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Scientific representative: Magnus Kronberg

Organisation: Swedish Nuclear Fuel and Waste Management Company (SKB)

Tel: +46 491 76 78 00

Fax: ---

E-mail: magnus.kronberg@skb.se

Project website address: <http://www.lucoex.eu/>



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Final Report of WP4 LUCOEX**

Authors: Magnus Kronberg and Jan Gugala, SKB

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LUCOEX



Summary

SKB and Posiva are developing a method for disposal of spent nuclear fuel. The method selected for the final repository is the KBS-3 method which employs copper canisters surrounded by bentonite buffer and placed at depth in crystalline bedrock. The reference design is KBS-3V employing vertical disposal of the canisters, where horizontal disposal of canisters, KBS-3H, is a possible alternative which is being explored and elaborated by the two organisations.

KBS-3H has been developed since 2001 and the development work is based on the KBS-3V method but with focus on KBS-3H specific issues. The key elements of the KBS-3H design are the:

- 300 m long inclined horizontal drifts,
- Supercontainers which constitute disposal packages made up of a canister surrounded by bentonite buffer with an outer perforated metallic shell,
- distance blocks which are made of bentonite and used to separate the Supercontainers hydraulically and thermally
- metallic plugs with their accompanying transition zones made up of pellets and bentonite blocks.

The KBS-3H reference design is called Drainage, Artificial Watering and air Evacuation (DAWE). It is based on using components standing on feet so that natural inflow in the drift drains underneath them during deposition. All voids around the components are artificially filled with water and the air evacuated after deposition. The DAWE design thus ensures an early initiation of the buffer saturation process.

Two deposition drifts (\varnothing 1.85 m) have earlier been excavated at the - 220 m level of the Äspö Hard Rock Laboratory (Äspö HRL), Sweden; one 15 m long and one 95 m long, (Bäckblom et al. 2005). The 95 m drift has been used to test and further develop a horizontal deposition machine for disposing full scale concrete dummy distance blocks and fully deployed (dummy) Supercontainers, while the 15 m drift has been used to test the compartment plug (SKB 2012).

Work Package 4 of the LUCOEX project, the Multi Purpose Test (MPT) is the next step of the KBS-3H development and integrates the key disposal components, including the Supercontainer, distance blocks, compartment plug, transition block and pellets filling. The experiment is installed in the innermost 19 m of the 95 m drift at the Äspö HRL. The MPT introduces bentonite buffer in the components which has not been demonstrated for KBS-3H previously. Hence, the MPT basically includes all steps for installing a reference design KBS-3H repository, including;

- drift characterisation and preparations (D4:03, Kronberg 2015)
- buffer manufacturing including the design and manufacturing of a new mould (D4:01, Johannesson 2014),
- component assembly (D4:03, Kronberg 2015)
- deposition of KBS-3H bentonite components (D4:03, Kronberg 2015 and D4:02, Ojala M and Von Numers T 2015)
- drift closure with a compartment plug (D4:03, Kronberg 2015)
- installation (D4:03, Kronberg 2015)
- monitoring of the early buffer evolution (D4:06 Pintado X, et al. 2015)

The MPT project also includes upgrading and rebuilding of the control system the deposition machine to ensure robust deposition sequences for all components (D4:02, Ojala M and Von Numers T 2015).

The MPT started 2011 and the installation was successfully completed end 2013 with monitoring of more than 200 sensors now ongoing (mid 2015).

Lots of experience were gained during the MPT and some implementation issues in need of further development were identified by the test, in particular a need to harmonise the water contents of the blocks inside the Supercontainer. The previous design with bentonite blocks of two different water contents (11% and 17 %) does not allow for fixating a relative humidity level in the assembly hall and subsequent storage that matches the water content of the blocks, this is something that will affect the assembled blocks in a negative way. Based on the MPT experiences, the KBS-3H design will now be updated with use of Supercontainer blocks with common water content.

Another implementation issue that was highlighted is the practical difficulties involved in welding the compartment plug (also being relevant for the drift plug which has a similar design). Similarly identified was the need for a drainage pipe at the lowermost part of the plug so naturally inflowing water can be drained prior to pellets filling. Difficulties in placing a contact grouting tube at the steel-casting interface highlighted the possibility of integrating the grouting tube in the plug design itself in order to allow for improved contact grouting. These experiences will all be brought to the drawing board and the KBS-3H plugs will be updated accordingly.

With respect to the KBS-3H deposition machine the MPT has demonstrated that a controlled and automated deposition sequence with good contact between components is possible already with the current prototype deposition machine. Further mechanical upgrades have also been suggested which if carried out will speed up and further improve the robustness of the deposition sequence.

In addition to the implementation issues presented above the KBS-3H project has gained a lot of experiences for possible future installations. Methodologies are now available for both assembly and installation of components including advanced sensor systems.

It can be concluded that the MPT has demonstrated the potential of the KBS-3H design, the strength of a slimmed system working with pre-assembled components. Key KBS-3H components have been tested in mutual combination according to the KBS-3H reference design DAWE. The actual function of the components will also be possible to start to assess as more sensor data is generated and through dismantling of the test.

Work Package 4 originally included the dismantling of the MPT but it has been postponed and subsequently removed from the LUCOEX. The EC instead invited SKB to include a steered core drilling operation also planned within the KBS-3H project at the Äspö HRL - 400 m level.

The KBS-3H design has strict requirements on the straightness of the deposition holes and steered core drilling is the method currently assess as the best option for fulfilling the requirements. The Äspö drilling is a step towards verifying the method and it was successful over its full length of 94 m, requiring only 2 steering actions. The results provide confidence that technology is available that should be able to achieve the 300 m deposition drifts which will be required. Methodologies and strategies for drilling and steering were improved and will be brought to Posivas facility, ONKALO, where a 300 m long core drilling test will be carried out 2015. For further details on the Äspö HRL drilling operation see D4:05, Nilsson 2015.

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1 LUCOEX Work Package 4

1.1 Context and Objectives

The common goal of SKB and Posiva is disposal of spent nuclear fuel from Swedish and Finnish nuclear power plants at depth in crystalline bedrock to ensure the safety of human beings and the environment for long periods of time. The method selected for the final repository is the KBS-3 method, Figure 1.1. The reference design is KBS-3V employing vertical disposal of waste canisters, where horizontal disposal of canisters, KBS-3H, is a possible alternative which is being explored and elaborated by the two organisations. SKB's and Posiva's current programmes for KBS-3 are detailed in SKB's RD&D-Programme (SKB 2013) and in Posiva's corresponding programme (Posiva 2009).

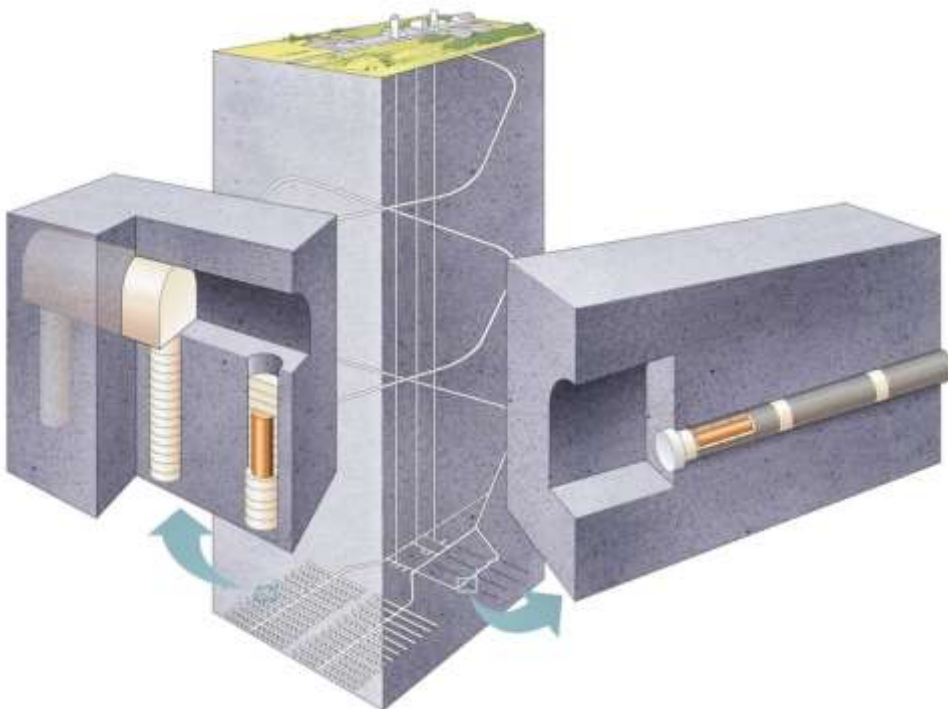


Figure 1.1 Schematic illustration of the KBS-3 method with its three barriers: the canister, the buffer and the rock. The vertical reference design is illustrated to the left and the horizontal alternative to the right.

KBS-3H development work started in 2001 based on the KBS-3V method with focus on KBS-3H specific issues. The layout of the KBS-3H drift is shown in Figure 1.2. The foremost elements of the design are the inclined horizontal drifts, the Supercontainers which constitute the disposal packages made up of a canister surrounded by bentonite buffer with an outer perforated metallic shell, the distance blocks made of bentonite buffer which separate the Supercontainers hydraulically and thermally and the metallic plugs with their accompanying transition zones made up of pellets and bentonite blocks. The compartment plug is designed to withstand the hydraulic pressure and limited buffer swelling pressure but the drift plug is designed to withstand full hydraulic and full buffer swelling pressure. Additionally there are filling components which are placed in positions of high water inflows.

The KBS-3H reference design is called Drainage, Artificial Watering and air Evacuation (DAWE). The DAWE design utilises that the KBS-3H components are installed on feet's so that inflowing water drains underneath them. When all components are installed in a 150 m section the voids around the components in the section are artificially filled with water through the compartment or drift plug while the air is evacuated.

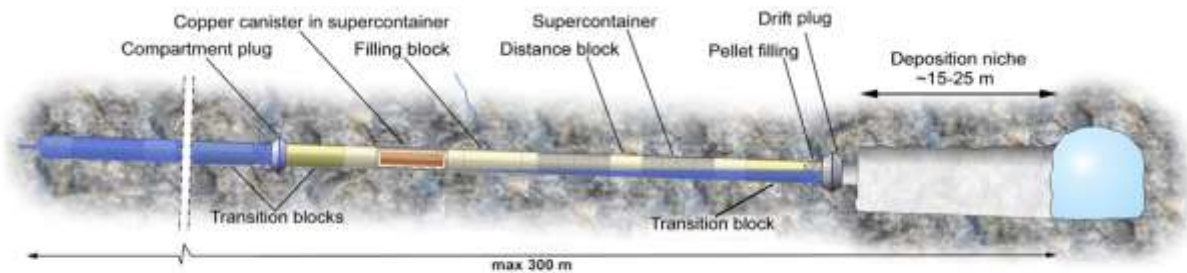


Figure 1.2 Illustration of the KBS-3H design, the current figure illustrates the water filling of the second compartment.

Further details on the KBS-3H design; including premises, requirements, safety assessments, construction and operation etc. can be viewed in KBS-3H Complementary studies, 2008-2010 (SKB 2012).

1.1.1 Multi Purpose Test (MPT)

In 2004-2005 two deposition drifts (\varnothing 1.85 m) were excavated at the -220 m level of the Äspö Hard Rock Laboratory (Äspö HRL), Sweden; one 15 m long and one 95 m long, (Bäckblom et al. 2005). The 95 m drift has been used to test and further develop a horizontal deposition machine for disposing full scale concrete dummy distance blocks and fully deployed (dummy) Supercontainers, while the 15 m drift has been used to test the compartment plug (SKB 2012).

The Multi Purpose Test (MPT) is the next step of the KBS-3H development and integrates the key disposal components, including the Supercontainer, distance blocks, compartment plug, transition block and pellets filling (D4:03, Kronberg 2015). It utilises the innermost 19 m of the 95 m drift at the Äspö HRL and for the first time introduces buffer manufacturing (D4:01, Johannesson 2014), assembly and deposition of KBS-3H bentonite components and closure by way of a compartment plug, followed by monitoring of the early buffer evolution. The MPT project also includes upgrading and rebuilding of the control system of the deposition machine (D4:02, Ojala M and Von Numers T 2015).

The MPT started 2011 and the installation was completed end 2013 and the monitoring of more than 200 sensors is now ongoing (mid 2015).

The test is basically a shortened non-heated installation of the KBS-3H reference design (DAWE), including the main KBS-3H components as shown in Figure 1.3. The test is installed according to DAWE after which the test conditions are monitored. Dismantling and analysis was originally planned for 2014 but is postponed and will be carried out at a later stage and the timing for this will be dependent on the measured data and projections made on evolution of the experiment.

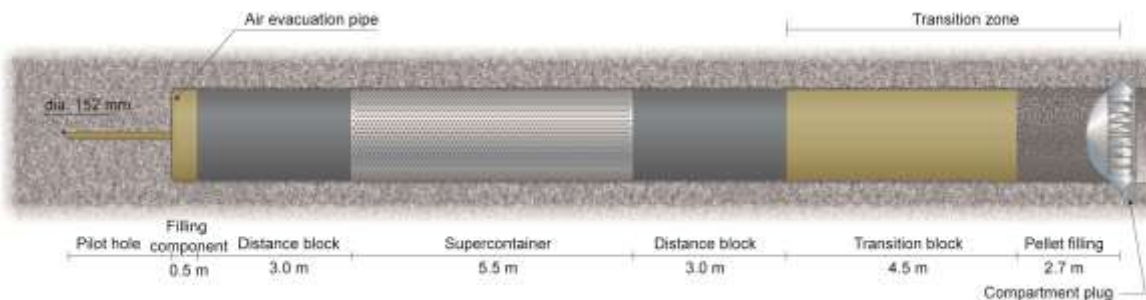


Figure 1.3 Schematic illustration of the MPT layout.

A guiding principle for the MPT has been to keep it as straightforward as possible, this was done to minimise the risk that the main objectives or the timeframe was compromised, for example, heaters are not used, effectively keeping the number of variables down.

The MPT is a sub-system test and will if SKB and Posiva choose to continue the KBS-3H development be followed by a full KBS-3H system test at repository level. Such a system test would include multiple and heated canisters together with all the KBS-3H disposal components.

The main objectives of the MPT are to test the system components in full scale and in combination with each other to obtain an initial verification of design implementation and component function. This includes the ability to manufacture full scale components, carry out installation (according to DAWE) and monitor the initial system state of the MPT and its subsequent evolution

Initial verification of the design implementation and component function is the main objective.

The test also provides important experiences from working in full scale at in situ conditions, thus enabling the recognition of potential implementation issues of the DAWE design.

1.1.2 Steered core drilling

With the MPT dismantling postponed and removed from the Lucoex project, the EC invited SKB to include a steered core drilling operation planned within the KBS-3H project (D4:05 Nilsson G, 2015).

The KBS-3H design utilises 300 m long horizontal, slightly upward inclined deposition drifts with a diameter of 1.85 m. The suggested technique for constructing the disposal drifts is to drill a 76 mm core drilled pilot hole, followed by stepwise reaming of the hole to the full size of the drift, i.e. \varnothing 1.85 m.

The KBS-3H drifts have strict requirements and there is thus high demands on pilot drilling accuracy. KBS-3H will most likely have to rely on steered core drilling in order to fulfill requirements. Steered core drilling in turn relies on accurate deviation measurements so that the position of the borehole in the rock can be measured. There are multiple suppliers of tools available for surveying boreholes, however, they have the inherent problem that the quality in the data produced is difficult to verify simply due to the fact that the holes are not available for independent geodetic control since they are located inside the rock. SKB has previously addressed this by the use of different measuring methods for measuring each hole. This improves the situation but doesn't address it fully. In order to further assess the quality of the data, SKB has therefore developed a 300 m long calibration facility at Äspö HRL. It basically constitutes a pipe on the surface that can be geodetically surveyed from the outside to define it's the true location prior to measurement with the deviation tools inside.

As mentioned previously, the KBS-3H project has a test site available at the -220 m level at the Äspö HRL, where two deposition drifts have been excavated (15 and 95 m long), (Bäckblom et al. 2005). A new test site, in the TAS08 tunnel, is being developed at the -400 m level, see Figure 1.4. Borehole K08028F01 in Figure 1.4 is the new KBS-3H borehole.

The new test site allows for demonstration and verification of the performance of pilot borehole drilling techniques with subsequent reaming to 1.85 m diameter at repository level. Afterwards, post grouting using the Mega Packer technique will also be tested, (Eriksson M and Lindström L 2008).

Very gentle steered drilling with associated deviation measurements were initially tested out in conjunction with drilling of K03009F01, Figure 1.4, and subsequently fully implemented in conjunction with drilling of K08028F01.

The drilling of K08028F01 is the drilling operation which is part of the LucoeX project and partly funded by the European Commission. It is drilled with the objective to demonstrate the fulfilment of the KBS-3H geometrical requirements for a 76 mm core pilot hole.

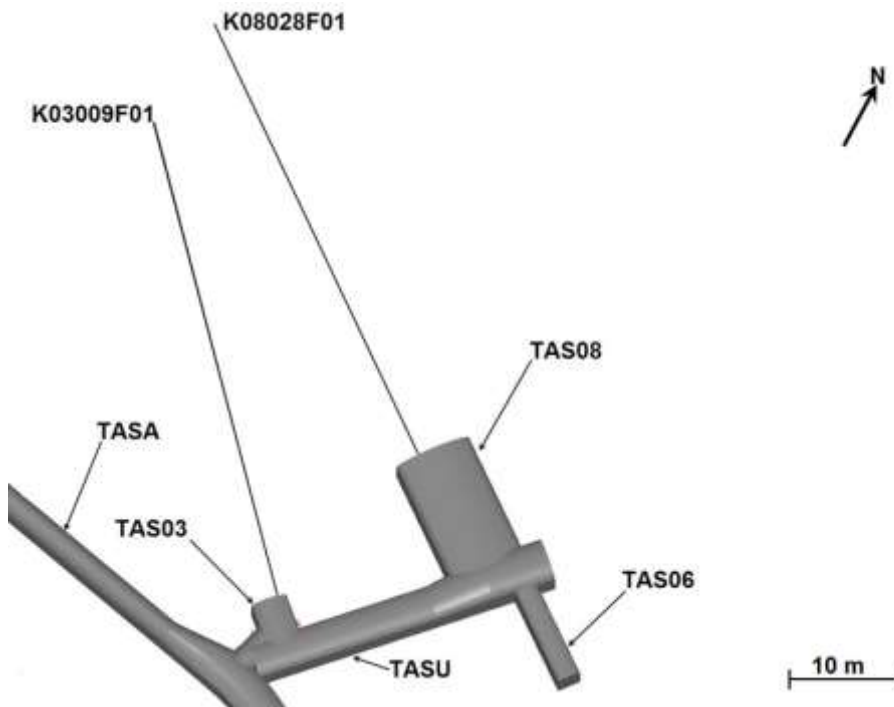


Figure 1.4 Schematic view showing the service tunnel TASU at the Äspö HRL with the connected KBS-3H experimental drift TAS08 and the DETUM niche TAS03. K08028F01 is the new KBS-3H borehole.

1.1.3 Purpose of this report

This report (D4.04) summarises the work done within WP4 of LucoeX and covers the mandatory EC Questioner. It is thus a compilation from the main deliveries where more details are presented. The main WP4 deliveries are:

- D4:01 KBS-3H. Manufacturing of buffer and filling components for the Multi Purpose Test
- D4:02 KBS-3H. Upgrading the deposition machine for the Multi Purpose Test
- D4:03 KBS-3H. Preparations, assembly and installation of the Multi Purpose Test
- D4:05 KBS-3H – DETUM. Steered core drilling of boreholes K03009F01 and K08028F01 at the Äspö HRL
- D4:06 KBS-3H. Initial data report for the Multi Purpose Test

1.2 Scientific and Technical Results, MPT

This section summarises the main results of the MPT, while Section 1.3 covers the steered core drilling operation.

1.2.1 Deposition machine development

The work done with the deposition machine during the MPT is detailed in delivery D4:02, KBS-3H. Deposition machine upgrades during the MPT, Ojala M, Von Numers T, 2015.

The KBS-3H deposition machine is the first prototype for demonstration of horizontal deposition in full scale. The machine was jointly designed by SKB and Posiva and manufactured by ECA in 2005–2006 within the 6th Framework programme “ESDRED” of the European Commission. The machine was first demonstrated in full scale tests in the Äspö HRL in 2007.

It utilises a water cushion transport principle, which works by stepwise movements inside the drift. A lifting and pushing sequence is repeated until the Supercontainer reaches its' destination in the drift. The water cushions and the heavy loads from the Supercontainer makes the control of the machine challenging. Machine testing before the MPT has been troublesome due to limited control ability and an incomplete software application.

The purpose of the MPT work was to develop the control system of the KBS-3H deposition machine to such a functional level, that the depositions in the MPT experiment could be reliably carried out and the horizontal deposition concept could be evaluated as a whole.

The development work was initiated by a control system investigation in order to assess the required correction work. Development plans were made for instrumentation of the machine, correction of the software structure and development of the control method.

In a first step the structural shortcomings in the control application were corrected and most of the communication problems between the modules were solved, and a basis for continued development was laid.

In a second step, the machine was thoroughly instrumented and an efficient logging system added so that the machine behaviour could be investigated in more detail. The control method was then enhanced by developing further all interacting functions one by one. The functionality was improved, but not completely solved. The mechanics of the machine was not completely controllable by the functions in use.

In a third step a new mechanical actuation system for steering the front of the machine was introduced and produced satisfying control stability.

Finally a composite control method utilizing all improved controls could be developed.

Additionally, the automation level of the machine was increased in order to avoid manual operation. New control functionality was developed to handle deposition of units of various lengths as well as the special cases of approaching the drift end and a previous component in the drift.

Supercontainer and distance block concrete dummies were used for testing during the soft- and hardware updates. Once all functions were tested with satisfying results for both the Supercontainer and the distance block dummies a pre-test with a real bentonite distance block was carried out. It included testing the bentonite distance block foot modules and planned sensor arrangements for the MPT components. The distance block was deposited and retrieved with good results. Splashing of water from the water cushion

system which is a known issue since start of testing was evident also on the bentonite distance block; however, it was not so extensive that it compromised the component integrity.

Based on these tests, the machine was considered sufficiently reliable and adequate for the deposition tasks in the MPT experiment.

1.2.2 Drift preparations

The drift preparation work is presented in detail in D4:03 KBS-3H Preparations, assembly and installation of the Multi Purpose Test, Kronberg 2015.

Characterisation

Prior to excavating the 95 m drift a pilot hole was drilled and characterised in 2003. After excavation, the drifts were mapped with focus on rock types, fracturing and groundwater inflows. Details about this characterisation are presented by (Bäckblom et al. 2005). Leakages from the drift have been monitored since excavation. For the MPT a renewed leakage study was made focusing on the inner 19 m, a summary of data in litres per day gives the approximations below:

- Full MPT section two months prior to installation ~32 l/day
 - Supercontainer section in 2012 ~19 l/day
 - Inner distance block section in 2012 ~8 l/day
 - Outer distance block, transition block and pellets 2012 ~3 l/day

Laser scanning and photography was carried out using a Leica scanner P20 with a Nikon 800 E system camera, for imaging see Kronberg 2015.

Compartment plug preparations

The compartment plug, Figure 1.5, is installed in two main steps of which the first, the fastening ring installation, is done during the drift preparation stage and the second, including the collar and cap, is done after deposition. A circular saw, mounted on a circumferential rail is used to cut out a slot for the compartment plug. Once the rock is removed the fastening ring is positioned, Figure 1.5, and contact grouting tubes placed in the interfaces after which it is casted in place. The tube at the metal-casting interface proved quite challenging to get into place, and future development would be favourable.

Once the casting of the fastening ring was done, its lower parts were filled with concrete to form a temporary bridge for the deposition machine to pass over.

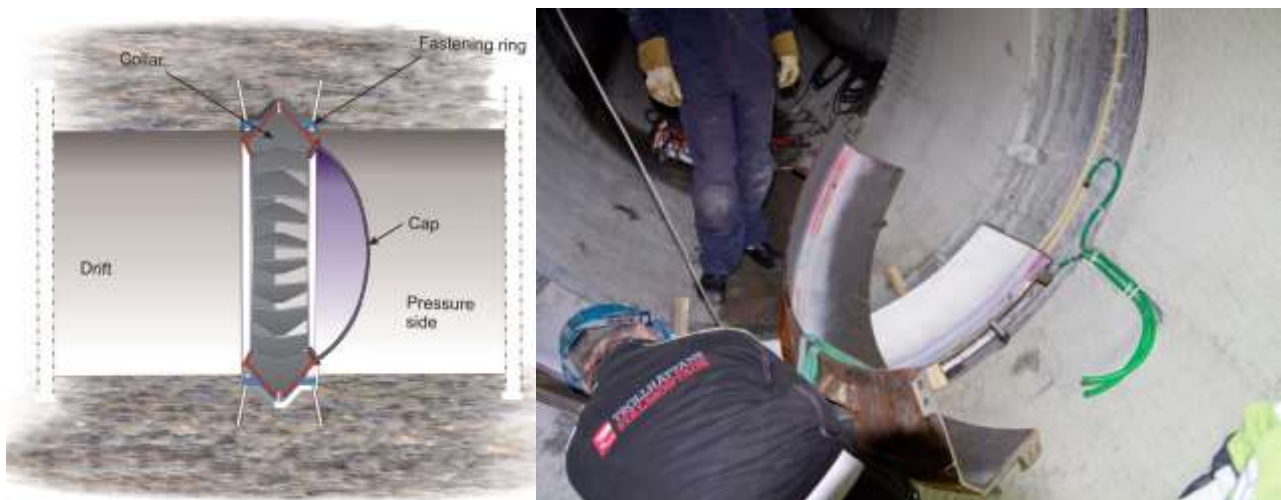


Figure 1.5 Left, schematic illustration of the compartment plug. Right, installation of the fastening ring.

Cable and rock sensor preparations

Since no tunnel is located nearby the MPT drift, and excavation of a parallel tunnel was outside the project scope, all cables had to be taken along the drift sides and out through the plug. Cabling is also constrained by the fact that there is limited annular space between the components and the drift wall (42.5 mm). For this reason all cabling had to be placed outside the drift periphery, i.e. cable notches had to be cut in the rock. The cut-outs are small close to the drift end and expand stepwise in size towards the plug as more and more sensor cables are added to the bundle. In the pellets section the cut-outs are further widened to form a cable storage where all cables had to be placed during component installation but before the plug was installed.

A standard concrete cutting saw fitted with a peripheral drift-shaped anchor that allowed parallel cutting was used to make the cable-cut-outs. Main pipes prepared for sensor cables were subsequently casted into the cut-outs, Figure 1.6.

Boreholes were also drilled for total- and pore pressure sensors which were casted in place prior to the MPT installation.

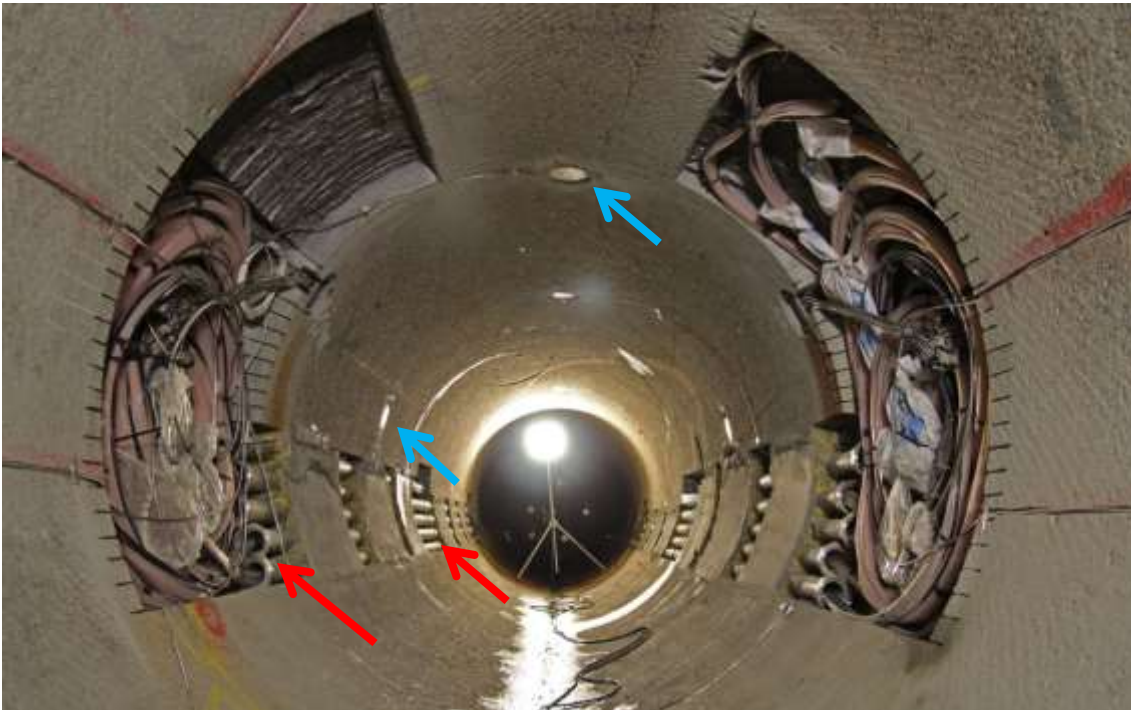


Figure 1.6 *The MPT drift prepared for installation. Red arrows mark the main piping and cable storages and the blue arrows marks some total pressure sensors.*

1.2.3 Manufacturing and assembly of the MPT component

A main objective of the MPT was the manufacturing and assembly of the MPT components. This included a first time assembly with bentonite blocks of the Supercontainer, Figure 1.7 and the distance/transition blocks, Figure 1.8. Additionally bentonite pellets for the transition zone were manufactured as well as a compartment plug.

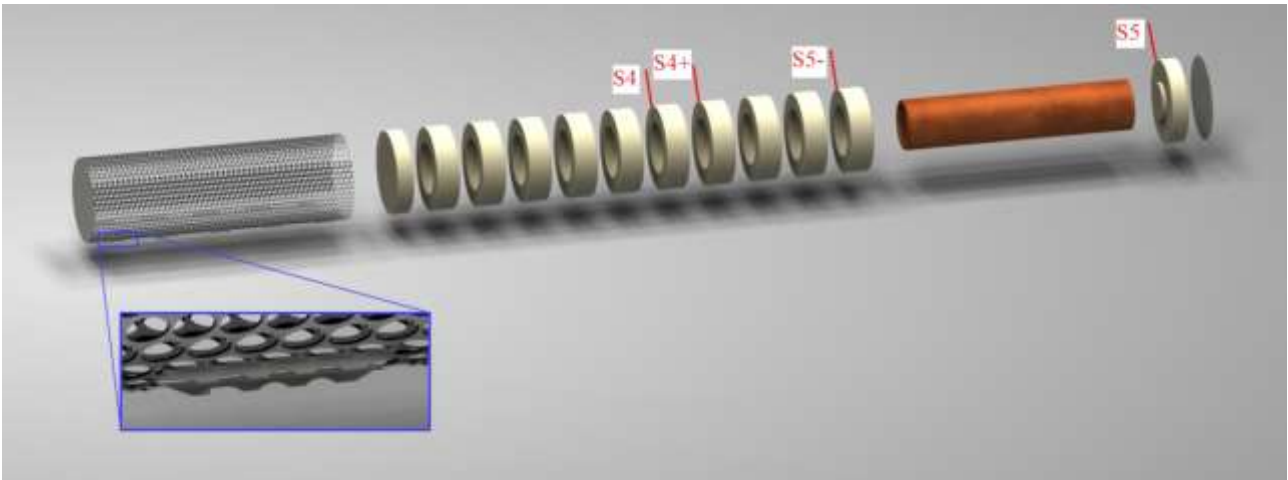


Figure 1.7 Schematic illustration of the Supercontainer made up of a canister surrounded by buffer rings and blocks with an outer perforated metal shell to keep the component together. Positions used for instrumentation in the MPT are marked, S4-S5.



Figure 1.8 Schematic illustrations of the distance- and transition blocks with their feet. Positions used for instrumentation in the MPT are marked, S1-S9.

Buffer manufacturing

The Manufacturing of buffer and filling components are described in detail in delivery D4:01, KBS-3H Manufacturing of buffer and filling components for the Multi Purpose Test (Johannesson 2014).

The KBS-3H blocks are larger than the KBS-3V blocks, hence a new uni-axial mould had to be manufactured. Its design is basically the same as that employed for KBS-3V earlier and both solid blocks and rings can be pressed with different adapters.

The buffer block manufacturing activities are listed in Table 1.1. The activities are listed in the order they were executed.

Table 1.1 A list of activities included in the manufacturing of the bentonite blocks.

Activity	Description
Control of delivered bentonite	Samples from some of the delivered big-bag of bentonite are taken and investigated with laboratory tests.
Mixing of bentonite	Water is added to the bentonite to yield the right water content.
Compaction of bentonite	Bentonite powder is compacted to blocks with a maximum compaction pressure of about 65 MPa.
Investigation of compacted blocks	A visual inspection of the compacted blocks is made. The weight and the dimensions of the blocks are measured.
Machining of the blocks	The compacted blocks are machined to stipulated shape.
Investigation of the machined blocks	A visual inspection of the machined blocks is made. The weight and the dimensions of the blocks are measured.

A delivery of bentonite, approximately 150 tons was purchased by SKB for different large scale experiments at Äspö during winter 2012. The bentonite was from Wyoming and of type MX-80 and produced by AMCOL International Corporation USA. Furthermore the bentonite was delivered in big-bags to Äspö (altogether 167 big-bags). A smaller amount of MX-80 from 2013 was also delivered and used by SKB at the production of the blocks.

A delivery control of the bentonite was made in June 2012 and in June 2013, and showed that the material requirements were fulfilled. For requirements and detailed material analysis results see D4:01,KBS-3H Manufacturing of buffer and filling components for the Multi Purpose Test, Johannesson 2014.

After delivery control an Eirich mixer was used to mix the material to the required water content. Approximately 350 kg of bentonite could be mixed in each batch.

Compaction was done using a uni-axial press, and the program included 12 rings and 31 solid cylinders with two different water contents.

When assessing the mixing, 95% confidence intervals of the water content were within the accepted variation, however, for the compacted blocks after machining, 95% confidence intervals of the dry densities of the produced blocks (ring shaped blocks and distance blocks) where not within the accepted variations. On the other hand, the calculated average densities of the produced blocks were within the acceptable variation. Therefore, the judgment was that although all water contents and dry densities did not fulfil the requirements the blocks could still be used for the Multi Purpose Test without affecting the expected outcome from the test in an essential way.

All individual manufactured blocks shall of course fulfil all the requirements and the reasons why they all didn't are of importance for future development. In the MPT case three main issues are identified.

- Small production series where the compaction parameters cannot be properly optimised during a compaction series. This meant that the first couple of blocks in each series could be outside the requirements, yet they could not be discarded in the MPT for cost and time reasons. A more industrialised process would also allow storage of bulk volumes of bentonite which should ensure a homogenous water content which is something the MPT big bags could not achieve.
- The manufacturing and machining equipment is not optimised; the press is generally used for manufacturing heat exchangers so the press height is limited. The machining equipment is very basic and machining involved long transports, between Sweden and Finland, of the blocks due to limitations in available machining facilities.
- Better equipment for dimensional control is also needed in order to calculate accurate densities.

Assembly

Previously, the KBS-3H project had only tested assembly of concrete dummies; a pre-test with a bentonite distance block was therefore carried out. The pre-test integrated all steps from assembly to deposition. It was initiated in February 2013, and it quickly proved that the original intention to protect the buffer blocks with plastic foil while drilling and preparing them for assembly would be inadequate. The relative humidity (RH) and temperature was logged and due to the winter season, the RH was between 15-25 % at the time and the distance blocks started to develop surface cracks within an hour in conjunction with drilling. Some of the blocks also had cracks already when the transport containers were opened, indicating that the containers were not air tight. Although the surface cracks were quite small initially they were still too large and prevented the use of the vacuum hoist tools and therefore halted the work.

The distance block have a water content of 21 % and equilibrate at a RH of approximately 86 %.

Several actions were taken in order to address the cracking problems; all transport containers were fitted with new rubber seals, plastic bags with aluminium foil and more rigid wooden pallets were purchased (the MPT includes more blocks than there were transport containers available). Plastic bags with size of the full scale components were also purchased. However, the installation of an industrial humidifier in the assembly facility was the solution to the problem. It allowed for a controlled environment during assembly, i.e. a RH of 86 % in the air during the assembly of the distance blocks.

Introduction of a controlled environment simplified the work considerably as cracking ceased and a full scale distance block could be assembled as planned, Figure 1.9.



Figure 1.9 Test distance block being moved out from the assembly facility. The red arrow marks part of the sensor arrangement, a cable block, in which sensor cabling can be placed during transport and deposition.

The experiences from the pre-test could be implemented in the actual MPT assembly which was later carried out basically as planned. One issue that arose was that the Supercontainer is designed with blocks of two different water contents; solid blocks with $11 \pm 1\%$ and rings with $17 \pm 1\%$. This means that the RH in the air in the assembly facility cannot be optimised for both block types, which equilibrates at approximately RH 50 % and 86 %, respectively. In the case of the MPT a RH in between the two stated equilibrium was selected, which worked out reasonably well, although some flaking was noted on the rings. This is an obvious design problem, which can only be addressed by harmonising the water contents in the solid blocks and rings. The KBS-3H project will add this design aspect into the current project phase.

For further details on the MPT assembly see D4:03 KBS-3H Preparations, assembly and installation of the Multi Purpose Test, Kronberg 2015.

1.2.4 MPT installation and monitoring

Installation

The installation results are presented in detail with data on dimensions and weights for the components in D4:03 KBS-3H Preparations, assembly and installation of the Multi Purpose Test, Kronberg 2015.

For KBS-3H, an efficient installation is a key part of the design. A preliminary assessment is that the components and the plug that make up a compartment have to be installed within 10 days to ensure that the buffer remains intact when the DAWE procedure is initiated.

With the MPT being strongly focused on the handling and installation of the full scale components it was decided to carry out the installation as fast as possible. At the same time, the test involved about 200 sensors that need to be taken into account. Figure 1.10 presents the as built time schedule. It is one day longer than planned at onset, mainly due to the pulling and connecting of cables taking longer time than expected. Originally the schedule had some slack during cable pulling and the data acquisition system (DAS) connection; however, this time was eventually needed in order to keep to the schedule.

Activity	November														December									
	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5	6	7
Filling components pilot holes	█																							
Inner distance block and cables	█																							
Supercontainer and cables		█	█	█																				
Outer distance block and cables					█																			
Transition block						█																		
Cables and sensors on last block							█	█	█															
Plug and cables								█	█	█	█	█	█	█	█									
Pellets filling															█									
Connecting the DAS																█	█	█	█	█	█	█	█	█
Contact grouting plug																							█	
DAWE																								█

Figure 1.10 The MPT installation schedule, basically one bentonite component per day, with connection of cables during the nights and with the Supercontainer installation requiring three days due to its many sensors. A week required for installing the plug with cables and a week for connecting the DAS.

The MPT installation basically worked out as planned with all components placed at their intended locations and with tight connection between them, Figure 1.11 illustrates the Supercontainer after deposition.



Figure 1.11 Supercontainer positioned in the drift with all its cables pulled. The tight fit between the Supercontainer and drift wall is clearly visible.

The inner distance block had a crack on its outer surface after installation, its origin is not fully known. However, it evidently endured the stepwise lifting and lowering during the deposition sequence in the order of 60 times so the crack could not be all that deep. If it was very deep, pieces of the block would have come loose. The integrity of the distance blocks is of highest importance and if such a large piece had come loose it could have caused a jamming of the machine.

This type of cracking was not experienced for the second distance block nor for the transition block. However, it is something that has to be avoided in the KBS-3H design. Future studies, with more extensive test series will have to verify that the distance blocks maintain their integrity during deposition. An option could be to develop a transport vehicle for distance blocks without water cushions, more like a fork lift.

Once all components were in place, the plug installation was simply a welding activity, given that the fastening ring is already cast in place, c.f. Section 1.2.2. It worked, however, welding and inspection proved quite difficult due to limited space between the rock and the metal components and a small hole was missed in inspection of the welds and later caused leakages that had to be re-welded. It was also noted that water started to build up inside the collar, Figure 1.5, once it was welded in place, for the MPT the flows were low so it didn't really impact the installation but a drainage pipe would be preferred in future design updates.

All cables were taken through the plug after which the void between it and the transition block was filled with pellets. This was followed by contact grouting of the steel-casting and casting-rock interfaces using silica sol.

Once the DAS had been connected and was up and running, water was filled, air evacuated and the pipes removed according to the DAWE reference design. This also worked out as planned, except, for the hole in the plug which had to be re-welded.

Assessment of relative speed of installation

Compared to the reference design where about 4 components are expected to be placed each 24 hours the corresponding MPT work was carried out at about a quarter of that speed. On the other hand, without the cabling, two components would have been managed in 24 hours during the MPT which would equal half the speed expected in a repository situation. At this stage of KBS-3H development this outcome is deemed acceptable. In a repository case the transport and starting tube handling would be managed by self-propelled vehicles, connections between the deposition machine and the control room would be wireless and the alignment of the vehicles with the drift would be automated. The deposition sequence could also be optimised with the transport tube being reloaded with a new component during deposition of the preceding component.

Concerning the plug, it is expected to be installed during one day in the repository situation, but it took a week in the MPT. Approximately half of the MPT time is due to management of sensor cabling, and the work was done without a night shift so the MPT plug installation is in the order of twice the time when it comes to actual working hours. This is also deemed acceptable in the current stage of development since the work was mainly done manually in the MPT and there is lots of time to be gained by automating the transportation of the plug parts, their placement and welding.

In the MPT, one day each was allotted for the pellets filling and post grouting of the plug. These activities would have to be speeded up considerably to 3 and 4 hours respectively. These kinds of speeds would require on-site customized equipment's, but should be feasible.

Water filling is pretty straight forward and takes the time decided. Pipe removal would have to be speeded up by an automated pulling system rather than retaining the more manual performance employed in the MPT.

Monitoring

The MPT is instrumented with the objective to study the behaviour of buffer- and filling components during the early part of the buffer evolution, and in addition to study the compartment plug behaviour.

The instrumentation is set up to monitor movements in the system, buffer water content, possible plug leakages, strain in the metal components, pore- and total pressure and buffer swelling pressure at the rock and plug interfaces. The development of swelling pressure acting on the rock wall is investigated e.g. to evaluate if the pressure reaches levels that could have a mitigating effect on thermally induced spalling. The development of swelling pressure exerted on the compartment plug during the operational phase (due to transition zone and distance blocks) is a question that is also addressed by the instrumentation. Another objective of the instrumentation is to increase the understanding of the relative effect and importance of three different flow paths, which are buffer, EDZ and near field rock.

Additionally, the short term influence of the Äspö water on different materials placed in the buffer is studied by the installation of metal coupons that can be examined after dismantling.

For details on the instrumentation and initial monitoring see D4:06 Pintado X, et al. 2015. Most of the system is up and running at the time of this reports publication (mid 2015); although a novel wireless system has malfunctioned. Initial monitoring data indicates that the MPT is evolving similar to what can be expected, the outermost parts of the blocks are affected by water while the inner parts are less so. Pressures at the rock inside the section are mostly that of the groundwater, with some exceptions where early bentonite swelling pressures can be measured.

A second data report is planned to be published 2016.

1.2.5 Results and conclusions

The performance of the MPT is part of the stepwise development and demonstration of the KBS-3H design and it has been preceded by a number of full scale in situ demonstrations at the Äspö HRL:

- The excavation of a KBS-3H drifts at the -200 m level (Bäckblom et al. 2005),
- The development and testing of a deposition machine with concrete dummies (Autio J, et al. 2008)
- Mega Packer post grouting (Eriksson M and Lindström L 2008)
- Pipe removal tests (Autio J, et al. 2008)
- Compartment plug tests (SKB 2012)

The MPT integrates earlier development work with the objective of obtaining an initial verification of the KBS-3H design implementation and the components mutual function when combined.

The MPT was also set up with the aim of gaining further experience from working in full scale at ambient in situ conditions, thus allowing for the recognition of potential implementation issues associated with the DAWE design.

Experiences from the MPT

It is concluded that the MPT has demonstrated the potential of the KBS-3H design, the inherent strength of a slimmed system working with pre-assembled components. The key KBS-3H components have been tested in mutual combination and the DAWE procedure has been carried out basically as intended. The actual function of the components will have to be assessed as more sensor data is generated and an eventual dismantling of the test.

Several implementation issues in need of further development have also been identified by the test, in particular the need to harmonise the water contents of the blocks inside the Supercontainer. The previous design with bentonite blocks of two different water contents, 11% and 17 %, does not allow for fixing a relative humidity level in the assembly hall and subsequent storage that matches the water content of the blocks. The challenges faced with cracking blocks during the MPT also illustrate the importance of establishing controlled environments during all steps when handling bentonite components. Based on the MPT experiences, the KBS-3H design will now be updated with use of Supercontainer blocks with common water content.

The MPT also highlights the need for improved geometrical measurements of components in order to ensure that the requirements are actually fulfilled. The slide caliper used should be replaced and improved methods established, possibly using laser scanning or simply approving the blocks at milling which is done with very high accuracy.

Another implementation issue that was highlighted is the practical difficulties involved in welding the compartment plug which also is relevant for the drift plug which has a similar design. Similarly identified was the need for a drainage pipe at the lowermost part of the plug collar, Figure 1.5, so naturally inflowing water can be drained prior to pellets filling. Difficulties in placing a contact grouting tube at the steel-casting interface highlighted the possibility of integrating the grouting tube in the plug design itself, in order to allow for improved contact grouting. These experiences will all be brought to the drawing board and the KBS-3H plugs will be updated accordingly. When updating the plug designs, a re-usable 'bridge' for the deposition machine to pass over the fastening ring, will also be considered as opposed to the simpler single use concrete 'bridge' employed in the MPT.

With respect to the KBS-3H deposition machine, the MPT has demonstrated that a controlled and automated deposition sequence with good contact between components is possible already with the

current deposition machine. It also identified that the current prototype is not fully compatible with the use of an air evacuation pipe, a finding to be addressed in future development work.

The issue of splashing of water onto bentonite components during transportation and deposition, which has been identified already in earlier development work, has to be addressed before doing any further full scale bentonite component installation. Splashing does not however appear to destroy or deteriorate the components immediately; however, since this problem can be solved by mechanical upgrades it should be incorporated in subsequent development work.

In addition to the implementation issues presented above the KBS-3H project has gained a lot of experiences for future installations. Methodologies are now available for both assembly and installation of components including advanced sensor systems.

1.3 Scientific and Technical Results, Steered Core Drilling

1.3.1 Requirements

The KBS-3H design is based on 300 m long drifts in which Supercontainers with canisters and other components are placed. Requirements on installed buffer density lead to strict geometrical requirements on the drifts, additionally; the Supercontainer is a rigid approximately 6 m long component which in turn puts requirements on the drift straightness. Thermal separation between adjacent drifts also adds requirements as well as the DAWE procedure which requires a constant inclination for natural drainage. The requirements are given below:

- The upward inclination should be $2^\circ \pm 1^\circ$. On no occasion should the inclination be negative (i.e. downward).
- The maximum horizontal deviation (azimuth) from the nominal position over a 300 m borehole length is ± 2 m.
- The maximum vertical offset in the pilot borehole should not exceed 10 mm from the straight line between any points of 6 m distance.
- The maximum horizontal offset in the pilot borehole should not exceed 20 mm from the straight line between any points of 6 m distance. (Note. 50 mm is used in D4:05 Nilsson G. 2015, but has since been adjusted downward).

1.3.2 Äspö deviation control facility

The Äspö surface-based deviation calibration facility was constructed by SKB in 2013, Figure 1.12. A 300 m long PVC pipe, simulating a borehole trajectory, is fastened to the ground with 151 non-magnetic pipe holders bolted to the ground whereof a third are reinforced with concrete pillars when the distance between the pipe and ground exceed 1 m. The location of the pipe is surveyed in using a total station at fixed positions (reflectors) at its starting and end points and on the pipe holder every second metre.

The facility allows for quality control of deviation measurement equipment's that are pulled through the pipe. Several tools were evaluated prior to the KBS-3H drilling operation, most of them perform quite well, especially for inclination, however, magnetically based tools were disturbed by areas of magnetic rock minerals along the facility, this affects the quality in horizontal data. Gyro based equipment perform well also horizontally; however, they are quite sensitive to the operators capability, with small mistakes leading to accelerating errors.

KBS-3H opted to use two tools, the Devishot (Pee-Wee) and the Reflex Gyro. The Pee-Wee tool is primarily used for orientation of the DeviDrill directional drilling system (toolface) but may of course also be used for complementary deviation measurements when so needed. The Reflex Gyro is not affected by magnetic disturbances and gives more accurate values especially horizontally.



Figure 1.12. Äspö deviation control facility is a 300 m long plastic tube ($\varnothing 75$ mm) secured firmly to the ground with 151 fastening devices. All material used in the construction is non-magnetic such as plastic and aluminium.

1.3.3 Steered Drilling

Pre-tests

Core hole K03009F01, Figure 1.4, was drilled before the KBS-3H borehole and tests of very fine application of the steering equipment was carried out. These confirmed that the very fine steering actions that would be required are possible, and give measurable results. Steering down to 0.1° were done, which compares to a more normal application of 1° steering.

Strategy

A set of actions were taken for the KBS-3H borehole in order to optimize conditions:

- A stable platform to prevent dislodging of the drill rig during drilling. This is essential because the borehole was applied 3.5 m above the tunnel floor.
- Careful alignment for drilling and installation of the casing, special equipment was developed.
- A powerful drilling rig so that drilling can be carefully controlled and not just run at full throttle.
- The directional core barrel must be in good condition. A variety of soft and hard drill bits, including the different dimensions of the reamer and stabilizer, must be available.
- Experienced staff that understands the purpose of the borehole and is familiar with the drill and control equipment, including the use of deviation measurement instruments.
- Finally, and perhaps decisive in order to obtain a straight borehole, is that the staff must have a good feeling for how the rock, drilling and measuring equipment function together.
- A clear strategy facilitates all decision-making, which often must be undertaken quickly at the drill site.

For details on the steering strategy see D4:05, KBS-3H – DETUM. Steered core drilling of boreholes K03009F01 and K08028F01 at the Äspö HRL Nilsson G. 2015

Drilling

The preparations undertaken payed of well and steering was not necessary until at 65 m. At 63 m length the distance was 12 cm to the right and 4 cm downwards, this is about half of the error that would prompt a steering according to the strategy implemented. However, if the borehole continues deviating to the right, the risk for performing a late steered drilling increases, which would be difficult to evaluate if it is carried out to close to the borehole end. The first steering action was prompted based on these conditions.

The effect was as expected with the borehole turning to the left, however, along with a larger upward inclination. A second steering was made at 73 m in order to stop the rise in inclination and continue to the left. It worked out as the rise in inclination was retarded and a smooth left turn was obtained, pointing the hole almost directly on target.

Figure 1.13 illustrates the drilling results in azimuth (horizontal) and inclination. When assessing the data in relation to the KBS-3H requirements, it was concluded that the inclination deviation was maximum -2.2 mm/6 m with ± 10 mm/6 m allowed and the azimuth deviation was maximum -3.5 mm/6 m with ± 50 mm/6 m allowed.

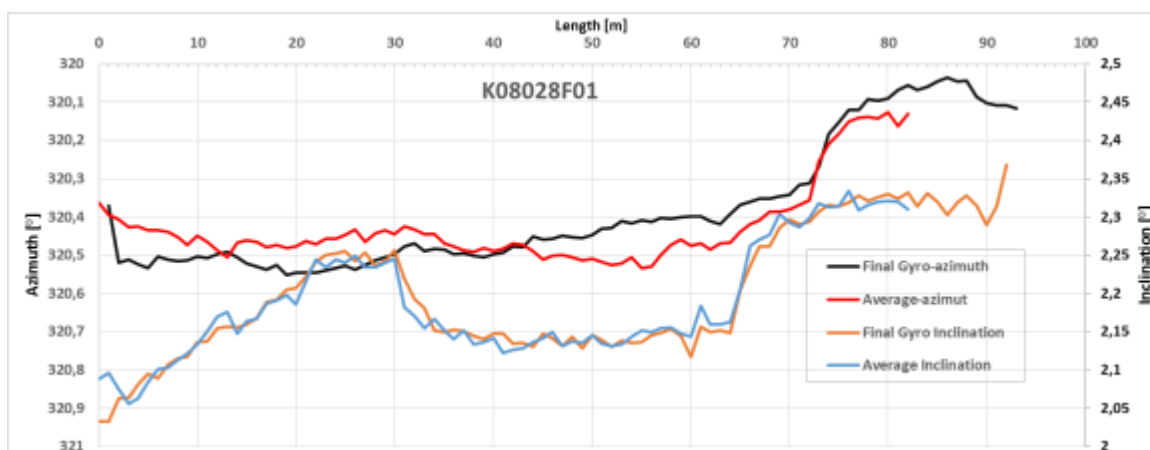


Figure 1.13 Final deviation measurements (azimuth and inclination) with Reflex Gyro and average calculated files in K08028F01.

The results clearly demonstrates that the KBS-3H geometrical requirements can be fulfilled over a 100 m length scale. It also provides experience and a strategy going forward and testing the full 300 m which will be done in ONKALO during 2015.

1.4 Impact

The Multi Purpose Test (MPT) experiment at Äspö HRL is a full scale demonstration of KBS-3H technology in granitic rock. It is done according to the KBS-3H reference design, Drainage, Artificial Watering and air Evacuation (DAWE), and it simulates the manufacturing, assembly and installation of the key KBS-3H components as well as the early evolution of the design, excluding the heat parameter which is not part of the MPT.

The engineering and demonstration components of the MPT are also part of SKB's participation in the EU project 'Large Underground CONcept EXperiments' (LUCOEX). The MPT experiment and its associated LUCOEX Work Package (WP4) are key projects for SKB and Posivas joint development of the KBS-3H design.

Technology for horizontal deposition of SKB/Posiva type canisters/Supercontainers has taken a large step forward during the MPT. Soft- and hardware upgrades on the deposition machine have considerably improved balancing of the full scale components during deposition. Overall, the MPT has demonstrated that a controlled and automated deposition sequence, achieving good contact between components, is possible with the upgraded KBS-3H deposition machine. A set of topics for further improvements on the deposition machine has also been identified and should, if they are implemented, result in a faster and even more robust deposition sequence. Suggestions for alternative deposition methods of distance blocks have also been raised during the MPT and could potentially improve the design even further.

Assembly of the KBS-3H Supercontainer has also taken a major step forward during the MPT, it had previously been carried out with concrete blocks but the MPT includes bentonite buffer blocks for the first time. All steps from manufacturing a mould, purchasing MX-80 bentonite, material quality control, mixing to proper water contents, compaction, machining, storage/transport, assembly and installation have been demonstrated.

Although the MPT is a non-heated test, a LUCOEX scholarship studying the effect from a hot canister on the bentonite buffer during assembly and storage has provided important input. It clearly indicates that there will be redistribution of water inside the Supercontainer once a hot canister is placed. This is something that has to be further studied within the KBS-3H project and something to consider for other organisations using similar designs as KBS-3H.

The MPT has also identified a few important implementation issues of the KBS-3H design that are in need of further development. In particular, the need to harmonise the water contents of the blocks inside the Supercontainer and more generally highlighting the importance of working in a controlled environment during all steps when handling bentonite components. Challenges faced in welding and inspecting the Compartment plug has also prompted design updates. These design changes will when implemented considerably improve the robustness of the KBS-3H design.

With respect to steered core drilling, the fulfilment of the strict KBS-3H requirements over a 100 m length scale provides confidence that technology is available that should be able to achieve the 300 m deposition drifts which will be required. Methodologies and strategies towards fulfilling the requirements have also been improved.

It can be concluded that the MPT and the steered drilling outcomes and findings will not only contribute in making the KBS-3H design more robust but it will also provide valuable experiences towards implementing of geological disposal in line with the Vision Report and initial roadmaps of IGD-TP and the 2020 objectives of the SET-Plan.

2 Acknowledgement

SKB thanks the European Union for supporting the MPT with the LUCOEX-project having received funding from the European Union's EUROATOM-research program (FP7) under grant agreement 269905 –LUCOEX.

SKB also thanks the LUCOEX partners ANDRA (France), NAGRA (Switzerland) and POSIVA (Finland) for the continuous discussion and knowledge exchange throughout this EU project and beyond.

The MPT is carried out at the Äspö HRL and the Project thanks the Äspö organisation and contractors.

The KBS-3H demonstration project also thanks the other Sub-Projects of the KBS-3H Project.

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APPENDIX I - SCIENTIFIC PUBLICATIONS

List of all scientific (peer reviewed) publications relating to the foreground of the project.

These tables are cumulative, which means that they should always show all publications and activities from the beginning until after the end of the project.

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES										
NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers ¹ (if available)	Is/Will open access ² provided to this publication?
1	<i>State-of-art, proof-of-concept installations for repository concepts based in crystalline rock</i>	<i>Magnus Kronberg</i>	<i>Mineralogical Magazine</i>	<i>Planned, 2015</i>		<i>UK</i>	<i>Planned, 2015</i>		<i>n/a</i>	<i>yes</i>
2	<i>Liggande kopparkapslar utreds för miljoner</i>	<i>Monica Kleja</i>	<i>Ny Teknik</i>	<i>Oct 16th 2014</i>	<i>Talentum Media AB</i>	<i>Sweden</i>	<i>2014</i>		<i>n/a</i>	<i>yes</i>

¹ A permanent identifier should be a persistent link to the published version full text if open access or abstract if article is pay per view) or to the final manuscript accepted for publication.

² Open Access is defined as free of charge access for anyone via Internet. Please answer "yes" if the open access to the publication is already established and also if the embargo period for open access is not yet over but you intend to establish open access afterwards.

APPENDIX II - DISSEMINATION ACTIVITIES

List of all dissemination activities (publications, conferences, workshops, web sites/applications, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters).

These tables are cumulative, which means that they should always show all publications and activities from the beginning until after the end of the project.

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	Type of activities ³	Main leader	Title	Date/Period	Place	Type of audience ⁴	Size of audience	Countries addressed
1	<i>website</i>	<i>SKB</i>	<i>Lucoex.eu</i>	<i>2011-</i>	<i>Internet</i>	<i>Scientific Community and open for all</i>		<i>worldwide</i>
2	<i>Workshop on instrumentation</i>	<i>SKB</i>	<i>Hydro Monitoring System (HMS) and Äspö instrumentation</i>	<i>2012 Sep 26-27</i>	<i>Bure, France</i>	<i>Scientific Community and open for all</i>	<i>~40</i>	<i>Europe</i>
3	<i>Workshop on instrumentation</i>	<i>SKB</i>	<i>Multi Purpose Test (MPT) Instrumentation</i>	<i>2012 Sep 26-27</i>	<i>Bure, France</i>	<i>Scientific Community and open for all</i>	<i>~40</i>	<i>Europe</i>
4	<i>Mid-term Workshop LucoeX</i>	<i>SKB</i>	<i>Emplacement concepts for SKB, Reference design KBS-3V</i>	<i>2012 Oct 25-26</i>	<i>Palais des congrès de Montpellier</i>	<i>Scientific Community and open for all</i>	<i>~60</i>	<i>Europe</i>
5	<i>Mid-term Workshop LucoeX</i>	<i>SKB</i>	<i>WP4, KBS-3H Multi Purpose Test, LucoeX</i>	<i>2012 Oct 25-26</i>	<i>Palais des congrès de</i>	<i>Scientific Community and open for all</i>	<i>~60</i>	<i>Europe</i>

³ publications, conferences, workshops, web, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters, Other.

⁴ Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias, Other ('multiple choices' is possible).

			<i>Midterm Workshop</i>		<i>Montpellier</i>			
6	<i>Mid-term Workshop LucoeX</i>	<i>SKB</i>	<i>Horizontal deposition using water cushion technology, the KBS-3H deposition machine</i>	<i>2012 Oct 25-26</i>	<i>Palais des congrès de Montpellier</i>	<i>Scientific Community and open for all</i>	<i>~60</i>	<i>Europe</i>
7	<i>Mid-term Workshop LucoeX</i>	<i>SKB</i>	<i>Buffer manufacturing using uni-axial compaction</i>	<i>2012 Oct 25-26</i>	<i>Palais des congrès de Montpellier</i>	<i>Scientific Community and open for all</i>	<i>~60</i>	<i>Europe</i>
8	<i>AutomaatioXX seminar</i>	<i>SKB</i>	<i>Spent nuclear fuel deposition machine lifting control and pallet adjustment</i>	<i>2013 May 22</i>	<i>Helsinki</i>	<i>Scientific Community and open for all</i>	<i>~100</i>	<i>Europe</i>
9	<i>LucoeX Workshop, Bentonite-Buffer, -Blocks and –Granulates</i>	<i>SKB</i>	<i>Experiences from the transportation and handling of uni-axially compressed buffer blocks</i>	<i>2013 Oct 2nd</i>	<i>Zurich, Switzerland</i>	<i>Scientific Community and open for all</i>	<i>~40</i>	<i>Europe</i>
10	<i>LucoeX Workshop, Bentonite-Buffer, -Blocks and –Granulates</i>	<i>SKB</i>	<i>From Raw material to buffer components – The production process using uni-axial compression</i>	<i>2013 Oct 2nd</i>	<i>Zurich, Switzerland</i>	<i>Scientific Community and open for all</i>	<i>~40</i>	<i>Europe</i>
11	<i>IGDTP-Geodisposal 2014</i>	<i>SKB/Posiva</i>	<i>Proof-of-concept installations for repository concepts based in crystalline rock, LucoeX WP4 and 5</i>	<i>2014 June 24th</i>	<i>Manchester, UK,</i>	<i>Scientific Community and open for all</i>	<i>~400</i>	<i>Europe</i>
12	<i>Clays in Natural and Engineered Barriers for Radioactive Waste Confinement, 6th International Conference, Brussels,</i>	<i>SKB/B+Tech/Aitemin</i>	<i>Poster: KBS-3H Multi Purpose Test</i>	<i>2015 Mar 23–26</i>	<i>Brussels</i>	<i>Scientific Community and open for all</i>	<i>~400</i>	<i>Europe</i>
13	<i>LucoeX Conference and Workshop</i>	<i>SKB</i>	<i>Multi Purpose Test, LUCOEX WP4, a full scale demonstration of KBS-3H technology</i>	<i>2015 June 2-4</i>	<i>Oskarshamn, Sweden</i>	<i>Scientific Community and open for all</i>	<i>~80</i>	<i>Europe</i>

14	<i>LucoeX Conference and Workshop</i>	<i>SKB</i>	<i>Multi Purpose Test, LUCOEX WP4, Instrumentation – Experiences from planning, installation and monitoring</i>	<i>2015 June 2-4</i>	<i>Oskarshamn, Sweden</i>	Scientific Community and open for all	~80	Europe
15	<i>LucoeX Conference and Workshop</i>	<i>SKB</i>	<i>KBS-3H, LUCOEX WP4 - Experiences from directional core drilling at the Äspö HRL</i>	<i>2015 June 2-4</i>	<i>Oskarshamn, Sweden</i>	Scientific Community and open for all	~80	Europe
16	<i>LucoeX Conference and Workshop</i>	<i>SKB</i>	<i>Production of buffer and backfill for the Multi-Purpose Test (MPT)</i>	<i>2015 June 2-4</i>	<i>Oskarshamn, Sweden</i>	Scientific Community and open for all	~80	Europe
17	<i>LucoeX Conference and Workshop</i>	<i>SKB</i>	<i>Poster: LUCOEX WP4 – Horizontal disposal in crystalline rock - M. Kronberg et al</i>	<i>2015 June 2-4</i>	<i>Oskarshamn, Sweden</i>	Scientific Community and open for all	~80	Europe
18								

APPENDIX III – CONFIDENTIAL INFORMATION

The applications for patents, trademarks, registered designs, etc. shall be listed according to the template B1 provided hereafter.

The list should, specify at least one unique identifier e.g. European Patent application reference. For patent applications, only if applicable, contributions to standards should be specified. This table is cumulative, which means that it should always show all applications from the beginning until after the end of the project.

TEMPLATE B1: LIST OF APPLICATIONS FOR PATENTS, TRADEMARKS, REGISTERED DESIGNS, ETC.					
Type of IP Rights ⁵ :	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Application reference(s) (e.g. EP123456)	Subject or title of application	Applicant (s) (as on the application)
n/a					

⁵ A drop down list allows choosing the type of IP rights: Patents, Trademarks, Registered designs, Utility models, Others.

Part B2

Please complete the table hereafter:

Type of Exploitable Foreground ⁶	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yy yy	Exploitable product(s) or measure(s)	Sector(s) of application ⁷	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
<i>n/a</i>								

In addition to the table, please provide a text to explain the exploitable foreground, in particular:

- Its purpose
- How the foreground might be exploited, when and by whom
- IPR exploitable measures taken or intended
- Further research necessary, if any
- Potential/expected impact (quantify where possible)

⁶ General advancement of knowledge, Commercial exploitation of R&D results, Exploitation of R&D results via standards, exploitation of results through EU policies, exploitation of results through (social) innovation.

⁷ NACE nomenclature: http://ec.europa.eu/competition/mergers/cases/index/nace_all.html

APPENDIX IV – EC QUESTIONAR

The following questions will assist the Commission to obtain statistics and indicators on societal and socio-economic issues addressed by projects. The questions are arranged in a number of key themes. As well as producing certain statistics, the replies will also help identify those projects that have shown a real engagement with wider societal issues, and thereby identify interesting approaches to these issues and best practices. The replies for individual projects will not be made public.

A General Information	
Grant Agreement Number:	269905
Title of Project:	LUCOEX
Name and Title of Coordinator:	Jan Gugala, Project Manager SKB AB

B Ethics	
<p>1. Did your WP undergo an Ethics Review (and/or Screening)?</p> <ul style="list-style-type: none"> If Yes: have you described the progress of compliance with the relevant Ethics Review/Screening Requirements in the frame of the periodic/final work package reports? <p>Special Reminder: the progress of compliance with the Ethics Review/Screening Requirements should be described in the Period/Final Work package Reports under the Section 3.2.2 'Work Progress and Achievements'</p>	No
<p>2. Please indicate whether your WP involved any of the following issues (tick box) :</p>	No
RESEARCH ON HUMANS	
• Did the work package involve children?	
• Did the work package involve patients?	
• Did the work package involve persons not able to give consent?	
• Did the work package involve adult healthy volunteers?	
• Did the work package involve Human genetic material?	
• Did the work package involve Human biological samples?	
• Did the work package involve Human data collection?	
RESEARCH ON HUMAN EMBRYO/FOETUS	
• Did the work package involve Human Embryos?	
• Did the work package involve Human Foetal Tissue / Cells?	
• Did the work package involve Human Embryonic Stem Cells (hESCs)?	
• Did the work package on human Embryonic Stem Cells involve cells in culture?	
• Did the work package on human Embryonic Stem Cells involve the derivation of cells from Embryos?	
PRIVACY	
• Did the work package involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	
• Did the work package involve tracking the location or observation of people?	
RESEARCH ON ANIMALS	
• Did the work package involve research on animals?	
• Were those animals transgenic small laboratory animals?	
• Were those animals transgenic farm animals?	
• Were those animals cloned farm animals?	
• Were those animals non-human primates?	
RESEARCH INVOLVING DEVELOPING COUNTRIES	
• Did the work package involve the use of local resources (genetic, animal, plant etc)?	
• Was the work package of benefit to local community (capacity building, access to healthcare, education etc)?	
DUAL USE	
• Research having direct military use	0 Yes 0 No
• Research having the potential for terrorist abuse	

C Workforce Statistics

3. Workforce statistics for the work package: Please indicate in the table below the number of people who worked on the work package (on a headcount basis).

Type of Position	Number of Women	Number of Men
Scientific Coordinator	0	4
Work package leaders	0	4
Experienced researchers (i.e. PhD holders)	0	3
PhD Students	1	1
Other	2	10

4. How many additional researchers (in companies and universities) were recruited specifically for this work package?

Of which, indicate the number of men:

D Gender Aspects

5. Did you carry out specific Gender Equality Actions under the work package? Yes No

6. Which of the following actions did you carry out and how effective were they?

- | | Not at all effective | Very effective |
|---|---|---|
| <input type="checkbox"/> Design and implement an equal opportunity policy | <input type="radio"/> <input type="radio"/> <input type="radio"/> <input type="radio"/> <input type="radio"/> | <input type="radio"/> <input type="radio"/> <input type="radio"/> <input type="radio"/> <input type="radio"/> |
| <input type="checkbox"/> Set targets to achieve a gender balance in the workforce | <input type="radio"/> <input type="radio"/> <input type="radio"/> <input type="radio"/> <input type="radio"/> | <input type="radio"/> <input type="radio"/> <input type="radio"/> <input type="radio"/> <input type="radio"/> |
| <input type="checkbox"/> Organise conferences and workshops on gender | <input type="radio"/> <input type="radio"/> <input type="radio"/> <input type="radio"/> <input type="radio"/> | <input type="radio"/> <input type="radio"/> <input type="radio"/> <input type="radio"/> <input type="radio"/> |
| <input type="checkbox"/> Actions to improve work-life balance | <input type="radio"/> <input type="radio"/> <input type="radio"/> <input type="radio"/> <input type="radio"/> | <input type="radio"/> <input type="radio"/> <input type="radio"/> <input type="radio"/> <input type="radio"/> |
| <input type="radio"/> Other: <input type="text"/> | | |

7. Was there a gender dimension associated with the research content – i.e. wherever people were the focus of the research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?

- Yes- please specify
- No

E Synergies with Science Education

8. Did your work package involve working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint work packages)?

Yes- please specify

It offered a master thesis opportunity

No

9. Did the work package generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?

Yes- please specify

No

F Interdisciplinarity

10. Which disciplines (see list below) are involved in your work package?

Main discipline: 1.4, 2.1 and 2.3

Associated discipline: 2.2

Associated discipline:

CLASSIFICATION OF SCIENTIFIC DISCIPLINES ACCORDING TO THE FRASCATI MANUAL

1. NATURAL SCIENCES

- 1.1 Mathematics and computer sciences [mathematics and other allied fields: computer sciences and other allied subjects (software development only; hardware development should be classified in the engineering fields)]
- 1.2 Physical sciences (astronomy and space sciences, physics and other allied subjects)
- 1.3 Chemical sciences (chemistry, other allied subjects)
- 1.4 Earth and related environmental sciences (geology, geophysics, mineralogy, physical geography and other geosciences, meteorology and other atmospheric sciences including climatic research, oceanography, vulcanology, palaeoecology, other allied sciences)
- 1.5 Biological sciences (biology, botany, bacteriology, microbiology, zoology, entomology, genetics, biochemistry, biophysics, other allied sciences, excluding clinical and veterinary sciences)

2 ENGINEERING AND TECHNOLOGY

- 2.1 Civil engineering (architecture engineering, building science and engineering, construction engineering, municipal and structural engineering and other allied subjects)
- 2.2 Electrical engineering, electronics [electrical engineering, electronics, communication engineering and systems, computer engineering (hardware only) and other allied subjects]
- 2.3. Other engineering sciences (such as chemical, aeronautical and space, mechanical, metallurgical and materials engineering, and their specialised subdivisions; forest products; applied sciences such as geodesy, industrial chemistry, etc.; the science and technology of food production; specialised technologies of interdisciplinary fields, e.g. systems analysis, metallurgy, mining, textile technology and other applied subjects)

3. MEDICAL SCIENCES

- 3.1 Basic medicine (anatomy, cytology, physiology, genetics, pharmacy, pharmacology, toxicology, immunology and immunohaematology, clinical chemistry, clinical microbiology, pathology)
- 3.2 Clinical medicine (anaesthesiology, paediatrics, obstetrics and gynaecology, internal medicine, surgery, dentistry, neurology, psychiatry, radiology, therapeutics, otorhinolaryngology, ophthalmology)
- 3.3 Health sciences (public health services, social medicine, hygiene, nursing, epidemiology)

4. AGRICULTURAL SCIENCES

- 4.1 Agriculture, forestry, fisheries and allied sciences (agronomy, animal husbandry, fisheries, forestry, horticulture, other allied subjects)
- 4.2 Veterinary medicine

5. SOCIAL SCIENCES

- 5.1 Psychology
- 5.2 Economics
- 5.3 Educational sciences (education and training and other allied subjects)
- 5.4 Other social sciences [anthropology (social and cultural) and ethnology, demography, geography (human, economic and social), town and country planning, management, law, linguistics, political sciences, sociology, organisation and methods, miscellaneous social sciences and interdisciplinary, methodological and historical S1T activities relating to subjects in this group. Physical anthropology, physical geography and psychophysiology should normally be classified with the natural sciences].

6. HUMANITIES

- 6.1 History (history, prehistory and history, together with auxiliary historical disciplines such as archaeology, numismatics, palaeography, genealogy, etc.)
- 6.2 Languages and literature (ancient and modern)
- 6.3 Other humanities [philosophy (including the history of science and technology) arts, history of art, art criticism, painting, sculpture, musicology, dramatic art excluding artistic "research" of any kind, religion, theology, other fields and subjects pertaining to the humanities, methodological, historical and other S1T activities relating to the subjects in this group]

G Engaging with Civil society and policy makers			
11a Did your work package engage with societal actors beyond the research community? (if 'No', go to Question 14)	<input type="radio"/> x <input type="radio"/>		Yes No
11b If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)? <ul style="list-style-type: none"> <input type="radio"/> No <input type="radio"/> Yes- in determining what research should be performed <input type="radio"/> Yes - in implementing the research <input checked="" type="radio"/> Yes, in communicating /disseminating / using the results of the work package 			
11c In doing so, did your work package involve actors whose role is mainly to organise the dialogue with citizens and organised civil society (e.g. professional mediator; communication company, science museums)?	x <input type="radio"/> <input type="radio"/>		Yes No
12. Did you engage with government / public bodies or policy makers (including international organisations)			
<ul style="list-style-type: none"> <input type="radio"/> No <input type="radio"/> Yes- in framing the research agenda <input type="radio"/> Yes - in implementing the research agenda <input checked="" type="radio"/> Yes, in communicating /disseminating / using the results of the work package 			
13a Will the work package generate outputs (expertise or scientific advice) which could be used by policy makers?			
<ul style="list-style-type: none"> <input type="radio"/> Yes – as a primary objective (please indicate areas below- multiple answers possible) <input checked="" type="radio"/> Yes – as a secondary objective (please indicate areas below - multiple answer possible) <input type="radio"/> No 			
13b If Yes, in which fields?			
Agriculture Audiovisual and Media Budget Competition Consumers Culture Customs Development Economic and Monetary Affairs Education, Training, Youth Employment and Social Affairs	<input checked="" type="checkbox"/> Energy Enlargement Enterprise Environment External Relations External Trade Fisheries and Maritime Affairs Food Safety Foreign and Security Policy Fraud Humanitarian aid	Human rights Information Society Institutional affairs Internal Market Justice, freedom and security Public Health Regional Policy <input checked="" type="checkbox"/> Research and Innovation Space Taxation Transport	

13c If Yes, at which level?

Local / regional levels

National level

European level

International level

H Use and dissemination		
14. How many Articles were published/accepted for publication in peer-reviewed journals?	2	
To how many of these is open access ⁸ provided?		
How many of these are published in open access journals?	all	
How many of these are published in open repositories?		
To how many of these is open access not provided?		
Please check all applicable reasons for not providing open access:		
<input type="checkbox"/> publisher's licensing agreement would not permit publishing in a repository <input type="checkbox"/> no suitable repository available <input type="checkbox"/> no suitable open access journal available <input type="checkbox"/> no funds available to publish in an open access journal <input type="checkbox"/> lack of time and resources <input type="checkbox"/> lack of information on open access <input type="checkbox"/> other ⁹ :		
15. How many new patent applications ('priority filings') have been made? <i>("Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant).</i>	0	
16. Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).	Trademark	0
	Registered design	0
	Other	0
17. How many spin-off companies were created / are planned as a direct result of the work package?	0	
<i>Indicate the approximate number of additional jobs in these companies:</i>		0
18. Please indicate whether your work package has a potential impact on employment, in comparison with the situation before your work package:		
<input type="checkbox"/> Increase in employment, or <input type="checkbox"/> Safeguard employment, or <input type="checkbox"/> Decrease in employment, <input type="checkbox"/> Difficult to estimate / not possible to quantify	<input type="checkbox"/> In small & medium-sized enterprises <input type="checkbox"/> In large companies <input checked="" type="checkbox"/> None of the above / not relevant to the work package	
19. For your work package partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (FTE = one person working fulltime for a year) jobs:	Indicate figure:	
Difficult to estimate / not possible to quantify	x <input type="checkbox"/>	

⁸ Open Access is defined as free of charge access for anyone via Internet.

⁹ For instance: classification for security project.

I Media and Communication to the general public

20. As part of the work package, were any of the beneficiaries professionals in communication or media relations?

Yes No

21. As part of the work package, have any beneficiaries received professional media / communication training / advice to improve communication with the general public?

Yes No

22 Which of the following have been used to communicate information about your work package to the general public, or have resulted from your work package?

- | | | |
|--|-------------------------------------|---|
| <input type="checkbox"/> Press Release | <input checked="" type="checkbox"/> | Coverage in specialist press |
| <input type="checkbox"/> Media briefing | <input type="checkbox"/> | Coverage in general (non-specialist) press |
| <input checked="" type="checkbox"/> TV coverage / report | <input checked="" type="checkbox"/> | Coverage in national press |
| <input type="checkbox"/> Radio coverage / report | <input type="checkbox"/> | Coverage in international press |
| <input type="checkbox"/> Brochures /posters / flyers | <input checked="" type="checkbox"/> | Website for the general public / internet |
| <input type="checkbox"/> DVD /Film /Multimedia | <input checked="" type="checkbox"/> | Event targeting general public (festival, conference, exhibition, science café) |

23 In which languages are the information products for the general public produced?

- | | | |
|---|-------------------------------------|---------|
| <input checked="" type="checkbox"/> Language of the coordinator | <input checked="" type="checkbox"/> | English |
| <input type="checkbox"/> Other language(s) | | |