Going Underground for Testing and Demonstration: Challenge of Implementation of a Disposal System - 14546

Tiina Jalonen, Ismo Aaltonen, and Timo Äikäs
Posiva Oy, Eurajoki, Finland

ABSTRACT

Posiva submitted in 2012 a license application for constructing an encapsulation plant and a deep repository for spent nuclear fuel at the Olkiluoto site in Western Finland. The current estimate for the handling period is two years and Posiva expects the license to be granted in 2015. Meanwhile the company gets ready to implement and finalise the disposal concept KBS-3. Posiva has planned a testing and demonstration programme for this purpose. The programme is divided in two phases: the first phase consists of design and construction of the prototypes of the machinery required to assemble the engineered barriers and testing of the prototype machinery above ground and underground in ONKALO. In the second phase, the assembly of the entire disposal system will be demonstrated with the prototype machinery. This is planned to be performed in 2016-2018, and once performed according to the defined acceptance criteria for the 'as designed' state, addresses the feasibility of the disposal system and thus the readiness for the submission of license application for operation. In parallel to preparations and the demonstration, the experience and feedback gained in the first phase tests will be gathered for updating the construction plans of the machinery and updating and finalizing the quality plans for the barriers for actual disposal operations. The challenge for the planned research and technical demonstration work is the need for an effective coordination with the construction and other implementation activities under the strict scrutiny of the safety authority.

INTRODUCTION

The long-term programme aiming at site selection for a deep repository for spent nuclear fuel was started in 1983 in Finland as a response to the Government decision on the principles and time schedule for nuclear waste management. The programme was divided into phases for carrying out the site selection research and the development of the technical concept for geologic disposal as well for safety assessment. In the early phase of the programme it was concluded that the presence of suitable generic underground rock laboratory (URL) in Sweden at Stripa (and later at Äspö), which was located in similar bedrock to those candidates being considered in Finland for deep disposal, precluded the need to develop the own generic URL in an early phase of the programme. It was proposed, however, to develop a site-specific underground research facility at the selected site, as the last phase of the detailed characterisation programme as a confirmation of the site properties. A possibility to operate a small underground test facility (known as the Research Tunnel) opened at the repository for low- and intermediate level waste at Olkiluoto once this was constructed during 1980s.

The most important objective of an underground characterisation and research facility (UCRF) like ONKALO is to allow an in-depth investigation of the selected geological environment and to provide the opportunity to acquire data and allow testing of models at more appropriate scales and conditions than can be achieved from the surface by borehole studies. In many countries, when planning underground research facilities, there has been announced that the planned facility will not be used as a repository which would require a license to be built.
In the Finnish licensing system the Decision-in-Principle (DiP) of the Government makes possible for the implementer to make a significant investment at the selected site before the actual construction license has been received. DiP is the first step of the licensing process and it is

required for a nuclear facility having considerable general significance. This is essentially a political decision: the Government decides if the construction project is in line with the overall good of society. The host municipality has a veto right and the Parliament has the choice of ratifying or not ratifying the decision.

Based on the Government's DiP in 2000 and its ratification by Parliament 2001, Posiva started to plan to go underground at Olkiluoto, the site which had been selected to host the deep repository. The main target of the ONKALO was to confirm the suitability of the Olkiluoto bedrock for a geological repository, to obtain further information for detailed design of the repository and to assess the long-term safety and construction engineering solutions. It was also obvious that ONKALO will enable the testing of repository technology under actual conditions.

The next step at the ONKALO is the testing and demonstration of the practical implementation of KBS-3 system. For this purpose experimental drifts, called demonstration tunnels, have been excavated at the planned disposal depth. The realisation of these tunnels follows the design and work procedures presented for deposition tunnels in construction license application. The aim is that the future testing for operation license purposes would take place in as representative conditions as possible.

Posiva submitted the construction license application for a disposal facility to Government at the end of 2012. The disposal facility consists of two separate nuclear facilities, according to Finnish nuclear energy legislation, the encapsulation plant and the repository. In addition and directly linked to the license application, Posiva delivered a large package of technical and safety documents to STUK. This package includes the safety case for long-term safety, preliminary safety assessment report (PSAR) and topical reports. The topical reports include e.g. the detailed description of the Site based on information gained during the construction of ONKALO, a program for monitoring the site in various phases of the disposal program, design of the nuclear and auxiliary facilities and the design of the disposal system and its barriers and their safety functions and design requirements. Posiva's conclusion on the application and the package delivered to STUK is that geological disposal is safe presuming that it will be performed according to the requirements and acceptance criteria that are described in the documentation.

The plan to move forward to solve the remaining open issues, to mitigate the uncertainties of the performance of the repository system and to verify that set requirements can be met, Posiva submitted to the Government the Nuclear Waste Management Programme (YJH-2012) in September 2012. This program describes the remaining research, development and technical design (RTD) work to complete the development of the KBS-3 disposal concept, the plans to demonstrate the operational and long-term safety of the repository and to reach the readiness to submit the operation license. STUK is reviewing this program in parallel to reviewing the application.

The plan is to commence the construction of the encapsulation plant and first disposal tunnels after receiving the construction license in 2015. The parallel work of detailed design and construction of the facilities, finishing the RTD work of the concept and demonstrating the operational and long-term safety causes challenges in coordinating the work and the configuration of the whole system. The parallel work within planned activities is illustrated in the Fig. 1. A procedure called configuration management system has been launched in Posiva to meet the challenge for coordinating between these activities.

The final step to enter to operation of repository is the application for an operation license, which Posiva plans to submit to Government in 2020. The goal is to start the geologic disposal of spent nuclear fuel at Olkiluoto in early 2020s. [1]

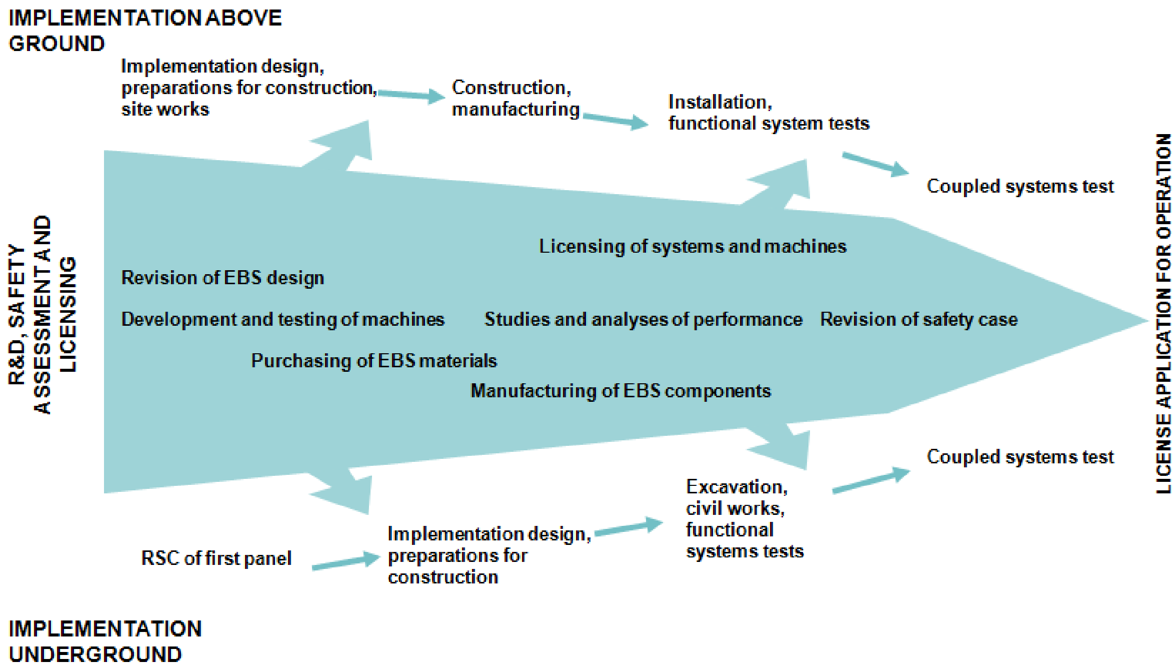

Fig. 1. Key task entities for planning and implementation regarding implementation taking place both above ground and underground for the purpose of achieving readiness for the operating licence application [1].

ONKALO

When Olkiluoto was selected in 1999 as the site for a deep geological repository for spent nuclear fuel, it was obvious that the knowledge gathered during the site selection had to be assessed underground for the detailed design and the accommodation of repository rooms to the characteristics of the local geology. As part of site confirmation Posiva decided to construct a UCRF to the planned disposal depth -420 m. The purpose of this facility, called ONKALO, was to produce detailed information for design and safety considerations which cannot be obtained from site investigations made from ground surface. ONKALO also provides an opportunity to test and demonstrate processes for assessment of rock suitability, design of repository rooms, their excavation and testing the implementation of the disposal system. In the rooms at disposal depth some essential methods for implementation can be tested at real site conditions. The implementation of ONKALO gives valuable experiences to personnel and is thus an important learning exercise.

Since ONKALO would be built at the selected site it was not intended solely for research purposes. It was designed to also serve as an access route to the repository when constructed. The Government's DiP has made possible for the safety authority STUK to supervise ONKALO construction as if it would be a nuclear facility. In this capacity STUK has made audits of Posiva to ascertain the work.

ONKALO has taken about 10 years to complete. The construction started in 2004 and reached the repository depth in 2010. Investigations have been carried out since the start of construction in conjunction with excavation. The information obtained from ONKALO largely confirms the conclusions drawn from the surface-based characterization carried out for the DiP in 2001. However, important new data has been obtained on, e.g., rock stress, geochemistry of the matrix waters and the detailed nature of fracturing at Olkiluoto.

The ONKALO consists of access tunnel, three vertical shafts and auxiliary rooms for technical systems (Fig. 2). Posiva has constructed demonstration facilities on the repository level in the ONKALO. They include four demonstration tunnels: two tunnels (~50 m and ~100 m) e.g. for testing the boring of disposal holes and other methods, two tunnels (both ~20 m) for plug test, and adjacent access tunnel.

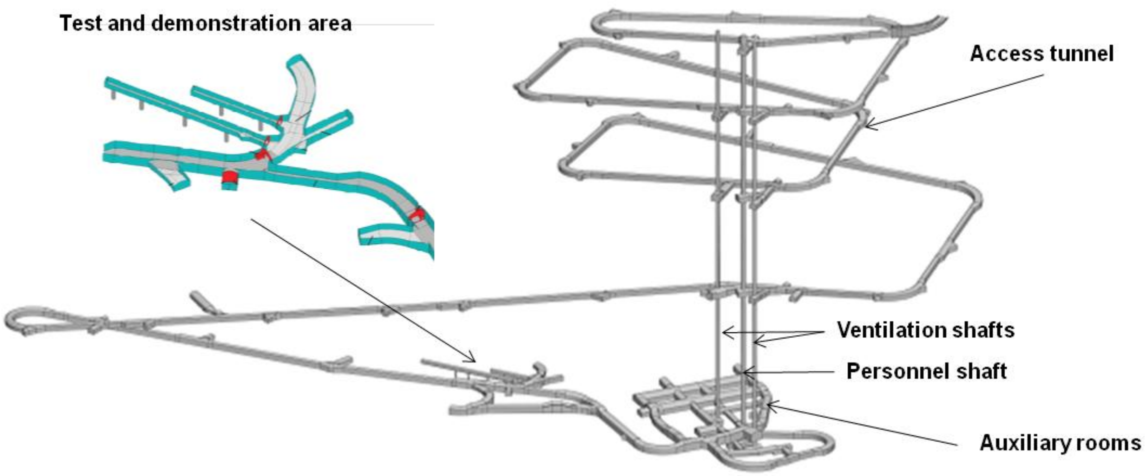

Fig. 2. Underground characterisation and research facility ONKALO and its test and demonstration area at Olkiluoto. Posiva Oy.

REACHING THE INITIAL STATE

The disposal system has to be assembled in the repository under active handling of radiation protection conditions, which leads to a requirement of remote handling. This is planned to happen at great depth underground, in rather small drifts. During the ongoing work attention has been paid to explore the feasibility of the operational aspects of the repository. The main effort has been paid on achieving the so called "initial state". This means the ‘as designed’ state which is used in the safety considerations as a starting point and which has been assessed with a great certainty to fulfil the safety criteria. Once this initial state is achieved and assured by quality control measures, the long-term safety will rest on the engineered barriers and on the geological environment, as planned.

The targeted initial states of the engineered barriers and the geological environment in Olkiluoto have been defined and described by requirements and acceptance criteria set to each barrier. The Finnish disposal system is based on the KBS-3 concept which comprises engineered barriers and crystalline bedrock as a natural barrier, illustrated in Figure 3.

The engineered barriers in the KBS-3 concept, which is adopted both by the Swedish and Finnish disposal programmes, include the disposal canister, the buffer and the backfill and plug of the deposition tunnel. The disposal canister, in which the spent nuclear fuel will be placed, consists of an outer copper canister that works as a barrier against corrosion and in inner nodular cast iron insert, which gives the mechanical strength required of the canister. The canister is surrounded and protected by bentonite buffer, which is highly compacted. The deposition tunnels will be backfilled with clay material with swelling capacities and plugged with a steel reinforced concrete plug.

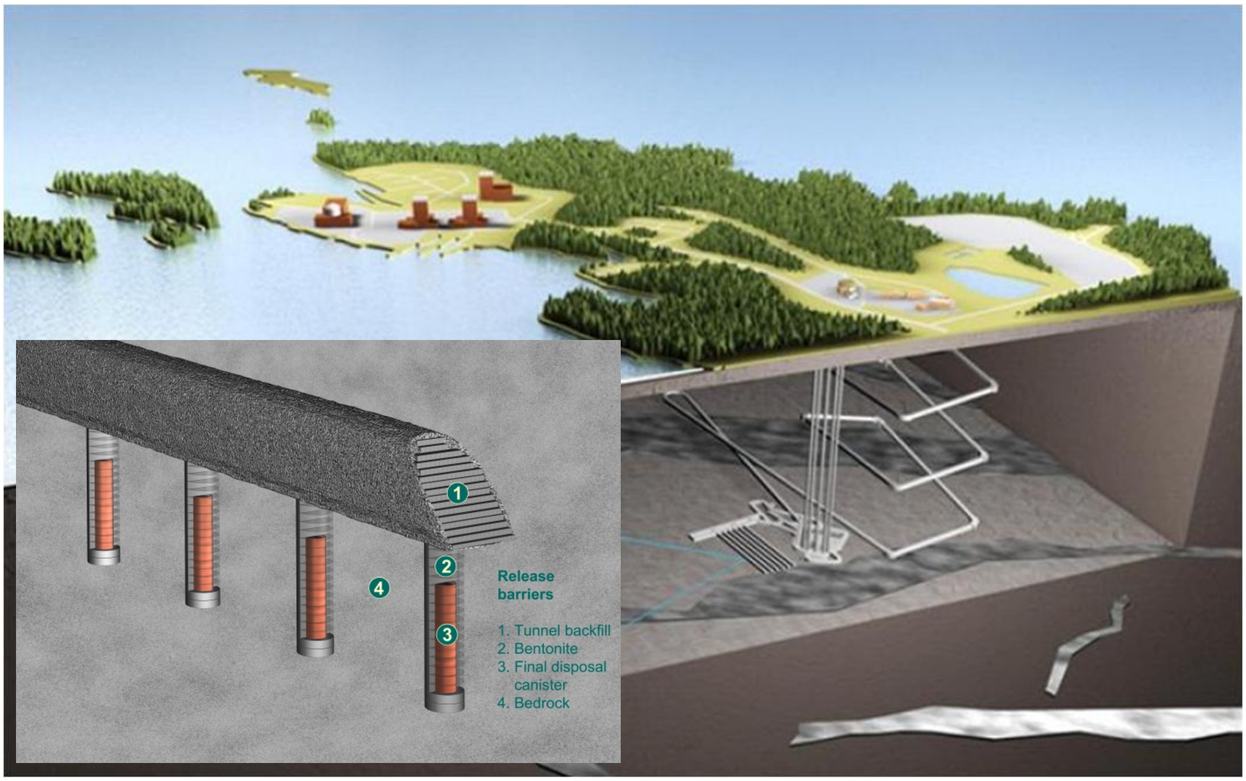

Fig. 3. Illustration of the KBS-3 repository and the barriers fitted to Olkiluoto site. Posiva Oy.

The main safety function of the canister is to ensure the complete containment of spent fuel for very long time periods. The safety assessment is usually stretched to 100,000 years and beyond. The safety function rests first and foremost on the mechanical strength of the canister insert and the corrosion resistance of the copper surrounding it. The safety functions of the buffer include the protection of the canisters from external processes that could compromise containment, and limitation and retardation of radionuclide releases in the event of canister failure. The safety functions of the host rock are to isolate the repository from the biosphere and normal human habitat, and to provide favourable and predictable mechanical, geochemical and hydrogeological conditions for the engineered barriers, protecting them from potentially detrimental processes taking place above and near the ground surface such that they contain the spent fuel. The rock also limits and retards inflow and release of harmful substances from the repository. Other system components like backfill, plugs, structural and sealing components, have not been assigned safety functions. They are designed to be compatible with, and support the safety functions of the other barriers [1].

Posiva has developed for the disposal system a comprehensive requirements management system called VAHA where the components of the disposal system, their roles in reaching the overall safety and requirements derived from the safety functions are presented. The VAHA presents subsystem performance requirements for each barrier. Due to the nature of long-term requirements, the validity of these subsystem performance requirements can only be addressed on the basis of models. The design requirements derived from the performance requirements for each barrier, in turn, shall be set so that they can be verified at the time of operation and that they imply the compliance of the whole disposal system once they are met. Further on, design specifications and acceptance criteria are set to each engineered barrier and to the host rock. The set design specifications and acceptance criteria form the frames for each barrier in which they must be fitted in during the operation. These frames are called targeted initial states and they act as an end point of the operational processes and as a basis for the consideration of long-term safety. The challenge in setting the requirements and verifying them is that they shall not be too strict to be fulfilled but on the other hand, they shall not be too loose to meet the safety criteria with good margin. The targeted initial states of each barrier are described in the topical reports of the construction license application, in the so called Production Line Reports [2,3,4,5]. The targeted initial states have been assessed with a great certainty to fulfil the safety criteria. Once these initial states are achieved and assured by quality control measures, the long-term safety will rest on the engineered barriers and on the geological environment, as planned.

To address that the targeted initial states of the barriers can be achieved in underground conditions and to test the quality control measures, a testing and demonstration programme has been established. A summary of the programme is included in the 3-year nuclear waste management programme "YJH-2012" published in September 2013 (in Finnish and translated later in English). [1]

HOST ROCK SUITABILITY

During the course of the ONKALO construction Posiva has developed the Rock Suitability Classification (RSC) system. RSC is needed in the future for locating suitable host rock volumes for repository facilities, their design and construction. The RSC system comprises both the classification criteria and the method for the suitability assessment during the construction of the repository. The aim of the classification is to identify and avoid host rock features which can be harmful to the favourable conditions within the repository. RSC work in Posiva includes also discussion of the RSC system implications for the fulfilment of the regulatory requirements concerning the host rock as a natural barrier and the site’s overall suitability.

The basis of the RSC criteria is in target properties, which set the general long-term safety-related requirements for the host rock. The criteria are measurable or observable parameters concerning rock stability i.e. fracturing and fault related issues, hydraulic properties, and groundwater chemistry. First, criteria version I were developed, the system was tested in ONKALO underground facilities and based on test results and further development the RSC-II was presented. The classification is carried out at four scales parallel to design and construction of the facilities: whole repository, disposal panel (that is a set of a central tunnel and deposition tunnels), deposition tunnels and, finally, deposition holes. Practical implementation of the RSC system as part of the repository construction procedure is described in RSC reporting and working instructions. Main goal in RSC work now is to produce a manual for the rock suitability assessment and its connections and relations to design and construction with descriptions of needed documentation and inspection.

The RSC implementation has been demonstrated during the construction of the demonstration tunnels of the ONKALO. Large set of geological, geophysical and hydrogeological data were collected from cored pilot holes drilled in the planned locations of the tunnels, and after the excavation the tunnels were mapped. Also, for example, charge potential measurement campaigns and tunnel seismic measurements were carried out. The data, interpretations and detailed scale bedrock model based on them were used in different stages of RSC implementation. RSC outputs were preliminary and final suitability assessments and, in the last phase, acceptance of single disposal holes.

The demonstration indicates that the RSC-II criteria are applicable in practise, and that the stages of investigation, modelling, suitability assessment, design, construction and decision-making process can be carried out successfully. [6]

TESTING IN PHASES

The testing and demonstration programme for KBS-3 is divided in two phases: the first phase consists of design and construction of the prototypes of the machinery to assemble the engineered barriers and testing of the prototype machinery first above ground and then underground in the ONKALO. As a part of the first phase, the designs, the production chain and quality plans of the engineered barrier components, and the construction plan of the deposition tunnel plug, will be finalized. In the second phase, the assembly of the entire disposal system will be demonstrated with the prototype machinery. The demonstration of the entire disposal system, which is planned to be performed in years 2016-2018, and once performed according to the defined acceptance criteria for the 'as designed' state, addresses the feasibility of the disposal system, and acts as a basis for long-term safety.

DEVELOPMENT AND TESTING OF DISPOSAL MACHINERY

The repository system and the most parts of it are first of a kind (FOAK). They have to be designed and constructed under well-developed safety culture where the culture of underground and machinery construction meets with the safety culture and regulations of nuclear facilities. Development and construction of a first of a kind system requires an iterative process where the most critical parts are first pre-tested and after gaining experience with the pre-tests, then constructed for the disposal purpose. The machinery that is needed to the deposition of the engineered barrier components allows no exception. Since there is no off-the-shelf machinery available for deposition tunnel dimensions and demanding installation accuracy to meet the set requirements with remote handling due to radiation, prototypes of installation machinery has been designed for the disposal canister, buffer components and for the backfill components. The prototype machinery will be constructed and tested to gain experience for the machinery that will be, after the successful tests, designed and constructed for disposal purposes. Posiva's overall schedule makes room for only one iterative round for the testing and demonstration program, which challenges to meet the set criteria at once and coordinate the work well with the final detailed design and construction of the actual machinery and the repository. This requires that the requirements and guidelines from the Finland's Radiation and Nuclear Safety Authority STUK are clearly interpreted.

Canister Installation

The canister is planned to be placed into the bentonite-lined deposition hole using the canister transfer and installation machinery as illustrated in Figure 4 on the right hand side. The installation tolerance is demanding since the nominal gap between the canister and the buffer is 10 mm in radius and the height of the canister varies from 3.5 m to 5.2 m for various spent fuel types. The weight of the canister varies from 18.8 to 29.0 metric tons. During the conceptual design of the prototype machinery, a solution with an installation cart was developed for each canister type, optimized for the length of the canister, and that all these devices can be moved by using the same tractor. The concept is similar to the transport cask transfer systems currently used at power plants.

After the machinery is parked in the designated location right above the deposition hole, the installation machinery is lifted to stand on its struts and leveled in its place. The radiation shield in where the canister is can then be rotated to a vertical position and the rear end of the radiation shield can be opened. This procedure has been developed for enabling even the installation of the more than 5-m-long canister into the deposition hole in a deposition tunnel with height of 4.4 m. The lowering of the canister can begin when the radiation shield is in a totally vertical position. To ensure that the process is successful and that the canister does not damage the bentonite buffer rings already placed in the hole, the lowering will be monitored with cameras. When the canister has been lowered into the bottom of the hole, the gripping mechanism can be removed from the canister cover lug and lifted back inside the radiation shield. After this, the radiation shield can be rotated back to a horizontal position and the vehicle can be driven out of the deposition tunnel. [2,4,7]

The development, design and construction of the prototype machinery for the canister installation have been divided into two phases. In the first phase, the main focus is in ensuring the operability of devices critical to the nuclear safety. This includes, for example, a canister handling equipment and a control mechanism for lowering the canister into the deposition hole aiming at meeting the strict installation tolerances between the canister and the buffer. In the second phase, the platform for machinery will be developed. The prototype now developed was dimensioned with the Olkiluoto reactors 1-2 spent fuel disposal canisters in mind. [1]

The testing of the prototype of canister installation machinery will begin next year in the testing facility and once the operation of the machinery has been shown acceptable, the machinery will be moved to ONKALO where it will be tested in the demonstration tunnel. A deposition hole bored in the demonstration tunnel will be lined with bentonite and the installation procedures with strict QA measures will be tested. The experiences gathered in these tests will be reported and used in design and construction of the actual canister installation machinery. [1]

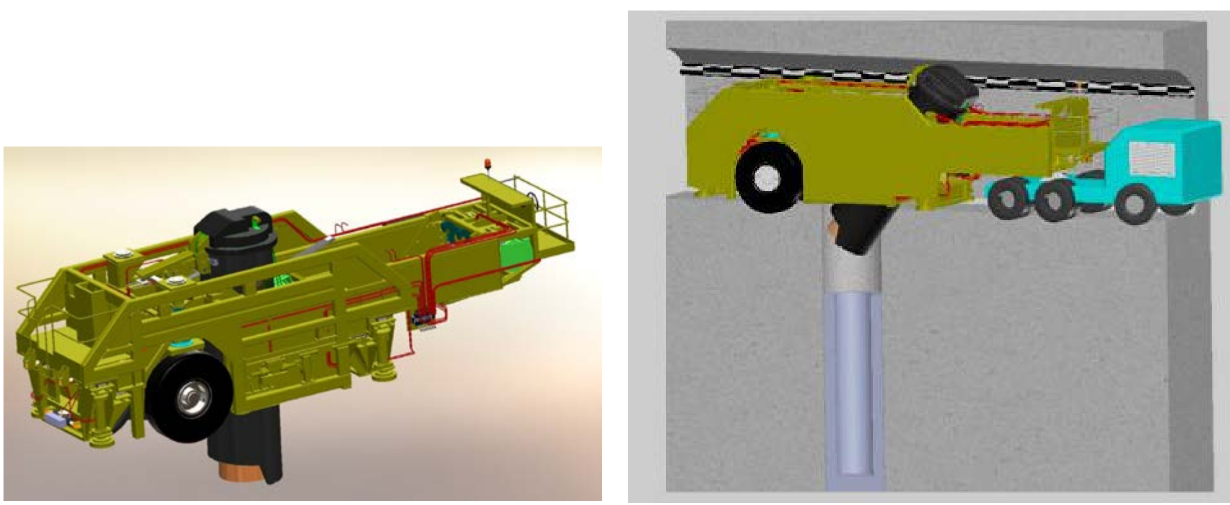

Fig. 4. Illustration of the canister installation machinery and the installation process. Posiva Oy.

Buffer Installation

The buffer consists of highly compacted bentonite blocks around the canister and compressed bentonite pellets between the bentonite blocks and the rock. The buffer blocks serve as the main components and the pellets are needed to allow the gap between the buffer and the rock a needed 50 mm width that makes the installation process possible without compromising the required density and swelling capacity of the whole buffer to ensure its performance. The prototype of the buffer installation machinery has been designed within a project called LUCOEX that is part of the EURATOM 7th framework program. The prototype buffer installation machinery consists of separate machinery for transporting the buffer components, the blocks and pellets, and for installing them into the deposition hole. The machinery is shown in figure 5.

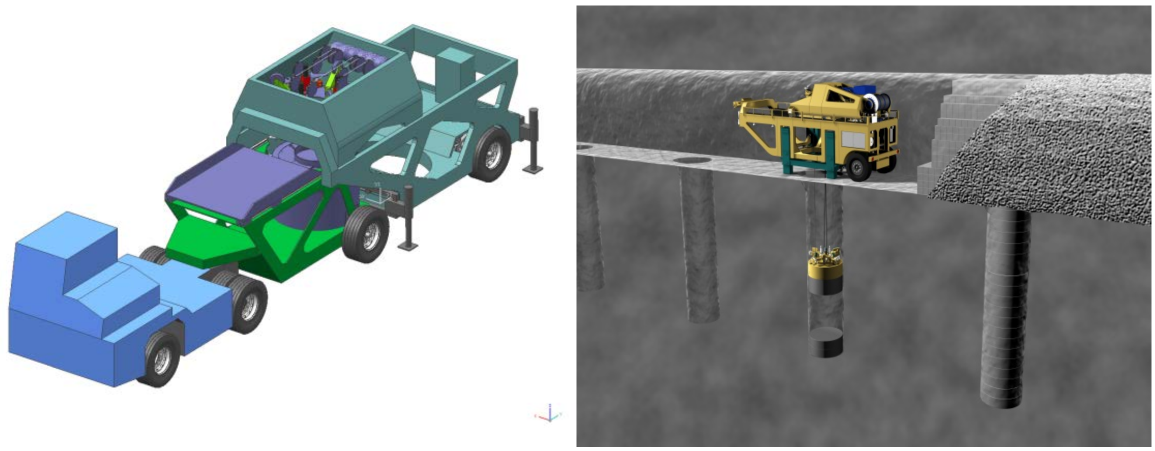

Fig. 5. Prototype of the buffer installation machinery and illustration of the installation process. Posiva Oy.

The machinery has been tested at the factory to confirm that it moves and performs according to requirements set to it. The pre-tests for installation will be conducted in a test facility above ground at the ONKALO site. The test facility is equipped with an artificial deposition hole. Normal operational procedures will be tested in larger campaigns and with operational speed. In addition, some incidents that can cause delays or others disturbances and that shall be taken into consideration in the design of the machinery or in the procedures of the installation process will be tested. Once the tests above ground have been performed successfully, the machinery will be brought into the ONKALO, where it will be tested in real repository conditions in demonstration tunnels. The tests will aim at confirming that the requirements set for the installed buffer components can be met with the designed machinery in the repository conditions. The tests will give feedback to the design and requirements of the buffer components and the machinery. In the case that some improvements are needed, the experiences with the prototype will be taken into consideration in designing the machinery for disposal purposes. The actual machinery is planned to be designed in year 2016.

Backfill Installation

The deposition tunnel backfill consists of pre-compacted blocks as the main backfill material. In addition, the deposition tunnel floor is levelled using an in situ compaction method similar to road construction and installation of pellets between the backfill blocks and the bedrock by spraying.

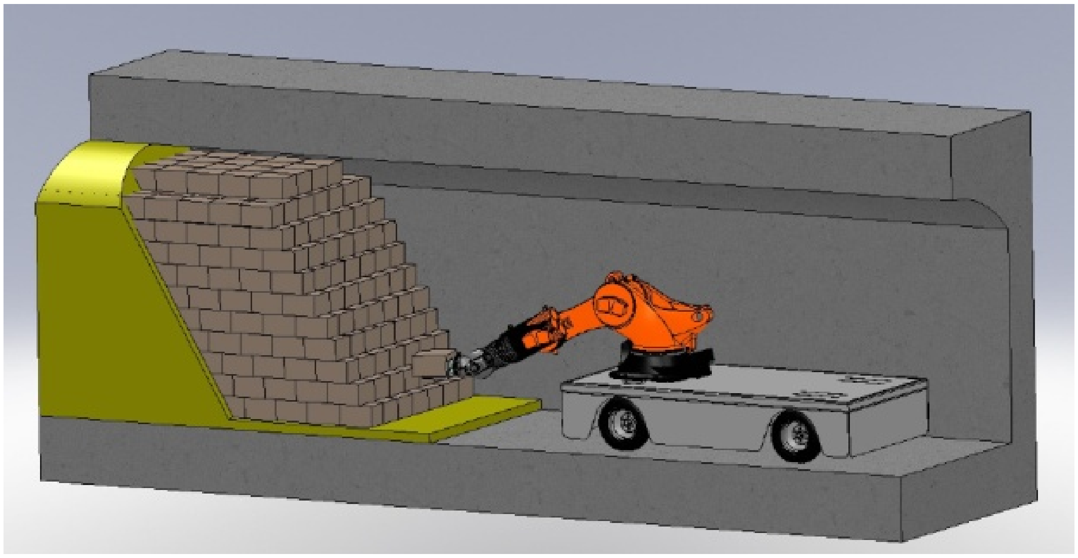

Fig. 6. Prototype of the backfilling robot.

The backfill blocks are planned to be installed on top of the leveled floor with an installation robot shown in Figure 6, which can be equipped with a spraying device. The prototype of the robot has been designed and is ready to be constructed. The robot will be tested first in the factory where it will be constructed and then in the testing facility at ONKALO site before moving it underground. The backfilling tests in ONKALO will be performed during 2014 -2015 and the special attention will be paid to handling of inflowing water from the bedrock fractures to prevent it from disturbing the installation of clay components that react easily with water. The operation of the repository, as a nuclear facility, involves that procedures are performed under strict scrutiny and high demands are set for quality assurance. The aim of these tests is to find out if the requirements on installation can be met and to gain experience in installations in real repository conditions. The testing will also address whether the excavated tunnel profile is appropriate for the installation or whether modification is needed in the excavation process. The experiences from the backfill tests will be gathered for the design and construction of the machinery for actual backfilling operations.

FULL-SCALE DISPOSAL SYSTEM DEMONSTRATION

The second phase of testing and demonstration plan will be launched once the first phase tests have been performed successfully. The aim of second phase demonstration is to address that the entire disposal system can be installed in one chain in the repository conditions according to set requirements and QA procedures. The demonstration is planned to be performed in a demonstration tunnel with a certain amount deposition holes bored in the tunnel floor. The demonstration will include full scale canisters, buffer components and backfilling and plugging of the tunnel, see figure 7. A specific attention will be paid in handling the inflowing water from the rock fractures to prevent it disturbing the installation and initial behaviour of the clay components. The demonstration will be equipped with instrumentation to follow the performance of the system after the plugging. However, such a large scale demo may give relatively little information on the long-term performance of the disposal system, since the processes that are of most interest in respect of long-term safety are typically very slow and hard to observe or measure.

Therefore, the full scale disposal system demonstration needs supported by lab-scale tests and modelling, modelled in whole in advance and the whole anticipated outcome of the demo and the instrumentation appropriate for the purpose needs to be planned thoroughly.

Since the deposition tunnels will not be accessible after the backfilling and plugging of a tunnel and the whole disposal system after the closure of the whole repository, all procedures shall comply with high accuracy the requirements set to them and they shall be documented carefully. These carefully planned procedures will be tested in the demonstration. The demonstration will be performed with the prototype machinery and the engineered barrier components will be obtained from separate component manufacture tests that are performed parallel to the first phase machinery tests.

ONKALO, which for the next coming years will serve as a test facility, is planned and constructed according to STUK requirements and under its strict surveillance in order to include ONKALO as a part of the repository. This limits also the use of foreign materials in ONKALO which sets challenges to tests and demonstrations. All the material that is needed only for testing purposes, even though it would be removed after use, shall go through a strict scrutiny of acceptance in Posiva, the same procedures that will be obeyed during the disposal operation.

The demonstration, which is planned to be performed in years 2016-2018, and once performed according to the defined acceptance criteria for the 'as designed' state, addresses the feasibility of the disposal system, and acts as a basis for long-term safety.

In parallel to preparations and performance of the demonstration, the experience and feedback gained in the first phase tests will be gathered for updating the construction plans of the machinery and for updating and finalizing the quality plans for the barriers for actual disposal operations. Once the machinery, the encapsulation plant and the underground facilities for the first phase of the operation have been constructed, and the demonstration has been performed successfully, the commissioning tests of the facilities will be started.

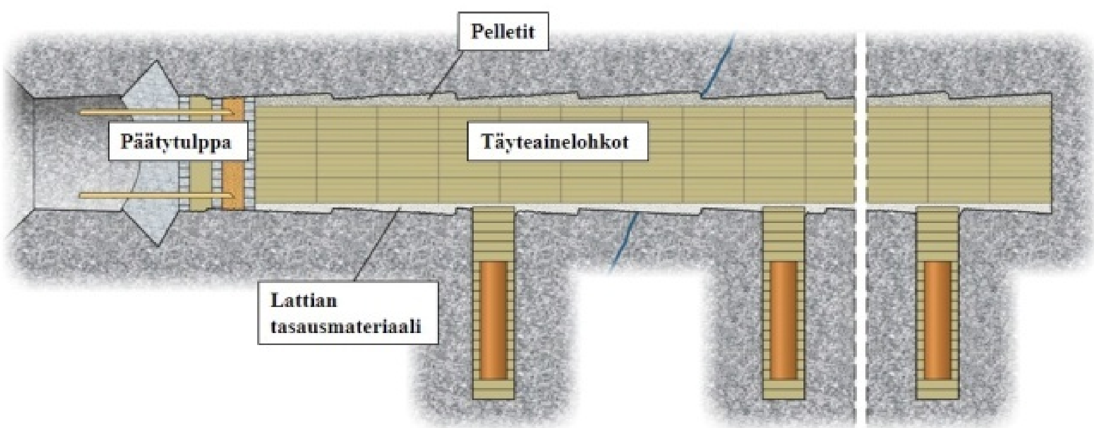

Fig. 7. Illustration of a full scale demonstration of the engineered barrier system.

DISCUSSION AND CONCLUSIONS

After the current licensing process Posiva is entering to implementation and aims at submitting the application for operation license. The challenge for the work in the future is to coordinate remaining RTD and implementation by an efficient way to ensure the smooth progress of the project to towards operation. The situation compared to an ordinary construction of power plants or other nuclear facilities will differ in terms of the completeness of repository design. Normally the detailed design is available before the start of the construction of a NPP but in the case of the underground facility this is not feasible and there has to be in place a management process to accommodate the accumulating new RTD information with the design of the facility for implementation.

The ONKALO construction and related RTD have produced plenty of valuable experience on the RTD and design procedures related to future repository construction. The planned programme for testing and demonstration will contribute to implementation design process and therefore the ambitious target is be carry out these tests "once through" and involve the safety authority in the process to accommodate their findings in the work process. The success in the testing and demonstration requires also that the careful interpretation of the regulatory guideline has been made.

REFERENCES

1. YJH-2012. Nuclear Waste Management at Olkiluoto and Loviisa Power Plants: Review of Current Status and Future Plans for 2013–2015. Posiva Oy, 2012.
2. Raiko H, Jalonen T, Nolvi L, Pastina B, Pitkänen J, Salonen T., (2012). "Canister Production Line 2012 - Design, production and initial state of the canister." POSIVA 2012-16, Posiva Oy, 2012, Eurajoki.
3. Juvankoski M, Ikonen K, Jalonen T., (2012). "Buffer Production Line 2012 - Design, production and initial state of the buffer." POSIVA 2012-17, Posiva Oy, 2012, Eurajoki.
4. Keto P, Hassan Md M, Karttunen P, Kiviranta L, Kumpulainen S, Sievänen U, Korkiala-Tanttu L, Koskinen V, Koho P, Jalonen T., (2012). "Backfill Production Line 2012 - Design, production and initial state of the deposition tunnel backfill and plug." POSIVA 2012-18, Posiva Oy, 2012, Eurajoki.
5. Mustonen S., (2012) "Underground Openings Production Line 2012 - Design, production and initial state of the underground openings." POSIVA-2022, Posiva Oy, Eurajoki.
6. McEwen T, Aro S, Kosunen P, Mattila J, Pere T, Käpyaho A, and Hellä P., (2012). "Rock Suitability Classification - RSC 2012". Posiva Report 2012-24. Posiva Oy, Eurajoki.
7. Wendelin T, Suikki M. 2008 Preliminary design for spent fuel canister handling system in a canister transfer and installation vehicle. Posiva Working report 2008-38. Posiva Oy, Eurajoki.