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Buffer protection for the installation phase

Design and testing

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Abstract

This report describes conducted work for development and testing of the buffer protection. This includes the design of a prototype for a buffer protection equipment to be used in a repository deposition hole. The buffer protection system will seal off rock seepage water, high relative humidity and prevent the buffer clay from swelling prior to the deposition tunnel backfilling.

The general conclusions from the performed development and testing are that the buffer protection worked as anticipated. The main remaining work is to develop the buffer protection system to an industrialised version that can be retrieved automatically.

Sammanfattning

Denna rapport redogör för arbetet med design och utveckling av buffertskyddskomponenter som ingår i KBS-3-konceptet. Funktionen hos dessa komponenter är att de under installationsfasen ska skydda bufferten mot den naturligt fuktiga miljön i berget och därigenom hindra bufferten från att börja svälla innan återfyllningen installerats ovanför deponeringshålen.

Arbetet har inkluderat vidareutveckling av den befintliga designen av främst bottenplattan och buffertskyddsduken, framtagning av prototyper samt testning av dessa prototyper. Resultatet från testerna visar att den framtagna lösningen uppfyller ställda krav.

Återstående arbete är att utveckla en modifierad version av buffertskyddet som kan installeras och tas bort automatiskt.

Contents

1 Introduction

1.1 Background

According to the current repository reference design (SKB 2010) a protection for the buffer is required for the installed buffer in the deposition hole until time for backfill installation. The buffer protection considered a simple and robust answer to seepage problems that might be present in the deposition holes of the final repository. The protection should prevent the buffer clay from absorbing water from seepage from the time of buffer installation to backfilling of the deposition tunnel above a deposition hole. This phase of the deposition works could (in the current reference design) last 3 months with risk of clay swelling and softening that at worst could lead to a forced reinstallation of the buffer with following time delay (Wimelius and Pusch 2008).

1.2 Designing and manufacturing the prototype

The aim of the design have been to produce a lightweight protection sheet that will be easy to handle and make a water tight seal enclosing the buffer from below and from the sides of the deposition hole. The protection sheet will at the top be closed with a metal lid installed inside the sheet.

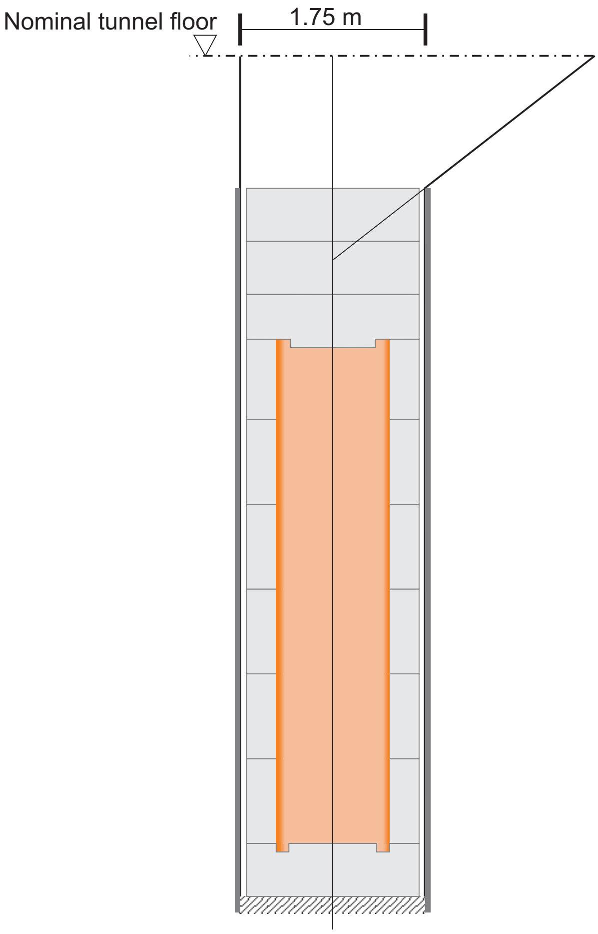

Figure 1-1. *The deposition hole dimensions in the reference design considered for this report.*

1.3 Test summary

The finished prototype has been tested at the Äspö Bentonite laboratory in a geometric mock-up of a deposition hole.

The objective and scope of the test was to evaluate the prototypes ability to keep the inside of the protection dry. In addition to this a water evacuation system was assembled and run for 18 days together with a separate simulated rock inflow with a prescribed inflow.

An extra 14 days test was made after the main test.

The result of the testing was that the buffer protection kept the buffer dry and the evacuations system was run without disruption for the test period of 14 days.

The test was carried out in the following main sequences:

- Preliminary test for water tightness of the bottom plate seal.
- Ultimate limit state testing of water tightness of bottom plate seal and lower part of the protection sheet with relative high water pressure.
- Test of water evacuation system with simulated rock water inflow.

An electric pump was used instead of the proposed ejector pump.

During the testing a number of sensors were collecting data at specific time intervals in addition to a number of manual observations. The data together with the documentation of the observations will support or reject the expected result.

2 Objective and scope

2.1 General

The reported work involves design and production of buffer protection components and testing of main design scope. The protection consists of three main components: bottom plate, protective sheet and top lid. These three components are a heritage from SKB Prototype Repository at Äspö Hard Rock Laboratory (HRL) (Börgesson et al. 2002) and the following first prototype project for buffer protection during the installation phase (Wimelius and Pusch 2008) where a rubber tube was used as protection sheet.

2.2 The new prototype

The main purpose for the new prototype described in this report was to further enhance the design of the previous protection system and get a lighter and more robust design.

The primary objectives for the design work were:

1. Design and manufacture a prototype for a buffer protection system that will protect the buffer clay from water outside the protection. This prototype shall be an developed version of SKB:s previous buffer protection prototype (Wimelius and Pusch 2008).
2. Design and manufacture a water evacuation system for rock drainage that collets in the space between the buffer protection and deposition hole wall.

The buffer protection sheet was preferably to be manufactured in a way that a rupture in the weave would generate a vertical rip rather than a horizontal one and thus be less likely to leave material behind in the deposition hole. In this project there have not been any studies carried out to estimate the minimum strength required for the sheet in any direction.

3 Equipment

In this section the equipment used to protect the buffer, remove water, adding water and measuring possible leakage is described.

3.1 Equipment designed in this project

3.1.1 Prototype components

The buffer protection prototype components have been design by SKB:s contractor in collaboration with SKB. The general descriptions of the components are shown in Figure 3-1 and Table 3-1.

Table 3-1. General description of prototype components.

Component	Purpose	General description
Bottom plate	Protect the buffer from water on the deposition hole bottom and connect to the sheet tube.	Flat, circular acid-proof steel plate with a groove at the circumference for attaching seal of protection sheet
Sheet tube	Protect the buffer from standing water at base of deposition hole and potential wetting from dripping water from the sides.	Tube shaped sheet with rubber seal at bottom and lifting loop at the top. The sheet is a two component fabric coated with Polyvinyl chloride, (PVC).
Top lid	Protect the buffer from dripping water and substantially reduce the air exchange from inside the buffer protection and the deposition hole and deposition tunnel.	Circular, hollow, steel box with cable conduits and cable fittings.

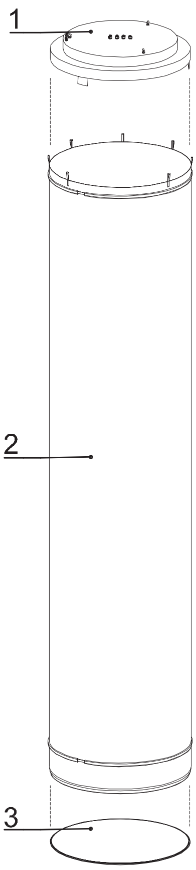

Figure 3-1. Schematic description of the three main components of the buffer protection prototype. 1) Top lid, 2) Sheet tube, 3) Bottom plate.

The Top lid

The prototype top lid is manufactured by 2 mm tick acid proof steel sheet metal, Figure 3-2. At the positions of the lift rings and cable fittings the sheet metal is strengthened with a ticker metal plate on the opposite side of the sheet metal. This top lid prototype is a test version i.e. it is designed with features only to be used in the test. The cable fittings and conduits are not intended to be used in the final version of the lid.

The Tube

The tube was designed to wrap the buffer blocks and connect to the bottom plate with a rubber seal (Figure 3-3). The components that constitute the tube are:

- Lifting loops.
- Top and bottom pockets with expansion rings.
- Protective sheet.
- Seal and O-ring.

These components are further described in following sections.

Protective sheet

The tube protective sheet is a woven material with a PVC coating. The woven material is carrying strength properties and the coating makes the fabric watertight. The weave or fabric is made out of two separate threads were the threads along the protection sheet tube is of higher strength. The difference in strength comes from the objective that a possible rip in the sheet is more likely to become vertical than horizontal. The sheet material was weaved and coated with PVC coating and later delivered on a roll with width 2 m. Then the sheet was cut to correct length and width and welded to a large sheet with height about 8 m and with in accordance to the finished diameter. On that sheet the bottom seal and pockets for stabilisation rings were glued. After this the sheet was welded to form a tube. This was carried out with welding of the PVC and gluing the seal. One of the most complex parts was to get a geometrically correct end cut on both sides of the seal. This was crucial for water tight fitting in the bottom plate groove.

The fabric was delivered by F.O.V. Fabrics AB in the town of Borås, Sweden. A technical specification for the used threads and finished fabric is given in Table 3-2.

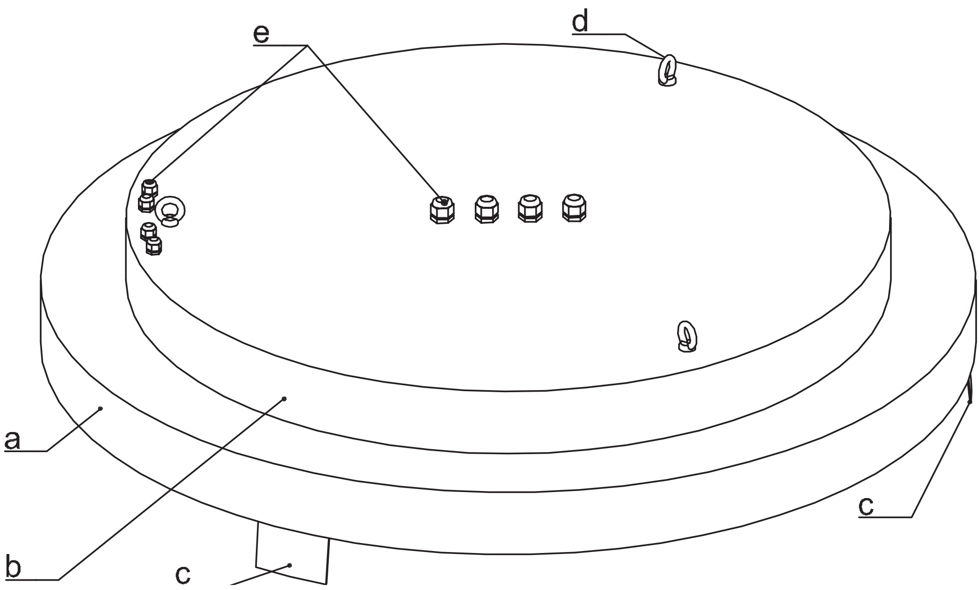

Figure 3-2. *Top lid: a) Lower side plate. b) Upper side plate. c) Steering plates (3 total) d) Lift ring. e) Cable fittings.*

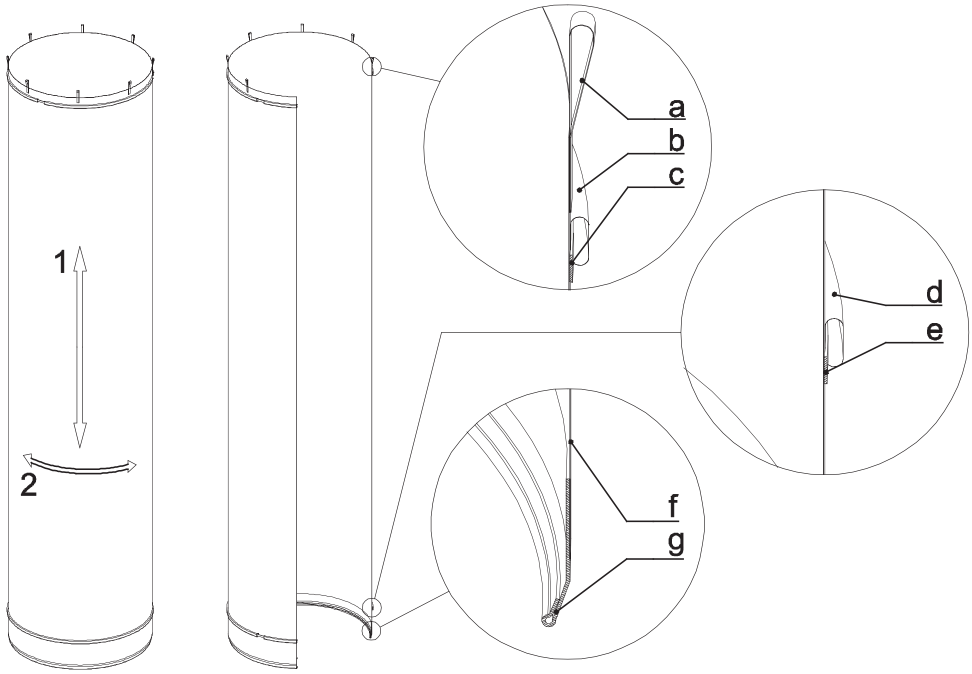

Figure 3-3. Tube. 1) Warp threads direction. 2) Weft threads direction. a) Lift loop. b) Upper expansion ring. c) Pocket for expansion ring by folded sheet. d) Pocket for expansion ring by glued on sheet. e) Lower expansion ring. f) Seal. g) Bottom fold of seal that will fit in bottom plate groove and be expanded with an o-ring.

Table 3-2. A selection of technical specifications for the sheet and sheet fabric components.

Material	Product name	Tensile strength	Direction in weave (Figure 3-3)	Weight	Purpose
PA 6.6	Vectran	≥ 8.5 kN / (5 cm)	Warp (1)		For strength
Aramid	Twaron	≥ 2.0 kN / (5 cm)	Weft (2)		For strength (but less than the tensile strength of the warp)
PVC	–	–			For water proofing
Sheet total				750 g/m²	

Lifting loops

The lifting loops were made of standard nylon weave (not the tube sheet material) with PCV coating. The lifting loops were glued and sewn to the protective sheet. There was no quantitative requirement for the loop tensile strength rather a qualitative requirement that one loop will be able to lift the tube sheet out of the bottom plate groove at disassembly and that the eight loops together can hold the tube itself. These requirements were judged to be satisfied with a comfortable margin.

Seal

The protection sheet is at the bottom end attached to a rubber seal. This rubber seal is glued to the bottom end of the fabric to make the connection water proof and strong enough to be able to release the seal from the bottom plate by pulling in the sheet top. The seal is a rubber profile delivered from a Swedish manufacturer (Trelleborg).

The seal was composed of an EPDM rubber profile with an angle and an end fold. The material properties of the seal are seen in Table 3-3. The seal was attached to the sheet with an “of the shelf” glue: polyurethane polymer glue (product name: Casco Liquisol) (Figure 3-4).

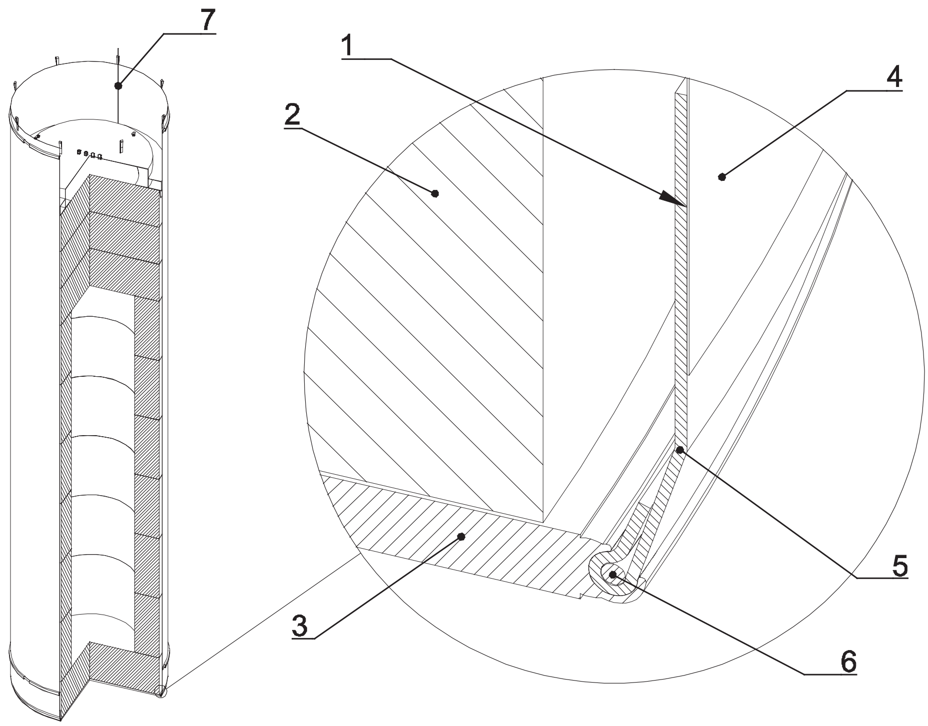

Figure 3-4. View of lower part of sheet where a rubber seal is glued to the sheet: 1) Polyurethane polymer glue. 2) Buffer block. 3) Bottom plate.4) Protective sheet. 5) Rubber Seal. 6) Rubber O-ring. 7) O-ring extension.

Table 3-3. Seal technical properties.

Material	Product name	Tensile strength	Hardness Shore	Density	Purpose
EPDM	–	–	60 Shore A		Waterproof connection of bottom plate and protective sheet.

O-ring

The o-ring is intended to expand the fold in the seal that is mounted in the bottom plate groove. The o-ring is not actually a ring rather than a rubber thread. This thread is placed in the groove to form a complete circle and then the loose end of the o-ring will hang from the top of the deposition hole. This is to be able to pull out the o-ring to easy the extraction of the seal and sheet. The o-ring is an EPDM rubber profile delivered from the Swedish manufacturer Trelleborg. The total practical minimal length of the used o-ring needed to be about 15 m (Figure 3-5).

3.1.2 Water evacuation system

The water evacuation system was supposed to be a pneumatic air driven ejector pump.

The prototype used did not have high enough capacity to pump up the water from the deposition hole in a reasonable time.

It was then decided to use an electric commercially available pump. It is controlled by the pressure gauge (water level gauge) and software (Figure 3-6).

Specification of the components compiling the water evacuation system is given in Table 3-4.

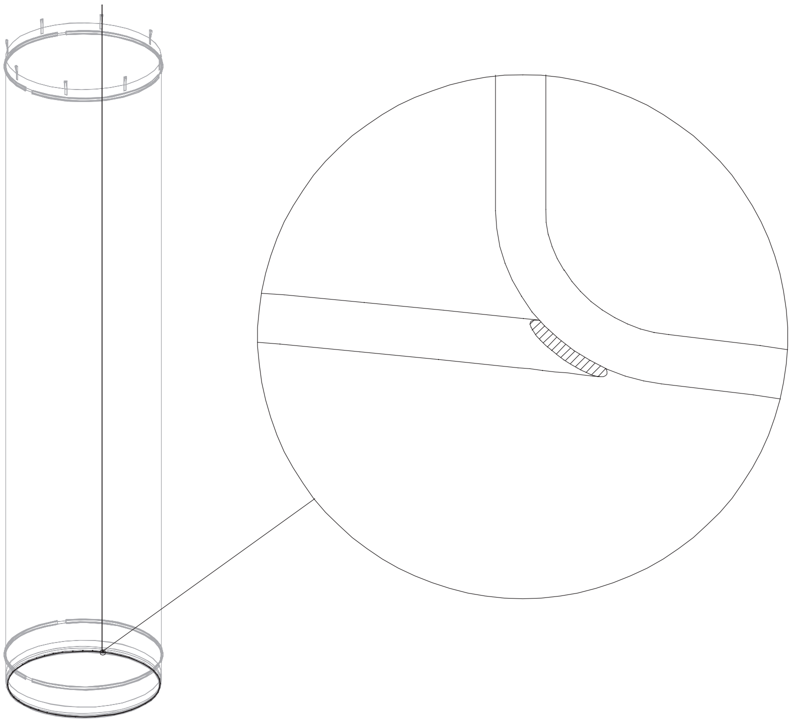

Figure 3-5. Sketch of the mounted O-ring. The o-ring makes a complete loop in the seal before extending up to the deposition hole top at "floor" level.

Figure 3-6. Water evacuation equipment.

Table 3-4. Equipment used for water evacuation.

Component	Product name	Specification	Porpose
Pump	Bredel SP/15		
Discharge hose	–	Outer diameter 20 mm	Leading water from the Pump up to the test facility floor and on into a drainage trench close to the hole.

3.2 Equipment for monitoring

3.2.1 Sensors used in the deposition hole

The sensors used in the experiment are listed in Table 3-5.

The sensors where connected to a National Fieldpoint DAQ and Labview software running on a desktop computer via cables. During the first phases of the tests the cables of the used sensors where hanging free from the hole top.

RH gauge

Used product

Used product for monitoring of relative humidity in the test is a Kimo TH300.

The device measures RH with a precision of ±1.5% according to the manual at 15–25°C. The devices are used with their factory calibration. The RH range in our test was expected to stretch from normal or low with no water leakage to close to 100% if there was leakage. Therefore the necessity of a dedicated calibration for these test were judged not to be justified.

Purpose of measurement

The RH-meters was supposed to detect small amounts of water passing the buffer protection. The scope was to be able to have a fine instrument for water detection than the water indicators (read the separate section about the water indicators below).

The use of the RH-gauges was a "test in test". The assumption made during the planning phase of the test, was that the RH-gauges would detect leaking water better than water indicators. A prerequisite for this monitoring to have a chance of success was to provide the test with dry and room tempered equipment especially the buffer dummies.

Pressure gauge

Used product

Used product for monitoring of water pressure in the test is a Druck PTX1830.

The used pressure sensors were checked manually in the beginning of the tests with a dip meter. The specifications of the pressure sensor is ±0.1% in the range 0 kPa–500 kPa (0 mH^20–5 mH^2O).

Table 3-5. List of sensors for continuous monitoring of water leakage during test.

Sensors	Count	Measure	Measure frequency	Unit
RH-gauge	2	Relative humidity within the buffer protection.	15 s	% / °C
Pressure gauge	1	Water pressure close to deposition hole bottom.	15 s	Cm (Pa)
Water indicator	2	Free water on the bottom plate surface inside the buffer protection.	15 s	On / Off (water present or not)
Temperature gauge	2	Measure temperature of bottom plate.		°C

Purpose of measurement

This sensor measures the water pressure and the data will be interpreted to a water depth. This was used to:

- Provide input to the control system for the water evacuation system. The sensor detects when the pressure generated by the water collecting outside the protection sheet exceeds one of two limits. If the interpreted water level was lower than the low limit the evacuation system was set to standby mode. If the interpreted water level was higher than the high limit the evacuation system was activated.
- Monitor the water level outside the buffer protection sheet during the test.

Water indicators

Used product

Used product for monitoring the presence of free water is Schabus SHT 5001.

Detects if water occurs between 2 sensorpins.

Purpose of measurement

This sensor was used to indicate leakage by detecting the presence of free water on the bottom plate. If the sensor was to detect free water the water depth on the bottom plate is estimated to be a few millimetres.

3.3 Simulating water inflow from rock

For testing of the water evacuation system an inflow of water was established. A prescribed flow rate was lead via a hose down between the deposition hole wall and protection sheet: Prescribed inflow flow rate: 30 Litres/h.

The equipment used for simulating the water inflow is listed in Table 3-6.

Flow rate control and checking

The inflow was controlled after the installation of the hose for water supply to the deposition hole. The control was carried out with a beaker. With this used equipment the flow rate was estimated to be within the following tolerances: Estimated flow rate check tolerance: ±0.1 Litres/minute.

Table 3-6 Equipment used for simulating the water inflow.

Component	Product name	Specification	Porpose
Metering pump	Grundfos Alldos DME 60	0–60 L/h	Provides an accurate prescribed flow rate to the deposition hole.
Supply hose		Outer diameter 20 mm	Ensured adequate water supply to the metering pump. The hose was connected to a tank.
Delivery hose	Tecalan	8 mm	Delivered the water from the metering pump to the deposition hole.

3.4 Other equipment

In this section some of the other equipment of relevance is described. In addition to the sub sections in this section there were a lot of additional equipment such as common hand tools and so on which is of minor importance to ensure an adequate description of the test gear.

3.4.1 Wheel-tool

A simple special tool was crafted to be able to install the protection sheet, Figure 3-7. This tool was a simple wheel attached to a short handle called "Wheel-tool". The intended use for the tool was to roll the seal bottom fold into the groove in the bottom plate. When the seal is properly fitted in the groove the o-ring is rolled down in the seal fold in the same manner to expand the seal fold in the bottom plate groove. To lower the friction between the o-ring rubber and seal rubber in the latter step some lubricant is applied inside the seal fold.

3.4.2 Lubricant for o-ring installation

The rubber seal is relatively easy to push into the bottom plate groove with the wheel-tool. But the o-ring installation created more resistance and to lower friction a lubricant is used. The specific lubricant used in the test was a spray on petroleum based gel (corresponding to e.g. Vaseline).

3.4.3 Bentonite buffer dummy blocks

To be able to fulfil the project aim of showing that bentonite buffer blocks can be installed in this version of the prototype buffer protection system the Äspö concrete buffer block were used. These were named "dummy blocks". These blocks have the same dimensions and approximately the same weight as the proposed reference blocks.

In the testing these blocks also serve as ballast and support for the protections sheet. This was necessary to keep the protection system from floating and the protection sheet from collapsing due to the outside water pressure.

3.4.4 The deposition hole

As the test is carried out at the bentonite laboratory at Äspö the deposition hole is an geometric copy of the repository nominal reference design deposition hole with the following exeptions:

- There is no bevel at the top of the hole in the laboratory.
- The wall material of the laboratory deposition hole version is stainless steel.
- The depth of the laboratory hole is some 10 cm deeper that the reference design. This does not have any influence on the performed test.
- The available height to ceiling above the hole is higher than in the deposition tunnel which makes the installation easier in the bentonite laboratory.

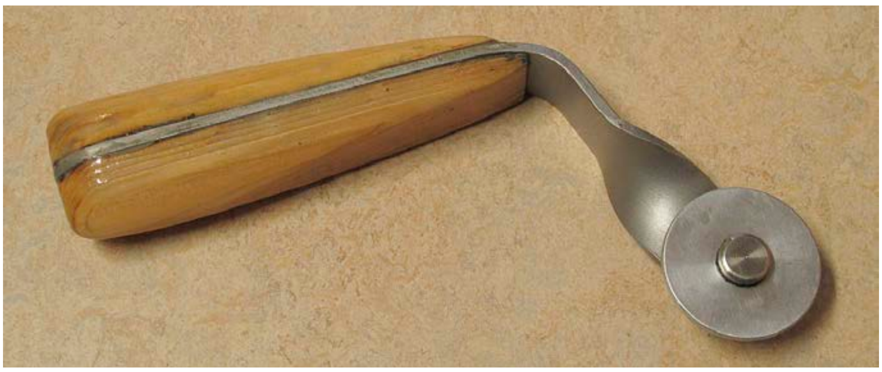

Figure 3-7. Wheel-tool for seal and o-ring installation into bottom plate.

4 Execution

Prior to the test execution the work with design and manufacturing of buffer protection system components was finished.

4.1 General

The test executes was executed in the following steps:

1. Installation test.
2. Preliminary test of water tightness.
3. Ultimate limit test of water tightness.
4. Serviceability test with water evacuation system, repeated with small changes to avoid condensation.
5. Disassembly test.
6. Additional test.

The installationtest was performed basically to show that the protection system prototype can be installed in a hole with deposition hole dimensions and the inner diameter was adequate for installing dummies of buffer blocks and buffer rings.

The preliminary test involved testing of water tightness of the lower part of buffer protection with the purpose to catch possible leakage by incorrect fitting or fractures in the materials of the bottom plate, rubber seal or adhesive joints. This test was carried out with only one buffer block installed inside the protection sheet.

The final test showed if the prototype was water proof for a specific maximum water depth outside the protection sheet. The most critical components were assessed to be the rubber seal with the o-ring and the adhesive joint closing the rubber seal to a ring.

Following the ultimate limit state test was the Serviceability test with the water evacuation system. This test uses pressure sensor to monitor the water level in the hole and software (Labview) to control the water pump. This test is carried out to show that the assembled water evacuation system can be operated without maintenance for a few days.

The additional test was carried out because there was some moisture on the deposition hole floor under the dummies after the Serviceability test. The bottom of the hole was dried and the dummy was positioned on steel distances to prevent condensation problems. The test procedure was the same as the Serviceability test (except without lid), and the duration was about two weeks.

4.2 Preparations

The main preparations for the test were:

- Setting up a system for water inflow.
- Setting up system for water evacuation.
- Make sure buffer dummy blocks were dry.

The general preparations were made such as ensure enough space in the test hall (Bentonite laboratory at Äspö) for easy handling of the buffer protection components, buffer blocks and other equipment.

The equipment for simulation of water inflow to the deposition hole were installed and tested the days before the test execution. Also the equipment for the water evacuation were acquired, installed and tested.

The used RH-gauges were supposed to measure sudden increase in RH if water leaks through the protection system. This was in advance judged to acquire dry and room tempered buffer dummy blocks. To get as dry blocks as possible without setting up separate drying system the blocks were stored indoors in the bentonite laboratory for some time prior to the test.

4.3 Execution of test

The tests were conducted in the bentonite laboratory at SKB:s facility at Äspö. The bentonite laboratory is a workshop with a laboratory version of a deposition hole in full scale and a over head crane and many other features.

4.3.1 Installation test

Assembly of buffer protection bottom plate and sheet

The first step of the test was to install the bottom plate and protective sheet (Figure 4-1). This was carried out using the overhead crane. The sheet and plate were assembled with the Wheel-tool and the inside of the seal fold of the sheet were lubricated prior to the assembly. The assembled bottom plate and sheet were placed on a pallet on the hall floor in vicinity of the deposition hole.

Lowering plate and sheet into deposition hole

The assembled plate and sheet were lowered into the deposition hole as one unit (Figure 4-2).

Figure 4-1. *Photo of the assembled bottom plate and buffer protection sheet in the bentonite laboratory at Äspö.*

Figure 4-2. Photo taken when the assembled bottom plate and buffer protection sheet were lowered into the deposition hole in the bentonite laboratory at Äspö.

4.3.2 Preliminary test of water tightness

To ensure that the bottom plate with the attached sheet did not float during the first test and to support the seal and lower most part of the protection sheet one buffer block was installed on top of the bottom plate. The test set up is presented in Figure 4-3. Initially a level of 50 cm was filled up. After an hour there was no sign of leakage.

4.3.3 Ultimate limit test of water tightness

Another buffer block was installed and the water level was increased to 2 meters, see Figure 4-4. The test was run overnight. In the morning there were no indications from the water indicator.

An attempt to pump the water with a simple injector pump was done with a bad result, only 1.5–1.9 L/min was achieved. Two Bredel pumps were used instead. It took about 2 hours to empty the hole. Inspection with a small inspection camera showed no water on the bottom plate but some drops. In the connection between plate and rubber, this could be a result from the small violence used to force down the camera. A short serviceability test was made during a weekend.

The water level was varied between 30 and 100 cm. Leakage was indicated after about 36 hours.

Total leakage during the weekend (65–70 hours) was about 2 litres.

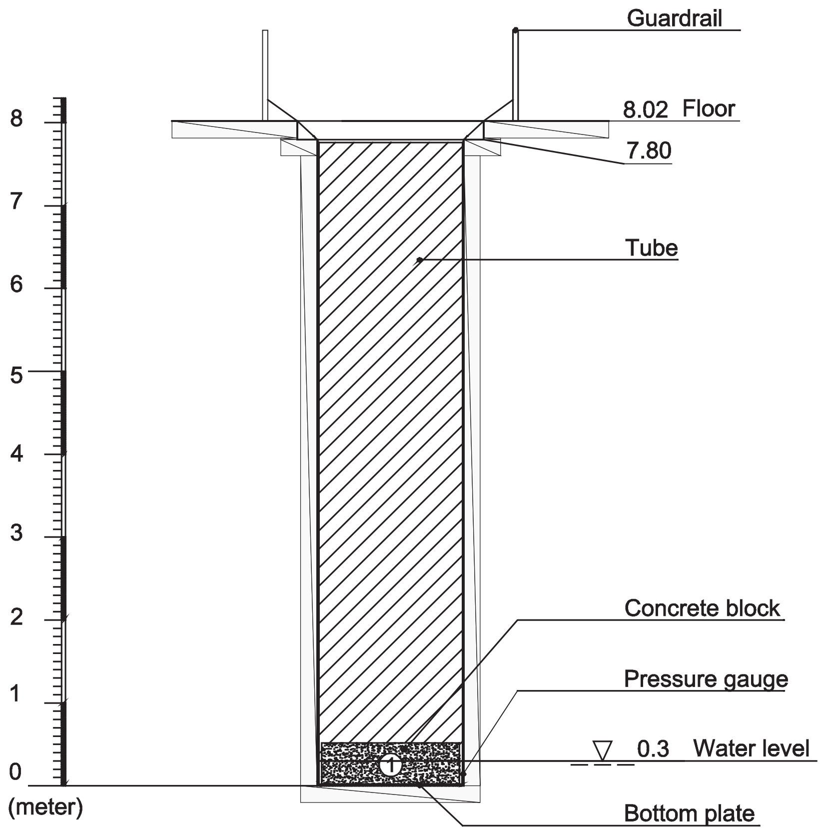

Figure 4-3. Figure showing the schematic setup of the preliminary test of water tightness of the lower part of the buffer protection system prototype.

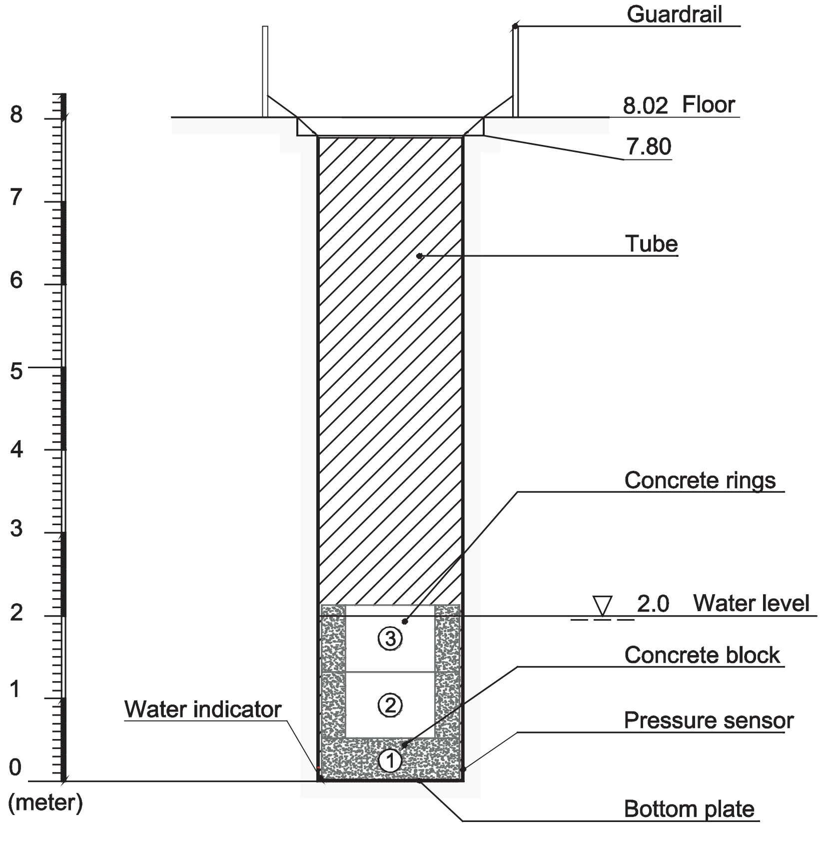

Figure 4-4. Figure showing the schematic setup of the ultimate limit test of water tightness of the lower part of the buffer protection system prototype.

4.3.4 Serviceability test with water evacuation system

After that the leakage had been identified and resolved this test was run for 18 days.

The water level was varied between 0.3 and 1 meter and everything worked properly and no leakage was indicated. However water had condensated on the cold bottom plate. The test set up is shown in Figure 4-5.

4.3.5 Serviceability test 2 with water evacuation system

One more test were actions to avoid condensation on the bottom plate were performed to further strengthen the verification of water tightness. The differences from Test 1 were:

- Only one concrete block.
- Distances under the block to decrease possibility for condensation.
- Extra temperature sensor measuring bottom plate temperature.

The test set up is presented in Figure 4-6.

4.3.6 Disassembly test

The testing of the disassembly of the buffer protection prototype system was carried out after a few days of running the water inflow and water evacuation system. The opening of the closed protection sheet and removal of the top lid was carried out without any significant problems. The critical part of this test was predicted to be the disassembly of the o-ring and later lifting of the sheet and thereby remove the seal from the bottom plate groove. The removal of the O-ring worked well and it was removed by hand with a small force, see Figure 4-7. The removal of the buffer was made with the over head crane without any difficulty, see Figure 4-8.

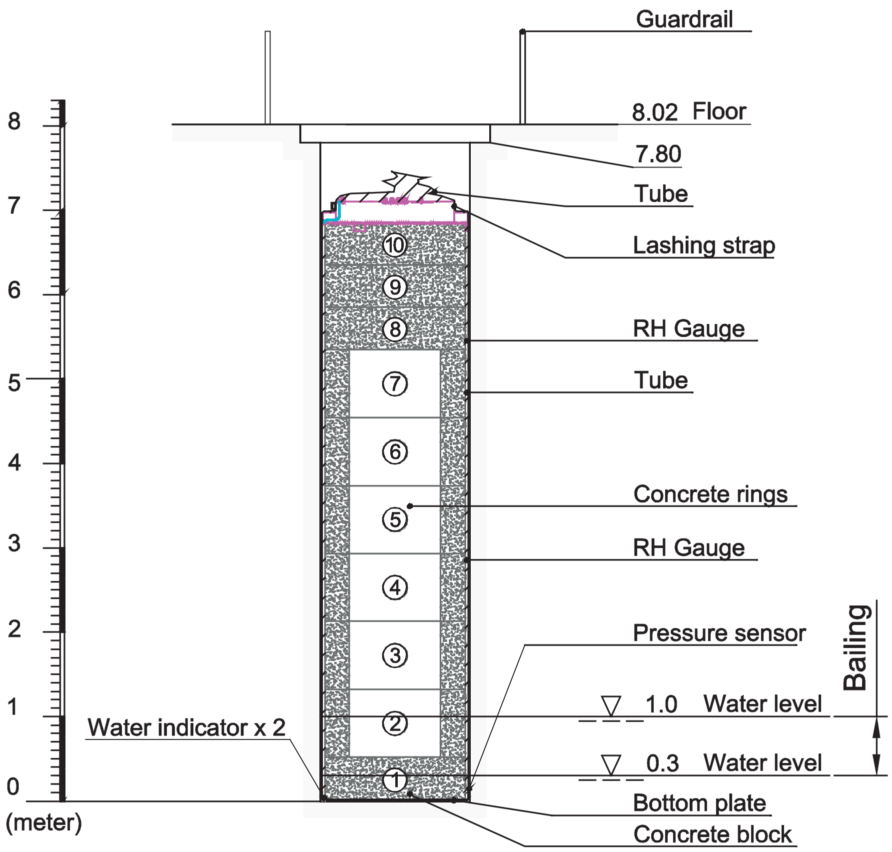

__Figure 4-5.__ Service limit state test setup 1. Figure showing the schematic setup of the serviceability test of with water evacuation system.

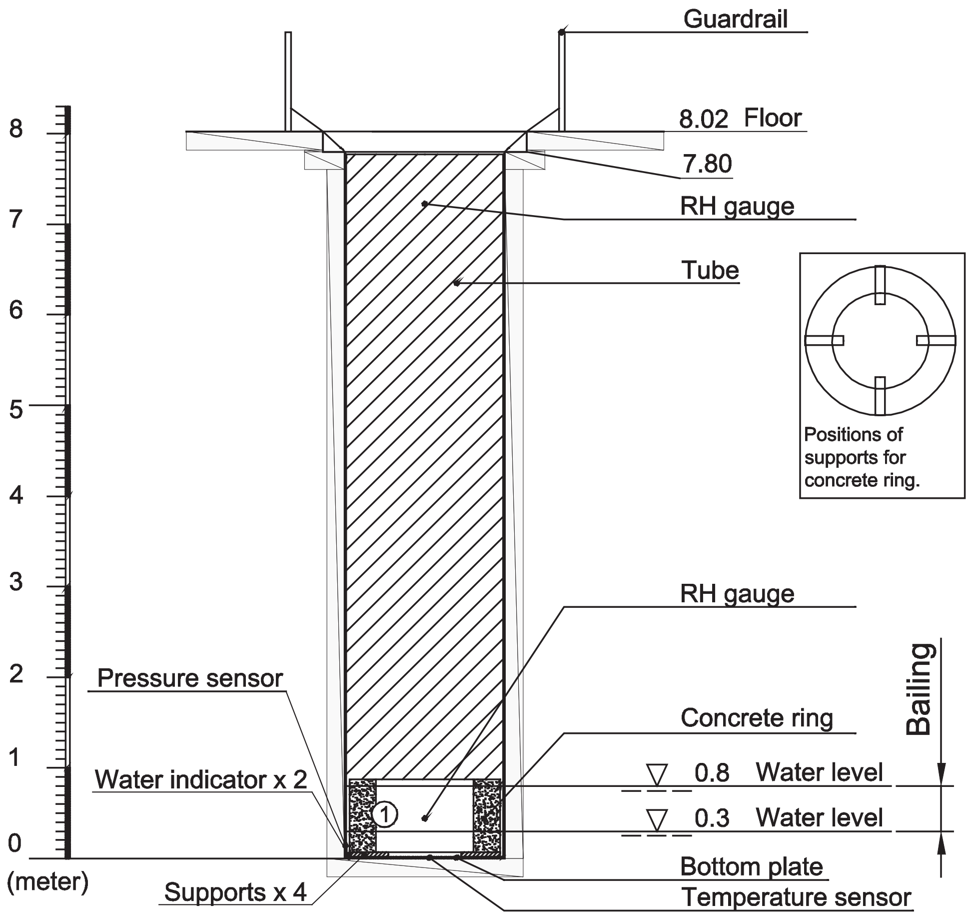

Figure 4-6. Service limit state test setup 2. Figure showing the schematic setup of the serviceability test of with water evacuation system.

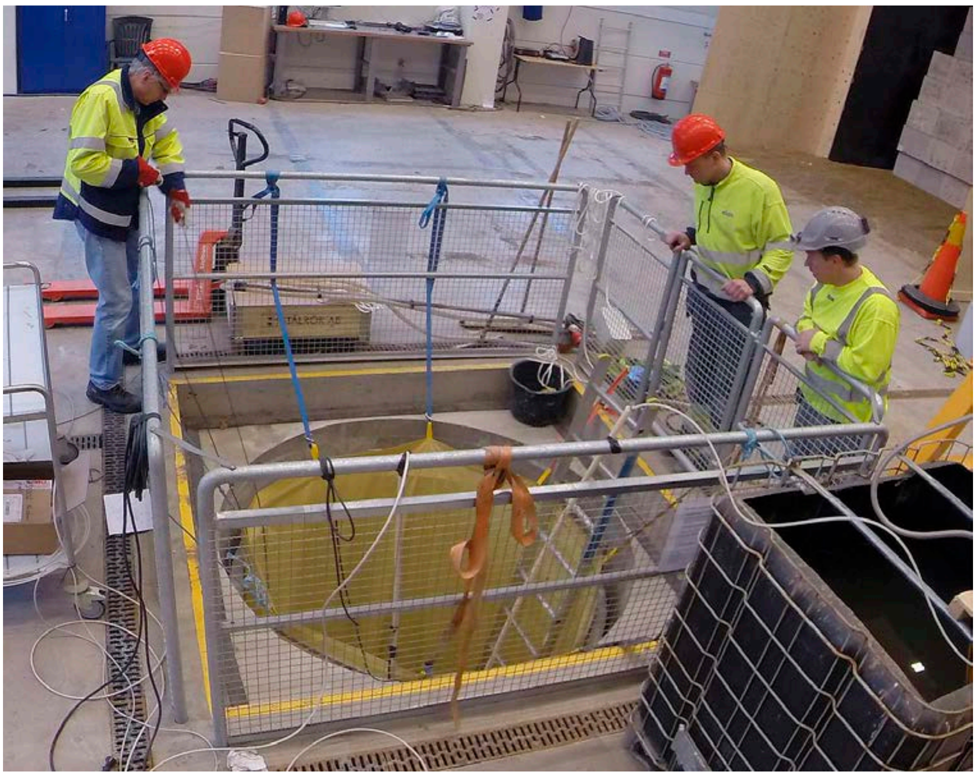

Figure 4-7. Photo taken when removing the o-ring .

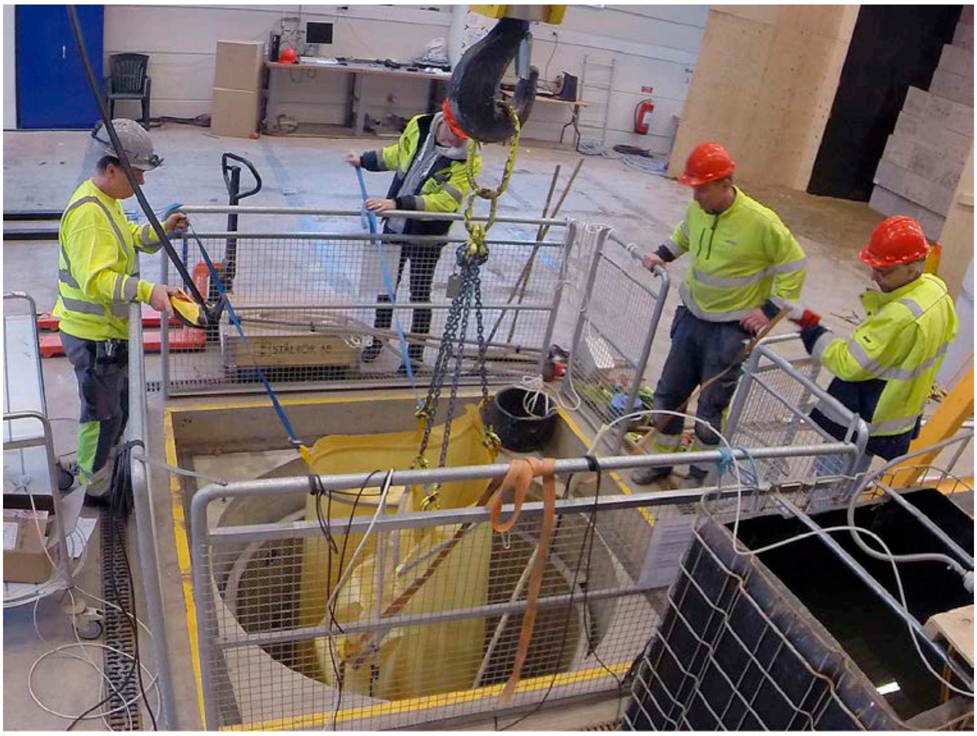

Figure 4-8. *Photo taken when removing the sheet.*

5 Results

The test results comprise interpretation of the data from sensors and observations during the tests. The results provided answers to/answered the following questions:

1. Installation: Was the installation of prototype of the buffer protection system successful?
2. Water tightness: Did the prototype for the buffer protection system preventing free water to reach the buffer dummies?
3. Water evacuation system: Was the water evacuation system considered compatible with the buffer protection system and did it operate as prescribed?
4. Disassembly: Was the disassembly of the top lid, o-ring and protective sheet successful?

The answers to these questions are shown and evaluated in the following text. A discussion of the results and other subjects are presented in Chapter 6.

The installation was successful. The protection sheet was considered light weight and easy to handle. Installation of bottom plate with attached protective sheet, buffer dummies and top lid was successful. Installation of bentonite blocks with the buffer installation equipment is considered similar to the installation of dummy blocks and no extra complications considering the installation of actual buffer blocks are anticipated.

The buffer protection system was water tight and no leakage could be detected once the small manufacturing mistake was corrected.

The sensors and water indicators worked as expected. The ejector pump did not work as expected and an electric pump was used instead. Measure the level with pressure gauge worked fine and software (Labview) had full control over the level.

The disassembly was successful, everything worked as expected.

6 Discussion

6.1 General

The developed buffer protection system described in this report is mainly applicable to use as an example of a robust water proof partly recoverable protection. The unique feature of this protection system is the mechanical sealing solution at the bottom plate. This eliminates the need for a system of compressed air and is considered more robust than an inflatable seal.

A wide range of possible suppliers have been involved during the project until the right contractor was found. This illustrates the general difficulties in performing prototype development and manufacturing with a little or distant future revenue for the contractor due to the far away deployment of the geological repository for spent nuclear fuel.

6.2 About the results

Even though the tests were successful it is of importance to understand that the conditions in a deposition tunnel at repository depth are quite different. The installation and disassembly procedures as well as other used equipment such as overhead crane will probably differ to the extent where they will have impact on the buffer protection system prototype design. Important differences between the installation in the bentonite laboratory and the conditions in the deposition tunnel include:

- Lower available height for installing and retrieving the buffer protection.
- Underground conditions.
- Manual/ automated procedures.
- Requirement on time for operations.

These different prerequisites set a number of requirements on the protection that will have an influence on the design of a buffer protection system.

6.3 Water evacuation system

The climate in the repository will raise the bar for climate protection of the electrical components in particular. For the ejector itself it will probably be able to handle dust and debris from the work performed in the tunnels.

The identified main weaknesses of the used water evacuation system:

- The used electrical components were not suitable for damp or corrosive environments.
- The used ejector equipment may not be able to handle dirty water contaminated by dust and debris from work executed in the repository tunnels.
- The injector pump requires compressed air which will then have to be available in the deposition tunnel.
- The prototype ejector was not performing with high enough capacity and therefore had electrical pumps were used.

6.4 The protective sheet

The developed protective sheet is relatively light weight and easy to handle compared to the previous prototype (Wimelius and Pusch 2008). One may still be concerned over handling agility in a future deposition tunnel in the repository where the space is limited in both vertical and horizontal direction. The current design for the buffer protection system may be considered rather labour intensive and needs to be improved for the production buffer installation in the repository.

In the development of the buffer protection the aim was to achieve a sheet that would rupture in vertical direction if it were to be clamped by rock fall out. This has been accomplished by differentiating the tread strings in the warp and weft. On the other hand there are no test proving this to have an impact of the amount of material left in a deposition hole if the sheet is clamped.

The identified main weaknesses of the protective sheet:

- Manual and relatively labour intensive installation.
- Manual disassembly.

6.5 The top lid

The prototype for the used top lid was designed to enable sensor cables to get trough. This feature was not used in the test. A possible final version of the top lid to be used in the repository will probably not have this feature.

The initial design for the seal around the top lid was an inflatable rubber ring integrated in the protective sheet. This would stretch the sheet and expand towards the center of the deposition hole and press against the top lid side wall and probably make/create a tight seal. In the manufactured prototype for the protective sheet all inflatable components were removed in favour for a mechanical seal.

6.6 The tube sheet

A preliminary test was carried out on a small square of the sheet and the short term water pressure it withstood both for the plan sheet and the welded joints were in the vicinity of 30 Bar (equivalent of about 300 mH_2O). This is above/exceeds the specified requirements of withstanding 2 m of water pressure.

7 Future R&D

7.1 General

This test was carried out in a laboratory environment. In the next development step the buffer protection equipment should be adapted to the environment in the repository.

The prototype for the buffer protection system is not adopted to be used with automated or remote controlled machines. This may become an issue in the installation and dismantling of the buffer protection system.

7.2 Water evacuation system

The used equipment for the water evacuation system may not be suitable for the deposition tunnels in the future repository for spent nuclear fuel. This calls for future testing of this system in an environment resembling the future deposition tunnels. The use of a water ejector requires compressed air.

7.3 Protective sheet and connection to bottom plate

By changing the mounting side of the o-ring from inside to outside the tube would enable easy mounting of tube at floor level.

7.4 Sealing of the top lid

The used seal at the top lid in the experiment had the purpose of minimizing the air and moisture exchange between inside and outside the buffer protection system prototype. It was not explicitly tested. The main future work with the top lid is to investigate the requirements for the seal:

- Find relevant properties for the seal.
- Derive measurable quantitative parameters that can be from the properties.

7.5 Protective sheet

Test for investigation of the sheet rupture behaviour and the amount of material left in the deposition hole if the sheet is clamped.

The tube sheet designed, manufactured and tested in this has a significant surplus capacity in its water proofing property. This goes for the plain sheet as well for the sheet weld joint. There would be significant advantages in handling and installation of the tube if the tube sheet material could be lighter and fold more easily. This calls for further development of sheet material.

References

SKB's (Svensk Kärnbränslehantering AB) publications can be found at www.skb.se/publications.

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