Regulatory Oversight of Disposal Facility Construction and Component Fabrication - 14244

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ABSTRACT

The Finnish nuclear legislation defines spent fuel as nuclear waste and requires that it has to be disposed of in the Finnish bedrock. The Finnish safety regulation has required that the bedrock in disposal site shall be characterized from disposal depth before submitting the construction license application. This requirement was further developed in Finnish Radiation and Nuclear Safety Authority (STUK) safety regulation which defined that characterization involves construction of research or characterization facility to the site. Posiva has been constructing since 2004 a unique underground rock characterization facility (URCF) that will later function as access route to the actual repository. The challenge for Posiva and STUK has been that for this type of underground nuclear facility, there is no experience, existing detailed safety requirements or procedures for regulatory oversight. For the construction Posiva has developed understanding of safety relevance of different aspects and STUK has developed regulatory approach to assure that facility is constructed inline with safety requirements. STUK regulatory work consists of review and assessment of design, comprehensive inspection program and review of as-built documentation. The next challenge for STUK is to broaden the regulatory approach to cover selection of suitable disposal positions, the design and construction of disposal tunnels and the fabrication engineered barrier components. STUK's strategy is to use existing regulatory requirements and strategy as basis and adapt it to this type of specific facility.

INTRODUCTION

Finland is one of the foremost countries in the world in developing the disposal of spent fuel. The Construction License application for the Olkiluoto spent fuel disposal facility has been submitted to the authorities at the end of 2012 and the facility is expected to start operation around 2020. [1] This has been a long-term project with over 30 years of parallel development of the repository project and the regulatory approach to spent fuel management.

In 1983 the Government made a strategy decision on the objectives and target time schedule for the research, development and technical planning of nuclear waste management. While the export of spent fuel was still the preferred option, the decision required the licensees without export possibility to prepare for disposal in Finland and it also gave the timeline for the milestones on the way to an operating disposal facility by 2020.

The licensing procedure for a disposal facility has several steps that are similar to all nuclear facilities in Finland and are defined in Nuclear Energy Act [2] and Degree [3]. These licensing steps are:

- Decision in Principle (DiP) is required for a nuclear facility having considerable general significance. This is essentially a political decision: The government decides if the proposed facility is in line with the overall good of society. The decision can be applied for one or more sites, the host municipality has a veto right and the parliament has the choice of ratifying or not ratifying the decision.
- Construction License is granted by the Government and authorizes the construction of the disposal facility. The actual construction is regulated by STUK and includes several review and approval steps, hold points and viewpoints.
- Operational License is granted by the Government and authorizes for the operation of the facility for a certain period. The operation license is needed before nuclear waste can be disposed. STUK

is regulating the actual operation and regulatory actions included defined review, approval and inspection steps.

The first step in the licensing process was reached at the end of 1999 when Posiva submitted the application for a DiP for a spent fuel disposal facility in the Olkiluoto. The DiP was made by the government in late 2000, approved by the host municipality and ratified by the parliament in early 2001. It gave Posiva the authorization to start to construct an underground rock characterization facility, to the depth of actual planned disposal, as required by regulation. [4]

The Finnish regulation requires that the bedrock in disposal site shall be characterized from disposal depth before submitting the construction license application. This requirement is further developed in STUK safety regulation, which defined that characterization involves construction of research or characterization facility to the site. Onkalo will first function as an underground rock characterization facility to ensure the suitability of the Olkiluoto site for repository purposes and then as an access route to the actual repository. The construction of Onkalo therefore has already meant “de facto” construction of the disposal facility because the access tunnel, the shafts and other underground parts will be utilized during disposal operation. STUK has implemented regulatory oversight of ONKALO construction and overseen it like it would be an access route to nuclear facility. However, a construction license is needed before starting construction of the encapsulation facility and the first disposal tunnels and disposal holes.

The concept of final confirming site characterization performed underground was included in Teollisuuden Voima's (TVO) and later Posiva's plans already in the early 1980's and the construction of an investigations facility was one of the main objectives set in the ten year R&D program that Posiva submitted to STUK in year 2000 [5]. According to Posiva’s assessment in Onkalo design phase, it was seen that separate characterization facility is a potential source for hydraulic and geochemical disturbances. For effective use of host rock volume and to avoid excess disturbances, Posiva proposed that the URCF would in future be part of disposal facility. This approach required the development of specific construction technology and monitoring program and development of STUK’s regulatory approach to ensure that the construction and operation of the URFC would not cause major disturbances to the properties of bedrock that are important for the post-closure safety.

DESIGN AND CONSTRUCTION OF ONKALO URCF

The safety of the Olkiluoto disposal facility is based on ensuring the integrity of the containment of the disposed waste i.e. (engineered) containment for a long period of time and, protection it from external impacts, and in the case this primary barrier becomes defective, effective limitation of the release of radioactive nuclides (retardation as well as protection from external impacts) following the KBS-3 concept (Figure 2). For long term safety it is vital that such chemical and mechanical conditions are maintained in the bedrock that the safety functions of the repository are not jeopardized over a long period of time in a variety of normal and abnormal circumstances.

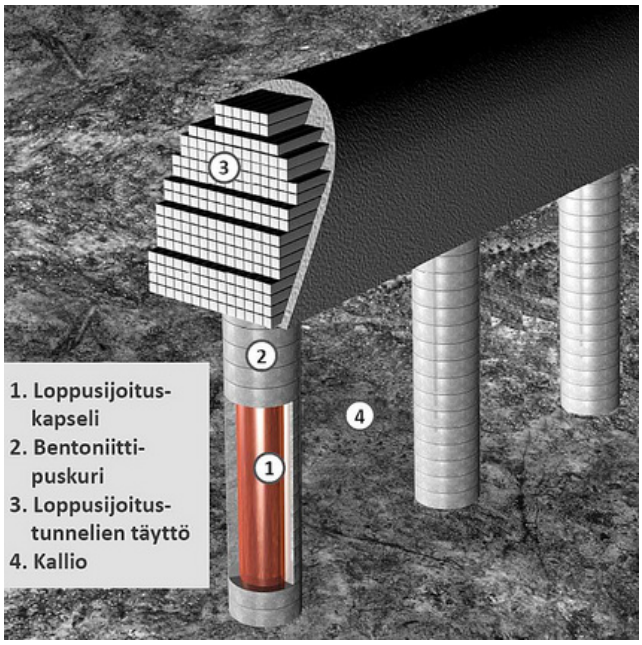

Figure 1: KBS-3V concept consisting of (1) Disposal canister, (2) Bentonite buffer, (3) Tunnel backfill and (4) crystalline host rock (www.posiva.fi)

After the site selection and DiP STUK made decision informing Posiva about the coming regulatory oversight and also informed about the content of information to be submitted before construction works start [6]. According to STUK request, Posiva prepared a set of URCF documentation that focused on the construction of the facility and on post-closure safety issues. The documentation consisted of (see www.posiva.fi):

- Baseline Conditions at Olkiluoto [7]
- ONKALO Underground Rock Characterisation Facility - Main Drawings Stage [8]
- Assessment of Disturbances Caused by Construction and Operation of ONKALO [19]
- Programme of Monitoring at Olkiluoto During Construction and Operation of the ONKALO [10]
- ONKALO Underground Characterisation and Research Programme (UCRP) [11]

STUK made a review of the documentation during year 2003 using as support reviews of four international expert groups. STUK assessed Posiva's understanding and plans against regulatory requirements and against the state-of-the-art understanding of post-closure safety. STUK submitted review findings to Posiva in early 2004. [12]

According to Posiva's assessment the most important aspects of construction disturbance were related to hydrological or geochemical disturbances. Hydrological changes would result from the inflow of groundwater to the open tunnels and shafts. The boreholes drilled in the Onkalo or its neighborhood could add to these effects. The hydraulic changes could entail geochemical effects, but further geochemical effects could also be caused by the foreign materials used in the construction and investigations activities. A special type of disturbance to the host rock would also be the excavation damage zone (EDZ) created around the tunnels and shafts.

To minimize the above disturbances Posiva firstly carefully selected the type and location of Onkalo URCF. The first designs of Onkalo comprised only one or two shafts, but later access tunnel was included for increasing possibilities for rock characterization and flexibility for facility access. Posiva selected combination of access tunnel and one shaft. Posiva expected this design lead to larger hydraulic

disturbances than one or two shafts. For this reason special attention was called to the location of the underground access routes so that they should be located close to each other to avoid hydraulic pressure differences between the openings and in the part of the host rock that was known to be relatively dry. Posiva compared a number of possible locations on this basis until they selected the present location in the southern part of the Olkiluoto island.

The need for controlling the actual construction activities was also acknowledged and Posiva decided to develop its own classification system for long-term safety issues and defined three safety classes (A, B and C). Later STUK also required Posiva to submit safety classification of systems, structures and components according to nuclear facility regulation. Posiva's classification identified safety relevant processes to be controlled

A. activities that had known effects on the host rock characteristics important for long-term safety
B. activities that had potential effects on the host rock characteristics important for long-term safety
C. other activities.

On the basis of an assessment Posiva identified four critical areas that required attention according to the highest (long-term) safety class A:

- the groundwater inflow to the Onkalo
- the rock damage resulting from the excavations (EDZ)
- the use of harmful foreign materials
- the drilling of boreholes in the Onkalo area.

The original design and plans for the underground facility were reported at the level of detail needed for a municipality construction permit and STUK's safety evaluation in 2003. Since then Posiva has made a number of changes in the layout of the Onkalo access tunnel, and the number of access shafts has been increased from one to three. Also the layout and the depth of the auxiliary rooms at the main characterization level have been updated to match with the current needs. The present design of Onkalo is shown in Figure 2.

The demonstration tunnels and main characterization areas are located at the depth of -420 meters, but the auxiliary rooms are deeper down at the depth of -437 meters. The excavation work has been almost completed during 2012 and the rest of the construction work should be ready in 2014. The total underground volume of the ONKALO will be approximately 365 000 m^3, the combined length of tunnels and shafts being 9.8 km. The access tunnel from the surface to the repository level consists of approximately 4.6 km of tunneling with an inclination of 1:10.

According to Posiva's preliminary plans the operating time of Olkiluoto disposal facility could be slightly over hundred years depending on the amount of spent fuel to be generated in future. This means that Onkalo design life is over 120 years.

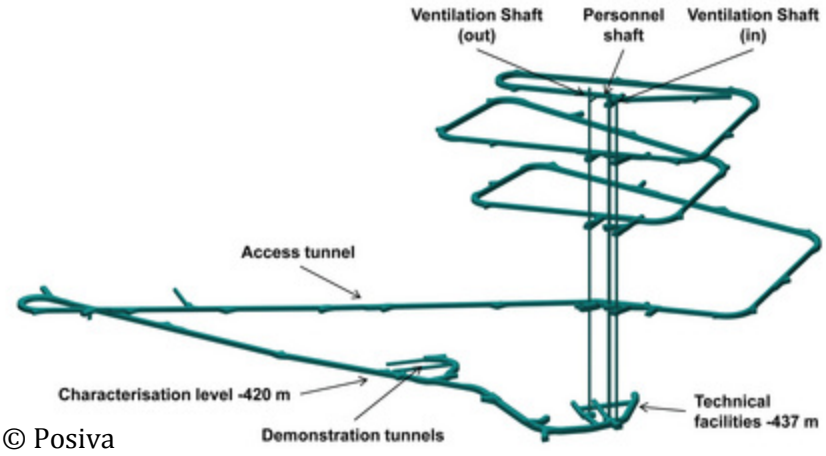

Figure 2: Onkalo URCF design (www.posiva.fi)

REGULATORY OVERSIGHT OF URCF CONSTRUCTION

Regulatory requirements

Construction of Onkalo to the planned disposal depth (c.a. -430m) disturbs the geological environment and conditions in a variety of ways, as described above. The purpose of STUK's regulatory control of Onkalo construction is primarily to ensure that the design, location, orientation and construction are carried out in such a manner that the geo-environment retains its favorable characteristics and conditions needed for the safety functions.

In particular, this implies the minimization of:

- Host rock responses to excavation, excavation disturbed areas and zones,
- Groundwater leakages to the ONKALO tunnels and shafts, and
- Introduction of foreign, potentially harmful substances to ONKALO during (cement and other grouting materials, reinforcement materials, explosives etc.).
- Pathways from surface to disposal rooms

The Finnish regulatory framework has requirements the implementer to define how long-term safety shall be taken into account in facility design and construction practices [13, 14]:

- License applicant shall describe safety functions and performance targets for disposal system barriers. In case of bedrock these include isolation of waste and engineered barrier system from surface and retardation of radionuclides after canister has breached.
- License applicant shall develop a rock classification system that will be used to classify for example rock structures and ground water conditions that can have an impact to long-term safety. Posiva is developing Rock Suitability Classification (RSC) that takes into account requirements arising from long-term safety and which needs to be implemented when making decisions of on rock suitability prior to excavation.
- The construction of the disposal facility construction shall aim at maintaining favorable rock characteristics important to long-term safety as well as possible.
- Impacts of construction shall be observed and recorded measured with a monitoring program that includes for example characterization and surveillance of changes in stress field, seismic activity, brittle deformation, hydrogeology and hydrogeochemistry.

STUK's regulatory activities (approvals, review and assessment, inspection,) are implemented in a graded approach. All the structures, systems and components of the facility are classified based on their significance to safety (safety classes 1, 2, 3 and to those which are not important to nuclear safety). This includes also constructed underground rooms. Since the management of the construction and related safety culture affect directly the safety and quality of the work and its long-term results, Posiva's management system is also subject to STUK's regulatory control.

Review and assessment

STUK has defined requirements for documents that are required to be submitted to STUK for review and approval. These documents include the preliminary safety analysis report, safety classification report and the description of constructing organization, staff competences, the regulations, codes and standards to be used in the construction, the management system (especially safety and quality management), design data, drawings, construction documentation, in-service inspection plan etc.

In addition, Posiva was required to submit to STUK a plan on how the company intends to communicate to STUK about the progress of the construction work. The purpose of this document is to facilitate well planned, timely and properly targeted and resourced regulatory activities synchronized with the actual construction activities and provide timely information for example on unexpected events underground. This documentation includes schedules, realization reports, as-built documentation, test results, information about research planned to be performed in Onkalo during construction, and information about Onkalo's unclassified systems.

In STUK's approach main focus is in reviewing the proposed design and supporting safety argumentation for planned underground rooms and ensuring through inspections that Posiva has effective quality assurance and control of construction activities. All the results and regulatory decisions, including their justifications, are documented and publicly available.

Inspection activities

ONKALO inspection activities cover all areas of STUK's responsibilities. Inspections are carried out in order to ensure that Posiva works in compliance with regulations, conditions and approvals of STUK in a high quality manner. Inspection activities can be divided into three areas, which are discussed in the following:

- Construction Inspection Program (CIP),
- Inspections concerning the readiness to begin excavation and other work phases, and
- Inspection concerning construction works on site.

Construction Inspection Program (CIP) – STUK has established a planned and systematic CIP-program. CIP is prepared, approved and implemented annually as a continuous process. The main levels of CIP are:

- Management system: Dealing with issues such as managing ONKALO construction, organization, safety culture, quality assurance, competence of staff, communication with STUK,
- Main Operations: construction project management and resources, safety issues, quality assurance for construction work, facility design,
- Functions and Activities: Posiva's inspections and QC, excavation and excavation disturbed zone, drillings, mapping of features and construction impacts to safety functions (to geochemistry, rock mechanics, hydrogeology, groundwater leakages to ONKALO, introduction of foreign potential hazardous materials to ONKALO, grouting, enforcement works and materials).

Inspections concerning the readiness to begin excavation and work phases – The ONKALO construction is divided into different phases. The purpose of the inspections related to these phases is to ensure that all

the arrangements and conditions at the construction site are in order for the next construction phase to start (previous phase is properly completed). Examples of this type of inspections are inspecting the preparedness to start a new excavation phase or the preparedness to begin shotcreting of a specified tunnel section.

Inspection concerning construction works on site – Inspections are targeted to excavation work processes, methods and practices, and their quality and compliance with approvals. Inspections are carried out approximately once in two weeks.

REGULATORY OVERSIGHT OF DISPOSAL FACILITY CONSTRUCTION AND COMPONENT FABRICATION

Posiva has submitted the construction license application and supporting documentation to the authorities in the end of 2012. STUK as a safety authority has started the review and assessment with a docketing review. The first phase is followed by thorough review and assessment against safety requirements and the outcome is documented in authority's safety evaluation report. The planned time period for review and assessment is from 1.5 to 2 years.

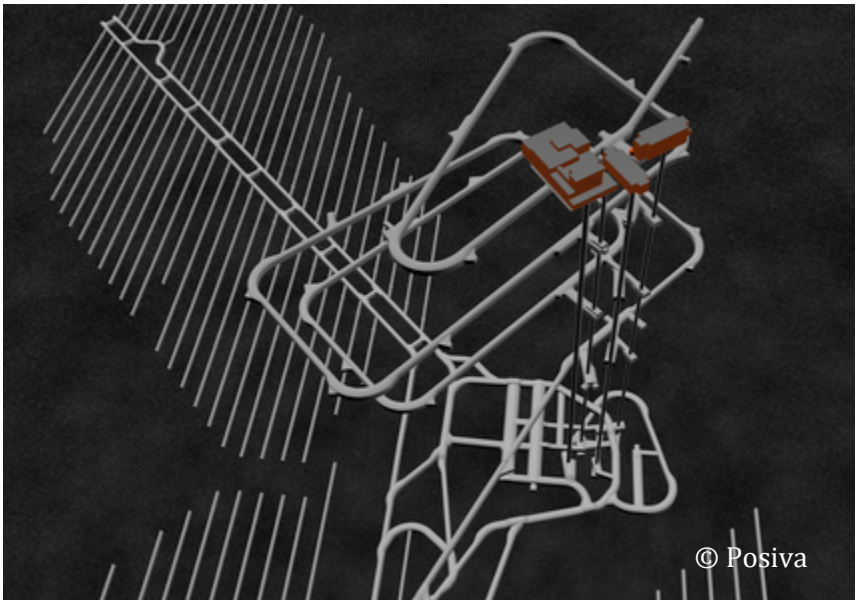

Figure 3: Visualization of planned encapsulation and disposal facility (www.posiva.fi)

The start of encapsulation and disposal facility construction is pending from license application approval. Posiva has scheduled the start of the construction works in early 2015. STUK has at this point also prepared draft approach for regulatory control that is graded based on post-closure safety relevance that takes into account these new elements. The goal is to bring these new regulatory procedures as part of STUK's safety regulation.

The most important change compared to Onkalo URCF construction is the more comprehensive evaluation of suitable location for tunnels and disposal holes. The Finnish safety regulation requires disposal operator to develop and implement a system for rock classification. The meet this requirement Posiva has been developing the RSC and related acceptance criteria for many years. The criteria and procedures have been tested in Onkalo access tunnel and demonstration tunnels that have been designated

for disposal system R&D and feasibility demonstrations. The quality requirements for tunnel excavation and limits for groundwater inflow will also be tightened.

Parallel with disposal facility excavation and regulatory oversight Posiva and STUK are also getting prepared for both commissioning and operational phases of the disposal facility. The disposal includes, according to KBS-3 design, iron-copper canisters, bentonite clay buffer components, tunnel backfill blocks fabricated from clay and massive concrete tunnel closure plugs. STUK is preparing control measures to follow and oversee also the preliminary tests and demonstrations, already started with devices, structures, systems and multiple systems while the licensee is gradually getting ready for the commissioning tests to be carried out around 2020.

STUK is developing the regulatory requirements and related oversight approach for the disposal system components. These requirements and oversight will cover detailed design, qualification of fabrication process and manufacturer and qualification of quality control procedures and personnel. The extent of oversight is related to safety significance of component and related safety class.

CONCLUSION

The spent fuel disposal program has proceeded to construction license review phase after Posiva submitted to the government application for Olkiluoto encapsulation and disposal facility construction. This phase was preceded with detailed host rock characterization and construction of underground rock characterization facility (Onkalo URCF). This facility is planned to be access route for the disposal facility and for that reason has been subjected to STUK's regulatory oversight.

Onkalo URCF is the first facility of this kind and has required comprehensive development of construction and quality assurance procedures from Posiva. It has also required STUK to adapt regulatory oversight for underground nuclear facility. The new and most important aspect has been long-term safety and how the maintain the favorable site characteristics that have been indentified important for post-closure safety.

Posiva and STUK have successfully implemented new approach for construction and related oversight and developed basis that can be followed in disposal facility design and construction.

REFERENCES

1. Posiva Oy, Rakentamislupahakemus Olkiluodon kapselointi- ja loppusijoituslaitoksen rakentamiseksi käyteyn ydinpolttoaineen loppusijoitusta varten, (2012), In Finnish
2. Nuclear Energy Act, (990/1987), (1987)
3. Nuclear Energy Decree, (161/1988), (1988)
4. Decision in Principle, DiP. Valtioneuvoston periaatepäätös 21 päivänä joulukuuta 2000 Posiva Oy:n hakemukseen Suomessa tuotetun käytetyn ydinpolttoaineen loppusijoituslaitoksen rakentamisesta, (2000), In Finnish
5. Posiva Oy, Disposal of spent fuel in Olkiluoto Bedrock Programme for reasearch, development and technical design for the pre-constrcution phase, POSIVA 2000-14 (2000)
6. STUK, Käytetyn ydinpolttoaineen loppusijoittaminen; Olkiluotoon rakennettavien maanalaisten tilojen valvonta, Y810/22, (2001), in Finnish
7. Posiva Oy, Baseline Conditions at Olkiluoto, POSIVA 2003-02, (2003)
8. Posiva Oy, ONKALO Underground Rock Characterisation Facility - Main Drawings Stage, WR 2003-26, (2003)
9. Posiva Oy, Assessment of Disturbances Caused by Construction and Operation of ONKALO, POSIVA 2003-06, (2003)

10. Posiva Oy, Programme of Monitoring at Olkiluoto During Construction and Operation of the ONKALO, WR 2003-05, (2003)
11. Posiva Oy, ONKALO Underground Characterisation and Research Programme (UCRP), POSIVA 2003-03, (2003)
12. STUK, Posiva Oy:n suunnitelmat ja selvitykset maanalaisesta tutkimustilasta (Onkalosta), Y811/44, (2004), In Finnish
13. Government Decree on the safety of disposal of nuclear waste, (736/2008), (2008)
14. STUK, YVL D.5 Disposal of Nuclear Waste, (2013)