4/5 and 11/12. The lift sensor is a simple toggle-arm fixed to the pallet and by gravity resting against the slide plate. The sensor has 5 fixed indication levels. The pallet is normally lifted 20 – 25 mm, which results in a lift of the Super Container of approximately 10 mm (space measured between the feet bottom part and the rock surface).

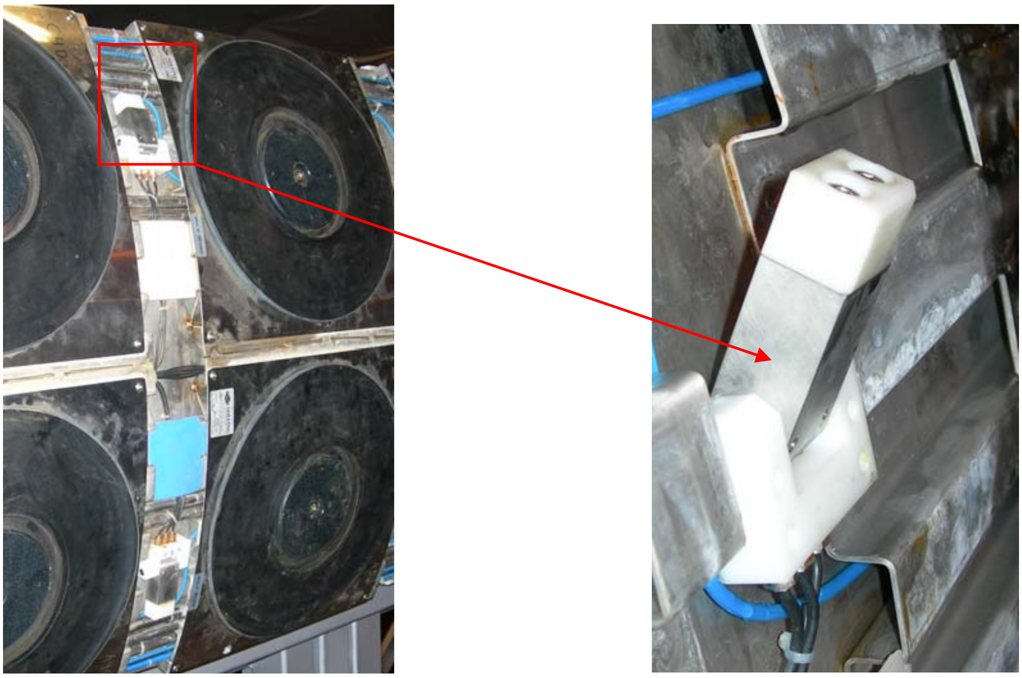

Figure 10 - Lift sensor for indication of the level of the pallet.

The control system and the Deposition Machine function is described in the Operation Manual, ref [7].

2.1.2.2 Test Programme

All tests are outlined in ref [4] “Test Plan – KBS-3H Deposition Equipment”.

The **SAT** was carried out in accordance with the detailed **SAT** Programme ref. [5] including the following check operations:

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
• Forward drive: manual mode
• Locking in stop position
• Backward drive: manual mode
• Recovery of the machine using the emergency winch
Deposition machine tests with load

• Docking of the Super Container
• Lifting pallet test
• Recovery of the Super Container
• Deposition of the Super Container
• Deposition of Distance Blocks
• Recovery of Distance Blocks

Due to time restraints, the deposition and recovery of Distance Blocks was not tested during the SAT period. This transportation is however considered to be easier than the transportation of the Super Container and it was decided that this could be tested later during the **Demonstration** test period per se.

2.1.2.3 Test results from SAT

All tests from the **SAT** are recorded in the test sheets in ref. [6]. What follows is only an overview of the main observations and results made during the tests and also an overview of the performance data with reference to the main functional requirements mentioned in earlier Deliverables.

The first tests with the machine showed, that there is a high risk that the rotation about the long axis of the container could increase cumulatively each time the container is moved due to the gap between the guides on the pallet and the slide plate. The gap is 5 mm, which allows the container to rotate approximately +/- 0.2 – 0.3 degrees. Tests showed however that this could be controlled with the ballast if the correction is done, as soon as an inclination deviation is indicated / observed. Therefore, the ballast system has been made active in automatic mode to compensate for the rotation that can occur within the remaining gaps between the guides.

An other observation made is that if the container together with the pallet and the slide plate is rotated more than 3.5 - 4 degrees, then this movement can create problems for the good functioning of the water cushions (due to the uneven load distribution which will result from such a configuration). As reported previously in Deliverable D4, the water cushions are sensitive to load variations. The problem that can occur with a too important rotation is that the cushions, which get more loaded than normal are not able anymore to lift the container. It is therefore considered not possible to handle properly an unbalanced Super Container with the present water cushion system.

It was also observed during the tests that the system is sensitive to alignment between the emplacement equipment and the drift. It is also of importance to have the best possible initial alignment between the deposition machine and the Super Container (which means that the initial position of the Super Container in the transport tube is very important too).

Besides the change of the requirement that the machine should be able to handle unbalanced containers, all the other requirements outlined in the Deliverable D1 have been fulfilled.

After completion of the first check tests, the Super Container was transported approximately 20 meters into the drift, see **Figure 11.** Both manual mode and automatic modes were tested.

Figure 11 - The deposition machine has entered the deposition drift (left) - The Super Container is placed approximately 20 meters into the deposition drift (right).

The average deposition speed reached during the **SAT** when running in automatic mode was measured to be approximately 15 mm/s, which is lower than the performance requirement of 20 mm/s and than what the speed reached during the **FAT** (19.8 mm/s). It was however at the time considered possible to reach the pre-determined requirements if the cycle times for lifting and lowering were further optimised.

The performance requirement for the average deposition speed of 20 mm/s was finally reached after correction of the water cushion control valves.

The cycle times which were measured for the transport and deposition of the Super Container are listed in the table below.

Cycle	**SAT**	**Tests after corrections of 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 Super Container has, during the **Demonstration** test period that started after the **SAT**, repeatedly times been transported to the far end of the deposition drift (95 meters) and recovered. According to the endurance test programme, the goal is to make one deposition and subsequent recovery per day. The cumulative deposition distance measured until beginning of July 2007 is approximately 4000 meters. The transportation has been performed in both manual and automatic modes.

The performance requirement for the average deposition speed of 20 mm/s was reached after corrections to the water cushion control valves. The water cushion pressure relief valves have however a permanent problem, since they have a tendency to jam after a period of operation, resulting in high cushion pressure that can damage the cushions and can also create an uneven lowering of the Super Container (the uneven lowering will result in rotation of the container, which the ballast system cannot compensate for). The function / reliability of these control valves are presently being reviewed.

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

The tests have also shown that it is not a problem to control the container rotation if the set-up is well aligned from the very start-up of operations. The system is however more sensitive when moving forward than when reversing due to the machine rotational flexing trend when extended.

Some initial tests with distance blocks have also been performed. The performance requirement regarding transport speed has however not yet been verified.

2.1.3 Conclusions of the tests for the KBS-3H deposition equipment

The tests performed so far have shown that the emplacement equipment tested is operating effectively for the transport & 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 the equipment for a longer period of time.

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

2.2 Part 2 – SAT of the Bentonite Rings Emplacement System for ANDRA

2.2.1 General

The main purpose of the SAT test is to verify that the equipment designed, manufactured and erected for the emplacement of sets (17 tonnes) of prefabricated bentonite (buffer) rings inside a perforated liner fulfils all the requirements which were outlined in Deliverable D1 ref. [1] ("Input Data & Functional Requirements"), i.e. that the equipment concept based on air cushion technology is technically suitable for emplacement of the sets of rings into a horizontal disposal cell (excavated in clay & lined with a perforated casing) with small annular clearances.

2.2.2 Description of Tests for Bentonite Rings Emplacement

The tests campaign related to the emplacement of the sets of Bentonite Rings took place from September 2006 to January 2007 (in fact, they followed the tests first implemented for the SF canister emplacement system). In other words, ANDRA's Part 3 preceded Part 2.This campaign started with an erection of the equipment necessary for that purpose. In the present case it was a modification of the test bench initially used for the SF canister.

The main configuration changes made to the SF canister emplacement system were:

- an adaptation of the structural frame supporting the bench (to deal with the change of diameter from one type of payload to the other),
- a new "test tube" composed of a perforated steel liner in its upper part (including a lateral polycarbonate window) and of a stainless steel sliding track in its invert lower part,
- the suppression of the sliding plate (emplacement of rings is continuous versus SF canister which is in 1m steps) and of the radioprotection shield which were attached to the electrical cart, whose wheel span was also adapted to the new guiding rails gauge (see **Figure 25**),
- a new air cushion pallet adapted to the payload (see **Figure 12, left**),
- a new PLC programming for control & monitoring.

The challenges in this test programme were of 3 types:

- fulfill all the technical performances specified in D1, including the successive emplacement (and later retrieval) of 2 sets of 4 dummy concrete rings (same weight and same dimensions as the real bentonite rings) in automatic mode, inside the perforated liner (the 2 sets being emplaced to make contact with each other, so as to create a continuity for an engineered barrier),
- down-load the set of 4 dummy rings on the launching table with the lifting (see **Figure 12, right**) and handling systems developed by the GME (Contractor of Module1, in charge of the design and fabrication of such devices). The interface between Module 1 and Module 3 was therefore very important,
- check the behaviour of the rings, which are disassembled after their loading onto the pallet, and their stability under the various accelerations induced by the emplacement operations.

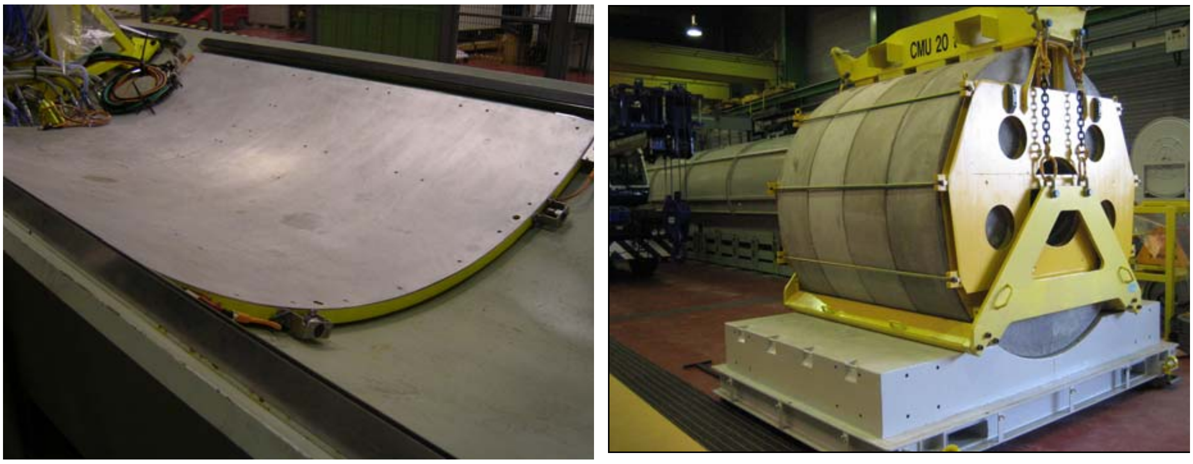

Figure 12 - The air cushion pallet on launch table (left) and a set of 4 concrete dummy rings on its transportation cradle (right), ready to be lifted

The **Figure 13** shows the layout of the test bench as configured for the testing of the Bentonite Rings emplacement system. The overall length of the bench is similar to that set up for the SF emplacement system, but the overall height and width are bigger, due to the change in diameter (OD changed approximately from 1.3m to 2.35m).

Figure 13 - ANDRA - Set-up of the emplacement equipment (Part 2) at the test site (HRB-SGN-Mécachimie's premises in Beaumont-Hague)

The **Figure 14** below shows (left) a set of Concrete Dummy Rings on the launch table, before emplacement and the same set once positioned inside the perforated liner (right).

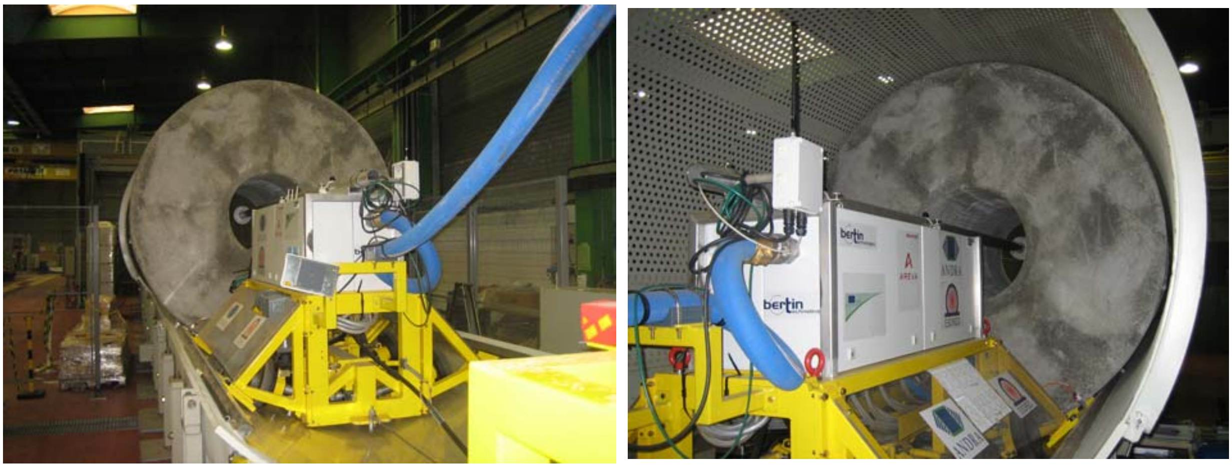

Figure 14 - Set of Rings before and after emplacement inside the perforated liner

The lifting of the set of rings before unloading on the launch table is shown below.

Figure 15 - Lifting of a set of rings for deposition on the launch table

The lifting height of the air cushions being too much and not easily adjustable, it was deemed necessary to increase the height of the guiding rails (to avoid derailing). That was done successfully, by adding a 5mm steel band underneath. However, and as a consequence of such a “last minute construction change”, the operational clearance between the lifting device frame (designed with a recess at zone of contact with the rail) and the outside face of the guiding rail was diminished to a critical “2mm gap” on each side, making even more difficult the down-loading of the set of rings on the launch table (see **Figure 16**).

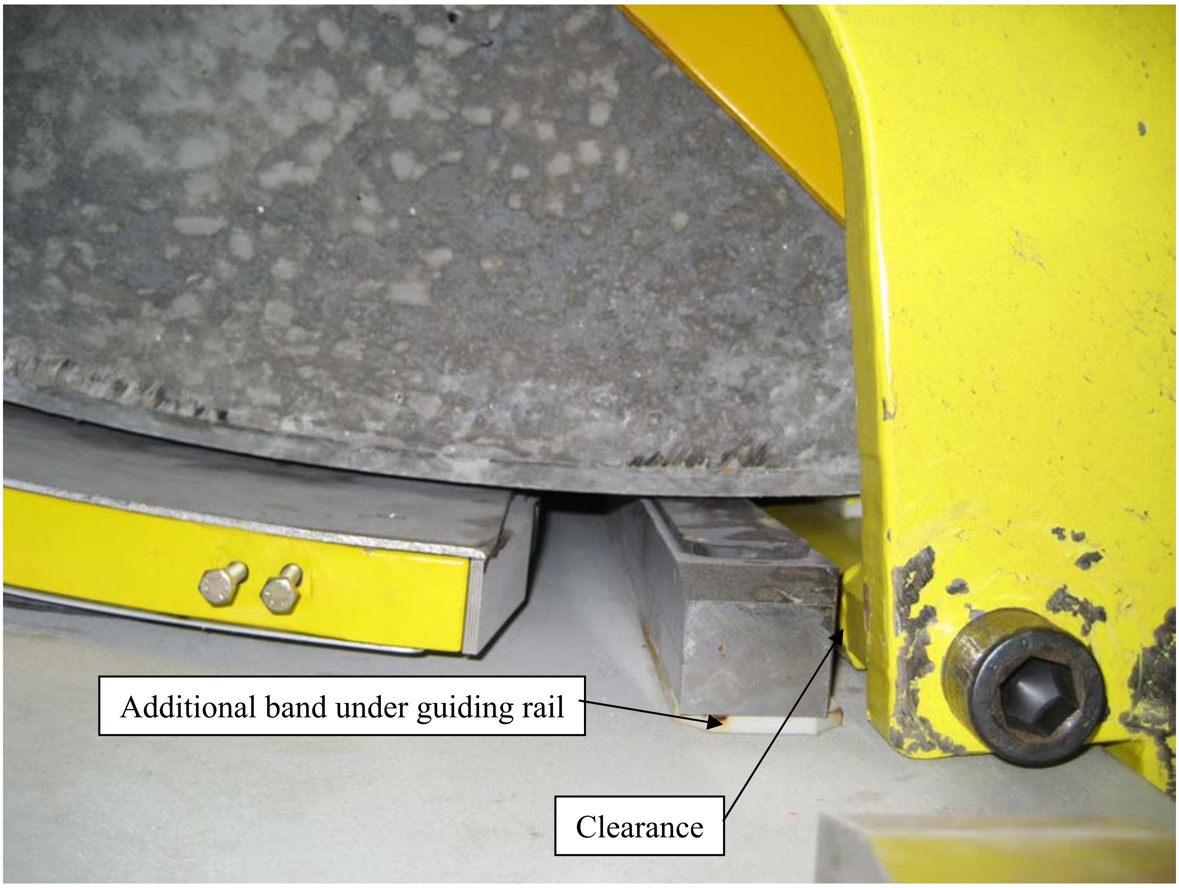

Figure 16 - Interface between lifting device frame (yellow) and external face of guiding rail (grey) showing a limited clearance

2.2.3 Conclusions related to the Tests of the Buffer Rings Emplacement System (Part 2)

All tests from the **FAT** & **SAT** are recorded in the Test Reports in ref. [13]. What follows is only an overview of the main observations and results made during the tests and also an overview of the performance with reference to the main functional requirements mentioned in earlier Deliverables:

- Since the trouble shooting of the emplacement system took place during the previous testing of the **Part 3** (i.e. the CU1 configuration), no particular difficulties were encountered during the test programme, **which turned out to be a complete success.**

- The specified emplacement performances were met (average emplacement speed over one cycle equal 6 m/mn versus 1.8 m/mn specified).
- The emplacement of the set of rings is very smooth, without shocks. Thus, the lateral stability of the rings (disassembled after their downloading on the air cushion pallet) is not affected.
- The air cushions (and the air flow control) being sensitive to water content in air, a compressor equipped with a dessicator was used and as a consequence, no separation of the cushion rubber part from its steel supporting plate was noticed (see Chapter 2.3.3 for more details).
- The air cushions turned out to be also quite sensitive to voids (gaps, rough surfaces), thus a temporary fibre glass carpet was positioned on the liner invert (see
- **Figure** 17) between the guiding rails. The installation of such a carpet was very easy and executed manually, since the carpet weight was limited and the access to the inside of the perforated liner compatible with man height (liner is about 2.3 m ID).

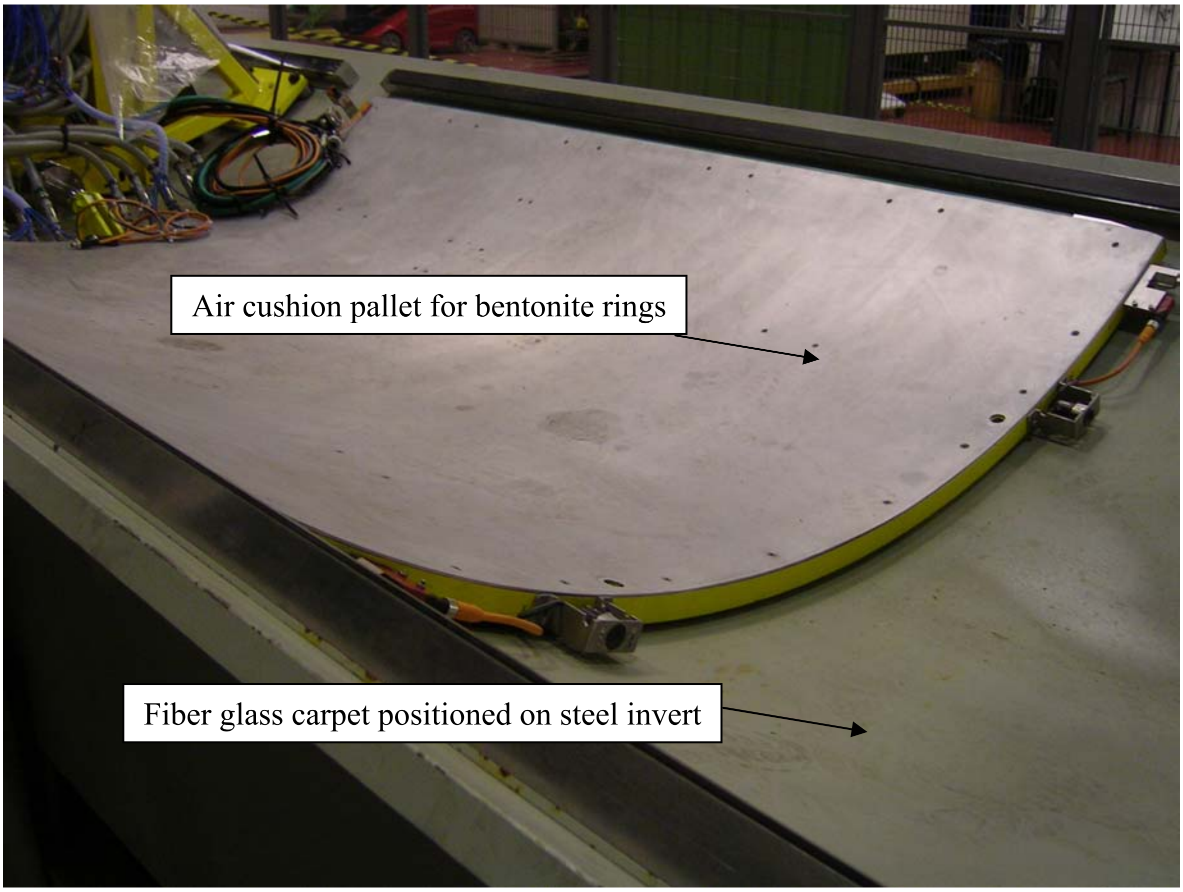

Figure 17 - Air cushion pallet and fibre glass carpet positioned on the liner invert, between the guiding rails

The remaining (i.e. not solved within the frame of the test programme) difficulties for operating the system are listed below (jointly with the remedial solutions):

- The air cushions are sensitive to load distribution, thus there is a need for a better air flow control,
- Air cushion lifting height must be monitored and controlled to avoid derailing of pallet with load (lifting height was in practice only monitored),
- Winding and unwinding of the air hose in automatic mode was not perfect and "needed a hand" from time to time, while the friction coefficient of the hose on the invert side track was creating a parasitic force. A different hose material would reduce the friction and the wear of the hose (and would also reduce the drag force exerted on the electrical trolley). Finally, a spooler mounted on the hose winch would facilitate the winding / unwinding of the hose (see **Figure 26**).

2.2.4 Considerations concerning other potential optimizations of the Buffer Rings Emplacement System (Part 2)

The handling and lifting devices used for the transport and downloading of the set of rings on the launch table were obviously not very convenient and not adapted to a future confined mining environment. A conceptual design is presented below (**Figure 18**) of what could be considered for an effective use underground, at time of construction of the disposal cell engineered barrier. This system would also be compatible with the access drift dimensions as presently designed in the repository.

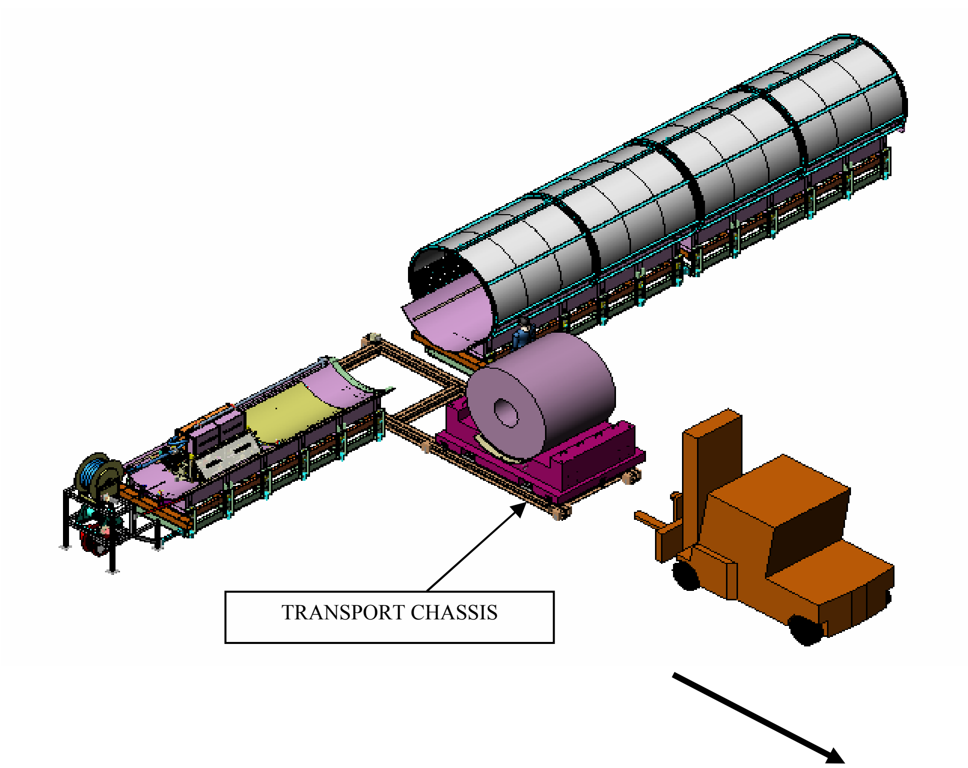

Figure 18 - Conceptual design of an optimized handling & lifting system for the deposition of the rings on the launch table, using a forklift underground

2.3 Part 3 – CU1 (Spent Fuel) Canister Emplacement for Andra

2.3.1 General

The main purpose of the **SAT** test is to verify that the equipment designed, manufactured and erected for the emplacement of Spent Fuel (CU1) canisters (43 tonnes) fulfils the requirements which were outlined in Deliverable D1 ref. [1] ("Input Data & Functional Requirements"), i.e. that the equipment concept based on air cushion technology is technically suitable for emplacement of CU1 canisters in a horizontal steel liner with small annular clearances.

2.3.2 Description of Tests for CU1 Canister Emplacement

The tests campaign related to the emplacement of the CU1 (SF) canister took place from May 2006 to September 2006 (they were followed by the tests implemented for the set of rings emplacement system – see Chapter 2.2 herein). This campaign started with an erection of the equipment necessary for that purpose. In the present case it was a complete erection of the test bench in the configuration shown below.

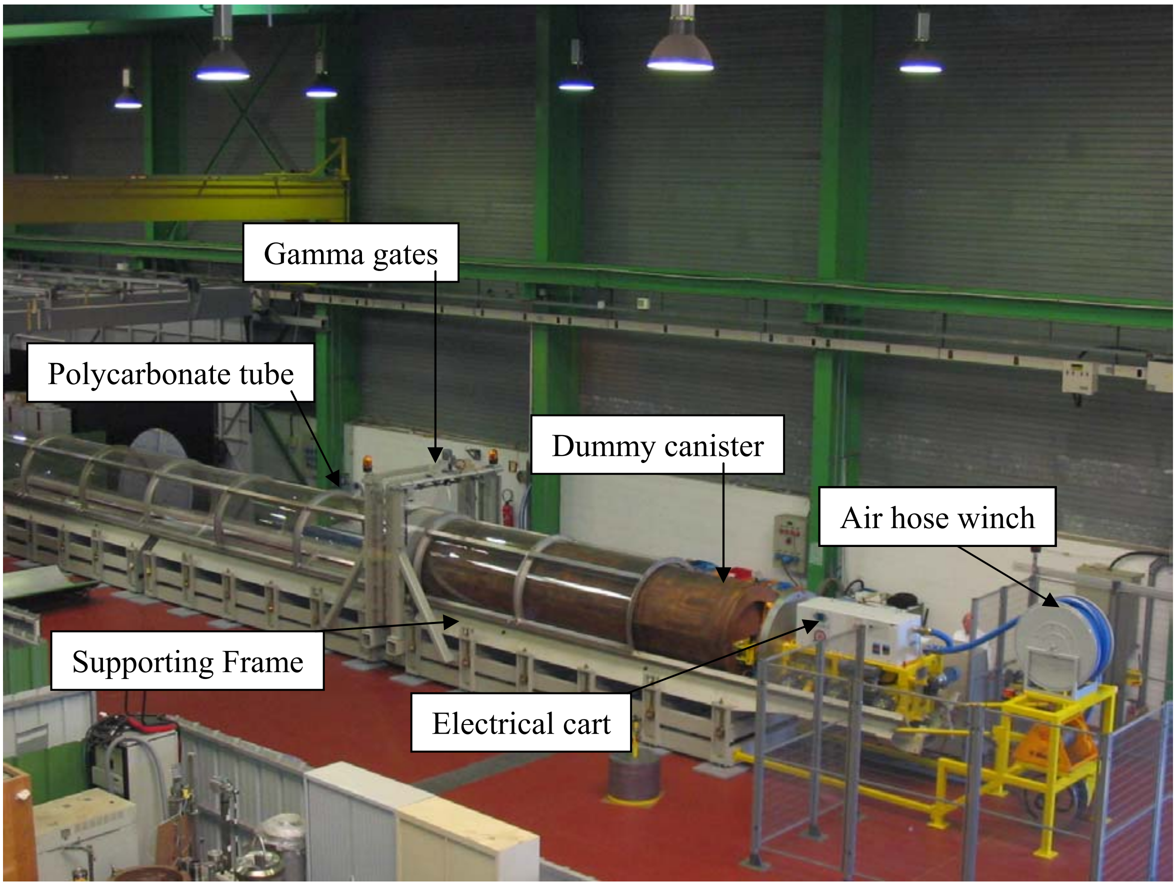

Figure 19 - ANDRA - Set-up of the CU1 emplacement system (Part 3) at the test site (HRB-SGN-Mécachimie's premises in Beaumont-Hague)

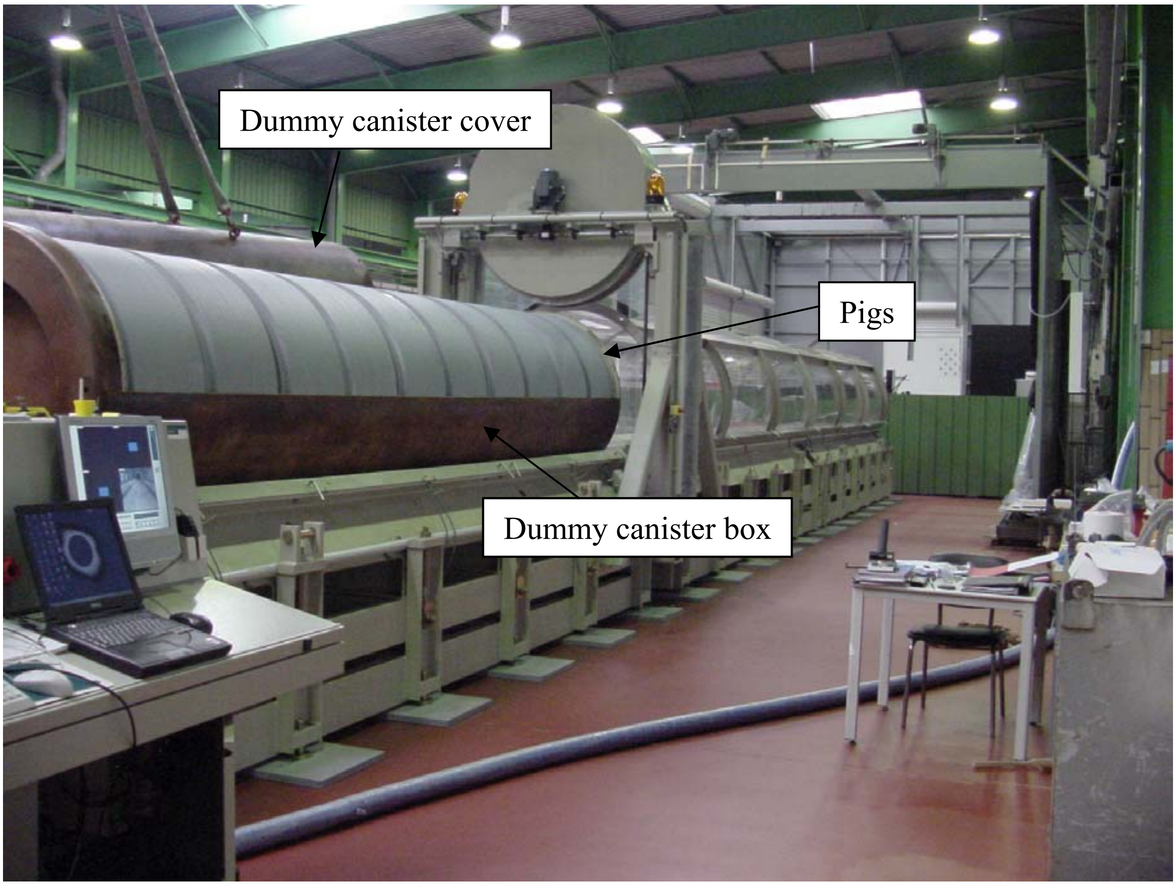

Figure 20 - ANDRA - Set-up of the CU1 dummy canister (43 tonnes)

The test bench per se is composed of the following main parts:

- A supporting frame equipped with adjustable feet, to simulate 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 cell mouth,
- A polycarbonate tube (whose ID diameter is in the range of the real steel sleeve) with a stainless steel sliding track in its invert,
- 2 Gamma gates: one attached to the cell mouth, one attached to the shielding cask. The cask gate is motorized and moves the 2 gates at a time,
- An electrical cart equipped with a radioprotection shield and an electrical pushing jack,
- A slide plate attached to the body of the cart,
- An air cushion pallet attached to the pushing jack (see **Figure 21, left**),
- A control & monitoring console (see **Figure 21, right**),
- A 43t dummy canister with an adjustable longitudinal and radial load unbalance (see **Figure 20**).

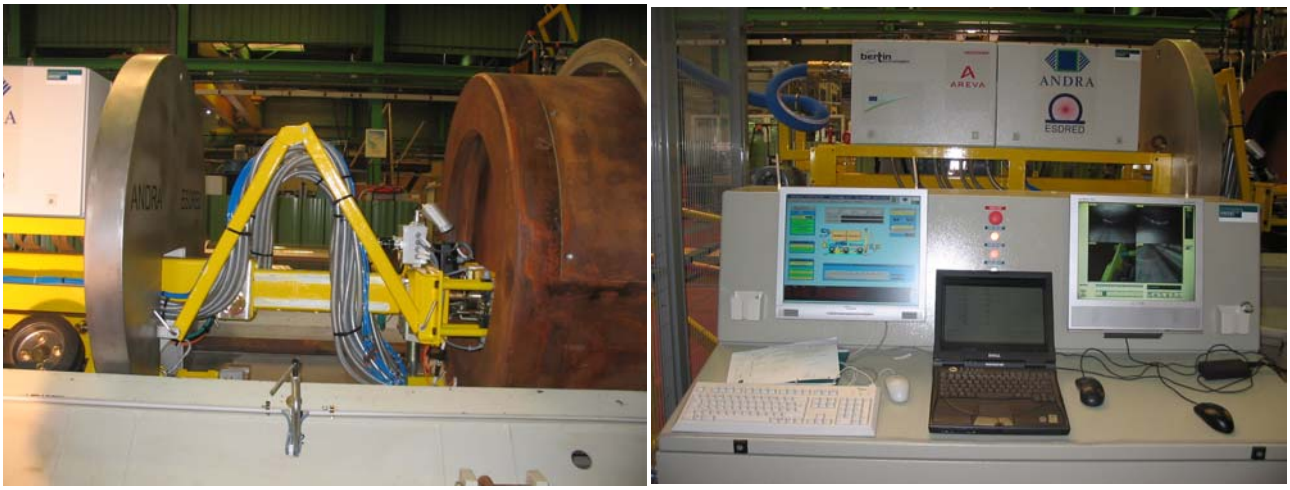

Figure 21 - Electrical pushing jack connected to the CU1 canister (left) – Control & Monitoring Console (right)

The challenges in this test programme were of various types:

- Fulfill all the technical performances specified in Deliverable D1 of Module 3, including the successive emplacement (and later retrieval) of the dummy CU1 canister in automatic mode, inside the polycarbonate steel sleeve, including the automatic shutting / opening of the gamma gates, at the specified travel speed (average over an emplacement cycle),
- Passing the obstacles (recesses in the door frames) created by the gates (see **Figure 22**) or the discontinuities between 2 consecutive sections of guiding rails (see **Figure 23**). For that purpose, the use of a sliding plate was considered,

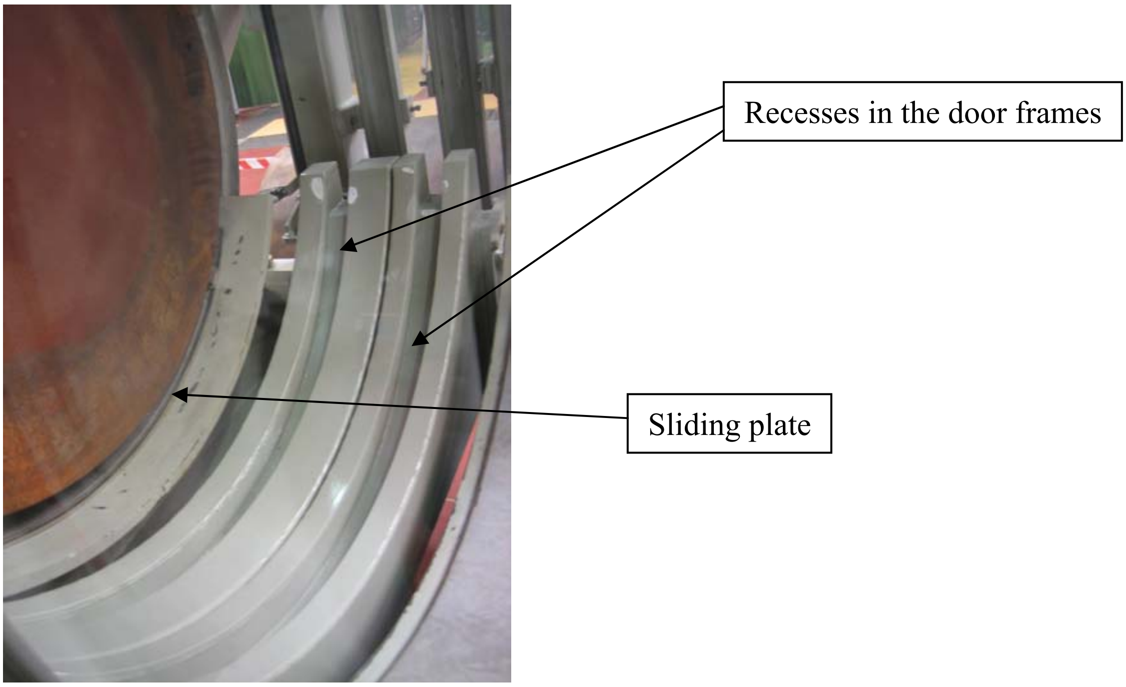

Figure 22 - CU1 canister & slide plate passing over the recesses in the door frames

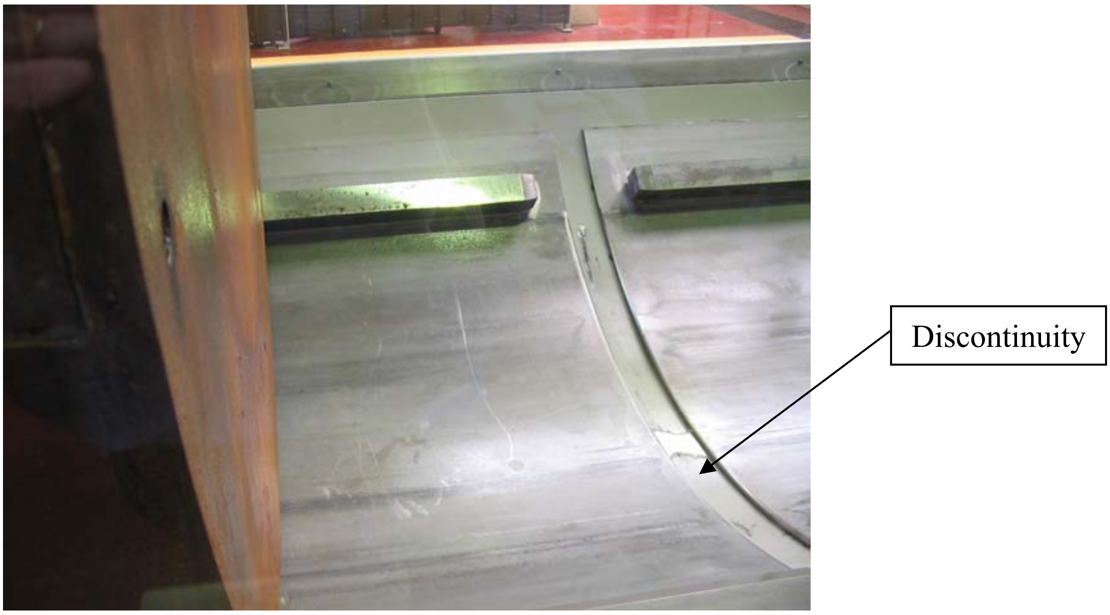

Figure 23 - Discontinuity between two (2) sections of guiding rails

- Check the sensitivity of the system to the various construction defaults (steps, misalignment) likely to be encountered underground or to the radial / longitudinal unbalance likely to be in the dummy canister,
- Identify the weak points of the system, likely to generate a re-engineering & a retrofitting in the real industrial application,
- Identify some potential improvements (mainly in terms of ruggedness and performance).

2.3.3 Conclusions related to the CU1 Canister Emplacement System (Part 2) Test Programme

All tests from the **FAT** & **SAT** are recorded in the test Report in ref. [17]. What follows is only an overview of the main observations and results made during the tests and of the performance with reference to the main functional requirements mentioned in earlier Deliverables.

- The trouble shooting of the emplacement system took place during the first months of testing the **Part 3** (namely the CU1 configuration), i.e. during the months of May & June 2006. PLC programming took a while during that period.
- The main difficulties encountered during this trouble shooting period (and their solutions) are listed below:
    - The friction coefficient between the lower face of the sliding plate and the invert (sliding track) of the steel sleeve turned out to be bigger than anticipated. As a consequence, the pushing force which had to be exerted by the electrical cart was higher than the available capacity. This problem was solved by fixing a Teflon sheet onto the lower face of the sliding plate.
    - At the end of each 1m stroke of the pushing jack (moving the air cushion pallet on the slide plate), the air cushions have to be deflated to lower and

sit the canister on the rails. Subsequently the sliding plate move forward 1m. The time needed for deflating and purging the air from the system turned out to be too long, thus detrimental to the duration of each cycle of emplacement (this was not compatible with the average travel speed posted in the specifications). This problem was solved by the installation of a quick relief valve upstream of the air inlet tube located in the control and monitoring pneumatic board.

- In a wet atmosphere, water condensation was noticed (due to the quick pressure drop of the compressed air), with a clear effect on the air cushions: separation of the rubber part from its steel supporting plate (see **Figure 24**). New cushions glued with a water resistant compound were supplied and installed.
- The presence of water in the air flow control was also detrimental to its good functioning. A regular purge of the electro-valves turned out to be necessary on a regular basis (at the end of every emplacement cycle).
- The air cushion pallet used to have a too high lifting height, inducing a tendency for derailing. This problem was solved by an increase of the guiding rails height (addition of a 5 mm band plate underneath),
- The air cushions turned out to be also quite sensitive to individual load variation which mainly appeared when simulating the longitudinal unbalance of the CU1 canister. In the most critical test case (combination of longitudinal unbalance with a change of inclination of a sleeve section), the canister could not be moved (the pallet and slide plate were colliding with the sleeve invert).

Figure 24 - Air cushion rubber part separated from support plate

The test programme turned out to be however a complete success:

- The specified emplacement performances were met (average emplacement speed over one cycle equal 1.8 m/mn versus 1.2 m/mn specified).
- The emplacement of the CU1 canister is very smooth, without shocks. The stability of the canister on the pallet is maintained even in case of radial load unbalance or of geometrical defaults in the steel sleeve.

*<u>Note</u>: The system developed to adapt the electrical cart wheel gauge to the change in diameter from the CU1 configuration to the Bentonite Rings configuration is shown in **Figure 25**.*

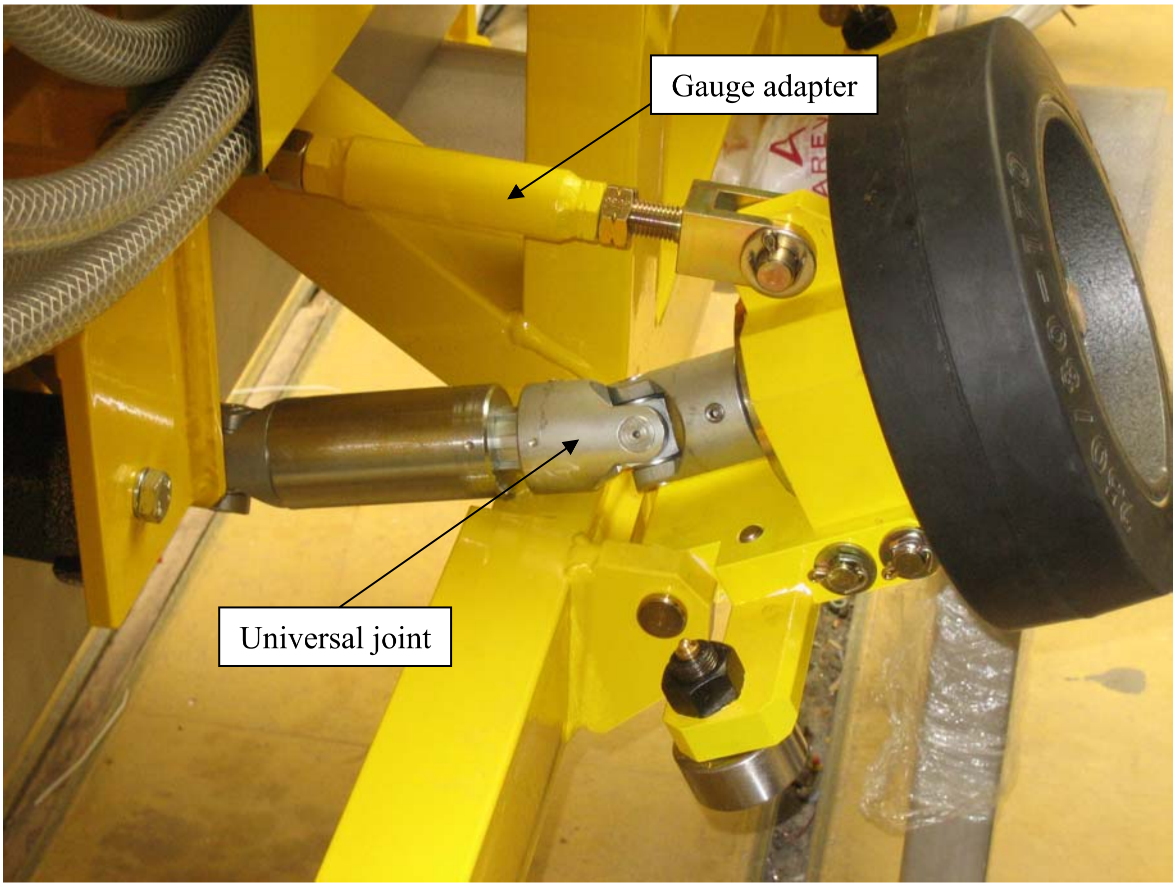

Figure 25 - View of electrical cart trolley at contact with guiding rail

2.3.4 Considerations concerning the potential optimizations of the CU1 Emplacement System (Part 3)

The remaining (i.e. not solved within the frame of the test programme) actions for operating more efficiently the system are listed below:

- Since the air cushions are sensitive to load variation, a more accurate air flow control is needed, allowing a fine tuning of each cushion,
- In order to avoid derailing of pallet, the air cushion lifting height must be not only monitored, but also controlled (see previous point),

- Since the air cushions are sensitive to water content in air, there is a need for a compressor equipped with a dessicator (this was effectively the case for the testing of **Part 2**),
- To activate more quickly the air cushions (and subsequently reduced the overall cycle time), the air feed inlet should be modified,
- Winding and unwinding the air hose in automatic mode was not perfect and “needed a hand” from time to time, while the friction coefficient of the hose on the invert side track was creating a parasitic force. A different hose material would reduce the friction and the wear of the hose (and would also reduce the drag force exerted on the electrical trolley). Finally, a spooler mounted on the hose winch would facilitate the winding / unwinding of the hose (see **Figure 26**).

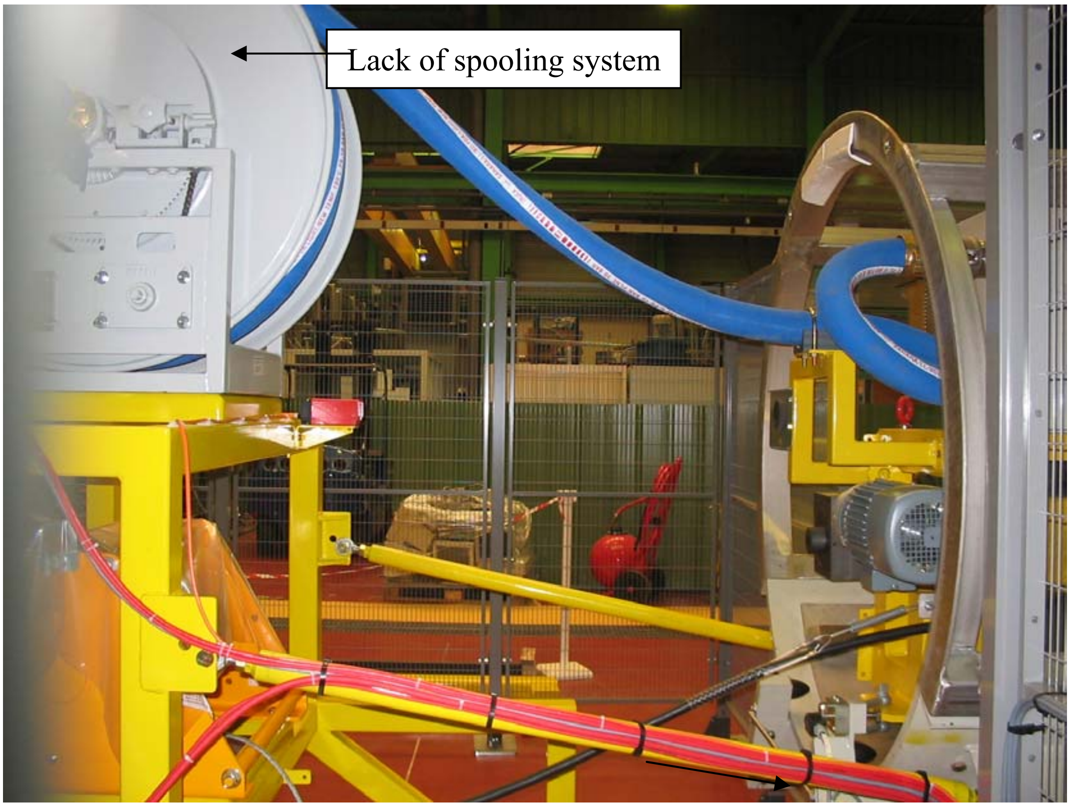

Figure 26 - Air hose winch showing a poor winding on the drum

- A more powerful electrical motor would compensate for the friction force (drag) exerted by the hose,
- The very heavy weight of the canister induced some inertia efforts, which were a strain on the electrical pushing jack frame, which used to emit some “cracking noise”. A stiffer frame would reduce the stresses and the bending effect on the jack (see **Figure 27**),

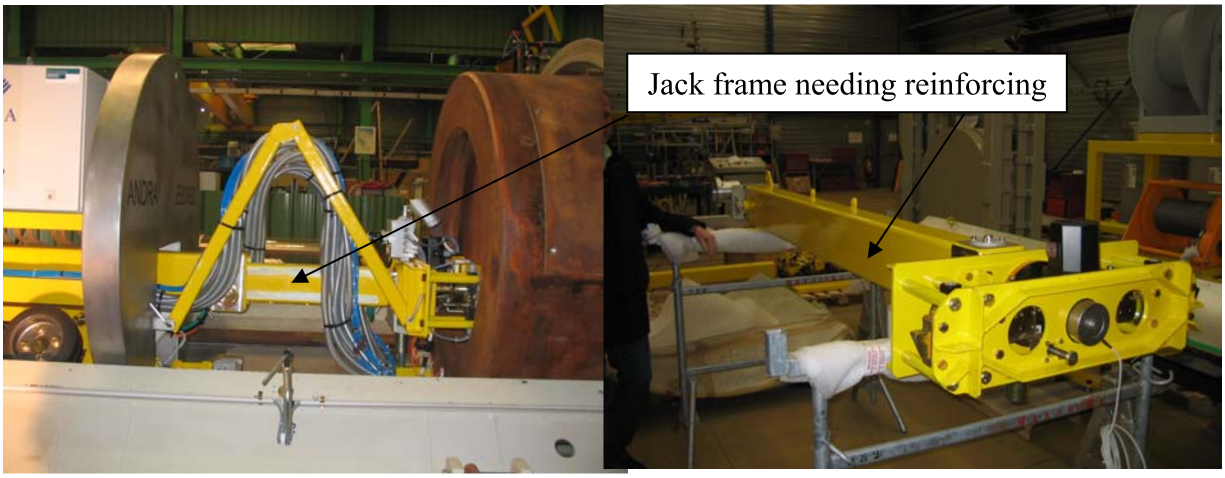

Figure 27 - Electrical pushing jack retracted (left) and (right) extended

- Finally a sliding plate made of composite material (carbon fibre or similar) instead of stainless steel would also reduce the friction at contact with the stainless steel sleeve invert.

3 - REFERENCES

3.1 ESDRED Project References

Reference Number	Reference Title	Dissemination Level
[1]	ESDRED, Deliverable Module 3 WP1 D1 - "Input Data and Functional Requirements"	PU
[2]	ESDRED, Deliverable Module 3 WP2 D2 - "Report on Prototype Test for Spent Fuel Canister CU1"	CO
[3]	ESDRED, Deliverable Module 3 WP3 D3 - "Detailed Design and Manufacturing of Equipment"	CO
[4]	ESDRED, Deliverable Module 3 WP3 D4 - "Commissioning Report"	CO

3.2 KBS-3H References for SKB

Reference Number	Reference Title	Dissemination Level
[5]	SKB Doc. Id 1049587 "Test Plan of KBS-3H Deposition Equipment"	CO
[6]	ED_79J007-GB, "Final Procedure of the Site Acceptance Test"	CO
[7]	ED_79J007-GB, "Report of the Final Procedure of the Site Acceptance Test"	CO
[8]	ED_ZZV002A, "Operation Manual"	CO

3.3 Bentonite Rings References for Andra

Reference Number	Reference Title	Dissemination Level
[9]	E NM 0MEA 05 001 "Methodical Catalogue"	CO
[10]	E NF 0MEA 05 9002 "Operating Mode"	CO
[11]	E NT 0MEA 05 2201 "User's Manual"	CO
[12]	E DPQ 0MEA 05 0902 "Test Programme"	CO
[13]	E CRE 0MEA 05 0904 "Test Report"	CO

3.4 CU1 (Spent Fuel) Canister References for Andra

Reference Number	Reference Title	Dissemination Level
[9]	E NM 0MEA 05 001 “Methodical Catalogue”	CO
[14]	E NF 0MEA 05 9001 “Operating Mode”	CO
[15]	E NT 0MEA 05 1302 “User’s Manual”	CO
[16]	E DPQ 0MEA 05 0901 “Test Programme”	CO
[17]	E CRE 0MEA 05 903 “Test Report”	CO