KBS-3H – DEVELOPMENT OF THE HORIZONTAL DISPOSAL CONCEPT

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ABSTRACT

SKB and Posiva are performing an R&D programme over the period of 2002-2007 with the overall aim to find out whether the KBS-3H concept can be regarded as an alternative to the KBS-3V concept for disposal of spent nuclear fuel. A feasibility study of the KBS-3H concept was carried out in 2002, followed by the setting up of basic design in 2003, and since 2004 the demonstration phase is ongoing, ending with the evaluation of the potential of the concept in 2007. In order to find out whether the concept can be regarded as a viable alternative to the KBS-3V concept demonstration and design work involve development of excavation technology of the drift, detailed studies on the function of the buffer bentonite, deposition equipment and methods for construction of low-pH shotcrete plugs. The investigations related to long-term safety are based on difference analyses between KBS-3V and KBS-3H and focus on KBS-3H specific processes. By the end of 2007 the KBS-3H concept will be reported including a preliminary safety case of the concept with Olkiluoto in Finland as a reference site.

1. Introduction

In 2001 SKB prepared an R&D programme /1/ for the KBS-3H (horizontal deposition) concept as an alternative disposal method to KBS-3V (vertical deposition). Both methods are based on the so-called KBS-3 concept with multi barrier systems but the orientation of the canister differs, Fig. 1. The repository for spent fuel is planned to be constructed at a depth of about 400-500 metres in crystalline bedrock.

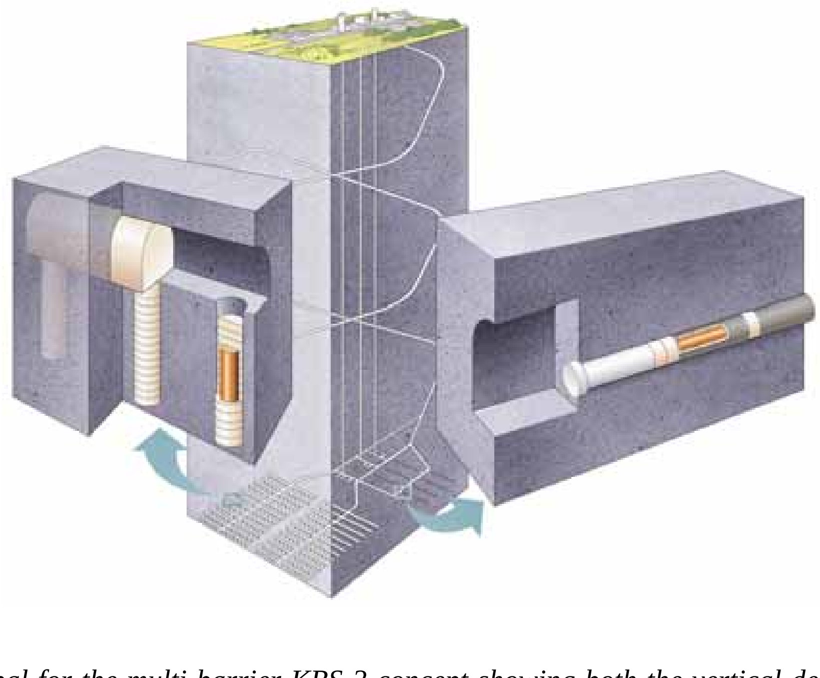

Fig. 1. *Principal for the multi barrier KBS-3 concept showing both the vertical deposition (KBS-3V) and the horizontal deposition (KBS-3H).*

In the fall of 2001, the boards of SKB and Posiva decided to start the common R&D programme on the alternative disposal method KBS-3H. The purpose of the programme carried out over the period 2002-2007 is to find out if KBS-3H can be regarded as an alternative to the KBS-3V concept. In order to fulfil the needs to evaluate the potential of the concept and if the R&D work should continue with the aim to become a viable alternative to the KBS-3V concept the following main activities are being carried out:

- Design and manufacturing of the deposition equipment.
- Development of KBS-3H design; all components to be emplaced in the drift, repository layout, and geological adaptation of the KBS-3H concept.
- Excavation of two horizontal drifts at the Äspö Hard Rock Laboratory (HRL) to be used for demonstration of the deposition equipment and design components.
- Compiling of a preliminary Safety Case of the KBS-3H concept with Olkiluoto as a reference site.

It should be noted that the deposition equipment since February 2004 is part of the technological project ESDRED: "Engineering Studies and Demonstration of repository Designs" and is co-funded by the European Commission (EC) as part of the sixth Euratom research and training Framework Programme (FP6) on nuclear energy (2002-2006)".

The development of the KBS-3H design and compilation of the safety case for the concept are the main topics of this paper.

2. KBS-3H concept

In the KBS-3H repository concept, multiple canisters containing spent fuel are emplaced in approximately 300 m long deposition drifts, slightly inclined towards the transport tunnel (Fig. 2). Each canister, with its surrounding bentonite buffer and a perforated steel shell, called supercontainer, is assembled in a handling cell in a cavern in the central area at repository level prior to emplacement in the drift. Each supercontainer is placed between two compacted bentonite distance blocks. In addition to providing the appropriate spacing to meet thermal loading requirements, the other main purpose of the distance blocks in the KBS-3H system is to separate the supercontainers from each other hydraulically, thus preventing the possibility of pathways for flow and advective transport along the drift.

The transport of the supercontainer in the drift is based on lifting of the container with a pallet with water cushions and alternating relative movement of the container and slide plate. The same machine will also be used for the transport of the distance blocks.

The spent fuel canisters are identical in both KBS-3V and KBS-3H and also the buffer material but the introduction of the steel supercontainer and also the serial emplacement of supercontainers in a drift are new features compared to the KBS-3V concept. Therefore the function and behaviour of the Engineered Barrier System (EBS) after emplacement is different and thus the long-term performance (safety case) for the two concepts will differ in some aspects.

3. Development of KBS-3H design

At present there are two different variations (called candidate designs) of KBS-3H design: a) Basic Design (BD) and b) design based on Drainage, Artificial Watering and air Evacuation (DAWE). BD alternative is based on assumption that the distance blocks will seal the supercontainer units in wet sections stepwise in sequence independently of each other. In DAWE design the drift can be artificially filled with water after plugging one compartment by a steel plug and sealing the compartment. The distance blocks will then also swell and isolate the supercontainer units simultaneously. These two KBS-3H candidate designs are at the moment being developed to proper level of details based on Olkiluoto bedrock data in order to evaluate the feasibility of the KBS-3H concept in 2007.

Both designs are based on the principle of dividing the deposition drift into compartments (Fig.2). The number of compartments depends on the water inflows and site-specific bedrock structure. The compartmentalisation is implemented by using a novel steel plug capable of taking the full hydrostatic force at 400-500 m level.

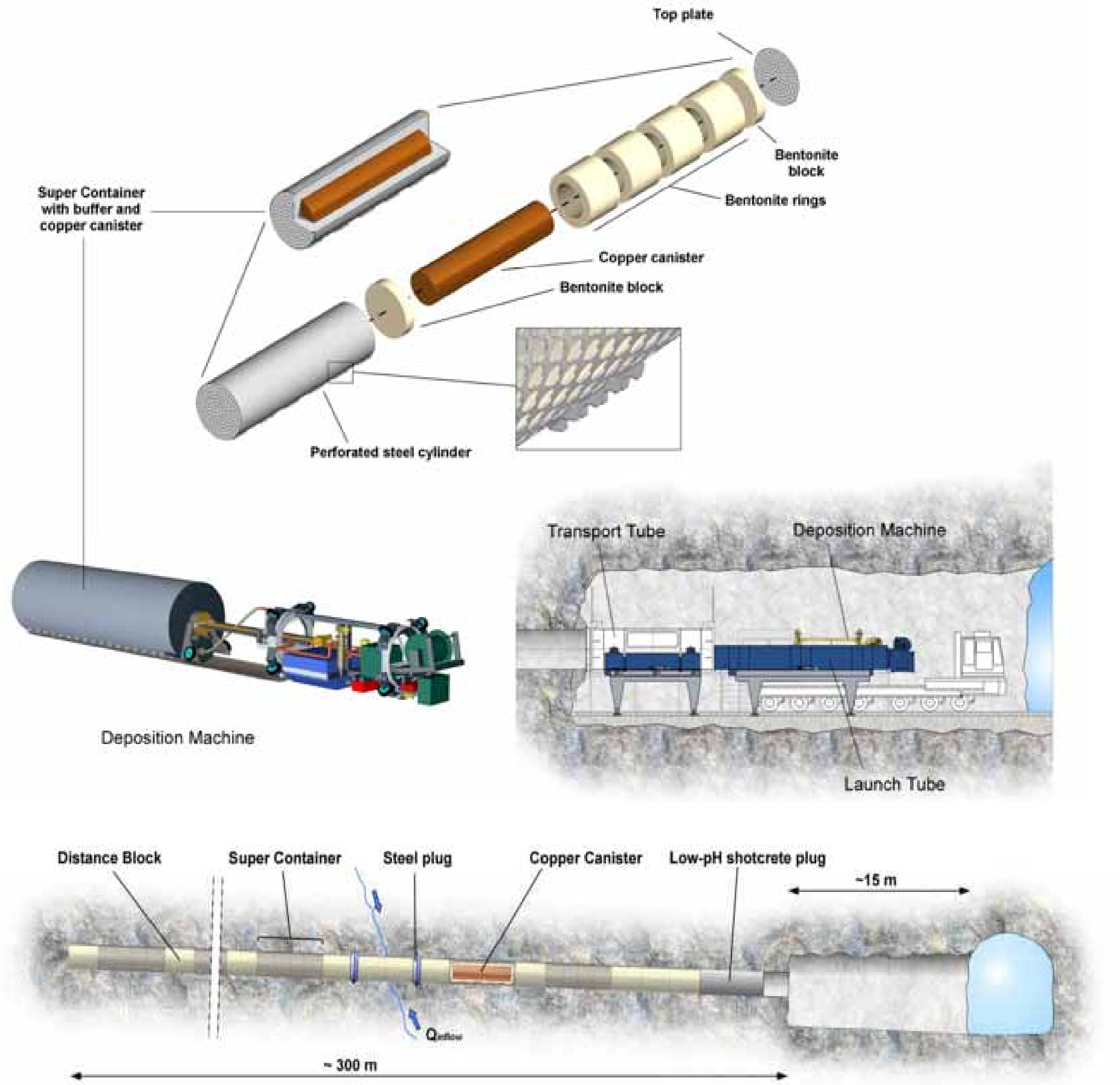

Fig.2 *Supercontainer, deposition equipment and the general arrangement of the drift.*

One important design factor of the concept is the groundwater control, which will affect the utilisation degree significantly. Therefore new approaches and techniques, such as a Mega Packer type injection device for post grouting by using low pH grouting materials, are investigated in order to improve the management of water inflows

Since the design includes new and not proven components, the functional analysis and testing of the design are significant part of the work. The work include testing of the most important design components at proper scales from laboratory up to full scale testing at the Äspö HRL in the two horizontal demonstration holes at -220 m level. The objective of these tests is to demonstrate that the individual fundamental components of the KBS-3H design function properly and that the design in total will fulfil the specified requirements and is sufficiently robust.

In order to evaluate the feasibility of the KBS-3H concept, an Olkiluoto specific layout adaptation is carried out to assess the site utilisation degree of the concept and to provide basis for safety assessment.

4. KBS-3H Safety Case

A preliminary Safety Case for the KBS-3H concept will be compiled at the end of 2007 with Olkiluoto as a reference site.

Only the significant differences with respect to KBS-3V are evaluated in detail, because the KBS-3H concept rests on the broad technical and scientific foundation of the KBS-3V experience with canister development, spent fuel studies, buffer studies, geosphere and biosphere issues and safety analysis. Thus, the requirements for providing a comprehensive synthesis of information are considerably reduced relative to that of a typical safety case. This 'difference analysis' approach is the foundation of the work for the KBS-3H safety case.

The processes that require special attention in both design and long-term safety studies are the early evolution of the system, related to the heterogeneous re-saturation of the buffer and distance block along the drift. The hydraulic conductivity, density and swelling pressure of the bentonite surrounding the canisters at the end of the period of transient THMCBG (Thermal, Hydraulic, Mechanical, Chemical, Biological and Geological) processes are key properties ensuring that the buffer carries out its safety role in both the KBS-3V and KBS-3H concepts. Thus, any processes during this transient phase leading to a loss or re-distribution of buffer mass are of particular concern. In the case of KBS-3H, piping and erosion have been identified as possible mechanisms leading to such a loss or re-distribution of mass /2/. Piping and erosion become less likely as the buffer saturates over time and increasing swelling pressure is exerted on the drift wall. Thus the magnitude and rate of increase in the hydraulic pressure differences that might create pipes and drive pipe flow are both relevant quantities. For the geosphere processes are, due to localised water flow effects, complex gas related processes in early phase, and possible reactivation of fractures in near-field rock (gas pressure) identified.

A key difference between KBS-3H and KBS-3V is the presence of additional steel components (e.g. supercontainer, steel plug) in KBS-3H that will corrode and introduce a complex set of gas issues in safety assessment, such as eventual gas bubble transport and transport of volatile radionuclides, accumulation of gas along the top of the drift, and its effect on groundwater transport. The eventual chemical alteration of bentonite, effect on rheological properties, swelling and hydraulic conductivity of bentonite due to the steel components are also of concern and these are being addressed /3, 4/.

Features, events and processes specific for KBS-3H will be described, analysed and discussed in the Process report. The report primarily aims at presenting the scientific knowledge and understanding of the internal processes and at providing a long-lasting basis for future assessments. As regards radionuclide transport analyses specific issues related to the KBS-3H are e.g., the fate of volatile radionuclides in gas phase (e.g. C-14). Fate of volatile radionuclides released from a defective canister during the re-saturation phase is somewhat different in KBS-3H vs. KBS-3V due to gas generation by the supercontainer and other structural materials.

The description and analyses of the evolution of the site and repository from emplacement of the first canisters in the repository over various transient phases into the far future forms together with the Process report the scientific basis for the preliminary Safety Case for a KBS-3H type spent fuel repository at Olkiluoto (Fig.3).

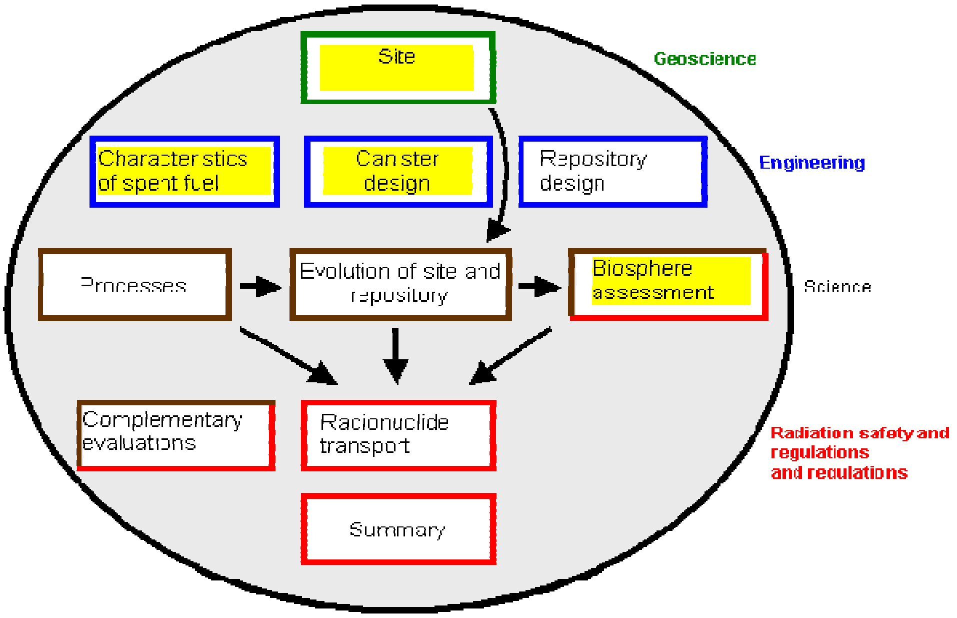

Fig. 3*:The reporting structure for the KBS-3H safety case 2007, The same reporting structure applies to the safety case for a KBS-3V type spent fuel repository at Olkiluoto /5/. The colours of the boxes indicate the areas covered by the different reports and arrows show the most important transfers of knowledge and data. Filling indicates reports common to the KBS-3V and -3H safety cases.*

5. Summary

The work within the KBS-3H concept study is reaching the milestone 2007 for the evaluation of the feasibility of the KBS-3H as an alternative for the KBS-3V concept.

The results of the evaluation of full-scale testing of the design components and the technical equipment needed in the concept will together with the safety case form the basis for the decision by SKB and Posiva how to proceed with the project, and for planning of further steps in development and testing work.

The KBS-3H-specific safety case focuses on major differences between the two KBS-3 concepts, which are largely related to the emplacement of the supercontainer and distance blocks and their subsequent evolution. Provided these aspects lead to limited differences in long-term evolution and performance of the system, there is expected to be little difference in the long-term safety of KBS-3V and KBS-3H.

6. References

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/3/ Carlson, L., Karnland, O., Olsson S., Smart, N. & Rance, A. 2006. Experimental studies on the interaction between corroding iron and bentonite. Posiva Working report 2006-60.

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