Challenges in Developing the Basic Design of the KBS-3 System into a Qualified and Industrially Viable Operation – 14465

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ABSTRACT

The programs for final disposal of spent nuclear fuel are similar in Sweden and Finland, and there has been extensive cooperation between the waste management organizations in the two countries over the years. This cooperation will now be deepened, aiming when possible for the same technical design. While a technically feasible reference design and layout is presented for the repositories in the two countries, detailed designs adapted to an industrialized process designed to fulfilling specific requirements on quality, cost and efficiency need still be developed. Also the repository layout needs to be adapted to the local conditions found when constructing the repository at depth. Both SKB and Posiva have developed design requirements and other conditions and presented these to the designer. However, the formulation of requirements such that they lead to designs that both meets long term safety and can be verified is not trivial and revision and harmonization between the organizations is needed. Essentially the detailed technical design need to be completed in time for the detailed design of the planned facilities in the KBS-3 repository system, i.e. the encapsulation plant, the facility for buffer and backfill bentonite component production and the underground repository.

INTRODUCTION

The programs for final disposal of spent nuclear fuel are similar in Sweden and Finland, and there has been extensive cooperation between the waste management organizations in the two countries over the years. In March 2011 the Swedish Nuclear Fuel and Waste Management Co. (SKB) submitted license applications according to the Act on Nuclear Activities and the Environmental Code for a final repository at Forsmark, Sweden. A comprehensive licensing review is currently undertaken by the Swedish Radiation Safety Authority (SSM) and the Environmental Court. Construction of the repository cannot begin until the necessary licenses have been granted. In December 2012 Posiva Oy, the expert organization responsible for the final disposal of spent nuclear fuel of the nuclear reactor owners in Finland, submitted a construction license application for the encapsulation plant and the disposal facility for the spent nuclear fuel produced in Finland. The application is currently reviewed by the Radiation and Nuclear Safety Authority in Finland, STUK. Since both programs now enter a stage of final design and implementation this cooperation will be deepened, aiming when possible for the same technical design.

The spent nuclear fuel repositories in Sweden and Finland will be constructed according to the KBS-3 method, see Figure 1, where the spent nuclear fuel will be emplaced in copper canisters with a cast iron insert, surrounded by a bentonite clay buffer and deposited in a repository at approximately 500 m below the ground surface in the saturated granitic rock in Forsmark and Olkiluoto, respectively. While a technically feasible reference design and layout is presented, detailed designs adapted to an industrialized process designed to fulfilling specific requirements on quality, cost and efficiency need still be developed. Also the repository layout needs to be adapted to the local conditions found when constructing the repository at depth.

To guide the future cooperation companies have developed a shared vision for the future. This vision *'Operating optimized facilities in 2030'* marks the objective and readiness to execute a plan for safe and economically optimized repository operation. The technology development for repository has been divided to the different phases: conceptual phase; design phase; implementation phase. The work within the conceptual phase will lead to the conceptual design, which means that a reference or alternative references has been selected according to the design basis. The design phase will lead first to the initial system design and thereafter to the detailed design and the aim is to show the fulfillment of requirements and have a developed production process for the component or system. The implementation phase will lead to the ready system or component, which can be handed over to the operation. The realization of the vision means, by joining forces, an attempt to make possible the most optimal burden to customers by licensing, manufacturing and procuring components jointly, by streamlining the operation procedures and supporting facilities and by aiming at further improvements.

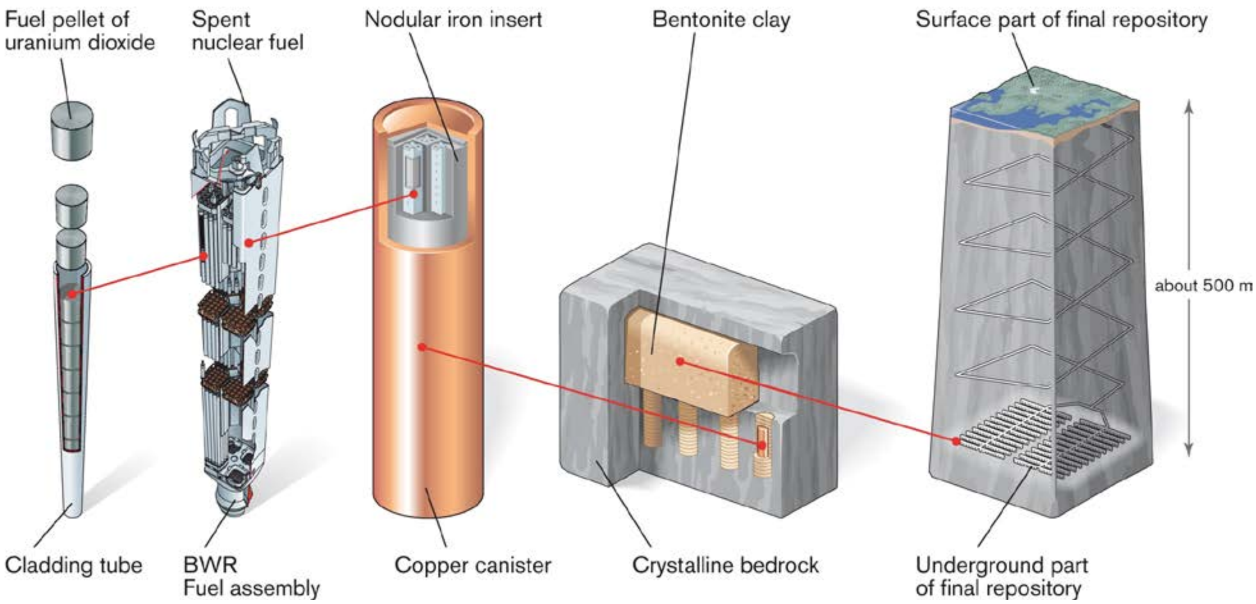

Fig. 1. The KBS-3 method.

METHODS

To be able to reach the shared company vision and make it possible, some strategic goals have to be recognized. The most important is that the KBS-3 method adopted by SKB and Posiva shall be technically similar. The prerequisite for this will be that the design basis and the requirements are the same or equivalent to the largest extent possible and lead to similar technical designs of the KBS-3 method. Having set this as a strategic goal requires that the work which is necessary to harmonize the requirements and technical solution shall be started and conducted in the near future. The contents of this work will form the basis for the cooperation in remaining R&D work of the KBS-3 method.

In practice, this means that the detailed technical design need to be completed in time for the detailed design of the planned facilities in the KBS-3 repository system, i.e. the encapsulation plant, the facility for buffer and backfill bentonite component production and the underground repository. However, technology development support will also be needed during implementation and start operation of these facilities. A technology development plan spanning the time from now until the license to start operation has been developed. This plan aims for a common holistic view and understanding of what is needed to reach the target operating facilities and it identifies the various development efforts needed in relation to the program plan for the spent nuclear fuel program with regard to time and resources.

REVISION AND HARMONIZATION OF DESIGN REQUIREMENTS

The repository design must be such that it results in a safe repository. For this reason, and in accordance with applicable regulations, both SKB and Posiva have developed design requirements and other conditions and presented these to the designer. The design requirements comprise requirements which the

KBS-3 facilities with their barriers must satisfy in order to ensure safety both during operation and after closure. These requirements specify e.g. what mechanical loads the barriers must be able to withstand, limitations concerning the composition and properties of the barrier materials, acceptable deviations in the dimensions of the barriers, and acceptance criteria for the various underground openings.

An initial set of design requirements is specified in the SKB and Posiva license applications, respectively. SKB has presented design requirements, actually called “design premises”, relating to post-closure safety [1] and demonstrated that the repository design assessed in the post closure safety assessment “SR-Site” [2] confirm to these requirement. In a similar manner, Posiva submitted their requirements, called “Design Basis” [3] as part of the license application submitted in December 2012. The safety of the resulting designs were assessed in “TURVA-2012” [4], which is Posiva’s safety case in support of application for a construction license for a disposal facility for spent nuclear fuel at the Olkiluoto site.

Both SKB’s and Posiva’s safety assessments clearly demonstrate that repositories will be safe. However, the formulation of what requirements shall be put on the design in order to ensure long term safety is not trivial. Safety Assessments usually study a few specific designs, and would generally not address if there are other designs that may also provide adequate safety. It is also easy to formulate rules that would lead to safety, but that are impossible to implement and verify. For this reason, the design requirements can only be developed iteratively.

A revision of the design premises that were presented in the applications is now being done based on experience from the ongoing technology development work and the safety assessments [2, 4] that were part of these applications, as well as relevant viewpoints that have emerged during the licensing process. A cross-check is made between design requirements for operation, post-closure safety and different production lines for the different barriers so that the reference design for the KBS-3 system and its subsystems agrees with the prevailing design premises. The aims of this revision are to:

- Harmonize the requirements formulated by SKB and Posiva, in order to set a common basis for the joint remaining technology development.
- Formulate requirements that are practically achievable and verifiable for all considered barriers.
- Strive for requirements that entail simple, robust and effective solutions.

Taken together, the design premises shall lead to compliance with requirements related to the safety of the entire Spent Fuel Repository both in Sweden and Finland.

These principles are used to weigh together requirements for fuel, canister, buffer, backfill, closure and underground openings. The revised requirements serve as a basis for the coming technology development and the updated safety assessments needed for approval of coming steps in the licensing process. Further revision of the design premises will be done in response to the conditions issued during the licensing process and in conjunction with the updating of the safety analysis reports. More detailed specification or re-appraisal of the relative importance of requirements between different systems may also need to be done during detailed design or prior to implementation.

QUALITY CONTROL

“Quality management and control” refer to the measures that need to be taken to provide assurance that the requirements made on the facilities during operation and after closure of the Spent Fuel Repository are satisfied. The goal is that the results obtained should conform to acceptable values for properties that contribute to safety and radiation protection.

Planned production as well as quality management and control in the production of the barriers for long-term safety were described in general terms in the license applications. As development of production and testing methods progresses, the work of quality management and control will also progress. Systems for quality management and control will be established and implemented to quality-assure the production of the barriers.

A number of important activities in this process are to:

- Establish principles for safety and quality classification.
- Establish what is to be quality-managed and -controlled, when quality management and control are to be performed and by whom in terms of first, second and third parties.
- Establish and qualify processes, methods, equipment and personnel for fabrication and installation, testing and inspection.
- Establish the procedures that are to be applied in production to make sure that the KBS-3 repository satisfies quality requirements.

While technology and processes already are well developed for the quality control, it is recognized that establishing and qualifying all aspects of the quality control system is a considerable undertaking. Especially noteworthy is the fact that many of the quality needs and requirements will be unique for the repository, which limits the possibilities to draw on experiences and procedures already developed in the nuclear industry.

TECHNOLOGY DEVELOPMENT PLANS

Essentially the detailed technical design need to be completed in time for the detailed design of the planned facilities in the KBS-3 repository system, i.e. the encapsulation plant, the facility for buffer and backfill bentonite component production and the underground repository. However, technology development support will also be needed during implementation and start operation of these facilities. A technology development plan spanning the time from now until the license to start operation has been developed. This plan aims for a common holistic view and understanding of what is needed to reach the target operating facilities and identifies the various development efforts needed in relation to the program plan for nuclear fuel program with regard to the time and resources.

The canister design is approaching its final detailed design status. However, some areas requiring additional attention remain, especially in verifying the canister strength and issues raised in connection with the ongoing review of both SKB's and Posiva's license applications. SKB has developed the Friction Stir Welding (FSW) to the stage of a system design. Posiva in parallel has developed the Electron Beam Welding (EBW) and plan to select between FSW and EBW during 2013. The work that remains entails bringing the current system design, including testing, into the actual designs and solutions to be implemented at the canister factory and at the encapsulation plants. Remaining challenges regarding the development of canister manufacturing technology and in devising the production systems include development of acceptance criteria for canister components, identification of suppliers, development of procurement specifications, development of quality systems and qualifications.

The detailed buffer and backfill system design should be completed and include a quality control plan for the production of the bentonite blocks and their installation in the deposition holes and deposition tunnels. This includes setting requirement specifications for the bentonite materials, decisions on press technology for buffer blocks and establishing manufacturing and quality control methods that work on an industrial scale for the production. Installation methods and methods for testing and control of the buffer and backfill must be designed in detail and verified, requiring full scale underground testing.

As a basis for the detailed design of the repository deposition areas, it is needed to show how the underground construction work and the detailed investigations will lead to the selection of deposition tunnels and holes in conformity with the pre-set design premises. These descriptions need to give a sufficiently clear picture of the work and the end result, but the development of detail can continue until the detailed design of the deposition area starts. Deposition tunnels will only be excavated when needed for deposition, and excavation of them is generally seen as part of repository operation. Also final decision on location of deposition tunnels and deposition holes will be decided at this point, based on the outcome of detailed investigations and preset plans for acceptance or rejection of tunnels and holes. However, the basic procedure for this operation, as well as the detailed design of the first repository tunnels, needs to be established earlier. Indeed, Posiva has already presented a Rock Suitability Classification (RSC) system developed for locating suitable rock volumes for repository design and construction [5]. However, the RSC demonstration program is still in progress and is currently evaluated against experiences gained from demonstration tunnels excavated at depth at the Olkiluoto site. SKB participates in this evaluation, but would eventually need to adapt its criteria to the site specific conditions to be found at depth at the Forsmark site. These testing and demonstration activities are expected to provide information that can be further used for improving the practical use of the RSC criteria and for applying the methodology to the repository-operations phase.

Before the safety report can be updated and the operational license applications can be submitted, commissioning tests of the entire KBS-3 system, ranging from canister manufacturing and covering all steps needed until a deposition tunnel is backfilled and plugged, are required. Before such commissioning tests can be undertaken different types of integration tests to ensure that the equipment and technological systems work together as intended would be needed and, if necessary, followed by modifications of the system.

DISCUSSION

The overall objective of the Posiva and SKB cooperation the forthcoming years is to finalize the development of the KBS-3 concept based on joint technical solutions and resolving outstanding issues for the KBS-3 concept. This is to be achieved through joint planning and joint projects. As of late 2013, planning for such joint activities has progressed into different specific areas that are planned to be the basis for joint projects. These areas include:

- Harmonization of requirements on the repository system.
- Canister design and encapsulation including welding and testing.
- Development of manufacturing technology and design of production system.
- Bentonite materials and supply chain.
- Bentonite-block and -pellet production.
- Buffer and backfill design, Deposition tunnel plug, (Installation techniques).
- Detailed investigations – including qualification of deposition tunnels and holes.
- Tunnel production.
- Research issues related to long term safety and to the foundation of the ongoing technology development.

Realization of these joint areas of development into specified projects is currently ongoing.

CONCLUSIONS

By the SKB's submittal of the license applications for a final repository at Forsmark, Sweden, and Posiva's submittal of a construction license application for the encapsulation plant and disposal facility for the spent nuclear fuel produced in Finland, a technically feasible reference design and site-adapted layouts of KBS-3 type repositories have been presented and shown to comply with the regulatory acceptance criteria in the respective countries. However, detailed designs adapted to an industrialized process designed to fulfilling specific requirements on quality, cost and efficiency remain to be developed. Since both the SKB's and Posiva's spent nuclear fuel disposal programs are now entering a stage of final design, implementation cooperation will be deepened, aiming when possible for the same technical design. Plans for these common developments are now being made jointly by the two companies.

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