The Radiation and Nuclear Safety Authority's safety assessment of the operating licence application for the Olkiluoto 3 nuclear power plant unit

SÄTEILYTURVAKESKUS
STRÅLSÄKERHETSCENTRALEN
RADIATION AND NUCLEAR SAFETY AUTHORITY

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1 Introduction

Teollisuuden Voima Oyj (TVO) has applied to the Finnish Government for an operating licence for the Olkiluoto 3 nuclear power plant unit with a letter that was delivered to the Ministry of Economic Affairs and Employment (TEM) on 14 April 2016. In its letter TEM/2555/08.04.01/2016, 18 May 2016, the Ministry of Economic Affairs and Employment requested the Radiation and Nuclear Safety Authority (STUK) to issue a statement on TVO's application. This safety review presents the justifications for STUK's statement.

The Olkiluoto 3 nuclear power plant unit is a European pressurised water reactor (EPR), with a thermal power of 4,300 MW and electrical power of 1,600 MW. The EPR plant type is based on French N4 plants and German Konvoi plants. According to the Finnish practice, the reactor's approved thermal power is recorded in the operating licence as the nominal power; the plant unit's electrical power may fluctuate by several per cent around the nominal electrical power depending on the efficiency achieved in the power plant's energy conversion process at each time.

On 17 February 2005, the Finnish Government issued a construction licence for the Olkiluoto 3 nuclear power plant unit. STUK has been supervising the unit's construction and preparation for operation throughout the project. STUK's regulatory control is described the safety assessment's Chapter 1.4.

1.1 Operating licence documentation

The documentation to be provided to STUK when applying for an operating licence is specified in Section 36 of the Nuclear Energy Decree. The documentation comprises the following documents:

1. *a final safety analysis report;*
2. *a probabilistic risk assessment;*
3. *a classification document, which shows the classification of structures, systems and components important to the safety of the nuclear facility, on the basis of their significance with respect to safety;*
4. *a quality management programme for the operation of the nuclear facility;*
5. *the Technical Specifications, which shall at least define limits for the process quantities that affect the safety of the facility in various operating states, provide regulations on operating restrictions that result from component failures, and set forth requirements for the testing of components important to safety;*
6. *a summary programme for periodic inspections;*
7. *plans for the arrangements for security and emergencies;*
8. *a description of how to arrange the safeguards that are necessary to prevent the proliferation of nuclear weapons;*
9. *administrative rules for the nuclear facility;*
10. *a description of the baseline environmental radiation conditions and a programme for radiation monitoring in the environment of the nuclear facility;*
11. *a description of how safety requirements are met;*
12. *a programme for the management of ageing, and*
13. *a plan for the decommissioning of the nuclear facility.*

TVO delivered the operating licence documentation to STUK in its entirety before the submission of the operating licence application, with the exception of certain fire risk analyses, which were delivered as agreed six months after the other documentation. During the processing of the operating licence documentation, TVO has delivered documentation updates to STUK.

The documents of the operating licence documentation must be kept up-to-date at all times, and the updated versions must be submitted to STUK on a regular basis. A summary of the processing of the documents referred to in Section 36 is presented in Appendix 2 to the statement.

1.2 Provisions concerning safety

The following is stipulated in the Nuclear Energy Act with regard to safety:

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 6a *Nuclear waste generated in connection with or as a result of 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*.

This safety assessment covers all aspects within STUK’s sphere of operations that are related to the operation of the Olkiluoto 3 nuclear power plant unit. The matters addressed in the document and their assessment criteria are presented in the nuclear energy and radiation safety legislation and the regulations issued based thereon. In conjunction with its revision in 2008, the Nuclear Energy Act was supplemented with more detailed safety-related requirements in Sections 7 a–p. Thereafter, specifications and additions have been made to many parts of the Act with regard to physical protection and related authorisations, and the Act has been refocused to provide better coverage for disposal activities.

The requirements laid down in the Nuclear Energy Act with regard to the safety of the use of nuclear energy, security and emergency arrangements, and waste management have been specified in the STUK regulations on each area. When the construction licence was issued, the government decisions on safety (VNp 395/1991), emergency preparedness (VNp 397/1991), physical protection (VNp 396/1991) and the disposal of power plant waste (VNp 398/1991) were still in force. In 2008, the decisions changed into government decrees, and some of them were updated further during the construction. However, the update did not involve significant changes to the required level of safety but instead raised factors previously presented in YVL Guides or separate decisions into the government decrees.

In July 2015, STUK was authorised to issue more specific regulations on the technical details of safety principles and requirements [Act amending the Nuclear

Energy Act (676/2015)]. The STUK regulations replaced the previous government decrees. The regulations entered into force on 1 January 2016. The regulations were

- Regulation on the Safety of a Nuclear Power Plant (STUK Y/1/2016)
- Regulation on the Emergency Arrangements of a Nuclear Power Plant (STUK Y/2/2016)
- Regulation on the Security in the Use of Nuclear Energy (STUK Y/3/2016)
- Regulation on the Safety of Disposal of Nuclear Waste (STUK Y/4/2016)
- Regulation on the Safety of Mining and Milling Operations (STUK Y/5/2016).

Some of the regulations in the government decrees were moved into the Nuclear Energy Decree (161/1988).

New versions of Regulations on Safety, on Emergency Arrangements and on Safety of Disposal of Nuclear Waste were published in December 2018.The needs for changes to the regulations and the implementation schedule are mainly dictated by external reasons: The implementation of the new reference levels of the Council Directive amending the Directive for the nuclear safety of nuclear installations (2014/87/EURATOM) and Directive of basic safety standards for protection against radiation (2013/59/EURATOM) and Western European Nuclear Regulators Association (WENRA) into national provisions.

The level of safety required by the regulations did not change in the update made in 2018. Olkiluoto 3 nuclear power plant unit conforms to the requirements of Regulation on the Safety of a Nuclear Power Plant (STUK Y/1/2018) and Regulation on the Safety of Disposal of Nuclear Waste (STUK Y/4/2018). In the Regulation on the Emergency Arrangements of a Nuclear Power Plant (STUK Y/2/2018), new requirements concerning preparedness to receive outside assistance and consideration of radiation workers and radiation safety assistants in emergency arrangements, were added. The requirements relate to TVO’s emergency arrangements in general, not only Olkiluoto 3 unit. STUK verifies compliance with the requirements as part of its normal oversight.

STUK's safety assessment was prepared before the regulations were updated. Since the changes to the regulations are not significant, the safety assessment has not been updated to comply with the updated regulations. The safety assessment is based on 2016 regulations. An assessment of compliance with the updated regulations is provided above.

1.2.1 STUK’s Regulatory Guides on nuclear safety (YVL Guides)

By virtue of Section 55(2)(3) of the Nuclear Energy Act, STUK lays down more detailed safety requirements concerning the implementation of the level of safety required by the Act and publishes them in the collection of STUK regulations (YVL Guides). According to Section 7 r of the Nuclear Energy Act, *the safety requirements of the Radiation and Nuclear Safety Authority (STUK) are binding on the licensee, while preserving the licensee’s right to propose an alternative procedure or solution to that provided for in the regulations. If the licensee can convincingly demonstrate that the proposed procedure or solution will implement safety standards in accordance* *with this Act, the Radiation and Nuclear Safety Authority (STUK) may approve the procedure or solution by which the safety level set forth is achieved.*

STUK is continuously assessing the currency of the nuclear safety provisions and their consistency with the international regulatory developments, especially within the framework of the International Atomic Energy Agency (IAEA) and the Western European Nuclear Regulators Association (WENRA). In updating its guides, STUK takes into account the developments in the technology and research in the field of nuclear and radiation safety, as well as foreign and domestic operating experiences.

During the construction of the Olkiluoto 3 nuclear power plant unit, STUK revised the YVL Guides. The revision took into account, for example, the lessons of the Fukushima-Daichi accident and the experiences from the Olkiluoto 3 project. With a few exceptions, the new guides were published on 1 December 2013. The new guides will be applied to plant units that are in operation or under construction only after a separate implementing decision has been issued for them to enforce the guides. For implementation, STUK sent TVO a request for clarification on the fulfilment of the requirements of the new YVL Guides in January 2014. At the beginning of 2016, TVO delivered to STUK its clarification on the applicability of the new YVL Guides and the fulfilment of the requirements at the Olkiluoto 3 nuclear power plant unit.

Implementation work has been carried out at STUK alongside the processing of the operating licence application. As a result of the implementation, the deviations and necessary licence holder’s development measures under which the YVL Guides will be implemented as a basis for requirements have been defined in the statements issued by the licence holder. The implementing decisions were made in 2017, and the new guides will enter into force for the Olkiluoto 3 nuclear power plant unit upon the granting of the operating licence. No significant deviations from the requirements of the new guides were found during the implementation work.

Because the new YVL Guides will enter into force upon the granting of the operating licence, and the Olkiluoto 3 nuclear power plant unit must then meet the requirements of the guides, the requirements of the revised guides have been used as the basis for drawing up this safety assessment. However, if the item under assessment is clearly related to activities that have already taken place during the construction, reference may be made to the YVL Guides valid at the time.

1.3 Structure of the safety assessment

This safety assessment covers matters related to nuclear safety in the order in which they are presented in the Radiation and Nuclear Safety Authority Regulation STUK Y/1/2016 “Radiation and Nuclear Safety Authority Regulation on the Safety of a Nuclear Power Plant”. Matters concerning nuclear waste management have been compiled under a separate chapter. The disposal of nuclear waste is subject to Regulation STUK Y/4/2016. Furthermore, the assessment covers matters related to the Radiation and Nuclear Safety Authority’s regulations STUK Y/3/2016 (security in the use of nuclear energy) and STUK Y/2/2016 (emergency arrangements) as well as nuclear safeguards. As in chapter 1.2 above has been presented, the safety assessment has not been updated to comply the new versions of the Regulations on

Safety, on Emergency Arrangements and on Safety of Disposal of Nuclear Waste that were published in December 2018.The safety assessment also addresses any prerequisites laid down in Section 20 of the Nuclear Energy Act that have not yet been incorporated in the current STUK Regulations but whose assessment falls within STUK's authority.

The text of the relevant STUK Regulation is presented in italics at the beginning of each section. Direct quotes from other provisions are also italicised. The practical interpretations of the requirements included by the STUK Regulations will be described briefly where necessary, along with any essential specifications presented in the YVL Guides. Each section evaluates how the requirements related to it have been implemented at the Olkiluoto 3 nuclear power plant unit. The evaluation specifically focuses on whether or not "... *the nuclear facility meets the safety requirements set, that the physical protection and emergency planning are sufficient, that the necessary control to prevent the proliferation of nuclear weapons has been arranged appropriately, and that the licensee of the nuclear facility has, as provided, arranged indemnification regarding liability in case of nuclear damage*" (Nuclear Energy Act, Section 20(2)(1)).

A summary of the assessment results is presented at the end of the safety assessment.

1.4 Description of STUK's regulatory control

While preparing the safety assessment, STUK also utilised the results of its regulatory control of the Olkiluoto 3 nuclear power plant unit, the licence applicant TVO and its most important subcontractors and not just conclusion drawn during the review of the operating licence application documents. Other forms of regulatory control included, for example, inspections carried out by STUK during the plant unit's construction, supervision at the plant site and the review of applications submitted to STUK during the construction. STUK has also utilised outside expert organisations to support its regulatory control.

During construction, STUK reviewed the detailed designs for the systems, structures and components. In addition to the design documents, STUK also reviewed, for example, analyses demonstrating the compliance of design (such as strength analyses connected to mechanical components and analyses of various fault situations), pre-operational testing plans of the plant and its systems, procedures and instructions followed in the project and at the site, deviation reports and reports of audits of the activities of the plant supplier or its subcontractors carried out by TVO. Since the granting of the construction licence, STUK has processed over 18,000 applications regarding the Olkiluoto 3 nuclear power plant unit.

Inspections carried out at the plant site or at the facilities of equipment suppliers' are an essential part of the regulatory control. STUK carries out two types of inspections: inspections connected to the licence holder's activities (the construction inspection programme RTO) and compliance inspections of components and structures.

The RTO inspections of the Olkiluoto 3 nuclear power plant unit have assessed and supervised TVO's organisation and activities to implement the plant, procedures connected to the plant's implementation in different fields of technology, TVO's expertise and application of said expertise, management, handling of safety matters as well as quality management and control. The inspection programme was launched for the Olkiluoto 3 nuclear power plant unit in 2005 when the plant's construction started. The number of inspections each year has varied between 9 and 15 inspections. Inspections have been focused based on the project phase; at first, the main operating processes were assessed, and in recent years inspections have focused on commissioning procedures and preparing for operation, in particular. Some topics, such as physical protection, quality management and safety culture, have been inspected regularly throughout the project.

Inspections connected to the compliance of components and structures are specified in the YVL Guides. Depending on the component/structure and its safety significance, the inspections include construction plan review, manufacturing control, supervision of factory testing, installation inspections and commissioning inspections. STUK's inspection activities have been comprehensive, and STUK has been convinced of the compliance of components and structures on their basis. There have been several hundreds of inspections per year. In addition to actual inspections, STUK has supervised the manufacturing of the main components, in particular, through regular control visits. The supervision was intended to ensure the appropriateness of the activities as well as the adequacy of the manufacturers', plant supplier's and TVO's own control.

In addition to the inspections listed above, STUK carries out general supervision at the plant site. STUK has five local inspectors at the Olkiluoto plant. The local inspectors also supervise the operating Olkiluoto 1 and 2 nuclear power plant units as well as the construction of Posiva's encapsulation and final disposal facility for spent nuclear fuel. The local inspectors have supervised the construction, installation activities and commissioning of the Olkiluoto 3 nuclear power plant unit. In addition to the local inspectors, inspectors from the main office have also supervised activities at the plant site, for example carrying out regular control visits to supervise physical protection. The installation and testing of electrical and I&C components and systems has been supervised through control visits. Furthermore, on its control visits, STUK has supervised the approval testing of the simulator used for operator training and the validation of guides in the simulator, for example. The supervision of select pre-operational tests is an important part of regulatory control at the plant site.

To support its assessment, STUK has commissioned studies and assessments from outside expert organisations. Independent comparative analyses on various accident situations were especially significant commissions. External expert organisations were also used for the assessment of I&C design. STUK has also ordered assessments on several individual questions, such as the fire safety of cables, consequences of an aircraft crash, information security, methods used for the assessment of human reliability and the Technical Specifications, etc. Over the course of the project, STUK has commissioned four reports on site safety culture.

The Olkiluoto 3 project is almost 10 years behind the original schedule, and its implementation has encountered several problems. In the early stages of the project, STUK launched two investigations; one was connected to the management of safety requirements at the site (due to issues with the casting of the concrete base slab and deficiencies observed in the manufacturing of the containment's steel lining, for example) and the other to the procurement of the emergency diesel generators and their auxiliary systems. There have also been problems in design (e.g. I&C), component manufacture (e.g. too large grain size of the main coolant pipes, undocumented repair welding, surface defects in small-diameter piping, extra heat treatments) as well as installations (e.g. getting valves mixed up during the installation phase, problems with welds).

The design has been redone for the necessary parts. Plant automation, in particular, has required redesign in order to ensure sufficient independence between the different levels of defence, for example. Design processes for I&C developed so that the design, its documentation and verification met STUK requirements and the requirements of international standards.

The deviations that surfaced during manufacture and installation have been corrected such as to meet the original quality requirements, or else compliance with the requirements has been demonstrated with additional inspections or analyses. Over the course of the project, the different parties have improved their activities based on observed deficiencies. Deficiencies in the parties’ activities and product quality have led to extra work to assess and correct the problems. This has affected the progress of the project but not the realisation of its qualitative objectives. The problems that have occurred do not prevent the achievement of the plant’s safety objectives.

2 General safety (STUK Y/1/2016 – Chapter 2)

2.1 Demonstration of compliance with safety requirements (Section 3)

The safety of a nuclear power plant shall be assessed when applying for a construction license and operating license, in connection with plant modifications, and at Periodic Safety Reviews during the operation of the plant. It shall be demonstrated in connection with the safety review that the nuclear power plant has been designed and implemented in a manner that meets the safety requirements. The safety review shall cover the operational states and accidents of the plant. The safety of a nuclear power plant shall also be assessed after accidents and, whenever necessary, on the basis of the safety research results.

Nuclear power plant safety and the technical solutions of its safety systems shall be assessed and substantiated analytically and, if necessary, experimentally.

The analyses shall be maintained and revised as necessary, taking into account operating experience from the plant itself and from other nuclear power plants, the results of safety research, plant modifications, and the advancement of calculation methods.

The analytical methods employed to demonstrate compliance with the safety requirements shall be reliable, verified and qualified for the purpose. The analyses shall demonstrate the conformity with the safety requirements with high certainty. Any uncertainty in the results shall be considered when assessing the meeting of the safety requirements.

2.1.1 Deterministic safety analyses

The events discussed in deterministic safety analyses are divided into the following categories based on their anticipated frequency of occurrence: normal operation, anticipated operational occurrences, postulated accidents (class 1 and 2) and severe accidents. Severe reactor accident refers to an accident in which a considerable part of the fuel in a reactor loses its original structure. Event combinations that are not naturally classifiably based on the frequency of their initiating events are also analysed. The purpose of these analyses is to justify the sufficient diversity of safety functions and to demonstrate that there exist no cliff edgephenomena immediately beyond the design basis events that would compromise the plant unit’s safety. These situations are referred to as Design Extension Conditions (DEC), which also include rare external events, such as aircraft crashes.

For each event category, the assumptions used in analyses and acceptance criteria have been specified. The initial and boundary condition assumptions of accident analyses also include assumptions that change the end result in a less favourable direction in terms of the acceptance criteria so that the uncertainties connected to design and analyses can be covered with sufficient reliability. The calculation methods used do not have built-in assumptions of unfavourableness. These same methods and models can be used to calculate the most probably course of events when using the most probable initial and boundary conditions.

Calculation models used

The calculation of loss-of-coolant accidents has been done using calculation programs with which the plant can be modelled in detail and which have detailed thermal hydraulic and flow dynamics models as well as sufficient models for calculating reactor power and fuel heat transfer. This calculation programs have been used to assess the coolability of fuel, meaning the maximum temperature and oxidation of the fuel cladding.

For analyses not connected to loss of coolant, calculation methods (calculation programs) that model the plant's primary and secondary circuit in detail have been used. In order to calculate fuel power, these models were used to model neutron kinetics either by point kinetics, one-dimensionally or three-dimensionally, depending on the problem being calculated. The programs also include a sufficient number of thermal hydraulic and flow dynamics models as well as models connected to fuel heat transfer. These programs have been used to calculate a fuel rod's power and margin on heat transfer crisis. In situations of rapid power changes, the fuel rod's energy increase (maximum enthalpy) is calculated.

The mechanical behaviour of fuel has been mapped with calculation programs, which can be used to calculate, for example, permanent deformation, ballooning and rupture of fuel cladding, fuel oxidation and hydriding, fuel cladding creep and stresses on the cladding. The boundary conditions related to thermal engineering and flow dynamics needed for the calculation method have been obtained from models used in operational occurrence and accident analyses. The programs have been used to assess the damage ratio of fuel rods in the core, also taking into account fuel burn-up.

Analyses of severe reactor accidents have been drawn up with calculation programs and manual calculation methods that are based on test results. The plant supplier has used different types of calculation software to analyse the different phases of a severe reactor accident and associated phenomena. The analyses are used to demonstrate that the plant's severe accident management strategy meets the set requirements, considering the failure criteria. Analyses of severe accidents cover all stages of a severe accident from the beginning of the accident to long-term core melt management and ensuring the containment safety function.

For the analysis of radiation doses to members of the public due to transients and accidents, the plant supplier has used calculation programs that model the passage of radioactive substances in the nuclear power plant's containment and in the environment as well as assess the radiation doses to the most exposed member of the public.

The calculation models used in the design of the Olkiluoto 3 nuclear power plant unit have been described with sufficient accuracy. The models have been qualified for the parameter range in which the calculation models have been used, by comparing the results received with observations made in real plant situations and with tranisients and accidents simulated with test equipment.

STUK has commissioned comparative analyses with independent calculation models, which have provided additional confirmation of the sufficiency of the calculation models used by the plant supplier and the analyses prepared using them. The confirming analyses have been updated after plant changes.

Analysed events

The analysed initiating events have been grouped further into six types of events based on the physical phenomena observed:

- decreased heat transfer to secondary circuit
- increased heat transfer to secondary circuit
- decreased main circulation flow
- reactivity and power disturbances
- increased volume of primary coolant
- loss of primary coolant
- primary circuit pressure increase or decrease
- leak between primary and secondary circuit.

The events have been analysed in different operational situations of the plant: normal power operation situations, plant ramp-down or start-up, hot and cold standby situations and outages where the reactor pressure vessel may be open or closed. In the context of all events, the long-term coolability of fuel has also been analysed.

The most important results of deterministic safety analyses as well as an assessment of the acceptability of the plant's design and operation based on them is presented in Chapter 4.3 of this safety assessment in terms of ensuring the integrity of the engineered release barriers for the dispersion of radioactive substances and in Chapter 3 in terms of limits for the release of radioactive substances and the dose limits for the general public.

Tests carried out to demonstrate safety

Tests have been used to demonstrate safety, especially in terms of the functioning of the reactor internals, coolant recirculation and management of severe accidents.

The internals of the Olkiluoto 3 reactor differ significantly from the corresponding components of the previous plants, which is why the functioning of the thermal hydraulic design of the reactor internals has been confirmed with separate tests.

In primary circuit leaks, in order to ensure fuel cooling, it is required in the long term that coolant recirculation from the containment must function reliably. A leak may damage heat insulation, causing foreign material to be released from the insulation into the containment, making it more difficult to keep water suction ducts open. In order to demonstrate the functioning of the flow routes and the associated filtration systems, the necessary tests have also been carried out in these unusual situations.

The technical solutions used for the plant's management of severe accidents are based on safety research, and the design basis of the plant's passive safety features, in particular, is experimental study. International phenomenon-based research of severe accidents and research focusing on components selected for the plant support the technical solutions selected for the plant.

2.1.2 Probabilistic risk assessments

In this context, probabilistic risk assessment (PRA) refers to quantitative assessments of probabilities and consequences of event sequences originating from threats affecting the safety of a nuclear power plant defined in Section 1 of the Nuclear Energy Decree (161/1988) and Section 2 of Regulation STUK Y/1/2016.

The PRA of a nuclear power plant and the qualitative and quantitative studies that complement it form the foundation for nuclear safety-related risk management. In the risk management relating to the safety of nuclear power plants, the PRA supports decision-making. Nuclear power plant risk management covers the design, construction, commissioning, operating and decommissioning phases.

The PRA is used to systematically analyse the occurrence of all operational occurrences and accidents judged to be possible as well as the implementation of the required safety functions, with due consideration to the possibilities of failure and error of each system, and their probabilities. Operational occurrences and accidents may result from equipment failures, fires, internal and external flooding, extreme weather conditions, earthquakes and human error, for example. PRA can be used to identify dependencies between systems, the significance of which might otherwise go unnoticed. In the analysis of the PRA, the initiating event is an individual event that causes an operational occurrence and requires the safety functions of the facility to be initiated. The initiating event can be an internal or external event of the facility. The PRA does not address acts of sabotage as initiating events. The analysis must cover initiating events in all operating states of the plant (power operation, low power and shutdown states and the transition sequences in between).

Level 1 is the first part of PRA. It determines the accident sequences leading to nuclear fuel damage and estimates their probability (core damage frequency, CDF). Level 2 is the second part of the PRA. It analyses the amount, probability and timing of a release of radioactive substances from the nuclear power plant to the environment (large release frequency, LRF). The quantitative criteria for level 1 and 2 results, i.e. core damage frequency and large release frequency, are laid down in Guide YVL A.7 (previously YVL 2.8). A large release is a release that exceeds the severe accident limiting value stipulated in Section 22 b of the Nuclear Energy Decree (161/1988). The criteria presented in Guide YVL A.7 are as follows:

- The mean value of the frequency of reactor core damage is less than $1.0 \cdot 10^{-5}$/year;
- The mean value of the frequency of a large radioactive release (> 100 Tbq ^{137}Cs) is less than $5.0 \cdot 10^{-7}$/year.

The plant supplier prepared for the Olkiluoto 3 nuclear power plant unit a design phase PRA, which was a part of the construction licence application. During construction, the PRA has been updated several times in order to correspond with the progression of the detailed design, and the results obtained have been reused to improve the design.

The PRA of the Olkiluoto 3 nuclear power plant unit covers a comprehensive range of different initiating events in all operating states of the plant, including annual outages. The analysis also covers possible sequences of events resulting in damage to spent fuel in the fuel building. The mean value of the frequency of core damage of the Olkiluoto 3 nuclear power plant unit is $3.2 \cdot 10^{-6}$ /a, and the mean value of the frequency of a large release is $1.1 \cdot 10^{-7}$ /a, so they do not exceed the criteria specified in Guide YVL A.7.

Section 22 b of the Nuclear Energy Decree requires that the possibility of a release in the early stages of an accident requiring measures to protect members of the public be extremely small. Protective measures may be required for release as low as under 100 TBq (Cs-137). For this reason, Guide YVL A.7 does not limit early release to large releases but instead requires that accident sequences in which the containment function fails or is lost in the early phase of a severe accident must have only a small contribution to the reactor *core damage frequency*. According to the analyses of level 2 of the Olkiluoto 3 nuclear power plant unit's PRA, the contribution of early (before 6 hours) release is less than 1%, which can be considered as low enough and as proof of the functioning of the severe accident management strategy.

Level 1 and 2 analyses are mainly based on conservative (unfavourable for the results) assumptions in that the main results presented above are conservative and meet the quantitative acceptance criteria with a good degree of confidence.

The safety of the Olkiluoto 3 nuclear power plant unit and the technical solutions of its safety systems have been analysed sufficiently to demonstrate compliance with the PRA's safety regulations and the requirements of YVL Guides.

In addition to the assessment of design solutions according to the YVL Guides, the PRA of the Olkiluoto 3 nuclear power plant unit has been utilised in, for example, the assessment of the Technical Specifications, specification of the safety classes of structures, systems and components, preparation of the in-service inspection programme, preparation of the periodic testing and preventive maintenance programmes, planning of simulator training for instructors as well as preparation ofemergency operating procedures.

2.1.3 Strength analyses

The strength analyses of the primary circuit components of the Olkiluoto 3 nuclear power plant unit have been carried out with application of the French RCC-M standard for the design of nuclear power plants. The strength analyses were carried out using commercial programs as well as programs developed by the plant supplier, the accuracy of which has been verified using comparison calculations and experimental results.

The strength analyses cover basic dimensioning against pressure and other mechanical design loads as well as tension, fatigue and brittle fracture analyses for critical points. The design loads account for the various operating and accident situations of the primary circuit as well as environmental conditions. Based on the analyses, the safety margins will remain sufficient through the plant unit's design life (60 years), and the breakage of the reactor pressure vessel and primary circuit can be considered extremely unlikely.

Inspections of thel piping analyses, such as the analyses of the integrity of pipelines of the emergency cooling systems, are still unfinished. Descriptions of forces caused by piping on connections of the main components of the primary circuit have not yet been submitted to STUK. The Radiation and Nuclear Safety Authority will review these analyses before operation of the plant starts.

2.1.4 Conclusion

The conclusion is that the fulfilment the safety requirements at the Olkiluoto 3 nuclear power plant unit has been demonstrated as intended in Section 3 of the Regulation.

2.2 Safety classification (Section 4)

The safety functions of a nuclear power plant shall be defined and the related systems, structures and components classified on the basis of their safety significance.

The actions taken on systems, structures and components that implement safety functions or are related to them in order to ascertain the requirements set for them and their compliance must be commensurate with the safety class of the location.

The detailed requirements related to classification clarifying Section 4 of Regulation STUK Y/1/2016 are presented in Guide YVL B.2. There are three Safety Classes (SC): SC1, SC2 and SC3, of which SC1 is the highest. The most significant change in Guide YVL B.2 compared to the previous Guide YVL 2.1 is connected to the removal of Safety Class 4, due to which the classification information of the Olkiluoto 3 nuclear power plant unit will be updated. Requirements set based on safety class and requirements connected to actions to ensure compliance have been specified in several different YVL Guides.

The classification principles of the Olkiluoto 3 nuclear power plant unit and the safety classifications for systems, structures and components are presented in the classification document. STUK has approved a classification document that was delivered with the operating licence application.

For systems and safety-classified (SC1–3) component groups, the functions that the system or component group contribute to or that define their safety class have been defined. The safety class for components is determined by the function with the highest safety class that the component contributes to. Therefore, the safety classification is entirely functional in nature. Alongside the classification based on significance to safety, there is also seismic classification, where systems, structures and components are classified based on the requirements set for their seismic resistance.

The scope and precision of TVO’s assessment, inspection and testing are determined by the safety class of the systems, structures and components involved. TVO has used the inspections to verify that the design and manufacturing processes of the plant supplier and its subcontractors and the routines observed in the installation work are commensurate with the safety significance of the systems, structures and components.

The safety significance of the components determines the quality requirements to be applied. A classification document specifies the safety class as well as the component's quality class, seismic classification and requirement in terms of aircraft crashes.

The conclusion is that the safety classification of the Olkiluoto 3 nuclear power plant unit as well as the requirements set based on the safety class and actions taken to ensure their compliance have been implemented as intended in Section 4 of the Regulation.

2.3 Ageing management (Section 5)

The design, construction, operation, condition monitoring and maintenance of a nuclear power plant shall provide for the ageing of systems, structures and components important to safety in order to ensure that they meet the design-basis requirements with necessary safety margins throughout the service life of the facility.

Systematic procedures shall be in place for preventing the ageing of systems, structures and components which may deteriorate their availability, and for the early detection of the need for their repair, modification and replacement. Safety requirements and applicability of new technology shall be periodically assessed in order to ensure that the technology applied is up to date, and the availability of the spare parts and the system support shall be monitored.

Mechanical components and structures

In the design of the Olkiluoto 3 nuclear power plant unit, the starting point of the material selections for structural materials of mechanical components has been recognising and preparing for the damage mechanisms of the materials. The structural materials of components have been selected such as to ensure that they are not prone to become sensitised to known damage mechanisms and that they retain their resilience and strength throughout their design life. The structural materials used are standardised materials with a long history in industry and at other nuclear facilities. In the material selections of manufacturing, engineering issues, such as weldability and processing properties, have been taken into consideration. This has been aimed at reducing the number of manufacturing defects. STUK has assessed potential ageing mechanisms of the structural materials of the primary circuit's main components based on analyses conducted during the construction. It can be stated that radiation embrittlement remains low in the structural materials of the reactor pressure vessel shell because the heavy reflector of the reactor pressure vessel's core area reduces the effects of neutron radiation in the reactor pressure vessel shell. STUK has assessed the radiation embrittlement monitoring programme for the structural material of the reactor pressure vessel shell, which is used to monitor the effects of radiation on the vessel material during operation.

TVO has organised ageing management for all of the Olkiluoto nuclear power plant units. The starting point of the ageing management programme of the Olkiluoto 3 nuclear power plant unit consists of programmes drawn up by the plant supplier. They describe the primary critical targets for ageing management and their ageing phenomena as well as measures to manage the ageing phenomena in all areas of engineering. The responsibility to maintain the Olkiluoto 3 nuclear power plant unit will transfer from the plant supplier to TVO during the commissioning of the plant unit.

TVO's ageing management programme will be taken to the level of device locations before the plant unit's fuel loading.

The specification of systems, structures and components important to safety is based on the Technical Specifications, safety classification and probabilistic risk analysis. Based on the specification, components are divided into maintenance classes 1–4, which determine their spare parts service, preventive maintenance and maintenance tasks. STUK will inspect the situation of the critical spare parts stored at the plant site of components needed for the management of operational occurrences and accidents before fuel loading. STUK has specified detailed requirements pertaining to ageing management in Guide YVL A.8.

The operability of mechanical components is monitored through regular load monitoring, in-service inspections in accordance with Guide YVL E.5 and erosion inspections. In addition to these, continuous condition monitoring systems have been installed at the Olkiluoto 3 nuclear power plant unit, including a primary circuit foreign material monitoring system, vibration monitoring systems, leak monitoring systems, a condition monitoring system for rotating equipment, valve condition monitoring system and temperature transient monitoring system. These help provide immediate information of any deterioration or failure of components' functional capacity. Ageing management also involves regular in-service inspections of systems and functional tests of components. The in-service inspections and functional tests as well as preventive maintenance programmes help monitor the progression of the ageing of systems and components. Necessary repair or maintenance activities can be launched based on the assessments.

Electrical and I&C systems and components

STUK's detailed ageing monitoring and reporting requirements for electrical and I&C systems and components are presented in Guide YVL A.8 as well as Guide YVL E.7.

The ageing management of the electrical and I&C components and associated cables is based on monitoring their condition and assessing their repair or replacement needs. The condition monitoring efforts ensure that the electrical and I&C components and cables are in the required condition and capable of functioning in the designed operating and accident conditions for the entire planned service life. The electrical equipment and cables of the Olkiluoto 3 nuclear power plant unit have mainly been qualified for a service life of 30 or 60 years. The service life of I&C components depends on the type and is shorter than that of electrical equipment.

Separate tolerance requirements for ambient conditions have been defined for electrical equipment located inside the reactor building, safeguards buildings and fuel buildings as well as in specific separate rooms. The qualification of the equipment has been used to demonstrate that the equipment can function reliably under intended conditions. The qualification included artificial ageing of the equipment as regards temperature and radiation before the equipment was exposed to actual accident conditions.

The qualification of I&C equipment is based on assessment of the manufacturer's quality of design and manufacture as well as environmental condition testing, radiation resistance testing, seismic testing, electromagnetic compatibility testing and, if the equipment is software-based, assessment of the software. The acceptability of the qualification of I&C equipment has been assessed in terms of Safety Class 2 and the essential accident instrumentation of Safety Class 3 by the license holder as well as the accredited type approval organisation, and by the license holder in terms of other Safety Class 3 equipment. As a part of system design, the plant supplier has assessed equipment performance, such as the response time and accuracy of measurements, and found them to be adequate.

At the Olkiluoto 3 nuclear power plant unit, the qualification of I&C equipment started at a late stage in regard to the project. According to TVO's notification, qualification tests have been completed successfully. Documentation of the test results is still under way.

Electrical equipment can be divided into two classes in terms of environmental qualification. Equipment without special requirements in terms of environmental conditions has, in principle, been qualified in accordance with general international standards for electrical equipment. Software-based electrical equipment has also been subjected to software qualification. The most significant software-based electrical equipment are the software-based protective relays of electrical equipment.

Electrical equipment that must tolerate special environmental conditions (radiation, temperature and pressure) in case of accidents, including severe accidents, has been subjected to special environmental qualification. Environmental qualification has been carried out for cables needed in accident conditions, electric motors, cable penetrations of the containment and cable connection and extension boxes, for example.

The result documentation of electrical and I&C equipment has been compiled for equipment-specific suitability analyses. They assess the existing type testing results and the results of additional tests done for the Olkiluoto 3 nuclear power plant unit. STUK has reviewed all suitability analyses of electrical equipment, but some of the I&C suitability analyses have not been submitted yet. The missing suitability analyses will be submitted early enough that STUK will have enough time to review them before the fuel loading starts.

The monitoring of feedback information on equipment maintenance, repair and modification work, among other data, will be utilised in the monitoring and management of ageing. The actual condition of the electrical and I&C systems, equipment and cables and their operation according to the design bases will also be observed by means of periodic tests, condition monitoring and the periodic inspections included in the preventive maintenance programme. The ageing of the cables inside the containment will also be monitored by means of cable samples.

STUK will monitor the appropriateness of the Olkiluoto 3 nuclear power plant unit's ageing management for electrical and I&C equipment, for example by following operational events, reviewing ageing reports and assessing ageing management in conjunction with inspections included in the periodic inspection programme.

Construction technology

STUK's detailed ageing monitoring and reporting requirements for construction technology and structures are presented in Guide YVL A.8 as well as Guide YVL E.6.

The ageing management of buildings and structures is based on structural design in accordance with the construction-technology service life (60 + 5 years) and on site quality management. Room-specific condition monitoring plans have been drawn up for buildings. A monitoring programme for condition monitoring has been drawn up for the containment. Furthermore, condition test pieces made during construction will be used in the condition monitoring of concrete structures.

STUK's ageing monitoring has started with the review of construction plans, has continued with inspections of concreting and site inspections and will continue further with the license holder's ageing and condition monitoring programme inspections.

Conclusion

The conclusion is that the ageing management of the Olkiluoto 3 nuclear power plant unit has been implemented as intended in Section 5 of the Regulation.

2.4 Management of human factors relating to safety at a nuclear facility (Section 6)

Attention shall be paid to the avoidance, detection and correction of human errors and the limiting of their effects throughout the service life of the nuclear power plant. The possibility of human error shall be taken into account in the design of the nuclear power plant and in the planning of its operations and maintenance, so that human error and deviations from normal plant operations due to human error do not endanger plant safety or lead to common cause failures.

Management of human factors in the design, construction and commissioning of the Olkiluoto 3 nuclear power plant unit

In the design of the Olkiluoto 3 nuclear power plant unit, provisions have been made for the failure of human actions by observing the redundancy, diversity and separation principles as well as the principles of defence in-depth with regard to the most important safety functions The principles help to limit the repercussions of possible human errors.

Human Factors Engineering (HFE) procedures have been used in the design of human-machine interfaces in order to reduce the possibility of human errors in operational activities. The procedures have been appropriate, and the interfaces have been improved based on their results.

The implementation of the HFE programme is still partly unfinished. The control room's integrated validation, which is the key indication of the functioning of the control room entity in the management of the plant's safety, has been designed to be carried out after the completion of operator training and before fuel loading. STUK will monitor the integrated validation. The validation of the plant's operation manuals from an HFE viewpoint will also be carried out in conjunction with the integrated validation.

The impact of human action on the overall safety of the Olkiluoto 3 nuclear power plant unit has been assessed in probabilistic risk analysis (PRA), one part of which is human reliability analysis (HRA). The HRA includes analysis of, for example, maintenance errors, disruption of safe operation of the plant due to human action as well as operator errors connected to the management of any accident. The HRA helps focus development actions to where the reliability of human action has the greatest effect on overall safety. The results of the HRA have been utilised in the planning of simulator training, for example.

Management of human factors in the operation of the Olkiluoto 3 nuclear power plant unit

During the operation phase of the Olkiluoto 3 nuclear power plant unit, the management of human factors will be based on the procedures used at TVO’s Olkiluoto 1 and 2 nuclear power plant units, focusing mainly on operating and maintenance functions as well as managing modifications.

The functions needed in case of operational occurrences and accidents in the short term (30 minutes) have been automated, so the on-shift personnel have time to recognise the plant status and the procedure required by the plant situation before the actions of the shift are needed.

The training of the operating personnel of the Olkiluoto 3 nuclear power plant unit has consisted of different types of training modules, including practice on a full-scale training simulator. In addition of technical contents, the training for operating personnel also addresses good operating practice and ways to improve the reliability of human action. The methods of the training for operating personnel help avoid and detect human errors as well as limit and remedy their consequences.

The planning of the service and maintenance work of the Olkiluoto 3 nuclear power plant unit limits the effects of any human errors by carrying out maintenance on systems that perform the same safety function at different times. Any errors in service and maintenance activities are detected in the testing carried out after the service or maintenance work. The implementation of maintenance work and the management of modificationss in general utilises the Human Performance (HU) procedures used at the Olkiluoto 1 and 2 nuclear power plant units, which are aimed at improving human reliability through systematic training in good work methods and practices. The procedures include kick-off meetings, post-job briefings, clear communication and peer checking by means of pair work or independent verification.

Management of human factors as a TVO activity

The precondition for improving the reliability of human activity is operational monitoring and development, for example based on operating experience. Operating experience activities are discussed in more detail with the review of Section 21 of the STUK Regulation.

Staff competence is an essential factor in the success of human activity. TVO’s management system includes comprehensive competence management procedures and staff training is regarded as continuous activity. Appropriate training promotes high-quality implementation of work tasks and staff’s awareness of the safety significance of their work tasks, thereby reducing the occurrence of human errors. Training is discussed in more detail with the assessment of Section 25 of the STUK Regulation.

The appropriate organisation and sufficient resourcing of work are absolute requirements for the success of human activities. TVO implemented an organisational change in 2015. After this, staff turnover has increased and employee tasks, areas of responsibility and work methods have been changed. Since the change, TVO's personnel have experienced more schedule pressures and resource shortages, which negatively affect the reliability of human activities and may increase the probability of human error. In 2017 and 2018, TVO has extensively surveyed its resource needs and recruited over 100 people. One basis for the recruitments has been the needs of the Olkiluoto 3 nuclear power plant unit during operation. The topic is discussed in more detail with the assessment of Section 25 of the STUK Regulation.

The organisation's safety culture speaks to the state of reliability of human activity. Safety culture indicators, such as appreciation of safety and understanding the safety significance of work, affect how employees commit to adhering to procedures and instructions, which, in turn, directly affects the success of human activities. The state of the safety culture is discussed in more detail with the assessment of Section 25 of the STUK Regulation.

Conclusion

TVO's management system includes procedures for managing human factors. These procedures have been used in the design, construction and commissioning of the Olkiluoto 3 nuclear power plant unit. During the operation phase of the Olkiluoto 3 nuclear power plant unit, the procedures used at the Olkiluoto 1 and 2 nuclear power plant units for managing human factors will be adopted at Olkiluoto 3. The procedures for the management of human factors are aimed at preventing and detecting human errors as well as limiting and correcting their consequences. TVO has striven to integrate the procedures for the management of human factors fully into its management system to make them a natural part of all operations.

The conclusion is that the management of human factors of the Olkiluoto 3 nuclear power plant unit has been implemented as intended in Section 5 of the Regulation.

Demonstrations of the functioning of the human-machine interfaces of the Olkiluoto 3 nuclear power plant unit according to the HFE programme and their operating manuals are still under way. Before fuel loading, STUK will check that the demonstrations have been completed with acceptable results.

3 Limitation of radiation exposure and releases of radioactive substances (Section 7)

Pursuant to Section 3 of the Radiation Act (592/1991), Section 2 and Chapter 9 of the Act also apply to the radiation exposure of the employees and members of the public in the vicinity of a nuclear power plant. The maximum values for workers' exposure to radiation are stipulated in Chapter 2 of the Radiation Decree (1512/1991).

The maximum values for radiation exposure caused to the population in the vicinity of a nuclear power plant due to its operation, anticipated operational occurrences or accidents are enacted in the Nuclear Energy Decree (161/1988).

These references to the Radiation Act, the Radiation Decree and the Nuclear Energy Decree have become obsolete as a result of legislative changes during the licensing process. Paragraphs 3.1 and 3.2 refer to the legislation currently in force.

3.1 Radiation safety of nuclear power plant workers

As regards radiation exposure, the ALARA principle (As Low As Reasonably Achievable) must be observed. The basic radiation protection philosophy has been presented in the recommendations of the International Commission on Radiological Protection, which were updated in 2007. However, the updates have not necessitated significant changes to the current national provisions on radiation protection.

The statutes addressing radiation exposure are the Radiation Act (859/2018), Government Decree on Ionizing Radiation (1034/2018), Radiation and Nuclear Safety Authority regulation on the investigation, assessment and monitoring of occupational exposure (STUK S/1/2018) and YVL Guides published by STUK. According to Government Decree on Ionizing Radiation (1034/2018), the effective dose of a radiation worker may not be higher than 20 millisieverts (mSv) a year. The equivalent dose of the lens of the eye may not be higher than 100 millisieverts during a time period of five consecutive years. However, during a single year, the dose may not be higher than 50 millisieverts. The equivalent dose of skin may not, as an average, be higher than 500 millisieverts a year on the most exposed skin area the size of a quadrat centimeter. The equivalent dose of hands, arms, feet and ankles may not be higher than 500 millisieverts a year.

Guide YVL C.1 presents detailed requirements for consideration of radiation safety aspects in plant design, and Guide YVL C.2 for the radiation protection of personnel and monitoring of radiation exposure.

Radiation safety aspects related to material selections have been considered in the design of the plant unit, for example in the minimisation of materials that easily become radioactive as well as the decontaminability and radiation resistance of components. Based on operating experience, special attention has been paid to cobalt management. However, some materials containing cobalt are used in the primary circuit in some items for which is it difficult to find a replacement material with adequate properties. The plant's design requirements consider accessibility, physical separation, structural shielding and the handling and storage areas of components. Separate recommendations have been provided for the design of work items causing the largest dose, for example in regard to remote control. These special items include regular maintenance and inspection activities connected to the reactor, fuel and primary circuit, for example.

The accumulation of the collective radiation dose has been assessed as required by Guide YVL C.1. Information compiled by the plant supplier of the operation of French N4 and German Konvoi pressurised water reactors has also been used in the assessments. The estimated collective dose (the unit of collective dose is mansievert, manSv) for work in the reactor building during annual outages is on average 0.28 manSv per year, and 0.096 manSv per year for work in other buildings in the controlled area. During an operating cycle, a dose of approximately 0.023 manSv is estimated to be accumulated in work in the reactor building. The most significant share of the annual collective dose is caused by maintenance and inspection of the reactor, main coolant pumps and steam generators. In terms of professional groups, the largest doses are in mechanical maintenance, non-destructive testing, isolation work and sanitation. The most exposed professional groups are the same as at other Finnish nuclear power plant units. According to the estimate, the average annual collective dose would be approximately 0.4 manSv, while the design limit corresponding to a net electrical output of 1,600 MW in accordance with Guide YVL C.1 is 0.8 manSv.

The ALARA programme of the Olkiluoto nuclear power plant includes a section on the Olkiluoto 3 nuclear power plant unit, which takes into account radiation protection objectives, limiting radiation doses as well as hydrochemistry, radiochemistry, process design and operational activities. According to the ALARA programme, the target value for the annual dose has been set at 0.5 manSv. The target set for a maximum personal dose is under 5 mSv. The limit on the annual internal dose caused by contamination is 0,5 mSv. Based on work-item specific dose estimates, it can be stated that it is possible to keep workers’ annual doses clearly below the dose constraints laid down in the Government Decree on Ionizing Radiation (1034/2018) and the limiting value presented in Guide YVL C.1.

In 2016, STUK issued TVO’s dosimetry service with a continued approval for a fixed term until 1 April 2021. The approval covers the Olkiluoto 1 and 2 nuclear power plant units as well as the Olkiluoto 3 nuclear power plant unit. In addition to photon and beta radiation, the approval also applies to the measurement of neutron radiation with thermoluminescent dosimeters. TVO investigated the need and procedure for measuring the equivalent dose for the lens of the eye in a power plant environment during the 2017 and 2018 annual outages of the Olkiluoto 1 and 2 nuclear power plant units. The need for using eye dosimetry for a particular job is assessed when making a radiation permit and, if necessary, at a work site.

The conclusion is that the radiation protection and dose monitoring of employees of the Olkiluoto 3 nuclear power plant unit has been implemented as intended in Section 7 of the Regulation.

3.2 Radiation exposure of members of the public in the vicinity

Keeping the radiation exposure caused by the operation of the nuclear power plant to member of the public in the vicinity as low as practically possible means observing principles of optimisation in radiation protection. Such applicable principles include the International Commission on Radiation Protection's (ICRP) ALARA principle and the EU's IPPC Directive BAT principle (Best Available Techniques).

Limiting the radiation exposure of members of the public in the vicinity according to ALARA and BAT principles has been described in the final safety analysis report of the Olkiluoto 3 nuclear power plant unit.

The conclusion is that the radiation exposure of members of the public in the vicinity of the Olkiluoto 3 nuclear power plant unit has been designed to be limited as referred to in the Radiation Act and the Nuclear Energy Decree.

The shortfall of the dose constraints set for the radiation exposure caused to members of the public in the vicinity by the operation, operational occurrences and accidents of the Olkiluoto 3 nuclear power plant unit are covered in Sections 3.2.1–3.2.3.

3.2.1 Constraint for normal operation [Nuclear Energy Decree 161/1988, Section 22 b(1)]

The annual dose constraint for an individual of the population arising from the normal operation of a nuclear power plant or another nuclear facility equipped with a nuclear reactor, shall be 0.1 mSv.

In the Nuclear Energy Decree (161/1988), the stipulation concerning the protection of individuals must be implemented alongside the ALARA requirement concerning the limitation of radiation exposure (Chapter 3.1). Guide YVL C.4 presents detailed requirements for calculation methods by which to estimate the radiation exposure of members of the public.

The Olkiluoto 3 nuclear power plant unit has been built in a site area that already holds two reactors. As such, the release limits of the official regulations take into account the releases of all three reactor units, which combined must not exceed the annual dose constraint of 0.1 mSv specified in the Nuclear Energy Decree to a representative person in the vicinity. According to TVO, the share of the Olkiluoto 3 nuclear power plant unit of these total releases is 10%, or up to 0.01 mSv per year. The plant has been designed according to the ALARA principle, minimising releases into water and air during normal operation and during anticipated operational occurrences.

The final safety analysis report (FSAR) presents the concentration of radioactive substances in various systems of the Olkiluoto 3 nuclear power plant unit. Nuclides that emit high-energy gamma radiation and have a sufficient half-life (over several hours) were selected as the nuclides analysed in the FSAR because they have a significant impact on radiation levels.

The radioactivity concentrations in the primary circuit can be used to directly derive the concentrations in the plant's other water systems when they are functioning in accordance with the design basis. The release levels have been assessed based on the radioactivity concentrations in different systems in a conservative manner (unfavourably for the results). Concentrations in waste systems depend on the situation and usage, so their assessment has been done using experience information from German power plants.

The concentrations of the most important fission products have been selected based on statistical analysis of the running plants. The concentrations of other fission products have been derived from the design basis. Corrosion products have been selected based on the experiences of the two plant types used for reference. The material selections and designed hydrochemical conditions of the plant are aimed at keeping the radiation doses caused by activation products and radioactive releases from the plant's operations as low as possible in accordance with the ALARA principle. Conservative procedures have been used in the assessment of the concentrations of radioactive substances.

The radiation exposure of members of the public living in the vicinity is analysed in the Olkiluoto 3 nuclear power plant unit's FSAR Chapter 11.3. The dose calculation of the FSAR has been carried out for several individuals at different distances from the plant: an adult, a child and an infant. The doses caused by both liquid and gaseous releases combined for all age groups are below the set constraint of 0.01 mSv.

The analysed released nuclides have been selected based on German official regulations (Federal Gazette No. 64a, 2012).

Based on calculations, the most important nuclides that cause doses in gaseous release are ^{14}C, ^{88}Kr, ^{133}Xe and elemental ^{131}I. Nuclide ^{41}Ar, which is generated in rooms around the reactor, has also been taken into account. However, it has very little relevance for the dose. In terms of liquid releases, the major nuclides causing the dose are ^{60}Co, ^{134}Cs and ^{137}Cs. The share of tritium is 1–2%.

The plant's anticipated release has been determined according to operating experiences from similar plants. The release has been selected such that it covers the largest realised annual releases of the reference plants in recent years. The dose effect caused by the anticipated release at a distance of 1 km of the plant is 0.00087 mSv for infants, 0.00059 mSv for children and 0.00054 mSv for adults over the course of one year.

The design release is a conservative annual release. When the plants operate normally, values remain significantly under the design release; values exceeding the design release would be the result of system failure at the plant unit. The dose effect caused by the design release at a distance of 1 km of the plant is 0.004 mSv for infants, 0.0031 mSv for children and 0.0028 mSv for adults over the course of one year. These values are below the constraint of 0.01 mSv set for the Olkiluoto 3 nuclear power plant unit by a large margin.

The dose calculations of the FSAR have been done in accordance with the requirements of Guide YVL C.4, applying the calculation formulas presented in German official regulations. STUK considers that the calculations have been done in a justified way using sufficient initial data. The parameters and initial data used in the dose calculations are conservative.

The Technical Specifications set limits for releases and emission rates of the Olkiluoto 3 nuclear power plant unit; if they are exceeded, operation must be restricted. The limits have been set such as to ensure that the plant's operation will not cause radiation exposure to a representative person in the vicinity exceeding the constraints laid down in Section 22 b of the Nuclear Energy Decree. The measuring instruments for monitoring releases are sensitive enough for reliable monitoring of the realisation of the Technical Specifications.

The conclusion is that the normal operation of the Olkiluoto 3 nuclear power plant unit is not expected to cause radioactive releases that would cause the annual radiation exposure constraint of 0.1 mSv, as laid down in the Nuclear Energy Decree, to be exceeded.

3.2.2 Constraint for an anticipated operational occurrence [Nuclear Energy Decree 161/1988, Section 22 b(2)]

As a result of an anticipated operational occurrence, the annual dose constraint for an individual of the population shall be 0.1 mSv.

Anticipated operational occurrence shall refer to a deviation from normal operational conditions that may be expected to occur once or several times over a period of a hundred years of operation. Detailed requirements for the analyses of anticipated operational occurrences are presented in Guides YVL B.3 and YVL C.3. If an operational occurrence can cause a release of radioactive substances, the radiation doses resulting from it must be determined. Guide YVL C.4 presents detailed requirements for calculation methods by which to estimate the radiation exposure of members of the public.

The FSAR for the Olkiluoto 3 nuclear power plant unit presents descriptions of the analyses of anticipated operational occurrences. The anticipated operational occurrences of the Olkiluoto 3 nuclear power plant unit are not expected to lead to releases of radioactive substances, as the fuel is not damaged or the plant unit's systems can retain the radioactive substances released. An exception from the above is an initiating event where a condenser vacuum is lost in the secondary circuit. Its analysis assumes that the steam generator has a small primary-secondary leak, due to which secondary condensate is allowed to contain a small amount of activity in normal operation. When the condenser is not in operation, decay heat removal is achieved by blowing secondary condensate into the atmosphere. The radiation dose caused to an individual by the event has been calculated to be less than 0.001 mSv.

The conclusion is that the anticipated operational occurrences of the Olkiluoto 3 nuclear power plant unit do not cause releases that would result in the annual radiation dose caused to a member of the public exceeding the annual dose constraint of 0.1 mSv specified in the Nuclear Energy Decree.

3.2.3 Constraints for accidents [Nuclear Energy Decree 161/1988, Section 22 b(3–6)]

The annual dose constraint for an individual of the population shall be 1 millisievert for class 1 postulated accidents, 5 millisieverts for class 2 postulated accidents, and 20 millisieverts for a design extension condition.

The release of radioactive substances caused by a severe accident at a nuclear power plant may not necessitate implementation of large-scale protective measures *for the population or any long-term restrictions on the use of extensive areas of land and water.*

In order to avoid long term restrictions, the limit for atmospheric releases of ^{137}Cs shall be 100 terabecquerel. The possibility of exceeding the limit shall be extremely small.

The possibility of a release occurring at an early phase of an accident requiring population protection measures shall be extremely small.

Guides YVL B.3, YVL C.3 and YVL C.4 contain detailed requirements on the calculation of accident analyses concerning plant behaviour, the calculation of related releases and radiation doses, and the acceptability of the results.

The FSAR for the Olkiluoto 3 nuclear power plant unit presents descriptions on the units' accident analyses (covered in more detail in the safety review's Chapter 2.1.1). The analysis methods concerning radiation exposure comply with the requirements of Guides YVL B.3 and YVL C.4. The methods include improbable assumptions, which, in reality, signify an overestimation of the radiation dose amounts calculated as consequent effects.

According to the definition of the Nuclear Energy Decree, class 1 postulated accidents can be assumed to occur less frequently than once during any period of a hundred years of operation, but at least once during any period of a thousand years of operation. According to the analyses of the Olkiluoto 3 nuclear power plant unit, in regard to class 1 postulated accidents, the maximum individual radiation dose is caused by a leak between the primary circuit and secondary circuit (tube rupture in one of the steam generator's heat transfer tubes). The maximum dose caused by the accident is 0.553 mSv, which is under the annual dose constraint of 1 mSv laid down in the Nuclear Energy Decree (161/1988). According to the analysis, the doses caused by other class 1 postulated accidents are lower.

According to the definition, class 2 postulated accidents are accidents that can be assumed to occur less frequently than once during any period of one thousand years of operation. In regard to class 2 postulated accidents, the largest dose according to the analyses of the Olkiluoto 3 nuclear power plant unit is caused by a leak between the primary circuit and secondary circuit (tube rupture in two of the steam generator's heat transfer tubes). The maximum individual radiation dose caused by the accident is 0.853 mSv, which is under the annual dose constraintof 5 mSv laid down in the Nuclear Energy Decree. According to the analyses, the doses caused by other class 2 postulated accidents are lower.

The conclusion is that class 1 and 2 postulated accidents at the Olkiluoto 3 nuclear power plant unit do not cause radioactive releases that would result in the radiation doses caused to a member of the public exceeding the annual dose constraint of 1 and 5 mSv, as set forth in the Nuclear Energy Decree.

Design extension condition refers to 1) an accident where an anticipated operational occurrence or class 1 postulated accident involves a common cause failure in a system required to execute a safety function; 2) an accident caused by a combination of failures identified as significant on the basis of a probabilistic risk analysis; or 3) an accident caused by a rare external event, and which the plant is required to withstand without severe fuel damage. In terms of the design extension conditions, according to the analyses, the crash of a large commercial airliner into the Olkiluoto 3 nuclear power plant unit would cause a radiation dose of up to 10 mSv to a member of the public. According to the analysis, a leak between the primary circuit and secondary circuit of the Olkiluoto 3 nuclear power plant unit (tube rupture in ten of the steam generator’s heat transfer tubes), a stuck-open valve in the steam overpressure protection system, and passage of primary and secondary coolant from the turbine hall roof into the environment will cause a radiation dose of up to 1.02 mSv to a member of the public. Both of the aforementioned radiation doses are lower than the annual dose constraint of 20 mSv laid down in the Nuclear Energy Decree. According to the analyses, the doses caused by other design extension conditions are lower.

The conclusion is that the design extension conditions of the Olkiluoto 3 nuclear power plant unit do not cause releases of radioactive substances that would result in the annual radiation dose caused to a member of the public exceeding the annual dose constraint of 20 mSv specified in the Nuclear Energy Decree.

Severe accident shall refer to an accident in which a considerable part of the fuel in a reactor or the spent fuel in a spent fuel pool or storage loses its original structure. In terms of severe accidents at the Olkiluoto 3 nuclear power plant unit, seven different scenarios were selected, and the release of radioactive substances from fuel was calculated for each scenario. Three of the scenarios were selected (a major and minor loss of coolant accident and a loss of off-site power) and analysed with the best-estimate method and presuming that radioactive substances will pass into the annular space of double containment and onward through the vent stack into the atmosphere. Furthermore, one of the aforementioned scenarios (major loss of coolant accident) was analysed presuming that 10% of the material passing into the annular space instead passed directly to the surrounding buildings and entered the atmosphere at a low height. In the most unfavourable scenario, the radiation dose of a member of the public was calculated to be up to 0.22 mSv and the ^{137}Cs release to be 0.0094 TBq. The individual radiation dose received as a result of the analysis does not require that members of the public take cover indoors or evacuate from the vicinity, and the ^{137}Cs release is lower than the limiting value of 100 TBq laid down in the Nuclear Energy Decree.

In addition to the aforementioned cases, PRA level 2 analyses the probabilities and radioactive releases of all severe accident scenarios that are considered possible. According to Chapter 2.1.2, based on the analyses, the probability of the requirement on the limiting value for ^{137}Cs releases not being met is extremely low. In addition to this, the probability of a release during the early phase of an accident requiring public protective measures is extremely low.

The conclusion is that the Olkiluoto 3 nuclear power plant unit meets the requirements of the Nuclear Energy Decree related to the consequences of a severe accident.

3.2.4 Conclusion

The conclusion is that the radiation exposure of members of the public in the vicinity of the Olkiluoto 3 nuclear power plant unit has been limited as referred to in Section 5-7 of the Radiation Act and Section 22 b of the Nuclear Energy Decree.

4 Nuclear safety (STUK Y/1/2016 – Chapter 3)

4.1 Site safety (Section 8)

The impact of local conditions on safety and on the implementation of the security and emergency arrangements shall be considered when selecting the site of a nuclear power plant. The site shall be such that the impediments and threats posed by the plant to its vicinity remain extremely minor and heat removal from the plant to the environment can be reliably implemented.

Requirements related to the location of a nuclear power plant are provided in Guides YVL A.1, A.2, A.3, A.7, A.11, B.1, B.7, C.3, C.4 and C.5, in particular. The concepts of site area, precautionary action zone and emergency planning zone are defined in Regulation STUK Y/2/2016.

There are no industrial facilities, storages, transport routes or other operations in the vicinity of Olkiluoto that might cause a hazardous situation at the plant. The northern shore of the island of Olkiluoto has a dock and harbour which are located on land that is owned by the applicant. Between 5 and 10 people are employed by the harbour's different functions. The nearest busy port is the Rauma deep-water port. There are no routes in the immediate vicinity of the plant that run large oil shipments or shipments of other hazardous materials. The closest the railway line between Rauma and Kokemäki comes to the power plant is 12.5 km. Main road 8 lies about 14 km from the plant. The closest airport is in Pori about 32 km from the Olkiluoto power plant, and the nearest flight paths run approx. 10 km from the power plant.

Small-scale field cultivation is carried out near the site area only in the eastern section of the Olkiluoto island. The nearby waters are used for recreational fishing. The most contiguous farm lands in the nearby areas of Olkiluoto are located 20–40 km to the east of the power plant and 25–35 km to the northeast. There are a few commercial gardens located approximately 10 kilometres from the power plant that produce vegetables mainly for the Rauma region. The nearest dairy is located in Pori at a distance of approximately 35 kilometres. There are three milk-producing farms within a 10-kilometre radius of the nuclear power plant.

Three schools are located within a radius of approximately 10 kilometres from the nuclear power plant. These are primary schools and their pupils are between 6 and 13 years old.

There are Natura areas in the immediate proximity of the energy management area of Olkiluoto, both on the island of Olkiluoto and in the sea areas in front of the island. The operations of the current plant units have not caused significant detriment to the protected habitat types in the Natura areas. The Act on the Selkämeri National Park was approved by the Finnish Parliament on 8 March 2011, with the area limitations presented in the legislation proposal. The Environment Committee amended the Act with the following section: "Conducting cooling water from a nuclear power plant. Notwithstanding the declarations of game preservation, activities required for the remote intake and discharge of cooling water from the Olkiluoto nuclear power plant may be performed in the area of the Selkämeri National Park, subject to permission from Metsähallitus."

Olkiluoto has a valid regional land use plan, master plan for shore areas and detailed plans that indicate areas for the construction of nuclear power plants. The Satakunta regional plan confirmed by the Ministry of the Environment in 2011 specifies a precautionary action zone that extends to a distance of approximately 5 km from the Olkiluoto power plant.

The detailed plan that is valid in the area of the current nuclear power plant units and Olkiluoto 3 nuclear power plant unit has been confirmed in 1997 and determined as up-to-date in 2014. The site area is marked as block area for industrial buildings and storage buildings into which the construction of nuclear power plants and other facilities and equipment intended for the generation, distribution and transfer of energy and their related buildings, structures and equipment may be constructed unless this has otherwise been limited.

Most of the water areas referred to in the detailed plan have been confirmed to be waters that may be used for the purposes of power plants, and into which the piers and other structures and components required for power plants may be constructed in the vicinity of the industrial areas and storage areas. The plan also indicates the waters where filling and embankment are allowed. Furthermore, the Olkiluoto area has block area plans confirmed in 2005 for the accommodation buildings serving energy production, and earlier local plans for shore areas concerning the eastern part of the island of Olkiluoto.

There are less than ten buildings intended for permanent residence on the island of Olkiluoto and the nearby island of Kornamaa. There are several buildings intended for permanent residence in the village of Ilavainen to the east of the island of Olkiluoto. The protective zone of the nuclear power plant has 303 constructed recreational settlements, 37 unconstructed recreational settlement sites and 70 constructed residential buildings. According to the population data from Statistics Finland, the precautionary action zone had a total of 50 inhabitants on 31 December 2014. It is STUK’s understanding that the number has not changed substantially after that.

The emergency planning zone includes the municipality of Eurajoki and the city of Rauma, with the exception of the former municipalities of Lappi and Kodisjoki – however, the Murtamo village of the former municipality of Lappi is included in the emergency planning zone. Some 49,000 people live within the emergency planning zone. Approximately 520,000 people live within 100 km of the plant.

The conditions set for protective zones are met at Olkiluoto. The number of permanent inhabitants inside the protective zone does not prevent effective rescue operations. Any activities that may jeopardise the safety of the plant unit are located sufficiently far. Limitations apply to land use in the nearby areas. Sufficient preparations have been made for the supervision of movement and transport within an area of limited movement and sojourn in accordance with the Ministry of the Interior’s Decree (480/2018) and the site area itself.

The procedures for warning members of the public and issuing protection instructions are described in the external emergency plan prepared by the Satakunta Rescue Department. The actions are connected to isolating the danger zone, taking cover indoors and the use, storage and distribution of iodine tablets as well as evacuation of members of the public from the power plant's protection zone. The rescue plan presents the transport, accommodation, provisioning and health care arrangements connected to evacuation. The license holder, in cooperation with the emergency services, must design warning arrangements for persons in the immediate vicinity of the nuclear power plant who may be directly threatened by an accident. Challenges connected to the rescue arrangements include measures to rescue summer residents of the archipelago, sparsely populated coastal areas and the accommodation village.

The archipelago conditions may slow down the process of warning the holiday residents and the possible evacuation of the precautionary action zone. Furthermore, the coastal of the emergency planning zone area, particularly to the north of the power plant, is fairly fragmented, which makes it more difficult to alert members of the public. Coast Guard boats can be used for warning members of the public in the archipelago and the fragmented coastal areas. The development of alarm and rescue arrangements is covered by administrative cooperation and, in the future, opportunities afforded by modern communications technology can be utilised in the development of the alarm arrangements. In STUK's understanding, the warning and rescue arrangements for members of the public in the vicinity can be implemented in the manner required by the applicable regulations.

The nuclear power plant's emergency response arrangements and cooperation with rescue authorities are also covered in Chapter 9 of this appendix and, based on STUK's assessment, the emergency response arrangements of the Olkiluoto power plant are up-to-date and sufficient.

The plant's environmental effects during normal operation are described in Chapter 3.2.1 while the effects of operational occurrences and accidents are described in Chapters 3.2.2 and 3.2.3. The effects of local conditions and external events on the safety of the Olkiluoto nuclear power plant and the reliability of decay heat removal are covered in Chapter 4.6. Physical protection is described in Chapter 8.

The conclusion is that the location of the Olkiluoto nuclear power plant meets the requirement of Section 8 of the Regulation.

4.2 Defence-in-depth (Section 9)

In order to prevent anticipated operational occurrences and accidents, and to mitigate the consequences thereof, the functional defence-in-depth principle shall be implemented in the design, construction and operation of a nuclear power plant.

In accordance with the functional defence-in-depth safety principle, the design must include the following levels of defence:

1. *prevention to ensure that the operation of the plant is reliable and deviations from normal operating conditions are rare;*
2. *control of deviations from the plant's normal operating conditions so that the plant is equipped with systems which are able to limit the development of operational occurrences into accidents and if required can bring the plant into a controlled state;*

3. *control of accident situations so that the nuclear plant is equipped with systems that function automatically and reliably to prevent severe fuel damage in postulated accidents and in design extension conditions; manually actuated systems can also be used to manage accident situations if it can be justified from a safety perspective;*
4. *confinement of a release of radioactive substances in severe reactor accidents by equipping the nuclear power plant with systems which ensure the sufficient leak-tightness of the containment in severe reactor accidents so that the limits for releases in severe reactor accidents are not exceeded;*
5. *mitigation of the consequences by means of emergency arrangements to limit the public's exposure to radiation in situations where radioactive substances are released from the plant into the environment.*

The levels of defence required under the defence-in-depth principle shall be as independent of one another as is reasonably achievable.

High quality proven technology is to be used for the different levels of the defence-in-depth.

The necessary measures to bring a situation under control or to prevent harmful effects of radiation must be planned in advance. When organising licensee's operations, it must be ensured that operational occurrences and accidents are reliably prevented. There shall be effective technical and administrative provisions to ensure staff's ability to operate in these situations.

According to Section 7 b of the Nuclear Energy Act (990/1987), 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), and this principle shall extend to the operational and structural safety of the plant. Detailed requirements for application of the principle are presented in Guide YVL B.1.

Level 1: Prevention

In order to prevent operational occurrences and accidents, the Olkiluoto 3 nuclear power plant unit will primarily use design, construction and operational solutions that are already in use at the latest French and German pressurised water reactors (plant types N4 and Konvoi serve as references) or which have been developed from reactors that are in operation with minor alterations. The Olkiluoto 3 nuclear power plant unit has been designed and constructed to prevent the development of operational occurrences by means of its technical characteristics. Various external and internal threats have been considered in its design. The design has been based on ensuring that the sufficient operation of systems, structures and equipment needed for managing the plant is not compromised by external or internal events. The reactor has been designed for natural stability in regard to minor power disturbances, and there are control systems in use to eliminate minor operational occurrences, reducing their effect on the operation of the plant to a minimum.

In order to prevent operational occurrences, all components affecting the safe operation of the plant have been manufactured and inspected with systematic quality assurance methods, and their condition will be monitored on a regular basis during the plant's operation.

In addition to the structure of the plant, the organisation operating the plant also plays a central role in the prevention of operational occurrences and accidents. In this respect, the most important areas of the organisation's operation are maintenance and operations and, at a later stage, the management of plant modifications. In maintenance and operational activities, the management of human factors is based on administrative procedures and operating principles, which are discussed in Sections 6.1, 6.4 and 7.1 of the safety assessment.

Level 2: Control of deviations from the plant's normal operating conditions

The plant has a limitation system to prevent minor faults or deviations of control or operating systems from developing into operational occurrences or accidents. This is most often implemented by dropping a few pre-selected control rods into the reactor core (partial scram), which reduces reactor power and makes the disturbance easier to control. Other limitation measures include closing the letdown of the primary circuit pressurizer and switching the pressurizer heating resistors on and off. The limitation measures are mainly done using the plant's normal operation systems, without the need to start the back-up systems intended for accidents.

Internal threats have been taken into account in the plant design by limiting internal events to one safety division, and the spreading of deviations into other rooms or subsystems important to safety has been prevented with room and location planning and by designing components to withstand stresses caused by internal threats. Furthermore, there are documented procedures in case of internal threats, which can be launched in time through the monitoring and alarm systems.

In some cases, the deviation itself is so major that the limitation system and the limitation measures it launches cannot control its consequences. Should this occur, the reactor is automatically shut down in order to prevent the deviation from becoming an accident.

Level 3: Control of accident situations

Accident situations are controlled through safety functions, which are automatically started by the Safety Class 2 protection system. The primary purpose of the protection system is to protect the integrity of the fuel cladding and the primary circuit by stopping the reactor when necessary. The system will also initiate the emergency cooling of the reactor if a coolant leak occurs in the primary circuit. In accident situations, the protection system closes the isolation valves in process pipelines that run through the containment wall in order to stop radioactive substances from passing into the environment. The protection system has been implemented with four parallel and mutually independent subsystems; the operation of two subsystems is sufficient for initiating the necessary protection function. The condition for triggering a scram when necessary can be received from at least two independent variables. Therefore, the common cause failure of all measurement probes of a specific type cannot prevent the safe shutdown of the reactor.

The protection system is based on programmable technology. Its functioning has been ensured with a back-up system; in case of anticipated operational occurrences and the most common class 1 accidents, the reactor can be brought to a controlled state even if the protection system fails to function as intended. The functions of the back-up system use hard-wired technology.

Common-cause failure in the systems performing safety functions as well as the most relevant combinations of failures have been taken into account in design. Sufficient physical separation or subsystems and the principles of diversity and redundancy have also been considered in the design.

Level 4: Confinement of release in a severe accident

Finnish law requires that the probability of the need to protect members of the public in the early stages of a severe accident must be very low. It also requires that the probability of a release exceeding the limit of 100 TBq laid down in the Nuclear Energy Decree must be very low. At the Olkiluoto 3 nuclear power plant unit, management of a severe accident has been prepared for with consideration of these requirements.

Management of a severe accident is aimed at ensuring containment integrity. When integrity of the containment remains intact, the legislative requirements can be fulfilled. In case of a severe accident, ensuring containment integrity is based on the containment's large volume and pressure resistance, active heat transfer from the containment into seawater as well as core melt management, which also includes primary circuit depressurization r to prevent failureof the reactor pressure vessel at high pressure. Hydrogen management also plays an important role in ensuring containment integrity. The management of a severe accident is described in the safety assessment's Chapter 4.3.

Level 5: Mitigation of consequences

Although the possibility of a severe accident at the Olkiluoto 3 nuclear power plant unit is vanishingly small, the remaining risk has been prepared for. Outside the plant, mitigation of consequences has been prepared for with similar preparedness methods as for the Olkiluoto 1 and 2 nuclear power plant units. The definitions of duties and areas of responsibility required in an accident situation are presented in the emergency response plan. The emergency response arrangements is described this safety assessment's Chapter 9.

Independence between the levels of defence

The systems designed for the different levels of defence-in-depth have mainly been designed to be independent of each other, so that the failure of a system operating on one level will not prevent the systems on the other levels from performing as intended.. All levels of defence have electrical and automation equipment and within each subsystem they are located in the same rooms. The cooling of these rooms is made by systems which have four physically separated parallel subsystems. Diversity principle has been applied in the design of the cooling systems, for example, by using different heat sinks: water or air. If the ventilation cooling systems are lost, it is also possible to keep room temperatures within allowed limits for a limited period of time by cooling the rooms with just outdoor air.

Summary

In conclusion, the design, construction and operational activities of the Olkiluoto 3 nuclear power plant unit follow the defence-in-depth principle. The defence-in-depth design includes all levels of defence, which are sufficiently independent from each other, and high quality proven technology is used for the different levels. There are sufficient procedures and administrative arrangements for the management of operational occurrences and accidents. The requirements of Section 9 are met.

4.3 Engineered barriers for preventing the dispersion of radioactive substances (Section 10)

In order to prevent the dispersion of radioactive substances, the structural defence-in-depth safety principle shall be implemented.

Structural defence-in-depth design shall prevent dispersion of radioactive substances into the environment by means of successive barriers, which are the fuel and its cladding, the reactor cooling circuit (primary circuit) and the containment.

The fuel, reactor, primary circuit of the reactor, and the cooling circuit (secondary circuit) of a pressurised water reactor removing heat from the primary circuit, water chemistry of the primary and secondary circuit, containment and safety functions shall be designed so as to meet the safety objectives laid down below.

The fulfilment of these requirements is assessed in Chapters 4.3.1–4.3.3.

4.3.1 Ensuring the integrity of fuel

In order to ensure the fuel integrity:

1. *the probability of fuel failure shall be low during normal operational conditions and anticipated operational occurrences;*
2. *in postulated accidents, the amount of fuel failures shall be kept small and fuel coolability must not be endangered; and*
3. *the possibility of a criticality accident shall be extremely small.*

The first propagation barrier for radioactive substances is the fuel material and the surrounding cladding. Enriched uranium dioxide with less than 5% of U-235 is used as the fuel at the Olkiluoto 3 nuclear power plant unit. This fuel material is used to manufacture the fuel pellets. The fuel pellets are stacked inside the cladding to form fuel rods, which are further grouped into a square lattice to form a fuel assembly. The selected cladding materials is M5, a zirconium alloy. Based on tests and operating experience, it has been found to have favourable properties in normal operational conditions and accidents than the previously used fuel cladding materials.

Normal operational conditions and anticipated operational occurrences

Factors that may jeopardise fuel integrity during normal reactor operation include manufacturing defects, excessively fast power changes or insufficient fuel cooling in the reactor in proportion to the power level, foreign material or impurity entering a fuel assembly or incorrect hydrochemistry in the reactor.

To prevent design and manufacturing defects, fuel procurement and quality management procedures have been specified in TVO's instructions. STUK has approved the licensing documentation of the fuel type.

TVO is responsible for control of manufacturing at the fuel factory. STUK carries out its own inspections at manufacturing sites in order to ensure that the licence holder's control is sufficient. TVO performs an acceptance test on fuel batches arriving at the Olkiluoto nuclear power plant, inspecting the fuel assemblies and channels in accordance with the instructions.

The reactor fuel and its loading to the core are planned separately for each operating cycle. The operational occurrence and accident analyses are also repeated to the required extent if the properties of the fuel or reactor are changed. STUK reviews the reactor and fuel behaviour report separately for each operating cycle.

Reactor power is controlled at the Olkiluoto 3 nuclear power plant unit, as in pressurised water reactors in general, with either control rods or the boron system. The speed at which control rods are moved and the need to move them cause a greater risk in terms of fuel integrity in normal operation. Adjustments made with boron are relatively slow and usually affect the whole core, so they do not cause problems for fuel integrity. At the Olkiluoto 3 nuclear power plant unit, the maximum acceptable local power response rate due to control rod movement has been specified significantly below the fuel damage limit demonstrated in fuel studies. The operating method and structure of the control rods are also aimed at minimising their effect on local power changes.

Sufficient fuel cooling is ensured by limiting the maximum linear power and preserving a sufficient margin on heat transfer crisis between the fuel cladding and coolant. These operational limits are continuously monitored with the core monitoring system.

Long-term reactivity control (compensation of excess reactivity) is carried out with a boric acid solution that is supplied to the primary circuit; its ^{10}B isotopes absorb neutrons. The boric acid concentration is highest at the beginning of the operating cycle, decreasing to zero by the end of the cycle.

In fuel and core design, it is essential that a sufficient margin on heat transfer crisis (rapid decrease in heat transfer from fuel to coolant) is also retained in all anticipated operational occurrences in order to prevent fuel damage.

In situations where rapid reactor power decrease – but not a full stop – is needed, it is possible to carry out a partial scram by lowering some of the control rods into the reactor. These automatic actions help ensure that the reactor's maximum acceptable linear power limit and minimum acceptable margin on heat transfer crisis are not deviated from in normal operation or during anticipated operational occurrences.

Operational occurrence analyses prepared for the Olkiluoto 3 nuclear power plant unit have examined faults and faulty controls that affect reactor power, pressure, cooling flow and heat transfer to the secondary circuit. Based on the analyses, the worst anticipated operational occurrence in terms of heat transfer crisis is a loss of off-site power that causes all main coolant pumps to stop simultaneously, rapidly decelerating main coolant flow. However, here as well as in other anticipated operational occurrences, the margin on the minimum value permitted by the acceptance criteria is large. STUK has commissioned an independent comparison analysis of this case, the results of which confirm the results of the licence applicant's analysis and meet the acceptance criteria.

Postulated accidents

Postulated accidents examine events that affect both reactor power and fuel cooling, which cause the biggest challenges for preserving fuel integrity. Safety functions for ensuring fuel integrity in accident situations are discussed in Chapter 4.4.

Accident situation analyses prepared for the Olkiluoto 3 nuclear power plant unit have examined several primary circuit leaks of differentsize. The largest leak examined was a complete axial break of the main coolant circuit's largest pipe. This case has been used for dimensioning the capacities of the emergency cooling systems, for example. According to analyses made by the plant supplier, the requirements set for fuel coolability and integrity in postulated accidents are met. STUK has commissioned independent comparison analyses of this case, which prove that the conclusion presented by the plant supplier is correct.

Primary circuit water may leak into the secondary circuit in case of damage to one or more heat transfer tubes of the steam generator. Water leaking from the primary circuit to the steam generator's secondary side may pass onward into outdoor air, generating a release of radioactive substances due to primary coolant activity. If the leak into the atmosphere were to continue for a long time, the boron-containing emergency cooling water used to replace the lost coolant could run out. The end of cooling would threaten fuel integrity. On the other hand, reducing primary circuit pressure under the secondary circuit would reverse the leak flow from the secondary side back to the primary circuit, in which case the initially boron-free water of the secondary side could form a plug with dilute boron concentration in the primary circuit. The management of primary-secondary leaks has been considered in the design of the Olkiluoto 3 nuclear power plant unit and in the dimensioning of the emergency cooling systems and the secondary side's pressure control. Furthermore, a strategy has been planned for managing the situation, minimising releases into the environment and the possibility of boron-free water from the secondary circuit entering the primary circuit in a later stage of the accident. According to the analyses, the Olkiluoto 3 nuclear power plant unit can withstand primary-secondary leaks in an acceptable manner.

The worst class 2 postulated accident that does not involve a primary circuit leak is a sudden reduction in main coolant flow due to a locked main coolant pump rotor or broken shaft. The plant supplier's analyses demonstrate that a part of the fuel would then go into a heat transfer crisis. Nevertheless, the result is acceptable because the number of rods that would do into a crisis is low, the number of damaged rods is clearly below the applied acceptance criteria and the fuel cladding temperature would not rise above the acceptance criteria temperature. STUK commissioned an independent comparison analysis of this case, the results of which confirm the results of the plant supplier's analysis.

Conventionally, the ejection of an individual control rod has been the worst postulated reactivity accident in a pressurised water reactor. At the Olkiluoto 3 nuclear power plant unit, the reactivity values of individual control rods are at their highest in partial power states during the start-up of the plant unit, but even then they have been restricted to such low levels that the rise in fuel enthalpy caused by the ejection of a control rod remains significantly below the acceptable limit. STUK also commissioned an independent comparison analysis of this case, and the results confirm the results of the plant supplier's analysis.

Criticality safety

Unintended supercriticality of the reactor could be caused either by the dilution of the primary circuit's boron concentration or by unexpected decrease in coolant temperature.

For the monitoring of boration and dilution, the feeding of make-up water to the primary circuit is equipped with quadruple continuous boron concentration measurement, which is based on measuring the neutron absorption of water fed to the primary circuit. Based on the measurement, unintended or over-long dilution is interrupted automatically. Sufficient boron concentration is ensured through sampling and laboratory analyses, which are particularly important in outage situations. During refuelling, criticality is also monitored through source area neutron flow measurements.

A minor primary circuit leak may involve a situation where steam condenses in the steam generator's heat transfer tubes. The boron-free water created in the condensation reaction collects into tube bends in cold legs and, when natural circulation starts, it may enter the reactor. Based on the analyses made by the plant supplier, it can be stated that clean water will mix with boron-containing water in the primary circuit to the extent that the reactor will not go recritical due to the event. Independent analyses commissioned by STUK support this view.

A plug of boron-free water may form in the primary circuit if clean water enters it, for example due to incorrect supply or heat exchanger leak when the main coolant pumps are stopped. Incorrect supply has been mainly prepared for at the Olkiluoto 3 nuclear power plant unit with an automatic protection system, which monitors the boron concentration of make-up water supplied into the primary circuit and stops the supply if the boron concentration of the supplied water is too low. Furthermore, the risk of a clean-water plug was been limited structurally and with measurements monitored from the control room, control systems and supplementary administrative instructions. The analyses made by the plant supplier demonstrate that even in a worst-case scenario, the amount of clean water entering the reactor due to incorrect supply will remain so low and mix with the boron-containing water in the primary circuit to such extent that the reactor does not go recritical due to the event. Dilution from other sources, such as heat exchanger leaks, will be detected early enough through continuous measurements.

The supercriticality risk caused by the cooling of the primary circuit primarily applies to potential recriticality of a reactor that was shut down after a steam line rupture because of negative feedback from temperature while cooling is still taking place. Based on the analyses presented, the reactivity increase caused by the cooling will be compensated with boron-containing water supplied by the safety systems. STUK has also commissioned an independent analysis of steam line breakage cases, the results of which demonstrate that recriticality will be avoided.

Summary

Analyses done by the plant supplier are available for the situations examined to ensure fuel integrity. STUK has also carried out and commissioned independent comparison analyses of the most important situations. The conclusion is that the fuel integrity of the Olkiluoto 3 nuclear power plant unit has been ensured as intended in Section 10 of the Regulation.

4.3.2 Ensuring primary and secondary circuit integrity

In order to ensure primary and secondary circuit integrity:

1. *the primary circuit of a nuclear power plant shall be designed and manufactured in compliance with high quality standards so that the probability of hazardous faults in structures and that of mechanisms threatening their integrity remains extremely low and any faults which occur can be detected reliably through inspections;*
2. *the primary circuit of a nuclear power plant shall, with sufficient margins, withstand the stresses arising in normal operational conditions, anticipated operational occurrences, postulated accidents and design extension conditions;*
3. *the primary circuit of a nuclear power plant and systems immediately connected to it, and components important to the safety of the secondary circuit of a pressurised water reactor, shall be reliably protected during anticipated operational occurrences and all accident scenarios, in order to prevent damage caused by over-pressurisation;*
4. *the hydrochemical conditions in the primary circuit of a nuclear power plant and the secondary circuit of a pressurised water reactor shall not result in mechanisms that threaten their integrity; and*
5. *the facility shall be equipped with sufficient leak monitoring systems.*

The pressure-retaining interface of the Olkiluoto 3 nuclear power plant unit's primary circuit includes the reactor pressure vessel, main coolant lines (hot, intermediate and cold leg), pressurizer, pressurizer surge line, steam generators, main coolant pumps and other pipelines connected directly to the primary circuit. Inside the steam generator, the pressure-retaining interface of the primary circuit consists of the steam generator heat transfer tubes and the tube plate.

The core area of the reactor pressure vessel and its weld seams are the most critical points in terms of radiation embrittlement of the pressure vessel. For this reason, radiation embrittlement of the reactor pressure vessel has been taken into account in the design, and its probability has been minimised by design measures. Radiation embrittlement of the reactor pressure vessel has been reduced by means of material selections, by optimising the composition (low copper and phosphorus content), by increasing the distance between the outer shell of the reactor core and the inner surface of the reactor pressure vessel (water gap) and by installing a heavy reflector between the reactor core and reactor pressure vessel. The heavy reflector reduces the stress on the pressure vessel, returning some of the fast neutrons to the core area.

In addition, the capacity of the medium head safety injection system is beneficial in terms of the brittle fracture risk, since the emergency cooling system feeds water at a pressure significantly lower than the normal operating pressure, reducing the pressure stresses on the reactor pressure vessel wall, particularly when cold emergency cooling water cools down the pressure vessel and causes thermal stresses on the vessel wall.

The Break Preclusion (BP) principle has been used in the design and manufacture of the main coolant lines in order to rule out complete break of a main coolant line. The principle means ensuring the integrity of the main coolant circuit by means of strength analyses exceeding the normal requirements for Safety Class 1 pressure equipment, high quality requirements and a sufficient in-service inspection programme.

In addition, it has been demonstrated by strength analyses that the Leak Before Break (LBB) principle is met in the main coolant lines. The Leak Before Break principle means that any faults in the material are detected by means of leak monitoring before the main coolant line breaks completely, allowing the plant to be brought into a state where there is no risk of a complete break.

Whip restraints have been installed on the main coolant lines, preventing the whipping of broken parts in the event of a pipe break and reducing jets from broken pipes. At the same time, the solution limits loads and pressure transients conveyed internally from the break location to various parts of the primary circuit that have been used as design criteria when dimensioning the supports of the primary circuit main components, internals of the reactor pressure vessel, heat transfer tubes and other internals of the steam generator as well as flywheels of the main coolant pumps.

The internals of the primary circuit main components (reactor core support cage, control piping of the control rods, heat transfer tubes of the steam generators and rotating parts of the main coolant pumps) have been analysed as events external to design in terms of complete break of the main coolant line. These non-dimensioning analyses are performed using the best estimate methods, assumptions and criteria. It has been demonstrated by these that permanent deformations in the reactor internals are so minor that fuel cooling is not compromised, the heat transfer tubes of the steam generators do not lose their leak-tightness and the flywheels of the main coolant pumps do not cause damage as a result of over-speed.

In spite of the whip restraints, complete break of a main coolant line has been considered a dimensioning criterion in the thermalhydraulic design of the reactor and in dimensioning the capacity of the emergency cooling system, environmental condition qualification of equipment used in an accident, containment integrity against global pressure and temperature loads as well as integrity of the rooms surrounding the primary circuit against the pressure differences generated.

During the pre-operational testing of the Olkiluoto 3 nuclear power plant unit, it emerged that the vibration of the surge line of a pressurizer that is a part of the primary circuit exceeds the set criteria. The root cause of the vibration has been investigated by the plant supplier and TVO, but it has not been fully assured. The current perception is that the excitations in the primary circuit match the same frequencies as the characteristic frequencies of the surge line. The excitations can be acoustic, flow-induced or mechanical excitation and combinations thereof. It is not yet known with certainty how fuel loading will affect the vibration.

Vibration can be limited by different types of suppressors. The suppressing solution to be installed has not yet been selected. The primary solution for TVO is a viscose suppressor. Tests on the accident behavior of the bitumen contained in the viscose suppressor are still partially in progress. The tests will determine if the bitumen can interfere with the accident management when the suppressor tank breaks down in a pipe crash accident. If the safety of bitumen usage cannot be demonstrated, the alternative is to install a mass suppressor. There is no similar concern about the accident behavior of the mass suppressor. The functionality of the mass suppressor has been tested with an EPR unit built in China. There is also a mass suppressor planned for the EPR unit under construction in France. STUK's position is that the discussed solutions will dampen the vibration sufficiently, and the final choice can be made after the completion of the bitumen experiments. STUK will review the detailed plans of the solution chosen by TVO, oversee the progress of the work and verify before fuel loading that modifications necessary for safe operation have been implemented and the necessary tests have been performed.

In the design and construction of the secondary circuit pipes, the break preclusion principle has been used for feed water and main steam pipes inside the containment, and for main steam pipes up to the fixed points after the isolation valves outside the containment. At the fixed point, the pipes have been fastened to structures such that they cannot move (in contrast to normal pipe supports, which allow for movement caused by thermal expansion, for instance). The structures are capable of receiving forces tending to cause movement. In addition to this, whip restraints are used in the secondary pipes.

The measures taken to ensure the integrity of the primary circuit and secondary circuit are sufficient.

Overpressure protection

Operational occurrences during which steam flow into the turbine condenser is obstructed or reactor shutdown fails may cause an increase in primary and secondary circuit pressure. In these situations, the primary circuit pressure is limited to an acceptable level by using the pressurizer spray system and the pressurizer safety valves, if necessary. The opening pressures of the three safety valves have been staggered, and their design has taken into account the effects of non-condensable gases and the discharge of steam-water mixture and water. The design basis is that, during anticipated operational occurrences, the primary circuit safety valves do not open and the primary circuit design pressure of 176 bar (abs) is not exceeded. The same safety valves are used for primary circuit overpressure protection at low operating temperatures, in which case their opening pressure is reduced and electric control valves are used for their control.

On the secondary side, each steam generator has one relief valve and two safety valves. The relief valve capacity is sufficient during anticipated operational occurrences, and the pressure does not reach the opening limit of the safety valves. The secondary side pressure remains below the design pressure of 100 bar (abs).

During postulated accidents, the primary and secondary side design pressure can be exceeded by at most 10%. Design extension conditions allow exceeding the design pressure by 20%.

The overpressure protection analyses that form the basis for the dimensioning of the overpressure protection system use unfavourable assumptions under Guide YVL B.5: for example, some of the relief and safety valves are assumed to remain closed and the first scram limit is not assumed to trigger a scram.

The overpressure protection function meets the principle of diversity under Section 11 of the regulation. The relief valves and safety valves on the secondary side are of different types. It has been proven by analysis that, on the primary side, the reactor pressure will remain below the approval limit of 120% even if the safety valves have a common cause failure, if the pressurizer spray system and secondary side overpressure protection system are operating as intended.

STUK has commissioned comparison analyses regarding overpressure protection on the basis of which it has been noted that the acceptance criteria are met during both operational occurrences and postulated accidents.

The conclusion is that overpressure protection of the Olkiluoto 3 nuclear power plant unit’s primary circuit and systems immediately connected to it as well as the safety-significant components of the secondary circuit has been implemented as intended in Section 10 of the regulation.

Primary and secondary circuit hydrochemistry

The purpose of the hydrochemistry maintained in the primary circuit is to prevent the corrosion of the entire circuit and the surfaces of the fuel assemblies, thereby maintaining, for its part, the integrity of the pressure boundaries and the nuclear fuel cladding. Carefully designed chemistry can contribute to high availability and long service life, which in turn promote safety. Chemistry can also be used to assist in minimising the spread of activated corrosion products onto the surfaces of process systems. The creation of activation products and their spreading across the entire primary circuit can be substantially affected by choosing the main chemistry parameters (boron, lithium and hydrogen) correctly and controlling their concentration, thereby contributing to the radiation safety of the plant and its personnel.

The hydrochemistry of the primary circuit largely concerns controlling the chemical effects of boron. Boron solution is used in the coolant in order to capture thermal neutrons. The acidity of boric acid is neutralised by means of lithium hydroxide.

Reactor conditions also continuously give rise to water radiolysis reactions that release oxygen and short-lived radicals such as oxygen compounds. In order to prevent these effects, excess hydrogen is added to the coolant. The excess hydrogen diluted in the coolant also creates reductive conditions that minimise the oxidation of the basic materials in the primary circuit and nuclear fuel.

A common goal for the secondary circuit hydrochemistry is to ensure the high availability of the plant, the integrity of the primary and secondary circuit pressure boundaries, long service life and the prevention of corrosion phenomena, in particular the effects of erosion corrosion. The purpose of the hydrazine–ammonia hydrochemistry maintained in the secondary circuit is to prevent the corrosion of the entire circuit and, in particular, the structures of the steam generators, thereby maintaining the integrity of the circuit and its components and the protective oxide layers.

The monitoring of impurities in the water and steam circulation can significantly affect the creation and spreading of corrosion products in the water and steam circulation, the conditions created on the secondary side of the steam generators and, thereby, the heat transfer capacity. Water is being continuously blown off from the secondary side of the steam generators in order to remove accumulated impurities and corrosion products. The blow-off condensate is cleaned by means of mechanical filters and ion exchange before it is returned into the condenser. Blow-off has a substantial effect on the water quality of the steam generators and the amount of impurities. The amount of corrosion products that may accumulate in the steam generators can also be reduced with the mechanical 100% condensate cleaning that has been connected to the feedwater system.

There is plenty of international operating experience available concerning the primary and secondary circuit hydrochemistry selected for the Olkiluoto 3 nuclear power plant unit.

The conclusion is that the hydrochemistry of the Olkiluoto 3 nuclear power plant unit has been implemented as intended in Section 10 of the regulation.

Leak monitoring systems

Leak monitoring systems have been installed in parts of the containment of the Olkiluoto 3 nuclear power plant unit that are closed during the operation of the plant. This enables the monitoring of any leaks from the primary circuit as well as the main feed water and steam lines. The integrity of the main coolant lines, main feed water lines and steam lines has been ensured during design by applying the Leak Before Break (LBB) principle. The leak monitoring systems have been designed to detect leaks caused by fracture-type failures resulting from loads during operation. Leaks can be detected by the leak monitoring systems before the failure poses a risk to the structure.

The systems measure the air humidity and temperature in the containment. In addition, they measure the amount of condensate from air conditioning coolers. The measurements enable starting repair work before the fracture grows and becomes critical to plant safety.

The Technical Specifications of the plant unit present requirements for bringing the plant to a safe state if the system measurements indicate a leak from the primary circuit on the basis of humidity or the amount of condensate from air conditioning.

The Technical Specifications also set requirements for the operability of the leak monitoring systems. The operation and leak detection sensitivity of the leak monitoring systems shall be tested in connection with the plant's commissioning tests.

The conclusion is that the leak monitoring of the Olkiluoto 3 nuclear power plant unit has been implemented as intended in Section 10 of the regulation.

Summary

The conclusion is that ensuring the primary circuit integrity of the Olkiluoto 3 nuclear power plant unit has been implemented as intended in Section 10 of the regulation.

4.3.3 Ensuring containment integrity

In order to ensure the containment integrity:

1. *the containment shall be designed to maintain its integrity during anticipated operational occurrences and, with a high degree of certainty, during all accident conditions;*
2. *pressure, radiation and temperature loads, radiation levels inside the plant, combustible gases, impacts of missiles and short-term high-energy phenomena resulting from an accident shall be considered in the design of the containment; and*
3. *the possibility of failure of the reactor pressure vessel in a severe accident so that the leak-tightness of the containment would be endangered shall be extremely small.*

The inner containment of the Olkiluoto 3 nuclear power plant unit, lined with steel liner, is not subjected to particular loads during normal operation or operational occurrences. The containment has been dimensioned according to loads caused by postulated accidents, taking into account the radiation, pressure and temperature loads during a severe reactor accident. The containment has been designed to withstand a large break in the primary circuit. Any possible local loads generated during accidents have also been taken into account.

The containment is equipped with a personnel airlock, emergency airlock and material hatch. The leak-tightness of the containment shall always be taken into account when passing through the airlock by keeping one of the airlock doors closed at all times. Closing the material hatch in the event of accidents during outages has been taken into account, and the leak-tightness of the containment can be ensured. The leak-tightness and operation of all containment penetrations and openings can be regularly tested. The durability and leak-tightness of the entire containment against the design pressure have been assured by pre-commissioning pressure and tightness test, after which the leak-tightness shall be periodically tested by means of a containment leakage test.

During severe reactor accidents, ensuring the integrity of the containment in the short term is based on its high volume and pressure tolerance as well as the management of molten core material, which is described in Chapter 4.3.4 below. In the long term, the integrity of the containment has been ensured by means of an active heat removal system, which transfers the decay heat from the molten core material into the sea via a separate cooling circuit. Overpressure caused by non-condensable gases is removed through a filtered venting system. During core melt accidents, the fuel cladding material is oxidised, forming hydrogen, which is removed from the containment using passive autocatalytic recombiners. In the recombiner, the hydrogen reacts with oxygen in a controlled manner, preventing the formation of the hydrogen content which could allow an explosion. Hydrogen fires may occur if substantial amounts of hydrogen are generated, but these do not pose a risk to the integrity of the containment.

Rupture of the reactor pressure vessel at high pressure, which would endanger the leak-tightness of the containment, has been practically prevented by means of a reliable pressure reduction system in the primary circuit.

The conclusion is that ensuring the containment integrity of the Olkiluoto 3 nuclear power plant unit has been implemented as intended in Section 10, item 3C of the regulation.

4.3.4 Stabilisation and cooling of molten core material

A nuclear power plant shall be equipped with systems to ensure the stabilisation and cooling of molten core material generated during a severe accident. Direct interaction of molten core material with the load bearing containment structure shall be reliably prevented.

The design of the EPR plant type includes preparations for severe reactor accidents by equipping the plant with a passive molten core management system. The molten core management strategy is based on the stabilisation and cooling of the molten reactor core in the spreading area inside the containment and on preventing the direct interaction of molten core material with the containment structures.

During a severe accident, molten core material flows from the reactor pressure vessel into the reactor pit, from which it proceeds, after delaying, to the spreading area via the discharge channel. The reactor pit, discharge channel and molten core spreading area are lined with sacrificial materials that, when mixed with the molten core, reduce the thermal load on the spreading area structures and contribute to preventing the direct interaction of molten core material with the containment structures. The spreading area and molten core material are cooled down with water, which transfers the decay heat power from the molten core into the ultimate heat sink.

The plant safety analyses have presented justifications for the molten core management strategy. Loads on the containment caused by the stabilisation and cooling of molten core material as well as the effect of molten core material on the reactor pit and the structures around the core catcher have been analysed. The analyses have also addressed re-criticality, molten core material spreading and cooling in the short and long term. Plenty of experimental research has been carried out to verify the measures for managing severe reactor accidents, and this is described in subsection 6.2.2 (Section 21) of the safety assessment.

The core melt stabilisation system ensures the stabilisation and cooling of molten core material during severe accidents.

The conclusion is that the stabilisation and cooling of molten core material in the Olkiluoto 3 nuclear power plant unit has been implemented as intended in Section 10, item 4 of the regulation.

4.4 Safety functions and provisions for ensuring them (Section 11)

In ensuring safety functions, inherent safety features attainable by design shall be primarily utilised. In particular, the combined effect of a nuclear reactor's physical feedback characteristics shall be such that it mitigates the increase in reactor power.

If inherent safety features cannot be utilised in ensuring a safety function, priority shall be given to systems and components which do not require a power supply or which, in consequence of a loss of power supply, will settle in a state preferable from the safety point of view.

In order to prevent accidents and mitigate the consequences thereof, a nuclear power plant shall be provided with systems for shutting down the reactor and maintaining it in a sub-critical state, for removing decay heat generated in the reactor, and for retaining radioactive materials within the plant. Design of such systems shall apply redundancy, separation and diversity principles that ensure implementation of a safety function even in the event of malfunctions.

The most important safety functions necessary to bring the plant to a controlled state and to maintain it must be ensured even if any individual component of a system providing the safety function is inoperable and even if any other component of a system providing the same safety function or of a supporting or auxiliary system necessary for its operation is simultaneously inoperable due to the necessity for its repair or maintenance.

Common cause failures shall only have minor impacts on plant safety.

A nuclear power plant shall have off-site and on-site electrical power supply systems to cope with anticipated operational occurrences and accidents. It shall be possible to supply the electrical power needed for safety functions using either of the two electrical power supply systems.

A nuclear power plant shall have the necessary components and procedures for securing the removal of decay heat from the fuel in the reactor and the spent fuel inside the storage pools for a period of three days independently of the off-site supply *of electricity and water in a situation caused by a rare external event or a disruption in the on-site electrical distribution system.*

The management of severe reactor accidents and the monitoring of the plant's status during severe accidents shall be implemented by means of systems that are independent of the systems designed for normal operation, anticipated operational occurrences and postulated accidents. The leak-tightness of the containment during a severe reactor accident shall be reliably ensured.

The plant shall be designed so that it can be brought into a safe state after a severe accident.

The most important safety functions of a nuclear power plant are reactor shutdown, removal of decay heat and retaining radioactive substances in the containment. The design and implementation of the Olkiluoto 3 nuclear power plant unit utilises inherent safety features to execute the aforementioned safety functions on the same level as in most other pressurised water reactors that are in operation. The amount of water contained in the nuclear power plant unit's steam generators ensures that, during a complete loss of AC power, for example, there is enough time to start the safety functions.

The reactor is stopped during operational occurrences with control rods that are dropped into the reactor core by gravity. The control rods drop into the reactor core as a result of loss of control power or when the I&C system disconnects the control power. Decay heat is discharged into the secondary circuit by means of the primary circuit's natural circulation due to differences in water density. Reactor emergency cooling is participated in by pressure accumulators pressurised by nitrogen gas that do not require an external power source. Overpressure protection of the primary and secondary circuit has also mainly been implemented without safety valves requiring an external power source.

The leak-tightness of the containment during a severe reactor accident is, in the short term, based on its high volume and pressure tolerance. Management of the molten reactor core is carried out using passive safety functions, which ensure the stabilisation and cooling of molten core material in the spreading area. In addition, the plant's hydrogen management has been implemented using passive functions, and hydrogen removal using autocatalytic recombiners is carried out without an external power source.

Reactor-physical feedback loops determining the stability of the reactor are designed on an operating cycle-specific basis such that they mitigate the increase in reactor power in the allowable operational states.

In addition to the aforementioned functions that take place without an external power source, the Olkiluoto 3 nuclear power plant unit has in place many active systems that execute safety functions. These systems require electricity to function and consist of several redundant systems.

Functions of the Olkiluoto 3 nuclear power plant unit's protection system for which an unambiguously safe state can be defined, such as the reactor scram, turbine trip and the closing of the main steam isolation valves, have been implemented such that, in a situation where operating power is lost, they enter a state that is favourable from the perspective of safety.

At the Olkiluoto 3 nuclear power plant unit, the reactor is shut down and kept subcritical using control rods and by increasing the boron concentration of the coolant. Control rods can be inserted into the reactor core using electromechanical actuators or by disconnecting the power supply to the control rod actuators, in which case the control rods are dropped into the reactor core by gravity. The reactor can also be shut down using a boron injection system, which meets the principle of diversity. To remove the decay heat generated in the reactor, there are redundant arrangements that meet the principles of separation and diversity. To prevent the spreading of radioactive materials, the Olkiluoto 3 nuclear power plant unit is equipped with redundant, consecutive dispersion barriers.

To ensure the cooling of fuel in the event of primary circuit leaks, the plant has an emergency cooling system consisting of four parallel subsystems fully separated from each other. During postulated accidents, each subsystem alone is capable of performing the emergency cooling safety function. Each subsystem has a medium-pressure and low-pressure section that can be used to pump boron-containing water into the primary circuit from a coolant tank located inside the containment. The coolant tank is at the bottom of the containment, so any water that leaks into the containment from the primary circuit is drained back into the tank. The low-pressure system also includes four passive, pressurised emergency makeup water tanks. The low-pressure system is equipped with heat exchangers, through which decay heat generated in the reactor can be transferred into the ultimate heat sink instead of using steam generators to transfer it.

Jet forces relating to possible primary leaks are harmful to thermal insulation, which has been installed into the containment to reduce heat loss (from the primary circuit and secondary circuit, for instance). Other loose material may also start moving due to the jet forces and flooding caused by the leak. Materials carried by water could damage the safety injection pumps or hinder the cooling of the reactor. To minimise the harmful effects, water entering the intake of the safety injection pumps is filtered using filters installed in the coolant tank, and the filters can be cleaned by flushing if necessary.

The safety functions of the Olkiluoto 3 nuclear power plant unit have been designed in accordance with the principle of redundancy. Deterministic safety analyses have demonstrated that systems implementing safety functions can manage operational occurrences and accidents, taking into account the inoperability of an individual piece of equipment and repairs or maintenance required by another piece of equipment, meeting the acceptance criteria set.

Preparations for common cause failures have been made in the design of the Olkiluoto 3 nuclear power plant unit by following the principle of diversity. The effects of common cause failures have been analysed as design extension conditions. These analyses have demonstrated that the nuclear power plant unit shall survive the most common class 1 accidents even in the event of a common cause failure in a safety system of primary importance for managing the situation.

The Olkiluoto 3 nuclear power plant unit has external electricity supply systems from 400 kV and 110 kV grids. If connections to both transfer networks are lost and no power supply is available from the nuclear power plant unit's own generator, the plant unit has four emergency diesel generators for ensuring internal power supply. To prepare for a common cause failure of the emergency diesel generators, there are two station blackout diesel generators meeting the principle of diversity that can be started if required. In addition, there is a gas turbine plant in the plant area that can be connected to supply loads significant to safety.

On the basis of the Fukushima Dai-ichi nuclear power plant accident and the disruption in electricity supply at Forsmark in 2006, the Government Decree on the Safety of Nuclear Power Plants 717/2013 (with an equivalent requirement currently presented in Regulation STUK Y/1/2016) was amended to include a requirement on decay heat removal in similar situations. According to the requirement, it must be possible to remove fuel decay heat for three days regardless of the supply of power and water from outside the plant. The requirement applies to both fuel in the reactor and spent fuel in the storage pools.

The requirement was not included in the original design bases of the Olkiluoto 3 nuclear power plant unit. However, the possibilities of feeding water in order to remove the decay heat of the fuel in the reactor were already improved in the construction licence phase, when preparations were made for the loss of the ultimate heat sink by adding fixed connections through which the emergency feed water tanks can be filled using the demineralised water distribution system. The water reserve in the emergency feed water tanks is sufficient for 24 hours, and the addition of demineralised water ensures that the 72-hour self-sufficiency criterion is met.

Heat transfer through the secondary circuit is not possible in all shutdown states. In this case, the decay heat generated by the fuel in the reactor is removed by boiling water into the reactor building and replacing the boiled water with water from the IRWST tank (in-containment refuelling water storage tank).

Decay heat removal of the fuel in the fuel pools is based on boiling the water in the pools if the cooling of the pools has been lost. Replacement water can be taken from the fire water system, for instance. The fire water system has enough water to fulfil the three-day criterion.

TVO has planned arrangements for the Olkiluoto 3 nuclear power plant unit that can be used to ensure decay heat removal during a loss of alternating current supply. The procedure includes the acquisition of replacement units for output units feeding equipment significant for safety functions and placing these such that any faulty electricity supply components can be rendered operable within a reasonable time. The arrangements shall be implemented at the nuclear power plant unit during the maintenance outage after the warranty period (start of commercial operation + 2 years). Due to the rarity of the situation, implementing the arrangement was not considered particularly urgent. The purpose of this schedule is to avoid risks caused by any solutions unintentionally impairing safety due to hurried design changes.

The design basis of the Olkiluoto 3 nuclear power plant unit is preparation for severe reactor accidents. Systems have been designed for the nuclear power plant unit that can be used to bring it to a safe state after a severe reactor accident and ensure the integrity and leak-tightness of the containment. In designing these systems, particular attention has been paid to independence of the nuclear power plant unit's other systems. For measures to manage severe accidents, such as monitoring the progress of severe accidents and implementation of safety functions as well as performing the necessary controls, the Olkiluoto 3 nuclear power plant unit has single-failure tolerant systems independent of the nuclear power plant unit's other systems. Overpressure caused by non-condensable gases during a severe accident is removed through a filtered venting system, making it possible to reduce the pressure difference over the containment's pressure interface to a level corresponding to a safe state after a severe accident.

The conclusion is that the safety functions of the Olkiluoto 3 nuclear power plant unit have been verified as intended in Section 11 of Regulation STUK Y/1/2016, taking into account the transitional provision in Section 27 of the Regulation of the Radiation and Nuclear Safety Authority regarding the self-sufficiency criterion presented in Section 11, item 7 of the regulation.

4.5 Safety of fuel handling and storage (Section 12)

Adequate fuel cooling and radiation protection shall be ensured when handling and storing nuclear fuel.

Nuclear fuel storage conditions shall be maintained such that the leak-tightness or mechanical endurance of a fuel assembly is not substantially degraded during the planned storage period.

Damage to the cladding of the fuel assemblies during handling and storage must be prevented with a high degree of confidence.

The possibility of a criticality accident shall be extremely small.

The probability of a severe accident shall be extremely low.

At the Olkiluoto 3 nuclear power plant unit, fresh fuel is first kept in dry storage, from where it is moved to the water pools in the fuel building. Spent fuel is stored in water pools. For the draining the pool, it can be divided into two sections, either of which can accommodate all of the fuel stored in the pool. Radiation shielding is based on keeping the fuel under water.

For cooling the fuel pools, there are cooling systems with parallel subsystems and additional systems to be used in the event of failure. If the actual fuel pool cooling system is lost as a result of, for example, complete loss of heat sink or loss of the external electrical grid and emergency diesel generators, the fuel pools shall be cooled by vaporising water from the pools and feeding make-up water into the pools using the fire water distribution system, fuel pool cleaning system or demineralised water distribution system.

The composition of water in the fuel storage pools is monitored and the water is cleaned using systems designed for this purpose. This is to ensure that the storage conditions do not harm the leak-tightness of the fuel assemblies. The storage racks in the pools have been designed to minimise damage to the fuel as a result of, for example, abrasion, bending or twisting. In order to ensure the integrity of the fuel assemblies stored on the storage racks, the lifting and transfer equipment has been designed to ensure a low risk of the load falling. This has been implemented using, for example, redundancy of the hoist ropes and two mutually independent means of gripping the fuel assembly. Furthermore, the paths of heavy lifting measures have been planned to avoid transfer above the storage pools.

The criticality safety of fuel on storage racks has been ensured in both the dry storage of fresh fuel and the fresh and spent fuel racks. The criticality safety is primarily based on fixed absorption structures. In addition, boron has been added to the water in the fuel pools, acting as a parallel absorber in relation to the fixed structures. Nevertheless, the fuel on the racks remains subcritical even if the pools are filled with clean, boron-free water. However, if a fuel assembly is erroneously placed upright outside the rack, a small amount of boron in the water is required to ensure subcriticality. The required amount is significantly lower than the boron concentration during normal operation, though. Based on this, it can be stated that the risk of a criticality accident is very low.

The risk of severe accidents has been minimised in the design. The design has considered, among other things, hazardous situations caused by lifting heavy loads, loss of fuel pool cooling, sufficient leak monitoring of the fuel pools and placement of pipeline connections to the fuel pools higher than the fuel racks.

The conclusion is that the safety of fuel handling and storage at the Olkiluoto 3 nuclear power plant unit has been implemented as intended in Section 12 of the regulation.

4.6 Protection against external hazards affecting safety (Section 14)

The design of a nuclear power plant shall take account of external hazards that may endanger safety functions. Systems, structures and components shall be designed, located and protected so that the impacts of external hazards deemed possible have only a minor impact on plant safety. The operability of systems, structures and components shall be demonstrated in their design basis external environmental conditions.

External hazards shall include exceptional weather conditions, seismic events, impact of accidents taking place in the plant's vicinity and other factors resulting from the environment or human activity. The design shall also consider unlawful actions with the aim of damaging the plant and a large commercial aircraft crash.

The design and dimensioning of the Olkiluoto 3 nuclear power plant unit has been based on ensuring that the sufficient operation of systems, structures and equipment needed for managing the plant is not compromised by external events. Particular attention has been paid to the ability to shut down the reactor and keep it in a controlled state also after the worst external events considered possible and in extreme environmental conditions.

External events could affect the safety of the plant unit in many different ways if not taken into account in designing the plant. For example, strong winds, blizzards or exceptionally high outdoor temperatures could cause problems in the external electrical grid connection; voltage or current pulses caused by lightning could damage the electrical and I&C systems; a blizzard could clog the combustion or cooling air intakes of emergency diesel generators; impurities in seawater could clog the supply of cooling water to the safety systems; and mechanical vibrations caused by an earthquake could damage the structures or equipment.

Conventional technical design methods have been used to protect the plant unit against external events, and the result has been assessed through both deterministic safety analyses and probabilistic risk assessment (PRA).

The selection of external events handled in the design of the plant unit and the safety analyses is based on site-specific review that takes into account domestic and international operating experiences as well as lists included in regulations and research reports regarding external events that could affect the safety of a nuclear power plant.

The design and safety analyses have also taken into account the consequences of external events at the plant unit and the possibility of simultaneous external events. Structural analyses have dealt with load combinations relating to simultaneous events. Probabilistic risk assessment has been used to identify simultaneous events affecting safety (multiple external events) and assess their effects on the operation of safety systems.

Various means have been used to protect the Olkiluoto 3 nuclear power plant unit against external events: sufficient design bases against the worst possible situations, separating redundant safety systems by protective structures or sufficient distances (for example, large aircraft crash) and particular protection systems (for example, lightning protection).

Extreme weather phenomena and other natural phenomena

The design of the Olkiluoto 3 nuclear power plant unit has considered, among other things, the following weather phenomena and comparable conditions: low and high outdoor air temperatures, air humidity, strong winds and objects loosened and/or carried by wind, low and high seawater temperatures, low and high seawater levels, rain and snow, lightning, clogging of seawater intake by ice, frazil ice, objects, aquatic plants or animals (algae, clams, fish) or oil releases, and clogging of air intakes due to a blizzard, for instance. Combinations of weather phenomena considered possible have also been reviewed.

The loads and capacity requirements caused by extreme weather phenomena have been taken into account in designing all safety-significant systems. Design bases relating to weather phenomena and other natural phenomena have been specified and assessed relying on the connection between the intensity and annual probability of the phenomena. The initial data used in the analyses includes weather phenomena and sea level measurement series at the plant site and in its vicinity. The analyses have been performed in cooperation with specialist organisations, such as the Finnish Meteorological Institute, at the licence holder’s initiative, and as part of the Finnish Research Programme on Nuclear Power Plant Safety, SAFIR. As regards extreme temperatures and wind speeds in whirlwinds, the design basis of the plant unit does not include very high margins compared to the highest values measured near the site. With regard to these phenomena, the safety effects of exceeding the design bases have also been reviewed. On the basis of the analyses, the safety of the plant unit would not be compromised even if the design bases were exceeded significantly.

Preparations have been made for loss of the external electrical grid connection using several emergency power supplies at the plant site (diesel generators, gas turbines). In order to prevent the clogging of the air intakes of air conditioning and the diesel engines of emergency power supply generators, the intakes shall be protected by means of structural solutions and, on the other hand, power supply has been ensured using several redundant and different power sources. Problems caused by lightning shall be prevented using a lightning protection system.

The design of the plant unit has also prepared for the loss of seawater cooling due to clogged water intakes. The clogging may be due to impurities in the seawater (algae, other biological impurities, large oil release). Screens and mechanical filters have been used to prepare for seawater impurities. Oil releases are covered in the section on threats relating to human activities. The clogging risk of seawater intakes due to frazil ice, or the sudden freezing of supercooled water, is prevented at the plant unit by circulating warmed water from the discharge side into the seawater intake channel. If the primary seawater intake is clogged, seawater can alternatively be taken for safety systems from the discharge side of the seawater systems.

In addition, the plant unit has prepared for three-day loss of seawater cooling due to external events or internal failures. Decay heat from the Olkiluoto 3 nuclear power plant unit could be removed via the secondary circuit directly into the atmosphere for several days. The emergency power supply generators of the plant unit are air-cooled, so the loss of seawater cooling does not affect their operation.

According to probabilistic risk assessment of the Olkiluoto 3 nuclear power plant unit, the proportion of weather phenomena and other aforementioned external events of the plant unit’s core damage frequency is a few per cent.

Preparation for extreme weather phenomena and other environmental conditions has been carried out to a sufficient degree at the Olkiluoto 3 nuclear power plant unit.

Earthquakes

Violent earthquakes are very rare in Finland, for which reason no particular seismic design is required in ordinary construction projects. However, seismic design requirements have been set for nuclear power plants.

The dimensioning earthquake used for the design of nuclear power plants has been specified such that its probability at the plant site is estimated to be once every 100,000 years at the most. For the design, earthquakes are measured in terms of peak ground acceleration (PGA) at the plant site. The assessment is based on observations made in Finland and nearby areas as well as basic geological information about the area. The Olkiluoto plant site’s estimated horizontal peak ground acceleration is lower than the IAEA’s recommended minimum value of 0.1 g ($g = 9.81\ m/s^2$), so the peak ground acceleration used as the design value is 0.1 g.

The systems, structures and equipment of the Olkiluoto 3 nuclear power plant unit are classified in terms of earthquake resistance. The classification is described in more detail in subsection 2.2. Parts of the plant unit implementing safety functions have been designed to fulfil their purpose even after a dimensioning earthquake. On the basis of common experimental and analytical information regarding the effects of earthquakes, it has been assessed that the occurrence of damage endangering nuclear safety would require an earthquake substantially more violent and rarer than the dimensioning earthquake.

The general principles followed in the seismic design of the Olkiluoto 3 nuclear power plant unit are acceptable. Earthquake resistance has been demonstrated by means of detailed analyses in connection with construction plans or in vibration resistance tests on the equipment. In September 2017, there was a seismic walkdown at the plant, ensuring the appropriateness of the seismic support and fastening solutions of the structures and equipment and ensuring that earthquakes do not cause interaction between different systems that could impare safety. STUK took part in the walkdown and has approved TVO's walkdown report.

The effects of earthquakes on the safety of the Olkiluoto 3 nuclear power plant unit have also been analysed in connection with the probabilistic risk assessment. The proportion of earthquakes of the plant unit's core damage frequency is about one per cent. Preparation for earthquakes has been carried out to a sufficient degree at the Olkiluoto 3 nuclear power plant unit.

Threats relating to human activities; unlawful action, aircraft crash

There are no industrial facilities, storages, transport routes or military facilities in the immediate vicinity of the Olkiluoto plant site that might compromise the safety of the plant unit due to explosions or toxic, corrosive or flammable chemical emissions. As regards oil releases from marine accidents, it can be noted that there are no routes used for large-scale oil transport in the immediate vicinity of the plant. Therefore, in the event an oil release, there would be time to shut down the plant and protect it by means of oil booms, for example. TVO has an agreement with the local emergency response centre ensuring that the power plant is notified of any oil releases.

The plant has also been designed to withstand unlawful action. In particular, the design has prepared for external threats, such as aircraft crash, electromagnetic interference and chemical and biological poisons. The plant's security arrangements (preventing unlawful actions and restricting their effects) are described in more detail in Chapter 8 in accordance with the applicable regulation, STUK Y/3/2016.

The requirement concerning preparation for the crashing of a large commercial aircraft was presented during the decision-in-principle stage of the design of the Olkiluoto 3 nuclear power plant unit, after the terrorist attacks in the United States on 11 September 2001. The amendment to the preliminary safety review stated the following: "*The effects of a crash must be assessed for both large passenger aircraft and military aircraft. The objective is to achieve technical solutions that need not be changed later, even if there are changes in aircraft technology or traffic volumes during the expected service life of at least 60 years.*" Later, the requirement concerning preparation for the crashing of a large commercial aircraft was included in the binding regulations.

The Olkiluoto 3 nuclear power plant unit is protected against the crashing of various aircraft, including a large commercial aircraft. The protection is based partially on reinforcing the buildings to withstand an aircraft crash and partially on locating safety systems at a sufficient distance from each other or in buildings on different sides of the plant unit on which an aircraft cannot crash at the same time. The design has also considered parts coming loose from the aircraft or buildings, drop formation and explosive combustion of aircraft fuel as well as loads on the safety system equipment from vibrations caused by the crash. The effects of an aircraft crash have been assessed by means of calculations, in addition to which, for example, VTT Technical Research Centre of Finland has conducted crash tests and experimental assessments of the drop formation of fuel.

The design of the Olkiluoto 3 nuclear power plant unit has also considered explosion pressure waves. Pressure waves may result from intentional damage to the plant or from external events, such as the breakage of large pressure vessels as a result of an earthquake.

Regulation STUK Y/3/2016 presents more detailed requirements concerning preparation for unlawful action, and their realisation is assessed in Chapter 8.

Analyses conducted due to the Fukushima incident

The Fukushima Dai-ichi incident in 2011 resulted in the rapid commencement of domestic safety analyses regarding external threats as well as extensive stress tests in the EU countries. The analyses did not identify new external threats or the need to take immediate action, but a decision was made to increase the plant's self-sufficiency in the event that power supply is lost. Safety improvements include the opportunity to feed water from the fire water system into the emergency feed water tanks using diesel pumps, feeding water into the fuel pools using moveable hoses and pumps as well as the opportunity to transfer fuel from the emergency diesel generator storage tanks to the station blackout diesel generator.

Conclusion

The conclusion is that external events endangering the safety functions at the Olkiluoto 3 nuclear power plant unit have been taken into account as intended in Section 14 of the regulation.

4.7 Protection against internal hazards affecting safety (Section 15)

The design of a nuclear power plant shall take account of any internal hazards that may endanger safety functions. Systems, structures and components shall be designed, located and protected so that the probability of internal hazards remains low and impacts on plant safety minor. The operability of systems, structures and components shall be demonstrated in the room specific environmental conditions used as their design bases.

Internal hazards to be considered include at least fire, flood, explosion, electromagnetic radiation, pipe breaks, container breakages, drop of heavy objects, missiles due to explosions or component failures, and other possible internal hazards.

4.7.1 Internal events

Fires

The functional and layout design of the Olkiluoto 3 nuclear power plant unit has considered fires and the related risk of a nuclear power plant accident. The redundancy, diversity and separation principles that guided the design of the plant also protect it against the consequences of a fire. The design of the plant's structural and active fire protection has utilised the defence-in-depth principle and conventional technical design solutions. The fire protection defence-in-depth principle refers to the prevention or restriction of the consequences of fire using consecutive protection levels, which are preventing combustion, detecting and extinguishing the fire, preventing the development and spreading of the fire and restricting the effects of the fire such that the safety functions can be reliably implemented regardless of the effects of the fire.

The safety systems have been divided into parallel subsystems in four safety divisions, which are primarily located in different safeguard buildings, and further into separate fire compartments. In addition, the buildings have been divided into fire compartments based on floor and mode of operation compartmentation. Large fire loads have also been placed in separate fire compartments. Due to the layout decisions, in exceptional cases, it has been necessary to route individual cables partially via another safety division. Safety-significant cables have been protected for the entire distance that they run in the other safety division.

Separating the subsystems into different safety divisions is not possible in all parts of the plant. Such spaces include the containment, the annular space between the inner and outer containment and the main control room. In these spaces, fire protection has been implemented by other means:

- In the containment, the subsystems have mainly been separated from each other by a sufficient distance and protective structures, since there are no separate fire compartments in the containment. In the containment, a fire endangering the operability of the subsystems of safety systems would be a situation in which a significant part of the lubrication oil volume in the main coolant pump's motor leaks onto the floor and catches fire. To prevent this, the spreading of the oil in the event of a leak has been restricted using protective enclosures for the most significant potential leak spots. It has been demonstrated by fire hazard analyses that, thanks to the protective enclosures, a restricted oil fire in the main coolant pump does not endanger the safety functions.
- The annular space between the inner and outer containment has been divided into areas such that parallel subsystem assemblies have been separated by a sufficient distance and fire barriers. It has been demonstrated by analyses that the failure of the cables or equipment of two subsystems due to fire is highly unlikely.

- Cables from all four subsystems of the safety systems are connected to the main control room and cannot practically be separated into their own safety divisions in the control room. For this reason, the cable space below the main control room has been protected with a gas fire-extinguishing system.

Other systems, structure and components that mainly serve the normal operation of the plant unit are located in their own buildings, such as the turbine building, switchgear building, auxiliary building and storage room for radioactive waste, so any fires in these buildings shall not prevent the implementation of the safety functions.

The Olkiluoto 3 nuclear power plant unit uses cables of the FRNC type (flame retardant, non-corrosive). The material properties and fire behaviour of the cables were assessed by means of a research programme ordered by the Radiation and Nuclear Safety Authority, which included small and medium-scale burning tests and fire simulations of the most important rooms. The research showed that the spread of cable fire is slow, the development of a large-scale fire in cable rooms is very unlikely and fire cannot endanger the functionality of fire compartmentation. Based on this, it is not necessary to protect cable spaces by means of fixed extinguishing systems.

Spaces containing large fire loads have been protected with fixed extinguishing systems. The main coolant pumps, diesel generators, diesel generator fuel tanks, large transformers and parts of the turbine building have been protected with fixed water-extinguishing systems. The cable space below the main control room has been protected with a gas fire-extinguishing system.

To prepare for a fire in the main control room, the plant has an independent remote shutdown station in accordance with Section 16 of Regulation STUK Y/1/2016. It has been demonstrated by fire hazard analyses that a single fire cannot endanger the operability of both the main control room and the remote shutdown station.

The most important electrical facilities and cable spaces in the safeguard buildings have been equipped with a smoke extraction system to facilitate operative fire protection and prevent the spreading of smoke.

The sufficiency of fire protection at the Olkiluoto 3 nuclear power plant unit has been demonstrated by deterministic fire hazard analyses. The sufficiency of the fire resistance of the structures has been demonstrated by building-specific, structural fire hazard analyses. Items important to plant safety have also been subjected to functional fire hazard analyses, which have shown that the plant can be shut down and cooled down into a safe state. The fire safety of the plant has also been assessed by means of a probabilistic risk assessment (fire PRA).

Floods

The design and dimensioning of the Olkiluoto 3 nuclear power plant unit has been based on ensuring that the sufficient operation of systems, structures and equipment needed for managing the plant is not compromised by internal floods.

Conventional technical design methods have been used to protect the plant unit against internal floods, and the result has been assessed through both deterministic safety analyses and probabilistic risk assessment (PRA).

Various means have been used to protect the Olkiluoto 3 nuclear power plant unit against internal floods: sufficient design bases against the worst possible flood situations, separating redundant safety systems by sufficient distances, restricting the spreading of floods between safety divisions, water routes to control flooding within a single safety division, leak monitoring systems to detect leaks and personnel actions to prevent leaks.

The safety analyses have taken into account the water volumes contained by the various systems, the possible flood spreading routes and the consequences of a flood at the plant unit. It has been demonstrated by analyses that the consequential effects of internal floods can be reliably restricted and that floods cannot endanger the load-bearing capacity of structures or the implementation of safety functions.

Pipe breaks

At the Olkiluoto 3 nuclear power plant unit, breaks in high-energy pipes have been taken into account such that they shall not endanger the operation of the safety systems needed in these cases. High-energy pipes are pipes containing water or steam whose pressure during the normal operation of the plant unit is over 20 bar or whose temperature is over 100 °C. In addition, pipes containing gas are always considered high-energy pipes. In plant unit facilities where complete physical separation into different rooms is not possible, structures have been installed to protect the safety system equipment from the effects of pipe breaks.

Loads falling

Heavy loads are lifted and moved during annual outages and other possible maintenance work at the nuclear power plant. Examples of heavy loads at the Olkiluoto 3 nuclear power plant unit include the cover unit of the reactor pressure vessel (195 t), reactor internals (120–180 t) and cover slabs (80 t). The falling of loads is prevented with a high degree of confidence by means of the design of the hoisting and transfer equipment, proper procedures for operation, competent personnel and condition monitoring of the equipment. In addition, the consequences of the falling of loads are minimised by designing the transfer routes and heights as well as administrative restrictions. The separation of the subsystems of safety systems by means of sufficient distances and structures also helps to mainly restrict the consequences of the falling of a load to a single subsystem. The separation principle of subsystems cannot be fully applied in the containment, in the annular space between the inner and outer containment or in the fuel building.

STUK has demanded that analyses regarding the falling of heavy loads take into account all safety-significant loads and lifting routes and heights as well as analyse the consequences of the falling of a load for systems, structures and equipment. As regards safety-significant buildings, it has been demonstrated by structural analyses and building-specific assessment reports that the concrete slab or other structure under a falling load withstands the impact from the fall. In buildings where it has not been possible to demonstrate sufficient resistance, heavy lifting shall only be performed once in the construction phase or the lifting height shall be restricted using accessories (small loads during operation). In addition, safety analyses have demonstrated that the falling of loads does not prevent shutting down the reactor into a safe state. They have also shown that as a consequence of a falling load, no event sequences leading to fuel melting are created in the reactor pressure vessel or fuel building pools, and in falls leading to mechanical damage of fuel, no radioactive emissions are created that exceed the limit values.

Explosions and missiles

The design and dimensioning of the Olkiluoto 3 nuclear power plant unit has been based on ensuring that the sufficient operation of systems, structures and equipment needed for managing the plant is not compromised by explosions or missiles.

Conventional technical design methods have been used to protect the plant unit against internal explosions and missiles, and the result has been assessed through deterministic safety analyses.

Explosions are covered in the analyses of the phenomena causing them. Detonations resulting from fire loads, arcs in power cables and burst pressure waves from pressure equipment are covered in connection with the assessment of the sufficiency of fire compartmentation. Vibration phenomena from aircraft crashes and explosions are covered in connection with earthquake resistance reviews.

Leaks caused by equipment breakage are covered in connection with the probabilistic risk assessment (PRA) as loss-of-coolant accidents or flood situations. Correspondingly, fires caused by explosions are included in the fire PRA. Probabilistic risk assessment is covered in Chapter 2.1.2.

Various means have been used to protect the Olkiluoto 3 nuclear power plant unit against internal explosions and missiles: sufficient design bases against the worst possible pressure shocks and missiles, separating redundant safety systems by sufficient distances or protective structures. The following measures are taken to prevent explosions or missiles:

- preventive maintenance and in-service inspection programmes of switchgears, rotating and pressure-retaining equipment
- over-speed protection of rotating equipment
- quick disconnection of the voltage in the event of switchgear arcs, which limits the pressure increase and prevents fires
- the aim has been to limit the use of explosive gases as far as possible in buildings important to safety and to prevent the creation of an explosive gas mixture.

It has been demonstrated by analyses that the consequential effects of explosions and missiles can be reliably restricted and that the load-bearing capacity of structures and the implementation of safety functions are not endangered.

Other internal events

Electromagnetic radiation created in the plant facilities and any arc short circuits in switchgears have been taken into account in designing the electrical and electronic equipment to ensure that these phenomena do not affect the operation of safety-significant equipment or their consequential effects are restricted to one safety division.

Conclusion

The conclusion is that internal events endangering the safety functions at the Olkiluoto 3 nuclear power plant unit have been taken into account as intended in Section 15 of the regulation.

4.8 Safety of monitoring and control (Section 16)

The control room of a nuclear power plant shall contain equipment that provides information on the operational state of the nuclear power plant and any deviations from normal operation.

A nuclear power plant shall be equipped with automatic systems that actuate safety functions as required, and that control and supervise their functioning during operational occurrences to prevent accidents and during accidents to mitigate their consequences.

These automatic systems shall be capable of maintaining the plant in a controlled state long enough to provide the operators with sufficient time to consider and implement the correct actions.

The nuclear power plant shall have a supplementary control room independent of the main control room, and the necessary local control systems for shutting down and cooling the nuclear reactor, and for removing decay heat from the fuel in the nuclear reactor and the spent fuel stored at the plant.

Section 5.2 “Instrumentation and control systems” and Section 5.3 “Control rooms” of Guide YVL B.1 present more specific requirements for the systems used in the monitoring and control of a nuclear power plant.

The Olkiluoto 3 nuclear power plant unit is monitored and controlled from the main control room. The control room’s main user interface is computer-based. With a view to the loss of the main user interface, the control room also has a conventional control panel. The user interfaces receive information about the state of the plant and alarms when the state of the plant or its systems is abnormal.

The Olkiluoto 3 nuclear power plant unit has I&C systems that monitor the state of the plant and start the necessary functions during operational occurrences and accidents. The systems have been divided in accordance with the defence-in-depth principle into the operational I&C system required in normal operating situations and the protection system required in accident situations. In addition to these, there is a backup protection system implemented using different technology for the loss of the programmable I&C system. With the backup system, operational occurrences and the most common class 1 accidents can be managed and the plant can be brought to a safe state. There is a separate I&C system for the management of severe accidents.

The protection system and its backup system have been designed according to the 30-minute rule. This means that, during operational occurrences or accidents, the controls required during the first 30 minutes are performed automatically. This gives the operators enough time to identify the situation and determine the correct measures.

With a view to the loss of the main control room, there is an remote shutdown station for bringing the plant to a safe state. The remote shutdown station has the same computed-based user interface as the main control room, so all the same functions are available. In addition, the remote shutdown station has a conventional panel displaying the key status information of the plant. The plant also has several local control positions. The remote shutdown station and local control positions can be used to shut down the reactor and ensure decay heat removal from the reactor and fuel pools also if the main control room is unavailable.

The threats affecting the control room and their prevention have been covered in the context of the sections of this safety assessment that address external and internal threats. In addition, the management of human factors as part of the operation of the plant unit is covered in Chapter 2.4 of the safety assessment.

In the construction licence phase, the plant's I&C design was at a very general level. The plant supplier had described the main I&C systems, but description of the entity formed by the systems, the I&C system architecture, was inadequate. For this reason, it was difficult to verify the separateness of the defence-in-depth lines, for instance. Nor had active faults (inadvertent functions) in the I&C systems been taken into account extensively. For these reasons, among other things, the I&C systems required redesign, on the basis of which numerous changes were made in the I&C system architecture and individual systems. The key changes concerned the separation of the severe accident management system from the other I&C systems, the placement of functions in different systems and the operation of the systems in different defence lines. Operating processes connected to I&C design were developed so that the design, its documentation and verification met STUK requirements and the requirements of international standards.

The conclusion is that the safety of the monitoring and control of the Olkiluoto 3 nuclear power plant unit has been implemented as intended in Section 16 of the regulation.

5 Safety of the construction and commissioning of a nuclear power plant (STUK Y/1/2016 – 4 luku)

5.1 Safety of construction (Section 18)

The holder of the nuclear power plant unit's construction license shall ensure during construction that the plant is constructed and implemented in conformity with the safety requirements and using approved plans and procedures.

The licensee shall ensure that the plant supplier and subcontractors providing safety-significant services and products are operating in compliance with the safety requirements.

To implement the Olkiluoto 3 nuclear power plant unit, TVO founded the Olkiluoto 3 project. One of the project's goals was to ensure that the plant is implemented in accordance with accepted safety and quality objectives. Another purpose of the project was to supervise manufacture, installation, testing and commissioning work as well as the plant supplier and its subcontractors. The project has followed the principles of TVO's management system where applicable and has also had its own project-specific quality management system. The goal has been to ensure and demonstrate that the requirements are met.

TVO's own supervision has consisted of a wide variety of functions, such as reviewing and approving the plans and descriptions delivered by the plant supplier, assessing deviations, internal and external audits, confirming the conformity, various reviews and monitoring of activities, including installation supervision. In its own supervision, STUK has confirmed that TVO has written procedures for ensuring the safety of construction and verified that the operations are in line with the procedures.

During the construction, there have been several significant quality deviations, which have led to extensive investigations to find the causes of the problems and to substantial corrective measures. Below are some examples of what kinds of deviations were detected and how they were solved.

In connection with the manufacture of the main components, issues requiring correction were observed, such as defects in welding and workmanship. Some of the defects could be repaired, and some of the parts were completely re-manufactured. In the manufacture of the main coolant lines, for example, there were problems in various phases. The large grain size of the pipe forging material led to the rejection of the forgings and manufacture of new ones, since the large grain size prevents their inspection using ultrasonic technology. During factory welding of the pipes' prefabricated parts, welded repairs not appropriately documented were found in the pipes. The repairs had been made to fill dents a few millimetres in depth that had appeared on the surface of the pipes due to their handling in the manufacture and inspection phases. The welding was interrupted until the acceptability of the repairs was demonstrated. While welding straight and bent pipe forgings together, fracture indications were detected in the base material near the weld junction. However, investigations showed that there were no indications deeper than the pipe surface, and the fractures were repaired.

Several deviations occurred in the manufacture and installation of the containment liner. Liner was stored without appropriate protection, resulting in pit corrosion. STUK asked an outside expert to assess the significance of the corrosion. According to the assessment, the corrosion was minor and had no significance for the steel lining. The surface of the liner was ground smooth at the corroded points. In addition, an incorrect welding procedure specification was used for welding the parts of the liner. The manufacture was interrupted until the issue had been investigated. The welds made using the incorrect specification were inspected by X-ray, and no welding errors were observed.

Similar problems were observed in the manufacture and installation or various components during the project. Depending on the type of the problem, the situation was rectified by either re-manufacturing the component or making the necessary changes and, in some cases, it could be demonstrated by inspections that the error had no effect on the quality of the end product.

I&C design was one of the key challenges in the project. The I&C systems required redesign in order to ensure, for example, sufficient independence between the different levels of defence. I&C design is covered briefly in Chapter 4.8. Operating processes connected to I&C design were developed so that the design, its documentation and verification met STUK requirements and the requirements of international standards.

The problems that occurred and the results of manufacturer and supplier audits showed that several actors had not observed the quality requirements of the nuclear sector in their operations. Due to the problems detected on the site and in supplier operations, STUK initiated, at the initial stage of the project, two investigations concerning the quality management procedures of TVO, the plant supplier and key suppliers in terms of the issues investigated, one of which was the management of safety requirements on the site and the other the procurement of emergency power supply diesel generators and their auxiliary systems.

On the basis of the experiences from the problems, both TVO and the plant supplier have developed their quality management procedures. The plant supplier and TVO have also significantly developed their configuration management and open issue management procedures during the project. Towards the end of the project in particular, TVO has taken a stronger role than could be expected of the client on the basis of the turnkey contract, facilitating the meeting of the quality objectives. For example, TVO has been involved in preparing documents to support the plant supplier and performed its own supplementary analyses.

The conclusion is that the meeting of the safety requirements of the Olkiluoto 3 nuclear power plant unit during construction has been ensured as intended in Section 18 of the regulation.

5.2 Safety of commissioning (Section 19)

In connection with the commissioning of a nuclear power plant, the licensee shall ensure that the systems, structures and components and the plant as a whole operate as designed.

At the commissioning stage, the licensee shall ensure that an expedient organisation is in place for the future operation of the nuclear power plant, alongside a sufficient number of qualified personnel and appropriate procedures.

In connection with the commissioning, the operation of the systems, structures and equipment as well as the entire plant is tested according to pre-defined pre-operational testing programmes. Pre-operational testing begins by testing the operation of components and proceeds to the testing of systems level and, eventually, the operation of the plant level.

The commissioning involves plans of various levels. The overall plant commissioning programme provides an upper-level description of the commissioning phases and their key goals and procedures. The detailed system commissioning programmes recognise the safety and operating functions of the systems, describe the tests performed on these and specify the preconditions and acceptance criteria for the tests. In addition to the system commissioning programmes, there are function-specific commissioning programmes for hydrochemistry, containment isolation or piping vibration, for instance. The commissioning programmes refer to detailed test procedures that describe the testing in practice. The plant's operating procedures (for example, periodic test procedures) shall be applied in the pre-operational testing to perform tests so that the functionality of the procedures can be ensured at the same time.

The pre-operational testing also tests the plant's ability to withstand various operational occurrences, such as a reactor or turbine trip, loss of off-site power or loss of main coolant pump or feed water pump, and verifies that the plant acts as anticipated in the various situations.

The same personnel that will be operating, supervising and maintaining the plant unit will participate in its commissioning. TVO has an operating line organisation and a nuclear safety organisation, which are described in more detail in TVO's organisation manual. TVO's personnel have participated in the technical implementation of the Olkiluoto 3 nuclear power plant unit and the evaluation and approval of its technical documentation. TVO's employees have been assigned position-specific qualification requirements and personal training plans. The personnel shall also take part in the commissioning as part of the orientation. In connection with the pre-operational testing, procedures relating to the conduct of operations shall be qualified as applicable. The procedures to be qualified include instructions from, for example, operating procedures, procedures for abnormal conditions and periodic test procedures. A plant simulator shall also be used in the qualification of the procedures.

TVO has a separate commissioning sub-project, which is responsible for the control and monitoring of the pre-operational testing and commissioning by participating in checking the commissioning programmes and performing the pre-operational testing, for example. In addition, there is an integrated operating organisation formed jointly by the plant supplier and TVO, which is responsible for the operation of the plant and supports the commissioning organisation during the commissioning. The integrated operating organisation shall be led by the plant supplier until fuel loading and by TVO after fuel loading. TVO's operating personnel shall participate in the commissioning and have the opportunity to familiarise themselves with the operation of the plant, operating procedures and other operational documentation. The operating personnel shall be involved in preparing for and performing the tests and analysing the results.

The conclusion is that the safety of commissioning of the Olkiluoto 3 nuclear power plant unit and preparation for plant operation during the commissioning have been implemented as intended in Section 19 of the regulation.

Preparations for the commissioning of the Olkiluoto 3 nuclear power plant unit and commencing its operation are still under way. In this respect, STUK bases its views on the related plans. STUK shall supervise the commissioning and review before fuel loading that the pre-loading testing has been performed and its results are acceptable, and that the prerequisites for safe operation are in place.

6 Safety of the operation of a nuclear power plant (STUK Y/1/2016 – Chapter 5)

6.1 Safety of operation (Section 20)

The organisation operating a nuclear power plant shall be responsible for the plant's safe operation.

The control room of the nuclear power plant shall be constantly manned by a sufficient number of operators aware of the status of the plant, systems and components. The control and supervision of a nuclear power plant shall utilise written procedures that correspond to the existing structure and the operational state of the plant. Written orders and related procedures shall be provided for the maintenance and repair of components.

For operational occurrences and accidents, appropriate procedures for the identification and control of incidents shall be available.

Operational measures concerning the nuclear power plant, as well as events having an impact on safety, shall be documented so that they can be analysed afterwards.

According to TVO's administrative rules, it shall be the licence holder's obligation to assure safe use of nuclear energy in accordance with Section 9 of the Nuclear Energy Act (990/1987). The structure of TVO's organisation, the task areas, responsibilities and authorisations for the organisation units, the general principles for developing the organisation and the principles for cooperation are described in the organisation manual. TVO's operations are led by the President and CEO, whose direct reports are the Directors of business and services. The President and CEO is assisted by the Management Group. Services are centrally produced by the service functions. One of the service functions is the Safety function, which is also responsible for supervision tasks that require independence.

The administrative rules describe the key tasks and responsibilities in terms of nuclear and radiation safety. The responsible manager as defined in Section 7 k of the Nuclear Energy Act is the same for all operating nuclear power plant units at Olkiluoto.

The minimum staffing of the Olkiluoto 3 nuclear power plant unit's operating shift and control room area is specified in the Technical Specifications (TechSpecs) of the plant unit. An operating shift monitors the state of the plant, systems and equipment by means of control room monitoring equipment, testing component operability and performing plant inspection walkdowns. Each state monitoring task and other duty of an operating shift is defined and instructed in TVO's operating manual. The on-duty shift supervisor is responsible for compliance with the TechSpecs and other plant procedures that ensure the safe operation of the plant.

The operators of the Olkiluoto 3 nuclear power plant unit have familiarised themselves with the plant during construction. The operators belong to the integrated operating organisation formed by the plant supplier and TVO, through which they have also been actively involved in the commissioning of the plant unit. The operator approval process was completed at the end of the year 2018. STUK supervised all the operators' demonstrations of professional skills in the training simulator and every operator's oral examination, which are part of the operator approval process. Based on the results of the demonstrations and the examinations STUK granted approvals to all OL3 operators in the late 2018.

The practices observed in the conduct of operations at the Olkiluoto 3 nuclear power plant unit are based on written procedures and operating orders and notices that are prepared as necessary. Operating orders are drawn up for changes to plant operating status or power, for example, whereas operating notices are prepared on deviating practices that are not intended to be permanent.

TVO has compiled the procedures into manuals, such as the operating and maintenance manuals. The operating manual contains the plant's operating instructions, i.e. normal operating procedures as well as procedures for abnormal conditions and emergency procedures. Alongside operating instructions, plant operation is governed by the plant unit-specific TechSpecs document which defines the requirements on the operability of the systems, structures and components that are most important to safety. The Technical Specifications document is covered in more detail in Chapter 6.3 of the safety assessment.

The operating procedures for plant operators are in electronic format. To prepare for failure of the electronic documentation, the control room of the Olkiluoto 3 nuclear power plant unit also has printed instructions similar to the electronic procedures. In addition to the aforementioned plant operating procedures, the operating manual also includes administrative procedures governing the conduct of operations of the plant unit, which have utilised the procedures in use at the Olkiluoto 1 and 2 nuclear power plant units by updating them to also cover the operations of the Olkiluoto 3 nuclear power plant unit. Where applicable, separate administrative procedures have also been prepared for the Olkiluoto 3 nuclear power plant unit.

TVO has specified organisation units responsible for updating and reviewing the procedures, and the related practices are described in the operating manual. To ensure that the procedures are up-to-date and sufficient, STUK shall review them before fuel loading and during the operation of the plant unit, for example, in connection with document updates and inspections of the periodic inspection programme.

Equipment maintenance and repairs are managed by TVO using its work management system, which shall be adopted at the start of the commercial operation of plant unit at the latest. Before this, during commissioning, the plant supplier's system shall be used. Work affecting the safety of the plant unit always requires a work permit from the shift supervisor. Operating orders shall be prepared for preventive maintenance of equipment subject to the TechSpecs.

The operating manual of the Olkiluoto 3 nuclear power plant unit includes procedures for abnormal and emergency operation. Procedures for abnormal operation consist of diagnosis procedure and the actual operating procedures. Emergency procedures consist of strategic and idiagnosis procedures, monitoring procedures for safety functions as well as the actual emergency operating procedures, which are either event- or symptom-based. Procedures for abnormal conditions and emergency procedures are provided as flow charts and have references to detailed operator procedures, which provide operators with instructions for the necessary measures. Background materials are created for the procedures for abnormal conditions and emergency procedures, providing justifications for the strategy and operator measures. Documents compiling the background materials shall be completed by the start of commercial operation of the plant unit. Until this, information corresponding to these materials shall be available from different sources, such as various analyses.

In addition to the aforementioned procedures for abnormal conditions and emergency procedures, separate severe accident management guidance document is being prepared for the Olkiluoto 3 nuclear power plant unit. The purpose of these procedures is to mitigate the consequences of a severe accident by ensuring the integrity of the containment. The criteria for adopting the severe accident management guidance are specified in the documentation. In these situations, the responsibility for managing the plant lies with the emergency response organisation.

The suitability of the plant's procedures for abnormal conditions and emergency procedures for their intended application is demonstrated by validation of the procedures using a replica training simulator. STUK has supervised the various phases of the validation process by reviewing the validation plans and by the supervision at the plant site. In addition, the result reports from the validation of the procedures shall be submitted to STUK for approval after the end of the validation process. As a result of the validation, several change requirements regarding the procedure concept and the procedures themselves have been specified. Some of the changes have not been implemented yet. After these have been made, the suitability of the procedures for their intended application must be demonstrated before fuel loading. STUK shall ensure that the demonstrations are made appropriately and to a sufficient extent.

The severe accident management guidelines shall also be validated. No validation plan has been submitted to STUK yet. Furthermore, as noted above, development of the procedures is still under way. At this stage, STUK cannot comment on the sufficiency of the severe accident management guidelines or their suitability for their intended application.

Operational measures at the Olkiluoto 3 nuclear power plant unit shall be documented using a plant operation logbook and shift change report, which are filled in by the operating shift in accordance with TVO's administrative procedures. Items to be recorded in the logbook include the operational state and changes therein, significant operational measures as well as events, including any operational occurrences. For the reporting of operational events, TVO also has separate procedures that take into account the requirements of Guide YVL A.10.

STUK's resident inspectors shall supervise the commencing conduct of operations at the plant site. In addition, after the operation of the plant has started, STUK shall inspect and verify that the conduct of operations corresponds to the practices described in the procedures and other documents. STUK inspects the conduct of operations through inspections prescribed in the periodic inspection programme and in conjunction with document reviews, for example.

The conclusion is that the practices regarding the conduct of operations at the Olkiluoto 3 nuclear power plant unit have been implemented as intended in Section 20 of the regulation with the following comments.

STUK has not yet received sufficient evidence that suitable procedures are available for the identification and control of incidents for operational occurrences and accidents. TVO has procedures in place to complete the work in question, so the aforementioned does not prevent the granting of the operating licence. STUK requires that the preparation and validation of operating procedures, including the severe accident management guidance document, be completed appropriately before starting operation. TVO must demonstrate to STUK before fuel loading that the procedures specified above form an entity that is appropriate for its intended purpose and sufficient for the start of safe operations of the Olkiluoto 3 nuclear power plant unit.

6.2 Taking operating experience and safety research into consideration in order to improve safety (Section 21)

Safety-significant operational events shall be investigated for the purpose of identifying the root causes as well as defining and implementing the corrective measures.

For further safety enhancement, operating experience from the plant and from other nuclear power plants, the results of safety research and technical developments must be regularly monitored and assessed.

Opportunities for improvements in technical and organisational safety, identified from operating experience, safety research and technical developments shall be assessed and implemented to the extent regarded as justified on the basis of the principles laid down in Section 7 a of the Nuclear Energy Act.

6.2.1 Operating experience feedback

The purpose of operating experience feedback during the operation of the plant is to learn from the operational events at the plant and other plants. A practical testament to this learning is that necessary plant-related or operational changes are implemented and the recurrence of the same faults and deficient operating methods is prevented.

Dedicated human resources are required for the use, maintenance and development of operating experience feedback activities and the handling of incident investigations. TVO has allocated responsibility for the operating experience feedback and event investigations at the Olkiluoto 3 nuclear power plant unit to the same organisation unit as the operating experience feedback and event investigations at the Olkiluoto 1 and 2 nuclear power plant units. The commissioning of the new plant unit will significantly increase the workload of the responsible unit. During its inspection work in 2016–2017, STUK noted that the resources for operating experience feedback are minor. As regards the Olkiluoto 3 nuclear power plant unit, an additional challenge is presented by the fact that the plant type is new for TVO. At the Olkiluoto 1 and 2 nuclear power plant units, the Swedish NordERF association plays an important role in external operating experience feedback in particular. Similar support for operating experience feedback at the Olkiluoto 3 nuclear power plant unit is not available to the same extent (cooperation with other EPR plants is only starting), so TVO's own input plays a decisive role. STUK required TVO to take measures, and TVO has improved the resourcing and organisation of the operating experience feedback and the development of the competence of the personnel. Through its control activities, STUK monitors that TVO commits to the changes it initiates, observes the effects of the changes and reacts to deficiencies where necessary. Vigilance is important since the Olkiluoto 3 nuclear power plant unit will significantly increase the workload, and several personnel changes occurred in 2017. New personnel will be inducted, and tasks will be transferred gradually. The agility to quickly allocate resources in different ways and for surprising needs will be limited, particularly during the transitional period.

With the operating experience feedback gained during the operation of the Olkiluoto 1 and 2 nuclear power plant units, there already are tried and tested, written procedures for handling events at the plants and for reporting and investigating the plant's own operational events, specifying and implementing measures and monitoring their progress. Therefore, it has not been necessary to create separate procedures for the Olkiluoto 3 nuclear power plant unit; instead, TVO has extended the existing procedures to also cover the operation of the Olkiluoto 3 nuclear power plant unit. On the basis of long-term experiences from the operation of the Olkiluoto 1 and 2 nuclear power plant units, TVO's procedures can be deemed to work. The activities are also familiar, since the management of deviations, event investigation and learning from experiences have already been part of the construction phase. The improvement targets identified in the operation of the Olkiluoto 1 and 2 nuclear power plant units and the development measures initiated also apply to and cover the operation of the Olkiluoto 3 nuclear power plant unit. Examples of these include the effectiveness of the operating experience feedback and its assessment.

TVO has taken into account the requirements of the new Guide YVL A.10 in its procedures and actions relating to the processing of internal and external operational events. The procedures created are currently being established and further developed.

STUK shall inspect the meeting of the requirements of Guide YVL A.10 at the Olkiluoto 3 nuclear power plant unit as part of its continuous monitoring. STUK shall assess TVO's procedures and inspect the resourcing, organisation of operations, development of personnel competence as well as the use, functionality and development of TVO's written procedures in connection with document inspections and during inspections conducted at the plant site.

The conclusion is that operating experience feedback during the operation of the Olkiluoto 3 nuclear power plant unit has been implemented as intended in Section 21 of the regulation.

6.2.2 Safety research

Extensive international safety research is being conducted by means of cooperation between various countries and in, for example, research programmes coordinated by the OECD. Experiments are also performed and research conducted within the framework of the Finnish Research Programme on Nuclear Power Plant Safety, SAFIR, benefiting the assessment of the Olkiluoto 3 nuclear power plant unit's design solutions and safety improvements.

The design of the EPR plant concept has been largely able to draw on experience from the design and operation of earlier French and German plants. New experiments have mainly been required in order to verify the characteristics of the EPR (and Olkiluoto 3 nuclear power plant unit) design insofar as they differ from the equivalent characteristics of earlier power plants, regarding, for example, the severe accident management strategy as well as the operation and filter structures of the emergency cooling system.

The possibility of a severe reactor accident has been considered in the design of the EPR plant, and plenty of experimental research has been carried out in order to verify the design bases. Research has been conducted to verify the entire control chain from the beginning of the accident to long-term core melt cooling. International phenomenon-based research of severe accidents supports the severe accident management strategy selected. Certain physical phenomena relating to severe accidents, such as hydrogen production and combustion and partially also the mixing of gases, are not plant type-specific; instead, their calculated and experimental research in the field of international phenomenon-based research supports the design of the Olkiluoto 3 nuclear power plant unit.

The characteristics of the EPR plant emergency cooling systems also differ from earlier plants. In order to improve the management of primary–secondary leaks, the head of the medium-pressure emergency cooling system pumps has been lowered. As a result, the functioning and efficiency of emergency cooling has required experimental confirmation, particularly in the case of medium-sized primary circuit leaks. The functioning of the emergency cooling system filter structures and the related acceptability of the containment insulation solutions have been demonstrated by comprehensive tests, whose monitoring has also involved STUK.

On the basis of safety research, improvements have been made at the Olkiluoto 3 nuclear power plant unit to solve the questions that arose in the construction licence phase and to confirm the design bases. TVO participates in several international research programmes as well as the Finnish SAFIR research programme, and further safety improvements shall be made on the basis of their results as necessary. The conclusion is that safety research has been utilised for safety improvement during the design and construction of the Olkiluoto 3 nuclear power plant unit as intended in Section 21. TVO must continue to provide sufficient resources for the monitoring and assessment of the results of safety research and carry out any safety improvements on their basis.

6.3 Operational Limits and Conditions (Section 22)

The Operational Limit and Conditions of a nuclear power plant shall include the technical and administrative requirements for ensuring the plant's operation in compliance with design bases and safety analyses. The requirements for ensuring the availability of systems, structures and components important to safety, as well as the limitations that are to be complied with when equipment is unavailable, shall also be included in the Operational Limits and Conditions.

The plant shall be operated in compliance with the requirements and restrictions set in the Operational Limits and Conditions, and compliance with them shall be monitored and any deviations reported.

The Operational Limits and Conditions, or Technical Specifications (TechSpecs), are an operating licence document as specified in Section 36 of the Nuclear Energy Decree. The TechSpecs and other instructions of the power plant together define the limits and operating methods by which the nuclear power plant can be operated safely in various situations. The safe operating range of the Olkiluoto 3 nuclear power plant unit as specified by the TechSpecs is presented using safety limits, systems, structures and components operability requirements as well as administrative requirements. Each operability requirement includes the actual requirement, the plant operational states in the which the requirement is applied, fault conditions and the related required actions and completion times. The completion times have been specified using a combination of deterministic and risk-based assessment.

In connection with the operability requirements, requirements have been presented for periodic tests and in-service inspections to ensure the operability of the safety-significant systems, structures and components, i.e. whether the TechSpecs requirement in question is met. If the requirement is not met, the fault condition specified in it becomes active. If the fault condition cannot be corrected within the completion time, the plant unit must be brought to a safe state as specified in the TechSpecs and within the time specified in the TechSpecs. The background of the operability requirements, fault condition completion times as well as the intervals of periodic tests and in-service inspections are justified for each requirement in the separate justification section of the TechSpecs.

The administrative requirements of the Olkiluoto 3 nuclear power plant unit's TechSpecs are based on the operating methods applied by TVO and the operating experiences from the Olkiluoto 1 and 2 nuclear power plant units, also taking into account the differences between boiling water reactors and pressurised water reactors.

The shift supervisor of the Olkiluoto 3 nuclear power plant unit is responsible for ensuring that the plant unit is operated in accordance with the TechSpecs. The meeting of the TechSpecs requirements shall be verified by means of periodic tests and in-service inspections performed on systems, structures and components as specified in the TechSpecs requirements. In addition, when the plant's operational mode is changed, the meeting of the requirements for the new mode shall be ensured according to the detailed instruction module for shift supervisors. Compliance with the TechSpecs requirements shall also be monitored by means of inspection rounds carried out by field operators as well as general supervision of the plant unit by operators using the main control room monitoring equipment. If the operating shift notices that a TechSpecs requirement is not met, the fault conditionspecified in the requirement becomes active and the shift performs the required actionsspecified. If necessary, the plant is brought to a safe operational mode in which the requirement is not applied.

In accordance with Chapter 5.5.4 of the TechSpecs, TVO shall report TechSpecs deviations to STUK as specified in Guide YVL A.10. STUK shall monitor compliance with the TechSpecs requirements using, for example, resident inspectors, inspections performed at the plant site and reports submitted to STUK.

STUK approved the TechSpecs by decision 22/G42242/2016. The decision presented requirements, and STUK required that a version of the TechSpecs updated according to the requirements be submitted to STUK for approval before the operation of the plant is started. The requirements necessitated, for example, that some completion times or test intervals be shortened, the presentation be made clearer and certain conditions be justified and determined better. TVO submitted the updated TechSpecs to STUK in summer 2018. STUK approved the updated TechSpecs with requirements by decision 38/G42242/2018. However, the requirements of the decision are of the type that does not prevent the granting of the operating licence. The updated TechSpecs shall be submitted to STUK for approval before the operation of the plant is started.

The conclusion is that the Technical Specifications of the Olkiluoto 3 nuclear power plant unit have been implemented as intended in Section 22 of the regulation.

6.4 Condition monitoring and maintenance to ensure the safety of the facility (Section 23)

Systems, structures and components important to the safety of a nuclear power plant shall be available as detailed in the design basis requirements.

Operability and the effects of the operating environment shall be monitored by means of inspections, tests, measurements and analyses. Operability shall be checked in advance by regular maintenance, and provisions shall be made for maintenance and repairs in the event of any deterioration in operability. Condition monitoring and maintenance shall be planned, supervised and implemented so that the integrity and operability of systems, structures and components are reliably preserved throughout their service life.

6.4.1 Maintenance operations

Maintenance of the Olkiluoto 3 nuclear power plant unit during commissioning is based on the maintenance concept prepared by the plant supplier. The starting points for this are the preventive maintenance programmes prepared by the equipment manufacturers, which have been supplemented on the basis of the plant supplier’s analyses and experiences. Responsibility for the maintenance tasks shall be transferred to TVO during the commissioning of the Olkiluoto 3 nuclear power plant unit. In connection with the transfer, the plant supplier’s maintenance database shall be transferred to TVO’s own system. The database also includes preventive maintenance programmes for the equipment, presenting the preventive maintenance measures to be performed and their scheduling. In its construction inspection programme, STUK has assessed the procedures relating to maintenance and TVO’s preparedness to take care of the maintenance of the plant unit.

TVO’s maintenance planning is based on the division of equipment positions into four maintenance classes. The selection of maintenance class depends on the safety significance of the equipment as well as the effect of the failure of the equipment on the operability of the entire plant. Class 1 equipment shall be maintained in working order at all times. Limited inoperability is permitted for class 2 equipment. Justified preventive maintenance is allowed for class 3 equipment, and normal operational monitoring is sufficient for class 4 equipment (no preventive maintenance).

STUK shall assess the equipment-specific condition monitoring procedures and monitor the maintenance of equipment as part of its continuous monitoring.

6.4.2 In-service inspections

Pressure equipment and piping

Guides YVL E.3 and YVL E.5 set forth detailed requirements for in-service inspections of pressure equipment and piping. Guide YVL E.5 sets forth requirements for non-destructive in-service inspections of pressure equipment. The qualification of these inspection methods has been implemented according to the requirements of Guide YVL E.5. STUK has inspected the qualification input information and the assessment reports prepared by the qualification body. The pre-service inspections performed as a reference for the in-service inspections have mainly been performed. STUK has inspected the pre-service inspection programme. STUK has supervised the pre-service inspections performed as a reference for the in-service inspections during the installation phase of the plant unit. Before fuel loading, STUK shall inspect the summary report of the pre-service inspections. The in-service inspection programme shall be submitted to STUK for assessment one year before the first planned refuelling outage.

Guide YVL E.3 sets forth periodic inspections of pressure equipment subject to registration as based on the pressure equipment legislation. The inspection intervals of these begin from the equipment commissioning inspections performed during the construction and commissioning of the plant unit. Periodic inspections to be performed on pressure equipment subject to registration include the internal inspection and operational inspection to be performed every four years as well the periodic pressure test to be performed in connection with every second internal inspection (every eight years). The operability of equipment and accessories connected to operational safety shall be inspected in connection with the operational inspections. Such accessories include safety valves, valves and control and measuring equipment. STUK shall monitor in-service inspections of registered pressure equipment.

A separate piping condition monitoring programme has been prepared for piping systems with a risk of erosion at the Olkiluoto 3 nuclear power plant unit. STUK has assessed the basic erosion corrosion measurement programme for these piping systems. STUK has inspected the basic measurement results during the installation of the plant unit. During the operation of the plant unit, the condition of the piping systems shall be monitored by means of regular thickness measurements. STUK shall separately assess the in-service inspection programme concerning the selection of in-service control points before the commissioning of the plant unit.

Electrical and I&C components

The in-service inspection programme of electrical and I&C components and systems that are important to safety is based on official regulations and guidelines, safety standards for electrical work, manufacturer instructions/recommendations, methods of using the equipment, and operating experiences regarding the equipment.

The equipment platforms of the main I&C systems feature advanced self-diagnostic and testing features. The in-service inspection programmes for I&C systems have been defined in such a way that the specific monitoring and periodic tests of the systems together provide the sufficient coverage to ensure the operability of the I&C systems.

The periodic inspection activities at the facility are guided and controlled by means of administrative procedures and information systems (e.g. work order system). The maintenance procedures determine the work, methods and approval criteria for specific components and areas in more detail.

Periodic inspections and tests of areas that are important to safety shall be conducted during the operation and annual maintenance of the plant units, and they have been defined and scheduled in the Technical Specifications. An essential part of the periodic tests shall be performed in connection with annual outages.

Concrete and steel structures

In-service inspections and separate investigations of structures are based on the quality control and ageing management programmes required by Guides YVL A.8 and YVL E.6. The selection criteria for the importance of structures are the nuclear safety classification and seismic classification such that the structures shall be kept in as-new condition by means of maintenance performed on the basis of in-service inspections and separate investigations as well as renovation construction as necessary. In addition, on the basis of future stresses, the containment, seawater structures and turbine foundations have been specified as items whose condition is to be monitored in more detail than that of the other structures, ensuring the ability of these structures to withstand the expected stresses by means of the planned tests, measurements and load and strength analyses.

STUK has approved the in-service inspections and separate investigation procedures regarding the selection of in-service control points of structural buildings and structures. Before fuel is loaded to the plant unit, STUK shall confirm that approved procedures have been compiled into maintenance procedures that cover the entire OL3 plant.

Conclusion

The conclusion is that the condition monitoring and maintenance of the Olkiluoto 3 nuclear power plant unit have been implemented as intended in Section 23 of the regulation.

6.5 Radiation monitoring and control of releases of radioactive materials (Section 24)

The radiation levels of nuclear power plant rooms and the activity concentrations of indoor air and the gases and liquids in the systems shall be measured, releases of *radioactive substances from the plant monitored and concentrations in the environment controlled.*

The detailed requirements related to Section 24 of Regulation STUK Y/1/2016 are presented in Guides YVL C.3, YVL C.6 and YVL C.7.

The Olkiluoto 3 nuclear power plant unit features an extensive radiation measurement system with approximately 150 individual measurements in total. The system is used to measure dose rates in rooms during normal operation and accident conditions as well as to determine concentrations of airborne radioactive substances in, for example, the rooms and ventilation systems.

The Olkiluoto 3 nuclear power plant unit uses processing systems for gaseous and liquid releases with which radioactive substances released into and contained by the facility's process systems are collected and stored. In terms of the safety of the environment and members of the public, only an insignificantly small portion of the radioactive substances is released into the environment. The radioactive substances are discharged into the air as gaseous or particulate releases through the ventilation stack and into the seawater tunnel and, further, into the marine environment as particles dissolved or mixed in the water. The radioactive releases into the air and the marine environment are monitored along all significant release routes through continuously operating radiation meters, sampling and nuclide-specific radioactivity specifications conducted in a laboratory.

Samples collected from the ventilation stack are analysed through gamma spectrometry for concentrations of radioactive substances present in radioactive noble gases and iodine or bound to aerosol particles. In addition, outlet water samples are analysed through gamma spectrometry. Collected air samples are analysed for concentrations of tritium and ^{14}C, and outlet water samples for tritium concentration, using a liquid scintillation counter. Air aerosol samples and discharge water samples are analysed for the total activity of alpha-active nuclides (nuclide-specific concentrations where necessary), and strontium nuclides ^{89}Sr and ^{90}Sr are determined. Continuously operating radiation monitoring systems are used to monitor the radioactivity of exhaust air from the ventilation stack in real-time through noble gas, iodine and aerosol measurements. The continuously operating radiation monitoring system in the water releases line allows for real-time monitoring of the releases and immediate response in case of any issues.

The methods used are suited to the purpose, and the measurement results can be used to monitor the fulfilment of the limit value in Section 22 b of the Nuclear Energy Decree.

An extensive environmental radioactivity monitoring programme is being implemented in the area surrounding the Olkiluoto nuclear power plant. In terms of releases from the Olkiluoto 3 nuclear power plant unit, important monitoring sites have already been added in the programme for environmental radiation surveillance in operation at the Olkiluoto 1 and 2 nuclear power plant units. Within the scope of this programme, the possible passage of radioactive substances into the environment is monitored constantly by analysing the radionuclide concentrations of foodstuffs produced in the area around the facility and samples indicating the propagation of other releases.

The environmental radiation monitoring targets passage routes that are significant in terms of radiation exposure. In addition to this, indicator organisms that efficiently collect radioactive substances from the habitats are analysed. The indicator organisms help to monitor the propagation of radionuclides from the power plants. The results from the programme for environmental radiation surveillance have been utilised in the Radiological environment baseline study according to Section 36 of the Nuclear Energy Decree before the commissioning of the Olkiluoto 3 nuclear power plant unit.

The programme for environmental radiation surveillance in the area surrounding the Olkiluoto power plant comprises more than 300 samples a year. Samples are taken of outdoor air, fallout, pasture grass, milk, grain, domestic water, seawater, groundwater and fish, for example. The samples are analysed for the nuclides that are most significant in terms of human radiation exposure: gamma emitters, such as ^{60}Co, ^{131}I and ^{137}Cs, beta emitters ^{3}H and ^{90}Sr and alpha emitters, such as ^{238}Pu, ^{239}Pu and ^{240}Pu. The programme for environmental radiation surveillance can be used for detecting the effect of the Olkiluoto 3 nuclear power plant unit on the concentrations of radioactive substances in the environment.

Guide YVL C.7 entered into force for the Olkiluoto nuclear facilities in 2018. Accordingly, STUK will perform independent regulatory monitoring in the environment of the nuclear facility during the operation of the nuclear facility by taking and analysing samples from the environment of the nuclear facility to a necessary extent. Similarly, TVO's own programme for radiation surveillance is narrower than before, so that STUK's monitoring and TVO's programme for radiation surveillance together correspond to the TVO’s previous programme for radiation surveillance.

The area surrounding the Olkiluoto power plant features an automatic external radiation measurement system, the purpose of which is to quickly indicate any changes in radiation level in the environment in a possible accident situation. In the site area, there is a meteorological system that can be used to estimate the spreading of any radioactive releases in the atmosphere.

The conclusion is that the radiation dose rates and passage of radioactive substances at the plant, and the releases of radioactive substances into the environment and their concentrations in the environment will be monitored at the Olkiluoto 3 nuclear power plant unit according to Section 24 of the Regulation.

7 Organisation and personnel (STUK Y/1/2016 – Chapter 6)

7.1 Section 25 Management, organisation and personnel: ensuring safety

7.1.1 Management system

Organisations participating in the design, construction, operation and decommissioning of a nuclear power plant shall employ a management system for ensuring the management of safety and quality. The objective of such a management system is to ensure that nuclear safety and radiation safety are prioritised without exception, and that quality management requirements correspond to the safety significance of the activity and function. The management system shall be systematically assessed and further developed.

The management system shall cover all organisational activities impacting the nuclear power plant's nuclear and radiation safety. For each function, requirements significant to safety shall be identified, and the planned measures described in order to ensure conformity with requirements. The operating methods of the organisation shall be systematic and instructed.

The licensee shall commit and oblige its employees and suppliers, subcontractors and other partners participating in functions affecting safety, to adhere to the systematic management of safety and quality.

Systematic procedures shall be in place for identifying and correcting deviations significant in terms of nuclear and radiation safety. If during construction or operation, it becomes necessary to make changes to approved designs, they are to be implemented in a systematic and controlled manner.

TVO's corporate-level management system documentation, also known as the management system, consists of a general section and functional section. The general section presents, among other things, TVO's vision, mission and values, company policies, organisation and areas of responsibility, general operational principles, quality assurance principles for functional processes, and general descriptions of resources. The functional section comprises more detailed descriptions of the functional processes, and manuals and instructions.

In addition to TVO's corporate-level management system, the OL3 NPP Management System includes OL3 NPP Management System documentation and the plant supplier's documentation for the Olkiluoto 3 project. The Olkiluoto 3 project will continue after the granting of the operating licence for the duration of the testing phase following fuel loading. The Olkiluoto 3 project instructions are valid until the end of the project, as the plant supplier still remains involved in the project and follows the same instructions. In the operation phase, following the transfer of the plant by the plant supplier, TVO's management system shall be implemented exclusively in a similar manner to that used at the Olkiluoto 1 and 2 nuclear power plant units at the moment.

The OL3 NPP Management System is an integrated management system combining systematic safety and quality management procedures. This ensures that nuclear safety significance is recognised and considered when making decisions and determining procedures. Initially, the system consisted of the quality manual, process diagrams, verbal process descriptions and procedures. In the commissioning phase, even before submitting the application for an operating licence, TVO integrated the construction-time project quality management system more closely with their activity-based management system. TVO replaced the project quality manual with the quality plan and TVO's management system with the general section.

In the operation phase, following the transfer of the plant by the plant supplier, the project quality plan shall be phased out, and TVO's management system implemented exclusively in a similar manner to that in use at the Olkiluoto 1 and 2 nuclear power plant units at the moment. The management system for the operation phase has been complemented with procedures and instructions regarding the Olkiluoto 3 nuclear power plant unit. The work is still under way. The users must also be trained in the instructions. Before fuel loading, STUK will ensure that the management system is up-to-date and the training requirements have been met.

The Olkiluoto 3 project quality plan requires that the plant supplier is committed to high quality standards and safety culture. The plant supplier uses a quality assurance programme including, for example, quality manuals and project quality plans. In addition to these, project, design, site, installation and commissioning manuals are used. Supply chain quality management has been ensured using a document specifying the requirements set for the quality management systems of the subcontractors. Quality, inspection and documentation requirements have also been applied to the suppliers and, in particular, manufacturers. The contents of the documents prepared and the procedures used have been improved during the project based on construction experience, audit findings and reports compiled.

TVO has several procedures by which to develop their operations. These include, for example, management reviews, internal audits, deviation reports and reports on the causes of non-conformities. Instructions for the deviation processing process are provided, and the interfaces between the plant supplier and licensee as well as the related procedures have been specified. The deviation processing process ensures the uniformity of the deviation classification and procedures of the various plant supplier parties.

The change management in the Olkiluoto 3 project has been the responsibility of a desing sub-project monitoring and evaluating that the changes conform to the requirements. Instructions for the change and configuration management have been provided, and the plant supplier has developed its related procedures markedly during the project. After the completion of the project, the procedures described in TVO's management system shall be implemented exclusively also in the processing of deviations and changes.

As a conclusion, it can be stated that valid construction-time quality management procedures have been implemented to the extent and purpose required by the safety significance of the systems, structures and equipment. TVO and the plant supplier have improved their operations based on the feedback received, resolving all quality issues and implementing corrective actions. The quality management of the plant supplier can be deemed to have improved during the project up to a level adequately fulfilling the hallmarks of a good quality management system.

The preparation of the operation-time instructions included in the Olkiluoto 3 nuclear power plant unit's management system is not yet finished. However, TVO has procedures in place to finish the work in question, so this does not prevent the granting of the operating licence. Before fuel loading, STUK will ensure that the construction- and operation-time management system is compliant with Section 25 of the Regulation in the fuel loading phase.

7.1.2 Personnel and competence

The lines of management in the licensee's organisation, as well as the positions and related responsibilities of employees, shall be defined and documented. The operation of the organisation shall be evaluated and continuously developed and the risks associated with the organisation's operation are to be evaluated regularly. The safety impacts of significant organisational changes are to be evaluated in advance.

Significant functions with respect to safety shall be designated. Training programmes shall be prepared for developing and maintaining of the professional qualifications of the persons working in such positions, and an adequate command of the functions in question must be verified.

The licensee shall as support for the responsible manager, have a group of experts, independent of the other parts of the organisation, convening on a regular basis to handle safety-related issues and giving recommendations thereon if necessary.

The licensee shall employ adequate and competent personnel for ensuring the safety of the nuclear power plant. The licensee shall have access to the professional expertise and technical knowledge required for the safe construction and operation of the plant, the maintenance of equipment important to safety, and the management of accidents.

A general description of TVO's organisation and duties is presented in the Organisation Manual. For the implementation of the Olkiluoto 3 nuclear power plant unit project, TVO has a project organisation that also utilises the resources of other organisation units in the company. The Olkiluoto 3 project will continue after the granting of the operating licence for the duration of the testing phase following the fuel loading.

In 2015, TVO carried out an organisational change in which the TVO organisation was divided into business units and service functions. Safety function is responsible for the supervision tasks that require independence. Nearly all human resources belong to these service functions. An external body assessed the safety impacts of the organisational change in advance and found the challenges to include securing the resources needed by the Olkiluoto 3 project and the complexity of the service operations model. After the organisational change, STUK noticed the staff turnover to be higher than normal and challenges to occur in resourcing. In TVO's staff questionnaire of 2016, it was found that the division of responsibilities under the new operating model was still seen as unclear.

STUK has verified that steps have been taken to correct issues due to the 2015 organisational change. TVO has developed its resource management and operating model procedures. In 2017, TVO implemented a smaller organisational change. One goal of the change was to clarify responsibilities and ensure a controlled transition to the Olkiluoto 3 nuclear power plant unit's operation phase. In order to ensure clear responsibilities, a plant manager was appointed for each nuclear power plant unit. The teams responsible for the maintenance of the Olkiluoto 3 nuclear power plant unit were appointed in the same context.

The operations unit of the Olkiluoto 3 nuclear power plant has been part of the operations unit operating under TVO's electricity production starting already from the construction phase. Within the operations unit, there is a separate operations division for each plant unit. In addition to the operations unit, other units operating under the electricity production include the fuel, maintenance and production support units common to all plant units. According to TVO's valid administrative rule, the responsibility for all operation taking place at the Olkiluoto 3 nuclear power plant unit after the granting of the operating licence to the unit shall lie with the senior vice president of electricity production and the electricity production business unit working under him or her.

TVO has prepared for the operation of the Olkiluoto 3 nuclear power plant unit by recruiting more personnel, in particular during the years 2017 and 2018, and by developing its procedures for the assessment of resources for future operational needs. Personnel training has been designed and implemented in accordance with the instructions in TVO's training manual. Based on the various tasks and responsibilities, the training manual includes requirements for basic qualification and work experience, required and recommended activity-specific qualification requirements, qualification requirements for special roles as well as permit-specific qualification and orientation requirements. Individual job descriptions consist of roles specified to the persons and described in their role cards. There is a separate tool for assessment and monitoring of competence. In addition to the training provided by TVO, the plant supplier has provided operation, maintenance and technical support training and job orientation for TVO personnel.

Because TVO has recruited a lot of new personnel during the last year, STUK has paid attention to the job orientation and professional skills of the personnel in its inspections. In order to provide a picture as complete as possible, VTT has interviewed various personnel groups, such as system owners, maintenance personnel and the Olkiluoto 3 nuclear power plant unit's field operators and operators, during 2018. TVO has appointed system owners for the systems, equipment owners for the Olkiluoto 3 nuclear power plant unit and increased the number of field operators. The orientation of new personnel is still under way.

Pressurised water reactor is a new type of plant for TVO. However, TVO has during the project familiarizes itself with the plant type and its characteristics and acquired the expertise required for the safe operation of the plant. The construction and commissioning of the plant unit have provided an excellent opportunity to get acquainted with the plant before the operation begins.

The supervisors are responsible for ensuring that the requirements have been met and the personnel is qualified to work independently. The competence of the personnel is maintained and enhanced through, for example, on-the-job learning, supplementary training, diversified work tasks, job orientation and practical training.

The tasks, authority and responsibilities of the responsible managers and their deputies as well as those of the personnel and their deputies responsible for the monitoring of the emergency response arrangements, physical protection and supervision of nuclear material are presented in the administrative rules. These are persons who have been appointed by TVO and approved by the Radiation and Nuclear Safety Authority. The responsible manager and respective deputies have been found to be familiar with the Olkiluoto 3 nuclear power plant unit in a level adequate for them to bear the responsibility placed upon them. The administrative rules also specify functions important to safety. TVO has appointed on an independent safety group supporting the responsible manager. The purpose of the safety group is to provide recommendations and statements in nuclear safety and quality management questions related to the structure, operation, decommissioning and fuel and nuclear waste management of the Olkiluoto nuclear power plant. The safety group has processed matters related to the safety and quality in the Olkiluoto 3 project, such as quality non-conformances, safety culture observations and issues emerged during commissioning. For example, the suggestions regarding the design and qualification of the equipment made by the plant supplier have been addressed.

Operational assessments at TVO are carried out by means of self-assessments, work atmosphere surveys and management system assessments, among other measures. Instructions have been provided for the review of organisational changes.

The conclusion is that the organisation of the Olkiluoto 3 nuclear power plant unit has met the requirements set for a nuclear power plant organisation during construction. The changes in lines of responsibility between TVO and the plant supplier upon the beginning of the operation have been taken into account in the plans and instructions. Introductory training to the operational phase procedures is still under way. During year 2018 STUK has inspected the resources and competences of the organisation and concluded that they meet the requirements of Section 25 of the Regulation.

7.1.3 Safety culture and management

When designing, constructing, operating and decommissioning a nuclear power plant, a good safety culture shall be maintained. Nuclear safety and radiation safety shall take priority in all operations. The decisions and activities of the management of each organisation participating in the abovementioned activities shall reflect its commitment to operational practices and solutions that promote safety. Personnel shall be encouraged to perform responsible work, and to identify, report, and eliminate factors endangering safety. Personnel shall be given the opportunity to contribute to the continuous improvement of safety.

In its organisation manual, TVO has defined that it requires the maintenance and continuous development of a high level of expertise and safety culture in its operations. In this context, high level of safety culture refers to the organisation-wide procedures and attitude ensuring that safety and operability aspects receive attention in proportion to their significance and are handled in an order highlighting safety in decision-making.

The Olkiluoto 3 project will continue after the granting of the operating licence for the duration of the testing phase following fuel loading. This chapter discusses the safety culture of both the project and the upcoming operation phase.

Safety culture during the project

In general, projects may face financial or schedule pressures threatening the priority of safety and affecting, for example, on the willingness to highlight quality non-conformity issues and which suppliers and technical solutions are chosen. In the Olkiluoto 3 project, this challenge has been considred in connection with non-conformities and by means of continuous safety culture monitoring. The significance of safety has been emphasised throughout the project network via, for example, communication and training. The commitment of the organisations and their employees operating at the site to operational practices that promote safety has been increased by, for example, improving their awareness of the safety significance of their respective work tasks. In essence, TVO's commitment to safety as an overriding priority is demonstrated by the allocation of resources to the design of safe technical solutions and the fact that components have been replaced and installation work carried out anew where necessary to meet the required level of quality.

According to TVO, it is a part of their good safety culture to maintain a work atmosphere at TVO that encourages people to report faults occurred and deviations or deficiencies observed and to handle matters in an open manner so that as much as possible is learned in order to prevent recurrences of such events. During the construction phase, various practices by which mistakes, deviations and concerns can be reported were developed at the Olkiluoto 3 site, and these have been used to correct any issues.

During the construction of the Olkiluoto 3 nuclear power plant unit, TVO has developed various ways to promote, assess and develop the safety culture. It took some years to come up with efficient methods for the assessment and development of the safety culture as there were no ready-made procedures available for the construction phase. Special characteristics in the construction phase include high turnover of employees and the multi-cultural and linguistic diversity at the site. The procedures for the assessment and development of the safety culture have, however, been diverse, and they have been utilised skilfully and in a situation-specific manner. The procedures have facilitated continuous improvement of operation throughout the supply chain.

Information on the state of the safety culture at the site has been collected since 2009 using, for example, surveys, field observations, interviews, audits and training and qualification register monitoring. TVO has had a safety culture coordinator and safety culture group at the Olkiluoto 3 nuclear power plant unit, tasked to monitor and develop the safety culture. The plant supplier has also developed similar practices for the site and supply chain.

To develop the safety culture and resolve the emerged issues, safety culture has been discussed in the initial training as well as during the various trainings and seminars arranged on the subject. In addition, employees have been interviewed and coached in the field. Development of the safety culture has also been facilitated by, for example, preparing language guides ensuring that the supervisors and employees have a common language and that the instructions are understood correctly.

To prevent and identify human errors, TVO uses various methods including pre- and post-job briefings, confirmed communication, pair work and independent verification of work. In addition to the above, the success of human activities is ensured by work permit policies in use already in the commissioning phase.

STUK has assessed the state of the safety culture of the Olkiluoto 3 project regularly through the construction inspection programme inspections and daily observations. In the construction phase, a safety culture-related inspection has been carried out every year. Furthermore, STUK has commissioned four independent studies from VTT on the safety culture at the Olkiluoto 3 nuclear power plant unit since 2008. The findings of the study conducted in 2008 indicated that many quality issues originated from failure to understand the safety significance of the work. This prompted requirements for the systematic development of the safety culture. The independent safety culture assessment conducted in 2013 showed improvement in the procedures to develop the safety culture. Awareness of the safety significance of the work and being responsible in a broad sense have been key improvement targets in the Olkiluoto 3 project. The results of the preliminary 2014 study mapping the challenges for the safety culture indicated that commissioning challenges include, for example, time pressures related to the operation, unclear divisions of responsibility, frustrations and personnel turnover due to the prolonged construction phase as well as temporary arrangements in use for a long time. Acknowledging the special nature of the commissioning phase, TVO has prepared a plan to ensure adequate safety culture during it.

In their 2017 assessment, VTT suggested improvement measures for TVO’s role in the commissioning, the interaction between various groups of personnel (e.g. TVO’s Operation and Commissioning) and work permit procedures. Positive findings included safety as an overriding priority and a shared commitment in bringing the project to fruition. TVO has taken steps to, for example, clarify its role in the commissioning and control room activities and also required the plant supplier to develop its work permit procedures. The commissioning tests have shown that there is still need for development in the sectors mentioned above and that the operating organisation and control room shifts experience schedule pressures. In its inspections, STUK shall verify that these issues are addressed before fuel loading.

Safety culture during operation

TVO has many practices for monitoring and assessing the state of the company’s safety culture. An extensive self-assessment of safety culture has been conducted every three years since 2004, and the latest one was completed in early 2017. In addition to this, safety culture is monitored via a questionnaire which can be answered by any TVO staff member. The state of safety culture is monitored by TVO’s safety culture group and the CAP (Corrective Action Program) group.

Description of the safety culture situation is presented in the safety monitoring report, which is published three times a year and processed by the management review. Event-based and peer assessments of safety culture are also conducted (WANO, OSART). The safety culture development measures decided based on the assessments are coordinated as part of more extensive development programmes. These procedures also apply to the Olkiluoto 3 nuclear power plant unit and any part of the organisation related to its operation and maintenance.

To enhance its safety culture, TVO has recently developed, for example, its decision-making procedures, communication of the grounds for the decisions, reporting of safety observations as well as the manner the supervisors collect information and interact with the personnel. There have been significant problems with the atmosphere at TVO in recent years, and the staff turnover has increased from previous years. The significance of a motivated, sufficient and competent staff in maintaining a good safety culture is essential. In addition to the aforementioned safety culture development measures, other essential improvements implemented by TVO include the extensive recruitments in 2017 and 2018, development of people management and practical measures to improve the fluency of work. These measures also affect the operational processes and personnel groups related to the Olkiluoto 3 nuclear power plant unit. Through its supervision, STUK has found that TVO has implemented systematic measures in the aforementioned areas. There is some preliminary evidence of the positive effects of the measures on TVO’s work atmosphere and safety culture, and STUK is still conducting intensified monitoring of their effectiveness.

Conclusion

The conclusion is that the elements of a good safety culture as required in Section 25 of the Regulation are verifiable in the operations of TVO and the plant supplier during the construction and commissioning phases of the Olkiluoto 3 nuclear power plant unit.

The operational culture at the Olkiluoto 3 nuclear power plant unit will find its final form when the operation of the plant unit begins. The culture is influenced by the organisational characteristics and atmosphere across TVO. STUK utilises the inspection programme and other control methods to ensure that the management of the licensee is aware of the state of the safety culture at the Olkiluoto 3 nuclear power plant unit and focus appropriate development measures on its continuous improvement.

8 Security arrangements (STUK Y/3/2016)

8.1 Provisions and requirements laid down by virtue thereof

The requirements regarding security arrangements are presented in the Nuclear Energy Act, the Nuclear Energy Decree and Regulation STUK Y/3/2016. The detailed derived requirements, application instructions and STUK's regulatory control measures are described in Guides YVL A.11, YVL A.12 and YVL D.2. Other YVL Guides also present requirements that take into account the need to prepare for the prevention of unlawful action. The design basis threat is presented in a separate decision by STUK.

According to Section 7 l of the Nuclear Energy Act, the security arrangements for the use of nuclear energy shall be based on threat scenarios applicable to the use of nuclear energy and analyses of the need for protection. A nuclear facility shall have security personnel trained for the planning and implementation of arrangements for security (security organisation). Security personnel shall also be employed for securing the transport and storage of nuclear material and nuclear waste. The tasks and qualification requirements of the security organisation and security personnel shall be defined and they shall have monitoring equipment, communication equipment, protective equipment and forcible means equipment available as required for their tasks. This forcible means equipment shall be proportioned to the threat scenarios and protection needs involved, so that they are suitable for the purpose. Measures belonging to the regular security control of a nuclear facility shall be appropriately communicated to the employees of the nuclear facility and other people transacting business within the nuclear facility site.

According to Section 7 n of the Nuclear Energy Act, more detailed provisions on the preparation of the security organisation for the prevention of unlawful action are laid down in the security standing order of a nuclear facility, as approved by the Radiation and Nuclear Safety Authority (STUK) subsequent to consultation with the Ministry of the Interior and the Advisory Committee as referred to in Section 56(3). The security standing order shall contain at least the following provisions:

1. *on how the security organisation is managed and its operations organised;*
2. *on the equipment and forcible means equipment in the organisation's possession; and*
3. *on when the police should be called and how responsibility should be transferred from the security organisation to the police once they have arrived on the scene.*

The basic qualification requirements for security personnel are provided by Government decree. Security standing order contains provisions for special training, paying particular attention to the skill level required for using the equipment and forcible means equipment, and demonstrating it.

Sections 7 m and 7 o of the Nuclear Energy Act include stipulations on security control and use of forcible means.

8.2 Responsibility and regulatory control

According to the law, the sole responsibility for the safety of a nuclear power plant lies with the licensee. However, the licensee's means and authorities alone are insufficient against the most severe unlawful actions, such as terrorism. Even in these situations, it must be possible to dimension the efficiency, scope and timing of emergency response measures and countermeasures according to the threat at hand. In addition to the licensee, the police and any other authorities that provide it with official assistance have statutory obligations relating to countermeasures and ensuring safety in threat situations. The cooperation between safety authorities and between authorities and nuclear power plants is extremely important in the context of threat situations and preparations for them.

STUK serves as the regulatory authority for security arrangements relating to the use of nuclear energy. It issues and sets requirements by virtue of the Nuclear Energy Act and oversees the fulfilment of statutes, regulations and requirements. STUK is responsible for maintaining the design basis threat, whereas the threat scenario serving as the basis for the design basis threat is maintained by the Finnish Security Intelligence Service.

For the purpose of addressing unlawful action and preparations for it, the Government has established the Advisory Committee on Nuclear Security tasked with regularly monitoring and assessing threat scenarios and changes in them, developing operational capabilities and information flow, and defining guidelines for nuclear security arrangements and making related initiatives. The Committee includes representatives of the most important Finnish police and other safety authorities. Nuclear facilities are represented in expert roles, through the STUK secretaries and by invitation in expert roles. The members of the Committee have access to an extensive international cooperation network, through which information and views on international developments are conveyed to the Committee. STUK receives information related to threat-related and situational information through international information exchange systems and, among other sources, from Finnish intelligence authorities in accordance with the international terrorism prevention strategy.

8.3 Licensee's security arrangements and their assessment

STUK has assessed TVO's security arrangement plans for the Olkiluoto 3 nuclear power plant unit against the provisions, regulations and requirements referred to in Chapter 8.1. Essential TVO security arrangement documents assessed are the security standing order, security plan and transport security plan with appendices and references containing the information security plans. Structural protection solutions and security surveillance system descriptions have been reviewed and approved during the processing of the construction licence application and the construction.

STUK reviewed TVO's security standing order, security plan and transport security plan as part of the operating licence documentation. STUK requested statements on the documents from the Advisory Committee on Nuclear Security (TJNK) and the Ministry of the Interior.

The content of the security arrangement documents is compliant with the stipulations in Sections 7 l–o of the Nuclear Energy Act. The current design basis threat (2/Y42217/2013, 30 May 2013) was not the original design basis for the Olkiluoto 3 nuclear power plant unit. However, based on the assessments made by TVO and STUK, its requirements are largely met. In conjunction with the implementation of the new YVL Guides, STUK required some improvement measures with regard to the technical and functional security arrangements, associated instructions and security arrangement assessments. Based on the assessment prepared for the implementing decision of the YVL Guides and the design basis threat and the review of TVO's security arrangement documents, the safety level specified in Regulation STUK Y/3/2016 is achieved in accordance with the current threat scenario.

The licensee must demonstrate the effectiveness of the security arrangement through assessments and drills, for example. TVO has implemented an extensive and independent assessment in 2018. Within the scope of its control measures, STUK assesses the licensee's methods for indicating effectiveness and the results of the methods. Functional threat scenario response exercises cannot be organised realistically until the power plant unit and its security arrangements are completed. Based on the changes in the threat scenario and control observations, STUK may, among other developments, require the operational capability of the security organisation and technical security arrangements to be improved in ways that can be implemented more flexibly than structural solutions. This is also in line with the principle of continuous improvement.

The implementation of the Olkiluoto 3 plant unit's security arrangements is not yet complete. STUK inspects the security arrangement implementation to ascertain it is sufficient before the fuel loading (Nuclear Energy Act, Section 20(2)(1)).

9 Emergency response arrangements (STUK Y/2/2016)

Pursuant to Section 7 p of the Nuclear Energy Act, *the planning of emergency response arrangements for the use of nuclear energy shall be based on analyses of operational occurrence and accident conditions, and the consequences assessed on the basis of these analyses. In planning emergency response arrangements for a nuclear facility, preparations shall be made for the release of a significant quantity of radioactive materials from the facility. The nuclear facility shall have persons trained in the planning of emergency response arrangements and emergencies (emergency response organisation), whose duties shall be specified and who shall have access to the facilities, equipment and communication systems required for their duties. Emergency response arrangements shall be consistent with the rescue and preparedness plans drawn up by the authorities, considering the provisions laid down in Section 48 of the Rescue Act (379/2011).*

The requirements regarding emergency response arrangements are presented in the Nuclear Energy Act, Nuclear Energy Decree and the Radiation and Nuclear Safety Authority Regulation on the Emergency Arrangements of a Nuclear Power Plant. During the construction of the Olkiluoto 3 nuclear power plant unit, the Government Decree on the Emergency Arrangements at Nuclear Power Plants was amended twice, first in 2008 (735/2008) and then in 2013 (716/2013). Decree 716/2013 particularly focused on specifying the design bases for the emergency response arrangements based on experiences gained from the Fukushima nuclear power plant disaster. As of the beginning of 2016, Government Decree 716/2013 was replaced with the Radiation and Nuclear Safety Authority Regulation on the Emergency Arrangements of a Nuclear Power Plant (STUK Y/2/2016).

The detailed application instructions of the requirements and STUK's regulatory control measures are described in Guide YVL C.5. Some other YVL Guides also present requirements on emergency response arrangements concerning the assessment of the radiation situation of the environment, radiation and release measurements and meteorological measurements.

9.1 Planning of emergency response arrangements and the emergency response organisation (Sections 3 and 6)

Pursuant to Section 3 of Regulation STUK Y/2/2016:

Emergency arrangements shall be planned to ensure that emergency situations are quickly brought under control, the safety of the individuals in the site area is assured, and timely action is taken to prevent or limit radiation exposure to the public in the emergency planning zone.

Planning shall take account of a simultaneous risk to nuclear safety occurring in all nuclear facilities in the site area and their potential consequences, especially the radiation situation on the site and in the surrounding area and the opportunities to access the area.

Planning shall take account of the fact that the emergency situation could continue for a prolonged period.

Planning shall be based on analyses of the time-behaviour progress of severe accident scenarios resulting in a potential release. In such a case, variations in the state of the plant, the development of events as a function of time, the radiation situation at the plant, radioactive releases, radioactive release routes and weather conditions shall all be taken into account.

Planning shall take account of events deteriorating safety, their controllability and the severity of consequences, and threats related to unlawful action and the potential consequences thereof.

Emergency arrangements shall be consistent with the operation, fire protection and nuclear security of a nuclear power plant.

Emergency arrangements shall be compatible with the external rescue plan prepared by the authorities for an accident at a nuclear power plant.

The design basis must be regularly assessed and always when seen to be necessary.

and pursuant to Section 6:

The licensee shall have a management system and organisation in place to ensure a timely response in an emergency situation. The tasks of people assigned to act during an emergency situation are to be defined in advance.

The licensee shall ensure that the personnel needed in emergency situations are promptly available. There shall also be enough personnel to bring a long-term emergency situation under control.

TVO has analysed accident situations and events that deteriorate safety, and the analyses have been presented in the safety analysis reports of all the TVO nuclear facilities and TVO's emergency plan. Similar analyses have been made for the Olkiluoto 3 nuclear power plant unit at different stages of its construction. The results of these analyses have been used in the planning and development of the Olkiluoto nuclear power plant's emergency response arrangements. TVO's emergency response plan is shared by all plant units and the spent fuel storage. After the Fukushima incident, the design bases were expanded to apply to a simultaneous emergency situation at all nuclear facilities in the site area.

Emergency situations are classified and described in the facility's emergency plan and safety analysis report. The emergency procedures describe the notifications and alarms required to be issued to plant personnel and authorities and the situational operating range of the emergency response organisation. The emergency planning and instructions ensure the safety of the personnel by planning the arrangements for warning them and evacuating unauthorised persons from the site area.

The Olkiluoto nuclear power plant units responsible for operation and security arrangements as well as the on-site fire brigade have participated in the preparation of the emergency plan. This ensures the compatibility of the arrangements. The changes caused by the regional arrangements of the rescue operations and the initiation of the emergency response centre operations have been updated into the emergency plan. TVO has participated in the preparation and updating of the external rescue plan drawn up by the Satakunta Rescue Department.

At TVO, the emergency response arrangements are handled by the person in charge of emergency response arrangements, as per Section 7 i of the Nuclear Energy Act, and two designated deputies. All persons have been approved by STUK in accordance with the applicable requirements. TVO's emergency response organisation has been specified in the emergency response plan of the Olkiluoto power plant. The emergency response organisation handles emergency situations at all of the nuclear facilities. The emergency response organisation is normally updated as needed, typically a few times a year. After the Fukushima accident, the emergency response organisation has been expanded to meet the requirements of a prolonged situation. Another significant change has been the need to expand the emergency response organisation by including roles required by the new plant type.

The individuals added to the organisation for the Olkiluoto 3 nuclear power plant unit have been specified in the emergency plan and trained to their respective duties. As members of the emergency response organisation, they will participate in training and exercises as part of the normal emergency response training programme. TVO is constantly assessing the suitability of its organisation in case of an emergency situation at the Olkiluoto 3 nuclear power plant unit, making changes to the organisation when necessary. The operative instructions of the emergency response organisation include a description of the organisation's alarm arrangements. In an alert situation, the emergency activities are handled by those leading the emergency response organisation and other personnel deemed necessary. In a site area emergency and general emergency, TVO's emergency response organisation is alerted in its entirety.

9.2 Preparedness (Section 4–5)

Pursuant to Section 4 of Regulation STUK Y/2/2016:

The licensee shall be prepared to carry out the measures required in emergency situations, the analysis of emergency situations and the consequences thereof, assessment of the anticipated development of emergency situations, the mitigatory actions needed to control or limit the accident, the continuous and effective exchange of information with the authorities, and communications to the media and the members of the public.

When analysing the situation, the technical status of the plant and release of radioactive materials, or threat thereof, and the radiation situation inside the plant and in the site area and emergency planning zone, shall be assessed.

In emergency situations, the licensee shall be prepared to carry out radiation monitoring in the site area and in the precautionary action zone. The licensee shall also take meteorological measurements and shall be capable of assessing the dispersion of radioactive substances and the resulting radiation exposure of the population in the emergency planning zone during an emergency situation.

To prepare for an emergency situation, the licensee shall have appropriate staff alarm systems, places of assembly in the site area, evacuation arrangements, the necessary personnel protective equipment, radiation measuring instruments and iodine tablets available.

The licensee shall provide arrangements for contamination measurements of personnel, and their decontamination.

To manage emergency operations, there shall be an emergency response centre, which shall be able to maintain proper working conditions during an emergency situation, and which shall also be available during prolonged power failures.

There shall be a designated centre outside the site area from which to direct the plant's emergency response operations, if the emergency response centre is not available.

There shall be reliable communication and alarm systems in place to manage emergency response operations for the purposes of internal and external communications of the nuclear power plant.

The licensee shall ensure that there are automatic data transmission systems in place to send information essential in terms of the emergency operations to the emergency response centre of the Radiation and Nuclear Safety Authority.

Licensee's management system and organisation shall ensure maintenance and development of the emergency arrangements.

and pursuant to Section 5.

In addition to what is enacted in Sections 35 and 36 of the Nuclear Energy Decree (161/1988) on regarding the emergency plan and in Section 48 of the Rescue Act (379/2011) regarding the rescue plan, the licensee must draw up the necessary the emergency procedures for the operation of the emergency response organisation.

The Olkiluoto nuclear power plant has prepared to conduct the measures required by an emergency situation and analyse the impacts of the situation and assess its development. Instructions for the emergency response organisation's operations are provided in the emergency plan. The premises of the emergency response organisation include all systems, information materials and other equipment that the organisation requires to perform its tasks. The data on the facility's process computer can be accessed through various terminals, which display the process state and radiation situation of the facility. In order to secure communication connections from the plant, TVO has procured VIRVE and satellite phones for its emergency response organisation.

The Olkiluoto nuclear power plant has made preparations to assess the radiation situation and the propagation of radioactive substances in accident situations. Equipment has been developed by renewing the external radiation dose rate measurements in the site area and a radius of 5 km in the summer of 2008. The system has been expanded with three new dose rate meters in the vicinity of the Olkiluoto 3 nuclear power plant unit. The weather mast's measurement system instrumentation was updated in the autumn of 2008. TVO uses the ROSA software to calculate the propagation of radioactive releases and environmental doses in the emergency planning zone. In addition, TVO uses the CRCS software for assessing the radiation situation at the plant and the dispersion of releases in case of an emergency situation at the Olkiluoto 3 nuclear power plant unit.

TVO sends the essential information needed to assess the situation to STUK's emergency response centre via an automatic data transfer link. A comprehensive update to the data transfer link is currently under way, in conjunction with which the transfer of the Olkiluoto 3 nuclear power plant unit's plant information was incorporated as part of the system in August 2017.

In accordance with TVO's operating principles, the emergency response organisation primarily assembles in the emergency response centre of the plant unit experiencing the emergency. Premises intended for commanding the Olkiluoto 3 nuclear power plant unit's emergency response activities have been reserved. The premises will be equipped with similar equipment than those of the Olkiluoto 1 and 2 nuclear power plant units. Once completed, the emergency response centre of the Olkiluoto 3 nuclear power plant unit will meet the requirements set for it. The emergency response organisation has an auxiliary command centre in the city of Rauma. It features a sufficient number of systems and documentation to command a situation where the facility cannot be accessed due to extraordinary weather conditions, for example.

The power plant features assembly locations for personnel, protective equipment for emergency situations and facilities for the contamination measurements and decontamination of personnel. The emergency response premises include sufficient opportunities for refreshment and rest in case of situations where the members of the emergency response organisation will have to spend an extended period of time there. TVO updated the procedures related to personnel evacuation in 2016. In conjunction with this, one of the three assembly locations was located at the Olkiluoto 3 nuclear power plant unit. TVO has acquired iodine tablets in the site area for the personnel.

Over the course of the current operating licence period of the operating plant units, TVO has developed the alarm arrangements of the emergency response organisation. The arrangement for alerting the emergency response organisation has been duplicated in such a way that, in addition to TVO's own alarm system, the rescue department can send alarm messages to TVO's emergency response organisation. The alarm arrangements and the ability to reach the appropriate personnel are tested on a regular basis. A high-power civil defence siren is available in the outdoor areas for alerting the personnel. Indoors, alarms are issued through speaker and telephone systems and alarm lights. TVO ensured the audibility of the alarms in the accommodation village in 2014. The last time a personnel assembly exercise was held was in 2018.

Communications to the media and the population has been planned and instructed in advance in the emergency response plan, and the measures are practised regularly in emergency exercises.

9.3 Maintenance of preparedness (Section 8)

Pursuant to Section 8 of Regulation STUK Y/2/2016:

The licensee shall arrange emergency training for all nuclear power plant personnel and other permanent or temporary employees working at the site area.

The licensee shall arrange emergency exercises on an annual basis. At least once every three years the emergency exercise shall be arranged as a co-operation exercise with the authorities. The emergency exercises shall be evaluated based on the set preparedness objectives.

The licensee shall draw up at least a three-year training plan to ensure that training is given on all aspects of preparedness to act at regular intervals.

Emergency arrangements shall be regularly evaluated. When developing the emergency arrangements, attention shall focus on the experience gained and conclusions drawn concerning the management of emergency situations, the experience gained from the exercises as well as on research and technical developments.

Facilities and equipment reserved for emergency situations shall be available and maintained in operational condition at all times.

The emergency plan and guidelines shall be kept up to date.

Emergency response training and exercises are arranged for the TVO’s emergency response organisation on an annual basis. TVO has implemented an emergency response training matrix, which includes an up-to-date emergency training plan for each member of the emergency response organisation for the next three years. The annual training plans have been delivered to STUK according to the relevant requirements. The emergency response training has included joint training for the entire emergency response organisation as well as group-specific training. The training has been provided as both classroom education and practical training. Members of the emergency response organisation must take part in the exercises regularly. In its Periodic Inspection Programme, STUK has annually ensured that the training has been provided.

TVO has organised emergency response exercises for different areas of emergency response on an annual basis. In addition less expansive exercises have been held.In addition to TVO, the annual emergency response exercises have been attended by the other essential actors in an emergency situation: STUK, the police and the rescue department. Dozens of organisations have participated in the joint cooperation exercises led by the rescue department and organised every three years. The scenarios of the emergency response exercises have ranged from plant events classified as alert situations to severe reactor accidents.

Feedback collected from the participants and evaluators of prior exercises have been used in planning the new exercises. .STUK shall evaluate the measures to be initiated based on the feedback on the exercise through its regulatory control efforts.

In spring 2017, TVO initiated exercises to exercise and develop the emergency response arrangements at the Olkiluoto 3 nuclear power plant unit with its own organization. Since then, TVO has organized a variety of internal exercises related to the management of OL3 emergency response situations. The scenario for the 2017 emergency response exercise OLKI17 was directed at the Olkiluoto 3 nuclear power plant unit. In OLKI17, TVO's organization was able to meet key goals. The emergency response exercise OLKI18, held in 2018, was combined with the extensive security arrangement exercise TURVA18. OLKI18 was also partly directed to the Olkiluoto 3 plant unit. STUK evaluated the emergency response exercises and provided feedback to TVO for developing the emergency response activities. TVO collected feedback also from TVO's own organisation and other outside evaluators

In addition to the training of the emergency response organisation, attention has been paid to the emergency response training of others working in the site area. Special attention has been paid to the induction training of the Olkiluoto 3 construction site and, within it, the site area activities required by an accident situation at the Olkiluoto 1 and 2 nuclear power plant units. During the commissioning of the Olkiluoto 3 nuclear power plant unit, emergency response training will be developed as planned on the basis of the identified needs.

The continuous operability of the emergency response premises and equipment has been ensured by means of the preventive maintenance programme. STUK inspects the emergency response premises and equipment as part of the Periodic Inspection Programme and regulatory control efforts. TVO has updated the emergency plan several times a year, as necessary. Other emergency procedures are updated as needed.

9.4 Action in an emergency situation (Sections 9–12)

The requirements for actions in an emergency situation are presented in Sections 9–12 of Regulation STUK Y/2/2016.

The operations of the Olkiluoto power plant's operating organisation in emergency situations are based on procedures, the most essential of which are the emergency operating procedures and the emergency plan. In addition to this, other procedures referred to in these procedures are used in emergency situations. The status of the procedures is addressed in Chapter 6.1.

The control rooms of the Olkiluoto nuclear power plant are constantly prepared to initiate activities in an emergency response situation. The shift manager serves as the emergency response manager until the actual emergency response manager appointed for the emergency response organisation assumes responsibility for handling the situation. The emergency response plan includes a description of the emergency response organisation at an early stage of operations as well as the actual emergency response organisation, including task descriptions. Communication of situational awareness in an emergency situation has been developed by, for example, adopting an electronic situation log that can be viewed by the cooperating authorities.

As a result of amendments to the applicable provisions, TVO's emergency plan and the related emergency procedures have been updated to comply with the current provisions and official procedures. The procedure for the emergency response manager includes operating instructions on issuing recommendations regarding protective actions to the head of rescue operations until STUK assumes responsibility.

TVO's emergency response organisation has appointed contact persons whom it will send to the rescue services command centre to provide expert assistance related to nuclear technology and radiation protection.

9.5 Measures pertaining to rescue operations (Section 13)

Section 48 of the Rescue Act 379/2011 obliges nuclear facilities to participate in the preparation of an external rescue plan for locations that present an extraordinary hazard. More specific provisions on the plan are laid down in the Decree of the Ministry of the Interior on an external rescue plan for locations that present an extraordinary hazard (612/2015).

The Satakunta Rescue Department has drawn up an external rescue plan for the Olkiluoto power plant. TVO has assisted in the preparation of the plan. Among other things, the plan consolidates the tasks of all essential actors and the measures to organise the cooperation. TVO has made preparations to assist the rescue department during and after emergencies to the extent required. One goal of the emergency exercises is to practice cooperation between organisations, which includes testing the external rescue plan.

TVO has actively participated in the operations of the Satakunta region's emergency response cooperation group, or SVP group, since its formation. The organisations in the group (TVO, Satakunta Rescue Department, Police Department of Eastern Uusimaa, STUK and Satakunta Hospital District) take part in planning exercises and processing exercise feedback, among other tasks. The Satakunta region's SVP group has followed the activity of the Eastern Uusimaa SVP group, and TVO has participated in the acquisition of an equipment container on the initiative of the Eastern Uusimaa SVP group. The equipment container includes emergency response equipment suitable for joint use, and it can be moved to a suitable location within a few hours.

TVO's plant fire brigade practices regularly with the units of the Satakunta Rescue Department and provides them with training on fire fighting and rescue operations at a nuclear power plant. Training has been provided at the Olkiluoto 3 nuclear power plant unit based on actual topical need throughout the construction.

Operating instructions for accident situations have been distributed to the population in the emergency planning zone in advance. TVO distributes iodine tablets to the population residing within the zone based on their expiration date.

Conclusion

TVO's emergency response organisation has been complemented with new roles required to manage emergency situations at the Olkiluoto 3 nuclear power plant unit. TVO's emergency preparedness plan for the Olkiluoto 3 nuclear power plant unit has been approved. The development of the operating organisation procedures used by TVO in emergency situations is still under way, and proper management of emergency situations at the Olkiluoto 3 nuclear power plant unit cannot be ensured until it is completed. The premises of the emergency response organisation must be equipped and reviewed to have the emergency response arrangements of the Olkiluoto 3 nuclear power plant unit meet the requirements.

In conjunction with the renewal of the operating licence for the Olkiluoto 1 and 2 nuclear power plant units, STUK requested the Ministry of the Interior's Rescue Department to provide a statement on the emergency response arrangements of the Olkiluoto nuclear power plant in accordance with Section 37 of the Nuclear Safety Act. In its statement, the Ministry of the Interior's Rescue Department states that TVO's emergency response plan has been prepared appropriately and that, with regard to its own area of responsibility, the Rescue Department has no comments concerning the contents of the plan.

The conclusion is that once TVO has completed the unfinished work, the emergency response arrangements of the Olkiluoto nuclear power plant have been implemented in accordance with Regulation STUK Y/2/2016 also for the Olkiluoto 3 nuclear power plant unit. STUK will verify compliance with requirements before nuclear fuel is transferred into the reactor.

10 Nuclear waste management (STUK Y/4/2016)

According to Section 20(1)(2) of the Nuclear Energy Act, one requirement for receiving an operating licence for a nuclear facility is that *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.*

According to Section 7 h of the Nuclear Energy Act, *the nuclear facility shall have the facilities, equipment and other arrangements required to ensure the safe handling and storage of nuclear material required by the plant and any nuclear waste generated during operation. Nuclear waste shall be managed so that after disposal of the waste no radiation exposure is caused, which would exceed the level considered acceptable at the time the final disposal is implemented. The disposal of nuclear waste in a manner intended as permanent shall be planned giving priority to safety and so that ensuring long-term safety does not require the surveillance of the final disposal site. Nuclear waste management plans shall be kept up to date as provided in section 28.*

10.1 Handling, storage and disposal of power plant waste

Pursuant to Section 13 of Regulation STUK Y/1/2016:

Waste generated during the operation of a nuclear power plant, the activity concentration of which exceeds the limits set by the Radiation and Nuclear Safety Authority (STUK), shall be treated as radioactive waste.

Waste shall be sorted, categorised and handled in an appropriate manner in terms of its storage and disposal, and stored safely.

The detailed requirements, application instructions and STUK's regulatory control measures issued on the basis of the Regulation are described in Guide D.4 covering the predisposal management of low and intermediate level nuclear waste at a plant unit. In addition to this, Regulation STUK Y/4/2016 lays down general requirements and Guide YVL D.5 detailed requirements for the safety of the disposal of nuclear waste.

The starting point for the management of the Olkiluoto 3 nuclear power plant unit's power plant waste has been to arrange for the handling up to disposal at the Olkiluoto plant area. Including the waste packages, the anticipated annual amount of low and intermediate level operational waste at the Olkiluoto 3 nuclear power plant unit is approximately 50–100 m^3. The total volume of operational waste generated during the 60-year service life of the plant unit is estimated to be around 3,000–6,000 m^3. The management of low and intermediate level waste at Olkiluoto has been developed systematically during the service life of the Olkiluoto 1 and 2 nuclear power plant units. In recent years, the Olkiluoto 3 nuclear power plant unit has also been taken into account in the waste management development projects.

The liquid intermediate level waste generated by the operation of the Olkiluoto 3 nuclear power plant unit is solidified with a purpose-built solidification method where waste is dried in drums. The plant unit has separate storage space for operational waste, in addition to which the storages for the low and intermediate level waste of the Olkiluoto 1 and 2 nuclear power plant units at the site area may be used.

In the operating licence application for the Olkiluoto 3 nuclear power plant unit, TVO applies for permission for intermediate storage of plant waste generated by the operation of the nuclear power plants situated on the island of Olkiluoto within the Olkiluoto 3 nuclear power plant unit until the end of 2038. The operating licence issued for the Olkiluoto 1 and 2 nuclear power plants on 20 September 2018 and the operating licence currently applied for the Olkiluoto 3 nuclear power plant unit allow for the intermediate storage of nuclear waste generated by the operation of the nuclear facilities situated on the island of Olkiluoto provided that the total waste volume, including the storage spaces of the Olkiluoto 3 nuclear power plant unit, never exceeds 30,000 m^3. If necessary, individual spaces suitable for intermediate storage can be expanded by means of a plant modification which is processed and approved by STUK in accordance with Section 112 of the Nuclear Energy Decree.

The low-level waste generated by the operation of the nuclear facilities on the Olkiluoto island is of the same type at all of the facilities – i.e. primarily mixed waste accumulated in repair and maintenance work. The same procedures are observed at all plant units with regard to the handling, storage and disposal of the waste and its release from regulatory control.

The safety of handling and storage of the Olkiluoto 3 nuclear power plant unit's nuclear waste in the MAJ and KAJ storages situated in the plant area was reviewed in conjunction with the renewal of the operating licence for the Olkiluoto 1 and 2 nuclear power plant units. As a result of the review, STUK delivered to the MEAE a statement appended with STUK's safety review (2/C42213/2017, 31 May 2018).

The handling of radioactive waste at the Olkiluoto 3 nuclear power plant unit is described in the final safety analysis report reviewed by STUK in conjunction with the operating licence application processing. The safety analysis report also discusses the intermediate storage of intermediate waste dried in drums in the KAJ storage, the amount of waste stored and the design basis in terms of radiation protection.

The disposal space (VLJ repository) for operational waste situated in the Olkiluoto site area was commissioned in 1992. The disposal facility for operational waste has a separate operating licence until the end of 2051. In 2012, TVO applied for an amendment in the operating licence for the disposal facility, in conjunction with which the disposal of waste generated from the Olkiluoto nuclear power plant unit in the VLJ repository was taken into consideration. As a result of the assessment, STUK delivered to the MEAE a statement appended with STUK's safety review (4/C42213/2011, 28 June 2012). Part of the Olkiluoto 3 nuclear power plant unit's low level maintenance waste may be disposed of in the current MAJ silo for low level waste, and once it is full, in the extension of the disposal facility. It has been planned that all intermediate waste of the Olkiluoto 3 nuclear power plant unit would be disposed of in the extension of the VLJ repository to be built later.

The conclusion is that the handling and storage of operational waste have been implemented as intended in Section 7 h and 20(1)(2) of the Nuclear Energy Act and

Section 13 of Regulation STUK Y/1/2016. According to STUK's assessment, the nuclear waste management at the Olkiluoto 3 nuclear power plant unit is handled in a safe manner, and the methods employed for the purpose are appropriate and sufficient.

10.2 Handling, storage and disposal of spent nuclear fuel

Spent fuel from the Olkiluoto 3 nuclear power plant unit will be stored in the water pools of the interim water pool storage situated in the fuel building and the interim storage for spent fuel (KPA storage) situated in the plant area until such time it is transferred to the Posiva Oy's encapsulation and final disposal facility at Olkiluoto. It is estimated that the capacity of the water pool storage situated in the fuel building is enough for it to be the sole storage for spent nuclear fuel for 7 years. The safety of fuel storage in the fuel building is addressed in Chapter 4.5 of this safety review.

The licence for the use of the KPA storage at Olkiluoto has been issued as part of the operating licence for the Olkiluoto 1 and 2 nuclear power plant units. In conjunction with the renewal of the operating licence for the Olkiluoto 1 and 2 nuclear power plant units in 2017, TVO applied for an extension to the licence for the use of the KPA storage. According to TVO's supplement to the licence application submitted to MEAE, a maximum of two of the KPA storage's fuel pools are reserved for the Olkiluoto 3 nuclear power plant unit. In total, these two pools can store 1,600 spent fuel assemblies, estimated to equal approximately 23 years of operation. The capacity of the water pools in the Olkiluoto 3 nuclear power plant unit's fuel building is 954 spent fuel assemblies.
In 2009–2014, the KPA storage was expanded to meet the need for storage of spent fuel from the Olkiluoto plant units. The KPA storage expansion project took into account the interim storage needs for spent fuel from the Olkiluoto 3 nuclear power plant unit. STUK prepared a safety review and approved the application for expanding the capacity of the KPA storage in 2015. In accordance with the decision, the storage of spent nuclear fuel generated by the operation of the Olkiluoto 3 plant unit in the KPA storage shall be processed separately at a later time. For example, the fuel transfer machine in the KPA storage must be modernised before spent nuclear fuel from the Olkiluoto 3 nuclear power plant unit can be handled and stored in the KPA storage. According to TVO, the intended method of transport of spent nuclear fuel between the reactor and KPA storage is wet transport, meaning that there is no need for modifications to the existing systems in the KPA storage. However, the handling systems of the Olkiluoto 3 nuclear power plant unit also enables the use of dry transport.

The final disposal plan for the spent nuclear fuel from the Olkiluoto nuclear power plant, including the spent nuclear fuel from the Olkiluoto 3 nuclear power plant unit, is based on the Posiva Oy's final disposal project with the government decision-in-principle confirmed by the Parliament in 2001. In 2015, STUK drew up a safety assessment of the construction licence application for the final disposal project and issued a statement to that effect to the Ministry of Economic Affairs and Employment. The Government granted the construction licence in March 2015. According to Posiva Oy's current schedule, the final disposal of spent nuclear fuel could begin at the beginning of 2024. Posiva is planning to submit an operating licence application for the encapsulation plant and final disposal facility in 2021.

The nuclear fuel management methods used by TVO and the plans for their further development are appropriate. The management of the full-scale storage of spent nuclear fuel from the Olkiluoto 3 nuclear power plant unit requires changes to the KPA storage before commencing the storage of spent nuclear fuel from the Olkiluoto 3 nuclear power plant unit in the KPA storage. The key changes required concern the modifications to the fuel transfer machine in the KPA facility so that it can handle the fuel from the Olkiluoto 3 nuclear power plant unit and the acquisition of racks for the spent fuel from the Olkiluoto 3 nuclear power plant unit at the end of the 2020s. TVO has provided STUK with a list of modifications to the KPA storage and when these are planned to be implemented in conjunction with the operating licence documentation for the Olkiluoto 1 and 2 nuclear power plant units.

10.3 Decommissioning of the plant unit

According to Section 7 g of the Nuclear Energy Act, *The design of a nuclear facility shall provide for the facility's decommissioning. The related decommissioning plan being kept up to date as provided in section 28 herein. 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.*

Pursuant to Section 17 of Regulation STUK Y/1/2016, *The design of a nuclear power plant and its operation shall take account of the decommissioning of plant units so that it is possible to limit the volume of nuclear waste for disposal accumulating during the dismantling of units, and radiation exposure to workers due to the dismantling of the plant, and to prevent radioactive materials from spreading into the environment during decommissioning and the handling of waste.*

TVO has submitted a plan describing the decommissioning of the Olkiluoto 3 nuclear power plant unit to STUK as part of the operating licence documentation. Section 28 of the Nuclear Energy Act requires licensees under a waste management obligation to prepare a plan for the decommissioning of the nuclear facility every six years. In future, the updated plan shall be submitted to the Ministry of Economic Affairs and Employment. STUK shall then issue a statement on the plan.

The requirements for radiation safety over the lifecycle of the Olkiluoto 3 nuclear power plant unit have been taken into account in the design. Conformity with significant radiation safety requirements relevant to the plant unit has been assessed in the system safety reviews presented by TVO and the first decommissioning plan submitted in conjunction with the operating licence application.

The starting point for the Olkiluoto 3 nuclear power plant unit's decommissioning plan is the closure of the power plant unit after 60 years of use. Immediate decommissioning has been chosen as the decommissioning strategy. The dismantling of the plant unit is estimated to take approximately nine years, and the work is divided into a preparatory, dismantling and final disposal stages.

All parts of the plant with activity exceeding the exemption levels shall be dismantled and placed in final disposal. The remaining portion can be released from regulatory control under the Nuclear Energy Act. The radioactive dismantling waste will be disposed of in facilities constructed in connection to the on-site final disposal facility for power plant waste. The estimated capacity requirement for the plant unit's decommissioning waste is approximately 15,000 m^3 of final disposal space. According to the plan, the reactor pressure vessel and other large components will be placed in final disposal without sectioning them into pieces.

The plan proposed by TVO for the decommissioning of the Olkiluoto 3 nuclear power plant unit fulfils the requirements for a decommissioning plan of a nuclear facility according to Section 36(13) of the Nuclear Energy Decree 161/2008. The decommissioning plan describes the matters related to the decommissioning of the plant unit and the subsequent nuclear waste management in sufficient detail for the purpose of the operating licence phase.

11 Safeguards of nuclear materials (Nuclear Energy Decree, Sections 118 and 118 b)

Pursuant to Section 118 of the Nuclear Energy Decree, STUK maintains a control system of nuclear materials with the purpose of carrying out the safeguards control of the use of nuclear energy that is necessary for the non-proliferation of nuclear weapons as well as the safeguards control that is related to the international agreements on nuclear energy to which Finland is a part. STUK sees to it that the licensee has the necessary expertise and preparedness to arrange the supervision and that the licensee for its own part implements the above-mentioned supervision in accordance with the pertinent regulations.

When maintaining the safeguards system referred to in Section 118(1) of the Nuclear Energy Decree, STUK shall take account of the obligations of Commission Regulation (Euratom) No. 302/2005 on the application of the provisions on Euratom safeguards. STUK acts as the site representative, as referred to in the Decree, for all sites.

In accordance with Section 118 b of the Nuclear Energy Decree, the use of nuclear energy shall be planned and implemented so that the obligations concerning the control of nuclear material are met. Such obligations are presented in the Nuclear Energy Act and the Treaty establishing the European Atomic Energy Community (Euratom) and provision and regulations issued thereunder. The facility shall not contain premises, materials or functions relevant to the control of nuclear materials, which are not included in the notified information. The licensee shall have an accounting and reporting system for nuclear material and other nuclear commodity which ensures the correctness, scope and consistency of information in order to implement the supervision necessary for the non-proliferation of nuclear weapons.

TVO has an approved nuclear safeguards manual, which meets the requirements set forth in Guide YVL D.1 also for the Olkiluoto 3 nuclear power plant. The operator's measures to arrange its own monitoring, to meet the requirements of export control in the nuclear energy field and to enable regulatory control by authorities and international organisations are appropriate.

At the Olkiluoto 3 nuclear power plant unit, the arrangements for the non-proliferation of nuclear weapons are up-to-date and sufficient.

12 Other requirements

In addition to the safety requirements in the STUK regulations, the Nuclear Energy Act imposes some requirements related to the safety of nuclear facilities. This chapter covers the financial and other prerequisites of the applicant to conduct the operations safely and in accordance with Finland's international agreement obligations (Nuclear Energy Act, Section 20(1)(4)), for the part that the matters fall within STUK's authority. In addition to this, the fulfilment of the conditions related to the construction licence of the Olkiluoto 3 nuclear power plant unit is examined.

12.1 The licensee's financial prerequisites for the operations

In order to receive an operating licence, the applicant must have the financial and other prerequisites to conduct the operations in a safe manner (Nuclear Energy Act, Section 20(1)(4)). The financial prerequisites are primarily assessed by authorities other than STUK (mainly the Ministry of Economic Affairs and Employment). The licensees have financial obligations related to, for example, preparing for the costs of nuclear waste management and fulfilling the nuclear liability. The licensees' finances and financial operating environment also affect the safety of the facilities, which is why STUK monitors, among other things, the trends of investments to improve safety, organisational changes and the number and competence of personnel at Finnish nuclear power plants.

The electrical market was opened in Finland some 20 years ago, so there is extensive experience in the country with regard to the operation of nuclear power plant companies on open markets. TVO has adhered to a policy according to which the economic efficiency of the operations is ensured by keeping the facility's utilisation rate high. This gives incentive to avoid even the smallest disturbances, which requires keeping the plant units in good condition. This, in turn, requires investments, which contribute to enhancing safety: the prevention of operational occurrences is the first goal in safety planning.

12.2 International agreements

International agreements in STUK's sphere of operations include international agreements that concern nuclear safeguards and matters regarding nuclear liability, nuclear safety and nuclear waste. In addition to this, Finland is subject to the Treaty establishing the European Atomic Energy Community (Euratom) and the obligations and decrees issued by virtue thereof. These agreements have been incorporated into national legislation, and the implementation of recently-updated directives into national legislation is under way.

Nuclear liability, i.e. the liabilities and obligations resulting from nuclear damage, is governed by the Nuclear Liability Act (484/1972). This Act takes into account the international agreements binding upon Finland that mainly set the minimum levels of liability for nuclear damage. More extensive liabilities can be set forth on a national level.

Finland's Nuclear Liability Act imposes on the licensee an unlimited liability to compensate for damage resulting from a nuclear accident that occurs in Finland. If an accident that occurs in Finland causes damage outside Finland, the licensee's liability for damages is SDR 600 million. The special drawing right (SDR) is a unit used by the International Monetary Fund (IMF), the value of which is determined based on essential currencies. SDR 600 million is roughly equivalent to €700 million.

Section 3 of the Nuclear Liability Act states that, in the application of the Act, two or more nuclear facilities of the same holder that are located in the same site area must be regarded as a single facility together with the holder's other premises storing nuclear materials in the site area.

TVO's liability insurance policies cover the separate nuclear facilities at the site, i.e. the Olkiluoto 1 and 2 nuclear power plant units, the VLJ repository and the MAJ, KAJ and KPA storages. The amounts insured meet the requirements in Section 18 of the effective Nuclear Liability Act. The Financial Supervisory Authority has assessed TVO's liability insurance policies and, in decision 52/02.03.13/2017, 21 December 2017 (STUK case 1/C41801/2018), stated that they are acceptable. According to Section 20(2) of the Nuclear Energy Act, operating a nuclear facility requires that the licensee's indemnification regarding liability in the case of nuclear damage has been arranged appropriately. TVO has made preparations to include the Olkiluoto 3 nuclear power plant unit in the liability insurance. Before the loading of the nuclear fuel, STUK will ensure that the indemnification regarding liability in the case of nuclear damage has been arranged appropriately also for the Olkiluoto 3 nuclear power plant unit.

STUK assesses liability insurances related to transport in conjunction with each instance of transport.

An international Convention on Nuclear Safety, Treaty Series 74/1996 (INFCIRC/449), was signed in 1994. It is a collection of highest level nuclear safety principles that is legally binding to the countries that have signed it. Finland has been part of the Convention, which has been effective since 1996, from the beginning.

Correspondingly, the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, Treaty Series 36/2001 (INFCIRC/546), was signed in 1997. It is a collection of principles regarding the handling of nuclear waste that is legally binding to the member countries. Finland joined the Convention, which has been effective since 2001, from the start.

The matters governed by the international conventions on nuclear safety and nuclear waste are addressed in Finnish legislation. Compliance with the conventions is assessed every three years in Review Meetings organised by the International Atomic Energy Agency (IAEA), for which each member country must prepare a report on its operations.

In STUK's view, TVO fulfils the obligations of the international conventions within STUK's sphere of operations in accordance with Section 20 of the Nuclear Energy Act.

12.3 Fulfilment of the conditions connected to the construction licence

The construction licence was granted for a nuclear power plant unit of the pressurised water type for electricity production, with a rated thermal output of 4,300

MW and general features and basic solutions for ensuring safety that correspond to what is presented in the application for a construction licence. It is also stated in the licence that the location of the unit shall be the island of Olkiluoto in the municipality of Eurajoki and that the construction must be started within two years from the beginning of the legal validity of the licence.

The conditions for the construction licence are met. Construction was started within the time specified, and even with the changes made to the design after the granting of the construction licence, the general characteristics and essential features of the Olkiluoto 3 nuclear power plant unit are as presented in the application for the construction licence. The rated thermal output is 4,300 MW.

13 Summary (Nuclear Energy Act, Section 20, Operation of a nuclear facility)

The following is laid down in Sections 5–7 of the Nuclear Energy Act (990/1987) with regard to safety in 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 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 use of nuclear energy is subject to a licence (Nuclear Energy Act, Section 8). According to Section 20 of the Nuclear Energy Act, the granting of an operating licence requires the following conditions to be met:

1. *the nuclear facility and its operation meet the safety requirements laid down in this Act, and appropriate account has been taken of the safety of workers and the population, and environmental protection; (23 May 2008/342)*
2. *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;*
3. *the applicant has sufficient expertise available and, in particular, the competence of the operating staff and the operating organisation of the nuclear facility are appropriate;*
4. *the applicant is otherwise considered to have the financial and other prerequisites to engage in operations safely and in accordance with Finland's international contractual obligations; and*

the planned nuclear facility and the operation thereof otherwise fulfils the principles laid down in sections 5-7.

Operation of the nuclear facility shall not be started on the basis of a licence granted:

1. *until the Radiation and Nuclear Safety Authority (STUK) has ascertained that the nuclear facility meets the safety requirements set, that the physical protection and emergency planning are sufficient, that the necessary control to prevent the proliferation of nuclear weapons has been arranged appropriately, and that the licensee of the nuclear facility has, as provided, arranged indemnification regarding liability in case of nuclear damage; and*

2. *until the Ministry of Economic Affairs and Employment has ascertained that provision for the cost of nuclear waste management has been arranged in accordance with the provisions of chapter 7.*

In this safety assessment, STUK has assessed compliance with the provisions falling within its authority as part of the safety assessment for the operating licence of the Olkiluoto 3 nuclear power plant unit.

As regards Sections 20(1)(1-3) of the Nuclear Energy Act, the arrangements of the Olkiluoto 3 nuclear power plant units and of the included buildings and storages required for the management of nuclear fuel and nuclear waste are sufficient and appropriate in terms of safety.

In reference to Section 20(1)(4) of the Nuclear Energy Act, STUK indicates that it lacks the authority and competence to assess the licensee's financial capacity for operating the power plant. In this statement and its appendices, STUK's assessment has focused particularly on the licensee's capabilities to conduct the operations safely and, with regard to matters under STUK's regulatory control, in accordance with Finland's international agreement obligations.

STUK's regulatory control efforts have not revealed any issues that would keep the licensee and the Olkiluoto 3 nuclear power plant from meeting the principles laid down in Sections 5–7 of the Nuclear Energy Act.

As regards Section 20(2)(1) of the Nuclear Energy Act, STUK states that it will conduct an inspection before the operation begins to verify the sufficiency and completion of the arrangements for preparations for operation that were incomplete at the time the safety assessment was drawn up.

13.1 Conclusion

In conclusion, STUK presents as its overall assessment that, as regards its sphere of authority and operations, the requirements of Sections 5–7 and 20(1) of the Nuclear Energy Act (990/1987) for granting an operating licence for the Olkiluoto 3 nuclear power plant unit are met with the following comments.

STUK has not yet received sufficient evidence that suitable procedures are available for the identification and control of operational occurrences and accidents. TVO has procedures in place to complete the work in question, so the aforementioned does not prevent the granting of the operating licence. STUK requires that the preparation and validation of operating procedures, including guidelines for severe accident managment, be completed appropriately before starting operation. TVO must demonstrate to STUK before fuel loading that the procedures specified above form an entity that is appropriate for its intended purpose and sufficient for the start of safe operations of the Olkiluoto 3 nuclear power plant unit.

During the pre-operational testing of the Olkiluoto 3 nuclear power plant unit, it emerged that the vibration of the surge line of a pressurizer that is a part of the primary circuit exceeds the set criteria. In order to bring the vibration to the permitted range, the surge line will be fitted with suppressors. After TVO has decided on the type of the suppressor, STUK will review the related detailed plans, oversee the progress of the work and, before the operation of the plant is started, verifies that the necessary modifications have been made and the acceptability of the solution has been demonstrated through sufficient testing.

Preparations for the commencement of operation of the Olkiluoto 3 nuclear power plant unit are still partially incomplete. The operation is considered to begin when the initial loading of nuclear fuel into the reactor begins. Implementation of security arrangements, pre-operational testing of equipment and systems and equipping the emergency response premises, for example, are still under way at the time of the statement. In addition, the preparation of the operation instructions and piping analyses is still partially incomplete. Some maintenance and repair work and final installation and construction work is also still being done.

STUK monitors the progress of the preparations in accordance with YVL Guides and will carry out an inspection before fuel loading to ascertain that the preparations have been completed and prerequisites for safe operation exist. According to the Nuclear Energy Act, the loading of nuclear fuel into the reactor must not begin before STUK has carried out the aforementioned inspection.

During the safety assessment for the operating licence, STUK has simultaneously prepared an extensive implementation of the YVL Guides revised at the end of 2013 for the Olkiluoto 3 nuclear power plant unit. As a result of the implementation process, STUK has, based on clarifications and presentations from the licence holder, defined the acceptable deviations from the new YVL Guides as well as the necessary licence holder measures to meet the requirements of the new YVL Guides. These measures have been considered in the safety assessment, and their implementation will be monitored as part of the continuous monitoring.

If the operating licence is granted until the end of 2038 as per the application, a periodic safety review must be conducted on the Olkiluoto 3 nuclear power plant unit in accordance with the Nuclear Energy Act. The relevant procedures are described in more detail in Guide YVL A.1. As a proposed licence condition, STUK presents that the licence holder must conduct a periodic safety review on the Olkiluoto 3 nuclear power plant unit and deliver it to STUK for approval by the end of 2028.