STUK-B 196 / NOVEMBER 2015

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STUK's statement and safety assessment on the construction of the Olkiluoto encapsulation plant and disposal facility for spent nuclear fuel

Säteilyturvakeskus
Strålsäkerhetscentralen
Radiation and Nuclear Safety Authority

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STUK • **SÄTEILYTURVAKESKUS**
STRÅLSÄKERHETSCENTRALEN
RADIATION AND NUCLEAR SAFETY AUTHORITY

Osoite/Address • Laippatie 4, 00880 Helsinki
Postiosoite / Postal address • PL / P.O.Box 14, FIN-00881 Helsinki, FINLAND
Puh./Tel. (09) 759 881, +358 9 759 881 • Fax (09) 759 88 500, +358 9 759 88 500 • www.stuk.fi

ISBN 978-952-309-290-7 (print) Erweko Oy, Helsinki 2015
ISBN 978-952-309-291-4 (pdf)
ISSN 0781-1713

STUK's statement and safety assessment on the construction of the Olkiluoto encapsulation plant and disposal facility for spent nuclear fuel. STUK-B 196. Helsinki 2015. 91 pp.

Keywords: nuclear waste, waste disposal, safety assessment report, construction licence, Olkiluoto, spent nuclear fuel, encapsulation plant, disposal facility

Summary

Posiva submitted the construction licence application for the encapsulation plant and the disposal facility in Olkiluoto to the Ministry of Employment and the Economy (MEE) in December 2012. The MEE requested from Radiation and Nuclear Safety Authority (STUK) a statement required by the Nuclear Energy Act section 23 and a safety assessment report required by the Nuclear Energy Decree section 36 in February 2013. This publication presents STUK's statement, safety assessment report and the statement from the nuclear safety advisory board as required by the Nuclear Energy Decree section 37. The statement was submitted to the MEE in February 2015.

STUK's safety assessment report and statement are based on the review of construction licence technical documentation and on the inspection programme carried out during the review. Based on the review STUK accepted Posiva's preliminary safety analysis report, post closure safety case, probabilistic risk assessment of the design stage, proposal for a classification document, description of quality management during the construction of the nuclear facility, preliminary plans for the arrangements for security and emergencies, a plan for arranging the safeguards control that is necessary to prevent the proliferation of nuclear weapons, and the applicant's arrangements for the implementation of regulatory oversight by STUK. The inspection programme focused on Posiva's safety culture, organization, management system, resources, competence and procedures. Inspections in accordance with the programme were extended also to Posiva's suppliers.

In STUK's safety assessment report and statement STUK concludes that, based on Posiva's construction licence application documentation, the encapsulation plant and the disposal facility for spent nuclear fuel proposed by Posiva can be constructed to be safe. Radiation doses for workers and local residents arising from the operation of the encapsulation plant and the disposal facility will be below the limits given in legislation with high probability. After the closure of the disposal facility radiation exposure for local residents and other biosphere will fall below the regulatory limits with high probability. As part of the radiation and nuclear safety review STUK assessed that Posiva's organization, management system, resources, arrangements for security, emergency preparedness and safeguards are at a sufficient level, so that the project can be carried out safely.

Contents

Statement of the Radiation and Nuclear Safety Authority on the construction of the Olkiluoto encapsulation plant and disposal facility for spent nuclear fuel

The Ministry of Employment and the Economy has requested a statement referred to in Section 23 of the Nuclear Energy Act (990/1987) from the Radiation and Nuclear Safety Authority (STUK) regarding the construction licence application by Posiva Oy (Posiva) concerning the Olkiluoto encapsulation plant and disposal facility for spent nuclear fuel[1].

Posiva has submitted the construction licence application and the documents required by Section 32 of the Nuclear Energy Decree (161/1988) to the Ministry of Employment and the Economy, and it also has separately submitted, to the Radiation and Nuclear Safety Authority (STUK), the documents in accordance with Section 35 of the Nuclear Energy Decree and Section 16 of the Government Decree on the Safety of Disposal of Nuclear Waste (736/2008), on which the safety assessment of the Radiation and Nuclear Safety Authority is primarily based. The documents and reports listed above have been delivered to the Radiation and Nuclear Safety Authority (STUK) in several batches and updated after the actual licence application was submitted during 2013 and 2014. The updates have been made and supplements added, both based on requests for clarification by the Radiation and Nuclear Safety Authority and the progress of Posiva's own design.

Posiva's construction licence application proposes the disposal of a maximum of 9,000 tU (tonnes of uranium) of spent nuclear fuel. The volume corresponds to the accumulation of spent nuclear fuel generated during the operation of Teollisuuden Voima Oyj's (TVO) operating plant units Olkiluoto 1 and 2, the plant unit Olkiluoto 3 under construction and the planned plant unit Olkiluoto 4, as well as the operating Loviisa 1 and 2 plant units of Fortum Power and Heat Oy (Fortum). The volume does not include the spent nuclear fuel delivered from the Loviisa plant units to the reprocessing facility in Mayak, Russia, in accordance with the agreement that remained in force until 1996.

The statement and the safety assessment by the Radiation and Nuclear Safety Authority on the safety of the Olkiluoto encapsulation plant and disposal facility and Posiva's project are valid, even if TVO's Olkiluoto 4 plant unit would not progress into the construction licence application phase and its spent nuclear fuel was left outside Posiva's construction licence. If the Olkiluoto 4 project were not to be realised, it would decrease the amount of spent fuel to be disposed of and decrease the surface area and rock volume required for the area needed for disposal.

Posiva's disposal project is based on the KBS-3 disposal concept in accordance with the multibarrier principle, in which the spent nuclear fuel packed into canisters made out of copper and iron is disposed of, after a minimum of 20 years of interim storage, in repositories to be built at the approximate depth of 430 metres in bedrock. The disposal canisters are protected by buffer material manufactured out of swelling clay, and the deposition tunnels are filled with clay material. Once the operation is over, the whole disposal facility will be closed by backfilling all excavated areas with clay material and crushed rock. Close to the surface, the underground rooms are filled in with structures that make intrusion into the repository difficult. The planned disposal of spent nuclear fuel will be passively safe after closure. Ensuring the safety of the facility will not require monitoring of the disposal site or other maintenance activities.

The Radiation and Nuclear Safety Authority has drawn up a safety assessment on the project, which can be found in Attachment 1 to this

1 In this statement, the term 'nuclear waste facility' is used for the encapsulation plant and disposal facility in accordance with the definition of the Government Decree 736/2008, which covers both facilities.

statement. Attachment 2 includes the statement from the Advisory Committee on Nuclear Safety, requested by the Radiation and Nuclear Safety Authority.

The nuclear waste facility is a nuclear facility of considerable general significance as referred to in Section 11 of the Nuclear Energy Act, which means that granting it a construction licence requires a valid Government decision-in-principle (Nuclear Energy Act, Section 18). The Government has issued a decision-in-principle regarding Posiva's project in December 2000, and the Parliament has ratified it in May 2001. This decision-in-principle covers the disposal of the spent fuel from the Olkiluoto 1 and 2 plant units as well as the Loviisa 1 and 2 plant units. In addition to the decision-in-principle confirmed in 2001, the Government has issued two separate decisions-in-principle in 2002 and 2010, on the basis of which the disposal project has been expanded to cover the disposal of the spent nuclear fuel from the Olkiluoto 3 and Olkiluoto 4 plant units. The Parliament confirmed both separate decisions-in-principle in the corresponding years. The first decision-in-principle was specified as valid for a period of 15 years. Posiva's construction licence application has been submitted at the end of 2012, which means that the requirement of a valid decision-in-principle is fulfilled for Posiva's project.

In addition to a valid decision-in-principle, the fulfilment of the prerequisites laid down in Section 19 of the Nuclear Energy Act is a condition for granting the construction licence. The Radiation and Nuclear Safety Authority has assessed the fulfilment of the prerequisites regarding nuclear and radiation safety in this statement and the attached safety assessment. The assessment of the Radiation and Nuclear Safety Authority on the fulfilment of the prerequisites laid down in Section 19 of the Nuclear Energy Act is as follows:

1) if plans concerning the nuclear facility meet the safety requirements laid down in this Act, and appropriate account has been taken of the safety of workers and the population when planning the operations in question;

The Olkiluoto encapsulation plant and disposal facility proposed by Posiva has been designed in such a way that the requirements on the nuclear and radiation safety during the operation of the facilities are fulfilled. The encapsulation plant as well as the necessary parts of the disposal facility follow the defence-in-depth safety principle. The structural safety of the facilities has been ensured by successive barriers; depending on the handling phase of the spent nuclear fuel, these barriers include the nuclear fuel cladding, nuclear fuel transport cask or the disposal canister, as well as the structures of the encapsulation plant and disposal facility. For functional safety, the removal of decay heat and the criticality safety of the fuel are managed structurally with passive solutions. Functions important for the management of radioactive substances include the nuclear fuel handling functions and filtration of exhaust air related to preventing the spread of radioactive substances, which are single failure tolerant at the encapsulation plant and disposal facility. Posiva will specify the detailed design requirements of the systems, for which the approval of the Radiation and Nuclear Safety Authority must be received as necessary, before construction of the facility's structures and the manufacturing of the components are initiated.

Posiva has prepared for operational occurrences and accidents at the encapsulation plant and disposal facility in accordance with safety requirements. Posiva has analysed the potential operational occurrences and accidents and prepared for them by following the redundancy, separation, and diversity principles as part of the defence-in-depth safety principle in the design of the systems that implement the safety functions.

Posiva has provided analyses on the releases and radiation doses caused by normal operation, operational occurrences and accidents at the encapsulation plant and disposal facility. The radiation doses caused by the operation of the encapsulation plant and disposal facility are lower than the maximum values of radiation exposure laid down in Government Decree 736/2008. The emergency arrangements required during the operation of the encapsulation and disposal facilities commensurate with the based on estimated radiation exposures.

Posiva has developed the KBS-3 concept described above for several decades together with the Swedish company Svensk Kärnbränslehantering AB (SKB). The manufacturability of the system components has been proved on a level sufficient for the construction licence by component-specific manufacturing tests, and correspondingly, the feasibility of constructing the bedrock facilities

has been proven by demonstrations at the underground rock characterisation facility (Onkalo) in Olkiluoto. It is important that the reliability of the rock suitability classification system related to the implementation of the bedrock facilities is assessed during the first construction phase of the repository. In cooperation with each other, Posiva and SKB have tested the emplacement of the disposal canister, buffer and tunnel backfill in accordance with the requirements at the Äspö hard rock laboratory in Sweden. In addition, Posiva has also initiated the installation tests of the disposal system's components carried out in Onkalo. The goal of the installation tests is to prove that the components of the disposal system can be installed in accordance with the accuracy requirements set. Under the decision-in-principle in 2001, Posiva has constructed an underground rock characterisation facility, which is planned to function as a part of the disposal facility. In the construction of the underground rock characterisation facility, Posiva has complied with the requirements for nuclear facilities, and STUK has regulated the construction of the rock characterisation facility with the same procedures used for constructing a nuclear facility.

The post-closure safety of the disposal facility is based on two objectives, which are achieved by barriers that complement each other. The primary objective is the containment of the radioactive material from the bedrock. The leak-tight disposal canister protected by the clay material emplaced around it, as well as the bedrock surrounding the repository that separates them from the surface environment, play a key role in this. The bedrock and the closure of the disposal facility create favourable and foreseeable conditions for the engineered barriers. The second objective of the barriers is to limit and retard the migration of radionuclides from the disposal depth to the ground surface in the event that a release of radionuclides occurs.

In order to demonstrate the post-closure safety, Posiva has presented an analysis in the licence application material regarding the anticipated future evolution scenario, as well as variant and possible disturbance scenarios of the disposal system and the surrounding environment. Based on its scenario analysis, Posiva has selected the most significant evolutions that lead to a release of radionuclides, and has analysed the radiation doses incurred to humans and surrounding environment, as well as the radionuclide releases into the environment. The results of the analyses remain under the limit values set in the Government Decree (736/2008).

In the review of the facility's post-closure safety case, development needs have been identified; by taking these needs into account, the clarity, traceability and reliability of the post-closure safety case can be improved. The Radiation and Nuclear Safety Authority has presented the areas for improvement in a separate decision addressed to Posiva, in which taking these development needs into account in the operating licence application material is required.

The plans presented by Posiva are appropriate and sufficient for the safety of the personnel and the population at the construction licence application phase, with the following observations and limitations:

- Posiva has submitted a plan on specifying the system design of the nuclear waste facility to the Radiation and Nuclear Safety Authority. The Radiation and Nuclear Safety Authority will have oversight of the progress of the design and verify the sufficient level of design in accordance with Section 108 of the Nuclear Energy Decree and YVL Guides before the construction of the facility’s structures and the manufacturing of the components begin.
- Posiva has submitted a plan on the installation tests of the disposal system's components to the Radiation and Nuclear Safety Authority. The Radiation and Nuclear Safety Authority will review the installability of the system as based on the tests before excavation of the deposition tunnels can begin.
- In connection with construction of the first deposition tunnels, Posiva must prove the reliability of the rock suitability classification system. The Radiation and Nuclear Safety Authority will review the functionality of the rock suitability classification system as part of the oversight of the placement of the first deposition tunnels and the rock construction.
- Posiva has submitted a development programme of the disposal concept focusing on the barriers to the Radiation and Nuclear Safety Authority, in which it has taken account of the same areas of improvement as the ones that the Radiation and Nuclear Safety Authority has

highlighted in the safety assessment. The Radiation and Nuclear Safety Authority will have oversight of the progress of the development work in accordance with the programme during the period between the construction and operating licences.

2) if the location of the nuclear facility is appropriate with respect to the safety of the planned operations and environmental protection has been taken into account appropriately when planning operations;

The proposed location has been found suitable as a disposal site in the decision-in-principle in 2001. Based on the decision-in-principle, the project received permission to proceed with the construction of the underground rock characterisation facility and the more detailed site-specific studies. After the decision-in-principle, an underground rock characterisation facility, Onkalo, has been constructed at the site, and the characterisation of the site has continued. Knowledge of the site has increased significantly after the decision-in-principle stage.

The studies of the disposal site and the analyses on the evolution scenarios of the site reaching far into the future are sufficient for the construction licence, and they have not introduced any matters on the basis of which the selected disposal site would not be favourable for post-closure safety. Based on the studies and analyses, the conclusion may be reached that the bedrock's characteristics are suitable for implementing the disposal as proposed. The disposal depth of 400–450 metres of the spent fuel is in accordance with the decision-in-principle issued for the Olkiluoto disposal facility and the safety requirements set by the Radiation and Nuclear Safety Authority. The disposal depth has been selected taking account of the post-closure safety of the disposal and the sufficient protection from above-ground phenomena and human activity.

Based on studies performed the planned site is appropriate for a nuclear waste facility with regard to operational and post-closure safety, and environmental protection has been taken into account in planning the operation.

3) if physical protection has been taken into account appropriately when planning operations;

Posiva has used Design Basis Threat and risk analyses in the design and assessment of the security arrangements and has also analysed the physical protection requirements. The principles, procedures and plans related to security arrangements and the planned information security principles have been described in the application material. In the actual design of the nuclear waste facility, various security zones have been presented in accordance with the defence-in-depth safety principle, and the protection of important structures and systems have been taken into account in the design.

Posiva has presented the security plan for the construction period of the nuclear facilities as well as the composition of the security organisation and its tasks, monitoring equipment, communications equipment, protective equipment and equipment for use of force. Together with TVO, Posiva has also presented joint security standing orders for confirmation, which must be in force before the construction of Posiva's nuclear waste facility is initiated.

Based on what has been presented above, Posiva's plans for the implementation of security arrangements are appropriate and sufficient, with the following specifying comments:

- The joint security standing orders of Posiva and TVO must be confirmed before construction begins.
- The details of the security arrangements planned for the construction period must be specified before construction begins. The detailed requirements concerning these issues have been given in a decision by the Radiation and Nuclear Safety Authority that is confidential (Act on the Openness of Government Activities 621/1999, Section 24(1), paragraph 7).

4) if a site has been reserved for the construction of a nuclear facility in a local detailed plan in accordance with the Land Use and Building Act (132/1999), and the applicant is in possession of the site required for the operation of the facility;

Reviewing whether the requirements of this section are fulfilled is not within the sphere of authority of the Radiation and Nuclear Safety Authority, and its realisation shall be reviewed by other authorities.

In the valid land use plan for the Olkiluoto region, an area has been reserved for a nuclear waste facility. In addition, the precautionary action zone required by Section 9(6) of the Government Decree 736/2008 has been reserved at the disposal area for the prohibitions on measures referred to in Section

63(1), paragraph 6 of the Nuclear Energy Act.

5) the methods available to the applicant for arranging nuclear waste management, including final disposal of nuclear waste and decommissioning of the facility, are sufficient and appropriate;

The low- and intermediate-level nuclear waste accumulated during the operation of Posiva's nuclear waste facility and from its decommissioning originates from the handling of spent fuel at the facility. Posiva has presented sufficient and appropriate arrangements and plans for the construction licence application phase regarding the handling and disposal of the nuclear waste generated as well as the decommissioning of the facility, with the following comments and limitations:

- Before construction of the disposal facility begins, Posiva must present specified, more detailed plans to the Radiation and Nuclear Safety Authority for the low- and intermediate-level waste repository at the disposal facility, as well as a specified estimate on the combined effects of the various types of nuclear waste to be placed into Posiva's disposal facility.

6) if the applicant's plans for arranging nuclear fuel management are sufficient and appropriate;

The purpose of the nuclear waste facility proposed in the construction licence application is the handling and disposal of spent nuclear fuel. There is no need to arrange nuclear fuel management for the facility.

The spent nuclear fuel handled at the nuclear waste facility is stored at the interim storages at nuclear power plants, from which it is transported into the encapsulation plant for disposal.

7) the applicant's arrangements for the implementation of control by the Radiation and Nuclear Safety Authority (STUK) as referred to in paragraph 3 of section 63 subsection 1, in Finland and abroad, and for the implementation of control as referred to in paragraph 4 of section 63 subsection 1 are sufficient;

The arrangements and procedures for implementations of the regulatory control described in the report submitted by Posiva have been found to be adequate at the construction licence application phase. With its decision, the Radiation and Nuclear Safety Authority has approved the report on arranging the control possibilities of the Radiation and Nuclear Safety Authority submitted by Posiva in connection with the construction licence application. Posiva has implemented the personnel training required in the decision of the Radiation and Nuclear Safety Authority on the practical actions required by the Radiation and Nuclear Safety Authority's control. Based on this, Posiva's arrangements for implementing the control are appropriate and sufficient.

8) if the applicant has the necessary expertise available;

The Radiation and Nuclear Safety Authority has assessed the competence of Posiva's personnel and the external expertise available to Posiva in connection with processing the construction licence application as well as based on the document reviews and a separate inspection programme. As a result, the Radiation and Nuclear Safety Authority states that Posiva has a sufficient and extensive expertise available for constructing a nuclear waste facility.

In the long term, the use of nuclear energy can only be considered in line with the overall good of society if society on its part commits to maintaining the social structures required by the safe use of nuclear energy as well as the educational and research infrastructure required. The long-term nature of disposal requires the society to invest in maintaining the resources and competence for the entire duration of the facility's operation. In particular, preparations must be made for maintaining sufficient expertise in areas related to the post-closure safety of the disposal of nuclear waste.

9) if the applicant has sufficient financial prerequisites to implement the project and carry on operations;

Posiva's owners, TVO and Fortum, are responsible for ensuring that Posiva has sufficient financial prerequisites to implement the project safely and carry on operations. In accordance with the agreement between the owners of Posiva, it will collect the costs of the spent fuel disposal project from its owners. TVO and Fortum will remain under a waste management obligation in accordance with the Nuclear Energy Act, and they are therefore responsible for the costs of nuclear waste management.

In accordance with the Nuclear Energy Act, TVO and Fortum have provided for the cost of nuclear waste management by paying fund holdings into the National Nuclear Waste Management Fund. Sufficient funds have been collected into the

National Nuclear Waste Management Fund for the processing and disposal of the currently existing nuclear waste. In this respect, the provisions strengthen the financial prerequisites.

Based on this, Posiva's arrangements are appropriate and sufficient.

10) if the applicant is otherwise considered to have the prerequisites to engage in operations safely and in accordance with Finland's international contractual obligations;

With regard to Section 19(10) of the Nuclear Energy Act, the field of the Radiation and Nuclear Safety Authority includes international agreements on nuclear safeguards, nuclear liability issues and EU Council directives as well as the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. The requirements of the international agreements are implemented via Finnish legislation and prevailing practice.

In accordance with Section 118 b of the Nuclear Energy Decree, the use of nuclear energy must be planned and implemented so that the obligations concerning nuclear safeguards, as provided in the Nuclear Energy Act and in the Euratom Treaty and provisions issued under them, are met. Posiva's facilities are the first of their type, and the regulatory control measures by the International Atomic Energy Agency (IAEA) and the European Commission have not yet been completely resolved. In its plan, Posiva has taken the known control needs and obligations during construction and operation into account. Similarly, the Radiation and Nuclear Safety Authority has taken the corresponding needs and obligations into account in its control system.

As a part of Section 19(10) of the Nuclear Energy Decree, the following covers the prerequisites related to the safe operation or implementation of the disposal project presented in the Nuclear Energy Act, the decisions-in-principle issued to Posiva, and the construction licence application.

The Radiation and Nuclear Safety Authority has approved the management system manual describing Posiva's management system. In the management system manual, Posiva emphasises giving safety first priority in all activities and creating as well as maintaining a good safety culture. The goal is that the personnel are aware of the safety significance of their own work. Posiva evaluates the management system and the operation of the organisation regularly and systematically with the continuous improvement of the operation as the goal.

Based on Posiva's application, the Radiation and Nuclear Safety Authority has approved the responsible manager for the construction of the nuclear waste facility. The Radiation and Nuclear Safety Authority has approved the deputy of the responsible manager conditionally, requiring additional instruction in the security arrangements. The approval becomes valid after the additional instruction has been provided. Correspondingly, Posiva must nominate a manager responsible for the operation and his/her deputy for the operational phase of the nuclear waste facility, and propose them to the Radiation and Nuclear Safety Authority for approval.

In the construction licence application, Posiva has presented a report on the re-openability of the repository and an estimate on the costs of the opening. The safe re-opening of the facilities and the return of the disposal canisters is feasible technically with currently available working methods. In the view of the Radiation and Nuclear Safety Authority, the retrievability of nuclear waste to be disposed of is feasible technically, and re-openability does not endanger the post-closure safety of the disposal.

In parallel with the vertical disposal solution described above, Posiva has developed a horizontal disposal solution (KBS-3H) based on the same safety principles, which have been presented in the construction licence application material. The Radiation and Nuclear Safety Authority is not aware of any issues why the horizontal disposal solution could not fulfil the safety requirements. The Radiation and Nuclear Safety Authority would be able to process the change upon separate application by Posiva, in accordance with Section 112 of the Nuclear Energy Decree. A change made during the construction of the disposal facility would probably cause a delay in the planned start of the disposal.

In the construction licence application, Posiva has presented a report on the transports of spent nuclear fuel and, in addition, it has presented a preliminary report to the Radiation and Nuclear Safety Authority on the transport arrangements

and the security for transport. The transports of spent nuclear fuel can be implemented as based on Posiva's plans. The safety of the transports is ensured separately and, in accordance with the Nuclear Energy Decree, a transport can only be carried out after the Radiation and Nuclear Safety Authority has ascertained that the transport arrangements and the required security and emergency planning arrangements meet the requirements set for them.

Summary

In addition to the Sections 18–19 of the Nuclear Energy Act, the general principles of the use of nuclear energy are presented in Sections 5–7 of the Nuclear Energy Act:

Section 5 The use of nuclear energy, taking into account its various effects, shall be in line with the overall good of society.

Section 6: The use of nuclear energy must be safe; it shall not cause injury to people, or damage to the environment or property.

Section 6 a Nuclear waste generated in connection with or as a result of the use of nuclear energy in Finland shall be handled, stored and permanently disposed of in Finland […], and

Section 7 Sufficient physical protection and emergency planning as well as other arrangements for limiting nuclear damage and for protecting nuclear energy against illegal activities shall be a prerequisite for the use of nuclear energy.

The planned disposal of spent nuclear fuel in Olkiluoto has been found to be in line with the overall good of society in the decisions-in-principle made by the Government, and in the long term, disposal is also a prerequisite for the safe use of nuclear energy. The nuclear waste facility proposed by Posiva is part of nuclear waste management as a whole, in accordance with Section 6 a of the Nuclear Energy Act. In the statement, the Radiation and Nuclear Safety Authority has presented the conclusions on the fulfilment of Section 7 of the Nuclear Energy Act.

As a conclusion and based on what has been presented in this statement and the attached safety assessment, the Radiation and Nuclear Safety Authority states that the prerequisites of Sections 18 and 19 of the Nuclear Energy Act for granting a construction licence and the principles laid down in Sections 5–7 have been fulfilled. The encapsulation plant and disposal facility for spent nuclear fuel proposed by Posiva can be constructed to be safe.

Director General Petteri Tiippana

Director Risto Paltemaa

1 Introduction

On 28 December 2012, Posiva Oy (Posiva) submitted an application to the Government for the construction of a spent nuclear fuel encapsulation plant and disposal facility at Olkiluoto in Eurajoki. The Ministry of Employment and the Economy has requested a statement from the Radiation and Nuclear Safety Authority (STUK) regarding the construction licence application for a nuclear facility by Posiva (TEM/2955/08.05.01/2012, 15 February 2013).

This safety assessment presents the grounds for STUK's statement. The safety assessment is based on the review of Posiva's construction licence application and the related documents delivered to STUK. It covers the project's nuclear safety and radiation safety, security arrangements, the planning of emergency response arrangements and nuclear safeguards. The conclusions of this safety assessment are based on the maximum volume of waste requiring disposal proposed by Posiva, but they are also valid for volumes of waste smaller than that.

1.1 The disposal project in general

In its construction licence application, Posiva proposes the disposal of spent nuclear fuel for a maximum of 9,000 tonnes of uranium (tU). This corresponds to the accumulation of spent nuclear fuel generated during the operation of Teollisuuden Voima Oyj's (TVO) operating plant units Olkiluoto 1 and 2, the plant unit Olkiluoto 3 under construction and the plant unit Olkiluoto 4 being planned, as well as the operating Loviisa 1 and 2 plant units of Fortum Power and Heat Oy (Fortum). The volume does not include the spent nuclear fuel delivered from the Loviisa plant units to the reprocessing facility in Mayak, Russia, in accordance with the agreement that remained in force until 1996.

The spent nuclear fuel is stored in interim storages at the nuclear power plants, from which it will be transported to the encapsulation plant for disposal. The encapsulation plant has not been designed for extensive storage of nuclear fuel; instead, only the amount of nuclear fuel intended for disposal will be transported there each time.

Posiva's disposal project is based on the KBS 3 concept in accordance with the multibarrier principle, in which the spent nuclear fuel is packed into canisters made out of copper and iron after a minimum of 20 years of interim storage and then disposed of in a repository to be built in bedrock. Posiva's nuclear waste facility consists of an encapsulation plant located on top of the disposal facility above ground as well as a disposal facility reaching down to a depth of approximately 450 metres.

At the encapsulation plant, the spent nuclear fuel is placed into a disposal canister and the canister's copper lid is welded. The finished disposal canisters are transferred from the encapsulation plant into the underground disposal facility via a shaft. The construction of the encapsulation plant will be completed before the operation of the nuclear waste facility begins.

In the disposal facility, the disposal canisters are transferred into the deposition tunnels and emplaced into disposal holes lined with bentonite clay. After the canisters have been emplaced, the tunnels are backfilled with clay material as the planned number of canisters is emplaced in them. More deposition tunnels are constructed in the disposal facility as the disposal progresses during the operating period.

A repository will also be constructed as part of the disposal facility for the disposal of waste containing radioactive substances generated during the operation of the encapsulation plant and disposal facility and in connection with its decommissioning.

After all the spent nuclear fuel and the nuclear waste produced during use and decommissioning have been disposed of, the operating period of the

nuclear waste facility will end with the decommissioning of the encapsulation plant located above ground and backfilling as well as sealing the rooms in the disposal facility underground. Close to the surface, the underground rooms are filled in with structures that make intrusion into the repositories difficult. The planned disposal of spent nuclear fuel will be passively safe after closure. Ensuring the safety of disposal will not require monitoring the disposal site or other maintenance activities after the disposal facility has been closed.

1.2 Safety regulations

Sections 5–7 of the Nuclear Energy Act (990/1987) contain provisions regarding the use of nuclear energy.

Section 5: The use of nuclear energy, taking into account its various effects, shall be in line with the overall good of society.

Section 6: The use of nuclear energy must be safe; it shall not cause injury to people, or damage to the environment or property.

Section 6 a: Nuclear waste generated in connection with or as a result of the use of nuclear energy in Finland shall be handled, stored and permanently disposed of in Finland […], and

Section 7: Sufficient physical protection and emergency planning as well as other arrangements for limiting nuclear damage and for protecting nuclear energy against illegal activities shall be a prerequisite for the use of nuclear energy.

The principles of Chapter 2 a of the Nuclear Energy Act must be followed in the use of nuclear energy: the safety of nuclear energy use must be maintained at as high a level as practically possible, safety must be ensured in accordance with the safety principle of defence-in-depth, the maximum values of radiation exposure of the plant's personnel or the environment must not be exceeded, and the design of the facility must provide for the possibility of operational occurrences and accidents. The safety of the nuclear facility must be proven reliably, and the overall safety must be assessed at regular intervals. Safety must take priority during the construction and operation of a nuclear facility, and preparations for the decommissioning of the facility, disposal of the nuclear materials and nuclear waste must be made already during the design phase of the facility. The licensee must have a sufficient number of qualified personnel suitable for the related tasks, a responsible manager as well as a management system at its disposal. The licensee of a nuclear facility must ensure that the necessary emergency response and security arrangements are in place.

The following Government decrees issued under Section 82 of the Nuclear Energy Act provide more specific safety regulations based on the general safety requirements set out in the Nuclear Energy Act:

- Government Decree on the Safety of Disposal of Nuclear Waste (736/2008)
- Government Decree on the Security in the Use of Nuclear Energy (734/2008)
- Government Decree on Emergency Response Arrangements at Nuclear Power Plants (716/2013).

In addition to these, the Radiation and Nuclear Safety Authority (STUK) has published a collection of regulations, the YVL Guides, which define the detailed safety requirements. The licensee has the right to present a procedure or solution that differs from the YVL Guides, but in that case the licensee must prove that the requirement or safety level laid down in the YVL Guides is met.

The material related to Posiva's construction licence application has been reviewed against the valid YVL Guides, which were published in 2013. In an international comparison, the requirement level of STUK's new guides is high. The guides were drawn up to fulfil the requirements by the International Atomic Energy Agency (IAEA) and the Western European Nuclear Regulators' Association (WENRA) that were up-to-date at the time of drawing up the guides. The validity of the guides is evaluated regularly, and they are updated as necessary.

STUK's renewed YVL Guides were published after Posiva had delivered the construction licence application as well as the construction licence application materials addressed to STUK. According to STUK's decision (1/0010/2011), Posiva has had the right to use the latest drafts of the YVL Guides under preparation in preparing its licence application. As far as possible, Posiva has used the drafts available during the preparation phase of the construction licence application, but changes to the drafts of the YVL Guides were still being made during 2013.

1.3 Other points of departure for the safety assessment and the structure of the safety assessment

The safety assessment is based on the technical materials in accordance with Section 35 of the Nuclear Energy Decree and Section 16 of Government Decree 736/2008, delivered to STUK by Posiva. The materials have been delivered to STUK in several batches and have been updated or otherwise supplemented during the application process, based on the remarks by STUK on the one hand and the progress of the facility design on the other.

STUK has reviewed the technical materials mentioned above in connection with reviewing the construction licence application and granted its approval for them:

- Preliminary safety analysis report, STUK decision 1/H42241/2012 10.2.2015
- Probabilistic risk assessment in the design stage, STUK decision 1/H42253/2012 10.2.2015
- Proposal for a classification document, STUK decision 3/H42261/2014 10.2.2015
- Report on the quality management of the construction of a nuclear facility, STUK decision 1/H41401/2014 24.6.2014
- Preliminary plan concerning security arrangements, STUK decision 2/H42217/2014 5.1.2015
- Preliminary plan concerning emergency response arrangements, STUK decision 3/H41501/2013 3.4.2014
- Plan for arranging the safeguards control necessary to prevent proliferation of nuclear weapons, STUK decision 18/H42212/2014 12.12.2014
- Report on the arrangements referred to in paragraph 7 of Section 19 of the Nuclear Energy Act (Ensuring the implementation of regulatory control by STUK), STUK decision 9/H42212/2013 9.12.2013
- The post-closure safety case of the disposal in Olkiluoto, STUK decision 1/H42252/2015, 10.2.2015

In the safety assessment, the safety of Posiva's project has been assessed against the requirements laid down in Government Decrees 736/2008, 734/2008 and 716/2013. The requirements of Government Decree 736/2008 have been presented in the safety assessment, but the structure is not directly based on that of the Decree on the Safety of Disposal of Nuclear Waste: rather, it has been written in sections focusing on various fields. Due to the method of discussion, the subsections of the sections of the Government decree have been discussed in parts as necessary, and each subsection has been presented in connection with the field in which the issue is covered. The requirements of the Government Decree on the Security in the Use of Nuclear Energy and the Decree on Emergency Response Arrangements at Nuclear Power Plants have not been presented in the safety assessment, but the issues required by the decrees have been reviewed. A summary of the results of the entire review is presented at the end of the safety assessment.

In addition to the aforementioned Government decrees, the safety assessment also covers the requirements of Sections 18 and 19 of the Nuclear Energy Act which have not been separately included in the current Government decrees, but the assessment of which is within STUK's field. This refers to paragraph 1 of Section 18 which concerns the decision-in-principle of the project and paragraphs 6–8 of Section 19 of the Nuclear Energy Act which concern the arrangement of nuclear fuel management, ensuring STUK's regulatory control and the expertise of the licence applicant. The safety assessment also covers the fulfilment of international agreements that are binding on Finland and concern nuclear safeguards, nuclear safety and nuclear waste management, also ensuring that the applicant otherwise has the prerequisites for the safe management of operations (Nuclear Energy Act, Section 19(10)).

In addition to the Government decrees and Sections 18 and 19 of the Nuclear Energy Act, the following fields have been covered in the safety assessment: the transport of spent nuclear fuel, the alternative horizontal disposal solution (KBS-3H), and the re-openability of the repository of spent nuclear fuel.

1.4 Scope of application of Government Decree 736/2008 and definitions

Section 1: Scope of application

This Decree shall apply to the disposal of spent nuclear fuel and other nuclear waste originating in a nuclear facility into a facility to be constructed in bedrock.

The decree shall also apply to radioactive waste

as referred to in section 10 of the Radiation Act (592/1991), if such waste is sited in a disposal facility for nuclear waste, as referred to in subsection 1.

Provisions on the handling and storage of spent nuclear fuel and other nuclear waste in a nuclear facility attached to a nuclear power plant are laid down in the Government Decree on the Safety of Nuclear Power Plants (733/2008)[1].

The Olkiluoto encapsulation plant and disposal facility is a plant complex designed for the disposal of spent nuclear fuel.

Section 2: Definitions

For the purposes of this Decree:

1) nuclear waste facility shall refer to a nuclear facility used for the encapsulation of spent nuclear fuel or conditioning of other nuclear waste for disposal, and to a disposal facility for spent nuclear fuel or other nuclear waste;

2) disposal facility shall refer to an entirety comprising the rooms for disposal of the waste packages (emplacement rooms) and the adjoining underground and above-ground auxiliary facilities.

3) disposal site shall refer to the location of the disposal facility and, after disposal has been completed, the area entered in the real estate register in accordance with Section 85 of the Nuclear Energy Decree (161/1988), and the underlying ground and bedrock.

4) short-lived waste shall refer to nuclear waste, the activity concentration of which after 500 years is below the level of 100 megabecquerels (MBq) per kilogram in each disposed waste package, and below an average value of 10 MBq per kilogram of waste in one emplacement room;

5) long-lived waste shall refer to nuclear waste, the activity concentration of which after 500 years is above the level of 100 megabecquerels (MBq) per kilogram in a disposed waste package, or above an average value of 10 MBq per kilogram of waste in one emplacement room;

6) annual dose shall refer to the sum of the effective dose arising from external radiation within the period of one year, and of the committed effective dose from the intake of radioactive substances within the same period of time;

7) long-term safety shall refer to the safety of disposal after the operational period of the disposal facility, taking account of radiological impacts on man and the environment;

8) safety case shall refer to documentation for demonstrating compliance with the long-term safety requirements;

9) safety functions shall refer to factors preventing and limiting the releases and migration of disposed radioactive materials;

10) barrier shall refer to an engineered or natural structure or material used for achieving safety functions;

11) assumed operational occurrence shall refer to an incident influencing the safety of a nuclear waste facility that can be expected to occur at least once during any period of a hundred operating years;

12) postulated accident shall refer to such incident influencing the safety of a nuclear waste facility that can be assumed to occur more rarely than once during any period of a hundred operating years; postulated accidents are grouped further into two classes on the basis of their frequency:

a) class 1 postulated accidents, which can be assumed to occur at least once during any period of a thousand operating years;

b) class 2 postulated accidents, which can be assumed to occur less frequently than once during any period of a thousand operating years;

13) expected evolution scenario shall refer to such change affecting the performance of barriers that has a high probability of causing radiation exposure during the assessment period and which can be caused by interactions occurring in the disposal facility, by geological or climatic phenomena, or by human action; and

14) unlikely events impairing long-term safety shall refer to such potential events significantly affecting the performance of barriers that have a low probability of causing radiation exposure during the assessment period and which can be caused by geological phenomena or by human action.

This safety assessment uses the definitions of Government Decree 736/2008. To specify the definition of paragraph 1, Posiva's nuclear waste facility in this safety assessment refers to the complex consisting of the encapsulation plant and disposal facility.

1 The Decree has been repealed by the Government Decree on the Safety of Nuclear Power Plants (717/2013)

Safety during operation refers to the operating period of the nuclear waste facility from the pre-operational tests to the decommissioning and closure of the facility. The decommissioning of the encapsulation plant includes dismantling the plant and taking care of the resulting active waste. The operating period of the disposal facility will end when the underground rooms have been closed by backfilling and plugging all tunnels and shafts excavated underground.

Section 22: Disposal in the ground

If nuclear waste, as referred to in the Nuclear Energy Act, will be disposed of in a facility constructed in the ground, said disposal shall be planned and implemented in compliance with the requirements laid down in sections 3—9 and 13—21 herein. Only very low-level waste, the average activity concentration of which does not exceed the value of 100 kBq per kilogram, and the total activity of which does not exceed the limits laid down in section 6 subsection 1 of the Nuclear Energy Decree, can be placed in a facility constructed in the ground.

Posiva's construction licence application does not include a disposal facility constructed in the ground; therefore, this section is not covered in this safety assessment.

2 The safety principles of the disposal system

2.1 General requirements

Implementing the disposal in stages

Section 10: General requirements concerning disposal

Disposal shall be implemented in stages, with particular attention paid to aspects affecting long-term safety. The planning of the construction, operation and closure of a disposal facility shall take account of reduction of the activity of nuclear waste through interim storage, the utilisation of high-quality technology and scientific data, and the need to ensure long-term safety via investigations and monitoring. However, the implementation of the various stages of disposal shall not be unnecessarily postponed.

The planning for the disposal of the spent fuel and the stages of progress have followed the schedule in the Government decision-in-principle issued in 1983, which has been later specified by decisions made by the Ministry of Trade and Industry and the Ministry of Employment and the Economy. There is no experience of the disposal of spent fuel in Finland or internationally, and the planning of the disposal – characterising the features of the disposal site and demonstrating the safety through analyses – has required a preparation period that has been much longer than for the other nuclear facilities operating or under construction in Finland.

During the interim storage of spent nuclear fuel, the activity and heat production of the fuel are reduced, which makes the disposal easier to implement both technically and for the radiation safety of the personnel. The starting point for the design of the encapsulation plant and disposal facility as well as the post-closure safety case has been at least 20 years of interim storage for the fuel assemblies to be handled and disposed of. Posiva has proposed that the fuel elements to be brought into the encapsulation plant should be stored for 30–50 years, during which time the activity and heat production of the fuel have been significantly reduced compared to a fuel element removed from the reactor. Due to the storage time required for the spent fuel generated by the use of the Olkiluoto 3 and Olkiluoto 4 plant units, the use of the encapsulation plant and disposal facility is planned to continue until 2120.

After the decision-in-principle concerning the disposal of spent nuclear fuel was ratified in 2001, Posiva moved on to the detailed site studies in accordance with the safety requirements and the plans presented in the application for a decision-in-principle, as a part of which Posiva has constructed an underground rock characterisation facility (Onkalo). Onkalo is planned to be a part of the disposal facility, and in constructing the underground rock characterisation facility, Posiva has followed the requirements for nuclear facilities applied to rock construction. STUK has regulated the construction of the research facility using the same procedures as for regulating the construction of a nuclear facility (STUK's decision Y810/22, 26 October 2001).

During the construction phase of the encapsulation plant and disposal facility, Posiva will construct the encapsulation plant, other rooms needed for the use of the facilities and the first stage of the repository. The construction of the disposal facility and the excavated rooms being open cause disturbances to the bedrock surrounding the disposal facility: for the sake of post-closure safety, the intention is to minimise the disturbances. For this reason, the disposal facility will be expanded during the operation of the facility as based on the needs of the progress of the disposal. The deposition tunnels and other excavated rooms will be closed off as the disposal in the tunnel or area in question is completed. The immediate closure of the deposition tunnels promotes the restoration of characteristics that are favourable to post-closure safety.

Conclusion

Posiva has taken the reduction of activity of the spent nuclear fuel by interim storage into account in the design of the encapsulation plant and disposal facility. The stages related to the life cycle of the disposal facility are construction, disposal activities and closure. Posiva has designed these stages in a way that is beneficial to post-closure safety. Posiva has proceeded in the disposal project for spent nuclear fuel in accordance with the schedule presented by the Government and the Ministry of Employment and the Economy, and the implementation of the various stages of disposal has not been postponed unnecessarily.

Selection of the disposal site

Sections 12(1) and 12(4): Disposal site

The geological characteristics of the disposal site shall, as a whole, be favourable to the isolation of the radioactive substances from the environment. ***Any area with a feature that is substantially adverse to post-closure safety shall not be selected as the disposal site.***

The depth of the waste emplacement rooms shall be selected appropriately as regards the waste type and local geological conditions. The goal related to disposal depth shall be that any impacts on the long-term safety of above-ground events, activities and environmental changes will remain minor and that intrusion into the waste emplacement rooms will be difficult.

Olkiluoto has been selected as the location of Posiva's disposal facility in the decision-in-principle in 2001. In connection with the choice of location, it has been estimated that the characteristics of bedrock in Olkiluoto are favourable on the general level for ensuring the post-closure safety of spent nuclear fuel disposal. In addition, no issues that would indicate the unsuitability of the disposal site have been found at the selected location. In the decision-in-principle, the disposal depth for spent fuel has been set as 400–700 metres.

In the construction licence application material, Posiva has studied the geological structures of the bedrock at the disposal site, the presence of water conductive structures and fractures, the technical properties of rock types, the water conductivity of the bedrock and the stresses in the bedrock and the chemical properties of groundwater as well as constructability in connection with the choice of disposal depth. In addition to these, the protection of depth against the effects of above-ground natural phenomena and human activities has been taken into account.

Deeper down, the frequency of fractures in the disposal bedrock and the flow rate of groundwater decrease, which is favourable to post-closure safety. In depths that exceed the selected disposal depth, the disadvantages due to unfavourable relationship between the stresses in the bedrock and the rock strength as well as the salinity of the groundwater increase. In addition, the depth is limited by the horizontal fracture zone: the intention is to avoid penetrating it by considered adaptation of the disposal facility. Posiva has estimated that at the selected disposal depth of 400–450 metres, the requirements for the post-closure safety and the constructability of the disposal facility are fulfilled.

The most important above-ground natural phenomena with regard to disposal are the changes of conditions due to an ice age as well as permafrost. Based on modelling, Posiva has estimated that the permafrost would reach the depth of 60–240 metres during a dry, cold period lasting 10,000 years. Using the same analysis, Posiva has estimated that permafrost extending to a depth of 400 metres would require a dry, cold period of 100,000 years, which it considers unlikely. There are uncertainties related to climate evolution analyses that extend far into the future, and for this reason, Posiva has also estimated the effects of permafrost that reaches the disposal depth on the performance of the engineered barriers.

The disposal site has been selected so that it has no particular natural resources that would increase interest in ore-prospecting or mining activities. Extensive use of groundwater as drinking water is not to be expected in Olkiluoto, because the groundwater is saline. No water intake plants are expected in Olkiluoto or its immediate vicinity, because the areas are not currently classified as groundwater areas. The choice of location and the disposal depth of several hundreds of metres reduce the risk of unintentional intrusion by humans in the disposal facility. In the safety case, the assessment of exposure pathways of various radioactive materials is required based on the Guide YVL D.5, one of which is a medium-deep drilled water well.

The suitability of the volume of bedrock planned

for disposal has been assessed in more detail in Section 7.1 of the safety assessment, and the fulfilment of the safety requirements as a result of various evolution scenarios has been assessed in Section 7.3 of the safety assessment.

Conclusion

The spent fuel disposal depth of 400–450 metres is in accordance with the decision-in-principle issued regarding the Olkiluoto disposal facility and the safety requirements set by STUK. The disposal depth has been selected with due attention given to the post-closure safety of the disposal and to sufficient protection against above-ground and human activities.

2.2. Multibarrier principle

Section 11: Multibarrier principle

The long-term safety of disposal shall be based on safety functions achieved through mutually complementary barriers, so that a deficiency of an individual safety function or a predictable geological change will not jeopardise the long-term safety.

Safety functions shall effectively prevent releases of disposed radioactive materials into the bedrock for a certain period, the length of which depends on the duration of the radioactivity in waste. For short-lived waste, this period shall be at least several hundreds of years, and for long-lived waste, at least several thousands of years.

The multibarrier principle is a principle guiding the design of the disposal of nuclear waste, which corresponds to the defence-in-depth safety principle required by Section 7 b of the Nuclear Energy Act. In disposal in the bedrock, the bedrock surrounding the repository acts as a natural barrier. The characteristics of the bedrock must be stable and maintain favourable conditions for the performance of the engineered barriers. The bedrock must also retard the migration of radioactive material into the biosphere above the bedrock. In designing the disposal system, the waste matrix, waste package, buffer surrounding the packages, backfill of the emplacement rooms and structures closing off the entire disposal facility must be taken into account as engineered barriers. The activity of the spent nuclear fuel, along with the risk caused by the radioactive substances, shall decrease by several orders of magnitude during the first few thousands of years. For this reason, the safety requirements separately state that the engineered barriers must effectively prevent the release of radioactive substances into the surrounding bedrock for several thousands of years. The activity concentration of the low- and intermediate-level waste generated during the use of the encapsulation plant is significantly lower than the activity concentration of the spent nuclear fuel, and the half-life of the radioactive materials is typically shorter; for this reason, the engineered barriers are required to contain the radionuclides for several hundreds of years for this type of waste.

The spent fuel disposal solution proposed by Posiva is primarily based on containment of the radioactive materials from the bedrock and the living environment. The containment is primarily based on maintaining the leak-tightness of the disposal canister. The performance of the canister is ensured by the bentonite buffer that surrounds it as well as the closure structures of the disposal facility and bedrock that surrounds the disposal facility, which creates favourable and foreseeable conditions for the disposal system. As the radionuclides are released from the disposal canister, the second objective of the disposal system is to isolate and retard the migration of radionuclides into organic nature.

Posiva has specified the following safety functions for the components of the spent fuel disposal system:

- The safety function of the disposal canister is
  - to ensure a prolonged period of containment of spent fuel within the protective structures. This safety function rests first and foremost on the mechanical strength of the canister's cast iron insert and the corrosion resistance of the copper surrounding it.
  - to ensure the subcriticality of the spent nuclear fuel in the long term.
- The safety functions of the buffer are intended to:
  - contribute to mechanical, geochemical and hydrogeological conditions that are favourable for the canister.
  - protect canisters from external processes that could compromise the safety function of complete containment of the spent fuel and associated radionuclides.
  - limit and retard radionuclide releases in the event of canister failure.

- The safety functions of backfilling the deposition tunnels are intended to:
  - contribute to favourable and predictable mechanical, geochemical and hydrogeological conditions for the buffer and canisters.
  - limit and retard radionuclide releases in the event of canister failure.
  - contribute to the mechanical stability of the rock adjacent to the deposition tunnels.
- The safety functions of the closure are intended to:
  - prevent the underground openings from compromising the long-term isolation of the repository from the surface environment and normal habitats for humans, plants and animals.
  - contribute to favourable and predictable geochemical and hydrogeological conditions for the other engineered barriers by preventing the formation of significant water conductive flow paths through the openings.
  - limit and retard inflow to and release of harmful substances from the repository.
- In Posiva's disposal solution, the bedrock acts as a natural barrier, and its safety functions are intended to:
  - isolate the spent fuel repository from the surface environment and normal habitats for humans, plants and animals and limit the possibilities of human intrusion, and isolate the repository from the changing conditions at the ground surface.
  - provide favourable and predictable mechanical, geochemical and hydrogeological conditions for the engineered barriers.
  - limit the transport and retard the migration of harmful substances that could be released from the repository.

Posiva has presented the roles of the barriers in the construction licence application material and specified their safety functions. Posiva does not specify safety functions for the spent nuclear fuel, even though the slow dissolution of the uranium oxide matrix of the spent nuclear fuel into the groundwater in the event that the disposal canister loses its leak-tightness is a key factor promoting safety. However, the characteristics of the fuel and the assumptions on fuel behaviour used in proving the safety as a part of the performance of the disposal system have been described in a way that is sufficient for the construction licence application phase. The safety functions specified by Posiva generally describe the tasks of the barriers and the functions related to containment and the limitation of the release and migration of radionuclides.

The performance targets of the bedrock and the engineered barriers and the fulfilment of the safety functions, as well as the evolution scenarios after the closure of the disposal facility, have been covered in Section 7 of the safety assessment.

Conclusion

The disposal system and the safety functions specified for the various barriers presented by Posiva are in accordance with the multibarrier principle.

2.3. Investigation and monitoring programme implemented during the operational period

Section 9: Disposal operations, subsection 4

The long-term performance of barriers shall be confirmed by establishing an investigation and monitoring programme, to be implemented during the operational period of the final disposal facility.

Section 10: General requirements concerning disposal

Disposal shall be implemented in stages, with particular attention paid to aspects affecting long-term safety. The planning of the construction, operation and closure of a disposal facility shall take account of reduction of the activity of nuclear waste through interim storage, the utilisation of high-quality technology and scientific data, and ***the need to ensure long-term safety via investigations and monitoring.*** *However, the implementation of the various stages of disposal shall not be unnecessarily postponed.*

As part of the construction licence application material, Posiva has delivered a monitoring programme to STUK that covers the period of time before the operation of the disposal facility. The programme describes Posiva's monitoring plans for the monitoring of bedrock mechanics, hydrology, hydrogeochemistry, the surface environment and foreign materials used in construction, as well as the behaviour of the engineered barriers. The plan proposed by Posiva focuses on the construction period during the first phase of the disposal facility,

but it also describes the general principles for monitoring during the operation of the disposal facility.

The results from the monitoring of the bedrock and groundwater are primarily used to verify the models that describe the evolution of the site. In addition, the results of the monitoring are used to monitor that the bedrock maintains the characteristics important to post-closure safety as effectively as possible (Government Decree 736/2008, Section 12) and that the rock construction will not cause unexpected or larger than estimated harmful effects. The disturbances caused by rock construction are covered in Section 4.2 of the safety assessment. The results from the monitoring of the above-ground environment are used as initial data in modelling the evolution of the environment.

The plans proposed by Posiva on monitoring the characteristics of the bedrock and groundwater as well as the effects of rock construction are based on the programme developed for monitoring the underground rock characterisation facility (Onkalo). Posiva has long experience in the characteristics to be monitored in addition to the technology used for monitoring based on the Olkiluoto site investigations and monitoring the construction of Onkalo. There is still development work remaining on the confirmation of bedrock characteristics related to the construction of the disposal facility and the measurements used in monitoring the disposal facility; this is covered in Section 7.1 of the safety assessment.

Posiva has presented the plans for monitoring the engineered barriers as a new field in the monitoring programme, in accordance with STUK's requirements. In the programme, Posiva has presented how it will utilise the tests related to the feasibility of disposal and the full-scale tests in developing the monitoring methods. The key principle in monitoring the engineered barriers is that the monitoring cannot interfere with the performance of the barriers or risk the safety of the disposal. The monitoring of the engineered barriers is particularly focused on the period when the disposal facility is in operation. Monitoring the engineered barriers is still at the development stage, and it requires the development of the monitoring objects and the technology, as well as the requirements by authorities. The development of the disposal monitoring programmes and measurement technology is emphasised internationally in EU's framework programmes and IAEA's projects, for example.

The environmental radiation monitoring programme related to the operation of a nuclear facility shall be submitted to STUK in connection with the operating licence application. As part of the construction licence application material, Posiva has supplied STUK with a programme to study the baseline state of the environment. The programme proposes ways to study the radiation in the environment before the facility is commissioned. The releases of radioactive substances into the environment that may occur from Posiva's nuclear waste facility are covered in Section 3.5 of the safety assessment, and the plans on preparing for the operation of the facility are covered in Chapter 5.

The disposal activities are planned to continue until the 2100s, and during this time, the licensee of the facility will be responsible for the monitoring related to the disposal. After the disposal of nuclear waste has been carried out in accordance with the requirements, the responsibility for the nuclear waste and any possible monitoring and control activities is transferred to the state in accordance with Section 34 of the Nuclear Energy Act.

Conclusion

Posiva has drawn up a programme on the monitoring of the bedrock and the above ground environment during the construction period of the disposal facility. The programme is extensively based on Posiva's experiences in monitoring the construction of the underground rock characterisation facility. The development of the monitoring programme must also be continued as based on the experiences and information gained during the construction of the disposal facility. Posiva has presented a plan for developing the monitoring of the engineered barriers during the operation of the disposal facility. With regard to monitoring the engineered barriers, there is also a need to specify the detailed requirements by the authorities.

The monitoring programme presented by Posiva fulfils the requirements laid down in Sections 9 and 10 of the Government Decree 736/2008 regarding the investigation and monitoring programme and the control measurements during the operational period of the disposal facility.

3 The design of the encapsulation plant and disposal facility with regard to the safety during operation

3.1. General safety principles of the nuclear waste facility

At Posiva's nuclear waste facility, the spent fuel is placed into disposal canisters, which are disposed of in the deposition holes drilled into the deposition tunnels. The key functions of the operation of the encapsulation plant and disposal facility are related to the handling of the spent nuclear fuel, fuel transport cask and disposal canister.

The key issue in designing the safe operation of the nuclear waste facility is the controlled handling of the fuel so that the risk of damaging the fuel is minimal. In addition, preserving the integrity of the fuel is ensured by maintaining the fuel in a subcritical state and taking care of removing the decay heat. The subcriticality of fuel that has cooled down for a long time and the removal of decay heat has been ensured by designing the structures that surround the fuel during the various handling stages, in such a way that the fuel is maintained in a subcritical state and the decay heat is removed in all situations without active measures.

Posiva has specified three safety functions for the nuclear waste facility: management of radioactive materials, management of reactivity and removal of decay heat. The management of radioactive materials includes ensuring the integrity of the fuel by handling the fuel in a controlled manner. If radioactive substances should be released at the facility, the air in the fuel handling cell and controlled area can be filtered. The filtration can also be implemented by gravity, if the power supply of the ventilation systems has been cut off. It follows from the above that the safety functions of the facilities can be implemented without an external power supply. At the facilities, the fuel handling functions have been designed so that they will stop in the event of a disturbance in the power supply.

Defence-in-depth safety principle

Nuclear Energy Act, Section 7 b Safety principle of defence-in-depth

The safety of a nuclear facility shall be ensured by means of successive levels of protection independent of each other (safety principle of defence-in-depth). This principle shall extend to the operational and structural safety of the plant.

According to the preliminary safety analysis report included in Posiva's construction licence application material, the defence-in-depth safety principle has been followed in the design of the encapsulation plant and disposal facility. In accordance with the safety requirements, Posiva follows the three first levels of the defence-in-depth safety principle.

The first level of the defence-in-depth safety principle means that the aim is to prevent the occurrence of operational occurrences and accidents in the design of the facility. This requires that the facility is constructed in compliance with the requirements and that it is operated reliably – which can be achieved by following high-quality requirements and sufficient safety margins during all stages of the facility's life cycle.

The second level of the defence-in-depth safety principle refers to preparing for deviations from normal operational conditions. The facility must have systems for detecting deviations and limiting the development of disturbances into accidents as well as guiding the facility into a controlled state, if necessary.

The third level of the defence-in-depth safety principle refers to accident management. Systems that limit the escalation of accidents, protect the barriers for confinement of radioactive materials and prevent the occurrence of severe fuel damage must be designed for the facility.

The following levels of the defence-in-depth

safety principle concern design extension conditions and severe accidents, which are not applied to the nuclear waste facility designed by Posiva. This is a definition in accordance with the safety requirements, on the basis that the volume of nuclear fuel and the activity inventory handled at the encapsulation plant at a time are small compared with the radiation dose limits that result from the releases caused by design extension conditions of the assumed accidents.

Applying the defence-in-depth safety principle to the safety functions

Section 6(3): Handling of spent nuclear fuel and other nuclear waste

In handling of spent nuclear fuel, any damage to the fuel and occurrence of a self-sustaining chain reaction of fissions shall be prevented, and sufficient cooling of the fuel shall be ensured, to a high degree of certainty.

The following presents the application of the defence-in-depth safety principle to safety functions during the operation of the encapsulation plant and disposal facilities.

Reactivity management

On the first level of the defence-in-depth safety principle, reactivity management has been taken into account in the design of the structures that contain fuel by ensuring subcriticality through structural design solutions. The structures that contain fuel include the fuel transport cask, fuel drying station and the disposal canister.

The structures must be designed in accordance with the safety requirements stated in the YVL Guides, so that the effective multiplication factor does not exceed 0.95 under normal circumstances or during operational occurrences, or the value 0.98 in other design basis scenarios – even if the structure containing fuel had been filled with water.

Despite the design basis described above, safety is further ensured by structural means by designing the structures containing fuel in a way that prevents water from coming in contact with the fuel in the handling cell.

In the criticality safety analyses, it has been found that the fuel cannot form a critical configuration under dry conditions during normal use. If the structures containing fuel should be filled with water, it is possible to prove that the criticality safety will not be endangered by taking the burn-up credit into account.

The potentiality of the fuel handled at the encapsulation plant becoming critical in an accident would require the configuration formed by the rod lattice of the fuel element to break and settle into a formation suitable for criticality. In addition, the free spaces in the fuel formation would need to become filled with water. The completion of both conditions in an accident is quite unlikely; therefore, it may be stated that the fuel will remain subcritical under normal circumstances as well as during operational occurrences and postulated accidents.

As a result, there is no need to take the second or third level of the defence-in-depth safety principle into account with regard to reactivity management.

Removal of decay heat

The spent fuel processed in the encapsulation plant and disposal facility has cooled down for a long time – or, in other words, the amount of radioactive substances and, as a result, the decay heat production of the fuel have significantly decreased due to radioactive decay. In the design of the encapsulation plant and disposal facility, it is assumed that the fuel has cooled down for a minimum of 20 years in the interim storage for spent fuel before it is transferred to the encapsulation plant. The assumption is conservative because, according to Posiva, the fuel transferred to the encapsulation plant has cooled down much longer than assumed during interim storage (30–50 years).

Following the first level of the defence-in-depth safety principle with regard to removing the decay heat means that the structures of the encapsulation plant and disposal facility must be designed so that the decay heat can transfer out of the fuel. When the fuel is transferred to the encapsulation plant, its temperature is 65–100 °C, depending on whether the fuel is brought in a water- or gas-filled transport cask. The residual thermal output of a single assembly is 114–460 W, depending on the type of facility the fuel assembly comes from.

Without active cooling, the fuel temperature can rise up to 120 °C during normal operation. During operational occurrences or accidents, the temperature may rise to 300 °C at maximum. This temperature is still far from a temperature that

could cause damage to the fuel structure. The fuel may be damaged due to heating at a temperature of approximately 800 °C. The safety requirements set a temperature limit of 650 °C for the fuel in reactor conditions during class 1 postulated accidents.

It can be stated that the fuel remains at sufficiently low temperatures with regard to permanent damage under normal circumstances as well as during operational occurrences and accidents at the encapsulation plant and disposal facility. However, due to reasons of operability, during normal operation the facilities containing fuel are actively cooled with air conditioning systems.

With regard to the removal of decay heat, the monitoring of fuel temperature so that the sufficiently low temperature of the fuel can be ensured applies to the second level of the defence-in-depth safety principle. The fuel temperature is monitored at the fuel drying station, and the temperature of the canister filled with fuel is monitored while the canister is in the canister transfer trolley. The cooling of the fuel handling and storage facilities is regulated as based on the air temperature.

Due to the low residual thermal output of fuel, decay heat cannot cause a postulated accident at the encapsulation plant or disposal facility, because the fuel integrity cannot be endangered due to heating caused by decay heat. For the removal of decay heat, it is not necessary to take the third level of the defence-in-depth safety principle into account in the design of the facility.

Management of radioactive substances

In the management of radioactive substances, the first level of the defence-in-depth safety principle includes prevention of the fuel from getting damaged. The fuel, transport cask and disposal canister must be handled safely so that the integrity of the fuel is not endangered. The safe handling of fuel is realised at the encapsulation plant by using planned movements and low lifting heights in handling the fuel. The fuel transport routes are predetermined, and an action by an operator is required for the transport to be realised. The protective automation system monitors that the allowed lifting and transport areas are not exceeded and stops the movement, if necessary. If paths cross, potential crashes are prevented by allowing the power supply of one device moving one component at a time.

With regard to the management of radioactive substances, the second level of the defence-in-depth safety principle includes measurement systems that observe radioactivity. The spread of radioactive substances within the facility is limited by maintaining the underpressure levels in the rooms and the leak-tightness of facilities containing radioactive substances. In those instances, the air flow moves into the direction of the more active room. Under normal circumstances, radioactive substances may spread from the fuel into the airspace of the handling cell and, during operational occurrences, also in the controlled area. The exhaust ventilation of the handling cell filters the air of the handling cell during fuel handling as well as based on radiation measurements, if necessary, thereby limiting the spread of radioactive substances into the environment. The filtration in the exhaust ventilation of the controlled area turns on as controlled by the protective automation if the exhaust ventilation radiation measurement system detects activity in the air.

In the postulated accidents at Posiva's nuclear waste facility, radioactive substances may be released at the facility. The third level of the defence-in-depth safety principle involves reducing the amount of released radioactive substances and mitigating the consequences of the accident by filtering the radioactivity with exhaust ventilation filters. In addition, it is possible to prevent the spread of radioactive substances from the controlled area into the environment by closing the ventilation's shut-off damper, which makes it possible to isolate the radioactive substances inside the encapsulation plant. During accidents, the emergency automation system carries out the safety functions' monitoring, control and protection measures, if the control and protective automation systems for normal situations and operational occurrences are out of operation.

Structural defence-in-depth safety principle

The structural defence-in-depth safety principle means that the facility has successive structures that back up each other, which are used to prevent and limit the spread of radioactive substances in the facility. The structural defence-in-depth safety principle is realised at Posiva's nuclear waste facility. The first barrier against spreading is the fuel cladding, and the next level at the various

stages of the fuel encapsulation and disposal is the fuel transport cask, the fuel handling cell or the disposal canister. The structures and filtration in the exhaust ventilation in the control area of the encapsulation plant act as the final barrier against spreading.

Strength and independence of the defence-in-depth levels

The strength and independence of the levels in accordance with the defence-in-depth safety principle have been taken into account in the safety design of Posiva's nuclear waste facility. The safety functions at the same safety level follow the redundancy, separation, and diversity principles.

The redundancy principle is realised through the doubling of the safety functions. In that case, the safety function can be implemented even if a component in the system would be inoperable. The redundancy principle has been applied to the suspension and transfer functions of the fuel handling systems, the systems that limit the spread of radioactive substances, and the measurement systems that monitor the areas of the facility. Of these functions, the power supply to the systems that monitor the facility and carry out alarm functions has been ensured in all situations.

The independence of the safety functions from each other is ensured by applying the principles of diversity and separation. The diversity principle has been followed in systems where the redundancy principle is not fully realised. For example, it is not possible to comply fully with the redundancy principle in lifting a transport cask. This has been complemented by a shock absorber implemented under the floor of the transport cask transfer corridor. In the event of a fall, the transport cask will maintain its leak-tightness, thanks to the shock absorber. The diversity principle is also realised in the grip of the fuel transfer machine, which has been secured by two separate methods.

The safety function separation principle is followed both structurally and functionally. In the functionally isolated systems, faults cannot transfer from one system into another on the same level of the defence-in-depth safety principle or from one level to another. The functional isolation has been applied to safety blocks in the separation of the subsystems of the electrical and automation systems.

Structural separation has been taken into account in systems where a disturbance caused by an external reason could spread from one safety function or subsystem into another. For example, the parallel subsystems carrying out the same safety function have been placed in different fire compartments, which means that a fire in a single compartment will not cause the loss of the whole safety function.

Conclusion

In connection with the construction licence application, Posiva has delivered a preliminary safety analysis report, which describes the facility level design bases at a sufficient level. Based on the design documentation, it can be stated that the facility can be implemented in a way that makes it possible to fulfil the safety requirements laid down in Government Decree 736/2008. Posiva will specify the system-specific design after the construction licence has been granted, so that the system design fulfils the sufficient level of detail specified in the YVL Guides for the design before construction of the structures and the manufacturing of the equipment of the nuclear waste facility is initiated.

Posiva has described the realisation of the defence-in-depth safety principle at a sufficient level in the construction licence application material. Posiva's nuclear waste facility follows the operational and structural defence-in-depth safety principle. The strength and independence of the levels in accordance with the defence-in-depth safety principle are sufficiently realised.

The functions of Posiva's nuclear waste facility have been designed so that, in accordance with Section 6(3) of the Government Decree 736/2008, any damage to the fuel and occurrence of a self-sustaining chain reaction of fissions will be prevented and sufficient cooling of the fuel will be ensured in the handling of spent nuclear fuel.

Radiation protection arrangements

Section 6(2): Handling of spent nuclear fuel and other nuclear waste

The nuclear waste facility shall employ effective radiation protection arrangements in order to limit the occupational radiation exposure and radiation impacts caused in the environment of the facility. In waste handling, releases of radioactive materials inside the facility and into the environment shall

be prevented and limited as necessary with containment, recovery and filtering systems. Sufficient radiation protection shall be ensured in handling of spent nuclear fuel or other highly irradiating nuclear waste by using remote handling and radiation shielding.

Posiva has estimated the external dose rates and the occurrence of contamination by radioactive material in the various areas of the encapsulation plant and disposal facility. Based on the estimate, the rooms in the controlled area are classified into radiation protection zones. The passage of employees in the controlled zone is monitored and restricted by passage and access control arrangements.

The radiation exposure of personnel is monitored with personal dosimeters. In addition, the facility has fixed dose rate meters. During the normal operation of the facility, the estimated collective annual dose of the personnel is 13 man-mSv. Most of the dose is collected during the maintenance of the fuel handling cell and its equipment.

The release of radioactive substances into the environment is monitored with continuously operating measuring instruments and samples taken from the release routes at regular intervals. The monitoring of releases is complemented with an environmental radiation monitoring programme.

The spent nuclear fuel is handled in an underpressurised handling cell whose exhaust air is filtered. The low- and intermediate-level nuclear waste generated during the handling of spent nuclear fuel is processed and packed in the facility's controlled area, where the ventilation can be filtered if necessary in the event of a possible operational occurrence or accident. If the waste packages are damaged, the corrective actions are planned on a case-by-case basis. The radioactive water produced by decontamination is collected by the drain system of the controlled area and processed in the active water processing system.

The spent fuel handled in the encapsulation plant and disposal facility is always in an enclosed space: inside a transport or transfer package, inside the handling cell or the inside the drying station connected to the handling cell or in the disposal canister.

The surface dose rate limit has been specified for the transport and transfer package in accordance with the transport requirements that are based on international recommendations. The realisation of the limits is ensured in connection with the separate permit process for the transport and transfer package. In the dimensioning of the thickness of the handling cell wall, the amount of radioactive substances contained by the fuel handled in the cell has been taken into account, in addition to ensuring that the dose rate on the other side of the wall is not too high for the radiation safety of the personnel. Similarly, the thicknesses of the walls in the handling and storage areas for disposal canisters that contain fuel are dimensioned to provide sufficient radiation protection. At the disposal facility, the canisters are transferred with a canister transfer vehicle, where the canister is inside a separate radiation shield. In the encapsulation plant and disposal facility, the fuel and the disposal canisters are handled via remote control due to the high dose rate.

Conclusion

The design of Posiva's nuclear waste facility takes account of limiting the radiation dose received by the personnel and the environment by all practical measures. Fuel handling is designed so that the release of radioactive substances in the facility and their spreading to the environment is limited as far as possible. The radiation exposure of the personnel is reduced by implementing the handling of fuel and the disposal canisters via remote control.

Disposal actions, waste accounting and the protection zone

Section 9(1), 9(5) and 9(6): Disposal operations

The transfer of waste packages into the emplacement rooms shall be carried out so that the possibility of accidents remain low and the packages cannot be damaged in any way that would affect long-term safety.

A record shall be maintained of disposed waste, including waste package specific data on the waste type, radioactive materials, location within the waste emplacement room, and other necessary data. The Radiation and Nuclear Safety Authority (STUK) shall arrange the permanent recording of information concerning the disposal facility and disposed waste.

An adequate protection zone shall be reserved round the disposal facility as a provision for the prohibitions on measures referred to in section 63 subsection 1 point 6 of the Nuclear Energy Act.

The spent nuclear fuel in the disposal canister is transferred from the encapsulation plant into the disposal facility via a canister lift. The canisters are transferred into the deposition tunnel either directly or after interim storage. During the canister transfers, the structures and functions that support the canister load are single failure tolerant, and the canister is prevented from tipping over. The transfer of the canister from the canister storage at the disposal facility into the deposition tunnel is carried out by means of a transfer and emplacement vehicle. During the transfer, the canister is placed inside a radiation shield that also functions as mechanical protection for the canister in the event of a possible tunnel collapse, or against rocks that may fall from the roof of the tunnel.

If the canister is damaged during any step of the disposal operation in a way that affects post-closure safety, the canister can be returned into the encapsulation plant to be reprocessed. If necessary, the fuel can be transferred into a new canister in the handling cell.

Posiva receives the data of the spent nuclear fuel to be disposed of from the licensees of the nuclear power plants that send the fuel. In the construction licence application material, Posiva has stated that a fuel data system will be developed for the nuclear waste accounting, in cooperation with the owners of Posiva. The plan for waste accounting is sufficient at the construction licence stage. Waste accounting must be in use by the time the operating licence application for Posiva's facility is submitted.

The permanent storage of information on the spent nuclear fuel to be disposed of has been specified as the task of the Radiation and Nuclear Safety Authority (STUK) in the Government decree. Because the duties of the National Archives Service include receiving and storing documents released by the authorities (Decree on the National Archives Service 832/1994), the permanent storage of the information is implemented in cooperation with the Radiation and Nuclear Safety Authority (STUK) and the National Archives Service. More specific plans for the permanent storage of the information have not been made yet, because it is currently estimated that the closure of Posiva's nuclear waste facility and the arrangement of the permanent storage of information will occur in the 2100s.

An area has been reserved for the nuclear waste facility in the currently valid land use plan of the Olkiluoto area. In addition, the protection zone required by Section 9(6) of Government Decree 736/2008 has been reserved in the disposal area for the prohibitions on measures referred to in Section 63(1), paragraph 6 of the Nuclear Energy Act.

Conclusion

Posiva's nuclear waste facility has been designed so that the transfer of the disposal canister into the repository can be implemented in such a way that the risk of accidents is low and the disposal canister will not be damaged in a way that affects post-closure safety. If the disposal canister is damaged, it can be transferred back into the encapsulation plant for reprocessing and the spent nuclear fuel can be transferred into a new canister, if necessary.

Posiva has a plan for developing nuclear waste accounting for the nuclear fuel subjected to disposal. The nuclear waste accounting must be in use before the operation begins. Together with the National Archives Service, the Radiation and Nuclear Safety Authority (STUK) arranges the storage of disposed waste in a permanent manner. The permanent storage of information will become timely after Posiva's nuclear waste facility is closed in the 2100s, as anticipated.

In the land use plan for the Olkiluoto island, the required precautionary action zone has been reserved for the disposal facility.

3.2. Operational occurrences and accidents

Section 8: Prevention of operational occurrences and accidents

In order to prevent operational occurrences and accidents, the design, construction and operation of a nuclear waste facility shall employ proven or otherwise carefully examined, high-quality technology. A nuclear waste facility shall encompass systems that facilitate quick and reliable detection of an operational occurrence or accident and prevent the aggravation of any event. Effective technical and administrative measures shall be provided for the mitigation of the consequences of potential accidents.

The functions at a nuclear waste facility, the failure of which could result in a significant release of radioactive materials or radiation exposure of

personnel at the facility, shall be ensured. Ensuring the functions important to safety shall primarily be based on inherent safety features, alongside systems and components that do not require external power supply or which, as a consequence of a loss of power supply, will settle into a state deemed preferable from the safety point of view.

The design of a nuclear waste facility shall take account of any impacts caused by potential natural phenomena and other events external to the facility. As external events, even unlawful activities aiming at damaging the facility shall be taken into account.

In a nuclear waste facility, the placement and protection of systems alongside operative methods shall ensure that fire, explosions or other events inside the facility do not pose a threat to safety.

In the functions of the encapsulation plant and disposal facility, the various lifting and transfer functions related to the fuel, transport cask and canister are essential. Equipments will be designed and manufactured for these functions; with the exception of the crane in the transport cask reception area, the equipment is unique and designed for the encapsulation plant and disposal facility. However, all devices are based on proven techniques including additional safety solutions to reach as high a level of nuclear safety as possible. Prototypes are made out of the devices, and their suitability for the planned purpose is proven through testing. Based on the tests, changes can be made if necessary in the design of the actual devices.

The principles and systems related to the observation and management of operational occurrences and accidents as well as the arrangements related to the mitigation of the consequences of accidents have been covered above, in Section 3.1.

The functions at Posiva's nuclear waste facility, the failure of which could result in a significant release of radioactive substances or radiation exposure of personnel at the facility or the population in the area surrounding the facility, have been ensured. The secured or single failure tolerant functions have been covered in more detail above in Section 3.1.

Out of the safety functions, maintaining subcriticality and the removal of decay heat are based on the natural safety features that do not require an external power source and will be realised even if external power source has been lost. This issue has been covered in more detail above, in Section 3.1. The spent nuclear fuel handling functions are designed in such a way that in the event of a fault situation or loss of external power source, the devices stop and remain in a controlled state.

The functions of Posiva's nuclear waste facility are designed in such a way that any of the handling functions can be interrupted for an unforeseen period. For this reason, the external threats with an impact on the durability of the structures are phenomena included in the potential external threats to be taken into account in the design of Posiva's nuclear waste facility. Such external threats include exceptional weather phenomena, such as storm winds, heavy rain and snow as well as lightning. Other external threats to be taken into account in the design include earthquakes, aircraft crash and explosions. The external threats are taken into account in the design of the structures of the nuclear waste facility as well as the dimensioning of the systems and the equipment. Illegal activity is covered in Section 10.

For the design of Posiva's nuclear facility, the potential internal threats have been investigated and an analysis on which of the same are relevant with regard to Posiva's nuclear waste facility has been completed. The relevant internal threats with regard to the encapsulation plant are fires and falling loads that may occur during the handling of spent nuclear fuel. The relevant internal threats related to the disposal facility are fires, collapsing structures, explosion accidents and flooding in the facility caused by groundwater. Fires have been taken into account in the design of the encapsulation plant and disposal facility by establishing fire compartments and designing the structures to be fire-resistant. Systems intended for fire protection and management have been designed for the nuclear waste facility. The other internal threats have been taken into account in a manner sufficient for nuclear and radiation safety in the design of the nuclear waste facility.

Conclusion

The design, construction and operation of Posiva's nuclear waste facility employ proven or otherwise carefully examined, high-quality technology. Prototypes will be made of the functions for which unique equipment is manufactured, in order to ensure functionality.

In accordance with the structural defence-in-depth safety principle, systems for detecting operational occurrences and accidents and preventing them from developing into more serious events have been designed for the facility. Preventing the release and spread of radioactive substances has been taken into account in the design of the nuclear waste facility. The natural safety features have been taken into account in the design of the safety functions.

Internal and external threats have been taken into account in the design of Posiva's nuclear waste facility, so that the threats considered possible do not affect the safety of the facility.

Operational safety analyses of the nuclear facility

Section 13: Operational safety of nuclear waste facility

Compliance with safety requirements concerning the operation of a nuclear waste facility shall be proven in connection with commissioning as far as possible. Insofar as this is not possible, operational safety shall be demonstrated through experimental or computational methods, or via a combination thereof. Computational methods shall be selected so that the actual risk or harm remains below the results of calculations, with a high degree of certainty. Computational methods shall be reliable and validated for dealing with the events under analysis. The selection of operational occurrences and accidents to be analysed shall take account of their estimated probabilities.

The fulfilment of the safety requirements on the operation of Posiva's nuclear waste facility is verified during the construction licence application phase as based on the facility design documentation and the analyses that describe the behaviour of the facility. Experimental and computational methods have been used to analyse the behaviour of Posiva's nuclear waste facility. Experimental methods have been used in the analysis describing the dimensioning of the shock absorber of the transport cask, for example. Computational methods have been used to implement, for example, the spent nuclear fuel criticality safety reviews, analyses describing the removal of decay heat, and the analyses on estimating releases of radioactive substances and the resulting radiation doses. The fire safety analyses have also been carried out using computational methods.

The computational methods have been selected in a way that ensures the cases are described in a conservative enough manner. The computational methods have been assessed to be sufficiently reliable and qualified for the cases. Out of the operational occurrences or accidents, only the cases estimated to result in releases of radioactive substances have been reviewed in detail.

Conclusion

Experimental and computational methods have been used in the analyses describing the behaviour of Posiva's nuclear waste facility. The calculation methods and initial assumptions of the analyses have been selected conservatively. The computational methods have been estimated to be sufficiently conservative and qualified for handling the events reviewed.

3.3. Safety classification and seismic classification

Section 7: Safety classification

The systems, structures and components of a nuclear waste facility shall be classified on the basis of their significance in terms of the operational safety of the facility, or the long-term safety of disposal. The required quality level of each classified object, and the inspections and testing necessary for verifying the quality, shall be adequate as regards the significance of the object in terms of safety.

The safety of the nuclear facility is ensured by safety functions; in order to control these functions, the facility must be divided into systems that form structural or functional units. In order to prove their safety significance, the nuclear facility's systems, structures and components must be grouped into safety classes 1, 2, and 3 and the Class EYT (non-nuclear safety classification), based on their safety significance. Post-closure safety must also be taken into account in the safety classification of the disposal facility's systems, structures and components. Structures important to post-closure safety in accordance with Guide YVL D.5 can include at least the waste packages and the buffer materials surrounding them, as well as special structures and the bedrock immediately surrounding the underground areas of the disposal facility.

In the encapsulation plant and disposal facility, spent nuclear fuel and the fuel basket of the fuel transport and transfer cask, insert of the disposal

canister and fuel rack of the fuel drying system as structures that ensure the criticality safety of nuclear fuel have been classified in safety class 2. Out of the functional systems, the most important for the implementation of safety functions and classified in the safety class 3 are the devices participating in the handling of the spent nuclear fuel and the disposal canister, the systems preventing and limiting the spread of radioactive substances, as well as the measurements and alarms important for safety.

In the disposal system proposed by Posiva, maintaining the integrity of the disposal canister is a key safety function, and the disposal canister has been classified in safety class 2, due to post-closure safety. As structures that ensure the performance of the canister and prevent the spread of radionuclides, the bentonite buffer, the backfill and closure structures of the deposition tunnel and the bedrock surrounding the repository have been classified in safety class 3.

The systems, structures and components of the nuclear facility must be classified according to the seismic resistance. Systems, structures and components assigned to seismic category S1 must maintain their integrity, leak-tightness, functionality and proper position in a loading situation caused by a design basis earthquake. Seismic category S2A comprises systems, structures and components, the maintenance of whose performance and integrity is not essential for the accomplishment of safety functions but which may have effects that may affect the safety-related operation, integrity or automated safety functions of seismic category S1 systems. Seismic category S2B comprises all other systems, structures and components at the nuclear facility.

The seismic classification concerns the operational safety of the facilities. In the encapsulation plant and disposal facility, the equipment required for preventing the spent fuel from falling, the structures and equipment preventing the release of radioactive substances as well as the measurements required in emergency situations have been classified in the seismic category S1. All of the structures and equipment, the collapse of which could damage the fuel or the disposal canister, have mainly been classified in safety class S2A. In the disposal facility, those structures in the bedrock facilities in which the disposal canister is not inside a radiation shield that provides mechanical protection have been placed in seismic category S2A.

The safety class determines the level of quality required in the design and implementation of the object and the extent of control procedures. The requirements and procedures typical to each field are applied to the various fields of technology. The requirements that concern these issues have been set in the YVL Guides on the various fields of technology. Posiva has determined the connection between the safety class and the required level of quality in the classification document delivered as part of the construction licence application material. The inspection classes proposed by Posiva, determining the quality level, mainly follow the safety classification.

Conclusion

As part of the construction licence application material, Posiva has presented a safety and seismic classification for the Olkiluoto encapsulation plant and disposal facility. In the safety classification, Posiva has taken the importance of the systems, structures and components for operational and post-closure safety into account. Posiva has also specified the connection between the safety importance of the systems, structures and components and the quality level. The safety classification proposed by Posiva fulfils the requirements of Section 7 of Government Decree 736/2008. Posiva's encapsulation plant and disposal facility are facilities of a new type, of which there is no extensive experience. For this reason, the safety importance and classifications of systems, structures and components must be evaluated and if necessary, the classifications must be changed during the design and construction.

3.4. Spent nuclear fuel

As a result of the planned operation of the Olkiluoto 1–4 and the Loviisa 1–2 plant units, it is estimated that a maximum of 9,000 tU of spent fuel will be accumulated with an activity inventory at the order of magnitude of $9 \cdot 10^{10}$ GBq and for the disposal of which 4,500 disposal canisters will be required. For the Loviisa 1–2 plant units, the annual discharge burn-up of the fuel element is planned to rise to the level of 47.5 MWd/kgU at maximum, for the Olkiluoto 1–2 plant units to

the level of 53 MWd/kgU at maximum and for the Olkiluoto 3–4 plant units to the level of 47 MWd/kgU at maximum. Correspondingly, the average burn-up for the various plant units is estimated to be 40.6 MWd/kgU for the Loviisa 1–2 plant units, 39.5 MWd/kgU for the Olkiluoto 1–2 plant units and 45.1 MWd/kgU for the Olkiluoto 3–4 plant units. The design basis of the encapsulation plant and disposal facility has been an average burn-up of 60 MWd/kgU for the fuel elements handled, and a cooling time of 20 years at minimum. Both design bases have been selected conservatively. STUK will approve increases in the burn-up and the fuel used at nuclear power plants separately, taking into account the entire life cycle of nuclear fuel up to the post-closure safety of disposal.

In the preliminary safety analysis report delivered as part of the construction licence application material, Posiva has described the characteristics of the spent fuel handled and disposed of at the encapsulation plant and disposal facility. The power plant-specific data on the various types of fuel have been presented in the memos delivered as topical reports of the preliminary safety analysis report. For the Olkiluoto 1-2 and the Loviisa 1-2 plant units, detailed data related to fuel have been presented. For the fuel of the Olkiluoto 3 plant unit, the data is still preliminary, and the data for the fuel of the Olkiluoto 4 plant unit are not yet available.

The key canister-specific criteria on the disposal of spent fuel are the radiation dose rate, production of decay heat and criticality safety. The fuel elements to be placed in the canister must be selected as based on the canister-specific loading plans and the fuel element acceptance criteria, taking the production of decay heat, radiation dose rate and reactivity of the spent fuel element into account. In addition, the selection of the fuel elements to be placed into the disposal canister must be optimised by the aid of the annual fuel accumulation, discharge burn-ups and operational periods of the plant units.

Fuel handling management is based on the fuel database planned by Posiva, which will be implemented together with the owners of Posiva, as well as the identification of the fuel elements aided by identification and location-based information.

The analyses of activity and decay heat have been presented comprehensively with various fuel types in accordance with several burn-ups and various enrichment levels.

According to Posiva, the handling and disposal of leaking and damaged fuel rods is normal, planned activity. Posiva has clarified the procedures separately with regard to the leaking fuel rods from Fortum and TVO. The damaged fuel rods from TVO are packed into rod capsules that are placed into rod magazines. Posiva proposes several procedures for the disposal of rod capsules. The fuel elements from Fortum that are found to leak will be transported to Olkiluoto as is, or packed into gas-tight cases. In both cases, the selection between methods will be made before the operation of the encapsulation plant begins. For post-closure safety, the fuel elements have been taken into account in the release rate of radioactive substances used as the source term of the analysis.

The fuel elements act as the source term for evaluating post-closure safety. Posiva sets 10-7/a as the relative radionuclide release rate from the fuel matrix. Posiva has characterised the fuel elements sufficiently and has provided sufficient grounds for the behaviours of the source term. Based on the probabilistic sensitivity analyses, the release of radionuclides from the fuel element is one of the most important parameters with regard to post-closure safety.

Conclusion

Sufficient information on fuel has been presented in Posiva's construction licence application material. Due to the great safety importance of the source term, Posiva must reduce the uncertainties related to it by applying for an operating licence. Posiva has not determined any other fuel acceptance criteria related to post-closure safety, than the criteria related to decay heat production and criticality safety. The acceptance criteria must be specified based on the factors used as the basis of the assessment of post-closure safety, such as the characteristics of the source term, by the time the application for an operating licence is submitted.

3.5. Realisation of the radiation dose constraints during operation

Section 3: Operation of nuclear waste facility

A nuclear waste facility and its operation shall be designed so that:

1) the radiation exposure of workers at the facil-

ity is limited by all practicable means and so that the maximum values laid down in the Radiation Decree (1512/1991) are not exceeded;

2) as a consequence of undisturbed operation of the facility, releases of radioactive materials into the environment remain insignificantly low;

3) as a consequence of assumed operational occurrences, the annual dose to the most exposed people other than personnel of the facility remains below the value of 0.1 millisievert (mSv); and

4) as consequence of a postulated accident, the annual dose to the most exposed people other than workers of the facility remains below:

a) the value of 1 mSv when a Class 1 postulated accident occurs;

b) the value of 5 mSv when a Class 2 postulated accident occurs.

When applying this section, radiation doses arising from natural radioactive materials in the host rock of or released from groundwater bodies into the underground rooms of the disposal facility, shall not be taken into account.

In accordance with the YVL Guides, the limitation of the radiation exposure of the plant personnel by all practical measures has been taken into account in the design of the encapsulation plant and disposal facility. The radiation exposure is decreased especially by the remote handling of the spent fuel and radiation shields.

During undisturbed operation of the encapsulation plant and disposal facility, releases of radioactive substances into the environment may occur if the cladding of a single fuel rod leaks upon its arrival to the encapsulation plant or if its leak-tightness is lost in connection with normal fuel handling in the handling cell. In these cases, gaseous and particulate radioactive matter is released from the fuel into the air. In the handling cell, fine matter containing radioactive substances may be released from the surface of the fuel and spread into the air and on surfaces. Radioactive wastewater and possibly also aerosols are created when the surfaces are cleaned. The surface of the fuel transport cask may also release radioactive substances that have become attached to it. However, the releases of radioactive substances that occur at the disposal facility in connection with normal operation are very small, because the disposal canisters and the packages of low- and intermediate-level waste handled at the facility are leak-tight, and their surface is clean from radioactive substances.

From the encapsulation plant, air from the controlled area or water used to clean the facilities is released into the environment in a controlled manner. The air and water containing radioactive substances is cleaned with the filters in the ventilation systems and the wastewater cleaning system, before it is released into the sea or into the atmosphere through the plant ventilation stack in a controlled and measured manner.

According to the estimate presented in the preliminary safety analysis report of the facility, the effective annual dose resulting from the releases of radioactive substances from the facility during normal operation is clearly under 0.0001 µSv to the most exposed individuals of the population, which is one hundred thousandth of the maximum limit set for an annual dose in the YVL Guides (0.01 mSv).

The postulated operational occurrences at the encapsulation plant and disposal facility have been covered in the preliminary safety analysis report in accordance with Guides YVL D.3 and YVL D.5. According to the analysis, damage to fuel elements in the handling cell will cause the largest annual dose on the part of operational occurrences to the most exposed individuals in the population. In the analysis, an erroneous attempt to set a fuel element into a fuel position in the drying system that already contains a fuel assembly has been assumed. In this case, it is postulated that 10% of the rods of both fuel assemblies are damaged. In this instance, the annual dose caused by the release is 0.00002 mSv based on the estimate, which is clearly under the maximum limit set for the annual dose for operational occurrences (0.1 mSv).

The postulated accidents at the encapsulation plant and disposal facility have been covered in the preliminary safety analysis report in accordance with Guides YVL D.3 and YVL D.5. Some of the postulated accidents (earthquake, aircraft crash, collapses in the underground area and explosion accidents) are nevertheless studied as external threats and initiating events of accidents. Posiva assumes conservatively that all postulated accidents are in class 1.

According to the analysis, failure of the canister lift and the disposal canister falling into the canister shaft, together with the lift car, will cause the highest annual dose out of the analysed accidents

to the most exposed individuals in the population. The release is filtered, in which case the annual dose is less than 0.01 mSv based on the estimate, i.e. clearly under 1 mSv, which is the limit value for an annual dose for the postulated accident.

In the construction licence application material, Posiva has reviewed the unfiltered releases of accidents in order to dimension the emergencies. The analyses are classified as design extension conditions of postulated accidents, and they describe which kind of radiation doses may be released from the encapsulation plant and disposal facility when taking account of rare combinations of failures. According to Guide YVL D.3, it is not necessary to study the design extension conditions of postulated accidents or take them into account in the design, because the amount of fuel contained by the encapsulation plant at a time does not exceed the limit value 100 tU. Based on the reviews by Posiva, the disposal canister being damaged in case of a failure of the canister lift would cause the highest annual dose of approximately 20 mSv to the most exposed individuals of the population, which corresponds to the limit value set for the annual dose for design extension conditions of postulated accidents.

Conclusion

The encapsulation plant and disposal facility can be constructed in a way that fulfils the requirements of Section 3 of the Government Decree 736/2008. The annual dose limits set for radiation exposure under normal circumstances, operational occurrences and accidents, are not reached in the cases analysed. The analysed events are selected in accordance with the largest potential releases. Based on the analyses, the limit values set in the regulations are not reached even in the case of unlikely events, such as an unfiltered release.

3.6. Probabilistic risk assessment in the design stage

The probabilistic risk assessment (PRA) in the design stage covers the fuel handling stages, starting from the arrival of spent fuel at the encapsulation plant and ending with its placement in the deposition hole underground. The design stage PRA has been drawn up as based on the preliminary design information, general equipment reliability data, conservative assumptions and expert assessments.

The design stage PRA has been drawn up in two stages. The analysis first includes a qualitative section, in which the identification of potential risks – including internal and external threats, risk assessment and elimination – were carried out comprehensively. At the second stage of analysis, quantitative models were created for the event sequences that were estimated to be the most significant with regard to risks. Quantitative analysis presents estimates on the release of radioactive substances into the environment and the radiation doses caused to the personnel of the facility with their probabilities. Quantitative analysis does not deal with the accidents that do not immediately result in a release or radiation exposure.

In the design stage PRA, significant environmental release can only occur in the events where one or more fuel assemblies are damaged and the filtration of the ventilation fails at the same time. The most important initiating event is the disposal canister falling into the deposition hole and the loss of the canister's leak-tightness. The filtration function significantly limits the environmental release, and the failure of filtration is mostly due to a postulated human error in connection with the maintenance of the system that has not been discovered in the testing carried out after maintenance. All identified environmental releases are under the limit of a large release presented in Guide YVL A.7 with a large margin.

The probability of the personnel becoming exposed to life-threatening radiation doses is very low, and it would require the person accessing the fuel handling cell or the weld inspection chamber. This is prevented with the help of design and instructions. The presence of personnel near the disposal canister suggests the low probability of this leading to the annual dose limit being exceeded, which may be a result of issues such as human error, failure in the sampling of the transport cask, or a collapse in the repository that prevents the person from exiting the area.

Conclusion

Based on the review by STUK, the design-phase PRA of the encapsulation plant and disposal facility has been implemented in accordance with the requirements presented by Guides YVL D.3 and YVL A.7. The encapsulation plant and disposal facility can be constructed in a way that fulfils the requirements of Section 8 of the Government Decree 736/2008 (covered above in Section 3.2). As the detailed design of the systems progresses, it should be ensured through the aid of PRA that the filtration functions in particular and the arrangements that prevent personnel from accessing the fuel handling cell or the canister weld inspection chamber when presence in these areas may result in significant radiation doses are as reliable as possible.

4 Constructing a nuclear waste facility

4.1. Encapsulation plant and the other buildings above ground

The nuclear waste facility complex designed by Posiva and constructed above ground includes the encapsulation plant and the other buildings above ground needed to support the operation of the facility, for example.

The potential internal and external threats to the facility have been taken into account in the design and placement of the encapsulation plant, of which the postulated earthquakes, extreme weather conditions, aircraft crash, explosions and fires in particular exert an impact on the design of the structures. The structure of the encapsulation plant is much simpler than e.g. a nuclear power plant, and it is not possible for temperatures or pressures comparable to a nuclear power plant to be generated during the encapsulation process that the structures would need to withstand.

In the encapsulation plant, an important single factor affecting the dimensioning of the structures is the radiation protection of the operating personnel, which has been planned to be implemented with the massive concrete structures surrounding the handling areas of the fuel and the canister. The building of the encapsulation plant is designed in accordance with the EN standards and the related Finnish national appendices. The areas of the facility where surface contamination is assumed to be likely to occur are equipped with a stainless steel lining that makes cleaning easier, and the other areas where occasional surface contamination may occur are surfaced with a surface treatment that is easy to clean.

In connection with constructing the underground rock characterisation facility, Posiva has constructed buildings at the site required for the construction of the research facility or the research activities. Out of these buildings, the disposal facility's ventilation building is important to the operational safety of the disposal facility in postulated accidents where the possibility exists of a release of radioactive substances. STUK has ensured and provided through regulation that the safety requirements of the ventilation building and ventilation systems that have already been implemented as part of the control of Onkalo have been fulfilled to the extent required by the YVL Guides.

According to STUK, the implementation of the encapsulation plant and the other buildings above ground is being carried out using proven technology used in constructing nuclear facilities, and they can be implemented in accordance with the requirements found in the YVL Guides.

4.2. Disposal facility

Section 9(3) Emplacement activities

The emplacement activities shall be separated from the excavation and construction work of the disposal facility in such a manner as to ensure that excavation and construction work cannot have any harmful impact on the operational safety of the facility or the long-term safety of disposed waste.

Section 12(3) Disposal site

The layout, excavation, construction and closure of underground facilities shall be implemented so that the characteristics of the host rock deemed important in terms of long-term safety are retained as far as possible.

Posiva has covered the construction of the underground sections of the disposal facility, phasing of the construction, use of the facilities and their closure in the preliminary safety analysis report delivered as part of the construction licence application material, and the background reports that complement it. Posiva has presented the development needs related to the construction of the repository in the disposal concept development

plan delivered to STUK as well as the reports that complement the construction licence application material.

The disturbance caused by the construction to the bedrock must remain controlled and less than the set design requirements, so that the anticipated mechanical, geochemical and hydrogeological conditions favourable to the engineered barriers are maintained during construction, and that they will begin to return towards the baseline conditions before construction, after a reasonable time from closure. Key issues taken into account by Posiva in the construction of the disposal facility to ensure the realisation of this goal include 1) the placement of the disposal facility's repository 2) the construction of the repository in phases, their operation and closure, as well as 3) the placement of bore and drill holes, sealing water leaks, limiting the excavation disturbance zone and limiting the chemical disturbance caused by construction materials detrimental to long-term performance.

Posiva places the repository with an aim to avoid geological and hydrogeological zones that are unfavourable for post-closure safety as well as fractures in the bedrock, in which significant dislocations may occur or that may – due to their water conductivity or flow characteristics – cause the groundwater chemistry to become unfavourable or act as rapid flow routes from the deposition holes to the surface. For this purpose, Posiva has developed a rock suitability classification (RSC), which is used as the basis for positioning the repository during the various stages according to the set criteria, all the way to the selection of the placement of a single deposition hole. Posiva must develop the rock suitability classification method further for the needs of post-closure safety, optimal use of space and positioning. More information about the rock suitability classification system and the related development needs can be found in Section 7.1 of the safety assessment.

The actual disposal activities are separated from the construction of the repository by dividing the construction and operation of the repository in phases. The excavation and construction work progresses ahead of the disposal¬ activities, and in a way that maintains a sufficient distance from the facilities in which disposal and closure of the tunnels is carried out, taking issues such as vibrations and explosion pressure caused by the excavation into account. Posiva has analysed the distance and delivered a report as a part of the construction licence application material. The closure of the deposition tunnels and eventually also the disposal panels progresses in stages. Dividing the construction, disposal activities and closure of the facilities in stages limits the number of facilities that are open simultaneously, which on its part reduces the disturbances caused by construction.

As other ways of limiting the disturbance caused by construction, Posiva aims to limit the excavation disturbance zone and to remove the disturbance zone at plug structure locations. Water leaks in the bedrock facilities cause hydrogeochemical disturbances in the groundwater environment, e.g. by conducting highly saline groundwater from great depths and fresh water from the surface towards the bedrock facilities, which in turn may alter the groundwater chemistry at the disposal depth to be more unfavourable to the engineered barriers. Posiva aims to limit these hydrogeochemical disturbances by sealing water leaks primarily by means of rock injections. With the use of various construction materials, foreign substances are introduced in the repository and the disposal bedrock: some of them may alter the conditions of the groundwater chemistry more unfavourable to the engineered barriers. Requirements regarding the placement of bore holes have been set on boring carried out from above ground and underground, so that the holes will not form rapid flow routes from the repository to important geological or hydrogeological zones, or directly to the surface.

The above-described factors affecting the performance of the disposal system have been taken into account during the construction of Onkalo, and procedures have been developed to manage them. There is still need for development of excavation planning and the detailed requirements set for excavation. Posiva must specify the limit values for disturbances that guide the design and construction before the repository is constructed.

Posiva has needs for the further development of rock construction related to the implementation in accordance with the design requirements. The development needs are related to issues such as the new work phases and construction materials used in the construction of the repository as well as the precision required from the working methods. In the excavation of the repository, Posiva must be

able to produce rooms compliant with the requirements repeatedly, which must be proven during the first construction phase of the repository. STUK oversees that the necessary construction requirements and procedures have been developed to a sufficient level before the construction of the repository begins.

As presented in the decision-in-principle, Posiva has constructed the Onkalo underground rock characterisation facility, which forms a part of the planned underground disposal facility. The extent of Onkalo covers a part of the connections to the surface and technical facilities. The same requirements have applied to the design and construction of Onkalo as the disposal facility, and STUK has overseen Onkalo at the extent needed and using procedures that correspond to the construction of a nuclear facility. The excavations of Onkalo are mainly complete, and Posiva is inspecting Onkalo's data on implementation, which is being used to prove that Onkalo's construction is compliant with the requirements.

Conclusion

The underground disposal facility can be constructed so that the disturbances caused by construction to the bedrock and groundwater environment remain controlled. There is still development work left in connection with the application of the rock suitability classification, which Posiva must continue when it introduces the developed method in placing the facilities. In addition, Posiva must develop the rock construction¬ methods and materials further in order to prove that it can produce bedrock facilities compliant with the requirements.

4.3. Quality management during construction

Section 17(1) Construction and commissioning

The holder of a construction licence for the nuclear waste facility shall ensure that the facility will be constructed in compliance with the approved plans and procedures. Moreover, the licensee shall ensure that the plant supplier and subcontractors producing services and products important in terms of safety act in an appropriate manner.

Posiva proposes that the nuclear waste facility should be constructed so that it fulfils the statutory requirements and the valid requirements by authorities. The construction of the facilities is monitored continuously during construction. The quality of the construction is assured by preplanning the activities, oversight and documenting the implementation. In addition, instructions are provided for the activities. Posiva requires a high level of quality and a good safety culture from the suppliers participating in the construction. As the party carrying out the project, Posiva will draw up a separate plan for the management and organisation of the entire construction project. The following presents the procedures and instructions developed by Posiva in order to reach the goals mentioned above.

For the implementation of the construction project, Posiva has established a project with the goal of implementing, within the approved schedule, the buildings, facilities, equipment and structures within the scope of the project and as required by disposal, in such a way that they fulfil the requirements set for them with regard to both quality and safety as well as technical performance characteristics. For project management, Posiva has drawn up a project plan, subproject plans for the encapsulation plant and disposal facility, a risk management plan, safety plan and resource plan. STUK has reviewed these plans.

Posiva has described the quality management and assurance of design, equipment manufacture and installation as well as construction in a separate report in accordance with Section 35(4) of the Nuclear Energy Decree. Posiva's management system shall be followed in the quality assurance of Posiva's construction activities. According to the report, the task of quality assurance is to ensure that the Finnish acts and decrees as well as the regulations and instructions issued by the authorities are followed in construction. In addition, the purpose of quality assurance is to ensure that Posiva has set quality requirements for its activities and that the activity complies with them. Posiva has provided instructions for the procedures related to the definition of the quality requirements and quality assurance requirements for products and functions.

Posiva's quality management is based on Posiva's management system and its processes and instructions. Posiva's management system is specified by the detailed procedures followed in the construction of nuclear facilities, such as quality planning, control and assurance as well as continuous improvement, and their organisation is described

in the quality plan of the facility project that refers to the processes, procedures and instructions used.

According to Posiva, it can utilise a quality group that acts as an independent party (QA) with regard to the construction implementation organisation; the group is tasked with ensuring that Posiva's management system is followed in the construction and that the construction is implemented in accordance with the requirements and instructions set as well as the plans that have been drawn up.

The design, construction and commissioning of a nuclear waste facility require systematic requirement management procedures so that it is possible to ensure that the facility being commissioned is compliant with the requirements. Posiva has provided instructions for the management of changes and technical requirements, for which Posiva's development department is responsible. It inspects and approves the system-specific requirement specifications, in the drawing up of which the project participates. The goal is to specify the requirements with enough detail that redesign required by the maintenance and changes during operation of the systems and equipment can be carried out throughout the life cycle of the facility.

The implementation plans of Posiva's nuclear facilities are drawn up in the facility project in accordance with the design process. In the project, the implementation of the product from design to commissioning is managed by system-specific quality plans.

According to Posiva's proposal, the main goal of the guidance of implementation design is to ensure that the design is implemented in accordance with the instructions and the goals set. In addition to ensuring that the implementation design process and the design result documentation are compliant with the requirements, the key goal of guidance is also to ensure implementation in accordance with the specified schedules.

Posiva monitors and guides the activities of the external design organisations through audits, follow-up meetings and reviews, among other things. According to Posiva's instructions, the key goal of technical design reviews is to identify problems related to safety, reliability, maintainability, manufacturability, installability, operation and maintenance, as well as present proposals for solving them. In addition, in the result data design review, for example, it is ensured that the design results are correct – meaning that the set safety, reliability and cost goals are reached. Design guidance includes reviews of initial and result data and intermediate reviews as necessary, based on issues such as the safety importance of the assignment, particularly demanding issues or interfaces between several technological sectors.

Manufacturing and construction management

According to Posiva, it can utilise a quality group that acts as an independent party (QA) with regard to the construction implementation organisation; the group is tasked with ensuring that the product fulfils the requirements set for it. The group inspects that the detailed inspection plans are in accordance with the general inspection plans, and that the construction, manufacturing and installation have also been implemented according to plan.

Posiva has described the quality assurance procedures during the installation phase in the installation manual. During the phase, the equipment and structures are installed, and the installation inspections are carried out in accordance with the inspection plan. Responsible persons are appointed for the installations, also tasked with monitoring the progress of the installation in accordance with a separate monitoring plan. The quality control group verifies that the installation is compliant with the requirements. The group's task is also to invite STUK or an inspection body to carry out the inspections in accordance with the inspection plan.

For commissioning management, Posiva has drawn up a separate commissioning plan that will be specified during the construction phase. According to the plan, Posiva will establish a separate commissioning organisation to take care of the implementation of the phase.

Monitoring the suppliers

The assessment and monitoring activities carried out by Posiva that are focused on the management system and quality assurance activities of the design and operations of equipment manufacture organisations are invariably also based on auditing.

Conclusion

Posiva has developed and introduced sufficient procedures for the guidance and monitoring of the nuclear waste facility construction project. In STUK's view, it is possible by following the procedures to ensure that the nuclear waste facility and its systems, components and structures are designed, manufactured, constructed, installed and commissioned in accordance with the approved plans and procedures.

5 Commissioning and operation

Commissioning the nuclear waste facility
Section 17(2) Commissioning and operation

In connection with the commissioning of a nuclear waste facility, the licensee shall ensure that the systems, structures and components and the facility as a whole operate in the planned manner. The licensee shall also ensure that an expedient organisation is in place for the future operation of the facility, alongside a sufficient number of qualified personnel and instructions suitable for the purpose.

Posiva states that it will ensure the usability and the safe operation of the nuclear waste facility with skilful design, construction and commissioning of high quality According to Posiva, it can utilise, in addition to that of its own personnel, the expertise of the personnel of its owners, TVO and Fortum, as well as its Finnish and foreign partners. The organisations that own Posiva have experience in the construction projects of several nuclear facilities. In addition to its owners, Posiva uses other external expertise in e.g. research, design and work related to the safety analyses.

In the design of the facility, drawing up the safety analyses and assessing the design and safety, Posiva utilises the experience of its owners in the design and use of facilities as well as their maintenance, in addition to the competence of its own personnel. In particular, Posiva orders expertise in nuclear waste management from Fortum.

The starting point of Posiva's long-term personnel plan has been to ensure that it has sufficient expertise available in the construction project. According to the plan, Posiva has strengthened the competence required during the design and construction phase by recruiting people with previous experience in the field of nuclear energy during the last few years. Posiva has estimated that its own personnel resources are sufficient to manage the facility's design basis and safety requirements and to ensure that the nuclear facility conforms to the requirements.

The conformity of the facility to the requirements and its safe use must be proven at the test-run phase. For the commissioning of the components, structures, systems and the facility, Posiva has drawn up a commissioning plan, which describes the planned trial run procedures for demonstrating that the facility, its systems, structures and components function in accordance with the requirements and operate safely. According to the plan, it is verified during the commissioning that the instructions drawn up for the operation of the facility are correct and sufficient.

Posiva's commissioning organisation is planned to be formed as based on the project and line organisations responsible for constructing Posiva's nuclear waste facility. Similarly, Posiva has specified the starting points on which the design of the future operating organisation and the total number of its personnel is based. Posiva's principle is that the operational functions important for safety at the encapsulation plant and disposal facility are carried out by Posiva's own organisation. In certain operation and maintenance tasks as well as radiation monitoring and laboratory services, among other things, Posiva may rely on TVO's personnel trained for these tasks; however, the overall responsibility remains with Posiva.

Posiva has estimated that the personnel resources of the operating department are 30–40 persons, and their theoretical training will begin well in advance before the test run begins, in accordance with the training programme. The training programme includes the personnel of the operating department participating in the test run of the facility, its systems and equipment. For Posiva, the goal of the training and the induction is that the personnel taking care of the operating tasks of the nuclear waste facility are sufficiently qualified to ensure the safe operation of the nuclear facility when the operating phase begins.

Conclusion

The Radiation and Nuclear Safety Authority (STUK) has assessed the competence of Posiva's personnel and the external expertise available to Posiva in connection with processing the construction licence application, as well as based on the document reviews and a separate inspection programme. As a result of the assessments and reviews, STUK states that Posiva has sufficient and extensive expertise available for constructing a nuclear waste facility and that, as an organisation, it has the capability to start the construction phase of a nuclear waste facility.

Posiva has drawn up sufficient plans with which it can ensure that the nuclear facility, its systems and equipment operate safely and in compliance with the requirements, through test runs carried out during the commissioning phase as well as comprehensive, validated instructions for operation. Posiva's plans also include arranging training at the correct time for the operating organisation for the structure and number of personnel, with regard to which Posiva has made preliminary plans.

Preparing for operation

Section 18 Operation

The operation of a nuclear waste facility shall be based on written instructions that correspond to the current structure and state of the facility. Instructions shall be made available for the identification and control of operational occurrences and accidents. Significant events influencing safety shall be documented so as to facilitate their later analysis.

The Operational Limits and Conditions of a nuclear waste facility shall include the technical and administrative requirements for ensuring the operation of the facility in compliance with design bases. The licensee shall operate the facility in compliance with these requirements and restrictions, and supervise compliance and report any deviations from them.

The nuclear waste facility shall have a condition monitoring and maintenance programme for ensuring the integrity and reliable operation of systems, structures and components. Written orders and appended instructions shall be issued for the service and repair of components.

Compliance with requirements concerning the operational radiation safety of the nuclear waste facility shall be ensured through continuous or periodic measurements inside the facility, in possible significant release routes and in the environs of the facility.

The operating instructions related to the operational activities of the nuclear waste facility and instructions for the identification and management of operational occurrences and accidents, as well as the Operational Limits and Conditions (OLC), are to be drawn up before the operating licence application is submitted. Similarly, the condition monitoring and maintenance programme for the nuclear waste facility must be drawn up before the operating licence application is submitted. Posiva has an existing condition monitoring and maintenance programme for the facilities and systems implemented as part of Onkalo.

In order to ensure radiation safety, radiation measurements have been designed for the facility in significant release routes. Posiva's own measuring devices will be placed in the surroundings of the facility, but Posiva will also utilise TVO's existing radiation measurement network in the facility environment.

Conclusion

Posiva has preliminary plans for preparations for activity during operation. The fulfilment of the requirements on operational activities will be assessed during the processing of the operating licence.

6 Decommissioning and closure

According to Section 7 g of the Nuclear Energy Act, *the design of a nuclear facility shall provide for the facility's decommissioning. […] When the operation of a nuclear facility has been terminated, the facility shall be decommissioned in accordance with a plan approved by the Radiation and Nuclear Safety Authority (STUK). Dismantling the facility and other measures taken for the decommissioning of the facility may not be postponed without due cause.*

Section 12(3) Disposal site

The layout, excavation, construction and closure of underground facilities shall be implemented so that the characteristics of the host rock deemed important in terms of long-term safety are retained, as far as possible.

With regard to a nuclear waste facility, decommissioning refers to dismantling the sections above ground so that no special actions are needed in the facility area due to radioactive substances originating from the facility. In this case, closure refers to closing off the rooms of the disposal facility in a manner intended to be permanent. The closure of the deposition tunnels in stages has been covered as a part of the engineered barriers in Section 7.2. The decommissioning and closure of facilities that have been carried out in an approved manner and in compliance with the requirements are a prerequisite for the expiry of waste management obligation in accordance with Section 32 of the Nuclear Energy Act. Posiva has covered the closure and decommissioning in the preliminary safety analysis report delivered as part of the construction licence application material.

Posiva has chosen immediate decommissioning as the decommissioning strategy. After the spent fuel disposal activities come to an end, the decommissioning of the encapsulation plant will begin with a year-long preparation phase, after which the components exceeding the levels for the concentration of radioactive substances will be dismantled and packed for disposal. The levels for radioactive substances and the detailed requirements for the decommissioning of nuclear facilities have been presented in STUK's YVL Guides.

There are only a few rooms and systems that will be significantly contaminated as a result of the normal operation of the encapsulation plant. In the preliminary safety analysis report, Posiva has briefly presented the techniques used for dismantling, an estimate on the amount of waste generated during decommissioning, and an estimate on the radiation doses caused to the personnel. The encapsulation plant will be decommissioned and the decommissioning waste will be disposed of in accordance with the plan proposed by Posiva within three years of the end of the operation. The operation of the encapsulation plant is planned to continue until the 2100s, which means that Posiva has time to develop detailed plans for decommissioning, based on the operating experiences. A detailed decommissioning plan must be submitted in connection with the operating licence application for the nuclear waste facility. The decommissioning plan for the nuclear facility must be updated every six years in accordance with Section 28 of the Nuclear Energy Decree, unless otherwise provided in the facility's licence conditions.

In the preliminary safety analysis report delivered as part of the construction licence application material as well as the safety case, Posiva has presented the principles of closing down the disposal facility and a preliminary plan on the structures and materials to be used for the closure. At this stage, the plan is sufficient for presenting a possible closure solution and the assumptions related

to proving post-closure safety. The starting point of Posiva's design has been to ensure that the favourable conditions of the bedrock remain, by restoring the excavated spaces so that they match the state before the bedrock facilities were constructed as closely as possible. The closure of the central tunnels of the disposal facility will begin after decades, and the closure of the other facilities will only begin at the end of the operating phase – which means that Posiva has time to develop detailed plans for closure, based on the experiences from disposal.

Conclusion

Posiva has submitted a sufficient description of the decommissioning of the encapsulation plant for the construction licence and has taken decommissioning into account in the facility's design requirements. In the construction licence application material, Posiva has presented the principles of closure in a way that is sufficient for the construction licence and has planned the closure to be implemented in such a way that the bedrock maintains the characteristics important to post-closure safety as effectively as possible.

7 Post-closure safety

Section 16: Presentation of, and updates to, the safety case

The safety case shall be presented in connection with the construction licence application and the operating licence application of the nuclear waste facility. The safety case shall be updated at 15 year intervals unless otherwise provided in the licence conditions. Furthermore, the safety case shall be updated prior to the permanent closure of the facility.

Detailed requirements pertaining to the contents of the safety case are presented in Guide YVL D.5. The requirements cover the specification of the safety functions of the barriers and setting the goals for their performance targets, constructing the scenarios, models and data needed for the calculations assessing the release and migration of radionuclides, the assessment of uncertainties as well as the complementary considerations. The guide also covers the principles followed in creating the safety case, its documentation and quality management.

In connection with the construction licence application, Posiva has submitted the safety case of the nuclear waste facility to STUK. The safety case describes the disposal concept, the disposal system and the barriers. Justification for the safety of the disposal concept is provided by the safety functions, for which performance targets are specified. The safety functions are covered more extensively in Section 2.2 of the safety assessment, the performance targets are covered in Section 7.3, and the performance of the barriers is covered in Sections 7.1 and 7.2.

The construction of scenarios (evolution schemes describing the potential future behaviour of the disposal system) used in providing justification for post-closure safety, scenario analysis, is covered in more detail in Section 7.3 of the safety assessment. The safety case has taken account of the amounts of radioactive substances released from the disposed spent nuclear fuel into the living environment through the barriers, as well as the resulting radiation doses. This is covered in more detail in Section 7.3 of the safety assessment, which also discusses how the results of Posiva's analyses comply with the safety requirements.

Section 7.4 of the safety assessment covers the description of the performance of the disposal system and the conditions of the disposal site with the help of both conceptual and mathematical models, as well as determining the required data.

The method of managing uncertainties is assessed in Section 7.4 of the safety assessment.

In the report on the fulfilment of the requirements laid down in Government Decree 736/2008 submitted to STUK by Posiva, it has been stated in accordance with the requirements that the safety case will be updated in connection with the operating licence application as well as before the facility is finally closed. Posiva states that it will submit the safety case to the authorities in connection with the construction and operating licence applications.

Conclusion

In a separate decision, STUK has found Posiva's safety case to be in compliance with the requirements and sufficient at the construction licence stage. Posiva will update the safety case in connection with the operating licence application and at intervals in accordance with the valid regulations, as well as before the facility is finally closed. Based on this, the requirement of the Government Decree is fulfilled.

7.1. Natural barrier

Sections 12(1) and 12(2): Disposal site

The geological characteristics of the disposal site shall, as a whole, be favourable to the isolation of the radioactive substances from the environment. Any area with a feature that is substantially adverse to post-closure safety shall not be selected as the disposal site.

The planned final disposal site shall contain sufficiently large, intact rock volumes that facilitate the construction of the waste emplacement rooms. For the purposes of disposal facility design and acquiring data required for safety assessments, the geological characteristics of the host rock at the site shall be characterized through investigations at the intended disposal depth, in addition to surface-based investigations.

Characteristics and performance of the natural barrier

Compared to the Finnish bedrock in general, Olkiluoto has been studied extensively. The characterisation work carried out to start the construction of the disposal site is sufficient. The characterisation work must continue as the construction progresses into the less studied sections of the disposal site. Posiva's description of the disposal site is based on the results of several research fields and methods, and there is still room for development in combining the information gained from them into an overall view. Combining the results from various fields of research and model descriptions must be continued and deepened in order to improve the reliability of the safety case.

A key part of the disposal site's performance analysis is estimating the effects of the future climate evolution on the disposal system. An important and justified starting point of the safety case is the information from the Weichselian glaciation and interpretations from the glaciation phases that preceded it. The description of climate evolution based on various observations and model calculations is sufficient at the construction licence stage, but it must be developed further no later than the submission period of the operating licence application by studying the effects of various options of climate evolution on the disposal system in a wider extent than what has been presented in the construction licence application material. The performance analyses can be further improved by describing how the disposal system as a whole responds to various mechanical, hydrostatic and chemical loads as well as dynamic conditions.

The performance analysis of Posiva's disposal site does not include the low- and intermediate-level waste repository to be constructed on the side of Onkalo's access tunnel. The repositories for spent fuel as well as for low- and intermediate-level waste must be handled as a single entity in the performance analysis. The repositories of low- and intermediate-level waste and spent fuel can affect each other, for example via chemical changes in the groundwater or a thermal change caused by the spent fuel. The interactions between the repositories of low- and intermediate-level waste and spent fuel must be taken into account in the performance assessment of the disposal site before the construction of the disposal rooms of low- and intermediate-level waste can be started.

Suitability of the disposal site

A key section of the disposal site description in the safety case focuses on interpretations related to the suitability and performance of the site as based on performance assessment. In addition to the properties and evolution of the site Posiva has specified post-closure safety requirements and detailed design criteria related to the bedrock, derived from the safety functions of the barriers.

Posiva has accumulated practical experience related to the stability of the bedrock in Olkiluoto during the excavation of the underground rock characterisation facilities. Based on that experience, it considers the bedrock to be sufficiently stable round the deposition tunnel and deposition holes. The understanding and measurements of the baseline stress of the bedrock are sufficient at the construction licence stage; however, Posiva will have to reduce specific uncertainties and deficiencies related to them before the construction of the disposal facilities can be started. Moreover, further investigations are required related to the impact of the heterogeneity of the bedrock to the stability of the bedrock and concerning the rock mechanical properties of the fracture zones on various scales.

Posiva explains the minor seismic activity in the bedrock in the Fennoscandian Shield with historical data and measurements. The materials support the assumption that the area will remain seismically stable in the future and that the risk

of a major earthquake in the area of the disposal facility, leading to broken disposal canisters, is very low. The seismic investigations conducted by Posiva are sufficient at the construction licence stage, but will need to be extended in order to improve the reliability of the safety case. The amount of collected data needs to be extended during the construction and operation of the facility, since the safety of the disposal will be evaluated over time-spans that clearly exceed the data coverage presented. Seismic risks need to be further investigated by taking account of the bedrock structures and their properties in Olkiluoto more diversely, as well as by assessing further magnitudes and frequencies of earthquakes under various geological circumstances. The seismic threat associated with the disposal system must be examined more extensively by conducting probabilistic consequence analyses which more extensively cover the mechanisms related to the occurrence and progress of earthquakes in addition to the spreading of faults into adjacent fracture structures. Posiva generalises large and small fracture zones into individual shape surfaces. Posiva must also examine modelling methods which characterise bedrock fractures in a more heterogeneous manner. Changing the angle of examination may affect, for example, the interpretation of earthquake magnitudes, fractured zone respect distances, and assumptions of the critical fracture sizes. Moreover, Posiva must more specifically analyse the impact of temperature rise on bedrock stability during the operation and thermal period following the closure of the disposal facility.

Posiva justifies the low groundwater flow round the disposal facility with the water tightness of the sparsely fractured rock in Olkiluoto, and with a rock classification system. Posiva claims that its classification system is suitable for selecting water tight sections of rock for disposal. While the justifications on the sufficient water tightness of the rock and low groundwater flow are sufficient, Posiva must prepare a clear summary of the rock groundwater flow model as background information for the safety assessment to be presented in the operating licence application. The reliability of measurement techniques must be ascertained due to uncertainties with regard to the measurements related to the characterisation of the hydraulic properties of the bedrock at the disposal site and disturbances caused by excavations. The various research and implementation stages of the disposal facilities must be designed to systematically ensure that the deposition tunnel complies with the set requirements at the excavation stage and when completed.

The reliability of the fracture network modelling concept must be ascertained during construction by comparing the hydrogeological modelling results of the disposal facilities with measurement data from actual tunnels. Alternative modelling options are available for describing water-bearing fractures in bedrock. The options describe rock heterogeneity in varying ways and should be taken into account at least in order to ascertain the sufficiency of the modelling method chosen by Posiva. Differing modelling methods may lead to predictions of disposal facilities which are drier than what is currently assumed, for example, as well as individual water flow channels that allow substantial flows.

Posiva's safety case provides plausible grounds for favourable groundwater chemistry in the bedrock at the disposal depth. The hydrochemical characterisation and the interpretation of the paleohydrogeochemical evolution of the Olkiluoto baseline represent some of the most solid grounds Posiva has provided for the stability of the rock surrounding the disposal facilities. The Posiva safety case includes an assessment of salinity developments over the next 50,000 years. Such evolutions seem overly pessimistic concerning groundwater dilution in the rock adjacent to the disposal facilities, because they do not account for the water-rock interactions occurring during meteoric water infiltration. Posiva must further elaborate on and comprehensively improve the hydrogeochemical evolution description. Also, a more detailed understanding is required of recovery after disturbances caused by construction once the various sections of the facility have been closed. An important aspect related to the stability of groundwater chemistry is investigating the reasons for the chemical inconsistency between porewater in the bedrock matrix and groundwater in the fracture zones of rock.

According to Posiva's understanding, the natural resources in Olkiluoto will not prove particularly interesting in the future, and the grounds provided by Posiva are sufficient for obtaining a construction licence. The data given in the operat-

ing licence application materials concerning natural resources require further clarification as well as updates as more geological information on the area becomes available.

Already in the early stages of developing the KBS-3 concept, Posiva has proposed rock requirements starting from preserving the performance of the engineered barriers. The performance assessment conducted by Posiva shows that according to expected lines of evolutions, the favourable properties of the rock surrounding the disposal facilities will continue to evolve in a stable and predictable manner, and the requirements imposed by Posiva on the bedrock are very likely to be fulfilled by a large margin.

The disposal facilities must be constructed with the objective of preserving those bedrock properties which favour post-closure safety. Posiva describes the objective on a general level within the context of the disposal facility safety concept. Posiva has set design requirements for the bedrock surrounding the repository, but long-term targets are not set regarding the safety functions and performance targets for the preservation of favourable properties of bedrock. Before the construction of the disposal facility can be started, Posiva must assess the favourable properties for the bedrock surrounding the disposal facility and justify the design requirements with them.

Positioning of the disposal facilities

Posiva uses a rock classification system to select suitable rock sections and to ensure the sufficient quality of the rock surrounding the disposal facilities. The system includes criteria and the confirmation of them on the scale of the disposal facility, panel area, deposition tunnel and deposition hole. The verification and approval of compliance with requirements will occur in phases. Posiva has prepared the instructions for the classification system that it intends to employ in launching the suitability assessment of the first deposition tunnels and deposition holes. It is very important that the reliability of the rock classification system is assessed during and after the first disposal facility construction phase, and that the continued development of the system accounts for user experiences. Classification criteria in the various construction phases and the prediction-outcome method, for example, require further development. Posiva must finalise the assessment process procedures and provide more specific rock classification development plans before the construction work can be started. The rock classification system will be fully assessed again in connection with processing the operating licence application.

The current classification particularly highlights the mechanical stability of the rock section to be selected for disposal and low groundwater flow in spite of construction. So far, Posiva's classification does not include requirements for all rock properties, which may be relevant for post-closure safety. Posiva must submit a clearer description of the connection between the rock classification criteria and the projected long-term target values with respect to the rock surrounding the disposal facilities. The operating licence application materials must include more specific grounds for determining the respect distances of the structures delimiting the disposal facility layout and for determining extensive individual fractures.

Conclusion

The investigations, performance assessment and conclusions regarding the suitability of the bedrock in Olkiluoto as a disposal site as provided in the construction licence application are sufficient for obtaining a construction licence. The requirements Posiva has set regarding the bedrock are very likely to be fulfilled by a large margin. Posiva has developed a rock classification system which it intends to further improve for the purpose of selecting intact rock volumes suitable for disposal and favourable in terms of post-closure safety.

7.2. Engineered barriers

Section 6: Handling of spent nuclear fuel and other nuclear waste, subsection 1

Spent nuclear fuel and other nuclear waste shall be conditioned and packed in accordance with disposal specifications. Waste packages shall be classified on the basis of their characteristics. Constraints and other quality specifications shall be defined for each class, necessary in terms of the operational safety of the nuclear waste facility and the post-closure safety of disposal, and which the waste packages are required to meet.

Section 9: Disposal operations, subsection 2

The disposal package containing spent nuclear fuel shall be designed so that no self-sustaining

chain reaction of fissions can occur, even under the disposal conditions.

Packaging of low- and intermediate-level waste

The facilities of Posiva generate radioactive operational waste. Such operational waste is liquid or solid radioactive waste generated by encapsulation facility operations. Radioactivity of the waste arises from the fission, corrosion or activation products of spent fuel.

The waste is classified into three types: waste dried in a barrel; dry, solid waste packaged in a barrel, and scrap metal. Liquid waste is solidified into 200-litre steel barrels, either by drying or by solidifying using clay-based substances. The disposable waste is packaged into 200-litre barrels based on the level of radioactivity. The long storage period of the waste at the disposal facility before the facility is closed must be taken into account when selecting the waste packaging material and ensuring the accessibility of the waste containers, so that their condition can be monitored at the disposal facility.

In accordance with Section 11 of Government Decree 736/2008, the safety functions of engineered barriers protecting short-lived waste shall prevent releases of disposed radioactive materials into the bedrock for a period of at least several hundreds of years.

The low- and intermediate-level waste disposal facility proposed by Posiva corresponds to the low- and intermediate-level waste disposal solution used by Finnish nuclear power plants. Based on user experiences, the proposed solution can be implemented in accordance with the requirements.

Disposal canister and engineered barriers

Spent nuclear fuel is encapsulated in the disposal canister. The gas- and watertight disposal canister has a copper overpack and a cast iron insert. Other engineered barriers include a buffer made of bentonite clay protecting the canister, a deposition tunnel backfill made of clay-based materials, and a concrete plug to seal the tunnel. More information on closing the disposal facility is provided in Chapter 6 of this safety assessment. Posiva has specified safety functions for the engineered barriers. Information on their conformity with the multibarrier principle is provided in Chapter 2.2 of this safety assessment.

Comprehensive, principle-level information on design criteria and principles related to post-closure safety has been issued in the preliminary safety analysis report and safety case submitted in connection with the construction licence application. Technical design requirements have been set for the engineered barriers. According to Posiva, the requirements are derived from the performance targets specified for the safety functions. The design basis and requirements take into account the selected evolutions and related future conditions impacting the disposal system. The safety case assesses the performance of the engineered barriers after the closure of the disposal facility.

The connection between the safety functions, performance targets and design requirements of the engineered barriers must be clarified before submitting the operating licence application, so as to facilitate the assessment of the performance analysis. There remain deficiencies in demonstrating the performance of the engineered barriers and in the description of the development of the barriers during future evolutions. These need to be investigated and developed before submitting the operating licence application. Such development needs are related to, for example, the corrosion resistance and mechanical durability of the copper in the disposal canister, the stability of the buffer and the tunnel backfill, the connection between swelling pressure, swelling capacity and design requirements, the homogenisation of the backfill and leakage water management, and more comprehensive modelling calculations concerning the interaction of the barriers.

One of the design requirements for the disposal canister is that the spent fuel must remain subcritical and that all residual heat must exit the fuel. These design requirements have been taken into account in the dimensioning of the canister structures. Moreover, the long-term performance of the canister imposes constraints with regard to the quantity of humidity contained in the fuel rods. The fuel rods must be dried before encapsulation in order to remove excess humidity. The drying will be performed at the drying station in the encapsulation facility's fuel handling cell before the fuel is placed into the disposal canister. The other characteristics of the fuel which will be placed inside the canister are determined according to the operation history of the fuel. A more detailed description of

the properties of the fuel is available in section 3.4 of this safety assessment.

Enrichment, burn-up, operation history and cooling periods affect fuel reactivity. Posiva applies burn-up credit in analysing the criticality safety of the disposal canisters. In burn-up credit, the burn-up of the nuclear fuel constitutes a mitigating factor in criticality safety analyses. Loading curves are prepared as based on the criticality safety analyses. The curves show the average minimum burn-up of the required fuel element in relation to the enrichment of the fuel element. Loading curves are prepared as based on the assumption that the disposal canister is filled with similar fuel elements. Posiva primarily uses loading curves to ensure criticality safety. The majority of the fuel elements fulfil the requirements of the loading curves. Separate criticality safety analyses and loading designs can be prepared for the elements which do not fulfil the requirements.

Based on the criticality analyses submitted by Posiva, the criticality of the disposal canister cannot be completely ruled out over the long term. In this respect, however, the analyses contain extremely conservative assumptions regarding the long-term evolution of disposal canister geometry, indicating that the recriticality of the disposed fuel is highly unlikely.

Posiva has supplemented the construction licence application with a disposal concept development programme containing research and development plans. The disposal concept development programme mainly takes account of the deficiencies detected by the Finnish Radiation and Nuclear Safety Authority (STUK). Posiva shall clearly present the connection between performance development needs and barrier safety functions.

The feasibility of the engineered barriers

The preliminary safety analysis report includes a description of the technical feasibility of the engineered barriers intended for the disposal of spent fuel (materials, manufacturing, inspection, installation). Posiva has specified preliminary quality requirements for the various components of the disposal canister and for the weld joint as well as the requirements for the properties of the canister materials. Operational safety and post-closure safety have been taken into account in preparing the requirements. The post-closure safety of the disposal canister is based on the chemical resistance of the copper overpack and the mechanical durability of the cast iron insert. Before the disposal, the canister filled with spent nuclear fuel serves as partial radiation protection, and its task is to contain the radioactive substances.

Posiva has developed manufacturing methods for the disposal canister and has manufactured disposal canister components that fulfil the preliminary quality requirements. Suppliers selected by Posiva are responsible for the manufacturing and assembly of the disposal canister components. After the spent fuel has been installed, the disposal canister is sealed in the encapsulation facility using friction stir welding.

In order to validate compliance with requirements, the manufacture and sealing of the disposal canister are monitored during the various process stages, using phase-specific inspections. Posiva has developed several non-destructive testing methods for the purpose of inspecting the quality of the disposal canister and its conformity with the requirements. Only canisters which fulfil the requirements are transported to the disposal facility. Posiva has proposed launching the qualification of the manufacturing procedures for disposal canister structures in 2015. The development of the inspection methods for verifying the conformity with requirements of the disposal canister components has almost advanced to the qualification stage.

Posiva has also developed manufacturing and emplacement procedures for other engineered barriers. Posiva and SKB have used bentonite and clay-based materials to manufacture buffer and backfill blocks. However, Posiva has not yet manufactured full-scale buffer blocks using its current reference method (isostatic pressing). Based on testing, Posiva has the technical readiness to manufacture buffer and backfill blocks.

In order to inspect the quality and compliance with requirements of the clay blocks, Posiva has presented the description of the inspection procedures in the preliminary safety analysis report. The quality assurance procedure described by Posiva covers the entire production chain from material acquisition to the verification of the conformity of installation with requirements. Posiva has proposed quality control methods, particularly

with regard to method development needs in the testing of clay-materials, in a disposal concept development programme submitted to STUK.

In the development of engineered barrier manufacturing procedures, Posiva has made the most progress with the disposal canister after having produced disposal canister components which fulfil the requirements. However, the processes of validating and inspecting the disposal canister and, in particular, the other engineered barriers still need to be developed. Posiva has prepared a disposal concept development programme, including plans regarding development targets in the manufacturing of engineered barriers, ascertaining conformity with requirements, and inspection work.

Posiva has prepared prototypes of the canister transfer and emplacement vehicle and buffer installation machine in order to be able to test the installation/emplacement of the engineered barriers. In 2014, Posiva started testing emplacement vehicles in an aboveground test hall in the Onkalo area. The prototype of the backfill emplacement machine is being produced, and according to current plans testing will begin in early 2015. The production test of the plug sealing the deposition tunnel was launched in the Onkalo demonstration facilities in 2014. In the disposal concept development programme, Posiva covers the objectives and schedules of the demonstrations related to the feasibility of the canister, the buffer and the backfill. Posiva's first full-scale concept feasibility demonstration has been scheduled to correspond with the construction of the facilities, starting in 2016 at the earliest, according to current plans. The objective of the installation tests is to demonstrate that the components of the disposal system can be installed/emplaced in accordance with the set accuracy requirements.

Conclusion

The requirements of the Government Decree concerning the design and the demonstration of long-term performance of the nuclear waste packages have been fulfilled at the construction licence stage. However, the design, feasibility and long-term performance of the engineered barriers involve development issues with regard to which Posiva has submitted a plan to STUK. STUK will inspect detailed conformity with safety requirements of the issues specified above in a timely fashion in relation to the implementation of the nuclear waste facility.

Posiva has described spent nuclear fuel handling and packaging methods and has set the preliminary requirements for the waste packages. Posiva has performed long-span manufacturing procedure development work for engineered barriers. However, development issues related to the manufacturing, verification of conformity with the requirements and inspection of the disposal canister and, in particular, other engineered barriers, have to be solved before the detailed plans concerning the components intended for disposal can be processed by the authorities and enter production.

With regard to the installation/emplacement of engineered barriers, Posiva has not yet shown that the disposal system components can be installed in accordance with the requirements. Posiva has submitted a plan to STUK concerning further installation/emplacement testing and a general plan for a full-scale test relevant to the entire disposal system. Posiva must demonstrate that the system components can be installed in accordance with requirements before initiating the construction of the deposition tunnels.

In the design of the disposal canister, the criticality safety requirements caused by spent fuel have been taken into account. The long-term criticality safety of the disposed fuel has been sufficiently demonstrated at the construction licence stage using conservative criticality analyses. Prior to submitting an operating licence application, analysis of the long-term evolution of the geometry of the disposal canister must be continued and the consequences caused by criticality must also be examined.

The connection between the safety functions, performance targets and design requirements of the engineered barriers must be clarified by the time the operating licence application is submitted. There remain deficiencies in demonstrating the performance of the engineered barriers and in the description of the development of the barriers during future evolutions. These need to be investigated and developed before submitting the operating licence application.

7.3. Post-closure safety analysis

Section 4: Long-term radiation impacts of disposal

Disposal of nuclear waste shall be planned so that radiation impacts arising as a consequence of expected evolution scenarios will not exceed the constraints given in subsections 2 and 3.

In any assessment period, during which the radiation exposure of humans can be assessed with sufficient reliability, and which shall extend at a minimum over several millennia:

1) the annual dose to the most exposed people shall remain below the value of 0.1 mSv; and

2) the average annual doses to other people shall remain insignificantly low.

During assessment periods after the period referred to above in subsection 2, average quantities of radioactive materials over long time periods, released into the living environment from the disposed nuclear waste, shall remain below the maximum values specified separately for each radionuclide by the Radiation and Nuclear Safety Authority (STUK). These constraints shall be specified so that:

1) at a maximum, radiation impacts caused by disposal can be equivalent to those caused by natural radioactive materials in the Earth's crust; and

2) on a large scale, the radiation impacts remain insignificantly low.

This chapter examines conformity with the constraints specified for long-term radiation impacts and the release of radionuclides in the safety case prepared by Posiva. The acceptability of the biosphere analysis performed by Posiva will be checked within the context of examining compliance with dose constraints. The analysis of long-term radiation impacts covers the release and migration to the surface environment of radionuclides. More information is given in Section 14. In examining radiation impacts within the context of this safety assessment, an annual dose refers to the sum of the effective dose arising from external radiation within the period of one year, and of the committed effective dose from the intake of radioactive substances within the same period of time in accordance with Government Decree 736/2008.

Radiation dose constraints

The radiation dose constraints specified in Section 4 subsection 2 of Government Decree 736/2008 are further specified in Guide YVL D.5. In applying radiation dose constraints, the changes in the living environment that arise from changes in ground and sea level must be taken into account. The climate type as well as human habits, nutritional needs and physiology can be assumed to remain unchanged. The guide determines the exposure pathways and groups of people which need to be analysed.

Posiva has analysed the doses from the radionuclides released from the closed disposal facility to the most exposed individuals of the population and other exposed individuals over the course of the first 10,000 years after closure. The period of analysis covers a period of several thousands of years as required. The analysis accounts for changes that arise from changes in ground and sea level in accordance with the regulations.

In accordance with Guide YVL D.5, the base scenario in the Posiva biosphere analysis is based on the assumption that the climate type and human habits, nutritional needs and physiology will remain unchanged. In the base scenario, the doses fall below the constraints specified in the Government Decree by a large margin. In addition to the base scenario, Posiva has analysed variant scenarios where the evolution is different from the base scenario. In the variant scenarios, the local population are exposed to larger doses than in the base scenario, but the doses still fall below the constraints.

Release constraints

Guide YVL D.5 specifies the maximum average quantities of radioactive substances released into the living environment over long time periods given in Section 4 subsection 3 of Government Decree 736/2008. The nuclide-specific maximum constraints shall apply to releases of radioactive substances arising from the expected evolution scenarios that may migrate to the living environment after several thousands of years at the earliest. These releases of radioactive substances can be averaged over 1,000 years at the most. The sum of the ratios between the nuclide-specific releases of radioactive substances and the respective permitted maximum values shall be less than one.

In accordance with the expected evolution scenarios, Posiva has calculated estimated radioactive releases from the disposal facility for the periods of time exceeding 10,000 years. The base scenario

is based on the assumption that the safety functions specified for the barriers will be realised, with the exception of one disposal canister with a manufacturing defect. The maximum yields of the base and variant scenario analyses fall below the constraints by a factor of approximately 10,000. In the calculation cases describing the declined performance of the safety functions, the released doses fall below the constraints by a factor of approximately 1,000.

Conclusion

Posiva has submitted the annual doses and radioactive releases calculated according to analyses of the expected evolution scenarios and analyses describing the declined performance of the safety functions. Posiva has compared the results with the set dose and release constraints. The results fall below the constraints, complying with the requirements of Section 4 of Government Decree 736/2008.

Unlikely events impairing post-closure safety

Section 5: Consideration of unlikely events

The significance of unlikely events impairing post-closure safety shall be assessed by evaluating the reality, probability and possible consequences of each event. Whenever possible, the acceptability of the expectancies of radiation impacts caused by such events shall be evaluated in relation to the annual dose and release rate constraints of radioactive materials, as referred to in section 4.

Guide YVL D.5 further specifies the requirements of Section 5. The unlikely events potentially impairing post-closure safety induced by natural phenomena to be considered shall at least include rock movements jeopardising the integrity of disposal canisters. Unlikely events caused by human actions to be considered shall at least include the boring of a medium-deep water well at the disposal site and core drilling or boring hitting a disposed waste package. In such a case, it is assumed that the existence of the disposed waste is not known and that the incident may only occur 200 years following the closure of the disposal facility at the earliest.

Posiva has examined the following unlikely events impairing post-closure safety: rock movements which may damage the disposal canisters, drilling hitting a disposal canister and the disposal facility, the boring of a medium-deep water well at the disposal site, and the rapid corrosion of the canister insert.

The impacts of rock movements have been examined in the periods 200 years, 40,000 years and 155,000 years after the closure of the disposal facility. In the first case, the doses have been assessed using a simplified dose coefficient model. Radioactive release rates were estimated in the latter two cases. In the latter cases, an analysis was also conducted based on the assumption that the buffer erodes as a result of a rock movement. Posiva has supplemented the analysis with a probabilistic analysis, in which the time of rock movement was varied between 200 and 50,000 years.

The maximum annual dose to the most exposed individuals of the population arising from a rock movement which intersects one of the disposal canisters after 200 years from closure is approximately 3 mSv. In a probabilistic analysis, the expected annual dose falls below the constraint of 0.1 mSv. In the event of rock movements occurring after 40,000 and 155,000 years, the release rates will fall below the constraints by approximately one order of magnitude, using the averaging provision of 1,000 years permitted in the YVL guide.

Posiva has analysed six calculation cases where either both the emplacement rooms and the canisters or one of these is hit by boring or core drilling. The analyses are based on the assumption that the boring will take place 1,000 years after the emplacement rooms have been closed. The expected dose values have been calculated for the employees who can be assumed to be most exposed. The maximum expected annual dose, resulting from drilling hitting a canister, is approximately $3 \cdot 10^{-3}$ mSv. The probability value used in the analysis was 10^{-7}.

Posiva has not analysed drilling which may take place during a period of time between 200 and 1,000 years after closure. Other possible consequences, such as from residual radioactive substances at the boring site or a boring hole that remains open, have not been analysed. Posiva concludes that drilling may cause the release of considerable doses, but that the likelihood of someone unknowingly hitting the disposal facility by boring is very low. Based on this, Posiva has provided sufficient boring and core drilling analyses at the construction licence stage and there is no call

for requiring additional information concerning the consequences of earlier boring or other issues mentioned above.

Posiva has analysed the boring of a medium-deep water well at the disposal site. The doses are estimated using dose conversion coefficients in calculations based on expected evolution scenarios, calculation cases which describe the impairment of safety functions, and in a calculation case describing the rapid corrosion of the canister insert. The maximum annual dose of approximately $4 \cdot 10^{-3}$ mSv, in the last case, will take place approximately 17,000 years after the disposal facility is closed.

The examination of the accelerated corrosion of the canister insert is based on the assumption that transport resistance is suddenly lost 15,000 years after closure. The consequent releases fall below the set constraints by approximately one order of magnitude.

Conclusion

Posiva has analysed unlikely events, including their probability and the consequent dose and radioactive release rates and expectation values. Posiva has compared the results with the set dose and release rate constraints. The requirements specified in Section 5 of the Government Decree have been fulfilled.

Safety case

Section 14: Long-term safety

Compliance with the requirements concerning long-term radiation safety, and the suitability of the disposal method and disposal site, shall be proven through a safety case that must analyse both expected evolution scenarios and unlikely events impairing post-closure safety. The safety case comprises a numerical analysis based on experimental studies and complementary considerations insofar as quantitative analyses are not feasible or involve considerable uncertainties.

Values which fall below the radiation exposure constraints for the most exposed people, as referred to in section 4 above, shall be proven by considering a community that derives nutrition from the immediate surroundings of the disposal site and is most exposed to radiation. In addition to impacts on people, possible impacts on flora and fauna shall be analysed.

The safety case shows that the post-closure safety requirements have been sufficiently fulfilled for obtaining a construction licence. However, the methodologies used – particularly the selection criteria of the analysed evolution scenarios – require further development at the operating licence stage. Compliance with the dose and radioactive release constraints set for post-closure safety is shown using a computational safety analysis, which involves analysing the release and migration of radionuclides based on evolution scenarios compromising the safety of disposal. The computational safety analysis is consistent and has been systematically implemented.

STUK has commissioned independent comparative calculations based on the calculation cases prepared by Posiva. The comparative calculations showed no significant deviations from the results presented by Posiva.

The safety analysis prepared by Posiva is based on deterministic computation, but has been supplemented with a probability-based sensitivity analysis. The sensitivity analysis has been conducted using a selected number of computational cases. The analysis examines the release and migration of radionuclides into the bedrock. Significant safety analysis parameters have been identified in the sensitivity analysis, and the examination is sufficient at the construction licence stage. In connection with the operating licence application, more comprehensive sensitivity analyses will need to be conducted using computational cases based on various scenarios and concerning the migration of radionuclides into, and within, the biosphere.

More specific requirements concerning the evaluation of human exposure as specified in Section 14 subsection 2 of the Government Decree are given in Guide YVL D.5. The dose constraint for the most exposed individuals, 0.1 mSv per year, stands for the average individual dose in a self-sustaining family or small village community living in the environs of the disposal site, where the highest radiation exposure arises through various pathways. In addition, assessment shall address the average annual doses to larger groups of people living near a large lake or at a coastal site.

The biosphere section of the safety analysis prepared by Posiva accounts for the existence of a small lake and the boring of a well in calculating the radiation dose to the most exposed individuals. In accordance with Guide YVL D.5, the

exposure pathways examined in the analysis are the use of contaminated water as household and irrigation water and for animal watering, as well as the nutritional use of contaminated natural products originating from terrestrial or aquatic environments or agricultural products. In addition to the most exposed group of individuals, Posiva has analysed potential doses to a more extensive group of people. From the assessment perspective, the biosphere model has not been documented in a fully transparent manner. However, the biosphere model developed by Posiva complies with the requirements as a whole.

A systematic construction of scenarios used to manage the uncertainties in the evolution of the disposal system is one of the elements of the safety case. Posiva has constructed the repository system base scenario based on the assumption that one or a few disposal canisters have an initial manufacturing defect and the other barriers perform as expected, fulfilling the performance targets specified for their safety functions. According to Posiva, the variant scenarios have been constructed by identifying incidental deviations leading to the release of radionuclides. The disturbance scenarios have been constructed by accounting for unlikely events impairing post-closure safety in accordance with Guide YVL D.5.

Posiva has defined scenarios as lines of evolution that may lead to failure of the canisters containing the spent nuclear fuel and to the releases of radionuclides. In the operating licence application, Posiva must examine the possibility in evolutions deviating from the expected evolution that one or several performance targets are not met more systematically and comprehensively, and it must examine the quality non-conformances in other barriers besides the disposal canister more carefully. Such an analysis of variant and disturbance scenarios requires forming an understanding of the possible impairment of the safety functions outside the performance-target criteria.

Posiva has specified safety functions and performance targets for the barriers. Posiva has defined the performance targets by means of a measurable or assessable characteristic of the barrier whenever possible. However, most performance targets lack a criterion defining this characteristic that is seen to ensure the performance of a safety function. Posiva does not clearly establish how it has determined the performance targets it has specified for the safety functions of the barriers.

The barrier performance analysis submitted by Posiva does not unequivocally support the specified performance targets due to the fact that clear grounds and criteria, in particular, are missing. Owing to this, it has been difficult for STUK to assess the sufficiency of the grounds for the performance targets specified for the safety functions. Moreover, the connection between the expected performance of the engineered barriers and the design of the disposal system remains somewhat unclear.

Posiva has improved the reliability of the safety case through complementary considerations, particularly with regard to the performance analysis. The complementary considerations include grounds that support the post-closure safety analysis and cannot be directly quantitatively assessed, but which are relevant to the understanding of phenomena and as justification for various solutions. According to Posiva, such considerations may include complementary qualitative analyses which have not been included elsewhere in Posiva's quantitative safety case material. Complementary considerations may improve the reliability of the performance analysis and the safety case, but are not suitable for the quantitative reduction of uncertainties. The complementary considerations which improve the reliability of Posiva's safety case can be deemed sufficient at this licence stage.

Protection of other living species

Guide YVL D.5 further specifies the requirements related to the possible impacts of the disposal on flora and fauna. Disposal of spent fuel shall not detrimentally affect species of fauna and flora. This shall be demonstrated by assessing the typical radiation exposures of terrestrial and aquatic populations in the disposal site environment, assuming the present kind of living populations. These assessed radiation exposures shall remain clearly below the levels which, on the basis of the best available scientific knowledge, would cause significant detriment to any living population.

The method used by Posiva to assess the impacts on other living species is state-of-the-art and adheres to good practices. Posiva has presented absorbed dose rates in flora and fauna. The highest dose rate in the base computational case is $2.6 \cdot 10^{-7}$ µGy/h for pike in a fresh water environ-

ment. The highest dose rate out of all computational cases is $1.3 \cdot 10^{-4}$ µGy/h in ducks in a fresh water environment. In the light of current information, the estimated dose rates fall below the rates considered hazardous to healthy animal populations by a large margin.

Conclusion

Posiva has submitted a sufficiently comprehensive safety case at the construction licence stage. The results of the computational safety analysis and other data given in the safety case are sufficient to show compliance with the requirements.

Posiva's method of constructing scenarios is sufficient at the construction licence stage, but it does not demonstrate that scenario analysis has systematically prepared for disposal system evolutions significant for the assessment of safety. At the point of submitting the operating licence application, Posiva's method of constructing scenarios needs to be clearer than it is in the safety case included in the construction licence application material, to make it easier to assess the coverage of scenarios in terms of the possible evolutions of the disposal system. At the operating licence stage, clearer grounds than the current ones are required for the selection of the scenarios in the safety case. Posiva's scenarios must then also show a more comprehensive preparedness for quality non-conformances in the barriers.

Posiva must combine the effects of low- and intermediate-level waste disposal into a scenario and safety analysis covering the entire disposal system by the operating licence stage.

Before submitting the operating licence application, Posiva must define the performance targets specified for the safety functions of the barriers more clearly than in the construction licence application. Each performance target must then be complete with a criterion describing a measurable or assessable characteristic of a barrier which, when met, ensures the performance of a safety function.

7.4. Reliability of the safety case

Section 15: Reliability of the safety case

The input data and models utilised in the safety case shall be based on high-quality research data and expert judgement. Data and models shall be validated as far as possible, and correspond to the conditions likely to prevail at the disposal site during the assessment period.

The basis for selecting the computational methods used shall be that the actual radiation exposure and quantities of radioactive materials released remain below the results of safety analyses, with a high degree of certainty. The uncertainties involved in the safety analysis, and their significance, shall be separately assessed.

The requirements of Section 15 of the Government Decree are further specified in an appendix to Guide YVL D.5 concerning the usable methods. The instructions also require that the safety case include an assessment of how reliably the safety requirements are fulfilled and of the most significant uncertainties affecting reliability.

The safety case and preliminary safety analysis report included in Posiva's construction licence application material examine post-closure safety. The key reports for determining the reliability of the safety case are the safety case synthesis, models and data, assessment of radionuclide releases, and performance assessment.

Posiva's analyses and data are largely of sufficiently high scientific quality and conservativeness at the construction licence stage.

In the safety case, Posiva has presented the safety functions and the open safety significant issues and the uncertainties involved. Posiva justifies the safety of the disposal based on safety functions.

Conceptual models are used to describe the safety functions and the factors affecting them. They serve a key role in forming an understanding of the declined performance of the safety functions and the scope of such declined performance. Posiva does not present conceptual models for all safety functions in the safety case material. The mathematical models and data can be deemed to be sufficiently explained at the construction licence stage. Posiva has constructed a group of scenarios and calculation cases based on them. To support the calculation cases, Posiva has presented supplementary calculations and a probabilistic sensitivity analysis.

Posiva has used data management and quality management procedures to increase the reliability of the safety case. However, inconsistencies have been detected in the data given in materials

compiled at different stages. For this reason, the uniformity of the data for the analyses needs to be improved, for example by "freezing" the used data sufficiently early in order to ensure it is harmonious in the safety case to be submitted together with the operating licence application.

Generally, the reliability of the data and the models can be deemed sufficient at the construction licence stage.

Even though the safety case submitted by Posiva can be deemed reliable, it requires further development. Elements which would facilitate assessing the reliability of the safety case include a more understandable and less ambiguous description of barrier evolution, the identification of the parameters most important to safety and of the most significant barriers as well as a summary of the uncertainty analysis and a comparison of that analysis with the concept development programme.

Also, the methods related to preparing the safety case require further development before the operating licence application can be submitted. Scenarios need to be constructed in a more systematic and comprehensive manner and the safety case description of the scenario construction process needs to be easier to follow. Safety functions and performance targets must be specified so that the performance of the barriers and the scenarios derived from impaired performance can be assessed in a less ambiguous manner.

The structure and representation of the safety case need to be developed so that the fulfilment of the safety requirements can be verified more effortlessly.

The references made in the safety case need to be clear and the reference material must be accessible at the point of submitting the operating licence application.

The safety case must also cover the entire disposal system, which means that the safety analysis concerning low- and intermediate-level waste must be linked to the safety case for the disposal of spent fuel.

Conclusion

Based on the review, the safety case is sufficiently reliable at the construction licence stage. However, before the operating licence application can be submitted, the performance and safety analyses require improvement, and the safety case needs to be modified in order to increase reliability.

In the safety case, Posiva does not always clearly express its position on matters related to safety or justify the choices made. In the future, Posiva must present its conclusions and their rationale more clearly.

8 Posiva's plan for arranging the safeguards control necessary to prevent proliferation of nuclear weapons

Basis of nuclear material safeguards

Safeguarding nuclear material is based on international treaties: the Treaty on the Non-Proliferation of Nuclear Weapons (INFCIRC/140), the Safeguards Agreement (INFCIRC/193), the additional protocol to the Safeguards Agreement (INFCIRC/193a8), and the Euratom Treaty. Each operator planning to use or currently using nuclear energy in Finland is, on its part, responsible for ensuring that Finland, in its capacity as a state, is capable of fulfilling its obligations under the relevant international treaties.

In connection with submitting a construction licence application and in accordance with the requirements of Section 35 subsection 7 of the Nuclear Energy Decree, Posiva has submitted a description of the arrangements for the implementation of control necessary to prevent the proliferation of nuclear weapons to the Finnish Radiation and Nuclear Safety Authority. In accordance with Section 118 b of the Nuclear Energy Decree, the planning, construction and operation of a nuclear facility shall be implemented so that the obligations concerning the control of nuclear material, as provided and defined in the Nuclear Energy Act and provisions issued thereunder as well as in the Euratom Treaty and provisions issued thereunder (such as European Commission Regulation 302/2005), are met.

The plan prepared by Posiva covers the required issue on a general level, various options are put forward for some technical solutions, and references are made to future development work. The nuclear waste facility constructed by Posiva is globally the first of its kind, and the control measures implemented by IAEA and the European Commission are still partly unresolved. The control measures by IAEA and the Commission may affect the detailed designs of the nuclear waste facility, which means that Posiva cannot be required to submit a final plan on nuclear material safeguards at this stage.

Nuclear material safeguards by Posiva during construction and operation of the research facility

STUK has overseen the construction of the Onkalo research facility in accordance with the principles that govern the construction of a nuclear power plant. In accordance with its nuclear non-proliferation manual, Posiva has submitted the data required for the oversight to STUK, and STUK has reviewed the data. In the same context, it was ascertained that Onkalo does not include unreported facilities or functions significant to the proliferation of nuclear weapons. Posiva has submitted the basic technical characteristics (BTC) of the facilities for regulation by IAEA and the European Commission and STUK has reported Posiva's facility area in accordance with the additional protocol to the IAEA Safeguards Agreement. IAEA and the European Commission have inspected the Posiva facility area and Onkalo and have issued reports related to the inspections. The reports did not contain objections concerning Finland or Posiva.

Nuclear material safeguards after the closure of the disposal facility

The application prepared by Posiva does not comment on safeguards after the closure of the disposal facility. In accordance with Section 11 of the decree on the enforcement of the Safeguards Agreement conforming to the Non-Proliferation Treaty, nuclear materials remain under the supervision of IAEA until it becomes practically impossible to retrieve them. The fuel disposed by Posiva can also be re-

trieved after the closure of the disposal facility (appendix 17 of the construction licence application), though this would require considerable costs and labour input. Nuclear safeguards measures do not, therefore, end with operations, but shall continue at least until the expiration of the Safeguards Agreement. Spent fuel is not highly suitable nuclear waste owing to its properties. However, the usability of the disposed fuel for nuclear weaponry improves over the course of several thousands of years, which constitutes grounds for long-term IAEA supervision. In accordance with the Nuclear Energy Act, the nuclear waste management obligation expires after the decommissioning of the nuclear facility, and the licensee has paid a lump sum to the State for the monitoring and control of the nuclear waste. The State shall be responsible thereafter for the nuclear waste management obligations respective to the decommissioned nuclear facility.

Conclusion

The plan prepared by Posiva accounts for the known and expected safeguards needs and the measures required to enable these. No issues that may prevent Posiva from carrying out nuclear safeguards at the disposal facility have been detected in the plan prepared by Posiva.

9 Emergency arrangements

General

The preliminary emergency plan is a document based on Section 35 of the Nuclear Energy Decree and must be submitted to STUK in connection with the construction licence application. In accordance with Section 1 of the Government Decree on Emergency Response Arrangements at Nuclear Plants (716/2013), the decree lays down provisions on emergency response arrangements at a nuclear power plant and shall apply, as necessary, to other nuclear facilities and to nuclear transport as required by the degree of the threat.

Emergencies cannot rise at the encapsulation facility during construction until spent fuel has been transported to the facility. However, Posiva has been preparing for potential emergencies at the operating nuclear power plant units of the power company Teollisuuden Voima Oyj (TVO) in Olkiluoto over a period of several years. The personnel working at the Onkalo construction site have received emergency response training. A safety plan has been prepared for the Onkalo construction site and places of assembly have been designated for possible evacuation. The construction site has also been taken into account in the emergency plan and instructions of the Olkiluoto nuclear power plant and in the training and drills arranged by the TVO emergency response organisation.

Planning of emergency response arrangements

The topic-specific report included in the preliminary safety report prepared by Posiva for the construction licence application, entitled "Operational safety analysis of the Olkiluoto encapsulation plant and disposal facility", includes an assessment of operational safety at the facilities and of the radiation doses the facility employees and the local population are exposed to during normal operation and emergencies. Posiva will specify its estimates of the radiation doses released in the event of more serious accidents causing releases into the environment as well as of the need for protective measures at varying distances from the encapsulation and disposal facilities. The results will be observed in preparing an emergency plan for the operating licence as well as an external emergency plan.

The emergency response arrangements prepared by Posiva will be consistent with the operations, fire prevention and security arrangements of the facility as well as the external emergency plan prepared by authorities for responding to nuclear power plant accidents.

The preliminary emergency plan includes a description of the facilities, devices and equipment required for emergency response measures, including reliable communication and alarm systems and a data transfer system for transmitting process parameters and radiation measurement results and weather information. The plan describes the estimation of the radiation situation, assessment of releases and formation of an assessment of the situation in the event of disturbances or accidents.

Posiva will ensure the safety of the personnel in emergency situations. The preliminary emergency response plan specifies places of assembly during the operating of the encapsulation and disposal facilities, personnel decontamination measures, and personal protective equipment and measurement equipment for radiation control. Posiva is not required to provide iodine pills for its personnel or the local population in the event of an accident, because fuel that has been stored for a long period of time only contains low doses of isotope iodine-129. Nevertheless, iodine pills have been reserved to prepare for accidents at the operating facilities in Olkiluoto.

The preliminary emergency response plan prepared by Posiva specifies the management pro-

cedures of the emergency response organisation, scope of the authority and responsibilities of the emergency response manager and line-up, areas of responsibility, operational capability, and resources of the emergency response organisation. Posiva also intends to utilise other resources and infrastructures available to TVO in Olkiluoto for the purpose of maintaining emergency response operations. The distribution of responsibilities will be specified at the latest when Posiva applies for the operating licence. With regard to the persons responsible for the emergency response arrangements, STUK has approved Posiva's emergency response arrangements coordinator. His/her deputy coordinator will be approved at the construction licence stage.

Preparedness

In accordance with the preliminary emergency response plan, Posiva can commission its emergency facilities after the hoisting equipment building and the emergency response centre located in the building are completed and equipped for commissioning. Before the operating licence is granted, the facilities, equipment and communication devices will be tested at the test run stage in a joint operation drill organised together with the rescue authorities.

The preliminary emergency response plan includes a description of the emergency response training for Posiva's emergency organisation and rehearsals organised for the TVO personnel participating in Posiva's emergency response activities and of the process of preparing the emergency response plans. Before the commissioning of the facility and during the commissioning stage, regular internal and independent assessments will be conducted in order to ensure that the emergency response arrangements function well. Other Posiva personnel and any personnel temporarily working in the area will receive emergency response training.

Action in an emergency situation

The preliminary emergency response plan includes a description of Posiva's actions in an emergency situation as well as of communications, joint operations and the classification of emergency situations, as well as notifications submitted to the authorities based on the classifications. More specific action instructions are provided in the emergency response instructions. The plan presents the authorisation and responsibilities of the emergency response manager as well as preparedness and action in the event of a threat to security. The plan also describes the procedures required to dismantle an emergency situation and to perform post-event actions, in addition to the safety principles concerning transportation.

Measures pertaining to rescue operations

Posiva will participate in preparing the external emergency plan and organising related training to the extent that this is necessary. The accident analyses to be specified at the construction stage will be utilised in the preparation of the external emergency plan and in dimensioning action. At the commissioning stage, Posiva will participate in preparing advance instructions to be distributed to the population together with the rescue officials. The notice will be sent to the local population and can be combined with the corresponding TVO notice to cover the entire Olkiluoto area. The plans related to rescue services will be presented in greater detail in connection with the emergency response plan and the operational instructions to be submitted with the operating licence application.

Statement of the Finnish Ministry of the Interior

Via its letter 1/H41501/2014 on 10 January 2014, STUK has requested a statement from the Ministry of the Interior's Department for Rescue Activities (Department for Rescue Services) concerning Posiva's preliminary emergency plan on 29 November 2013 (version 2) in accordance with Section 37 of the Nuclear Energy Decree and a request for a statement by the Ministry of Employment and the Economy. The Department for Rescue Services has submitted its statement (SMDno/2014/104, 24 February 2014) to STUK. According to the statement, the Department for Rescue Services, among other things, considers it worthwhile that Posiva should aim to utilise the existing TVO resources and infrastructure in preparing for emergency situations, and stresses the importance of cooperation in notifying the population, too. Moreover, the Department for Rescue Services considers cooperation between Posiva and the local rescue services and any parties participating in rescue activities an important element.

Conclusion

STUK has reviewed the preliminary emergency plan and related updates submitted by Posiva in connection with processing the construction licence application. STUK has taken the statement of the Ministry of the Interior into account in its assessment. Via its letter 3/H41501/2013 on 3 April 2014, STUK has approved the preliminary emergency plan prepared by Posiva. The planning of emergency arrangements and the plans related to emergency measures at the Olkiluoto encapsulation plant and disposal facility are sufficient.

10 Security arrangements

Section 7: Physical protection and emergency planning and other comparable arrangements

Sufficient physical protection and emergency planning as well as other arrangements for limiting nuclear damage and for protecting nuclear energy against illegal activities shall be a prerequisite for the use of nuclear energy.

More detailed requirements related to security planning by the licensee are laid down in the Nuclear Energy Act, Government Decree 734/2008 on the Security in the Use of Nuclear Energy and the STUK guides YVL A.11 (Security of a nuclear facility), A.12 (Information security management of a nuclear facility), D.2 (Transport of nuclear materials and nuclear waste) and in document Design basis threat for the use of nuclear energy and use of radiation (STUK decision 2/Y42217/2013). In processing the construction licence application materials, STUK has assessed the organisation of security arrangements with regard to the requirements listed above.

In accordance with paragraph 5 of Section 35 subsection 1 of the Nuclear Energy Decree, preliminary plans for the arrangements for security and emergencies shall be submitted to STUK. In accordance with subsection 2 of the same section, an applicant for a licence shall also provide the Radiation and Nuclear Safety Authority with any other reports that STUK considers necessary.

At various stages, Posiva has submitted to STUK documents concerning security arrangements, the majority of which have been classified by STUK in accordance with paragraph 7 of subsection 1 of Section 24 of the Act on the Openness of Government Activities and Section 78 of the Nuclear Energy Act. This public safety assessment does not contain a detailed description of security arrangements based on the grounds presented above.

STUK has approved documents which detail how the licence applicant intends to carry out the security arrangements under its responsibility during both construction and operation. The same security arrangements are not required during operation as during construction, because the consequences of any illegal activities to people and the environment are considerably less significant than during operation. This is due to the fact, for example, that no spent nuclear fuel has been used at the intended encapsulation and disposal facilities during construction. This risk-aware, classifying approach is applied in assessing the sufficiency of the security arrangements in accordance with Section 7 of the Nuclear Energy Act. This has also been presented in the IAEA Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities, NSS 13, INFCIRC/225/Rev. 5 as Fundamental Principle H: Graded Approach.

Based on the materials, Posiva has employed Design Basis Threat and risk analysis in the planning and assessment of the security arrangements, and has analysed the need for physical protection. The plans for a nuclear power plant present information security principles and various security zones in accordance with the defence-in-depth principle, and observe the protection of important structures and systems.

Posiva has presented a plan for security arrangements during construction, including the line-up and tasks, supervision and communication equipment, protective equipment and use-of-force equipment of a security organisation. With regard to security control, Posiva has described the procedures required to implement security control in accordance with related authorisation. Posiva has also presented the principles for the use of force and related procedures, trustworthiness pro-

cedures, plans and grounds for the implementation of security arrangements, procedures for conducting affairs at the nuclear power plant, and for supervising human and goods traffic. The materials also present an operational plan for an alarm and management centre, and measures for preparing for threats and submitting notices to STUK.

STUK is in the process of confirming the joint security standing order of Posiva and TVO in accordance with Section 7 of the Nuclear Energy Act. According to STUK, the standing order must enter into force before the construction work is started, in order to ensure sufficient security arrangements during construction. The standing order specifies the organisation and equipment of and use of force by the security organisation, among other things. It is an essential document, because a security standing order is a precondition for granting security personnel the authorisation to act.

The administrative, technical and functional security arrangements, including information security, require further development before construction can be started. These issues are discussed in the STUK decisions regarding the security arrangements prepared by Posiva. The issues are not discussed in this safety assessment because the decision concerning security arrangements must be kept confidential and constitutes classified material based on its contents.

Via its letter 2/H42217/2014 on 26 September 2014, STUK has requested the Ministry of the Interior for a statement concerning the construction licence application documents related to security arrangements by Posiva, based on paragraph 3 of Section 37 of the Nuclear Energy Decree. The Ministry of the Interior has submitted to STUK its statement SMDno-2014-2458 on 27 October 2014 (the statement is classified as "confidential" in accordance with protection level III described in subparagraph 7 of paragraph 1 of section 24 of the Act on the Openness of Government Activities, 621/1999). STUK will consider the observations of the Ministry of the Interior in its decision concerning security arrangements.

Conclusion

The sufficiency requirement concerning security arrangements, based on the Nuclear Energy Act, and the requirement concerning preliminary security arrangements, based on the Nuclear Energy Decree, are fulfilled so that nothing in terms of security arrangements prevents granting a construction licence in accordance with sections 18 and 19 of the Nuclear Energy Act. A precondition for beginning the construction work is confirming the security standing order presented in this assessment and the fulfilment of the detailed security requirements specified in the decision issued by STUK. No further details of the requirements mentioned above can be given here, because the information is classified as confidential (subparagraph 7 of paragraph 1 of Section 24 of the Act on the Openness of Government Activities) and Section 78 of the Nuclear Energy Act).

11 Management system and safety culture

Safety culture

Section 19: Safety culture

When designing, constructing, operating and decommissioning or closing a nuclear waste facility, a good safety culture shall be maintained. In its decisions and operations, the management of the organisation concerned shall demonstrate its commitment to procedures and solutions promoting safety. Personnel shall be motivated to perform responsible work, and an open working atmosphere shall be promoted in the working community in order to encourage the identification, reporting and elimination of factors endangering safety. Personnel shall be given the opportunity to contribute to the continuous enhancement of safety.

STUK has assessed the organisation and safety culture of Posiva through, for example, document reviews and inspections and interviews conducted at the facility site, and by oversight of the construction of the underground Onkalo research facility. External safety culture assessment expertise has been utilised to support the assessment. The oversight and inspections conducted by STUK covered Posiva's procedures for guiding its suppliers in the development and maintenance of a good safety culture. STUK has also inspected some of Posiva's suppliers. One of the objectives of such inspections was to assess the safety culture of these organisations.

STUK has also assessed the documents related to safety culture submitted by Posiva. Such documents include the Posiva management system manual, a safety management and safety culture report, a construction quality management report, code of safety culture team, construction project quality plan, and project plans. Below are the observations based on the documentary review.

Posiva requires all organisations participating in the nuclear waste facility project to have clear principles and objectives, determined and confirmed by their administrative boards, which ensure that actions appropriately observe any factors affecting safety in accordance with the significance to safety of that factor. Posiva specifies the objectives and goals determined by the management of Posiva in its management system manual. Posiva also requires that the identification of factors affecting safety, and safety itself, are prioritised in all activities in situations where decisions need to be made between safety and other factors, such as factors related to schedule and production.

The objective of the Posiva management system is to ensure that operations comply with requirements and to meet the company's strategic goals, support a good safety culture, manage risks and, above all, ensure conformity with safety and quality requirements. Within the context of the management system, safety means nuclear and radiation safety, post-closure safety and industrial safety. The management of safety and quality have been combined into a single complex under the management system. Posiva has included the continuous improvement of safety as a nuclear and radiation safety objective.

In terms of action policy, the management of Posiva have specified the establishment and maintenance of a good safety culture in all company operations as one of the company's organisational objectives. Moreover, the Posiva management system manual specifies that the company management must demonstrate commitment to solutions promoting safety through decisions and actions. According to Posiva, a good safety culture also entails offering the personnel the opportunity to participate in the continuous improvement of the management system as well as an open work community atmosphere, which encourages the identification, reporting and elimination of factors threatening safety.

Safety culture is one of the themes of the Posiva induction training for permanent personnel, fixed-

term employees and the employees of Posiva suppliers performing work for Posiva. A particular objective of the training is understanding the significance of one's work input to safety. The training must be repeated at three-year intervals. In safety-classified assignments not performed at the facility site, suppliers are required to familiarise their personnel and subcontractors with the assignment requirements and procedures. Personnel safety culture training is one of the requirements. Training sessions need to be recorded so that Posiva may verify that the required training has been organised as necessary. Posiva will deliver safety culture-related training materials to the subcontractors as necessary. Posiva assesses the safety culture of the suppliers through audits, supplier oversight, reviews and follow-up meetings.

Posiva aims to provide safety culture-related communications on a monthly basis in personnel meetings and supervisor meetings. Posiva is in the process of systematically developing its internal communications. The future internal communication channels and tools offer new opportunities for safety culture communications, too. STUK requires Posiva to ensure that the significance of a safety culture is enhanced through regular internal communications.

Posiva has submitted to STUK a report including a description of the current state of its safety culture and of the measures intended to further improve the safety culture. Posiva has monitored the state of the safety culture through self-assessments and internal reviews as well as through the aid of external appraisers. In 2010, a separate work group assessed the occupational safety activities at Posiva. Posiva has investigated the current state of the organisation's safety culture by commissioning a special report from VTT Technical Research Centre of Finland in 2013.

In the report, Posiva specifies short- and long-term measures for the monitoring, assessment and further improvement of their safety culture. Posiva has established a separate safety culture team to promote safety culture. An external supplier well-versed in safety culture supports the team. However, the inspections conducted by STUK have shown that so far, Posiva's measures are individual development and monitoring activities, and are not governed by a target-oriented long-term plan. Posiva has been intending to prepare a safety culture programme but does not have a detailed schedule for the completion and commissioning of the programme. STUK requires Posiva to prepare and launch a permanent safety culture programme by 30 April 2015.

In addition to document checks, STUK has verified Posiva's safety culture through inspections based on a separate inspection programme. The inspections have been targeted at Posiva's key operations, including management, construction preparations, quality assurance, design, supplier management, requirement management, information security and safety culture. The inspections have entailed searching for indications of the organisation's attitude concerning, for example, the primary nature of safety, understanding the safety implications of one's work, non-conformance management, and management and personnel commitment to safety.

STUK has overseen the construction of the Onkalo research facility. Oversight has been carried out because the facilities will constitute part of the disposal facility. Oversight has been based on inspections, monitoring visits to the research facility and follow-up meetings. The experiences and observations accumulated during the oversight activities have been used to support decision-making in assessing the state of safety culture at Posiva.

Conclusion

Based on the assessments, control and inspections carried out by STUK, Posiva and its suppliers have the resources and preparedness to implement the nuclear power plant construction project in accordance with good safety culture. According to STUK's estimation, Posiva management and personnel have demonstrated commitment to high safety standards in practice.

Safety and quality management

Section 20: Safety and quality management

Organisations participating in the design, construction, operation and decommissioning or closure of a nuclear waste facility shall employ a management system for ensuring the management of safety and quality. The objective of the management system is to ensure that safety is prioritised without exception, and that quality management requirements are commensurate with the significance to safety of the activity. This management system shall be systematically assessed and further developed.

Safety and quality management shall cover all activities influencing the safety of the nuclear waste facility. For each function, requirements significant in safety terms shall be identified, and the planned measures described in order to ensure compliance with requirements. The processes and procedures shall be systematic and based on instructions.

Systematic procedures shall be in place for identifying and correcting deviations significant in safety terms.

The licensee shall commit and oblige its employees and suppliers, subcontractors and other partners contributing to safety relevant activities to engage in systematic safety and quality management.

Posiva has integrated quality, environment and safety management into a single complex under its management system, within the framework of which safety management is systematically performed. The system allows identifying risks affecting nuclear waste management at the operational planning stage and targeting the focus of quality and safety management at those elements which are most significant to safety. In accordance with the requirements of the management system, safety overrides economic motives in all Posiva operations.

The Posiva management system is based on international quality standards and observes the requirements of the YVL guides and IAEA standard GS-R-3 concerning management systems, quality assurance and quality management. Within the context of the system, Posiva has specified the objective that all organisations affecting the safety of the design, construction and commissioning of the nuclear waste facility must apply the quality standards in question as well as the YVL guides and IAEA standard in their quality management systems and supplier-specific quality plans.

Posiva has regularly commissioned external, independent assessments of its management system. Posiva has appropriately processed the non-conformances and recommendations specified in the assessments in accordance with the non-conformance management procedure.

Posiva employs management system processes to direct its operations in accordance with its strategy. The purpose of its operations is to begin disposal in 2022. The processes developed for line organisation activities have been divided into management, main and support processes. The main processes Posiva intends to use to reach the set goal are disposal solution management and disposal solution implementation.

The project process description presents the processes Posiva has developed for the nuclear waste facility construction project.

According to STUK's estimations, the management system and project processes have been designed and implemented in accordance with the requirements in the YVL guides. Posiva monitors the implementation and effectiveness of the processes through management reviews.

The procedures governing the line organisation and project operations at Posiva have been compiled into a set of manuals covering different areas. The manuals include e.g. a research and development manual, a procurement manual, a design manual, a production manual and a construction manual. According to STUK's assessment, Posiva has prepared, approved and implemented the instructions in the manuals sufficiently extensively for construction operations.

STUK requires the licensee to prepare instructions concerning procedures related to determining the quality and quality assurance requirements of products and operations. Posiva has prepared instructions in order to ensure the allocation of the available resources to the products and operations which are most significant for safety. According to the instructions, a key factor in the processing of the quality and quality assurance requirements of products and activities is their importance to nuclear and radiation safety. However, the significance of products and activities to the different aspects of corporate safety will also be observed in specifying the requirements.

Posiva has prepared instructions for non-conformance management during projects. The instructions concerning reports on non-conformances detected by suppliers are given in the supplier requirements. All processing related to non-conformances is recorded in the Posiva system. The system is used to classify and group non-conformances. The supplier is required to attach the materials related to non-conformances to the final documentation.

Posiva's training programme includes a compulsory course for all Posiva's permanent and fixed-term personnel and external company personnel performing work for Posiva. The objective of the

training is to cover the key contents of the management system. The course offers a general understanding of, for example, the management system and its structure and continuous improvement and Posiva's quality objectives. The course covers, for example, the identification of non-conformances related to procedures, human factors, suggestion schemes and official regulations. Posiva distributes information on the management system and changes in the system to its personnel through internal briefings and the Posiva Intra system as necessary.

In early 2013, STUK launched an inspection programme to be completed during the processing of Posiva's construction licence application. The purpose of the programme was to assess Posiva's procedures for the construction of a safe, high-quality nuclear power plant. The objective of the inspections was to verify the quality assurance procedures presented in the application documents prepared by Posiva, as well as the performance of those procedures. A total of 17 inspections were carried out in accordance with the programme, some of which were targeted at Posiva's suppliers, whose operations are significant to nuclear and radiation safety. The aim of the inspections was to assess the control and regulation Posiva carries out concerning its suppliers, and the performance and effectiveness of the related procedures. STUK presented a total of 70 requirements of varying levels of safety significance for the purpose of further improving Posiva's operations. Subsequently, Posiva has planned and implemented corrective measures in response to all the requirements which are relevant for the operations of the organisation and for launching construction activities.

Conclusion

To sum up, STUK mentions that Posiva's management system, including the processes and software, have been developed and introduced into use in accordance with the quality management requirements specified by STUK in the YVL guides. Compliance with the management system gives Posiva the capability and resources to manage the quality and safety of the design, construction and commissioning of the nuclear power plant. The measures carried out by Posiva in order to identify, clarify and process operational and product non-conformances fulfil STUK's requirements. Posiva is improving the management system as structured. STUK has approved Posiva's management system manual. In the future, Posiva must submit all major changes to the manual for approval by STUK.

Lines of management, responsibilities and expertise

Section 21: Lines of management, responsibilities and expertise

The lines of management in the organisation of a nuclear waste facility, alongside the positions and related responsibilities of employees, shall be defined and documented. The organisation shall have access to the professional expertise and technical knowledge required for the safe operation of the nuclear waste facility and long-term safety of nuclear waste disposal.

Duties significant to safety shall be designated. Training programmes shall be prepared for the development and maintenance of the professional skills of the persons working in these positions, and adequate command of the functions in question must be verified.

The organisational structure and the duties, authorities and responsibilities of the personnel, as well as the procedures related to decision-making concerning the operations of the nuclear waste facility, shall be documented in an organisation manual prepared by Posiva. Posiva shall prepare administrative for the operation stage rules in accordance with Guide YVL A.4 and submit them to STUK for approval in connection with applying for an operating licence. The administrative rules shall determine the duties, authority and responsibilities of the designated responsible manager of a nuclear facility, his/her deputy and the rest of the personnel needed for operation of the nuclear facility.

Posiva shall define the duties important to safety by recording the related areas of responsibility and main duties in the task descriptions. The task descriptions shall also include related competence requirements. Posiva must also specify when personnel members are required to demonstrate their competence and professional skills before taking on duties important to safety, and at regular intervals as necessary.

Posiva selects personnel and provides training with the objective of recruiting a suitable and competent personnel. Training measures at Posiva

are based on the principle of preparing a personal training plan for each Posiva employee on the basis of a development plan prepared in connection with development discussions. The organisational procedures for managing personnel recruitment and the preparing, implementation and monitoring of competence and skills requirements are specified in the Posiva management system. The management system also presents measures for the maintenance of further development of skills.

Conclusion

Based on STUK's assessment, Posiva has specified sufficient arrangements for the recruitment and training of its personnel and organisation, with which Posiva plans to ensure the personnel have sufficient professional skills for the safe operation of the nuclear facility. In addition to basic training, detailed personnel training plans are used to ensure sufficient for refreshing and updating training.

12 Other requirements

12.1 Ageing management

Posiva has submitted a preliminary report on the plan for the principles of ageing management in connection with the construction licence application.

The plan presents the principles of encapsulation and disposal facility ageing management. The plan also describes a plan for preparing an ageing management programme and attaching it to the operating licence application.

The plan of principles will be applied in selecting design solutions for the facilities; assessing the need and appropriate schedules for major structural modifications; collecting and processing user-based information related to the ageing of systems, structures and equipment; planning the surveillance and maintenance of functional and reliable systems, structures and equipment; assessing modification schedules and the connection between different modification work in planning modifications and periodic inspections; and performing various assessments related to the ageing management programme.

The plan specifies the organisational distribution of ageing management responsibilities as well as ageing management procedures. The basic principle is the objective of maintaining the encapsulation and disposal facility in the condition required by the design basis throughout its service life by a sufficient margin. The procedures are divided into preparing for ageing through planning, procurement and production, and preparing for ageing through operations.

The plan for principles also presents the principles for the qualification of the facility parts.

Conclusion

Posiva describes the principles of ageing management at the encapsulation and disposal facility on a very general level. The plan of principles for ageing management at the encapsulation and disposal facility complies with the requirements of Guide YVL A.8. The ageing management programme attached to the operating licence application must describe the practical implementation of the plan of principles for ageing management.

12.2 Ensuring the implementation of regulatory control by STUK

Section 19 of the Nuclear Energy Act

7) the applicant's arrangements for the implementation of control by the Radiation and Nuclear Safety Authority (STUK) as referred to in paragraph 3 of section 63 subsection 1, in Finland and abroad, and for the implementation of control as referred to in paragraph 4 of section 63 subsection 1 are sufficient;

Section 63: Supervisory rights

The Radiation and Nuclear Safety Authority (STUK) shall be entitled, in order to carry out the supervision required under this Act, and by the provisions issued hereunder and by Finland's international treaties in the field of nuclear energy, to:

1) inspect and control operations referred to in paragraphs 1–6 of section 2 subsection 1, and in paragraph 2 of section 2 subsection 2, and for this purpose have access to any place where such an operation is being carried out, as well as to carry out measurements required for supervision, to take and to receive samples and to install equipment necessary for such supervision; (23 May 2008/342)

2) oblige the licence applicant to arrange entry for the Radiation and Nuclear Safety Authority (STUK) to carry out inspections and measurements and to take samples on the premises where, according to the application, the operation referred to in paragraphs 1–6 of section 2 subsection 1 would be carried out; (23 May 2008/342)

3) require that nuclear fuel or the buildings and equipment intended as parts of the nuclear facility

be manufactured in a manner approved of by the Radiation and Nuclear Safety Authority (STUK), and oblige the licensee or licence applicant to arrange for STUK sufficient opportunity to control manufacture of the fuel or such buildings or equipment;

4) receive necessary information and be provided with the plans and contracts and their grounds concerning the fabrication, quality control or processing of nuclear materials, nuclear waste, the nuclear facility and its structures and equipment, as well as any material, device and equipment referred to in paragraph 5 of section 2 subsection 1 (23 May 2008/342).

According to Section 19 of the Nuclear Energy Act, one of the conditions for granting a construction licence is that the applicant has made sufficient arrangements for the implementation of control by the Radiation and Nuclear Safety Authority (STUK) in Finland and abroad as specified in paragraph 3 of Section 63 subsection 1, and for the implementation of control as specified in paragraph 4 of section 63 subsection 1.

In accordance with Section 35 of the Nuclear Energy Decree, Posiva has submitted a report on the arrangements for the implementation of control to STUK. In the report, Posiva describes the official measures concerning the official processing of documents related to equipment, structures and systems important to safety as well as the assessment and approval of the design and manufacturing organisations. Moreover, the report describes the official measures related to manufacture control, and event investigation by STUK. In the report, Posiva also specifies the preparation measures it has carried out to implement the practical arrangements required for regulation by STUK.

Within the framework of the control arrangements formulated by Posiva, the holder of the licence must, before implementation, obtain approval from STUK for the general safety concepts at the nuclear facility and for the detailed system, equipment and structure designs important to safety. In addition to the approval, the holder of the licence must provide STUK with the possibility to ensure that the design, manufacture, installation and commissioning processes of the intended nuclear facility components important to safety comply with STUK's requirements.

In accordance with the requirements of the YVL guides, Posiva shall apply for STUK's approval for the design and manufacture organisations or submit a related report to STUK. These measures are included in the agreements made with suppliers. Posiva will submit the quality manuals concerning the management of suppliers essential for the project to STUK for information. Posiva's procedures account for the participation of STUK in Posiva audits of the operations of suppliers important to safety as necessary.

According to the report, arrangements have been made so that STUK can observe and control type and other tests conducted, using test equipment, to examine the design requirements and related compliance in systems, equipment and structures. The control targets include the demonstration tests conducted at the disposal facility.

Sufficient control rooms complete with the proper equipment, including information systems, must be provided for the later control of construction, installation and commissioning by STUK at the facility site. STUK will detail these rooms and equipment later in connection with launching nuclear facility construction control at the facility site.

The arrangements for control by STUK have been integrated into Posiva's procedures and agreement documents. Based on the agreement documents, the requirements will be transferred along the supply chains related to product procurement. There have been no problems so far with providing STUK access to control structure and equipment production on site and to conduct inspections of Posiva's suppliers.

Conclusion

The arrangements made to allow regulation by STUK as described in the report prepared by Posiva are sufficient. However, all parties need to share an understanding of the approval required for different documentation before equipment construction can be started and of the role of STUK as a control authority. For this reason, Posiva has trained its personnel concerning the regulatory measures and rights of STUK.

12.3 The retrievability of the disposed spent nuclear fuel

According to the Government decision-in-principle made in 2001 concerning the disposal of spent fuel, the organisation responsible for the project shall

present specified, sufficiently detailed reports concerning the opening of the disposal facility as well as factors which may affect the opening of the facility, in addition to the technology and safety criteria of opening the facility, before obtaining a construction licence. An up-to-date estimate of the costs of opening the facility is also required. The plans must ensure that post-closure safety shall not be impaired as a result of enabling opening and retrievability. The disposal is meant to isolate the spent fuel from living species, and the aim is not to facilitate opening the facilities.

The Government decision concerning the disposal of spent fuel (478/1999) which was valid at the time of making the decision-in-principle required that the disposal facility can be opened if the option becomes expedient as a result of technical progress. The Government decision has been replaced with the Government Decree on the safety of disposal of nuclear waste (736/2008), which does not impose requirements related to opening the disposal facility. In the design of the disposal, Posiva has taken the requirement of the decision-in-principle concerning re-openability and the retrievability of the nuclear waste that has been disposed of into account.

In the construction licence application for the Olkiluoto encapsulation and disposal facility, Posiva has described the principle governing the opening of the disposal facility and the retrieval of the disposal canisters at the various disposal stages and after closure of the disposal facility. Posiva has submitted to STUK as part of the preliminary safety analysis report a description concerning the opening of the disposal facility and the related work stages.

The retrieval of the disposal canisters is based on a period of time during which the canisters can be assumed, with a high degree of certainty, to have remained tight. The disposal concept principle presented by Posiva allows for the opening of the facilities at various stages of the project without compromising the safety. The iron-copper disposal canister has been designed to remain tight for a very long period of time, allowing for retrieval without the risk of radioactive contamination. The disposal facilities to be excavated in rock will endure even technical opening measures. Together with SKB, Posiva has developed canister retrieval technology and has tested the removal of the bentonite clay surrounding the canister using saline water. According to STUK's review, the technique is suitable for the removal of bentonite and has been sufficiently demonstrated to function.

In the construction licence application, Posiva discusses factors related to the retrieval of the canisters which need to be observed should the decision be made to open the deposition tunnel in the future. Such factors include a rise in rock temperature due to residual heat and radiation protection for the employees participating in the opening process, and the retrieval of the canisters.

Conclusion

Posiva has included a report concerning the opening of the disposal facilities and an estimate of the related costs in the construction licence application. Technically, the facilities can be opened and the disposal canisters safely retrieved using current work methods. Posiva has developed a retrieval technique together with SKB and has submitted a description of the functionality of the technique. According to STUK, the nuclear waste to be disposed can be technically retrieved, and the retrieval option does not jeopardise the post-closure safety of the disposal.

12.4 An alternate horizontal disposal solution for spent fuel (KBS-3H)

In the construction licence application submitted to the Government concerning the Olkiluoto encapsulation and disposal facility, Posiva applied for permission for a horizontal canister disposal solution (KBS-3H) in addition to a vertical disposal solution (KBS-3V), and requested permission for the Radiation and Nuclear Safety Authority to approve the modifications to the proposed design solutions.

In the horizontal disposal solution, the disposal canisters and surrounding bentonite buffers are situated in horizontal holes drilled at the disposal depth. Posiva has been developing the horizontal disposal solution together with SKB since 2002. In the KBS-3H solution, the disposal canisters are packed into a perforated protective cylinder together with a bentonite buffer before disposal. The emplacement packages are situated in horizontal disposal holes no longer than 300 metres in length, using an emplacement device. The design of the disposal canisters and bentonite buffers corresponds to that of the vertical disposal solution.

According to Posiva's assessment, the potential benefits of the KBS-3H solution are the more effortless quality management of the canister and buffer emplacement, fewer disturbances in the rock conditions and the environment at the disposal site as the result of a lower excavation volume, and reduced costs owing to less excavation and a lower tunnel filling volume. No separate deposition tunnels are required in the KBS-3H solution, which means that there is no need to fill the deposition tunnels required in the vertical solution. At this point, one of the possible weaknesses of the solution compared with vertical disposal is the risk of uneven buffer material distribution owing to water leakage in the long horizontal hole, which may affect buffer density and, thereby, performance. The horizontal solution may also be more sensitive to rock faulting caused by an earthquake. Drilling the long horizontal tunnel required for the KBS-3H solution is technically more challenging.

In the period from 2003 to 2007, Posiva prepared a comprehensive safety assessment of the KBS-3H solution, including an assessment of the differences of the solution options and the safety of the horizontal disposal solution. STUK has assessed the comprehensive KBS-3H safety case and has submitted the conclusions of the assessment to Posiva in 2009 (H221/4, 15 October 2009). After the comparison report in 2008, Posiva's development measures have focused on the further investigation of identified safety issues and the technical development of the horizontal disposal solution. Neither the assessment completed by STUK in 2009 or the review of the construction licence application materials for the Olkiluoto encapsulation and disposal facility showed any reason to assume that the proposed horizontal disposal solution could not fulfil the safety requirements set in the Government decree (736/2008). However, Posiva has not yet submitted comprehensive safety materials to STUK to serve as a basis for assessing conformity with safety requirements in detail.

Posiva has conducted tests related to the technical feasibility of the KBS-3H solution in the Äspö Hard Rock Laboratory in Sweden together with SKB. They drilled a 95-metre-long horizontal hole for the purpose of testing the placement of the emplacement package. In its most recent nuclear waste management programme (YJH-2012), Posiva presented a plan for obtaining a sufficiently high level of technical development and safety assessment for implementing the solution. As part of the construction licence application materials, Posiva submitted to STUK a report on the current state of the KBS-3H solution, including development targets and on-going development work. Key research and development targets include:

- The production, transport and emplacement of the components according to requirements
- Testing the drilling of the long horizontal disposal hole (300 m) in accordance with requirements, and verifying related conformity
- Developing a bentonite buffer production technique and demonstrating its performance
- Preparing rock classification criteria for the horizontal disposal holes
- Assessing the significance of the phenomena and processes affecting the long-term performance of the horizontal disposal solution in various ways, such as bentonite erosion caused by groundwater, or rock movements.

In its most recent nuclear waste management programme and its response to STUK's statement concerning the YJH-2012 programme, Posiva proposed completing a comprehensive comparative assessment of the vertical and horizontal solutions in 2016. A precondition for modifying the disposal solution is that Posiva obtains advance approval from STUK for the plans and documents approved by STUK and affected by the change (Section 112 of the Nuclear Energy Act). At the construction stage preceding the operating licence for the disposal facility, the modification requires the submission of the necessary updated documents and safety case for approval by STUK in accordance with Section 35 of the Nuclear Energy Decree. Posiva must also demonstrate the feasibility of the horizontal disposal solution with a sufficiently high degree of certainty before beginning to drill the long disposal holes. The modification of the disposal method at the construction stage would be highly likely to postpone the intended starting date of disposing the spent fuel.

Conclusion

In addition to the vertical disposal solution, Posiva has proposed a horizontal disposal solution based on the same safety principles. Both options are subject to the same safety requirements governing

the disposal of nuclear waste. STUK has not observed a reason why the horizontal disposal solution could not fulfil the set requirements.

Posiva has proposed to complete an assessment of the vertical and horizontal solutions in 2016 in order to be able make a decision about future measures. Because the horizontal disposal solution may also fulfil the set safety requirements in STUK's understanding, the modification can be processed in accordance with Section 112 of the Nuclear Energy Decree as a modification and part of the construction licence to be granted. The modification of the disposal method at the construction stage would be quite likely to postpone the intended starting date of disposing the spent fuel.

12.5 Transportation

Transporting spent nuclear fuel is part of the use of nuclear energy in accordance with the Nuclear Energy Act. According to the Nuclear Energy Act, the Radiation and Nuclear Safety Authority is responsible for regulating the transportation and approving the transportation plans. Transporting spent nuclear fuel must adhere to the applicable legislation and regulatory requirements. The safety of the transports must be ensured through careful planning and safety analyses. The safety principles set in the legislation governing nuclear energy apply to transporting nuclear fuel. In accordance with the Nuclear Energy Decree, the transport cannot be commenced until STUK has ascertained that the transport arrangements, security arrangements and emergency planning meet the requirements set for them.

Posiva has included a report on the transportation of spent nuclear fuel in the construction licence application. The report includes an examination of the risk management related to the transportation. Posiva has also submitted to STUK a preliminary report on the transportation arrangements and a preliminary plan for the security arrangements during transportation.

Conclusion

STUK has assessed Posiva's plans in terms of the feasibility of the spent fuel transportation arrangements. Based on Posiva's plans, the spent fuel transportations are feasible. STUK will ascertain conformity with transport safety requirements through a separate transport authorisation process. In connection with applying for an operating licence, Posiva shall submit a report on the transport arrangements and also describe the related security arrangements in a nuclear waste transport plan, in accordance with Guide YVL D.2.

13 Summary

Posiva has submitted the safety materials required in Section 35 of the Nuclear Energy Decree and Section 16 of the Government Decree 736/2008 to STUK in connection with submitting a construction licence application. The submitted materials are sufficient for granting a construction licence. However, a review conducted by STUK raised issues on which Posiva will specify before constructing the encapsulation and disposal facility or further develop before submitting an operating licence application.

The encapsulation and disposal facilities described by Posiva in the construction licence application are to a large extent unique and represent the first facilities of their kind. While the facilities are for the most part based on tested and studied technology, no experience related to the construction of similar facilities is available in Finland or other countries. Likewise, highly restricted experiences are globally available related to designing and ascertaining the post-closure safety of the facilities.

YVL guides and international regulations concerning disposal safety are currently more general in nature than requirements concerning other nuclear facilities, supporting a step-by-step approach in the project. Issuing technical specifications has not been deemed expedient in the absence of experience-based data on factors affecting safety.

The updated YVL guides issued by STUK have affected the preparation and inspection of the construction licence application materials. The guides have been updated to better account for all nuclear facilities. Even though they were published after Posiva had submitted the construction licence application, the encapsulation and disposal facility construction licence application materials have been prepared according to the YVL guide drafts made available to Posiva.

Because of the reasons listed above, an incremental approach is reasonable in designing and ascertaining the safety of Posiva's encapsulation and disposal facility. The construction licence application materials present the key safety principles and design requirements and show conformity with the safety requirements concerning the encapsulation and disposal facility, and require no further changes. The specific properties of the disposal site and the performance of the disposal system still involve assumptions and uncertainties which can be verified or reduced based on a research and monitoring programme covering additional information acquired during the construction of the disposal facility, on the actual disposal facility construction process, and on the operation of the disposal facility. The programme entails monitoring the disposal site and the engineered barriers as well as long-term testing as necessary. Such a gradual approach also conforms to the principles of the international guidelines on nuclear waste management.

In its decisions submitted to Posiva, STUK has specified how Posiva must specify the processes of designing the facility and ascertaining the safety of the facility at the construction stage and in the operating licence materials.

In the safety assessment, STUK has presented conclusions related to compliance with the requirements set in Government decrees 736/2008, 734/2008 and 716/2013 as well as factors which must be considered in the construction of the nuclear facility and in the preparation of the operating licence application materials. The criteria for granting the construction licence are given in Section 19 of the Nuclear Energy Act. Below are the paragraphs of Section 19 which fall under the responsibility of STUK, and the conclusions based on the safety assessment are presented after them.

1) if plans concerning the nuclear facility meet the safety requirements laid down in this Act, and appropriate account has been taken of the safety of workers and the population when planning the operations in question;

2) if the location of the nuclear facility is appropriate with respect to the safety of the planned operations and environmental protection has been taken into account appropriately when planning operations;

3) if physical protection has been taken into account appropriately when planning operations;

5) the methods available to the applicant for arranging nuclear waste management, including disposal of nuclear waste and decommissioning of the facility, are sufficient and appropriate;

7) the applicant's arrangements for the implementation of control by the Radiation and Nuclear Safety Authority (STUK) as referred to in paragraph 3 of section 63 subsection 1, in Finland and abroad, and for the implementation of control as referred to in paragraph 4 of section 63 subsection 1 are sufficient;

8) if the applicant has the necessary expertise available;

10) if the applicant is otherwise considered to have the prerequisites to engage in operations safely and in accordance with Finland's international contractual obligations.

Operational safety of the encapsulation and disposal facility

The Olkiluoto encapsulation and disposal facilities proposed by Posiva are designed to fulfil the requirements on operational nuclear and radiation safety in the facilities. The encapsulation plant, and the disposal facility as necessary, adhere to the defence in depth principle. The structural safety of the facilities has been ensured using consecutive barriers comprising, in accordance with the handling stage of the spent nuclear fuel, a nuclear fuel cladding, transportation cask or disposal canister, and the structures of the encapsulation and disposal facilities. In terms of operational safety, passive solutions are used to manage the removal of residual heat and the criticality safety of the fuel. Functions which are important to radioactive substance management include nuclear fuel processing functions and filtering exhaust air to prevent the spreading of radioactive substances. Both functions in the encapsulation and disposal facilities are single failure tolerant. Before beginning the construction of the encapsulation and disposal facilities and the manufacturing of related equipment, Posiva must specify the related design requirements which require approval from STUK before construction of the facilities can be started.

Posiva has prepared for operational occurrences and accidents at the encapsulation and disposal facilities in accordance with safety requirements. Posiva has analysed possible operational occurrences and accidents at the facilities and prepared for these by adhering to the principles of redundancy, diversity and separation in accordance with the defence in depth principle in designing the systems which implement safety functions.

Posiva has presented analyses concerning the release and radiation doses due to normal operation and operational occurrences and assumed accidents at the encapsulation and disposal facilities. The radiation doses due to the operation of the encapsulation and disposal facilities fall below constraints set to radiation exposure in Government Decree 736/2008. The emergency arrangements required during the operation of the encapsulation and disposal facilities have been dimensioned based on estimated radiation exposures.

The disposal system and post-closure safety of disposal

Posiva has been developing the KBS-3 concept described above together with the Swedish Svensk Kärnbränslehantering AB over a period of several decades. The fabricability of the system components has been demonstrated sufficiently for obtaining a construction licence through component-specific manufacturing tests. Likewise, the feasibility of the rock facilities has been demonstrated with the demonstration facilities constructed in the underground research facility in Olkiluoto. Assessing the reliability of the classification system related to the implementation of the rock facilities is important during the first construction phase. Posiva and SKB have jointly tested the installation of the disposal canister and the emplacement of the buffer and tunnel backfill, in compliance with requirements in the Äspö Hard Rock Laboratory in Sweden. Posiva has also launched disposal system component installation tests in the Onkalo facilities. The installation tests are meant

to demonstrate that the components of the disposal system can be installed in accordance with the set accuracy requirements. In accordance with the decision-in-principle issued in 2001, Posiva has constructed an underground research facility that is designed to serve as part of the disposal facility. Posiva has complied with the requirements concerning nuclear facilities in constructing the underground research facility, and STUK has supervised the construction of the research facility as based on the supervision measures applied to the construction of a nuclear facility.

Post-closure safety of Posiva's disposal facility is based on two objectives to be implemented with complementary barriers. The primary objective is to contain the radioactive substances from the bedrock. The disposal canister has a key role in this. It is protected by clay material emplaced around it as well as the bedrock surrounding the disposal facility and by separating the disposal facility from the surface environment. The bedrock and the closure of the disposal facility create favourable and foreseeable conditions for the engineered barriers. The second objective of the barriers is to isolate and retard the migration of any released radionuclides to the surface environment.

To demonstrate post-closure safety, Posiva has presented an analysis of the expected and deviating evolutions and possible disturbances in the disposal system, as well as the adjacent environment in the licence application material. Based on the scenario analysis, Posiva has selected the most important evolutions leading to the release of radionuclides and analysed the resulting radiation doses to individuals as well as to other living environment and the radionuclide releases into the living environment. The results of the analyses fall below the constraints specified in Government Decree 736/2008 for radiation doses and releases of radioactive substances.

By taking into consideration the development needs found in the review of the facility's post-closure safety case, the clarity, traceability and reliability of the safety case can be improved. In connection with the review, STUK has presented the development needs to Posiva in the form of a separate decision requiring that the development needs are taken into account in the operating licence application materials.

The site of the encapsulation and disposal facility

The proposed site has been found suitable as a disposal site in the decision-in-principle in 2001. Based on the decision-in-principle, the project was granted permission to proceed with the construction of the underground rock characterisation facility and with more detailed site-specific investigations. After the decision-in-principle was issued, the underground rock characterisation facility Onkalo has been constructed at the site and investigations of the site have been continued. Considerably more knowledge of the site has been accumulated since the making of the decision-in-principle.

The research and very long-term analyses of the evolution of the disposal site are sufficient for granting a construction licence and have not raised issues which would suggest that the disposal site is unfavourable in terms of post-closure safety. Based on the research and analyses, we can conclude that the properties of the rock are suitable for implementing the disposal as proposed. The disposal depth of spent nuclear fuel, 400 to 450 metres, complies with the decision-in-principle issued concerning the Olkiluoto disposal facility, as well as the safety requirements set by STUK. The disposal depth has been selected with due attention to post-closure safety and to sufficient protection against aboveground and human activities.

Based on continuing research, the site of the nuclear facility is appropriate with respect to the operational and post-closure safety of the planned operations, and environmental protection has been taken into account appropriately when planning operations.

Nuclear waste management and decommissioning of the nuclear facility

While Posiva operates the nuclear facility and during the decommissioning of the nuclear facility, all low- and intermediate-level nuclear wastes are generated through processing fuel at the facility. Posiva has presented sufficient and appropriate arrangements and plans for handling and disposing nuclear waste generated during operations and for decommissioning the facility to obtain a construction licence.

Security of the nuclear facility

Posiva has employed Design Basis Threat principle and risk analysis in the planning and assessment of security arrangements and has analysed the need for physical protection. The application materials describe the principles, measures, plans and intended information security principles related to security arrangements. The actual plans for the nuclear facility present the various security zones in accordance with the defence-in-depth principle, and observe the protection of structures and systems important to design.

Posiva has presented a plan for the security arrangements of the nuclear facilities during construction, including line-up and tasks, supervision and communication equipment, protective equipment and use-of-force equipment of the safety organisation. Posiva and TVO have also submitted a joint security standing order for approval. The standing order must become valid before Posiva begins the construction of the nuclear waste facility.

The Posiva management system and available expertise

STUK has assessed the competence of Posiva's personnel and of the external expertise available to Posiva in connection with processing the construction licence application through document reviews and a separate inspection programme. Based on these, STUK has ascertained that Posiva has the use of sufficient and extensive expertise for the construction of a nuclear waste facility.

STUK has approved the management system manual describing the management system employed by Posiva. In the management system manual, Posiva stresses the priority status of safety in all activities as well as the creation and maintenance of a good safety culture. The goal is for the personnel to be aware of the significance of their work to safety. Posiva assesses the management system and the operations of the organisation regularly with the objective of continuously improving operations.

The Radiation and Nuclear Safety Authority's regulatory requirements

The arrangements and measures described in the report submitted by Posiva in order to ensure regulatory possibilities have been ascertained to be sufficient at the construction licence stage. STUK has issued a decision to approve the report concerning arrangements for regulatory possibilities, submitted by Posiva in connection with the construction licence. Posiva has carried out personnel training concerning practical arrangements for regulatory measures, in accordance with the requirements of the decision issued by STUK. Based on this, Posiva has carried out sufficient and appropriate arrangements for ensuring the implementation of regulatory measures.

Other reports

Posiva has included a report concerning the opening of the disposal facilities and an estimate of the related costs in the construction licence application. Technically, the facilities can be opened and the disposal canisters safely retrieved using current work methods. According to STUK, the nuclear waste to be disposed can be technically retrieved and the possibility for the opening of the facilities does not jeopardise the post-closure safety of the disposal.

In addition to the vertical disposal solution, Posiva has proposed a horizontal disposal solution (KBS-3H) based on the safety principles described in the construction licence application materials. STUK is not aware of any reason why the horizontal disposal solution could not fulfil the set requirements. STUK may process the modification at the separate request of Posiva according to Section 112 of the Nuclear Energy Decree. A modification made at the construction stage of the disposal facility would be highly likely to postpone the intended starting date of the disposal.

In the construction licence application, Posiva has presented a report concerning the transportation of the spent nuclear fuel as well as a preliminary report to STUK concerning the transport arrangements and related security arrangements. The spent nuclear fuel can be transported based on the plans prepared by Posiva. The safety of the transport will be separately ascertained. In accordance with the Nuclear Energy Decree, the transport cannot be commenced until STUK has ascertained that the transport arrangements and the required security and emergency planning arrangements meet the requirements set for them.

Conformity with general principles and requirements related to safety

In addition to conformity with sections 18 and 19 of Nuclear Energy Act assessed at the construction stage, general guidelines related to the use of nuclear energy are given in sections 5–7 of the Nuclear Energy Decree:

Section 5: The use of nuclear energy, taking into account its various effects, shall be in line with the overall good of society.

Section 6: The use of nuclear energy must be safe; it shall not cause injury to people, or damage to the environment or property.

Section 6 a: Nuclear waste generated in connection with or as a result of the use of nuclear energy in Finland shall be handled, stored and permanently disposed of in Finland […], and

Section 7: Sufficient physical protection and emergency planning as well as other arrangements for limiting nuclear damage and for protecting nuclear energy against illegal activities shall be a prerequisite for the use of nuclear energy.

Decisions-in-principle made by the Government have ascertained that the nuclear fuel disposal designed to take place in Olkiluoto is in line with the overall good of the society, in addition to which the disposal is a precondition for the safe use of nuclear energy in the long term. The nuclear waste facility proposed by Posiva is part of nuclear waste management in accordance with Section 6 a of the Nuclear Energy Act. STUK has presented its conclusions concerning compliance with the requirements of Section 7 of the Nuclear Energy Act in a statement.

As its conclusion, STUK ascertains compliance with the requirements set in sections 18 and 19 of the Nuclear Energy Act and the principles set in sections 5–7. The encapsulation plant and disposal facility for spent nuclear fuel proposed by Posiva can be constructed so that it is safe. The plans presented by Posiva are sufficient and appropriate for obtaining a construction licence with due attention to the following observations and restrictions:

- Posiva has submitted a plan concerning the specification of the nuclear waste facility system design to STUK. According to this plan, STUK will supervise the design progress and ascertain its sufficient level before the construction of the facilities.
- Posiva has submitted a plan for installation testing the components of the disposal system to STUK. Based on the tests, STUK will ascertain that the system can be installed before the excavation of the deposition tunnels can be started.
- Posiva must demonstrate the reliability of the rock classification system in connection with constructing the first deposition tunnels. STUK will ascertain the performance of the rock classification system as part of regulating the positioning and rock construction of the first deposition tunnels.
- Posiva has submitted a disposal concept development programme concerning the barriers to STUK. The programme covers the development targets pointed out by STUK in the safety assessment. STUK shall supervise the progress of development work in accordance with the programme during the interval between the construction and operating licences.
- Before the construction of the low- and intermediate-level waste disposal room can be started, Posiva must submit more specific plans to STUK concerning the low- and intermediate-level waste disposal rooms to be located in the disposal facility and a more detailed estimate of the joint impacts of the different types of nuclear waste to be disposed in Posiva's disposal facility.
- The joint security standing order of Posiva and TVO must be confirmed before construction work can be started.
- The details of the security arrangements planned for the construction period must be specified before construction begins. More specific requirements related to these issues are given in a confidential STUK decision (paragraph 7 of Section 24 subsection 1 of the Act on the Openness of Government Activities, 621/1999).

STUK's safety assessment concerning the safety of the Olkiluoto encapsulation and disposal facility and the Posiva project remains valid, even if the TVO facility unit Olkiluoto 4 does not advance to the construction licence application stage and the spent nuclear fuel from Olkiluoto 4 is excluded from the construction licence granted to Posiva. Not implementing the Olkiluoto 4 project would reduce the quantity of the spent fuel requiring disposal, and would reduce the surface area and rock volume required for disposal.

Statement from the Advisory Committee on Nuclear Safety

Posiva Oy's construction licence application for the construction of an encapsulation plant and disposal facility at Olkiluoto for the disposal of spent nuclear fuel

With reference to the request for a statement by the Radiation and Nuclear Safety Authority (STUK) (20/H42212/2014, 11 December 2014), the draft statement by STUK and the safety assessment, the Advisory Commission on Nuclear Safety issues the following statement regarding the construction licence application for a spent nuclear fuel encapsulation plant and disposal facility. During its meeting on 11 December 2014, the Commission received a presentation on STUK's draft statement on the construction licence application and the related draft safety assessment. Furthermore, during earlier meetings in the autumn of 2014, the Commission has received presentations on STUK's opinions on matters related to the assessment of the construction licence application. The Commission is familiar with STUK's draft proposal (1/H42212/2013) and the related draft safety assessment (11 December 2014).

The Radiation and Nuclear Safety Authority (STUK) has requested the Commission to pay specific attention on:

- whether the regulations, requirements and objectives concerning safety are up to date with regard to issuing a construction licence
- whether safety, security arrangements, emergency arrangements and nuclear safeguards have been taken into consideration to a sufficient level of detail and by applying sufficient expertise
- whether the results of the assessment are acceptable.

Furthermore, STUK has requested the Commission to include in its statement any other aspects concerning the construction licence application and the safety assessment.

Overview of the plant project

The aspects concerning the disposal of spent nuclear fuel have already been discussed quite extensively within the scope of international co-operation on multiple forums and in national development projects. In Finland, the need for creating a long-term development programme with interim goals for nuclear waste management and disposal was already expressed at early stages of the operation of the current Finnish nuclear power plant units. In November 1983, the Government issued a decision in principle regarding research, investigation and planning objectives in terms of nuclear waste management. The decision presented specific target schedules for the different stages of preparing for the disposal of spent nuclear fuel. They included a requirement to carry out detailed disposal site surveys for the disposal of spent nuclear fuel and a requirement to select, by the end of 2000, a disposal site that meets the safety and environmental protection criteria. Furthermore, the decision required the licensees to prepare the plans necessary for the construction licence application for an encapsulation plant and disposal facility, allowing a presentation to the regulatory authorities by the end of 2010. In 2003, the overall schedule for the construction of the encapsulation plant and disposal facility was specified by a decision of the Ministry of Trade and Industry, which stated that the construction licence application must be submitted by the end of 2012.

Additionally, concerning nuclear waste management, the 1983 decision required the licensees to annually present to the Ministry of Trade and Industry, together or individually, a plan of the research and investigation work scheduled for the next calendar year and an account of the work carried out in the previous year for regulatory purposes. The current regulations require a presentation to the Ministry of Employment and the Economy every three years. The Ministry of Trade and

Industry (replaced by the Ministry of Employment and the Economy as of 2008) and STUK have assessed the power companies' and Posiva Oy's plans and the documentation concerning the status of research and development projects. On the basis on these assessments, STUK and the Ministry have presented requirements for the planned further research.

In December 2012, Posiva Oy submitted to the authorities for assessment a detailed documentation concerning the construction licence application. In international comparison, Finland is at the forefront in projects that aim at a practical implementation of the disposal of spent nuclear fuel. Posiva and other Finnish organisations have worked in extensive co-operation with their Swedish counterparts, which has improved the scope of the projects. However, in Sweden, the commissioning of a spent nuclear fuel disposal facility is scheduled for a later timeframe than the current implementation schedule of Posiva Oy.

Posiva as an operator, organisation and resources, management system, safety culture and management of safety and quality

The Commission shares STUK's understanding that Posiva employs sufficient and extensive expertise concerning the construction of a nuclear waste facility. However, before the commissioning stage and at early stages of operation it must be ensured that, in spite of the organisational changes in early 2015 (between Posiva and TVO), Posiva has sufficient prerequisites to maintain and develop the competence of its personnel for further improving the security of the constructed facility. The Commission also shares STUK's opinion that Posiva's management system, its processes and instructions have been developed and implemented in accordance with the quality management requirements presented in the YVL Guides. With its management system, Posiva is considered to have the ability and readiness to ensure quality and safety during the planning, construction and commissioning of a nuclear waste facility.

The Commission shares STUK's opinion that Posiva and its suppliers have the prerequisites and readiness to maintain a good safety culture when implementing the nuclear waste facility construction project. STUK finds that Posiva's management and personnel have demonstrated on a practical level their commitment to a high level of safety. STUK also finds that, in terms of ensuring the safe operation of the nuclear waste facility, Posiva has sufficient arrangements in place for establishing and training the organisation and the necessary personnel.

Status of regulations, requirements and objectives concerning safety with regard to issuing a construction licence

Already before Posiva Oy submitted an application for a Decision-in-Principle in May 1999, Government Decision 478/1999 had confirmed the essential safety requirements concerning the safety of disposal of spent nuclear fuel. The requirements specify that "In any assessment period, disposal shall not cause health or environmental effects that would exceed the maximum level considered acceptable during the implementation of disposal." At an early stage, more detailed regulations were included in STUK's guides "Long-term safety of disposal of spent nuclear fuel" (YVL 8.4) and "Operational safety of a disposal facility for spent nuclear fuel" (YVL 8.5), which came officially into force on 1 December 2001. At the next stage, Government Decree 736/2008, which replaced Government Decision 478/1999, was prepared. This Decree still remains in force. The Decree specifies the general requirements, whereas the more detailed requirements are presented in guide YVL D.5 (Disposal of Nuclear Waste), whose final version entered into force as of 1 December 2013. However, when preparing its construction licence application, Posiva had access to a nearly finalized draft of YVL D.5.

In Finland, the development of regulations concerning the safety of the disposal of nuclear waste has advanced significantly faster and has reached a more detailed level than in most other countries. International organisations such as EU, IAEA and OECD/NEA have discussed the safety requirements for the disposal of nuclear waste on quite a general level. International assessments of the Finnish country reports that have been prepared within IAEA's Joint Convention have found that the Finnish implementation and plans for nuclear waste management meet the common international requirements. IAEA's Integrated Regulatory Review Service (IRRS) assessment has found that

STUK's operations and national arrangements meet IAEA's requirements.

The Commission finds that the regulations, requirements and objectives concerning safety are up to date with regard to issuing a construction licence.

Safety principles of the disposal system

The Commission shares STUK's understanding that, when planning an encapsulation plant and disposal facility, Posiva has taken into account the decrease of the activity of spent nuclear fuel by means of interim storage and planned the lifetime stages of the disposal facility (construction, disposal operations and closure) in a way that contributes to long-term safety. The selection of the disposal depth takes into account long-term safety and provision of sufficient protection against above-ground phenomena and human activities.

The safety functions of the disposal system presented by Posiva (disposal canister, buffer material surrounding the canister, tunnel filling, closure of facilities and the host rock that acts as a natural barrier) follow the multi-barrier principle. The Commission shares STUK's opinion that, in the operating licence phase, the descriptions of the safety functions must indicate in more detail the factors that affect the performance of each barrier.

During the operation of the disposal facility, the performance of the engineered barriers shall be monitored before the final closure of the facilities in accordance with Government Decree 736/2008, Section 9. Section 10 of this Decree includes an ambiguous reference to ensuring long-term safety with follow-up monitoring, which could be interpreted to refer to post-closure monitoring. This, however, would be in conflict with the principle presented in Section 7h of the Nuclear Energy Act, according to which the disposal of nuclear waste in a manner intended as permanent does not require surveillance of the disposal site for ensuring long-term safety. There is enough time for quite extensive follow-up monitoring during the operation stage before the final closure of the disposal facility as the first disposal tunnels will be closed up to a hundred years before the closure of the entire disposal facility. Monitoring during construction and before closure should consider the possible changes in the properties of the host rock and groundwater. Posiva has presented a plan for monitoring operations during construction.

The Commission shares STUK's opinion that the monitoring of engineered barriers before the closure of the disposal facility still requires further development in terms of monitoring technology and the object of monitoring as well as the applicable requirements by the authorities.

Planning of the encapsulation plant and disposal facility with regard to operational safety

The nuclear fuel encapsulation plant and disposal facility is a nuclear facility. When planning the safety of the facility, Posiva has applied the principle of defence-in-depth and defined three safety functions: management of radioactive materials, management of reactivity and removal of residual heat. The safety functions are the same as for nuclear power plants, but the fuel handling conditions are different. The amount of fuel present at a given time is considerably lower compared to a power plant and the fuel is not subjected to high pressures or temperatures. Fuel creates less residual heat than in power plants and, therefore, residual heat can be removed by passive means without a power source. As the facility does not intend to bring fuel into a critical state for achieving a chain reaction, subcriticality can be ensured by reliable structural means. Criticality of fuel would require the simultaneous occurrence of several diverse and highly unlikely accident conditions. However, unlike in a power plant, fuel assemblies are handled (e.g. when drying) and lifted in the air uncovered, which requires utmost care in order to prevent any damage. Due to the management of radioactive materials, all the stages of the process take place in closed, sealed facilities, whose ventilation systems enable filtering during normal and accident conditions. All processes are remote-controlled for the purposes of radiation protection of the personnel.

There is no international experience available on similar plants. There is, however, experience in handling spent nuclear fuel in reprocessing facilities, for example.

The sealed canisters are transported from the interim storage at the encapsulation plant to the disposal facility with a canister lift and transfer and installation vehicles. The canister is protected on vehicles with a combined mechanical and radiation shield. The design of the process enables

returning canisters from any stage to the encapsulation plant for additional processing in case they become damaged.

Disturbances and accidents

The essential operational functions of an encapsulation plant and disposal facility include different lifting and transfer functions. Nearly each piece of equipment designed for these functions is unique, but they all are based on proven technology. Functions whose failure could result in releases of radioactive substances or radiation exposure of personnel at the facility have been ensured against a single equipment failure.

Of the safety functions, maintaining the subcritical state of fuel (i.e. preventing a chain reaction) and residual heat removal are based on inherent safety features and do not require a power source. Similarly, the handling functions are designed such that the equipment stops in a controlled state in case the power source is lost.

The potential disturbances of operational functions as well as internal and external threats have been analysed in terms of nuclear and radiation safety. The designs make provisions for essential disturbances: drops of loads, fires, collapsing structures and flooding. The design basis analyses have used both experimental and computational methods. The analyses focus on conditions that could result in releases of radioactive substances.

The amount of radioactive materials that could be released at the different stages of encapsulation and disposal depends on the properties of the handled nuclear fuel. Power plant operators have archived individual data for each fuel assembly, which enables planning how each disposal canister is filled in a way that radiation dose rates, heat generation and criticality safety can be managed. This information will be archived into the Posiva database in full. However, safety calculations will use a conservative assumption that a disposal canister that becomes damaged contains the highest possible quantity of radioactive materials. It is also assumed that all of the fuel in the canister becomes damaged and the contained radioactive materials are released at a conservatively estimated rate that does not underestimate the source term of the radioactive materials in any case. However, STUK requires that Posiva provides a more specific value for the release rate at a later time before its operating licence application because this value also has an essential impact on demonstrating long-term safety.

The design of a nuclear waste facility takes into account the minimising of the radiation doses to the personnel and to the environment. The rooms of the facility will be classified into radiation protection zones with the related access prevention and control arrangements. The thickness of the handling chamber walls has been dimensioned in a manner to protect the personnel controlling the processes remotely. The canister transport vehicle is equipped with a separate radiation shield for the canister. Releases into the environment are tracked by continuously operating monitoring systems and sampling. The design of the encapsulating plant includes effective filtering and cleaning systems for releases of radioactive substances that are assumed to enter into the rooms of the plant as well as a processing system for any generated waste.

In addition to the safety analyses, a probabilistic risk assessment (PRA) has been prepared for the design phase of the nuclear waste facility. The PRA uses preliminary design information, general data on equipment reliability, conservative estimates and expert judgement. During the operation of the plant, significant releases can only occur if a fuel assembly becomes damaged and, simultaneously, ventilation filtering fails. The most significant initiating event would be dropping a canister during handling at the encapsulation plant. However, even in this case filtering would limit the release, and, basically, the failure of the ventilation filtering could only be caused by a human error during the maintenance of the filtering system. Posiva has also investigated the consequences of such simultaneous events even though their analysis is not required due to their low probability.

Posiva has presented risk management calculations also for the transport of nuclear fuel. STUK estimates that they can be implemented according to Posiva's plan. Separate licences for transports will be issued at a later time.

STUK has systematically assessed Posiva's operational plans for the nuclear waste facility and the analyses they are based on in terms of achieving the principle of defence-in-depth and the specified safety functions. STUK has found the plans and the radiation protection arrangements to be sufficient.

However, the high reliability of filtering systems and access prevention and control arrangements that prevent the personnel from accessing closed facilities during the operation of the encapsulation plant must be ensured as design work progresses.

STUK has also assessed the safety and seismic classification that Posiva has proposed for the nuclear waste facility and found it to be sufficient at this time. However, due to the novel type of the plant, STUK states that Posiva must continue assessing the safety significance of the system components and structures and modify the classifications as necessary.

The Commission agrees with the above conclusions.

Construction of the nuclear waste facility

According to Posiva's design, the above-ground nuclear waste facility comprises an encapsulation plant and other buildings that are necessary for supporting the operational activities of the facility, for example. The design and location of the encapsulation plant take into account the potential internal and external threats to the plant. Amongst these threats the structural design is most affected by postulated earthquakes, extreme weather phenomena, aircraft collisions, explosions and fires.

Radiation protection of the operating personnel is a significant individual factor that affects the dimensioning of the structures. According to the plans, it will be implemented by massive concrete structures that surround the facilities for handling fuel and canisters. The encapsulation plant building will be designed in accordance with the requirements of EN standards and their related national Finnish appendixes. The plant's facilities that are likely to be the subjects to the surface contamination will use stainless-steel coating to facilitate decontamination. Other rooms subject to sporadic contamination will similarly use a coating that facilitates decontamination.

The buildings for the encapsulation plant and other above-ground structures will use technology proven in the construction of nuclear facilities, which can be implemented in accordance with the requirements presented in the YVL Guides.

The disposal functions in underground facilities must be separated from the excavation and construction work of the disposal facility such that excavation and construction work cannot have any harmful impact on the operational safety of the facility or the long-term safety of disposed waste. Furthermore, the layout, excavation, construction and closure of underground facilities must be implemented such that the host rock retains, to the highest possible degree, its characteristics deemed important in terms of long-term safety.

When planning the locations of the facilities, Posiva avoids rock joints and geological and hydrogeological zones that may have adverse effects to long-term safety. This is in order to control the disturbance to the host rock from construction within the set targets. For this purpose, Posiva has developed a Rock Suitability Classification (RSC), which is used as a basis for determining the locations according to the criteria set for each phase, all the way to each individual disposal hole. Posiva must further develop the Rock Suitability Classification for the needs of long-term safety and optimal positioning and use of facilities.

As outlined in the Decision-in-Principle, Posiva has constructed Onkalo, an underground research facility, which will be a part of the planned underground disposal facility. Onkalo comprises some of the above-ground connections and technical facilities. Onkalo's design and construction are subject to the same requirements as the disposal facility, and STUK's regulatory control over the work at Onkalo is equivalent to the regulatory control of the construction of a nuclear facility. The excavation for Onkalo is nearly complete and Posiva is in the process of reviewing Onkalo's result documentation that indicates regulatory compliance of Onkalo's construction.

The Commission agrees with STUK's assessment that the underground disposal facility can be built in the manner that the disturbance to the bedrock and groundwater environment from the construction can be controlled. The Commission finds, however, that Posiva must further develop its Rock Suitability Classification as it applies the method when determining the locations of the disposal tunnels and individual disposal holes. STUK also finds that the rock construction methods and materials must be developed further so that Posiva can demonstrate the regulatory compliance of the underground facilities.

As required for quality management and intermediate assessment during construction, the facility must be constructed in compliance with

the approved plans and procedures. Moreover, the licensee must ensure that also the plant supplier and subcontractors producing services and products important in terms of safety perform in an appropriate manner. Posiva requires high quality and a good safety culture from the suppliers that participate in the construction. As Posiva has overall responsibility for the project, it must prepare a separate plan for the management and organisation of all construction work.

Posiva's quality assurance in terms of construction follows Posiva's management system. Posiva's management system is subject to specific procedures for the construction of nuclear facilities, such as the planning, control and management, assurance and continuous improvement of quality and organisation of work. These issues are presented in the street plan of the facility project, which specifies the processes, procedures and instructions applicable to the project. According to Posiva, the quality group of the safety unit (QA) acts independently of the organisation responsible for the different stages of construction and ensures that the construction work follows Posiva's management system as well as the relevant plans, requirements and instructions. According to the Commission, it is very important to ensure that the facility is constructed according to the approved plans and procedures.

The Commission agrees with STUK's assessment that Posiva has developed and implemented sufficient procedures for control and supervision regarding the construction of the nuclear waste facility. By complying with the procedures, it is possible to ensure that the nuclear waste facility and its systems, components and structures are designed, manufactured, built, installed and commissioned in accordance with the approved plans and procedures.

Commissioning and operation of the nuclear waste facility

In connection with the commissioning of the nuclear waste facility, the licensee shall ensure that the systems, structures and components and the facility as a whole operate in the planned manner. Furthermore, it must be ensured that an expedient organisation is in place for the future operation of the facility, alongside a sufficient number of qualified personnel and instructions suitable for the purpose. Based on STUK's assessments and inspections, the Commission finds that Posiva has prepared sufficient plans for verifying, by means of test operation at the commissioning stage, the safe and compliant operation of the nuclear facility, its systems and components and that its operating instructions are comprehensive and validated. Posiva's plans also include providing timely training for the operating organisation, for which Posiva has planned a tentative structure and number of personnel.

The operating instructions, instructions for the identification and control of transients and accidents and Operating Limits and Conditions related to the operation of the nuclear waste facility must be prepared before submitting an operating licence application. Similarly, a condition monitoring and maintenance programme for the nuclear waste facility must be prepared before submitting an operating licence application. Posiva has in place a condition monitoring and maintenance programme for the facilities and systems implemented as part of the Onkalo project.

For ensuring radiation safety, the plans include radiation monitoring at the significant release routes during the operation of the facility. The surroundings of the facility will include Posiva's own monitoring equipment, but Posiva will also utilise TVO's existing radiation monitoring network already in place in the area.

Decommissioning and dismantling of the nuclear waste facility

For nuclear waste facilities, decommissioning refers to dismantling the above-ground elements so that, after decommissioning, no special measures due to radioactive materials originating from the dismantled facility are required on the site. For the purposes of the construction licence, Posiva has submitted a sufficient description of the decommissioning of the encapsulation plant and taken decommissioning into account in the design requirements of the plant. In the documentation for the construction licence application, Posiva has presented the principles of closure in a sufficient manner for the purposes of the construction licence and designed the closure of the disposal facility such that the host rock retains, to the highest possible degree, its characteristics deemed important in terms of long-term safety.

Ageing management

In connection with the construction licence application, Posiva has submitted a preliminary account on the plan of the principles of ageing management. The plan describes the principles of ageing management with regard to the encapsulation plant and disposal facility. Furthermore, the plan includes preparing an ageing management programme and enclosing it with the operating licence application. STUK has approved the preliminary plan of the principles of ageing management for the encapsulation plant and disposal facility and finds it to be in accordance with the requirements presented in Guide YVL A.8. According to STUK, the ageing management programme that Posiva encloses with the operating licence application must describe how the ageing management principles presented in the preliminary plan are implemented in practice.

Long-term safety

In connection with the construction licence application, Posiva has submitted to STUK the safety case for the nuclear waste facility, which especially discusses the long-term safety of the disposal facility. The safety case describes the disposal concept, disposal system and barriers. The safety of the disposal concept is justified with the safety functions, but the safety case does not indicate how the actual safety functions were selected.

Government Decree 736/2008 requires the safety case to be presented in connection with the construction licence application and the operating licence application of the nuclear waste facility. Detailed requirements pertaining to the content of the safety case are specified in Guide YVL D.5. The Commission share's STUK's overall conclusion that the requirement of the Government Decree is met but Posiva must update its safety case in connection with the operating licence application.

Section 12 of Government Decree 736/2008 presents general requirements for the geological characteristics of the disposal site. Among other things, STUK states that Olkiluoto's bedrock has been researched in diverse ways. The characterisation is sufficient for starting the construction of the disposal site. However, characterisation must be continued as the construction project progresses to less researched parts of the disposal site. Posiva's description of the disposal site is based on the results of several different fields and methods of research, and combining the data to form an overall understanding requires further development efforts. STUK also finds that Posiva's current operability analysis for the disposal site does not include the disposal facility for low and intermediate waste, which will be constructed along the Onkalo vehicle access tunnel. STUK requires that the disposal facilities for spent fuel and low and intermediate waste are discussed as a whole in the performance assessment. The construction licence application presents disposal site research reports, performance assessments and conclusions that the Olkiluoto bedrock is suitable for a disposal site. The Commission shares the understanding presented in STUK's conclusions that these are sufficient for the construction licence stage. The requirements that Posiva has set for the host rock are achieved with high probability and by a large margin.

Sections 6 and 9 of the Government Decree present requirements for engineered barriers. As regards the disposal canister and other engineered barriers, STUK states that the design bases and principles concerning long-term safety are presented comprehensively on the level of principles in the preliminary safety analysis and safety case, which were presented as part of the documentation for the construction licence application. There are still shortcomings in demonstrating the performance of engineered barriers and describing the potential developments concerning the release barriers. These shortcomings require research and development before submitting an operating licence application. Furthermore, STUK requires that the relation between the safety functions and the performance targets of and the design requirements for the engineered barriers must be clarified before submitting an operating licence application; the justifications of safety must be documented in a traceable and transparent manner.

One design requirement for disposal canisters is that the fuel must remain subcritical. In this regard, STUK finds that Posiva's criticality safety analyses cannot entirely rule out the possibility for criticality of a disposal canister on a very long time span. However, as these analyses use highly conservative assumptions on the development of the geometry of the disposal canister in the long term, it is STUK's understanding that recriticality of disposed fuel would be very unlikely.

As regards the development of manufacturing methods for engineered barriers, Posiva's work on disposal canisters has advanced the furthest: Posiva has manufactured components of disposal canisters that meet the applicable requirements. However, there are still development needs concerning the manufacture of the disposal canisters and especially the other engineered barriers as well as the demonstration and verification of their regulatory compliance.

With regard to the long-term safety of final disposal, Section 4 of Government Decree 736/2008 presents requirements of expected evolution scenarios concerning the probable long-term radiation impacts. The Commission concurs with STUK's conclusion that, based on the analyses of expected evolution scenarios and the analyses describing the reduction of the safety functions, the annual doses and releases of radioactive materials are below the set limits.

Similarly, Section 5 of Government Decree 736/2008 presents requirements for consideration of unlikely events that impair long-term safety. Posiva has considered rock displacements that damage disposal canisters, bore penetrations of disposed canisters and the disposal facility, boring a medium-depth water well at the disposal site and rapid corrosion of the internal components of the canister as unlikely events that impair long-term safety. Posiva has reviewed the unlikely events, their probabilities and expectation values of the resulting radiation exposures and releases of radioactive substances. Compared to the dose and release limits, the calculation results meet the requirements of Section 5 of the Decree.

One aspect of the safety case is to systematically create scenarios that assess the uncertainty of how the disposal system behaves over time. As part of the process describing the potential future developments of the disposal system, Posiva has defined possible scenarios that may lead to the failure of disposal canisters and release of radionuclides due to a single factor. STUK requires that, with regard to developments that deviate from the expected behaviour, Posiva also considers in the operating licence application the possibility that one or more performance targets are not met.

Section 14 of Government Decree 736/2008 presents additional requirements for items concerning long-term safety in the safety case and requires that, in addition to radiation exposure impacts on people, possible impacts on flora and fauna are analysed. According to STUK's assessment, Posiva's biosphere model is overall in accordance with the requirements. With reference to the Decree's requirement, detailed requirements concerning the protection of other living nature and the possible impacts of disposal on flora and fauna are presented in Guide YVL D.5. According to the requirements, disposal of spent fuel shall not affect detrimentally to species of fauna and flora. This shall be demonstrated by assessing the typical radiation exposures of terrestrial and aquatic populations in the disposal site environment, assuming the present kind of living populations. The method that Posiva uses for evaluating the impact on other living nature is up to date and in line with the best practices. Posiva has presented the accumulation rates of the absorbed dose for flora and fauna. The estimated dose rates are, by a large margin, below the currently estimated harmful dose rates for healthy animal populations.

The Commission agrees with STUK's overall assessment of the safety case that Posiva has presented the safety case in a sufficient scope for the construction licence stage. The results of the safety analysis and the other aspects presented in the safety case are sufficient to demonstrate that the requirements are met. STUK finds that Posiva's method of forming scenarios is sufficient for the construction licence stage but based on the current reviews it cannot be said with certainty that the scenario analysis makes systematic provisions for the developments of the disposal system that are significant in terms of assessing safety.

Section 15 of Government Decree 736/2008 states that the input data and models utilised in the safety case shall be based on high-quality research data and expert judgement. Data and models shall be validated as far as possible, and correspond to the conditions likely to prevail at the disposal site during the assessment period. The Commission shares STUK's understanding that, based on the review, the scope of the safety case is sufficient for the construction licence stage. However, the operability and safety analysis require further development and changes that extend the scope of the safety case before submitting an operating licence application.

With regard to other requirements, STUK's

safety assessment also discusses an alternative solution (KBS-3H) for the disposal of spent nuclear fuel, in which the canisters are placed horizontally. In its preliminary review, STUK has not encountered any aspects that would prevent horizontal placement from meeting the applicable requirements. Posiva has stated that it will compare vertical and horizontal placement in 2016. STUK has stated that it is able to process the modifications to the basic solution in accordance with Section 112 of the Nuclear Energy Decree. STUK, however, comments that it is highly likely that implementing a significant modification at the construction stage postpones the planned starting time of the disposal of spent nuclear fuel.

Retrievability of disposed spent nuclear fuel

Government Decision on the Safety of Disposal of Spent Nuclear Fuel (478/1999), which was in effect when the first Decision-in-Principle on the disposal of spent nuclear fuel was issued, required that retrievability of the waste canisters is maintained to provide for such development of technology that makes it a preferred option. This Government Decision was repealed by Government Decree on the Safety of Disposal of Nuclear Waste (736/2008), which does not contain any requirements on the post-closure opening of the disposal facility.

As the Decision-in-Principle, which was confirmed by the Government in 2001, presented a retrievability requirement, Posiva has presented a concept for opening the disposal facility and retrieving the disposal canisters at different stages of disposal, including time periods after the closure of the disposal facility, in an appendix to the construction licence application for the Olkiluoto encapsulation plant and disposal facility. STUK has assessed that the principle of Posiva's disposal concept enables opening the facilities without compromising safety.

Nuclear safeguards, security arrangements and emergency arrangements

Posiva has submitted to STUK a plan on arranging the control required for the non-proliferation of nuclear weapons. IAEA and the European Commission monitor the operations in addition to Posiva and STUK. As Posiva's nuclear waste facility is the first of its type in the world, there are yet no detailed international regulations on all aspects of regulatory control. Therefore, Posiva's plan only discusses the general level of control and a final plan is not yet required.

According to the plans, Posiva's research facility Onkalo will form part of the nuclear waste facility. STUK has supervised the construction of Onkalo from the outset similarly to a nuclear waste facility and ensured that the disposal facility does not contain any unnecessary facilities that are significant in terms of proliferation of nuclear weapons. Posiva's plant area has been reported to IAEA in accordance with the Additional Protocol to the Safeguards Agreement and IAEA has had no comments.

Posiva has submitted to STUK a preliminary emergency plan. At the encapsulation plant and disposal facility, Posiva's own operations can only create emergency conditions when spent nuclear fuel has been brought into the encapsulation plant or the final disposal facility. However, due to Teollisuuden Voima Oyj's (TVO) operating nuclear power plants in Olkiluoto, there are emergency plans and organisations also for the Onkalo worksite and the worksite is considered in the emergency plans of the nuclear power plants. Posiva's emergency plan will be specified in greater detail in connection with the operating licence application.

The Commission recommends co-operating with TVO but also finds it important that Posiva has its own expert resources for emergency planning and arrangements.

When planning and assessing the security arrangements, Posiva has used the design basis threat and risk analyses and analysed protection needs. STUK finds that the administrative, technical and operational security arrangements, e.g. regarding information security, still need further development before starting the construction of the nuclear waste facility but the preliminary plan is sufficient for issuing a construction licence. The Advisory Commission on Nuclear Safety has not received any detailed (confidential) plans for the security arrangements. The Advisory Commission on Nuclear Security will issue a statement on such documents.

Summary

In conclusion, the Advisory Commission on Nuclear Safety finds that the requirements concerning safety are up to date with regard to issuing a construction licence. It is the considered opinion of the Commission that STUK has carried out a comprehensive and professional safety assessment on the construction licence application. In its assessment, STUK has indicated aspects for which the design documentation must be supplemented as work progresses closer to the implementation of the disposal system and ultimately up to the preparation of an operating licence application. Considering that the project for the disposal of spent nuclear fuel is pioneering on a global scale, it is justified to advance gradually in planning and implementation. STUK has found that the prerequisites for issuing a construction licence are met. The Commission is not aware of any aspects of operational or long-term safety that would prevent issuing a construction licence.

Seppo Vuori	Riitta Kyrki-Rajamäki
Chairman	Member of the Advisory Commission