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Safety assessment of the Olkiluoto 1 and 2 nuclear power plant units and the KPA, KAJ, MAJ and component storages

Table of Contents

1 Introduction

On 26 January 2017, Teollisuuden Voima Oyj (TVO) submitted to the Government an operating licence application pursuant to Section 20 of the Nuclear Energy Act (990/1987) for the following purposes:

1. to operate the Olkiluoto 1 and 2 units of the Olkiluoto nuclear power plant at a nominal thermal power of 2,500 MW to produce electricity from the beginning of 2019 to 31 December 2038

2. to use the interim storage for spent nuclear fuel (KPA storage) for the interim storage of spent nuclear fuel generated by the operations of the Olkiluoto nuclear power plant from the beginning of 2019 to 31 December 2038

3. to use the interim storage for intermediate-level waste (KAJ) storage, interim storage for low-level waste (MAJ storage) and component storage for the interim storage of low- and intermediate-level waste generated by the operation of the nuclear facilities on the Olkiluoto island from the beginning of 2019 to 31 December 2038

4. to temporarily store the low- and intermediate-level waste generated by the operations of the nuclear facilities on the Olkiluoto island at Olkiluoto 1 and Olkiluoto 2 from the beginning of 2019 to 31 December 2038

TVO supplemented the application to the Government (TVO-11038) on 5 June 2017. The purpose of the supplementation is to clarify the plans for nuclear waste management at the nuclear facilities. In the operating licence application, TVO requested permission to use the processing and storage capacity of the various Olkiluoto nuclear facilities flexibly in such a way that the total volume of stored nuclear waste never exceeds 30,000m^3. The total volume also considers the storage capacity required by the use of the Olkiluoto 3 plant unit.

In its letter TEM/2555/08.04.01/2016, 1 February 2017 (record no. 2/C42213/2017), the Ministry of Economic Affairs and Employment (MEAE) requested the Radiation and Nuclear Safety Authority (STUK) to issue a statement on TVO's application.

TVO has provided the MEAE with an operating licence application and requisite appendices necessitated by Section 34 of the Nuclear Energy Act. The procedure to be followed when an application for the renewal of an operating licence for a nuclear facility currently in operation is filed is the same as that for filing an application for an operating licence for a new nuclear facility. The renewal of an operating licence always includes a periodic safety review for which the licensee must provide STUK with the safety reports and descriptions listed in Guide YVL A.1, Annex A, Section A.4 Renewal of the operating licence and periodic safety review.

A37. The documents referred to in Section 36 of the Nuclear Energy Decree.
A38. Description demonstrating compliance with the requirements of Government Decrees and YVL Guides

A39. Description of the reassessment of the design bases of the facility site
A40. Summary of the previous periodic safety review
A41. Description of the facility's ageing and ageing management
A42. Description of the environmental qualification of equipment
A43. Summary of renewed safety analyses
A44. Summary of the plant's safety indicators
A45. Description of the licensee's safety culture and safety management
A46. Summary of plant procedures
A47. Summary of the plant's radiation protection arrangements
A48. Summary of the waste management procedures and decommissioning of the facility
A49. Summary of the plant's operational experience feedback and research activities and plant improvements
A50. Summary of fulfilment of the requirements laid down in Section 20 of the Nuclear Energy Act and compliance with the conditions of the operating licence
A51. Summary of the periodic safety review and action plan for improving plant safety

Instructions for carrying out the periodic safety review are provided in the IAEA Safety Standards Series, Specific Safety Guide No SSG-25, Periodic Safety Review of Nuclear Power Plants.

TVO provided STUK with the reports pertaining to the periodic safety review in letter TVO-STUK-15824, 29 December 2016 (STUK document no. 1/C42213/2017). STUK submitted a request for clarification (1/C42213/2017, 21 April 2017), based on the requirements of which TVO supplemented the materials. TVO submitted the updated reports to STUK via letter TVO-STUK-17017, 27 July 2017 (STUK case no. 5/C42213/2017).

The periodic safety review is primarily based on the following documents referred to in Section 36 of the Nuclear Energy Decree (161/1988):

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 period 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 an environmental radiation monitoring programme for the vicinity of the nuclear facility;*(31 October 2013/755)
11) *a description of how safety requirements are met*(17 December 2015/1532)*;*
12) *a programme for the management of ageing; and*(17 December 2015/1532)
13) *a plan for the decommission of the nuclear facility*(17 December 2015/1532)

The documents must be kept up-to-date at all times, and the updated versions must be submitted to STUK on a regular basis. Upon renewal of the operating licence or in connection with a periodic safety review, the documents may be submitted to STUK only insofar as they have been amended since the previous updates. Furthermore, the licensee must provide a summary of the most significant changes made to the documents since the previous operating licence was granted and a description of the up-to-dateness of the documents. The documents referred to in Section 36 of the Nuclear Energy Act are addressed in Appendix 2.

In accordance with the licence terms of the valid operating licence, TVO conducted the periodic safety review by the end of 2008 during the current operating licence period. TVO submitted the related documentation to STUK on 30 December 2008. STUK approved TVO's periodic safety review and appended the decision with its own safety assessment (C213/55, 28 October 2009). STUK stated in its decision that the state of safety at the nuclear power plant units is sufficiently good and that the licensee has sufficient arrangements in place to continue safe operation. Based on its periodic safety review, TVO presented STUK with an action plan on the further development of safety at the plant units. STUK's decision also laid down requirements supplementing these measures. STUK has monitored the implementation of the development targets identified in conjunction with the previous periodic safety review through continuous monitoring and inspection activities. TVO has implemented the majority of the development requirements as proposed. However, the implementation method or schedule of some development targets has changed from the 2008 plans. The most significant individual development target that is currently not met is the implementation of an alternative safety function trip that fulfils the diversity principle and utilises float chambers. TVO has planned to implement the modification at the plant units between 2019 and 2021.

Furthermore, STUK last estimated the safety of the spent nuclear fuel storage (KPA storage) on a wider scale in conjunction with expanding the capacity of the storage in 2013. In the context of the application to increase the capacity of the KPA storage, STUK conducted a safety assessment of the KPA storage (2/E42242/2013, 23 June 2015).

This safety assessment primarily focuses on assessing the review period following the previous periodic safety review as well as the measures proposed by TVO for the upcoming operating licence period. The safety review presents the justifications for STUK's statement. The safety review is a summary of STUK's inspections and reviews of various issues and documents, a review of the safety review provided by the licence applicant, as well as the results of continuous control.

1.1 Provisions concerning safety

1.1.1 Nuclear Energy Act and STUK's general safety regulations

Safety provisions are laid down in the Nuclear Energy Act (1987/990):

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*.

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 1 and 2 nuclear power plant units. The matters addressed in the document and their assessment criteria are presented in the nuclear and radiation safety legislation and the regulations issued based thereon. 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 Radiation and Nuclear Safety Authority's regulations issued by virtue of Section 7 q of the Nuclear Energy Act. These include the following STUK regulations:

- safety of a nuclear power plant (STUK Y/1/2016).
- the emergency arrangements of a nuclear power plant (STUK Y/2/2016),
- security in the use of nuclear energy (STUK Y/3/2016)
- safety of disposal of nuclear waste (STUK Y/4/2016).

The STUK regulations replaced the relevant Government Decrees (VNA 717/2013, VNA 734/2008, VNA 716/2013 and VNA 736/2008) at the beginning of 2016. Some of the safety regulations in the Government Decrees, such as the dose limits, were transferred under the Nuclear Energy Decree (161/1988).

The STUK regulations are also being updated, and the new versions will most likely enter into force during 2018. However, the level of safety required by the regulations does not change and there are no significant foreseeable impacts on the Olkiluoto 1 and 2 nuclear power plant units.

1.1.2 STUK's detailed safety requirements

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 Nuclear Energy 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.

The purpose of preparing the YVL Guides is to ensure the continuous improvement of safety. The provisions are developed to match the level that can be reached at least at new nuclear power plants. For this reason, it is not possible or purposeful to consider the new YVL Guides binding to all operating facilities.

The design bases concerning the structures, systems and components of the Olkiluoto 1 and 2 nuclear power plant units were primarily issued in the 1970s. Although the safety of the plant units has been improved with numerous modifications, it is impossible to bring the operating plant units in line with all the technical requirements imposed on new nuclear power plant units.

In order to specify the scope of application, a decision determining the area for operating or incomplete nuclear facilities is prepared based on each new or updated YVL Guide. The implementing decision presents in detail the measures that the licensee, for example, must take by virtue of the Guide. The Guide does not alter STUK's decisions made before its entry into force unless otherwise stated by STUK. On the other hand, STUK requires that the need and opportunities for increasing the level of safety be assessed based on the new YVL Guides. The assessment can be used as a basis for demanding more measures to improve safety, when said measures are deemed to be warranted.

STUK’s total reform of the YVL Guides was completed in 2013. For implementation, STUK sent TVO a request for clarification on the fulfilment of the requirements of the new YVL Guides in early 2014. STUK requested TVO to present its justified assessment of the fulfilment of the requirements presented in the new YVL Guides at the licensee’s nuclear facilities and their operation and, particularly, to the extent that the requirements were not met, provide a proposal and schedule for improvement measures. TVO submitted the guide-specific assessments to STUK for approval towards the end of 2014.

Over the course of 2015, STUK assessed how well the Olkiluoto 1 and 2 nuclear power plant units meet the requirements of the updated YVL Guides and issued decisions on the application of the requirements and the areas where safety improvements were still needed. Significant needs for technical changes did not arise in the context of these implementation decision since the most essential ones of the new requirements had already been met or the implementation was under way based on the safety reviews conducted after the Fukushima Daiichi nuclear disaster. The implemented and planned improvement measures have been taken into account in this safety assessment.

1.2 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. Matters concerning nuclear waste management have been compiled under a separate chapter. 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), nuclear safeguards and implementation of the conditions connected to the facility's current operating licence. 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 in the STUK Regulations will be described briefly where necessary, along with any essential specifications presented in the YVL Guides. Each section evaluates how the relevant requirements have been implemented at the Olkiluoto 1 and 2 nuclear power plant units. 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 inspection results is presented at the end of the safety assessment.

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 assessment that the nuclear power plant has been designed and implemented in a manner that meets the safety requirements. The safety assessment 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 Operational occurrence and accident analyses

The requirements that specify the transient and accident analyses in Section 3 of Regulation STUK Y/1/2016 are set forth in Guide YVL B.3.

The purpose of the analyses is to demonstrate the facility's capability to withstand various transients and accidents safely. In accordance with Guide YVL B.3, the analyses prepared by TVO must cover transients and accidents that are of different types in terms of their nature and severity. The progress of the transients and accidents has been analysed starting from the initiating event and ending in a safe state.

TVO has renewed nearly all of the transient and accident analyses described in Chapter 9 of the safety analysis report. The new analyses have taken into account the completed and planned plant modifications. The analyses describe the plant as it is in the early years of the new operating licence period. In addition to this, the commissioning of new fuel types has been taken into account.

The calculation methods developed by the supplier of the plant units have been used to analyse the plant's normal operating state, transients and postulated accidents. The methods were qualified to an extent that meets the level that has been found appropriate on an international scale. The calculation methods are primarily the same as the ones in the previous periodic safety review. Plenty of experience on them has been accumulated in Finland and Sweden with regard to describing the behaviour of the plant type. Due to the uncertainty related to the accuracy of the calculation methods, it is essential that sufficient safety margins are used when assessing the fulfilment of the analyses' approval criteria.

The analyses described in the FSAR and the related topical reports indicate and justify the initial values and assumptions used that affect the end results, as well as the sensitivity studies performed. The sensitivity studies are necessary to assess and reduce the significance of uncertainties usually related to the calculation methods and assumptions. STUK has reviewed the new analyses submitted to it and the descriptions of the calculation methods employed, and commissioned independent verification analyses of certain cases.

The analyses in the safety analysis report cover anticipated operational occurrences, the postulated accidents used as design bases for the safety systems, and severe reactor accidents. As a result of regulatory changes, analyses of design extension conditions were added to the safety analysis report.

The analyses of severe reactor accidents prepared by TVO examine plant behaviour, the progress over time of accidents and the environmental impacts in the context of various types of severe reactor accidents. The analyses assess the environmental emissions of radioactive substances and the radiation doses they cause both as individual doses and collective doses to the population in various accident scenarios. The aim of the analyses of severe reactor accidents is to show that the plant's severe accident management strategy and systems fulfil the relevant requirements. The analyses submitted in conjunction with the operating licence application have been supplemented to cover plant modifications. The analyses have been supplemented with an entirely new case where the high-pressure make-up water system delays damage to the reactor core.

The accident analyses that assess the functional capacity of the safety systems are addressed in Chapter 4.3 of the safety assessment with regard to fuel, primary circuit and containment integrity, and in Chapters 3.3 and 3.4 with regard to radiation safety.

The conclusion is that the transient and accident analyses of the Olkiluoto 1 and 2 nuclear power plant units have been implemented as intended in Section 3 of Regulation STUK Y/1/2016.

2.1.2 Probabilistic risk assessments

In this connection, PRA (probabilistic risk assessment) 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. Adverse effects here refer to the amount of radioactive substances released and the resulting radiation doses.

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. Detailed requirements for a PRA are given in Guide YVL A.7 and numerous other YVL Guides in accordance with Section 7 r of the Nuclear Energy Act (990/1987), which is why the assessment of the coverage and acceptability of the PRA is carried out against the requirement level of the YVL Guides. 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 assess the occurrence of transients and the implementation of the required safety functions, with due consideration to the possibilities of failure and error of each system, and their probabilities. Transients and accidents may result from equipment failures, fires, internal and external floods, extreme weather conditions, earthquakes and human error, for example. The PRA can be used to identify dependencies between systems and estimate their strength.

Level 1 of the PRA determines the accident sequences leading to core damage and estimates their probability (core damage frequency, CDF). Level 2 analyses the amount, probability and timing of a release of radioactive substances from the nuclear power plant to the environment in the event of an accident (large release frequency, LRF). Based on the amounts of accident releases, the radiation doses caused to the population in the area are assessed separately.

A nuclear power plant's PRA analyses events that can be initiated in any of the plant's normal operating states (power operation, low power and shutdown states and the transition sequences in between). The licensee must keep the PRA continuously up-to-date and specify it based on operating experience, plant modifications, new research results and developments in calculation methods in order to ensure that the results depict the prevalent situation at the facility. STUK has assessed safety at the plants based on the risk analyses supplied to it in conjunction with the renewal of the operating licence. The analyses correspond to the situation at the Olkiluoto 1 and 2 nuclear power plant units in December 2016.

In the analysis of the PRA, the initiating event causes an operational transient 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 plant units' PRA does not address the intentional damaging of a plant as an initiating event. Separate reviews on hazards caused by intentional human activity have been conducted using PRA methods, but they are not encompassed by the PRA models of the plant units. According to the risk analyses submitted in conjunction with the operating licence application, most of the core damage frequency of the Olkiluoto 1 and 2 nuclear power plant units – about 75% – is attributable to events during power operation, while 25% is attributable to other events during operating states.

Internal initiating events include operational occurrences initiated by equipment failures, falling of heavy loads, loss of off-site power supply, internal floods, fires or human error of plant personnel. Internal flood events include internal flooding caused by pipe or vessel breakage resulting in an operational occurrence and losses of equipment important to safety. Fire events include fires in the site area and switchyard that cause an operational occurrence. According to the risk analyses submitted in conjunction with the operating licence application, internal events of the Olkiluoto 1 and 2 nuclear power plant units cause approximately 75% of the core damage frequency. The processing of fires and other internal hazards in the context of the PRA is also described in Chapter 4.7 of the safety assessment.

External initiating events are operational occurrences caused by weather phenomena and earthquakes as well as disturbances in the plant environment due to human action. The weather phenomena examined in the PRA include extreme temperatures of the atmosphere and sea water, variations in sea level, strong wind, snow and rain fall, lightning and electromagnetic disturbances. Phenomena that cause a blockage hazard in the sea water system, such as frazil ice, clams, jellyfish and dense algae growth, are also covered by the PRA of external hazard. In 2011, the external threat analysis was expanded to cover significant oil spills at sea. In 2014, the analyses were also expanded to cover other external threats inadvertently caused by human activity. External fires or explosions have not been estimated to cause a substantial hazard to the facility as there are no storages of flammable or explosive substances or related transport routes in the vicinity. In addition to individual phenomena, the impacts of multiple external events have been analysed. According to the risk analyses presented in conjunction with the periodic safety review, slightly over one-tenth of the core damage frequency is attributable to external hazards. The results of the PRA of external events are presented in Chapter 4.6 of the safety assessment. Furthermore, off-site conditions are covered to a limited degree in Chapter 4.1 discussing the safety of the site.

TVO initiated the development of the PRA process for the Olkiluoto 1 and 2 nuclear power plant units in 1984, and the first level 1 PRA including internal initiating events was completed in 1989. Since then, the risks caused by internal and external hazards have been identified and mitigated through numerous plant modifications and guide updates. The overall results of the risk assessment have also changed in conjunction with the specification of the analyses. The PRA has been kept continuously up to date through regular updates, and it has been expanded to cover new initiating events and operating states. In 2012, the previous joint PRA model of the Olkiluoto 1 and 2 nuclear power plant units was replaced with plant unit-specific PRA models. The unit-specific models were necessary because substantial plant modifications are implemented at the units at different times. Guide YVL A.7 lays down the limit value for the core damage frequency of nuclear power plants. In accordance with the Guide YVL A.7 implementation decision for Olkiluoto 1 and 2 nuclear power plant units, the limit values in question are not binding on the Olkiluoto 1 and 2 units. Instead, they are to be regarded as target values that are striven for in accordance with the principles of continuous improvement. The Olkiluoto 1 nuclear power plant unit meets the limit value set forth in Guide YVL A.7. The Olkiluoto 2 nuclear power plant unit does not meet the core damage frequency limit value set in Guide YVL A.7, as some of the modifications that are important to safety are yet to be implemented at the Olkiluoto 2 nuclear power plant unit. The modifications at the Olkiluoto 2 unit are estimated to be completed during 2018 and 2019. In addition to this, a steam turbine-driven high-pressure make-up water system and a low-pressure make-up water system based utilising firewater supply are in the implementation phase for the Olkiluoto 1 and 2 units. These systems are planned to be completed in 2018. Based on the PRA on them, the core damage frequency will drop to two-thirds of the current level. The Olkiluoto 1 and 2 units also meet the core damage frequency target value set for operating plants by the International Atomic Energy Agency (IAEA).

The limit values for the large release frequency of nuclear power plants are laid down in Guide YVL A.7. A large release is a release that exceeds the severe accident limit value stipulated in Section 22 b of the Nuclear Energy Decree (161/1988). Based on the PRA level 2 analyses, the large release frequency at the Olkiluoto 1 and 2 units exceeds the large release frequency set in the Guide. In accordance with the Guide YVL A.7 implementation decision, the limit values in question are not binding on the Olkiluoto 1 and 2 units. Instead, they are to be regarded as target values that are striven for in accordance with the principles of continuous improvement. About one-fourth of the core damage situations analysed lead to a large release. One-third of these take place during the annual maintenance, at which point core damage situations lead to a large release because the containment is not tight during annual maintenance and does not limit the release. In core damage situations where the containment function is not inherently lost, large releases are successfully prevented in roughly 75% of the cases.

According to requirement 306 b in Guide YVL A.7, 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. This requirement is not met at the Olkiluoto 1 and 2 nuclear power plant units. TVO applied for a deviation from this requirement and, in December 2017, submitted to STUK a description of events leading to an early release and the measures taken to reduce the risk of early release. Based on the description, the most efficient way to prevent early releases as well as other radioactive releases is to prevent accidents that lead to core damage. Plant modifications that significantly reduce the core damage frequency and early release frequency have been implemented and are currently under way at the Olkiluoto 1 and 2 nuclear power plant units. Based on the description, the proportion of the early release could be reduced by implementing increased restrictions on operating situations where the containment is not inerted. STUK approved the deviation from requirement 306 b, but required TVO to provide a description of the possibilities of changing the containment inerting practices and their effects on the early release risk. However, the total frequency of a release that occurs at an early phase of an accident and requires population protection measures under Section 22(b)(6) of the Nuclear Energy Decree (161/1988) is extremely low.

The coverage and applications of the PRA have been expanded to also cover the storage and handling of nuclear fuel removed from the reactor by preparing separate PRA analyses for the spent nuclear fuel storage (KPA storage) in 2013 and for the fuel pools of the Olkiluoto 1 and 2 reactor halls in 2016. The PRA of the KPA storage and reactor hall identified and assessed equipment damage and event chains that lead to the boiling of the pool water or the fuel being uncovered. Events that directly lead to fuel uncovery, such as significant pool leaks, were not identified. In chains of events that lead to the uncovering of nuclear fuel, pool cooling is presumed to be lost and the supply of more water into the pools is presumed to be impossible, which leads to the nuclear fuel being uncovered as the water level in the pools drops due to boiling. Based on the analyses, the frequency of fuel uncovery is significantly lower than the large release frequency laid down in Guide YVL A.7.

In relation to the management of outage risks, a separate hourly calculation has been prepared for the Olkiluoto 1 and 2 nuclear power plant units since 2014, in which the PRA model has been used to calculate momentary core damage and release frequencies according to the planned plant unit-specific work schedules. The analysis can be used to guide the work schedule planning by identifying the times at which the planned work would excessively elevate the risk level.

The PRA of the Olkiluoto 1 and 2 nuclear power plant units has been utilised in accordance with the YVL Guides. The PRA is used together with deterministic analyses and radiation safety analyses to estimate the acceptability of plant modifications. The PRA of the Olkiluoto 1 and 2 nuclear power plant units has been used in a risk-informed in-service inspection programme (RI-ISI) for piping. The RI-ISI for piping was implemented at the Olkiluoto 2 nuclear power plant unit in 2012 and at the Olkiluoto 1 nuclear power plant unit in 2013. The PRA is used when assessing the balance of the Technical Specifications (TechSpecs), acceptability of the changes and the significance of the deviations. In addition to this, the PRA has been used to support safety classification and assess a variety of plant transients and incidents.

The conclusion is that the safety and related technical solutions at the Olkiluoto 1 and 2 nuclear power plant units have been justified using probabilistic risk assessment in compliance with Section 3 of Regulation STUK Y/1/2016.

2.1.3 Strength analyses

The primary circuit equipment of the Olkiluoto 1 and 2 nuclear power plant units have been designed and manufactured in accordance with the American ASME III standard. In conjunction with the renewal of the operating licence, TVO updated the strength analyses of the primary circuit. The analyses cover the Safety Class 1 pipes, the reactor pressure vessel and the reactor pressure vessel internals. The updated load and strength analyses are based on Articles NB-3200 and NB-3600 of the ASME III standard. The articles cover the strength analyses conducted on Safety Class 1 components.

The fulfilment of the safety requirements is justified based on the strength analyses presented in the construction plans of mechanical equipment, which indicate that the Safety Class 1 pressure equipment meets the approval criteria of the ASME III standard with a sufficient margin. The analyses use commercial programmes and the PAMS calculation system developed by TVO. The accuracy of these methods has been verified by means of comparison calculations and test results.

The strength analyses cover dimensioning against pressure and other mechanical design loads as well as tension and fatigue analyses for critical points. The design loads account for the various operating and accident situations of the primary circuit as well as environmental effects. Based on the analyses, the safety margins remain sufficient for the entire planned 60-year service life of the plant unit. Instances where the approval criteria are exceeded are justified by conducting more detailed calculations, increasing inspections at critical points or changing the structure. STUK finds this procedure to be acceptable.

The process of ensuring primary circuit integrity is addressed in more detail in Chapter 4.3.2 of the safety assessment.

The conclusion is that the safety assessment of the Olkiluoto 1 and 2 nuclear power plant units by means of strength analyses has been implemented as intended in Section 3 of Regulation STUK Y/1/2016.

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 Section 4 of Regulation STUK Y/1/2016 are presented in Guide YVL B.2.

The systems, structures and components of the Olkiluoto 1 and 2 nuclear power plant units have been categorised into safety classes 1, 2, 3 and EYT based on safety significance. The structures and components have also been divided into classes S1, S2A and S2B describing earthquake resistance and requirements.

The safety classification and classification principles of the structures and equipment of the systems of the Olkiluoto 1 and 2 nuclear power plant units are presented in a continuously updated safety classification document. The classification document presents the systems' safety classification diagrams, lists the systems' safety-classified components, presents the quality and inspection classes set for the components based on the safety classification – which are used as a basis for determining the quality and inspection requirements – and the seismic classifications of the structures and components.

STUK has reviewed and approved the latest update to the classification document, in which the document has been updated to meet the requirements of Regulation STUK Y/1/2016 and Guide YVL B.2.

As a potential development measure, TVO has proposed the development of the presentation method of the equipment location-specific classification and the supplementation of equipment location-specific additional information into equipment classification lists. TVO will supplement the additional information with justifications for the safety classification and seismic classification of equipment locations. STUK will monitor the implementation of the development measures as part of its control activities.

The conclusion is that the safety classification of the Olkiluoto 1 and 2 nuclear power plant units has been implemented as intended in Section 3 of Regulation STUK Y/1/2016.

2.3 Ageing management (Section 5)

1. 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.

2. 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.

The aim of the ageing management of the Olkiluoto 1 and 2 nuclear power plant units and the KPA storage is to keep the structures and components (SSCs) continuously up-to-date and in good condition in terms of safety and production capacity. TVO has an ageing management programme which entails the functions, tasks and responsibilities to ensure the operability of the SSCs related to the safety of the nuclear facility for the entire duration of their service life. TVO shall supplement the current ageing management programme in accordance with the requirements of Guide YVL A.8 with SSC-specific information that is essential for maintaining operability. In these cases the ageing management programme presents the operating conditions and situations of SSCs as well as the resulting stresses and loads in design basis conditions (from normal operation to severe accidents). The ageing mechanisms assumed to deteriorate the operability of SSCs are listed, and a summary is presented of procedures employed by TVO to monitor and maintain the operability of individual SSCs. Depending on the SSC, the selection of procedures includes inspections, tests, advance maintenance, time-limited environmental qualifications and time-limited fatigue analyses.

The ageing management measures and responsibilities at the Olkiluoto nuclear power plant are defined in the organisation manual and separate instructions. Ageing management is included in the tasks for technical experts and maintenance personnel. TVO also has access to a network of experts including representatives from the plant supplier, equipment manufacturers, research institutions and cooperation bodies formed by power companies. System and equipment owners have been appointed for systems and equipment; they are responsible for ensuring, on their part, that the systems and equipment remain operable. From time to time, the system and equipment owners prepare a report for their own area of responsibility that discusses ageing and operability. The other key reports related to the detection of ageing are the quality control revision report, annual maintenance report, summary report for primary circuit loads and the summary report for the ageing of electrical and I&C equipment. A list is kept of upcoming necessary measures, which includes an assessment of required measures over the course of the next ten years. The list will be updated annually based on the information that is current at any given time. A follow-up report on ageing management is also prepared each year in accordance with YVL A.8 and delivered to STUK for information.

TVO's ageing management covers all SSCs that are significant to safety. The selection criteria for ageing management are safety classification and probabilistic risk analyses as well as the Technical Specifications, which meets the requirements regarding the scope of ageing management. In practice, ageing management is implemented in accordance with the maintenance class set for the SSC in question. The maintenance class determines the SSC ageing management coverage and phasing, preventive maintenance needs and other factors influencing the efficacy of ageing management. The condition monitoring and maintenance activities to ensure plant safety are presented in more detail in Chapter 5.4 of the safety assessment.

Alongside maintenance, ageing management involves systematic modernisation aimed at improving the safety of the facility and the availability, reliability and performance of the systems and components, and ensuring the availability of product support and spare parts from the equipment supplier. Large plant unit modifications are primarily implemented as long-term design projects in plant update projects. Extensive modifications have continued during the past operating licence period. Examples of such on-going projects are modernisations of the emergency diesel generators, main circulation pumps and feedwater distributors and the installation of a new steam turbine-operated high-pressure make-up water system.

STUK has assessed the ageing management of the plant units by means of numerous on-site inspections in accordance with the Periodic Inspection Programme. They address the implementation of ageing management and targeting it towards individual SSCs and ageing phenomena in various technical areas. The technical observations have typically been related to resources, functions and procedures that TVO utilises to ensure the operability of the plant units' systems, structures and components in the short term and in the long term. Alongside physical ageing, the topics have included obsolescence, which is typical at plants that have operated for a long time and which may result in the availability of spare parts or technical support deteriorating or being completed lost.

Mechanical technology

In the inspections conducted during the annual maintenance of the Olkiluoto 1 and 2 nuclear power plant units in 2014, multiple cracks were discovered in the convergence point of the feedwater system and the pipe lines from the shut-down cooling system where flows at different temperatures mix together. Upon mixing together, the flows cause continuous temperature variation in the structural material at hot standby and low-power feedwater adjustment. This exposes the mixing point to fatigue. In its decisions, STUK necessitated a change to the operating method and the replacement of the pipe sections at the mixing points during the annual maintenance of 2015. All mixing points were repaired in the annual maintenance of 2015–2016, which is why it can be assumed that the repaired mixing points will last for at least 20 years. The mixing points were last replaced in 1986. At this time, the construction was changed by adding a water mixer in the T joint. Previously, water was fed into the pipe from the bottom, so fractures appeared in the bottom area of the pipe. Branches that are susceptive to thermal mixing phenomena are covered by the periodic inspection programme. In addition to this, TVO is planning a system modification which would reduce the thermal stress on the mixing points.

During the past operating licence period, more indications of the occurrence of intergranular stress corrosion cracking (IGSCC) were found in nickel-dominated alloys. These materials have been used in the safe-end pieces of reactor pressure vessel connections. In the inspection conducted during the past operating licence period, cracks were found in the Olkiluoto 2 nuclear power plant unit in the safe-end joint welds of the reactor pressure vessel's feedwater system and reactor core injection system. At the beginning of 2016, TVO submitted to STUK for approval a plan on repairing the cracked connections. TVO conducted the planned repairs during the Olkiluoto 2 nuclear power plant unit's annual maintenance in 2017. A local repair weld was implemented, in conjunction to which the majority of the crack was removed. The weld's filler coating was renewed with a material that is more resistant to stress corrosion. After the repairs, the crack can only be exacerbated by fatigue, which is minor in both connections, based on the analyses conducted. The reactor pressure vessels of both plant units feature a total of 10 connections. TVO will confirm their operability during the upcoming operating licence period by conducting regular inspections in accordance with the periodic inspection programme. In addition to this, TVO will maintain repair readiness in case of possible new connection repairs.

TVO has comprehensively analysed the damage mechanisms of the reactor pressure vessel and its internals, and analysed their long-term durability. The TVO analysis covers the following ageing phenomena with regard to the use of the boiling water reactor: radiation embrittlement, thermal ageing, fatigue, stress corrosion, general corrosion, local corrosion, erosion corrosion/FAC, creep and mechanical wear. Initially, a screening is performed to identify the critical points and the related ageing mechanisms. The screening is based on material information, structural geometry, weld location, environmental conditions, loads and assessment of the probability of the ageing mechanism in the structure as well as numeric criteria, which are used to assess the targets of comprehensive analyses on various ageing mechanisms. The result is a risk assessment of damage on the reactor pressure vessel and its internals. Based on the analysis, the most critical point of the reactor pressure vessel is the feedwater connection, which TVO repaired in the 2017 annual maintenance. The damage risk to other parts will not be significant even if the plant's operating life were to be extended from 40 to 60 years.

Electrical and I&C technology

STUK's detailed ageing management and reporting requirements for electrical and I&C systems and devices are presented in Guides YVL A.8 and YVL E.7.

There has been a separate ageing management programme for all technical areas of the electrical and I&C systems of the Olkiluoto 1 and 2 nuclear power plant units (including relevant instructions), which has been merged at the end of the operating licence period with the ageing management programme required by Guide YVL A.8.

The ageing management of the electrical and I&C equipment and related cables is based on the monitoring of their condition. The condition monitoring efforts ensure that the electrical and automation equipment and cables are in the required condition and capable of functioning in the designed situations. The most important electrical and I&C systems are situated outside the containment and process spaces in separate electrical and I&C rooms,. The accident detection or management equipment in the containment has been qualified to withstand operating and accident conditions. Their condition is monitored on a regular basis. The ageing of the cables inside the containment is monitored by means of samples taken every five years.

The electrical and I&C systems/components are not updated at any fixed intervals. Instead, the renewals are triggered by actual physical ageing or obsolescence or other strategic reasons. Some SSCs are updated at shorter and others at longer intervals, while some may not be updated at all. The SSC updates are conducted in a controlled fashion, considering the various aspects.

The monitoring of feedback information on equipment repair and modification work, among other data, is utilised in the monitoring and management of ageing. The actual condition of the electrical and I&C systems, equipment and cables and their design-basis operation are also monitored by means periodic tests, condition monitoring and the periodic inspections included in the preventive maintenance programme.

During the current operating licence period, significant modifications have been implemented to the electrical systems of the Olkiluoto 1 and 2 nuclear power plant units, including replacements of the most operationally critical containment-internal LOCA cables, updates to the cable penetrations between the containment's wetwell and drywell spaces, updates to electrical actuators, update of the main generator of both plant units, trip modifications at the 400 kV field and modifications to the main generator's voltage adjustment cabinet to prevent overcurrent to the plants' internal consumption grid. Significant modifications also include updates to the following: house load transformers, cable connections from the gas turbine plant to both plant units, low-voltage switchgears in alternating current power grid systems (including updates of distribution transformers and cables), improvements of the selectivity of the UPS system's short-circuit protection and overvoltage protection, and rectifiers of the direct current power systems. The batteries of the direct current systems have been updated based on condition monitoring, and the battery supports have been converted to be earthquake resistant in the same context.

Examples of significant current and upcoming modernisation projects regarding electrical equipment and systems are updates to the following: emergency diesel generators (2019–2022), electrical drives of the main circulation pumps (2016–2018), UPS equipment (2016–2019) and gear motors of the control rod drives (from 2019).

During the current operating licence period, some of the Olkiluoto 1 and 2 nuclear power plant unit I&C systems have been updated, such as the weather monitoring system and related data transfer systems (2008). In addition to this, new level measurement devices usable in conjunction with rare external events were installed in the fuel pools (2016) and various parts of the turbine island's protection system were updated, including the separation of the turbine control and protection system and the neutron flow measurement calibration system. The components of the plant units' fixed radiation measurement systems have also been updated, new measurement channels have been installed, and the radiation measurement equipment has been modernised and expanded to cover the needs of the Olkiluoto 3 plant unit. The previous emergency control posts have been replaced with remote shutdown stations including the requisite measurement displays and controls. One reason for these updates was obsolete technology. In order to ensure the availability and operational reliability of the protection I&C, TVO has, together with nuclear power companies using the same plant type and the spare parts supplier, agreed on the supply of essential spare parts for the protection I&C.

In the previous periodic safety review, TVO stated that the preliminary planning for a project aiming at the modernisation of the reactor and protection I&C has been initiated. The phased modernisation was estimated to begin between 2015 and 2016 and the plan was to replace a significant portion of the then-current analogue technology with programmable equipment. Furthermore, it was estimated that in the current operating licence period, the safety-significant task will be to plan and implement a diversification principle that can be applied in I&C systems.

Of the aforementioned update plans, one measurement cabinet and one equipment control cabinet were replaced with a corresponding model made from a new material. This was done as a pilot project in 2015 at the Olkiluoto 2 nuclear power plant unit. As part of the periodic safety review, TVO states that there are no plans to significantly modernise the current analogue reactor and protection I&C with digital technology. Based on STUK's monitoring of the ageing management of electrical and I&C equipment and the review of the periodic safety review documentation, STUK presented to TVO a request for clarification that demanded more detailed information about the ageing of the safety I&C and related development plans. In the clarification supplied in December 2017, TVO described the ageing status of the I&C and the necessary plans and development measures. Among other measures, TVO will, over the course of 2018, determine the remaining service life of the safety I&C sensors and availability of spare parts, and it will prepare the requisite update plans. In addition to this, TVO will finalise a condition survey on the neutron flux measurement systems in the spring of 2018. STUK will monitor the progress of the development measures as part of its control activities.

The diversity principle applied to I&C systems is covered in Chapter 4.4 of this safety assessment.

Construction technology

The detailed construction technology requirements related to Section 5 of Regulation STUK Y/1/2016 are presented in Guides YVL A.8 and E.6.

The condition of the buildings and structures of the Olkiluoto 1 and 2 nuclear power plant units is monitored regularly by means of periodic inspections and separate investigations. TVO has selected the most essential structures in terms of nuclear safety, such as the containment and seawater structures, for which more comprehensive condition monitoring instructions have been prepared than for other structures. The most typical ageing mechanisms of the containment concrete structures are creep and prestressing tendon relaxation. The deformations caused by these effects are monitored and the results are used to estimate the long-term durability of the structures. Other areas where ageing is monitored are the environmental conditions and expansion joints of steel parts. Mechanisms that deteriorate the condition of seawater structures include reinforcement steel corrosion and biological organisms, which have been considered in the context of modifications and periodic inspections.

The monitoring of operating environment conditions of structures susceptible to corrosion is conducted by means of temperature and humidity measurements. Tightness tests and leak monitoring are used to monitor the condition of the liners and penetrations of the containment and pool structures. The radiation tolerance of structures has been monitored in the case of sealing seams of the condensation pool, for example. In addition to this, the identification and measurement of cracks in concrete structures is conducted in accordance with the ASME III standard in conjunction with tightness tests.

Numerous new construction projects and significant plant improvements have been implemented and are under way at the Olkiluoto 1 and 2 nuclear power plant units, including an expansion to the KPA storage, remote shutdown stations and updates to the emergency diesel generators. During the current operating licence period, there have been no significant modification needs due to ageing with regard to buildings. The floor surface in the basement of the turbine buildings has been replaced with an alternative that can withstand the environmental conditions. The cracks observed previously have been caused by a lack of expansion joints in the slab and the excessively hard and brittle surface material that has caused a soil contamination risk. Pendulums that measure deformations in the exterior wall of the containment over the long-term and during containment pressure tests are currently being installed at the plant units. The pendulum system supplements the deformation measurements of the expansion joint between the containment and the reactor building and the stress-strain sensor measurements. With the pendulum system, the displacement measurement can be brought in line with the ASME requirements. Leaks have been observed in the KPA storage pools, which have been detected with a variety of measures and repaired. All fuel pools feature a leak monitoring system.

STUK monitors the implementation of the maintenance programme through inspections under the Periodic Inspection Programme. The results indicate that TVO's activities have been proactive and no significant requirements are needed.

Summary

According to STUK's assessment, ageing management at the Olkiluoto 1 and 2 nuclear power plant units has been organised in an appropriate manner. The ageing management of the plant units is one of TVO's focus areas. TVO's aim is to keep the plants continuously up to date and in good condition in terms of both safety and production capacity. Early identification of the relevant SSCs and the related prevalent ageing phenomena makes possible far-reaching predictions on the requisite basic improvements and maintenance tasks.

The conclusion is that ageing management at the Olkiluoto nuclear power plant is being implemented as intended in Section 5 of Regulation STUK Y/1/2016. However, in recent years, some plant events have been brought to light where the cause or one of the influencing factors has been the ageing of equipment or structures. STUK will monitor the development of the events during the upcoming operating licence period.

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 of the Olkiluoto 1 and 2 nuclear power plant units

Solutions have been sought in the design of the Olkiluoto 1 and 2 nuclear power plant units that reduce the significance of the reliability of human activities on plant safety. Preparations for the failure of human activities have been made 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.

The protection and safety systems of the Olkiluoto 1 and 2 nuclear power plant units have been designed such that the plant's operating personnel do not need to conduct control activities during the initial 30 minutes of design-based failure situations. This design principle helps to prevent human errors caused by stress, work load or time constraints in the management of error situations.

Control room ergonomics have been taken into account in the design of the Olkiluoto 1 and 2 control rooms. Control room design can affect the prevention and detection of human errors as well as efficient error detection and correction.

The planning and management of modifications play an important role in the use and maintenance of ageing plants.

Management of human factors in the operation of the Olkiluoto 1 and 2 nuclear power plant units

The operational activities at the Olkiluoto 1 and 2 nuclear power plant units are governed by a comprehensive set of procedures and instructions. The procedures have been verified and qualified, and they are used in staff training and orientation. The aim of providing operational procedures is to prevent human errors.

In the event of plant transients, the operating personnel has access to symptom-based emergency instructions that can be used to avoid misinterpretations of plant events due to human error and limit possible consequences. The status of the plant's operating instructions is addressed in more detail in Chapter 5.1 of the safety assessment.

Procedures that support task performance (Human Performance tools) are aimed at preventing and detecting human errors. The Human Performance (HU) procedures used by TVO include kick-off meeting, post-job briefing, clear communication and peer checking by means of pair work or independent verification. The HU procedures have been adopted particularly in operating activities. As regards other functions, such as maintenance and design, the use of the procedures is not as advanced.

The risk of human error due to staff fatigue is managed by monitoring the durations of work periods. The operating personnel working in the control room have the opportunity for controlled rest during a work shift. The fatigue management procedures are aimed at preventing and detecting human errors.

In the implementation of modifications, human factors are managed by not modifying all subsystems of the safety systems simultaneously. This procedure aims to prevent the occurrence of common cause failures.

Management of human errors as a TVO activity

The precondition for improving the reliability of human activity is operational monitoring and development. TVO conducts operating experience activities that also cover the operations of individuals and the organisation in connection to the plant's operational events. Operating experience activities are addressed in more detail in Chapter 5.2.2 of the safety assessment.

Staff competence is an essential factor in the success of human activity. TVO's activity management system includes a variety of 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. TVO has identified development needs in competence management. The development of orientation training, in particular, is related to the management of human factors. Training activities are addressed in more detail in Chapter 6.1.2 of the safety assessment.

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, responsibility areas and work methods have been changed. Since the change, TVO's personnel have experienced more schedule pressure and resource shortages, which negatively affect the reliability of human activities and may increase the probability of human error. The organisational change and related matters are covered in more detail in Chapter 6.1 of the safety assessment.

The organisation's safety culture speaks to the 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 practices and instructions, which, in turn, directly affects the success of human activities. The state of the safety culture is covered in more detail in Chapter 6.1.1 of the safety assessment.

Conclusion

The possibility of safety-related human errors has been taken into account in the design of the Olkiluoto 1 and 2 nuclear power plant units by ensuring that the technical design solutions of the plants seek to reduce the frequency of human errors and limit the impact of possible errors.

As regards the operation of the plant units, TVO's activity management system includes procedures for managing factors related to safety-related human errors. These procedures are used in the operation of the Olkiluoto 1 and 2 nuclear power plant units. Procedures for managing human errors are aimed at preventing and detecting human errors as well as limiting and correcting their consequences. TVO has strived to integrate the procedures fully into its activity management system to make them a natural part of all operations.

The conclusion is that the management of safety-related human errors at the Olkiluoto 1 and 2 nuclear power plant units has been implemented as intended in Section 6 of the Regulation. STUK will monitor the development of TVO's HU procedures and modification-related procedures of human error management as part of its continuous monitoring efforts.

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

According 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 the population 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).

3.1 Radiation safety of nuclear power plant workers

The statutes addressing radiation exposure are the Radiation Act (592/1991), Radiation Decree (1512/1991), and the ST and YVL Guides published by STUK. According to Section 3 of the Radiation Decree, the effective dose caused to a worker by radiation work shall not exceed an average of 20 millisieverts (mSv) per year reckoned over a period of five years, nor 50 mSv in any one year. The annual equivalent dose in the lens of the eye shall not exceed 150 mSv, nor shall the annual equivalent dose at any point on the hands, feet or skin exceed 500 mSv.

As regards radiation exposure, the radiation dose optimisation principle – i.e. ALARA (As Low As Reasonably Achievable) – must be observed and, in accordance with Guide YVL C.2, the nuclear facility must have a written programme for limiting radiation doses (ALARA action programme). TVO's ALARA programme combines the most important goals and procedures concerning the radiation protection of workers and the reduction of their doses. The ALARA programme is an instruction document included in TVO's radiation protection manual, which is updated periodically.

TVO's ALARA programme also includes a goal stating that no employee radiation dose received at the Olkiluoto 1 and 2 nuclear power plant units may exceed 10 mSv per year, and that no annual dose caused by internal contamination may exceed 0.5 mSv. In 2016, TVO set 1.9 manSv/GW as the limit value for the collective radiation dose, which means that the annual overall dose is maintained below 1.7 manSv, on average, at the Olkiluoto 1 and 2 nuclear power plant units.

The total annual radiation of the nuclear power plant units has remained below 1 manSv since 2010, and doses below 1 mSv are prevalent in the distribution of annual radiation doses among the personnel. Since 2015, over 70% of the personal doses recorded in statistics were between 0.10–1.00 mSv. The highest annual personal dose last exceeded 10 mSv in 2006.

In international comparisons (e.g. the ISOE dose database of the OECD's NEA, Nuclear Energy Agency – Information System on Occupational Exposure), the Olkiluoto 1 and 2 nuclear power plant units have been among the best boiling water reactors when comparing the personal doses of workers and collective radiation doses.

Occupational radiation exposure is significantly impacted by radiation dose rates and the amount and nature of work conducted during annual maintenance. For the Olkiluoto 1 and 2 nuclear power plant unit turbine plants, the dose rates of the intermediate superheating system pipelines and main steam piping have continued to drop after the commissioning of the new steam driers. The new steam dryer was commissioned in 2006 at the Olkiluoto 1 nuclear power plant unit and in 2005 at the Olkiluoto 2 nuclear power plant unit.

Since 2001, the plant units have had an alternating annual maintenance and refuelling outage. The typical length of the maintenance outage is 2–3 weeks, while the refuelling outages normally takes about a week. A risk-informed in-service inspection programme (RI-ISI) for piping was adopted in 2012 at the Olkiluoto 2 nuclear power plant unit and in 2013 at the Olkiluoto 1 nuclear power plant unit. The most important effect of the programme is to reduce inspections in pipe chutes and the pump rooms of the shutdown reactor cooling system, where dose rates are high. In 2015, TVO commissioned high dose rate rooms (PP rooms), where the dose rate can exceed 30 mSv/h. These rooms are classified as red, and a separate key is used for them.

The dose measurement service must be approved by STUK, and approval may be granted for a maximum period of five years. Doseco Oy is responsible for determining the personal doses of people working at the Olkiluoto nuclear power plant. Within the scope of TVO's dosimetric service, Doseco Oy takes care of dosimeter replacements, reading, dose specifications, storage of results in TVO's information systems and STUK’s dose register, and TLD equipment maintenance. TVO is responsible for dose record-keeping. The annual quality control tests on the dosimetric service have indicated that the accuracy has remained compliant with the requirements laid down in international standards. The extension of the fixed-term approval for TVO’s dosimetric service will remain valid until 1 April 2021, under certain conditions.

The conclusion is that radiation protection and occupational exposure monitoring at the Olkiluoto 1 and 2 nuclear power plant units have been implemented as intended in Section 7 of Regulation STUK Y/1/2016.

3.2 Radiation exposure of the population in the vicinity

Keeping the radiation exposure caused by the operation of the nuclear power plant to the population in the vicinity as low as practically possible means observing a principle 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 the population in the vicinity under ALARA and BAT is examined in the final safety analysis report of the Olkiluoto 1 and 2 nuclear power plant units and the power plant’s ALARA action programme.

According to the independent analysis commissioned by TVO, the Olkiluoto 1 and 2 nuclear power plant units’ releases of radioactive substances into air and water are at a level equal to or lower than at Swedish boiling water reactors. Despite the numerous fuel leaks during the review period, the releases of the plant units have remained clearly below the annual release limits laid down in the Technical Specifications (TechSpecs). During the last ten years, the plant units’ water releases have decreased as TVO has improved its process water treatment technology.

In its 2010 ALARA programme, TVO set target values, as prescribed in Guide YVL C.3, for annual radioactive substance releases from the Olkiluoto 1 and 2 nuclear power plant units and the radiation dose of an individual representing the most exposed population group. Remaining below stricter target values than those laid down in the TechSpecs is an indication of good operations and adherence to the principles of continuous improvement. The annual calculated radiation dose of an individual representing the most exposed population group in the vicinity has been equal to or lower than TVO’s 0.40 mSv target value and clearly below the 0.1 mSv maximum value laid down in the Nuclear Energy Decree.

The conclusion is that the radiation safety of the population in the vicinity of the Olkiluoto 1 and 2 nuclear power plant units has been ensured as intended in Section 7 of Regulation STUK Y/1/2016.

The shortfall of the maximum values set for the radiation exposure caused to the population in the vicinity by the operation, operational occurrences and accidents of the Olkiluoto 1 and 2 nuclear power plant units are covered in Chapters 3.3–3.5 of the safety assessment.

3.3 Limiting value for normal operation (Nuclear Energy Decree 161/1988, Section 22 b(1))

The limit for the annual dose of an individual in the population, arising from the normal operation of a nuclear power plant or another type of nuclear facility equipped with a nuclear reactor, is 0.1 millisievert.

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 and the BAT principle (safety assessment chapters 3.1 and 3.2). Guide C.4 presents detailed requirements for calculation methods by which to estimate the radiation exposure of the population.

The Olkiluoto 1 and 2 nuclear power plant units use efficient systems to process liquid and gas releases to ensure a very low level of releases into the environment during normal operation. The impact of the releases on people living in the vicinity of the plant is so low that it can only be assessed by means of calculation.

The Olkiluoto nuclear power plant's release limits for radioactive substances have been determined in the Technical Specifications concerning the use of the plant units, which have been approved by STUK. Limits have been set separately for radioactive noble gas and iodine releases into the atmosphere and for water releases into the sea. A separate nuclide-specific release limit for radioactive tritium has also been set for water releases. The purpose of the release limits is to keep the annual radiation exposure caused to the population in the vicinity by the operation of the plant units well below the limit value of 0.1 mSv set in Section 22 b of the Nuclear Energy Decree. In addition to these, TVO has set target values for the activity releases of the Olkiluoto 1 and 2, which are stricter than the release limits imposed in the Technical Specifications. A target limit has also been set for the radiation does of an individual representing the most exposed population group. The target values are not binding. Instead, staying below them is an indication of good operational practices.

The licensee must monitor the releases and radioactive substances occurring in the vicinity of the plant continuously and report any abnormal situations to STUK without delay.

When calculating the radiation dose caused by radioactive releases to a member of the population, the average radiation exposure in the group with the highest exposure is examined. The group represents a hypothetical collection of individuals for whom the highest estimated radiation exposure is calculated based on their place of residence and lifestyle.

STUK has approved the release monitoring instructions and the method used to calculate the radiation doses of the population, which are included in the operating instructions of the Olkiluoto nuclear power plant. TVO provides STUK with an annual summary of releases and calculated doses and reports the results of measurements on the amounts of radioactive substances in the environment. STUK ensures the reliability of TVO's operations by means of regular on-site inspections and by conducting independent measurements in the area surrounding the plant site. The monitoring of radioactive releases is covered in more detail in Chapter 5.5 of the safety assessment.

The calculated dose commitment of an individual of the most exposed population in the vicinity of the Olkiluoto nuclear power plant was reported by TVO to be 0.26 μSv of the 2015 releases (the average dose caused to an individual by natural radiation in Finland was 1 mSv). The calculated dose has been in this range for long, since the mid-90s, after measures were implemented at the Olkiluoto nuclear power plant to limit radioactive water releases to the sea. The radioactive releases of the Olkiluoto 1 and 2 nuclear power plant units have been clearly below the release limits laid down in the Technical Specifications and are equal to or lower than those of Swedish boiling water reactors.

The oxygen in the reactor water is activated by neutron radiation when passing through the reactor, which creates the short-lived but strongly-radiating isotope nitrogen-16. In boiling water reactors, the nitrogen-16 travels into the turbines, which causes an increase of radiation levels in the turbine building and its immediate proximity. At full reactor power, the radiation increase caused by the nitrogen-16 is approx. 1 μSv/h in the area between the turbine buildings of the Olkiluoto 1 and 2 nuclear power plant units. The slightly elevated dose rate is taken into account in operations in this area. A few hundred metres from the turbine buildings, the radiation level no longer deviates from the level of natural background radiation.

The conclusion is that the operation of the Olkiluoto 1 and 2 nuclear power plant units have not caused releases of radioactive substances or radiation exposure levels that would have exceeded the annual exposure limit value of 0.1 mSv, as laid down in Section 22(b)(1) of the Government Decree 161/1988l It is to be expected that the calculated dose to an individual of the most exposed population group by the normal annual radioactive substance releases of the plant units will remain low and far below the aforementioned limit values.

3.4 Limiting value for an anticipated operational occurrence (Nuclear Energy Decree 161/1988, Section 22 b(2))

The limit for the annual dose of an individual in the population, arising as the result of an anticipated operational occurrence, shall be 0.1 millisievert.

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 Guide YVL B.3. If an operational occurrence can cause releases of radioactive substances, the radiation doses resulting from them must be determined. Guide YVL C.4 presents detailed requirements for calculation methods by which to estimate the radiation exposure of the population.

The FSAR for the Olkiluoto 1 and 2 nuclear power plant units present descriptions of the analyses of anticipated operational occurrences. These analyses are covered in Chapter 2.1.1 of the safety assessment with regard to plant behaviour. According to the analysis results, the expected operational occurrences do not cause fuel damage. The operational occurrences are not expected to lead to a significant release of radioactive substances since the fuel is not expected to be damaged and the possible releases into the environment would only be comprised of radioactive substances normally occurring in primary circuit water or the purification systems. The plant systems are capable of retaining these radioactive substances effectively. Therefore, radiation doses caused to members of the population by anticipated operational occurrences have not been estimated by means of calculations.

There have been no operational occurrences at the Olkiluoto nuclear power plant where an increase in radioactive releases would have been observed in comparison to the normal situation.

The conclusion is that the anticipated operational occurrences of the Olkiluoto 1 and 2 nuclear power plant units do not cause releases that would result in the annual radiation doses caused to a member of the population to exceed the limit value of 0.1 mSv laid down in Section 22(b)(2) of the Nuclear Energy Decree.

3.5 Limiting values for accidents (Nuclear Energy Decree 161/1988, Section 22(b)(3–6))

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

The release of radioactive substances caused by a severe reactor accident or a severe accident at a nuclear power plant may not result in the need for large-scale population protection measures or prolonged restrictions on the use of large areas of land and water.

To limit long-term effects, the limit for an atmospheric release of caesium-137 shall be 100 terabecquerel. The probability of exceeding this limit shall be extremely small.

The probability of a release in the early stages of an accident requiring measures to protect the population shall be extremely low.

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 of radioactive substances and radiation doses, and the acceptability of the results.

The analyses and their calculation methods are under constant maintenance and development during the entire service life of the nuclear power plant. The safety analysis report for the Olkiluoto 1 and 2 nuclear power plant units presents descriptions on the units' accident analyses (covered in more detail in Chapter 2.1.1 of the safety assessment). TVO's analysis methods concerning radiation exposure have been developed over the years, and they comply with the requirements of Guide YVL C.4. The methods include conservative assumptions, which, in reality, signify an overestimation of the radiation dose amounts calculated as consequent effects. Based on the analyses, measures to improve safety will be taken as necessary. TVO redone the analyses of radiation doses caused to the population by accidents for the operating licence application.

Class 1 postulated accidents

According to the definition of the Nuclear Energy Decree 161/1988, 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.

Among the class 1 postulated accidents analysed for the Olkiluoto 1 and 2 nuclear power plant units, the most significant calculated release is caused by a fire of fixed waste (ion exchange resin) in the plant unit's waste building. This is estimated to cause an individual outside the power plant area a maximum annual dose of 0.055 mSv, which is clearly lower than the 1 mSv limit value presented in the Decree.

The conclusion is that class 1 postulated accidents at the Olkiluoto 1 and 2 nuclear power plant units do not cause radioactive releases that would result in the annual radiation doses caused to a member of the population to exceed the limiting value of 1 mSv, as set forth in the Nuclear Energy Decree.

Class 2 postulated accidents

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.

Among analysed class 2 postulated accidents, the most significant calculated releases at the Olkiluoto 1 and 2 nuclear power plant units are caused by a transfer cask full of spent fuel falling in the reactor building or a single main steam pipe breaking inside the containment.

The falling of a transfer cask is presumed to lead to mechanical damage to all rod cladding of the fuel assemblies in the cask, leading to a release of 5% of the noble gases(except 10% of isotope Kr-85), 5% of iodine and 12% of caesium. The majority of the released iodine and caesium isotopes are assumed to be filtered out before release into the atmosphere. The accident is estimated to cause a maximum annual dose of 3 mSv to an individual outside the power plant area.

In the analysis regarding the breakage of a main steam pipe, the pipe is presumed to break entire and the containment isolation is presumed to work as planned. Of the fuel assembly rods in the reactor core, loss of tightness is assumed to occur in 10%, in accordance to YVL B.3, as a result of which a maximum of 5% of the rods' noble gases, iodine and caesium will be released. The containment spray system is presumed to effectively clean the gas space of the iodine and caesium released into it. However, some of the released substances are presumed to leak out of the containment into the reactor building and the turbine building, with only the portion leaking into the reactor building being filtered out before the radioactive substances are released into the environment. The accident is estimated to cause a maximum annual dose of 0.16 mSv to an individual outside the power plant area.

The estimated doses in the context of both of the aforementioned class 2 postulated accidents are lower than the 5 mSv limit value presented in the Decree.

The conclusion is that class 2 postulated accidents at the Olkiluoto 1 and 2 nuclear power plant units do not cause radioactive releases that would result in the annual radiation doses caused to a member of the population to exceed the limiting value of 5 mSv, as set forth in the Nuclear Energy Decree.

Design extension conditions

A design extension condition is an accident which the plant is required to withstand without sustaining severe fuel failure, and where an anticipated operational occurrence or class 1 postulated accident involves a common cause failure in a safety system or which is caused by a combination of failures identified as significant on the basis of a probabilistic risk assessment or a rare external event.

As regards design extension conditions, analyses have not been conducted on situations that could cause fuel damage at the Olkiluoto 1 and 2 nuclear power plant units, with the exception of the blockage of the reactor's single fuel assembly channel. Another exception is an aeroplane crash, which is covered in Chapter 4.6 of the safety assessment. The radiation exposure caused to a member of the population has been analysed with regard to a blockage of the reactor's single fuel assembly channel and a breakage of a single main steam pipe in the containment, assuming that the steam condensation fails.

The full blockage of a fuel channel has been assumed to lead to the partial melting of a single fuel assembly. The analysis presumes that the noble gases are fully released from the damaged assembly into the primary circuit and that 30% and 25% of the iodine and caesium, respectively, is released. The containment function is assumed to be fulfilled as planned, but some of the released radioactive substances are presumed to have time to travel outside the containment through the main steam pipes before the isolation valves of the pipes are closed. The majority of the iodine and caesium that escapes the containment is assumed to be caught by the vent gas system and filtered out before release into the environment. The accident is estimated to cause a maximum annual dose of 0.046 mSv to a member of the population outside the power plant area.

According to the analysis, the pressure increase following the breakage of a main steam pipe and the failure of steam condensation will not cause fuel failure, but the integrity and tightness of the containment will be lost for 60 minutes. During this time, the radioactive substances released into the containment gas space can escape into the environment unfiltered. The accident is estimated to cause a maximum annual dose of 0.3 mSv to a member of the population outside the power plant area.

The conclusion is that the Olkiluoto 1 and 2 nuclear power plant units meet the Nuclear Energy Decree's limit value of 20 mSv for radiation doses caused to a member of the population from a design extension condition as well as practically possible, taking into account the transition provision of Section 27 of Regulation STUK Y/1/2016 for Section 14 of Regulation STUK Y/1/2016 and to the extent that is justified based on the principle set forth in Section 7(a) of the Nuclear Energy Act.

Severe accident

During the construction of the Olkiluoto 1 and 2 nuclear power plant units, designing the plants in such a way that they can handle anticipated operational occurrences and postulated accidents without the fuel in the reactor sustaining extensive damage was found to ensure a sufficient level of safety. The requirement to limit releases related to severe accidents in which the reactor core melts partially or fully was not introduced before the completion of the plant units, due to nuclear disasters that occurred in other parts of the world. The plant units have been updated by changing the operating method of and installing some entirely new systems, components and structures. TVO conducted its most significant plant modifications in 1988 and 1989, at which point a filtered blowdown line, among other solutions, was installed in both plant units. This line can be used to blow out steam and uncondensed gases, thereby preventing the uncontrolled over-pressurisation of the containment and the resulting possible containment failure.

The progress of a severe accident in a situation where the accident control systems function as planned are examined in the accident analyses presented in the safety analysis report, which describe the operation of the containment in a variety of accident situations. Analysis regarding the releases of radioactive substances have been prepared for seven cases dimensioning severe accidents. An accident in which the reactor feedwater line breaks and the plant loses electricity is presumed to lead to core failure in the shortest possible time. Full loss of power, in turn, can be regarded as the most likely case leading to core damage. When the containment retains its tightness, the pressure in the containment increases until steam and uncondensed gases begin to be discharged from the containment. The blowdown takes place through a filter which effectively retains all radioactive substances except noble gases and organic iodine. This keeps the long-term effects of the release at a low level, and the releases of isotope caesium-137 remain well below the limit value of 100 TBq (maximum estimated release 0.012 TBq). Furthermore, the release does not cause immediate health detriments, although, according to the results of the calculations using the most conservative assumptions, effective radiation doses near the power plant area are notably high (highest estimated annual dose 165 mSv without measures to protect the population) but lower than the 500 mSv dose that causes immediate health detriments. The majority of this radiation dose is attributable to the external dose in the context of a noble gas release.

In relation to the implementation of Guide YVL C.3, TVO has analysed whether not a release of radioactive substances due to a severe accident at the Olkiluoto 1 and 2 nuclear power plant units will result in a need for large-scale population protection measures or long-term restrictions on using land and water areas. Guide YVL C.3 states that, for new reactors, the need for evacuating the population must be limited to the precautionary action zone (approx. 5 km) and the need to take shelter indoors must be limited to the emergency planning zone (approx. 20 km). According to TVO's analyses, a severe accident does not lead to long-term restrictions on the use of land and water areas. As regards the protection measures, it remains unclear whether or not the Olkiluoto 1 and 2 nuclear power plant units meet the requirements placed on new reactors in Guide YVL C.3 because the processing of the matter is under way. According to analyses provided by TVO, the evacuation need extends to a maximum of 15 km and the need to take shelter indoors extends beyond 40 km. However, more realistic analyses might indicate that the requirement is fulfilled. STUK accounts for the transition provision of the Nuclear Energy Decree 1001/2017 and the principle laid down in Section 7(a) of the Nuclear Energy Act in the processing of the matter. However, if practical means cannot be used in the assessment of radiation doses to demonstrate that the results meet the protection measure requirement of Guide YVL C.3 or that the noble gas releases can be sufficiently reduced by means of plant unit modifications, the Olkiluoto 1 and 2 nuclear power plant units can be granted the right to deviate from the Guide requirement by virtue of the transitional provision of the Nuclear Energy Decree (1001/2017).

The reliability of the accident management systems has been examined in the probabilistic risk assessment prepared by TVO. For the purposes of the analysis, the mechanisms that may lead to containment damage were determined and the extent of the damage caused by each mechanism was assessed. The analysis estimates the probabilities of the aforementioned mechanisms during an accident as well as the scale of releases caused by any possible damage. Releases caused by containment isolation failure and their probabilities were also assessed. The probabilistic risk assessment is addressed in more detail in Chapter 2.1.2 of the safety assessment.

The results of the probabilistic risk assessment indicate that in the event of an accident where a significant portion of the reactor core melts and containment tightness is lost to the extent that the resulting caesium release exceeds the limit value 100 TBq, the estimated frequency is low but exceeds the design value imposed on new reactors in Guide YVL A.7. According to the analysis results, the most significant risk is caused by situations where there is an early unfiltered release from the containment's upper drywell, an early release is caused by the failure of the upper drywell or the flooding of the containment's lower drywell is delayed. In addition to this, the probability of a release of radioactive substances during an early phase of an accident requiring population protective measures is extremely low. The matter is addressed more extensively in Chapter 2.1.2 of the safety assessment. Development measures to reduce the probability of a large release are covered in Chapters 2.1.2, 4.6 and 4.7 of the safety assessment.

The conclusion is that the Olkiluoto 1 and 2 nuclear power plant units meet the stipulations of the Nuclear Energy Decree on severe accidents as well as practically possible, considering the transitional provision of the Nuclear Energy Decree 1001/2017 and to the extent that is justified based on the principle set forth in Section 7(a) of the Nuclear Energy Act.

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.

Detailed location requirements related to Section 8 of Regulation STUK Y/1/2016 are presented in Guides YVL A.1, YVL A.2, YVL A.3, YVL A.7, YVL A.11, YVL B.1, YVL B.7, YVL C.3, YVL C.4 and YVL C.5. Furthermore, the Nuclear Energy Act states the following with regard to the site of the nuclear facility: *The site of the nuclear facility must be appropriate with respect to the safety of the planned operations, and environmental protection must be taken into account appropriately when planning operations* (Nuclear Energy Act, Section 19(2)). The concepts of site area, precautionary action zone and emergency planning zone are defined in Regulation STUK Y/2/2016.

The Olkiluoto site area is located on the Olkiluoto island in the municipality of Eurajoki. The site is located approximately 13 kilometres from Rauma, and 33 kilometres from Pori. Olkiluoto is the site of the operating nuclear power plant units Olkiluoto 1 and 2, and the construction site of unit Olkiluoto 3. The site area and its immediate vicinity holds numerous buildings and facilities related to energy production, such as the spent nuclear fuel storage (KPA storage), power plant waste storages, power plant waste repository (VLJ repository), work site of the nuclear fuel encapsulation plant and repository implemented by Posiva Oy, accommodation villages, guest centre, office and training facilities, wind power plant and the joint gas turbine power plant of Fingrid Oyj and TVO.

The normal operation of the nuclear power plant or anticipated operational occurrences do not limit land use outside the site area. In the environment surrounding the nuclear power plant, however, precautions in the form of land use and public protection plans must be taken with a view to the possibility of an accident. Nuclear power plants are among the sites, as listed in Section 48 of the Rescue Act (379/2011), that pose a particular hazard due to which the rescue department and the operator must prepare an external emergency plan for them. The vicinity of the nuclear power plant must not include any facilities or population centre where it is difficult to implement the protective measures required in an emergency situation, such as taking shelter indoors or evacuation. In the plant's vicinity, no activities may be carried out that could pose a threat at the nuclear power plant.

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 licence applicant. The nearest large industrial facilities are situated within a range of 12–14 km: the Rauma pulp mill, the UPM paper mill in Rauma and RMC's Rauma dock, which was previously owned by STX Europe and Aker Yards. Raikka Oy’s explosive factory, which manufactures charges, detonators and pyrotechnic products and conducts explosive classification tests, is located in Eurajoki approx. 11 km from the power plant.

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.

The aforementioned industrial facilities and transport routes are far enough from the Olkiluoto power plant that the effects of a possible accident on one of these routes will not extend to the site area.

Small-scale field cultivation is carried out near the site area 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.

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 approx. 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 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 equipment 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 over the course of the past three years.

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. The area is restricted in accordance with Ministry of the Interior Decree 1348/2015 (power plant area), and sufficient measures are in place to control access and transport to the area. The security arrangements of the plant are covered in more detail in Chapter 7 of the safety assessment. The procedures for warning the population and issuing protection instructions are described in the external emergency plan prepared by the Satakunta Rescue Department in accordance with Section 48 of the Rescue Act 379/2011.

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 the population. Coast Guard boats can be used for warning the population in the archipelago and the fragmented coastal areas. The development of alarm and rescue arrangements is covered by administrative cooperation and, in the future, alarm arrangements can be developed by means of opportunities afforded by modern communications technology. In STUK's understanding, the warming and rescue arrangements for the population in the environment 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 8 of the safety assessment and, based on STUK's assessment, the emergency response arrangements of the Olkiluoto power plant are up-to-date and sufficient.

The environmental impacts of the plant during normal use are described in Chapters 3.2 and 3.3 of the safety assessment, and the effects of transient and accident situations are covered in Chapters 3.4. and 3.5. 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 of the safety assessment.

The geological and seismological properties of the location that affect the safety of the nuclear power plants have been examined in conjunction with the design of the operating plant units, nuclear waste disposal facilities and the Olkiluoto 3 plant unit. Olkiluoto lies in a seismically stable area. The design basis earthquake of the plant site was approved for the Olkiluoto 3 project in 2001. The process of updating the earthquake analyses is under way, and the first phase was completed in 2016.

Extreme weather conditions and sea water level limits have been studied in connection with the risk analyses of the plant units in cooperation with the Finnish Meteorological Institute, for example. The sea level fluctuations in the coastal areas of the Bothnian Sea are relatively minor. In the current operating licence period, TVO has improved the KPA storage's protection against the rising sea level. There are no exceptional special features in the ice conditions of the area. The occurrence of extreme weather phenomena and the effects of climate changes have also been studied through SAFIR research programmes conduct since 2007 by the Finnish Meteorological Institute, among other bodies. Preparation for external events is covered in Chapter 4.6 of the safety assessment.

The natural conditions of the plant also affect the handling of emergency situations in the site area. The subject was also addressed in conjunction with the analyses conducted due to the Fukushima nuclear disaster. The persons dispatched to handle the emergency situation must be able to access the location, in addition to which it must be possible to remove unnecessary persons from the site area regardless of the rescue operations performed outside the site area. In an emergency situation, it may be necessary to transport equipment and consumables required for operation to the facility. It may even be necessary to continue bringing in new personnel and consumables for a long period of time. In addition to TVO's plant fire brigade, the facility may need equipment from rescue services, and it must be possible to transport this equipment to the location. Being able to transport people and materials to the site is particularly important in emergency situations resulting from external hazards, as accessing the facility may be difficult due to trees that have fallen on the road or a rising sea level, for example.

Only one roads runs to the Olkiluoto site area, but a variety of routes can be taken to access the area located a few kilometres from the plant. TVO and the rescue department have plans for restoring traffic links in extraordinary situations. If necessary, the rescue department can receive assistance from the Finnish Defence Forces to restore connections. It can be stated with good confidence that the quantity of necessary consumables stored in the site area will last until access has been restored. The site area features a pier, which provides the possibility to transport personnel and materials by sea, if necessary. The traffic links leading to the plant site and the plans related to restoring them are sufficient for handling emergency situations. TVO is developing preparedness arrangements for emergency situations.

The conclusion is that the location of the Olkiluoto nuclear power plant meets the requirement of Section 8 of Regulation STUK Y/1/2016.

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.

The requirements that specify the principle of defence-in-depth in Section 9 of Regulation STUK Y/1/2016 are set forth in Guide YVL B.1.

The operation of the Olkiluoto 1 and 2 nuclear power plant units has been reliable and there have been very few safety-significant deviations from normal operating conditions over the course of the plants' operating history. The plant units have continuously utilised the experience and knowledge that the plant supplier accumulated in the design, construction and operation of the Swedish sister plants. The solutions implemented by TVO have primarily been similar to their counterparts at the Swedish plants, which is why it has been possible to utilise experiences at the Swedish plants as references even in the context of retrofitted modifications after the construction phase. Continued operational reliability will require that the facility's operating measures, maintenance and modifications are performed in a planned and guided manner, and that these measures are targeted and timed correctly. The clarity of the instructions and the training of the personnel are crucially important in preventing disturbances caused by human error.

The plant units feature adjustment and limitation functions that are activated automatically when the plant operating parameters deviate from the normal operating conditions and that seek to limit changes in these parameters so that the functions reserved for postulated accidents do not need to be activated. Deviating situations can also be addressed by the plant operators' manual controls in accordance with the operating procedures prepared in case of such events. These procedures can be used to bring the facility to a controlled state. However, a separate defence in-depth level limiting disturbances separately from normal operation and accident management systems was not included in the plant's original design. The most important separate restricting functions are the main circulation pump ramp-down that reduces plant power quickly in case of emergency and the partial scram.

The Olkiluoto 1 and 2 nuclear power plant units have functions that are designed for postulated accidents, the main purpose of which is to ensure reactor shutdown and fuel cooling leading to fuel integrity as well as containment isolation to prevent the propagation of activity. These functions are activated automatically when certain parameters pass preset limits. The reactor protection system has been implemented with four parallel and independent subsystems in order to improve reliability. The required function is started if two of the four subsystems are operating. The reactor protection system is based on tried and tested relay technology. The aim of automatically activated functions is to bring the plant to a controlled state in all situations. Manual operator measures are also used to transfer the plant from a controlled state to a safe state in accordance with relevant procedures. Plant unit controllers have access to procedures for emergencies and disturbances, which are covered in more detail in Chapter 5.1 of the safety assessment.

The original design of the Olkiluoto 1 and 2 nuclear power plant units did not include the design extension conditions presented in the current provisions. However, extensive modifications to improve safety in these situations have been and are currently being implemented at the plant. The most important goal with the modifications has been to reduce dependence on the plant's power supply systems and seawater cooling.

Furthermore, the functions for controlling severe accidents were not included in the original design of the facility. Instead, they were retrofitted primarily in the 1990s. The functions ensure containment integrity in such a way that, in the event of severe reactor damage, the radioactive releases from the containment are kept so low that there is no need for extensive population protection measures in the vicinity of the plant.

The emergency response arrangements planned to reduce the repercussions of accidents are covered in more detail in Chapter 8 of the safety assessment.

The conclusion is that, considering the implemented and on-going safety improvement modifications at the Olkiluoto 1 and 2 nuclear power plant units, defence in-depth has been realised as intended in Section 9 of Regulation STUK Y/1/2016.

4.3 Engineered barriers for preventing the dispersion of radioactive materials (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 the following chapters.

4.3.1 In order to assure the integrity of fuel

a) In order to assure the integrity of fuel,

i. the probability of fuel failure shall be low during normal operating conditions and anticipated operational occurrences;

ii. during postulated accidents, the rate of fuel failures shall remain low and fuel coolability shall not be endangered; and

iii. the possibility of a criticality accident shall be extremely low.

Detailed requirements for ensuring fuel integrity are presented in Guides YVL B.3, YVL B.4 and YVL E.2.

The first propagation barrier for radioactive substances is the ceramic nuclear fuel material and the surrounding cladding, which consists of the protective tube and the end stops. Together these form the hermetically sealed fuel rod. Enriched uranium dioxide with less than 5% of U-235 is used as the fuel at the Olkiluoto 1 and 2 nuclear power plant units. This fuel material is used to manufacture the fuel pellets stacked inside the fuel rod. Zirconium-based metal alloys are used as the cladding material – there is a wealth of experience on their use in reactors spanning decades. The fuel rods are further collected into square-latticed fuel assemblies with other components, such as end pieces and intermediate supports.

Factors that may jeopardise fuel integrity during normal reactor operation are errors in manufacture, excessively fast power changes or insufficient fuel cooling in the reactor in proportion to the power level. However, foreign objects entering a fuel assembly through the cooling circuit form one of the most common causes of fuel failure.

TVO's fuel procurement and quality management process is described in the instructions of the quality manual for nuclear fuel procurement. Through these procedures, TVO aims to prevent possible design and manufacturing faults in the fuel. A fuel type suitability analysis reviewed and approved by TVO indicates that the fuel type can be safely used at the plant. STUK first approves the fuel licence documentation, i.e. suitability analysis for each fuel type separately, followed by the construction plan before the manufacture of each fuel batch.

By means of monitoring during the production of fuel batches TVO ensures that the fuel is manufactured in accordance with approved licensing documentation. STUK oversees the sufficiency of the licensee's production control by assessing the coverage of the control plan and participating in production control visits. TVO performs an acceptance test on fuel batches arriving at the Olkiluoto nuclear power plant, in which the condition of the fuel assemblies and channels is inspected in accordance with the instructions after transport.

Fuel layout in the reactor core is planned for each operating cycle. The transient and accident analyses are also repeated to the required extent if the properties of the fuel or reactor are changed. STUK reviews and approves the reactor and fuel behaviour report for each operating cycle.

The maintenance of fuel integrity in the event of power variations related to normal reactor operation is ensured by means of power change rate limitations included i the suitability analysis. The restrictions are primarily based on studies conducted on test reactors and user experiences from corresponding Swedish nuclear power plants and other facilities with regard to the fuel type in question. In addition to this, the suitability analysis places restrictions on the linear power of the fuel rods and the dryout coefficient which describes the proportion of fuel assembly power and coolant flow.

During the last operating cycle, the moving speed and steps of the control rods had to be limited more than before at the Olkiluoto 1 nuclear power plant unit due to fuel leaks that were more frequent than normal during a single operating cycle. By ensuring conformance between the reactor operating method and fuel design limits, the aim is to keep the likelihood of fuel failure as low as possible during normal operation. Fuel leaks that have occurred at the Olkiluoto 1 power plant unit are covered in Chapter 5.2.1 of the safety assessment.

The maintenance of fuel integrity during anticipated operational occurrences is indicated by means of calculated analyses and derived limit values for variables (mainly linear rod load and dryout coefficient) that are important to safety during normal operation. In conjunction with the operating licence application, TVO redid all analyses of operational occurrences at the Olkiluoto 1 and 2 nuclear power plant units, taking into account the plant modifications conducted during the operating licence period and the changes to fuel design. Based on the analysis results, the likelihood of fuel failure during an operational occurrence is low when the limit values for normal use are set correctly.

In addition to this, the amount of fuel damage in postulated accidents is estimated by means of calculated analyses. In conjunction with the operating licence application, TVO also redid all analyses of postulated accidents at the Olkiluoto 1 and 2 nuclear power plant units, taking into account the plant modifications conducted during the operating licence period and fuel changes. The accident situations examined include operational occurrences linked to a scram delay or partial inoperability of scram, reactivity and coolant loss accidents, and fuel handling accidents. Based on the analysis results the limit values set for fuel integrity and environmental radiation doses are not exceeded.

STUK has commissioned independent comparison analyses from VTT on the most restrictive transient and accident situation. Based on the results, the analyses supplied by TVO have been conducted in a sufficiently conservative manner. Based on both analyses, the case that determines the limit values for normal reactor and fuel operation is a pressure transient resulting from a sudden stop of reactor steam flow.

The possibility of a criticality accident during outages and refuelling outages is reduced by preventing the simultaneous extraction of multiple control rods from the core by means of technical and administrative restrictions. These methods include disconnecting power supply from the control rod motors or preventing rod extraction by means of the reactor protection system. The prevention of unintended criticality has also been considered in the plant's fuel storage and handling systems that are covered in more detail in Chapter 4.5 of the safety assessment.

On the basis of the Fukushima accident, the Olkiluoto 1 and 2 nuclear power plant units have implemented or are implementing plant modifications that secure fuel integrity in the event of a rare loss of power or seawater by reducing the reactor's auxiliary feedwater system's dependence on seawater cooling, and by high- and low-pressure make-up water systems independent of power supply. Furthermore, enabling the air cooling of the emergency diesel generators in the upcoming modernisation will reduce dependence on seawater.

The conclusion is that fuel integrity at the Olkiluoto 1 and 2 nuclear power plant units has been ensured as intended in Section 10 of Regulation STUK Y/1/2016.

4.3.2 Ensuring primary circuit integrity

b) In order to ensure primary and secondary circuit integrity,

i. 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;

ii. the primary circuit shall, with sufficient margins, withstand the stresses arising in normal operational conditions, anticipated operational occurrences, postulated accidents and design extension conditions;

iii. 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;

...

v. the plant shall be equipped with reliable leak monitoring systems.

The primary circuit of the Olkiluoto 1 and 2 nuclear power plant units comprises the reactor pressure vessel and the related internal main circulation pumps, including their heat exchangers, as well as piping connected to the pressure vessel, including accessories, all the way to the outermost isolation valves. These parts have primarily been designed and manufactured in accordance with the American pressure equipment standard ASME Boiler and Pressure Vessel Code Section III, Article NB (ASME III), which is intended for safety class 1 pressure vessels and piping.

The material choices have been made to prepare for the primary circuit's ageing phenomena in line with the best knowledge available at the time of manufacture. The reactor pressure vessel is made of low-alloy MnMoNi steel, which is cladded with austenitic stainless steel by means of welding, with the exception of the main circulation pump chambers. The reactor's main steam pipes and their valves as well as the main circulation pump heat exchangers are made of carbon steel. The carbon steel parts are not exposed to the general corrosion that thins the wall since the operating temperature is low and the steam is dry. In these conditions, the erosion rate of the main steam pipes is also low, which has been ensured by means of measurements. The other components are made of austenitic stainless steel.

The design has minimised the loads caused by the temperature differences of intersecting flows. In a feedwater connection, this is usually done with the ejected principle, which causes reverse flow into the gap between the reactor connection and feedwater distributor. After commissioning, it has been observed that the increase of feedwater needed in reactor startup and shutdown causes thermal loads. In order to reduce them, feedwater adjustment at low flow rates have been specified, in addition to which the situation has been analysed to clarify the situation.

Preparations have been made for the breaking of primary circuit pipes by means of whip restraints and the requisite dynamic investigations. The leak-before-break criterion has not been applied on primary circuit pipes. However, the containment features a leak monitoring system that meets current official requirements and enables the reliable detection of minor leaks.

In terms of ageing, the most critical points for the primary circuit are pipeline mixing points and safe-end pieces. Their ageing is examined in Chapter 2.3 of the safety assessment.

The load, stress and fatigue analyses of the reactor pressure vessel and safety class 1 pipes that were attached to the original construction plans have been fully updated. The cumulative numbers of pressure and temperature transients have developed as expected over the course of the current operating licence period. At the end of the current operating licence, the number of most transients can be expected to be below the transient number used in design. The original design basis was 40 years of operation. For the purpose of fatigue analyses, TVO has expanded the accrual of pressure and temperature transients to correspond to 60 years of operation.

The strength analyses of the reactor pressure vessel and its connections and internals, the stability examinations and the radiation amount calculation have been updated to match 60 years of operation. In addition to this, TVO has gone through the reactor pressure vessel's damage mechanisms and analysed long-term durability. Based on the analysis, the most critical point of the reactor pressure vessel is the feedwater connection, which was repaired at the Olkiluoto 2 nuclear power plant unit during the 2017 annual maintenance. The damage risk to other parts will not be significant even if the plant's operating life were to be extended from 40 to 60 years. The ageing of the internals may be accelerated by the varying forms of stress corrosion (intergranular and radiation corrosion).

STUK has demanded the reactor pressure vessel's brittle fracture analyses to be updated because they do not match the planned 60 years of operation. The analyses must take into account accident loads and the effects of ageing phenomena on material properties. The brittle fracture risk of the reactor pressure vessel is significantly lower in a boiling water reactor than in a pressurised water reactor, because the distance between the reactor core and pressure vessel wall, i.e. the "water gap", is larger in a boiling water reactor is larger. A large water gap reduces the fast neuron load on the wall and slows down the embrittlement of the reactor pressure vessel wall. The test results of the reactor pressure vessel's surveillance programme are presented in report VTT-R-05020-14. The test results imply that the embrittlement of the reactor pressure vessels at the Olkiluoto 1 and 2 nuclear power plant units is minor. The updated brittle fracture analyses will be delivered to STUK by 31 August 2018, and STUK will review them as part of the continuous plant monitoring.

The load, strength and fatigue analyses of safety class 1 pipes and their supports have been updated with regard to the reactor's main steam pipes (311), feedwater system (312), blowdown system (314), shut-down reactor cooling system (321), reactor core spray system (323), reactor pressure vessel cover spray system (326), auxiliary feedwater system (327), boron system (351) and scram system (354). In addition to this, the analyses cover the piping of the new high-pressure make-up water system (329).

In terms of extreme loads, the critical points of the piping systems are the T piece of the auxiliary feedwater system, the reactor blowdown system's pipe bend and five supports (systems 316, 326, 327, 351). The reactor's main steam pipes are the most critical piping system in terms of fatigue. The critical points are the welds, T joints, pipe bends and chokes. Analyses and corrective measures are used to indicate the sufficiency of safety margins in all load situations, including normal use, operational occurrences and accidents. STUK monitors and controls the implementation of the measures proposed by TVO.

Pressure equipment subject to registration under the Finnish pressure equipment legislation must be subjected to a pressure test at no less than eight-year intervals using a pressure that is 1.3 times the highest allowed operating pressure. At the Olkiluoto 1 and 2 nuclear power plant units, the primary circuit's periodic pressure test has not been performed after the commissioning of the plant units. By STUK's decisions, periodic pressure tests have been replaced with tightness tests (1.02 x operating pressure) conducted at 8-year intervals, which is permitted by ASME XI for reactor plants planned and inspected in accordance with ASME requirements. When the pressure test was originally replaced with a tightness test compliant with ASME XI, it was not known that the service life of the plant units would be longer than the 40 years presumed in the ASME version effective at the time. For this reason, STUK has, based on its own periodic safety review, required that the periodic primary circuit tightness test prescribed by the current procedure must be replaced with a periodic pressure test conducted every eight year at the maximum allowable operating pressure. The purpose of the pressure test is to demonstrate through tests that the known or any possible latent ageing mechanisms have not weakened the integrity of the primary circuit once the plant units have reached their original design life span. The first pressure tests on the Olkiluoto 2 nuclear power plant must be conducted in 2019 and the first tests on the Olkiluoto 1 unit must be performed in 2020.

TVO has updated nearly all accident and reliability analyses in the context of the operating licence application. Based on the analyses conducted, the pressure control of the Olkiluoto 1 and 2 primary circuit has been implemented in such a way that, in the event of operational occurrences, postulated accidents and design extension conditions, the primary circuit pressure remains below the approval criteria with a sufficient margin.

In situations that lead to a pressure increase in the primary circuit, the circuit and connected systems are protected against over-pressure with blowdown and safety valves. The valves of the overpressure protection systems at the Olkiluoto 1 and 2 nuclear power plant units lead the primary circuit steam into the condensation pool in the containment, within which the steam condenses into water. The overpressure protection system features valves that operate on different principles, which means that it meets the requirements of the diversity principle.

The conclusion is that primary circuit integrity at the Olkiluoto 1 and 2 nuclear power plant units has been ensured as intended in Section 10 of Regulation STUK Y/1/2016.

4.3.3 Primary circuit hydrochemistry

b) In order to ensure primary and secondary circuit integrity,

iv. 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

The water chemistry of the Olkiluoto 1 and 2 nuclear power plant units' reactor circuit represents what is called normal water chemistry (NWC) and is based on EPRI's (Electric Power Research Institute) Water Chemistry Guidelines. The parameters measuring hydrochemical conditions have been divided into control parameters and additional parameters. The control parameters affect corrosion and fuel condition and they are measured and monitored to maintain plant availability and operation. The control parameters include conductivity, corrosion-inducing anions, pH, oxygen and impurities. Additional parameters provide information on system status. These parameters include metal concentrations. Action levels have been defined for the control parameters, to which time limits for restoring normal status are connected. In addition to limit values related to action levels, target values that are normally reached or should be reached are applied to water chemistry parameters. Only target values are used for additional parameters. Significant changes related to water chemistry during the assessment period include a tightening of the hydrochemical requirements of reactor and storage pools in the Technical Specifications.

The control parameters for the Olkiluoto 1 and 2 nuclear power plant units, including limit values and action levels, are defined in the Technical Specifications and chemistry procedures. The additional parameters and their target values are only specified in the chemistry procedures. TVO monitors chemistry parameters by means of both continuous measurements and laboratory analyses. The chemistry laboratory has access to a data system into which the analysis results are recorded and which can be used to monitor compliance with the set limit values and examine the long-term developments of the chemistry parameters.

The water chemistry of the reactor circuit at the Olkiluoto 1 and 2 nuclear power plant units has primarily remained in line with target values. The conductivity of the primary circuit and feedwater has been very low. The concentrations of anions, sulphate and chloride that cause stress corrosion have remained within the reference value range, with a few individual exceptions. In these cases, the cause has been found and eliminated. The updates to the seawater condensers that will take place between 2017 and 2018 will improve the situation even further. Concentrations of iron that causes deposits on the fuel cladding have also remained within the target values.

During the past assessment period, the Olkiluoto 1 and 2 nuclear power plant units have had a total of 14 leaking fuel assemblies – eight at the Olkiluoto 1 unit and six at the Olkiluoto 2 unit. The leaks were detected by means of chemical reactor water measurements and gamma spectrometer measurements of the exhaust gas. With the exception of three assemblies, the leaks have been minor and the assemblies have primarily been removed during the annual outage following leak detection. During the additional refuelling outage of 2016, TVO replaced three assemblies that presented significant cladding damage. In addition to this, three assemblies more were replaced during the actual annual maintenance. In conjunction with the additional refuelling outage of 2017, TVO replaced one assembly. Fuel leaks that have led to additional refuelling outages are covered in Chapter 5.2.1 of the safety assessment.

In summary, it can be stated that the water chemistry of the Olkiluoto 1 and 2 reactor circuit has remained at a good level during the current operating licence period. The excellent international WANO chemistry index level is another testament to this.

The conclusion is that the management of the primary circuit's water chemistry at the Olkiluoto 1 and 2 nuclear power plant units has been ensured as intended in Section 10 of Regulation STUK Y/1/2016.

4.3.4 Ensuring containment integrity

c) In order to ensure containment building integrity,

i. the containment shall be designed to maintain its integrity during anticipated operational occurrences and, with a high degree of certainty, during all accident conditions;

ii. pressure, radiation and temperature loads, radiation levels on plant premises, 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

iii. the possibility of failure of the reactor pressure vessel in a severe accident so that the leaktightness of the containment would be endangered shall be extremely small.

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 general goals for ensuring containment integrity are presented above at the beginning of Chapter 4.3. The detailed goals are listed in Guide YVL B.6.

The Olkiluoto 1 and 2 nuclear power plant units feature containment buildings, the functional purpose of which is to limit possible releases of radioactive substances. In transient and accident situations, the containment is isolated and its tightness is ensured. Containment isolation is achieved by closing the isolation valves of the pipelines that penetrate the containment interface. There are primarily two of these pipelines, one outside and another inside the containment.

Large-scale pipe break accidents in the primary circuit and feedwater system, and the resulting loads, have been taken into account in containment design. The containment of the Olkiluoto 1 and 2 nuclear power plant units has been dimensioned for a design basis accident corresponding to a current class 2 postulated accident.

Pressure control in accident situations is based on the containment pressure suppression principle, which involves leading steam from the primary circuit break into the condensation pool. The containment wetwell and drywell must be separated to ensure the success of the principle. In case of leaks, the containment features a separate overpressure protection system, which can be used to limit containment pressure to a safe level independent of the pressure suppression principle.

STUK has commissioned comparative containment analyses from VTT. The analyses examined accidents in which a main steam line pipe breaks. The goal was to determine how the temperature behaviour of condensation pool is dependent of seawater temperature. The results indicate that the heat transfer capacity of the condensation pool system and the cooling system that cools it is quite good, even at high seawater temperatures. At the highest seawater temperature examined (27°C), the temperature of the condensation pool does not exceed the design value or limit at which pool cooling capacity is lost.

The containments of the Olkiluoto 1 and 2 nuclear power plant units were not originally dimensioned for loads caused by severe reactor accidents. After commissioning, modernisations and modifications have been conducted with the aim of securing the management of severe reactor accidents and ensuring containment integrity in all situations. Alongside containment pressure control, molten core stabilisation and cooling within the containment are encompassed by the management of severe reactor accidents.

In the event of a severe reactor accident, containment pressure is reduced by means of the containment's filtered blowdown system. The system prevents containment pressurisation by means of controlled and filtered gas and steam blowdown. The system is designed to limit the amount of radioactive substances released in connection to blowdown to the permissible level.

The management of combustible gases, such as hydrogen, is based on the inerting of the containment. The containment is filled with nitrogen gas in order to prevent gas combustion. In addition to this, the containment is equipped with a recombination system which can be used for the controlled burning combustible that are generated by water radiolysis caused by radiation over the long term.

Reactor pressure vessel breakage at high pressure must be prevented in a reliable manner as the situation can directly threaten the integrity of the containment. Reactor pressure vessel rupture at high pressure is prevented by means of primary circuit pressure reduction before core melt Pressure is relieved by means of the blowdown system – some of the system's valves are kept open with pressurised nitrogen or the fire water system. The blowdown system is the same one used for protecting the reactor against overpressure in accident situations. Therefore, the system does not meet the requirement of severe accident management systems being separate from systems used in other plant situations. However, the blowdown system fulfils the diversity principle with regard to the pressure reduction function.

In order to ensure containment integrity and molten core management in the event of severe reactor accidents, TVO has developed a molten core management strategy for the Olkiluoto 1 and 2 units, which is based on flooding the drywell. In accordance with the molten core management strategy, the management and stabilisation of molten core is conducted inside the containment and interaction between the molten core and the containment is prevented. In a severe reactor accident, the drywell below the reactor is flooded with water from the condensation pool. In the same way as the primary circuit pressure reduction for severe accidents, the containment spray system used for the flooding function is part of the facility's original systems. The components of the containment spray system that are used to implement the flooding function are not involved with the implementation of other system safety functions, which means that the components have only been designed for managing severe accidents.

The conclusion is that the containment integrity at the Olkiluoto 1 and 2 nuclear power plant units has been implemented as intended in Section 10 of Regulation STUK Y/1/2016, with due consideration to the transitional provision of Section 27.

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 subcritical 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 a 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 residual 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 requirements for safety functions and ensuring them that specify Section 11 of Regulation STUK Y/1/2016 are set forth in Guide YVL B.1.

The basic safety functions of a nuclear power plant are as follows: reactor shutdown, removal of residual heat from the reactor into the ultimate heat sink and retaining radioactive substances in the containment. These functions must be ensured in normal operating situations, anticipated operational occurrences and accidents.

Natural reactor physical feedback couplings are utilised in the design of the Olkiluoto 1 and 2 reactors and their refuelling in such a way that the combined effect limits the increase of reactor power in transient and accident situations. This is demonstrated by means of calculations after each refuelling outage in conjunction with start-up.

Control rods are primarily used for shutting down the reactor and maintaining it in the shut-down state. Control rods can be moved by either driving them with electric motors or without external power by pushing them into the reactor's nitrogen tanks by means of stored pressure upon scram. The refuelling of the Olkiluoto 1 and 2 nuclear power plant units have been designed in such a way that, during normal operation, anticipated operational occurrences and postulated accidents, the reactor can be stopped with control rods even if the most effective control rod group is inoperable. In addition to using the control rods, the reactor can be shut down with a boron system that features diesel-backed power supply and meets the diversity principle.

Decay heat is removed from the reactor by either the shut-down reactor cooling system or by blowing steam from the reactor pressure vessel into the condensation pool inside the containment via the pressure control system. The auxiliary feedwater and emergency cooling systems that meet the redundancy principle and consist of four parallel subsystems maintain a sufficient coolant level in the reactor. From the condensation pool, the heat can be led further to the sea or similarly discharged through shut-down reactor intermediate cooling and seawater system consisting of our parallel subsystems. These systems require active components that are supplied with power by diesel-backed power sources. The four subsystems of the safety systems enable the execution of the safety function even if an individual system device related to any function is inoperable while any device related to the same function is simultaneously unavailable due to repair or maintenance needs.

The decay heat removal systems of the Olkiluoto 1 and 2 nuclear power plant units were not originally designed in accordance with the diversity principle. The filtered blowdown designed for severe reactor accidents in cases where the seawater that functions as the final heat sink is lost can also be used to transfer decay heat into the atmosphere. The filtered blowdown can be used without compromising the management of severe accidents.

In an accident situation, the containment must be brought to a tight state in order to prevent releases of radioactive discharges into the environment. The pipelines that penetrate the containment primarily feature two isolation valves: one inside the containment and another outside it. In the event of an accident, the reactor protection system closes the isolation valves as necessary.

In the decision issued on the previous periodic safety review (C213/55, 30 October 2009), TVO was required to provide a comprehensive report on the sufficient implementation of the diversity principle at the Olkiluoto 1 and 2 nuclear power plant units as well as an action plan for relevant development measures to reduce the risk caused by common cause failures. Based on the comprehensive report and the additional analyses conducted on the basis of the Fukushima disaster, the plant units have initiated and partially completed a wide range of plant modifications to strengthen the fulfilment of the diversity principle. In addition to this, TVO has provided STUK with a report presenting the diversity principle with regard to electrical and I&C equipment. STUK has approved the plan presented by TVO, according to which the diversity principle is fulfilled on a case-by-case basis, drawing from risk-based assessments. The equipment updates to electrical and I&C systems are part of continuous operations, and the modernisations will be continued during the upcoming operating licence period in accordance with the diversity principles.

In order to ensure reactor water supply in accident situations, the following solutions will be implemented alongside the auxiliary feedwater systems: a high-pressure make-up water system that is independent of electrical power supply and is driven by the reactor's steam pressure, and a low-pressure make-up water system that feeds water into the reactor with the help of fire water pumps. In case of seawater system failure, the reactor auxiliary feedwater system's dependence on seawater cooling will be reduced significantly by leading the system's circulation line back to the demineralised water reservoirs. Another possible route for decay heat removal into seawater will be implemented so that filtered blowdown into the atmosphere is not required outside full seawater loss. An alternative float chamber-based trip that meets the diversity principle has been designed for the essential function of reactor water level measurement. In conjunction with updating the reactor's main circulation pumps, a sufficient amount of inertia was added to their shaft. This ensures that the pump rotation speed is reduced passively in the event of scram or power loss and the previous electrically connected and separate flywheels will no longer be required to ensure fuel integrity in the context of these transients.

With the help of the steam turbine-operated high-pressure make-up water system and the arrangements implemented to feed fire water into the reactor, decay heat can be removed from spent fuel for the requisite three days regardless of external electricity supply or make-up water supply.

The functions required in design basis accidents of the Olkiluoto 1 and 2 protection I&C have been implemented by means of a four-channel arrangement in such a way that the functions are executed despite any individual channel device being inoperable while any device of another channel or its support or auxiliary function is unavailable. In a situation where operating power is lost, the components of these channels enter a state that is favourable to safety. Physical separation has been observed in the design of parallel channels in the protection I&C systems. The implementation varies depending on the target and area. In conjunction with processing documents related to renewing the operating licence, STUK required TVO to provide clearer descriptions of the application of the diversity principle in the protection I&C systems, because the description of the principle is not entirely clear in the current documents. Furthermore, the current proportion of common cause failure in the protection channel terminal relays has been found be approx. 8% of the plant units' core damage frequency, so STUK has, based on its own periodic safety review required TVO to provide a risk reduction plan.

The Olkiluoto 1 and 2 nuclear power plant units have external electricity supply systems from 400 kV and 110 kV grids. If connections to both transfer networks area lost, both plant units have four emergency diesel generators for ensuring internal power supply. The safety functions can be executed with either of the two electrical power supply systems. In addition to this, the plant units have access to a gas turbine plant completed in 2008, which can operate almost independently of the alternating current power sources planned for operating situations and postulated accidents. The on-going modernisation efforts of the emergency diesel generators include the addition of the possibility of air cooling the generators, which will further reduce the dependence on seawater systems.

Preparing for severe reactor accidents was not originally part of the design bases of the Olkiluoto 1 and 2 nuclear power plant units. A strategy for managing severe reactor accidents has been developed for the plant units, which has been implemented by utilising the facility's original systems and through plant modifications and modernisations. The plant additions after commissioning include a containment monitoring system intended for managing severe reactor accidents, filtered venting system and containment flooding system. These systems meet the requirements placed on severe accident management systems with regard to single-failure tolerance and independence of systems used in other plant situations.

The monitoring of accident progress and plant status is implemented by means of a containment monitoring system. During a severe reactor accident, the system transmits information on containment pressure, temperatures, water levels and the pressure differential between the wetwell and drywell. In addition to monitoring the situation, the measurement results are used to time measures related to severe accidents.

The most essential safety functions in the event of a severe accident are primary circuit venting, molten core cooling and stabilisation inside the containment, containment pressure control to ensure containment integrity and combustible gas management in accident situations. The safety functions ensure the integrity of the containment. The measures to manage severe accidents are covered in more detail in Chapter 4.3.4 of the safety assessment. Alongside the systems, parts of the containment have been modified to withstand severe accident loads. For example, the structures and connections of the lower drywell have been improved to withstand the loads caused by the cooling and stabilisation of molten core.

The Olkiluoto 1 and 2 nuclear power plant units can be brought to a safe state after a severe accident by means of the containment flooding system, which is used to spray water from the fire water system into the containment. Spraying is also used to remove radioactive substances in the containment atmosphere and delay the pressurisation of the containment. Water level in the containment is raised to the highest fuel level during normal operation.

Pressure relief during severe reactor accidents is handled with the same blowdown system used for the overpressure protection of the reactor circuit and for pressure reduction in the context of postulated accidents. In this regard, the requirement of Section 11 of Regulation STUK Y/1/2016 on the independence of severe accident systems is not met. Otherwise, the systems used for the management of severe accidents are independent of the systems designed for normal operations, operational occurrences and postulated accidents.

The conclusion is that the safety functions at the Olkiluoto 1 and 2 nuclear power plant units have been ensured as intended in Section 11 of Regulation STUK Y/1/2016, with due consideration to the transitional provision of Section 27 and the on-going plant modifications. It is of extremely high importance for the on-going plant modifications aimed at securing safety functions in event of possible common cause failures, seawater loss and electricity loss to be completed within the next few years.

4.5 Safety of fuel handling and storage (Section 12)

Section 12 of Regulation STUK Y/1/2016 stipulates the following:

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.

Guides YVL E.2, B.4 and D.3 form the basis for the requirements in Section 12 of Regulation STUK Y/1/2016.

At the Olkiluoto 1 and 2 nuclear power plant units, fresh fuel is stored in dry storage and pools of water. Spent fuel is stored in water pools. The fuel pools of both the reactor building and spent nuclear fuel storage are cooled with separate cooling systems, and preparations have been made for the failure of these systems. The Olkiluoto nuclear power plant has worked to improve the arrangements to ensure fuel pool cooling and the condition monitoring instrumentation by means of plant modifications implemented after the Fukushima disaster. The radiation shielding of the fuel pools is primarily based on keeping the fuel assemblies sufficiently deep underwater.

Instructions on the procedures for safe fuel transport, handling and storage are provided in TVO's fuel manual and the fuel use planning and supervision manual. The spent fuel condition monitoring programme presents the methods with which the condition of spent fuel is monitored at the Olkiluoto 1 and 2 nuclear power plant units and the spent nuclear fuel storage. The nuclear fuel's operation condition and performance are monitored and controlled during operation and by means of post-irradiation inspections and examinations in accordance with the operation control programme necessitated by Guide YVL E.2. The composition of water in the storage pools is monitored and the water is cleaned for systems designed for this purpose. This and the design of storage racks are aimed to ensure that the storage conditions do not compromise the tightness of fuel assemblies.

In order to ensure the integrity of the storage racks and the fuel assemblies stored on them, the lifting and transfer equipment has been designed to ensure a low risk of the load falling. Furthermore, the paths of heavy lifting measures have been planned and restricted to avoid transfer on storage pools. At the KPA storage, the probability of the fuel pool covers falling has been reduced by means of technical solutions. In addition to this, the cover element is moved to the desired location of the pool to be covered in such a way that the longitudinal direction of the cover is always travelling along the lateral axis of the pool. This minimises the risk of the cover element falling into the fuel pool. Based on the risk analyses conducted, the consequences of the cover element falling are clearly below the limit value set for class 1 postulated accidents.

The criticality safety of spent nuclear fuel placed in storage racks is based on the distance between fuel assemblies – with new dense fuel racks, another basis is fixed absorption structures. Criticality safety analyses have been conducted on all storage and transport racks. Criticality safety is ensured with criticality safety analyses conducted in conjunction with fuel suitability analyses, which indicate that all fuel racks used at the plant site meet the criticality safety requirement of Guide YVL B.4, taking into account the uncertainties of the calculation system, storage conditions and fuel irradiation history. The approval criterion for the analyses is that the safety requirement must be met even if the entire rack is filled with the most reactive possible fuel. Based on this, it can be stated that the risk of a criticality accident is very low.

A fire water system independent of the electricity supply can be used for fuel cooling in case the actual cooling systems are inoperable. Sufficient cooling capacity has been demonstrated by means of analyses.

The conclusion is that fuel management at the Olkiluoto nuclear power plant is being implemented as intended in Section 12 of Regulation STUK Y/1/2016.

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 detailed requirements related to Section 14 of Regulation STUK Y/1/2016 are presented in Guides YVL A.11, YVL B.1, YVL B.2, YVL B.7 and YVL E.6.

Loads and conditions caused by natural phenomena have been taken into account in the structural design of the Olkiluoto 1 and 2 nuclear power plant units in accordance with Finnish building regulations effective at the time of construction. The most important natural phenomena and their combinations have also been taken into account in the functional planning of the systems. The original design did not include precautions for phenomena as severe as those required to be considered in the design of new nuclear power plants.

Starting from the 1990s, TVO has examined risks caused by external events as part of the probabilistic risk assessment. The analysed events include rare weather conditions, high seawater temperature, exceptional high seawater level and phenomena causing a risk of blockage in seawater systems, such as frazil ice, clams, algae and oil spills at sea as well as earthquakes.

According to the analyses, the most important external events are the loss of the external power grid simultaneously with the blockage of the seawater systems' inlet channels due to storm as well as high seawater temperature occurring at the same time as high outdoor temperature.

The Fukushima incident of 2011 sparked domestic safety analyses that were carried out on a tight schedule, along with coordinated safety analyses in EU countries, which were called stress tests. The analyses did not identify new threats or need for immediately measures at the Olkiluoto 1 and 2 nuclear power plant units. However, based on analyses, TVO decided to improve preparedness particularly for complete loss of AC power and loss of seawater cooling. One of the most important plant modifications with regard to preparing for external threats are changes to the auxiliary feedwater system's circulation line and the construction of a high- and low-pressure reactor make-up water system.

TVO intends to change the system used for cooling the reactor in reactor transient and accident situations in such a way that its short-term operation does not require seawater cooling. The modification has been implemented at the Olkiluoto 1 and it is planned to be implemented at the Olkiluoto 2 unit between 2018 and 2019. The change also improves plant safety in situations where seawater cooling is lost due to a blockage caused by external sources.

TVO is implementing a new high-pressure make-up water system powered by steam generated by the reactor. It can be used to provide early reactor cooling in the event of a complete loss of AC power sources, for example. In the long-term, cooling can be handled by means of a low-pressure make-up water system that feeds water into the reactor from a fire water system that utilises diesel pumps.

In order to secure the cooling of the reactor hall's spent fuel pools in connection to a complete loss of AC power, the opportunity has been added for the plant units to feed water from the fire water system into the fuel pools.

TVO had initiated a project to update the emergency diesel generators even before the Fukushima disaster. The Olkiluoto 1 and 2 nuclear power plant units feature a total of eight emergency diesel generators, which are now being updated. In addition to the seawater cooling capability that was used before, the updated generators will provide the opportunity for air cooling. This change will improve the reliability of power supply to safety systems in the content of a seawater system blockage due to external events. Alongside the modernisation efforts, TVO will be constructing an entire new ninth air-cooled emergency diesel generator.

TVO has improved the preparedness of the Olkiluoto 1 and 2 nuclear power plant units for oil spills from ship traffic at sea that may potentially contaminate the seawater systems and, in the worst case scenario, block them. Oil booms have been positioned on islands near the facility to provide rapid protection for the straits leading to the plant site in the event of an oil spill. TVO has an agreement with the Satakunta Emergency Response Centre on informing the Olkiluoto power plant about oil spills at sea.

The vicinity of the plant does not feature industrial facilities or storages where accidents would need to be considered in the design of the plant.

Earthquake loads were not examined separately in the original planning and design of the Olkiluoto 1 and 2 nuclear power plant units. The earthquake resistance of the plant units has been examined since the end of 1990s in conjunction with the probabilistic risk assessment. Based on the risk analyses, it was found that the support arrangements for some of the important components was insufficient to provide protection against earthquake loads. The supports of batteries and many electrical equipment, among other components, have been reinforced. The improvement efforts have been continued by updating batteries nearing the end of their planned life span. After the Fukushima disaster, earthquake resistance has been assessed more extensively than before. Plant walkdowns performed by experts in seismic design have been conducted at the plant units and at the fire water pumping station, for example. Structural vibration calculations have also been redone. Based on the assessment, possible problem areas have been improve especially with regard to equipment supports, such as the fire water system's ring lines. Thanks to the plant modifications, the risk caused by earthquakes is no longer significant. The seismic analyses of the plant, which are used as the starting point for earthquake safety investigations, were approved for the Olkiluoto 3 project in 2001. The updating of the analyses is under way and, according to the preliminary results, the changes do not affect the current view earthquake safety of the Olkiluoto 1 and 2 nuclear power plant units.

The spent nuclear fuel storage (KPA), which is located in connection to the Olkiluoto power plant, was built at the beginning of the 1990s and expanded in the 2010s. Earthquake loads have been considered in its design from the start. The protection of the KPA storage against an aeroplane crash was improved in conjunction with an expansion, with particular attention to the collision of a large commercial airliner. The protection is based on shielding provided by the surrounding buildings and earth barrier, which prevents direct collision, and on fuel pool covers that have been dimensioned for protecting the spent nuclear fuel in the storage pools from debris generated by the collision. After the Fukushima disaster, the protection of the KPA storage against external floods have been improved, along with constructing connections for feeding cooling water into the pools with external pumps from a fire engine, for example, if normal cooling systems are lost for a prolonged period of time.

According to STUK's assessment, the Olkiluoto 1 and 2 nuclear power plant units' protection arrangements against external threats are up-to-date and sufficient, considering the plant's original technical solutions, the resulting limitations and the on-going improvements. The plant modifications implemented have reduced the risk caused by external hazards. TVO continues to develop its preparations against external hazards and follow developments and research in the field.

Based on the probabilistic risk assessment, the proportion of the core damage frequency attributable to external events is fairly low. The share of earthquakes is around 2% and the share of other external events is slightly over 10%.

Aeroplane collisions have been taken into account in plant design at a lower requirement level than is expected of new nuclear power plants. The design of the Olkiluoto 1 and 2 nuclear power plants does not include preparations for the collision of a large commercial airliner. It is not practically possible to bring operating nuclear power plants fully in line with all new requirements. For this reason, the binding regulations include transitional provisions for them. The effective transitional provision has been presented in Section 27 of STUK Y/1/2016. It states that Section 14 is to be applied to a nuclear power plant unit for which an operating licence was issued prior to the entry into force of the regulation to the extent required under the principle laid down in Section 7 a of the Nuclear Energy Act.

Intentional damaging of the plant is covered in Chapter 7 of the safety assessment on security arrangements.

The conclusion is that the Olkiluoto 1 and 2 nuclear power plant units' protection against external hazards meets the requirement in Section 14 of Regulation STUK Y/1/2016 to the extent that is justified by virtue of the principle laid down in Section 27 of Regulation

STUK Y/1/2016 and Section 7 a of the Nuclear Energy Act, considering the plant's technical solutions and the resulting limitations.

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.

The detailed requirements related to Section 15 of Regulation STUK Y/1/2016 are presented in Guides YVL B.1, YVL B.2, YVL B.7 and YVL E.6, for example.

Preparations for the possibility of fires and resulting accident risks have been made in the design of the buildings and systems of the Olkiluoto 1 and 2 nuclear power plant units. The solutions have been retroactively improved in many areas, and the Olkiluoto 1 and 2 nuclear power plant units meet the general requirements presented in Section 15 of Regulation STUK Y/1/2016 with regard to the placement, separation and protection of systems and devices. However, the fire compartmentation does not meet all requirements of Guide YVL B.8 with regard to fire separation because the relevant requirements were not as strict as they are now when the plant was originally constructed. Due to deficiencies in the original design, it has been important to develop fire detection and extinguishing systems as well as structural fire prevention.

During the operating history of the Olkiluoto 1 and 2 nuclear power plant units, TVO has updated its sprinkler systems in many of the plant premises, such as the turbine hall and cable tunnels. In addition to this, the fire detection system was modernised and changed to an addressed arrangement, which expedites the detection, positioning and automatic extinguishing of fires. A new fire station has been commissioned and the operative fire protection equipment has been updated.

According to STUK’s assessment, fire safety has been improved at the Olkiluoto 1 and 2 nuclear power plant units during the current operating licence period. The fire safety of the cable rooms has been improved in conjunction with the modernisation of the water extinguishing systems by changing nozzle layout and replacing some systems with gas extinguishing systems, for example. Water jets have been installed in the turbine hall to protect the maintenance platform. The amount of combustible material has been reduced at the plant units by switching to metal scaffolding, for example.

The flood analysis estimates risk related to plant-internal flood events. In earlier considerations, the significance of a major seawater pipe leak in the cooling water intake building or turbine building was found to be major enough an initiating event to warrant TVO to implement plant modifications that ensure early detection of flooding and seawater pump stoppage.

Preparations for the falling of heavy loads have been made in the basic planning of the Olkiluoto 1 and 2 nuclear power plant units. The outage risk analysis uses structural analyses to assess the impacts of heavy loads falling and possible initiating event risks, among other aspects. The risk caused by loads falling is low.

As regards the KPA storage, the durability has been assessed with regard to the falling of heavy loads. The most dimensioning of these events is the falling of a fuel transfer cask, with regard to which it has been demonstrated that pool tightness is not compromised. Consequently, it can be stated that, in relation to lifting objects lighter than a transfer cask, pool tightness is not lost even in the case of a falling fuel pool cover.

TVO has prepared a new analysis on the impacts of turbine missiles during the current operating licence period. The main focus in reducing the risks caused by turbine missiles has been on prevention. A full inspection of the turbines is conducted at regular interval and their condition is monitored on a regular basis. In the worst case scenario, turbine missiles can break structures and components of parallel subsystems, but in terms of safety, the probabilities of the most significant chains of events are very low and there are no cliff-edge phenomena. The risk of turbine missiles has been reduced by updating the low-pressure turbines and improving the reliability of the turbine plant protection system.

TVO continues to develop its preparations against internal hazards and follow developments and research in the field. According to STUK's assessment, the Olkiluoto 1 and 2 nuclear power plant units' protection arrangements against internal hazards are up-to-date and sufficient, considering the plant's original technical solutions and the resulting limitations.

The conclusion is that the protection against internal hazards at the Olkiluoto 1 and 2 nuclear power plant units meets the requirement in Section 15 of Regulation STUK Y/1/2016 to the extent that is justified considering the plant's technical solutions and the resulting limitations.

4.7.1 Qualification of structures, systems and equipment

According to the IAEA guide SSG-25 "Periodic Safety Review for Nuclear Power Plants", one purpose of the periodic safety review is to assess that the qualification of SSCs important to safety can be maintained in continuous effect through the necessary additional measures. Therefore, the SSCs must be able to perform their safety objective in design basis operating conditions and accidents, taking into account the loads and environmental conditions during these events at least until the next periodic safety review.

According to Section 3.9 of Guide YVL B.1 systems, structure and components (SSC) important to safety must be qualified for their intended use. The qualification process must demonstrate that the SSCs are suitable for their intended use and satisfy the safety requirements. Pursuant to Guide YVL A.8, the required operability of a SSC must reliable retain the required operability despite the effects of ageing, even under the most unfavourable design basis operating conditions. The uncertainty factors related to operability must be examined and reduced to an extent that takes into account the safety significance of each SSC.

Mechanical components

New components are qualified by means of tests, inspections and calculations. Environmental conditions are generally taken into account by selecting materials suitable for the conditions in question. STUK reviews the construction plans and performs construction inspection in conjunction with manufacturing and installation. Over the course of the current operating licence period, TVO has conducted device-specific qualification tests on the new steam turbine-operated pump of the make-up water system and the new main circulation pumps. A replacement of diesel generators supplying back-up power is planned.

Time-limited qualification is performed on components that are in operation. The time-limited qualification of mechanical components is carried out by means of calculations (e.g. fatigue and brittle fracture analyses) and periodic tests (e.g. pressure tests of pressure vessels and piping). During the current operating licence period, TVO has conducted time-limited qualification of reactor pressure vessels and safety-class 1 pipes by updating the strength analyses to match the 60-year service life. In addition to this, changes in the materials of the reactor pressure vessel and moderator tank materials are monitored by means of sample pieces installed in the reactor.

Electrical and I&C system and equipment

According to Guides YVL B.1 and YVL E.7 on electrical and I&C systems, the safety-classified electrical and I&C systems of nuclear facilities, as well as their components and cables, must be qualified for their purpose of use. The purpose of qualification is to verify the conformity of the systems and their components with the requirements, and to ensure their capability to fulfil their tasks in all designed operating conditions. The qualification must take place in accordance with the YVL Guides and internationally accepted standards.

The design and approval of the environmental tolerance of electrical and I&C systems and components are based on TVO procedures that take into account the following requirements, among other things: planned operating conditions, storage, transport, seismic conditions, radiation and EMC. Information on the condition-related qualification tests performed on electrical and I&C equipment have previously been presented in various documents related to plant documentation. More recently, this information has been provided in equipment and cable suitability assessments related to plant unit changes.

The original design of the Olkiluoto 1 and 2 nuclear power plant unit did not account for earthquakes, which is why the plant units' original electrical and I&C components generally fail to meet the current earthquake resistance requirements. Currently, considering the seismic classification as specified in Guide YVL B.2 is included in TVO's requirements for the design of electrical and I&C equipment. TVO has conducted modifications at both plant units to support safety-classified electrical cabinets and batteries and improve earthquake resistance.

The demanding qualification requirements related to environmental conditions primarily apply to components and cabinets inside the reactor containment buildings, because the prevalent conditions in the event of an accident are less severe outside the containment. Containment-external equipment do not have special accident condition requirements. The operating condition of these components is ensured by means of preventive maintenance and periodic tests.

It is particularly important to know the service life of equipment qualified for accident situations. The remaining service life of cables is ensured by tests carried out using sample pieces. As regards updated equipment, the remaining qualification life span remains valid if the equipment structure, environmental conditions and functional requirements have remained within the original limits.

In addition to electrical and I&C equipment, there are other components (e.g. pneumatic actuators) that have operational requirements for transient and accident situations under special conditions, or periods following them. The operability of pneumatic equipment is ensured by means of planned preventive maintenance, component replacements and periodic tests that cover all essential pneumatic devices with the exception of piping and pipe joints, which STUK has paid attention to in its inspections.

In STUK's assessment, TVO has presented requirements for the qualification plans and pertinent result documentation for electrical and I&C systems as well as their software and hardware components. In conjunction with implementing Guide YVL E.7, TVO updated its instructions related to system design during 2017.

The qualification of components of safety class 2 components for accident conditions and key safety class 3 accident instrumentation, as specified in Guide YVL E.7, as well as some components related to programmable automation requires type approval in accordance with nuclear technology qualification standards. TVO has considered this requirement level in its equipment procurement activities.

In 2013, TVO established a programme for the life cycle management of containment-internal electrical and I&C equipment (the ELMA programme). TVO uses the ELMA programme to confirm the qualified life spans of containment-internal electrical and I&C equipment and cables. It is TVO's intention to update the containment-internal electrical and I&C equipment in accordance with the action plan prepare or extend their qualified service life.

<u>Summary</u>

In STUK's assessment, the SSC qualification practices are sufficient to ensure and maintain the operability of the SSCs.

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.

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

Currently, the main control rooms of the Olkiluoto 1 and 2 nuclear power plant units include all of the systems required for monitoring and controlling the process and relaying information, which allow for managing the monitoring and control of the plant unit under all operating and outage states and most postulated accident situations.

The main control rooms are hybrid control rooms where monitoring and control are carried out using both the original panels and computer-based systems. Through updates and modernisations, the availability of plant status information to operators has been increased and new computer-based display devices have been implemented for presenting this information, particularly on the turbine side. Instead of traditional panels, monitoring and control functions are increasingly performed through computer-based operating systems. However, the control room changes during the safety review period have been limited since fewer new plant systems or modifications have been implemented than during the preceding assessment period.

Considering standards regarding control room design and international best practices has led to developments especially in terms of human-machine interface design (HMI, HFE). During the current assessment period, TVO has adopted a procedure on designing and implementing control room changes, which the control room development group can use to participate in control room-related modification projects.

Over the course of the current assessment period, there have been no significant changes to functions related to the activation, control and monitoring of safety functions at the Olkiluoto 1 and 2 nuclear power plant units. Changes that have affected monitoring and control automation have primarily been equipment updates. Functional changes have been minor. No changes have been made to the “30-min rule” included in the plant’s original design bases. The protection I&C systems have functioned as planned during operational occurrences at the plant.

The monitoring and control arrangements at the Olkiluoto 1 and 2 nuclear power plant units do not currently fully fulfil the diversity principle and the requirement specified in Section 11 of Regulation STUK Y/1/2016 on preparedness for common cause failures.. The most significant shortcoming is that the reactor water level measurement, which is extremely important in terms of the activation of reactor monitoring and safety functions, is only conducted with one method based on pressure differentials. The plant is currently conducting a project to implement an alternative trip arrangement for activating safety functions that meets the diversity principle and is based one float chambers. The intention is to implement this between 2019 and 2021´. The fulfilment of the diversity principle is examined in Chapter 4.4. of the safety assessment.

New separate remote shutdown stations were commissioned at the Olkiluoto 1 and 2 nuclear power plant units during annual outages between 2015 and 2016. The instructions intended for situations where the main control room is lost was updated to match the situation after the implementation of the remote shutdown stations. The operators were also instructed on the updated procedures. After the modification, the plant units now have an remote shutdown station which is independent of the main control and can be used for the monitoring and control of reactor shutdown and spent fuel removal. Bringing the plant to a safe state also requires local controls.

The conclusion is that the monitoring and control arrangements at the Olkiluoto 1 and 2 nuclear power plant units has been ensured as intended in Section 16 of Regulation STUK Y/1/2016.

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

5.1 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.

The detailed requirements related to Section 20 of Regulation STUK Y/1/2016 are presented in Guide YVL A.6.

The minimum staffing of the Olkiluoto 1 and 2 control room area is specified in the Technical Specifications (TechSpecs) of each plant unit. Shift tasks are determined in the power plant's instruction documents. 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 safety operation of the plant.

The turbine and reactor operators and shift supervisors of the Olkiluoto 1 and 2 nuclear power plant units are required to have STUK's operator approval. As regards the competences of the nuclear power plant operators, the requirements of Guide YVL A.4, Annex E are observed. STUK supervises the oral examinations included in operator approval and, to the extent it deems necessary, the operators' demonstrations of work proficiency. TVO ensures the sufficiency of operators by organising groups for training new operators as necessary, normally every few years. The training of new operators includes comprehensive basic training and practical training periods. Operator trainees working in the control room are required to have STUK's approval for serving as operator trainees.

The practices observed in the operating activities of the Olkiluoto 1 and 2 nuclear plant units are based on written instructions 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 instructions 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 transient and emergency procedures that cover postulated accidents and design extension conditions. 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 5.3 of the safety assessment.

The disturbance and emergency procedures for the Olkiluoto 1 and 2 nuclear power plant units comprise system-specific disturbance procedures, plant-specific disturbance procedures included in the operating instructions, emergency procedures and disturbance monitoring procedures. In addition to this, support, background and justification materials have been prepared for the disturbance and emergency procedures.

The system-specific operating procedures include a disturbance portion that describes the measures to resolve normal failures and transients affecting individuals systems.

Plant-specific disturbance procedures have been prepared for anticipated operational occurrences. The plant-specific disturbance procedures are event-based, meaning that their timely introduction requires that the operators identify the event in question directly or the transition to the disturbance procedure is made from other procedures. Since 2012, TVO has been developing disturbance procedures by supplementing them with flow charts that facilitate event identification and that the operating shift can use to ensure that the correct procedure is selected for each plant situation. Furthermore, some of the disturbance procedures have used flow charts to clarify the division of duties between operators. Entirely new disturbance procedures were also created in conjunction with the development efforts – for example, a procedure prepared in case of oil spills at sea was introduced in 2016. In conjunction with the development work, the procedures were verified and qualified, and justification materials were prepared for them. The development efforts were completed in 2017.

The emergency procedures cover postulated accidents and design extension conditions. These procedures provide operating instructions for restoring the plant's safety functions or implementing substitutive arrangements so that the plant can be brought to a controlled state (reactor is shut down and decay heat removal is secured). The methods for bringing the plant from a controlled state into a safe state (the reactor has been shut down and depressurised and its decay heat removal has been secured) have also been specified. The emergency procedures consists of a disturbance follow-up procedure, five reactor procedures and four containment procedures as well as a power loss procedure and a procedure on preparations for severe reactor damage. The emergency procedures are symptom-based or combinations of symptom- and event-based procedures. The disturbance follow-up procedure is a general procedure that the shift supervisor adopts in conjunction with disturbances that lead to a change in plant power. The disturbance follow-up procedure provides instructions for applying the correct emergency procedure based on the relevant symptoms. The procedure on preparations for severe reactor damage, which is encompassed by the emergency procedures, is adopted in a situation where reactor damage is imminent. The aim of the procedure is to alleviate the consequences of accident as efficiently as possible by initiating containment flooding, for example. Support materials have been prepared for emergency procedures to provide assistance in emergency situations. These documents are intended to support the management of accident situations that go beyond the relevant design bases at the plant units. The documents present information that is essential to accident management and the behaviour of certain key variables during accident situations.

The disturbance and emergency procedures are updated continuously based on operating experience, analyses conducted, plant modifications and feedback from work shifts. The updated procedures are delivered to STUK for information in accordance with Guide YVL A.6. TVO has indicated that it will continue the development of disturbance and emergency instructions between 2017 and 2019. The development targets identified by TVO include improving the consideration of the loss of the final heat sink or AC power, outage state events and risk significance of operator measures in the procedures. In STUK's view, it is important that TVO reserves the sufficient resources for the development of disturbance and emergency procedures and that the development work proceeds according to the planned schedule. During the upcoming operating licence period, STUK will monitor the progress of the procedure development efforts as part of its control operations relating to the operation of the Olkiluoto 1 and 2 nuclear power plant units.

The conclusion is that the management of the procedure concerning operating activities at the Olkiluoto 1 and 2 nuclear power plant units have been implemented as intended in Section 20 of Regulation STUK Y/1/2016.

5.2 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.

5.2.1 Operating experiences during the current assessment period

The aim is to ensure that the plant and its operations are planned and implemented in a safe manner. This must also be ensured by a variety of means, including the identifying, recording and addressing deficiencies. On an annual basis, TVO reviews many of its own observations (incl. failures, deviations and deficiencies) and events reported by other facilities. Analysis and resolution are sufficient measures for most observations. Some events initiate an event investigation, as specified in Guide YVL A.10. The aim of the event investigation is to identify the causes of the event and improve the plant and its operations to prevent similar events in the future.

TVO has prepared procedures for identifying, reporting and investigating internal deficiencies and events, and determining and implementing corrective measures. In addition to this, TVO has procedures for screening, assessing and learning from events at other facilities.

As part of its continuous control activities, STUK ensures that TVO identifies shortcomings that are significant in terms of radiation and nuclear safety and resolves them to the extent required by their safety significance. In order to handle this task, STUK requires that the results of internal event investigations that meet the reporting criteria of Guide YVL A.10 are also delivered to STUK. Furthermore, immediate notifications are required on the most significant events both orally and in writing. During the current assessment period (2008–2016), TVO provided STUK with an average of 15 event investigation result reports per year. In addition to the events reported to STUK, TVO investigated an average of eight other events at operating power plants each year. The numbers indicate that TVO identifies and investigates internal events. STUK receives information on the processing of events at other plants through TVO's annual reporting, inspections and through STUK's internal working group covering international operating experiences. During the assessment period (2008–2016), TVO initiated the processing of an average of 270 new international plant events a year.

When examining the 2008–2016 events as a whole, it can be stated that each one of TVO's own event investigations primarily pertains to an individual event. One interpretation per year, on average, was a more extensive thematic investigation or root cause analysis that pertained to multiple events, a recurring phenomenon or multifaceted event. Only a small number of the events are simple technical faults. Most of the events are somehow related to the activities of individuals and the organisations; for example, sufficient instruction on a work method has not been provided, the procedure is not known or observed, or there are deficiencies in the adoption of a new method and staff orientation.

When the events in 2008–2016 are viewed in light of the International Nuclear and Radiological Event Scale (INES), there are no events that would have significantly affected safety (INES 2–7). Of the events, 15 were anomalous events affecting safety (INES 1), while the rest had no significance in terms of nuclear and radiation safety (INES 0 or not classified). After observing INES 1-classified events, TVO, among other measures, improved the efficiency of maintenance programme for parts of the diesel generators belonging to the auxiliary power system and the inspection programme of the decay heat removal system's valves. In the same context, TVO also improved the timing management of certain outage tasks in relation to managing certain types of accidents.

During the current assessment period, an exceptionally high number of fuel leaks took place at the Olkiluoto 1 nuclear power plant unit in 2016. During an additional refuelling outage arranged in April 2016, TVO removed three leaking assemblies that exhibited severe cladding damage from the Olkiluoto 1 reactor. Furthermore, TVO removed another three leaking assemblies from the reactor during the actual annual outage. The type of damage on the assemblies removed from the reactor in 2016 is not indicative of damage caused by foreign objects, and no such damage found in the fuel elements inspected. The longitudinal cracks observed are typical examples of secondary damage that is caused by water entering the rod through primary damage. Cladding weakened by hybrids is fractured due power changes caused by control rod movements. The leaks began at the time of control rod movement, which strongly suggests the likelihood of PCI-type (Pellet Cladding Interaction) damage. Nothing certain can be said of the cause of the primary damage before more detailed investigations. TVO will continue the investigation of the root cause together with the fuel supplier.

In October 2017, an additional refuelling outage was organised at the Olkiluoto 1 nuclear power plant unit, during which TVO removed one leaking fuel assembly from the reactor. TVO will try to determine the root cause in the inspections conducted in conjunction with repairing the assembly. According to the current plan, the repair will be performed in the autumn of 2018. The possibility of PCI-type damage has been practically ruled out since the rod was in the reactor for the first cycle, during which the gas gap between the pellet stack and cladding pipe is still open even at high linear power, which means that the tensile stress needed to propagate a PCI fracture is not formed on the cladding. In addition to this, no significant control rod extractions took place at the time of observing the leak and the leaking rod is situated far away from the control rod. Based on these facts, it can be estimated that the assembly damage has no connection to the 2016 fuel leaks. Instead, the leak appears to be an isolated incident. STUK for monitor the efforts of TVO and the fuel supplier to determine the root cause as part of its continuous control activities.

In its own periodic safety review, TVO presents the most important achievements and lessons learned during the assessment period as a result of the internal and external operating experience activities. TVO’s description is a list of plant modifications implemented based on individual events. In STUK’s view, this perspective on the matter is too narrow. As a result, TVO has identified the development need and initiated work to develop the monitoring and assessment procedures pertaining to the effects of operating experience activities. Resources have also been assigned for the task. Through its inspection efforts, STUK ensures that TVO completes the initiated development work and can continue to perform more comprehensive analyses on the efficacy of the operating experience activities and improvement needs.

In summary, it can be stated that operational events at the Olkiluoto nuclear power plant have not substantially deteriorated the safety of the facility or affected the radiation safety of the population or the environment.

5.2.2 Operating experience feedback

The operating experience feedback activities is aimed at learning from internal events and events at 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. In terms of success, it is important to collect observations from all workers and operational areas as well as other plants, screen and process the observations according to the priority and depth necessitated by their safety significance, and employ diverse expertise and systematic procedures in event investigation, thereby ensuring the identification of the correct root causes. It must be possible to affect the identified causes through measures and activities. Efficacy must be assesses so that any possible shortcomings in operating experience feedback practices are observed and the operations can be developed. This is a challenging collection of tasks to manage. It requires human resources, administrative support and ensuring the commitment of all employees.

The licensee's entire staff and the external operators all have a role related to operating experience feedback. Everyone should report any deficiencies they observe, and everyone is also needed in the implementation of the necessary measures, when adopting new procedures that apply to all employees, for example. Dedicated human resources are required for the use, maintenance and development of operating experience feedback activities and the handling of incident investigations. In its inspection activities, STUK has paid attention to the scarcity of human resources assigned to operating experience feedback activities and incident investigations. Alongside their basic tasks, the personnel has not had enough time or opportunities to develop their own expertise or the practices related to operating experience feedback. A particular challenge has been to organise operations when other responsibilities and duties that are important to safety are competing for the working hours of the same persons. Due to their backgrounds or suitability, certain staff members have also been used for other temporary tasks. Furthermore, before 2016, a portion of the staff changed regularly as a result of a internal task rotation arrangement, but this situation has now been rectified. The sparse human resources and multiple areas of responsibility assigned to the same persons are also directly reflected by the substitution arrangements related to operating experience feedback activities. Longer absences have not been successfully managed by means of appropriate substitution arrangements and the distribution of occasional work loads has not been fully successful. STUK required TVO take measures. TVO found it necessary to improve the management of the operating experience feedback activities (i.e. resourcing and organisation) and the development of staff competence. The situation has improved. 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 commissioning of the Olkiluoto 3 plant unit will significantly increase the work load of the responsible unit.

The new Guide YVL A.10 on operating experience feedback specified and increased the requirement level in 2015. This required long-term efforts to develop the expertise of TVO's staff and create, adopt, establish and further develop new practices and procedures. STUK has deemed it necessary to influence the progress of the development measures to a degree by requiring faster progress in the inspection of 2016 and 2017, or more dramatic operational changes. Furthermore, STUK's inspection efforts have revealed factors that may make learning from internal events more difficult. For this reason, STUK has required TVO to improve its investigation process. On the other hand, STUK has found that TVO is capable of reacting to any shortcomings observed internally and by other parties. Indications of this are the on-going measures to improve the processing of observations, response to recurring deficiencies observed in the implementation phase of measures (delays) and initiation of improvement measures. STUK's overall goal will continue to be to ensure that TVO can achieve the goal of the operating experience feedback activities – i.e. learn from events at its own plants and other plants. The achievement of this goal manifests itself in that the operating licence activities achieve actual changes in operations and at the plant.

The conclusion is that the operating experience feedback activities at the Olkiluoto 1 and 2 nuclear power plant units have been implemented as intended in Section 21 of Regulation STUK Y/1/2016. TVO found it necessary to improve the management of the operating experience feedback activities (i.e. resourcing and organisation) and the development of staff competence. TVO is in the process of establishing and developing procedures created due to updated official requirements. In order ensure the continuous improvement of operations, TVO has also initiated projects to develop the processing of observations and improve the implementation of measures defined based on operational events. STUK monitors the progress of initiated measures through its inspection programme and other control activities.

5.2.3 Safety research

TVO has divided its own research and development activities into three programmes under the themes Safety research, Plant technology research and Waste management research. The programmes are compiled into five-year arrangements, 15 of which are currently under way. A service life management project will be initiated as a new initiative, with the aim of bolstering competence and ensuring the availability and safety of the plants.

In all programmes, TVO participates in national research efforts as well as international projects and working groups. In addition to this, TVO orders its own commissioned studies. The results are used for the modernisation, maintenance and operations of the plant units.

In national research efforts, the most essential programme is SAFIR2018, which TVO also uses to follow results from international research programmes. TVO's experts participate in the activities of all of the research programme's support and steering groups as well as the management team. Alongside the SAFIR2018 programme, TVO takes part in a number of research projects funded by TEKES. The Nordic cooperation consists of the Nordisk Owners Group (NOG) and Energiforsk programmes. Other international programmes include the OECD/NEA and IAEA programmes. TVO follows these programmes and participates in individual projects within them. As regards research on water chemistry, TVO has participated in in the EPRI Chemistry programme for many years.

TVO also commissioned a master's thesis on how its research efforts and results could be better utilised at the Olkiluoto 1 and 2 nuclear power plant units. The thesis concentrated on research and development efforts in 2008–2015. It focused on research efforts that support the operation, development and improvement of power plants.

In conclusion, TVO's efforts to follow and participate in research in the field of nuclear power have been arranged as intended in Section 21 of Regulation STUK Y/1/2016.

5.3 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 detailed requirements related to Section 22 of Regulation STUK Y/1/2016 are presented in Guide YVL A.6.

The Operational Limits and Conditions, or Technical Specifications (TechSpecs), and other instructions of the power plant together define the limits and operating methods by which the nuclear power plant can be operated safety in various situations.

TVO has TechSpecs that cover the Olkiluoto 1 and 2 nuclear power plant units and the spent nuclear fuel storage. The TechSpecs use process variables to define limits for various operating states, specify operational restrictions for various failure situations and presents periodic test requirements for systems, structures and devices under TechSpecs. It is the on-duty shift supervisor's responsibility to ensure that the plant unit is operated in accordance with the TechSpecs.

TVO has instructed maintenance procedures that are used to ensure that the TechSpecs documents are up to date. Needs to make changes to TechSpecs documents are caused by plant modifications, administrative changes, updated safety analyses and TechSpecs reviews conducted TVO, for example. TVO reviews all TechSpecs values at least every four years. The purpose of the review is to ensure that the TechSpecs are up to date.

In accordance with Guide YVL A.6, TechSpecs changes require STUK's approval before implementation. During the current assessment period, the annual number of TechSpecs amendment proposals delivered to STUK varied a great deal (10–30 pcs). Numbers of change proposals are affected by major maintenance outages and larger administrative changes. STUK usually approves the change proposals as they are or, if necessary, presents additional requirements or update needs in its approval decisions. STUK has found occasional deficiencies in the TechSpecs change proposal applications provide by TVO (with regard to safety impacts and justifications, for example), as a result of which STUK has needed to request additional clarifications from TVO to continue the processing of the matter.

In some cases, it may be necessary to deviate from the TechSpecs. Such cases include ensuring occupational safety and performing modifications that improve safety. The procedures for deviating from the TechSpecs are described in TVO's instructions. Permission to Deviate from the TechSpecs must always be applied for with STUK in advance in accordance with Guide YVL A.6. The deviation application must justify the acceptability of the deviation, taking the safety significance of the situation into account. Safety must not be significantly compromised during the deviation and, if necessary, substitutive measures must be implemented to maintain safety during the deviation. TVO has applied for permission for TechSpecs deviation seven times a year on average. Primarily, the need to deviate from the TechSpecs arises in conjunction with plant modifications.

TVO has documented procedures for reporting situations that violate the TechSpecs to STUK in the manner specified in Guide YVL A.10. During the past 10 years (2008–2017), an average of three violations of the TechSpecs have been reported to STUK per year. As an example, deviations have occurred in situations where a system governed by the TechSpecs has been brought to an inoperable state without permission or there has been a deviation from the administrative requirements of the TechSpecs. TVO has documented procedures for assessing the safety significance of deviations, determining the causes and specifying corrective measures.

In conjunction with the periodic safety review of the Olkiluoto 1 and 2 nuclear power plant units conducted in 2008, TVO initiated a development project on the requirement and justification values, with the core aim of clarifying the requirements and justifications. A further aim was to clarify the justification section to make the interpretations of the requirements more unambiguous. The requirement section was divided into clearer parts and specified where necessary. The first TechSpecs chapters updated during the development project were delivered to STUK for approval in 2012. The development project was completed in the autumn of 2017 when the TechSpecs chapters on heavy reactor building transports were delivered to STUK for approval.

STUK has reviewed and approved the updated TechSpecs chapters. Some of the updated chapters warranted specifications and additional requirements based on STUK's review observations. In STUK's view, the updated TechSpecs document as a whole is clearer and the requirements are justified better than before. TVO has planned to continue the TechSpecs development work by reviewing the chapter on the periodic systems of TechSpecs systems in detail. The purpose of the development work is to ensure the content and timeliness of the periodic tests and the correctness of the test criteria. STUK monitors the development of the TechSpecs as parts of continuous control activities.

The conclusion is that the TechSpecs of the Olkiluoto 1 and 2 nuclear power plant units have been implemented as intended in Section 22 of Regulation STUK Y/1/2016.

5.4 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.

5.4.1 Maintenance operations

The goal of the maintenance operations is to ensure the safe and uninterrupted operation of the Olkiluoto 1 and 2 nuclear power plant units. The TechSpecs determine the periodic tests and inspections of systems, structures and components that ensures their operability in design basis situations. When operability may be maintained for a limited time only and tests or inspections cannot provide sufficient information on the integrity or operability of systems stressed by their operating conditions, operability is verified by means of separate qualification or calculated analysis. All new electrical and I&C systems and components are qualified.

The plant unit maintenance procedures and instructions have been compiled into the maintenance manual. Maintenance is divided into preventive maintenance, corrective maintenance and improving maintenance. The process equipment of the process has been divided into equipment responsibility areas for which an equipment owner has been appointed to bear the responsibility for the maintenance planning within the specific area of responsibility. Maintenance planning includes, for example, planning the preventive maintenance and condition monitoring programmes for the equipment of their equipment responsibility area as well as spare parts planning, presenting the modification and modernisation needs of equipment, and the maintenance and development of defect repair readiness. The operating and defect history of each equipment position is used for the planning and control of maintenance. The planning, control, execution and reporting of the implementation of plant work is done through the work management system.

Equipment maintenance planning is based on the division of equipment positions into four maintenance classes. The selection of maintenance class depends on the significance of the failure of the equipment for the functioning of the system and the entire plant. The importance of the equipment's operational reliability and its safety significance and maintenance costs are taken into account in the classification. Among other information, a probabilistic priority specification which indicates how failure affects the plant unit's total core damage frequency is used in the definition. The division of the maintenance classes is roughly as follows:

- Class 1: the equipment is maintained in working order at all times
- Class 2: limited unavailability is allowed for the equipment

- Class 3: financially justified preventive maintenance is allowed
- Class 4: preventive maintenance has not been planned for the equipment

The maintenance class determines, for example, the organisation of spare parts supply and the selection of preventive maintenance and condition monitoring tasks.

The systematic inspection and maintenance of buildings and structures is presented in the maintenance procedure for the power plant buildings. The inspection targets have been divided into weather-exposed structures, rooms and technical systems. The maintenance classification of the rooms determines the requirement level and criteria for the visual inspection as well as the inspection period. The maintenance personnel are tasked with maintaining the operability and functional capacity of the targets or restore them to the original level.

Alongside the measures recorded in the preventive maintenance programme, TVO monitors systems, components and rooms in the context of normal operation and daily rounds. Some of the most important components, such as the main circulation pumps and the turbine are equipped with continuously operating condition monitoring devices.

The systems maintaining measurement accuracy that are included in periodic preventive maintenance at the Olkiluoto 1 and 2 nuclear power plant units include separate measurement devices that are required for SSC maintenance, process measurement instrumentation and other functions, such as mechanical measurements as well as measurement systems for chemistry and radiation parameters. During the current operating licence period, the development of the system for maintaining measurement accuracy was continued. The coverage of the maintenance of process measurements was expanded. There are still some exceptions in the processing.

5.4.2 Periodic inspections and tests

The periodic inspection and test programmes of SSCs that are important to safety are based on official regulations and guidelines, standards, manufacturer instructions/recommendations, methods of using the equipment, and operating experiences regarding the equipment.

The scope and frequency of the periodic inspections and tests of individual SSCs is determined in conjunction with the qualification process of the SSCs in question or their modifications, with due consideration to the safety significance of each item.

The periodic inspection activities at the facility are guided and controlled by means of administrative procedures and information systems (e.g. work request system). The maintenance procedures determine the work, methods and approval criteria for specific components and areas in more detail. The procedures are updated every four years or when necessary. Periodic inspections and tests of areas that are important to safety are conducted during the operation and annual maintenance of the plant units, and they have been defined and scheduled in the Technical Specifications, the validity and accuracy of which TVO assesses on a regular basis.

An essential portion of the periodic tests that are important to the safety of the power plant are conducted in conjunction with annual outages, during which STUK performs test control measures by reviewing test records and assessing test coverage and the pertinence of the test procedures. STUK also assesses the state of the test instructions in conjunction with inspections specified in the Periodic Inspection Programme.

Pressure equipment and piping

The condition of the pressure-bearing components of the Olkiluoto 1 and 2 nuclear power plant units is ensured by means of periodic inspections. During outages, periodically repeatable inspections are conducted on the primary circuit equipment by means of non-destructive testing methods in accordance with Guide YVL E.5. The results of the in-service inspections are compared with the results of prior inspection or basic inspections performed before device commissioning.

The periodic inspection programmes are submitted to STUK for approval before each inspection. The programmes and the related inspection instructions are changed as necessary, with consideration to the development of the requirements and standards in the field, developments in inspection technology, inspection experiences, and nuclear power plant operating experiences in Finland and abroad.

The aim has been to select the areas where faults are most likely to occur for the inspections. These include positions that are susceptible to fatigue or stress corrosion due to temperature variation, for example. The process of selecting inspection areas is under constant development. For this purpose, the Olkiluoto 1 and 2 nuclear power plant units have implemented a risk-informed periodic inspection programme for piping. For the purposes of selecting the inspections and optimising the inspection intervals, risk-informed methods are used when preparing the programmes for the following inspection periods.

In the context of periodic non-destructive inspections, the inspection period is usually ten years. For components that are susceptible to thermal fatigue, the period is three years and, for components are susceptible to stress corrosion, the period is three or five years.

The latest editions of Guide YVL E.5 and ASME Code, Section XI are used as the approval criteria for the periodic inspection programmes and procedures. A qualification system has been developed for periodic inspections in accordance with European practices. Qualification will be obtained for all ultrasonic, eddy current and surface inspection systems used in the periodic inspections prescribed in Guide YVL E.5. The majority of the qualifications have been conducted and STUK has approved them.

In addition to the inspections mentioned above, the following physical inspections of pressure vessel condition and reliability are conducted as periodic pressure equipment inspections compliant with the Finnish pressure vessel legislation: a full inspection, internal inspection and operation inspection. These inspection include non-destructive tests as well as pressure and leakage tests. Specifications for pipe inspections are provided in the system-specific condition monitoring programmes. These periodic inspections are covered in Guides YVL E.3, YVL E.8 and YVL E.9. The periodic test programmes of the Olkiluoto 1 and 2 nuclear power plant units meet the requirements placed in YVL Guides on inspection numbers and technology.

The reliability of the non-destructive inspection methods of the primary circuit piping and equipment has been substantially improved after the commissioning of the Olkiluoto 1 and 2 nuclear power plant units. The qualification system for periodic inspections can be stated to be a significant operational development target.

Electrical and I&C components

The periodic operability inspections of electrical and I&C systems and components that are important to safety are performed in the form of periodic tests necessitated by Guide YVL A.6. The relevant timing and instructions are defined in the Technical Specifications. In addition to this, the periodic tests required by electrical safety standards are performed on protective relays, for example.

Concrete and steel structures

The condition of the concrete and steel structures of the Olkiluoto 1 and 2 nuclear power plant units is ensured by means of periodic inspections and separate investigations. The condition monitoring and maintenance programme specified in Guides YVL A.8 and YVL E.6 as well as the ageing management programme serve as the bases. The lengths of the inspection periods vary based on the estimated safety significance of each structure, and TVO has selected certain critical structures, such as the containment and seawater structures to be subjected to more extensive condition monitoring than other structures.

The procedure for the periodic inspections of structures is updated every four years, taking observations pertaining to operating experience feedback and inspection activities into account. The inspections are divided into general visual inspections as well as surveys and measurements of building elements. Things that are taken into account in the visual inspections of rooms and building elements are fractures in concrete structures, moisture and corrosion damage, functional deficiencies of various steel structures, changes in surface materials, deficiencies in covering structures and water leaks in underground spaces. The inspections are conducted in accordance with procedures specified in ASME XI, and the periodic inspection procedure determines the condition monitoring arrangements at the power plant units.

TVO's most important construction-related programmes and measures are presented in separate documents, including containment and expansion joint deformations, concrete fracture monitoring, temperature measurements, leak and moisture monitoring, containment tightness, monitoring of and procedures for concrete, steel, prestressing tendon and expansion joint properties, and procedures for the condition monitoring of reinforced concrete seawater channels.

The displacement between the plant units' containment and reactor building frame and the base slab and containment wall is monitored by means of measurements during annual maintenance.

Fractures in concrete structures are surveyed visually once a year during the maintenance outage, in accordance with the ASME XI standard. In addition to this, the survey is conducted before the tightness test as well as during and after it. In addition to monitoring existing fractures, the goal is to detect any possible new fractures. The limit value for fracture width is determined in accordance with the Concrete Code BY65, and any sections where the limit value is exceeded are repaired, if a corrosion risk exists.

The deformation of the containment is monitored by means of strain sensors installed in connection to the original steel reinforcements. The measurements are conducted once a year during maintenance outages or tightness tests. According to the results, deformation capacity of the containment concrete structures has been maintained and the displacements are within the planned elastic range. The measurements are supplemented by means of the pendulum systems being installed at the plant units. In addition to this, the reporting of measurement results is supplemented with load and strength analyses.

Periodic inspections ensure that the buildings and structures function according to plan so that the essential changes related to the safety and operational reliability of the plant units can be observed and rectified sufficiently early on.

Conclusions

The conclusion is that condition monitoring and maintenance tests of the Olkiluoto nuclear power plant have been implemented as intended in Section 23 of Regulation STUK Y/1/2016.

5.5 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 Guide YVL C.3, YVL C.6 and YVL 7.7. STUK has also published Guide YVL C.7, which will eventually replace Guide YVL 7.7 and which is currently in the process of receiving an implementation decision.

The Olkiluoto 1 and 2 nuclear power plant units feature technical systems for collecting and storing the majority of radioactive substances released into and contained by the facility's process systems. Only a small portion of the radioactive substances is released into the environment. The radioactive substances are discharged into the air as gases or particulates through the ventilation stack and into the seawater tunnel dissolved or mixed in the water and, further, into the marine environment through the discharge channel.

The plant units have continuously operating systems for monitoring external radiation in rooms as well as radiation in processes, releases and the environment. In addition to the radiation and activity measurements, TVO utilises portable radiation measurement equipment. Sampling and laboratory measurements are also used for the purpose of monitoring.

TVO updated the fixed radiation measurement systems of the plant units extensively between 2007 and 2016. New portable and moveable radiation measurement devices have been modernised during the current assessment period. During the modifications, the requirements of Guide YVL C.3 on measurement scope were taken into account and the reliability of process controls based on measurements were improved. TVO intends to update the radiation measurement systems of the KPA storage and VLJ repository in 2019–2020.

The measurement arrangement for radioactive releases into the air in the context of renewing the continuously operating radiation meters monitoring the various release routes were duplicated in case of a severe accident. After the update, the monitoring of iodine and particulates in the ventilation stack is ensured by means continuously operating radiation measurements compliant with Guide YVL C.3, in addition to sampling and laboratory analyses.

In connection to the staff exit, the boundary of the controlled area features efficient and modern gate monitors and duplicate shoe boundary arrangements.

STUK has reviewed the procedures for radiation measurements, sampling and laboratory specifications and monitors the activities on a regular basis.

An extensive environmental radioactivity monitoring programme approved by STUK is being implemented in the area surrounding the Olkiluoto nuclear power plant. Within the scope of this programme, the possible passage of radioactive substances into the environment is monitored by analysing the radionuclide concentrations of foodstuffs produced in the area around the facility and samples indicating the propagation of other releases. The results of the monitoring serve to verify and secure the monitoring of radioactive releases at the Olkiluoto nuclear power plant. The radiation monitoring programme has been updated for 2012–2016, and it is based on Guide YVL 7.7. As a result of the amendments to the Nuclear Energy Act and Radiation Act, the radiological monitoring of the environments of nuclear facilities has been regarded as regulatory control as of 1 July 2015. By STUK decision 3/0111/2015, 18 June 2015, the environmental radiation monitoring programme will be continued in accordance with the programme approved in 2012, until STUK issues an implementation decision on Guide YVL C.7 "Radiological monitoring of the environment of a nuclear facility" for the operating Olkiluoto nuclear power plant units. Since the beginning of July 2015, STUK has conducted environmental radiation monitoring as an independent authority. The new responsibility arrangements, practices and methods regarding environmental radiation monitoring are included in the new Guide YVL C.7, which was published on 19 December 2016. The implementing decision for the operating Olkiluoto nuclear power plants will be completed in spring 2018.

The radiation monitoring programme includes about 300 annual samples. The sample types include milk, meat, fish, grain and vegetables as well as water and airborne aerosols. In addition to this, soil and water environment samples are taken from indicator organisms that effectively accumulate radioactive substances from their habitat. 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 ^{89,90}Sr and alpha emitters, such as ^{238}Pu and ^{239,240}Pu.

In recent years, the emissions of radioactive substances have been clearly below the applicable limit values (Chapter 3.3 of the safety assessment). In terms of activity values, releases into the air have been predominantly noble gases, ^{14}C and tritium. For water releases, tritium has been most prevalent. The released nuclides observed in the environment have been activated corrosion products (e.g. ^{60}Co, ^{54}Mn) and tritium. Radioactive substances originating from the nuclear power plant have been mainly observed terrestrial environments mainly during annual maintenance in air, fallout and rain samples and regularly in indicator samples take from aquatic environments. The concentrations are very low and bear no significance for humans or the environment in terms of radiation protection. Radioactive substances from the Chernobyl disaster are also prevalent in the environmental samples of the Olkiluoto nuclear power plant. Although the concentrations of radioactive substances in the environmental samples were already low, a downward trend can be seen in ^{60}Co concentration measurements for indicator organisms in marine environments and sinking materials.

The Olkiluoto nuclear power plant area 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. Three new external radiation dose rate meters will be implemented in the site area before the commissioning of the Olkiluoto 3 nuclear power plant unit. The results of the meteorological system near the plant, which was updated during the assessment period, will be used to estimate the spreading of radioactive releases in the atmosphere.

The results of radioactive release measurements and the environmental radiological monitoring programme will are reported to STUK in quarterly and annual reports in accordance with Guide YVL A.9.

The conclusion is that the room dose rates, systems and releases and concentrations of radioactive substances inside and around the Olkiluoto 1 and 2 nuclear power plant units are measured as intended in Section 24 of Regulation STUK Y/1/2016.

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

6.1 Section 25 Management, organisation and personnel: ensuring safety

6.1.1 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.

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.

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.

In its activity management system, 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, safety culture refers collectively to the operation modes of the organisation and the attitudes of individual persons as the result of which the factors affecting the safety of the nuclear power plant each receive the attention required by their importance and take precedence when making decisions.

In recent years, TVO has been more systematic than before in documenting its approach to ensuring a good safety culture. Since 2015, TVO has had in place a safety culture programme, which presents the target state for safety culture, the measures to ensure the continuous maintenance and assessment of safety culture, the indicators used for monitoring safety culture, the principles for developing safety culture and any topical measures required.

TVO has many practices for monitoring and assessing the state of its safety culture. A self-assessment of safety culture has been conducted every three years since 2004, and the latest one was completed in early 2017. The self-assessment includes a questionnaire which can be answered by any TVO staff member. At TVO, the state of safety culture is monitored by the safety culture group and CAP (Corrective Action Program) group, among other parties. Observations related to safety culture are presented in the safety monitoring report, which is published three times a year and processed by the management. The achievement of TVO's safety indicator is also reported in conjunction with the safety monitoring reports. The safety indicator consists approx. 90 different indicators describing various areas of safety, which means that the management can obtain an overall view of the quality and safety of the organisation's operations. Event-based and peer assessments of safety culture are also conducted (WANO, OSART).

TVO uses IAEA's three-tier scale in illustrating the state of its safety culture. According to its own estimation, it currently not on the target level of 3. Based on STUK's control activities, development has been needed in the processing of safety issues in decision-making and the openness of the atmosphere, among other areas, to ensure that safety is prioritised in practice and any issues that may compromise safety are reported and resolved efficiently. In addition to this, TVO has exhibited significant problems related to work atmosphere in recent years and the staff turnover has increased from previous years. Staff motivation and competence are essential in maintaining a good safety culture. Over the course of its control activities, STUK has noticed that TVO's seemingly comprehensive procedures to assess the safety culture, atmosphere and quality of organisational activities have not provided the management with a clear and harmonious view of the acceptability of TVO's safety culture and development needs in the organisation's operations. The implementation of measures that would affect the challenges related to atmosphere and safety culture has been delayed.

Due to the challenges with work atmosphere, TVO has initiated extensive programmes aiming towards a strong safety culture, good work atmosphere and management. Among other areas, the practical measures of the programmes are aimed at the supervisors' leadership skills and capabilities of managing changes, as well as improving work well-being and the fluency of work. In 2017 and 2018, STUK has carried out intensified monitoring on the implementation and efficacy of the TVO's measures. STUK has found it important for TVO to particularly improve the leadership skills of the management, the processing of safety matters, communications in the context of decision-making, unambiguity of responsibilities and operating methods and the human resources situation. Based on the intensified monitoring, STUK can state that TVO has taken measures in all of the aforementioned areas. There is some preliminary proof of the positive effects of the measures on TVO's work atmosphere and safety culture, but STUK is still conducting intensified monitoring of their effectiveness. During the first half of 2018, TVO independently identified realising the management's expectations, measures to correct attitudes, timely completion of other work tasks, ensuring sufficient resources, and interaction between the management and personnel, for example, as important development areas. TVO has initiated concrete measures focusing on these areas. Based on its own periodic safety review, STUK has required TVO to provide periodic reporting on the development of the safety culture and work atmosphere.

In its corporate-level policy, TVO requires that other persons working at Olkiluoto also commit to a high level of safety culture and high-quality operation. The suppliers of products or services are evaluated and related information is kept up-to-date in TVO's information systems. Supplier subcontractors are assessed by applying the principle of considering safety significance. The assessments are conducted at the beginning of a procurement or project and at regular intervals to ensure the relevant supplier's capability of supplying the required product or service. Agreements are also used to ensure that supplier are committed to high quality in their operations. There have been changes in the field of nuclear power operators, and there are inexperienced workers among the personnel of Finnish nuclear power organisations. TVO has identified the need to develop the orientation training and monitoring of subcontractors.

TVO's manager responsible for operation is supported by a safety group, which is independent of the rest of the organisation and provides recommendations and statements in matters related to nuclear safety and quality management. The majority of the safety group consists of persons that are not part of the Electricity Production business unit and the OL3 project. In addition to this, the safety group currently includes two expert members from outside TVO. The group convenes at least every three months. The safety group can be considered to meet the applicable regulation's requirement for an expert group that is independent of the rest of the organisation.

6.1.2 Human resources 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 per-

sons working in such positions, and an adequate command of the functions in question must be verified.

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 which is kept up to date and appended with an organisation diagram. TVO's management relationship are presented in the administrative rules. Among other things, the rules list the duties, authorisations and responsibilities of persons and organisational units that participate in operational measures, monitoring of reactor operation, emergency response arrangements, security arrangements and nuclear safeguards. In addition to this, the administrative rules present the duties, authorisations and responsibilities of the responsible managers and their deputies. These are persons who have been appointed by TVO and approved by STUK. At TVO, the manager responsible for operation bears the responsibility of all three nuclear power plant units. The responsible manager is the manager of electricity production who, according to the administrative rules, is responsible for all activities that take place at the Olkiluoto 1, 2 and 3 nuclear power plant units after fuelling.

Documented procedures have been provided for the safety review of organisational changes. An independent assessment is prepared on significant organisational changes. At TVO, changes that affect management structure, department-level changes and significant changes to business operations are regarded as significant organisational changes.

In 2015, TVO carried out an organisational change in which the TVO organisation was divided into business units and service functions. The service functions include technical services, safety and support services. Safety is also 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 OL3 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 conjunction with organisational changes, TVO also carried out staff reduction, which is a deviation from the company's earlier operating practices. 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. In addition to this, many responses emphasised the scarcity of resources, particularly in I&C and maintenance functions.

TVO has developed its resource management tool and the further development of the organisation's operating model is still under way. In TVO's service model, the supervisors are responsible for resource sufficiency. Between 2016 and 2017, TVO conducted an extensive competence survey project with the aim of determining function-specific tasks and the requisite competence for all three plant units. The competencies were further divided into competence elements. More detailed procedures for the execution of training and qualification activities are presented in the training manual. The results of the competence survey are assessed by the management group and they are used as a basis for recruitment.

In 2017, TVO implemented an organisational change in which the managers of electricity production and the safety function switched duties, and separate plant managers were appointed for the Olkiluoto 1, 2 and 3 nuclear power plant units. At the same time, the maintenance function was reorganised and resources were added.

In its inspections, STUK has reviewed resource planning and the estimate of human resources required at the Olkiluoto 1, 2 and 3 nuclear power plant units. At the beginning of 2018, TVO made the transition to a running 12-month plan that is updated on a monthly basis. In STUK's assessment, the resource planning is justified. TVO has implemented large-scale recruitment processes in 2017. However, further recruitments are still needed for the maintenance and technology functions, for example. At the beginning of 2018, STUK imposed some requirements on rectifying the resource situation and it is now monitoring the development within the scope of its inspection programme.

6.1.3 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.

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.

The licensee's corporate-level management system documentation, also known as the activity management system, consists of a general section and functional section. The activity management system covers the production activities, maintaining and developing the production capacity, construction of additional production capacity and the functions required for their control and resourcing. TVO's activity management system also covers the Olkiluoto 3 plant unit. The plant unit's quality management during the construction and commissioning phase is supplemented by a separate quality plan approved by STUK.

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. Operational principles include continuous improvement and the assurance of safety and competence. TVO's operations manual presents the general section of TVO's activity-based management system as well as the operative procedures needed for quality management activities. The operations manual is available to everyone working at TVO.

The functional section describes the functional processes with short general descriptions and partly with more detailed process models. The aim is to make overall arrangements more understandable. Process modelling is used as part of the specification to describe the company's operations to the necessary degree and the relationships between the operational elements. Owners have been determined for processes, which are measured in the manner specified in the annual strategy process. The functional processes are steered by manuals and more detailed instructions. According to STUK's observations, the process-like operations are not very advanced at TVO but they comply with the regulations. There is still much to develop in the management of process-like operations and the manuals and procedures that support processes.

Operations are developed systematically by means of a variety of projects. The projects are planned through long-term and annual project planning. TVO's investment process instructions determine the operating methods and procedures related to target selection and assessment. This ensures the correct maintenance and development targets from the perspective of the plants' safety and availability. Project plans are prepared for the projects, the scope of which is determined according to the difficulty of the project or modification. The plans cover change management, schedule and cost control as well as descriptions of project-related risks and preparations for them, for example. Project risks are assessed according to the investment process by utilising TVO's risk assessment tool. The aim of the methodology is to identify all risks that are significant to nuclear and radiation safety. Based on STUK's control activities, TVO has prepared procedures for its project operations, but the practices applied by project managers still require development in terms of risk management, securing resources and managing external operators.

Operational assessments at TVO are carried by means of audits and self-assessments, among other measures. They are used to produce objective information about the level of activities for the management and the persons responsible for functions. Audits are conducted as internal audits, supplier audits, independent audits performed by external experts and management system assessments, for example. STUK has inspected TVO's procedures and monitors the assessment of supplier by participating in supplier audits, for example. Since 2009, TVO has been assessing the functionality and coverage of its management system every three years. In 2016, the assessment of the management system's functionality and coverage was combined with a self-assessment of safety culture. This combined assessment is to be conducted every four years. In recent years, the staff questionnaire (includes work atmosphere, for example) has been performed more frequently due to problems observed with the atmosphere.

The recommendations, other observations and discrepancies revealed by the assessments are processed within a single TVO information system. Deviations are documented systematically in accordance with procedure "Handling of deviations and other findings". Responsibilities and schedules are clearly specified for the corrective measures. The status of corrective measures is covered in management reviews, but the process of assessing the effectiveness of the measures is still under development. In recent years, TVO has faced challenges in keeping to the schedules it has defined for the implementation of corrective measures.

TVO has document management procedures and configuration management procedure that are aimed at ensuring the implementation of documentation changes in a planned and controlled manner.

6.1.4 Conclusion

In accordance with Section 25 of Regulation STUK Y/1/2016, .TVO's management system includes procedures for assessing and developing safety culture, managing human resources and handling quality management. In STUK's assessment, TVO is also applying these procedures.

The organisation and operating model change implemented by TVO in 2015 resulted in the need to develop management, the management system and operating culture, which is still on-going. TVO's work atmosphere issues and the high staff turnover in recent years at the same as the commissioning of the Olkiluoto 3 nuclear power plant unit present a challenge for high-quality and safety-informed work. Based on STUK's control activities, TVO has implemented development measures related to management, safety culture and development measure related to staff resourcing and competence in a systematic manner. In STUK's assessment, the aspects necessitated by Section 25 of Regulation STUK Y/1/2016 are at an acceptable level. The implementation of development measures related to management, safety culture as well as staff resourcing and competence must be continued, and STUK will monitor their effectiveness as part of their control efforts.

7 Security arrangements (STUK Y/3/2016)

A nuclear facility's security arrangements are part of overall safety. They help secure operational safety during normal plant operation through access control and guidance, for example. The primary aim is to safeguard the use of nuclear energy against unlawful activity: prevent threats, detect possible threats – physical and data security threats – and implement the responses required by each situation.

7.1 Provisions and requirements laid down by virtue thereof

The statutes regarding security arrangements are presented in the Nuclear Energy Act, the Nuclear Energy Decree and Regulation STUK Y/3/2016. The 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 STUK's decision 2/Y42217/2013.

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

7.2 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 operational threats, 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 National Police Board. The practical arrangements are handled 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.

7.3 Licensee's security arrangements and their assessment

At TVO, the security arrangements are handled by a responsible person approved by STUK and this person's deputy, as required in Section 7(i) of the Nuclear Energy Act.

In accordance with the updated requirements and implementing decisions, TVO has updated the essential security arrangement documents: security standing order, security plan and transport security plan, including appendices and references. STUK processed the documents in 2016 and issued requests for clarification on them. TVO provided updated documents in response to the requests for clarification, and approving decisions on the documents were issued in July 2017, with some requirements. During its processing activities, STUK requested statements on the security standing order and security plans from the Advisory Committee on Nuclear Security (TJNK) and the Ministry of the Interior. The Committee's statement has been taken into account in the decisions. The Ministry of the Interior presented no requirements. The requirements in STUK's decision mainly pertain to procedural descriptions. TVO has updated the security standing order and transport security plan with regard to the aforementioned decision requirements. The operations compliant with the approved documents will fulfil the requirements of Regulation STUK Y/3/2016. The content of the security arrangement documents is compliant with the stipulations in Sections 7(l–o) of the Nuclear Energy Act. TVO has supplied the essential data security documents necessitated by the new requirements, and STUK has approved them.

New YVL Guides and implementing decisions pertaining to the design basis threat have been prepared for TVO. The current design basis threat is was not the original design basis for the Olkiluoto 1 and 2 nuclear power plant units. The improvement measures suggested by TVO or required by STUK will be monitored based on the design basis threat and the implementing decision of Guide YVL A.11. The practical implementation of the security arrangements is also otherwise developed i accordance with technological developments, for example. Measures, such as the modernisation of access control, are under way. Based on the changes in the threat scenario and control observations, STUK may, among other developments, may require the operational capability of the security organisation and technical security arrangements to be improved in ways that can be implemented in ways that are more flexible than structural solutions. This is also in line with the principle of continuous improvement.

The requirements of Guides YVL A.12 and YVL D.2 are fulfilled without deviations as is or by means of some measures.

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 planned an extensive and independent assessment in 2018 when the implementation of the Olkiluoto 3 plant unit's security arrangements could also be evaluated. Within the scope of its control measures, STUK assesses the licensee's methods for indicating effectiveness and the results of the methods. The planning and reporting of threat scenario response exercises remains a development target. As part of the security plan update, STUK has reviewed and approved TVO's analysis on the effectiveness and efficiency of the security arrangements.

Conclusions

Based on reviewed security arrangement documents and the inspections prescribed in the Periodic Inspection Programme, the safety level required by Regulation STUK Y/3/2016 in accordance with the current threat scenario. The implementing decisions of the design basis threat and Guide YVL A.11 have granted derogations and, based on the decisions improvement measures suggested by TVO or required by STUK will be monitored.

8 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 (468/2003).*

The statutes 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 past operating licence period, the Government Decree on Emergency Response Arrangements at Nuclear Power Plants was amended twice: 735/2008 and 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). In terms of content, not significant changes were made to it at the time.

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 concerning emergency response arrangements, with regard to assessing the radiation situation of the environment, radiation and release measurements, and meteorological measurements.

8.1 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 situation and events that deteriorate safety. They have been described in the safety analysis reports of all TVO nuclear power plant units and TVO's emergency response plan. The results of these analyses are 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 plat units and the KPA 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. During the past operating licence period of the Olkiluoto 1 and 2 nuclear power plant units, new analyses have been conducted due to plant modifications and the broadening of the design basis. The emergency response has been continuously developed to correspond to a site area situation where the variable factor has been the construction site of the Olkiluoto 3 nuclear power plant unit. Emergency situations are classified and described in the facility's emergency plan and FSAR. The emergency response plan describes the notifications and alarms required by the various emergency situation classes 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 persons not necessary for the emergency situation from the power plant 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. This has ensured 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 Emergency Services 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 the two designated deputies. All person 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 nuclear 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. The changes made to the regulations' design bases after the Fukushima disaster have led to the emergency response organisation being expanded to meet the requirements of a prolonged situation. TVO is constantly assessing the suitability of its organisation for various emergency situations and making the necessary changes. A sufficient number of trained persons have been appointed to the emergency response organisation to ensure the various emergency situations at the plant units. The operative instructions of the emergency response organisation includes a description of the organisation's alarm arrangements. The entire emergency response organisation of TVO is alerted in all emergency situations.

8.2 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 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 emergency response organisation's premises provide access to all systems, information materials and other equipment that the organisation needs to perform its tasks related to emergency situations at the Olkiluoto 1 and 2 nuclear power plant units. 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 redoing the external radiation dose rate measurements in the site area and a radius of 5 km in the summer of 2008. The system was expanded during 2017 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. The ROSA software is used to calculate the propagation of radioactive releases and environmental doses in the emergency planning zone.

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 the context of which the data transfer capacity will be increased and the facility will be enabled to send data on all plant units at the same time. TVO’s training simulator is connected to the data transfer link, and the arrangement is used to relay the plant scenario of emergency response exercises to STUK.

The Olkiluoto 1 and 2 nuclear power plant units both have an emergency response centre with identical equipment and capabilities. 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. The emergency response centre of the other plant unit serves as the auxiliary response centre, in addition to which the emergency response organisation has access to a prepared auxiliary command centre in a civil defence centre in the city of Rauma. In the auxiliary command centre in Rauma, TVO’s emergency response organisation has access to 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. TVO updated the procedures related to personnel evacuation in 2016. In the same context, it reduced the number of personnel assembly locations to three in order to simplify the operations. TVO has acquired iodine tablets in the site area for the personnel.

Over the course of the current operating licence period, 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 and nearby residents. 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 personnel last rehearsed assembly in conjunction with the emergency response exercise of 2017 and in the personnel assembly exercise held in December 2017.

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

8.3 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. In its Periodic Inspection Programme, STUK has annually ensured that the training has been provided.

Emergency response exercises compliant with the requirement level of the YVL Guides have been organised on an annual basis, in addition to which 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 emergency department and organised every three years. The scenarios of the emergency response exercises have ranged from plant events classified as emergency situations to severe reactor accidents. After the entry into force of the expanded design basis, TVO has practiced a concurrent emergency situation at both operating plant units and the KPA storage in the autumn of 2016. Feedback collected from the participants and evaluators of prior exercises have been used in planning the new exercises. Members of the emergency response organisation must take part in the exercises regularly. Feedback on the exercises is also assessed in STUK's inspections according to STUK's Periodic Inspection Programme.

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.

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 through inspections prescribed in the Periodic Inspection Programme and regular control operations. TVO has updated the emergency response plan several times a year, as necessary. In 2017, TVO has provided STUK with two update batches to the emergency response plan. Other emergency procedures are updated as needed.

8.4 Action in an emergency situation(Sections 9-12)

The requirements for action 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 transient and emergency procedure and the emergency plan. In addition to this, other procedures referred to in these procedures are used in emergency situations.

The control rooms of the Olkiluoto 1 and 2 nuclear power plant units 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 the time of commencing the operations as well as the complete emergency response organisation, including task descriptions. TVO has developed the arrangements for relaying situational awareness in emergency situations by implementing an electronic situation log that can be viewed by the cooperating authorities. During the operating licence period, the VIRVE SVP talk group was also established to ensure swift transmission of situational information between the heads of emergency response organisations.

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

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

8.5 Measures pertaining to rescue operations (Section 13)

Section 48 of the Rescue Act 379/2011 obliges nuclear power plants to participate in the preparation of a external rescue plan for locations that present an extraordinary hazard. More specific provisions on the plan are laid down in Decree of the Ministry of the Interior Decree 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 emergency services 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 SVP group since is 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 SVP group has followed the activity of the Eastern Uusimaa SVEPP group, and TVO has participated in the acquisition of an equipment container on the initiative of the Eastern Uusimaa SVEPP group. The equipment container includes emergency response equipment suitable for joint use, and it can be moved to suitable location in the Satakunta region 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.

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. Tablets were last distributed in the spring of 2013.

<u>Conclusions</u>

The emergency response arrangements of the Olkiluoto nuclear power plant are at the required level, and TVO continues to develop preparedness for emergency situations. 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 the 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 on the plan.

The conclusion is that the emergency response arrangements at the Olkiluoto nuclear power plant have been implemented as intended in Regulation STUK Y/2/2016. TVO's emergency response arrangements with regard to the commissioning of the Olkiluoto 3 nuclear power plant unit will be addressed in conjunction with the operating licence application for the Olkiluoto 3 plant unit.

9 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 7h 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.*

9.1 Handling, storage and final 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.

Guide YVL D.4 presents more detailed requirements on the processing of low- and intermediate-level nuclear waste and the decommissioning of nuclear facilities. Regulation STUK Y/4/2016 presents general requirements for the safety of the final disposal of nuclear waste, and Guide YVL D.5 covers the requirements for the full life cycle of final disposal facilities for nuclear waste (location surveys, planning, construction, operation and closure) and applies to the safety of the use of final disposal facilities and demonstrating the long-term safety of final disposal.

The starting point for the management of power plant waste at the Olkiluoto 1 and 2 nuclear power plant units has been to arrange handling and final disposal in the site area. No significant issues have occurred in the management of low- and intermediate-level waste that would have compromised safety during the past operating cycle. At the end of 2016, the full amount of low- and intermediate-level waste was approximately 6,500 m^3, of which waste in final disposal constituted about 94%.

During the current operating licence period, TVO has had a variety of development projects related to the handling of low- and intermediate-level waste. Among other aspects, they are related to the reduction of waste volumes, development of waste processing through technical improvements and outsourced processing services, and research related to new processing methods for waste types.

The final disposal facility for low- and intermediate-level waste (VLJ repository) is located in the site area and it includes two waste silos constructed at a depth of 60–100 metres, one for low-level and the other for intermediate-level operational waste. In addition to this, the final disposal facility features a storage space for radioactive waste held by the state (small-user waste). The final disposal facility has a separate operating licence, which will remain valid until 2051. On 22 November 2012, the Finnish Government approved the changes to the operating licence terms of the VLJ repository, based on which the disposal facility can be used for the final disposal of operational waste from the Olkiluoto 3 plant unit and small-user waste under the responsibility of the state.

Changing the operating licence terms

TVO's operating licence application describes the operational waste storages and their primary purpose of use, and the application requests a licence for using the intermediate-level waste storage, low-level waste storage and the connected component storage as well as the waste facilities of the Olkiluoto 1 and 2 nuclear power plant units for the intermediate storage of low- and intermediate-level operational waste generated by the operation of the nuclear facilities on the Olkiluoto island from the beginning of 2019 to the end of 2038. In its supplementation application delivered to the MEAE, TVO proposes that it should be permitted to hold, produce, handle and store the operational waste generated by the operations of the nuclear facilities on the Olkiluoto island in such a way that a total storage capacity of 30,000 m^3 is not exceeded at any point. The nuclear facilities on the Olkiluoto island are the nuclear facilities owned by TVO, i.e. the Olkiluoto 1, 2 and 3 nuclear power plant units and the KPA; KAJ and MAJ storages related to nuclear waste management and the VLJ repository.

TVO has estimated that over the course of the 20-year operating licence period, the Olkiluoto 1 and 2 nuclear power plant units will generate 7,000 m^3 of nuclear waste and the Olkiluoto 3 unit is estimated to produce an equal amount. The total amounts to roughly half of the storage capacity presented in the application. According to TVO, the flexible use of the waste storages will ensure safe and efficient waste processing. The long-term storage of operational waste enables processing the waste in larger batches for final disposal or release from regulatory control. The 30,000 m^3 presented in TVO's application is equal to volume of operational waste generated during approximately two 20-year operating licence periods. The storage capacity corresponds to a higher volume than is available at the current waste storages and processing facilities, which means that the design has accounted for a possible expansion of the premises in the future. Each operational waste storage facility and its capacity are described in more detail in the final safety analysis report for the Olkiluoto 1 and 2 nuclear power plant units, and the documents also mention the possibility of expanding the storages if necessary.

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 final disposal of the waste and its release from regulatory control.

The intermediate-level waste generated by the operation of the nuclear facilities on the Olkiluoto island varies between the facilities. At the Olkiluoto 1 and 2 nuclear power plant units, intermediate-level waste is solidified in bitumen, placed in drum storage at the plant and finally delivered into the VLJ repository after a short storage period. The liquid waste generated at the Olkiluoto 3 power plant units is dried into 200-litre drums (in-drum drying) and it is stored for approx. 10 years in the drum storage of the Olkiluoto 3 nuclear power plant unit. Once the storage is full, the waste will be stored in the intermediate-level waste storage until the expansion of the VLJ repository is completed. TVO has prepared an analysis of the storage of in-drum dried waste in the intermediate-level waste storage and assessed the radiation dose rates caused by the accumulated waste volume as well as the necessary radiation protection inside and outside the storage. STUK has processed the analysis in conjunction with processing the operating licence application of the Olkiluoto 3 nuclear power plant unit.

Conclusions

The change in operating licence terms enables the processing and longer-term storage of nuclear power plant waste from the Olkiluoto island at the Olkiluoto 1 and 2 nuclear power plant units and the site area waste storages mentioned in the operating licence application in such a way that the total waste volume never exceeds 30,000 m^3, the storage space of the Olkiluoto 3 plant unit included. STUK's total assessment is that the change in operating licence terms can be approved. By means of its control activities, STUK aims to ensure that the waste is handled and stored in accordance with the general principles described in the nuclear energy legislation and with due consideration of the procedures approved by STUK, taking the relevant aspects of radiation protection into account, and that the origin of the waste can be traced in all phases of handling, storage and final disposal. STUK monitors the filling of the storages. If necessary, individual storages 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 conclusion is that the handling and storage of operational waste have been implemented as intended in Regulation STUK Y/1/2016. According to STUK's assessment, the operational waste management at the Olkiluoto 1 and 2 nuclear power plant units is handled in a safe manner and the methods employed for the purpose are appropriate and sufficient.

STUK has assessed the safety of the final disposal facility for low- and intermediate-level waste in conjunction with the changing of the operating licence terms for TVO's VLJ repository. As a result of the assessment, STUK delivered to the MEAE a statement appended with STUK's safety assessment (4/C42213/2011, 28 June 2012). The conclusion was that the preconditions laid down in Sections 5–7 and 20(1) of the Nuclear Energy

Act have been fulfilled for granting an operating licence for TVO's VLJ repository and that the final disposal of the low- and intermediate-level waste has been implemented as intended in the Government Decree 736/2008 (presently Regulation STUK Y/4/2016).

9.2 Handling, storage and final disposal of spent nuclear fuel

Section 12 of Regulation STUK Y/1/2016 concerns the handling and storage of nuclear fuel, and its fulfilment is addressed in Chapter 4.5 of this safety assessment. Section 13 of Regulation STUK Y/1/2016 includes a corresponding requirement for radioactive waste. Chapter 4.5 covers the fulfilment of the safety principles required in the Section listed above in relation to the handling and storage of spent nuclear fuel at the Olkiluoto nuclear power plant. TVO has implemented safety improvements to the fuel pools at the Olkiluoto 1 and 2 nuclear power plant units and the spent nuclear fuel storage (KPA storage) that ensure fuel cooling. These improvements are covered in Chapter 4.5 of the safety assessment.

In the operating licence (31/812/96 KTM) issued by the Government in 1998, TVO was granted permission to store spent nuclear fuel in the amount of 1,800 tonnes of uranium at the Olkiluoto KPA storage, provided that STUK approves the expansion of the KPA storage's capacity to meet this value. STUK granted permission for expanding the capacity of the KPA storage in 2015. STUK's decision applied to spent nuclear fuel generated at the Olkiluoto 1 and 2 nuclear power plant units. In its decision, STUK stated that the procurement of new fuel racks and the expansion of the fuel transfer machine's operating area to cover the new pools would be processed later as separate modifications. Furthermore, STUK indicated that the storage of spent nuclear fuel generated by the operation of the Olkiluoto 3 plant unit would be processed separately at a later time. The KPA storage was commissioned in 1987. Initially, three storage pools and one handling pool were constructed in the KPA storage. In 2013, the KPA storage was expanded with three additional pools, taking into account the planned service life extension of the Olkiluoto 1 and 2 nuclear power plant units from the original 40 years to 60 years as well as the commissioning of the new Olkiluoto 3 nuclear power plant unit. The original design life of the KPA is 60 years. For the expansion, the design basis has been a service life of 100 years.

STUK last estimated the safety of the KPA storage on a wider scale in conjunction with expanding the capacity of the storage in 2013. In the context of the application to increase the capacity of the KPA storage, STUK conducted a safety assessment of the KPA storage (2/E42242/2013, 23 June 2015).

TVO updated the documents related to the final safety analysis report after the expansion of the KPA storage and responded to the requirements presented in STUK's decisions. The final safety analysis report and the KPA storage classification document take into account the requirements of Guide YVL B.2, including the changed requirements concerning the safety classification of systems and the seismic classification. The KPA storage's final safety analysis report and classification document are up to date.

Currently, the three pools used in the KPA storage have room for 7,146 fuel assemblies, the weight of which equals to approx. 1,330 tonnes of uranium. Two pools use open fuel racks while one pool uses dense racks. By replacing the existing open racks with dense racks, the fuel storage capacity can be increased further from the current level.

In its operating licence supplement (TVO-11038, 5 June 2017), TVO proposed that the licensee would be permitted to use the KPA storage to hold, handle and store a maximum quantity of 12,400 (approx. 2,300 tU) spent fuel assemblies generated by the operation of the Olkiluoto 1 and 2 nuclear power plant units and a maximum of 1,600 (approx. 870 tU) spent fuel assemblies generated by the operation of the Olkiluoto 3 plant unit. A maximum of five of the KPA storage pools have been reserved for the interim storage of spent nuclear fuel from the Olkiluoto 1 and 2 nuclear power plant units and two pools have been reserved for the interim storage of spent nuclear fuel from the Olkiluoto 3 plant unit. Currently, the KPA storage has been approved for a fuel volume equal to 1,800 tonnes of uranium (corresponds to approx. 9,650 assemblies) from the Olkiluoto 1 and 2 nuclear power plant units. The amount of spent nuclear fuel to be stored according to the operating licence application is higher that has so far been permitted by STUK. If the intention is to use the KPA storage to hold an amount of spent nuclear fuel that exceeds the level permitted by STUK, the licensee must obtain STUK's approval for the change before its implementation, as required in Section 112 of the Nuclear Energy Decree. Furthermore, in the operating licence supplement for the Olkiluoto 1 and 2 nuclear power plant units, TVO proposed that the licensee would be permitted to use the fuel pools of the Olkiluoto 1 nuclear power plant unit to hold, handle and store a maximum quantity of 1,520 (approx. 285 tU) spent fuel assemblies generated by the operation of the Olkiluoto 1 and 2 nuclear power plant units and the fuels pools of the Olkiluoto 2 nuclear power plant unit to hold a maximum of 2,520 (approx. 470 tU) of these spent fuel assemblies. In its application, TVO presented the quantities as fuel assemblies when, in the earlier licence, the amounts were presented as uranium masses. In the effective licence, the amounts have been set to 280 tonnes of uranium for the Olkiluoto 1 nuclear power plant unit and 450 tonnes of uranium for the Olkiluoto 2 nuclear power plant unit. If the intention is to use the fuel pools to hold an amount of nuclear fuel that exceeds the level permitted by STUK, the licensee must obtain STUK's approval for the change before its implementation, as required in Section 112 of the Nuclear Energy Decree.

In the action plan to develop plant safety that it delivered in conjunction with the periodic safety review, TVO identified several measures related to the KPA storage which are intended as preparation for the increasing volume of stored fuel generated by the continued operation of the Olkiluoto 1 and 2 nuclear power plant units and, at a later time, by the need to store spent nuclear fuel from the Olkiluoto 3 nuclear power plant unit. According to current estimates, the maximum capacity of the decay heat removal systems of the KPA storage will be reached in 2026.

Final disposal of spent nuclear fuel

Posiva Oy (Posiva) was established to handle the final disposal of the spent nuclear fuel of TVO and Fortum Power and Heat Oy (Fortum). Posiva submitted a construction licence application for an encapsulation final disposal facility to the Government at the end of 2012. STUK delivered a statement and safety assessment to the MEAE at the beginning of 2015. The Government granted the construction licence to Posiva on 12 November 2015. The final disposal has been planned to begin no earlier than 2024.

Conclusion

The conclusion is that the storage of the spent nuclear fuel of the Olkiluoto 1 and 2 nuclear power plant units has been implemented as required in Section 13 of Regulation STUK Y/1/2016. If the intention is to use the KPA storage or reactor hall fuel pools to hold an amount of nuclear fuel that exceeds the level permitted by STUK, the licensee must obtain STUK's approval for the change before its implementation, as required in Section 112 of the Nuclear Energy Decree.

Posiva is responsible for the final disposal of TVO's spent fuel. On 12 November 2015, the Government granted a construction licence to Posiva for the construction of an encapsulation and final disposal facility for spent nuclear fuel in Olkiluoto. STUK oversees Posiva's operations in accordance with the Nuclear Energy Act and Regulation STUK Y/4/2016.

9.3 Decommissioning of plant units

According to Section 7 g of the Nuclear Energy Act, *The design of a nuclear facility shall provide for the facility's decommissioning. The decommissioning of a nuclear facility shall prioritise safety. Dismantling the facility and other measures taken for the decommissioning of the facility may not be postponed without due cause.*

The licence applicant and licence holder shall prepare a plan for the decommissioning of the nuclear facility. Unless otherwise stipulated in the licence terms and if the operations continue, the licence holder shall present a plan for the decommissioning of the nuclear facility to the Radiation and Nuclear Safety Authority (STUK) for assessment at regular intervals and at least every six years.

The operation of the nuclear facility has been concluded, the licence holder shall be responsible to ensure that the facility is decommissioned in accordance with the terms of the licence pursuant to Section 20(a), the relevant safety requirements and the plan approved by STUK.

More detailed provisions on the reports to be included in the plans, the delivery of documents and the processing of the plan are laid down by Government decree.

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.*

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. TVO updated the decommissioning plan for the Olkiluoto nuclear power plant in 2014, and the Ministry of Economic Affairs and Employment (MEAE/2167/08.05.01/2014).

For the Olkiluoto 1 and 2 nuclear power plant units, the starting point for the Olkiluoto nuclear power plant's decommissioning plan is the closure of the power plant units after 60 years of use. Delayed dismantling has been chosen as the decommissioning strategy. This means that the nuclear power plant units will be maintained for approx. 30 years in a controlled manner before beginning the actual decommissioning phase, i.e. the dismantling of the systems and structures. During the decommissioning all of the plant units' systems and structures containing radioactive substances will be dismantled so that radiation monitoring will no longer be needed. The radioactive dismantling waste will be disposed of in facilities constructed in connection to the on-site final disposal facility for power plant waste. According to the plan, the reactor pressure vessels will be placed in the final disposal facility without dismantling them.

Conclusions

STUK has issued a statement on the Olkiluoto nuclear power plant's decommissioning plan to the Ministry of Economic Affairs and Employment (2/C48401/2014, 28.4.2015). According to the statement, the decommissioning plan is sufficiently detailed and comprehensive. The plan meets the decommissioning requirements laid down in Section 17 of Regulation STUK Y/1/2016.

10 Nuclear safeguards (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 his 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.

Pursuant to Section 118 b of the Nuclear Energy Decree, the planning, construction and operation of a nuclear facility shall be implemented so that the obligations concerning nuclear safeguards, as provided and defined in the Nuclear Energy Act and provisions issued thereunder, and in the Euratom Treaty and provisions issued thereunder, are met. A nuclear facility or another location where nuclear energy is used shall not contain premises, materials or functions, relevant to the nuclear safeguards, which are not included in the design information. The licensee shall have an accounting and reporting system for nuclear materials and other nuclear use items 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. 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 have been appropriate.

Transfers of spent nuclear fuel to Posiva will begin during the upcoming operating licence period (in 2024). The details of these activities will be processed before commencing the transfer, at which point STUK will assess the sufficiency of the plans with regard to nuclear safeguards and other requirements.

In STUK's assessment, the nuclear safeguards required to prevent the proliferation of nuclear weapons are up to date and sufficient at the Olkiluoto nuclear power plant.

11 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 current operating licence of the Olkiluoto 1 and 2 nuclear power plant units will be examined. The chapter also describes the international peer reviews conducted at the Olkiluoto 1 and 2 nuclear power plant units during the operating licence period.

11.1 The licensee's financial prerequisites for the operations

In order to receive an operating, 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 preparing for the costs of nuclear waste management, for example, (for technical aspects related to the matter, see Chapter 9) and fulfilling the nuclear liability (Chapter 11.2). 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 always the first goal in safety planning.

The electrical market is currently in a state of change, so STUK will continue to keep a close eye on the developments to ensure that, in the context of any possible larger structural changes, the safety aspects are taken into account in accordance with Section 20 of the Nuclear Energy Act, STUK's regulations and the YVL Guides.

On an annual level, STUK monitors the amount of investments in nuclear power plant maintenance and the variation in them in present currency. In recent years, the investments have been close to the average between 1981 and 2017. The largest individual plant modification project during the current assessment period was the update of the emergency diesel generators, which is still on-going. Other sizeable investments have included the modernisation of the main circulation pumps and their frequency converters, and the construction of an remote shutdown station.

11.2 International agreements

International agreements in STUK's sphere of operations includes 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 57/02.03.16/2013, 19 December 2013 (STUK case 1/C41801/2016), 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.

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.

11.3 Fulfilment of the conditions connected to the facility's current operating licence

By decision 31/812/96, the Government granted Teollisuuden Voima Oy (Teollisuuden Voima Oyj as of 1 January 2008) an operating licence for the Olkiluoto nuclear power plant on 20 August 1998. The operating licence for the Olkiluoto 1 and 2 nuclear power plant units and the buildings required for the nuclear fuel management and nuclear waste management arrangements included in their operations will remain valid until 31 December 2018. The operating licence specifies the rated thermal output of the Olkiluoto 1 and 2 nuclear power plant units to be 2,500 MW. The operating licence presents the following conditions for the licence.

1. *Under the licence granted with this decision, the licensee may possess, produce, handle, use and store nuclear waste and nuclear materials as well as other nuclear use items as follows:*

    1.1. *280 tU of spent nuclear fuel generated by the operation of the Olkiluoto nuclear power plant at the Olkiluoto 1 plant unit, 450 tU at the Olkiluoto 2 plant unit and 1,800 tU in the interim storage for spent nuclear fuel. Increasing the capacity of the spent fuel interim storage to 1,800 tU requires for STUK to approve the increase of the storage capacity in accordance with Section 112 of the Nuclear Energy Decree.*

    1.2. *400 m^3 of power plant waste generated by the operation of the Olkiluoto nuclear power plant at the Olkiluoto 1 and 2 nuclear power plant units, respectively, 5,000 m^3 in the interim storage for intermediate-level waste and 3,000 m^3 in the interim storage for low-level waste. Increasing the capacity of the interim storages for intermediate- and low-level waste to the proposed levels requires for STUK to approve the increase of the storage capacity in accordance with Section 112 of the Nuclear Energy Decree.*

    1.3. *The operation of the Olkiluoto nuclear power plant requires fresh nuclear fuel, which has been imported in accordance with the provisions of the Nuclear Energy Act and Nuclear Energy Decree.*

    1.4. *Other nuclear commodities are required in the operation of the Olkiluoto nuclear power plant as follows: materials, components and equipment that are already at the plant site and nuclear materials that are referred to in Section*

2(1)(4) of the Nuclear Energy Act, which have been imported in accordance with the provisions of the Nuclear Energy Act and the Nuclear Energy Decree.

2. *The licensee must conduct a comprehensive interim assessment of safety at the Olkiluoto nuclear power plant by the end of 2008. STUK will issue more specific regulations on the content of the assessment in a separate decision.*

The Olkiluoto power plant holds, handles, uses and stores only spent nuclear fuel generated by the facility' s own operations. All of the spent nuclear fuel produced at the nuclear power plant during the operating licence period will be kept at the Olkiluoto 1 and 2 nuclear power plant units or stored in the storage for spent nuclear fuel. The amount of spent nuclear fuel at the plant site has remained below the limit values set in the operating licence terms for the entire duration of the operating licence period. At the end of 2016, the Olkiluoto 1 power plant unit held 187 tonnes of uranium, the Olkiluoto 2 unit held 187 tonnes of uranium and the spent nuclear fuel storage held 1,220 of uranium.

During the current operating licence period, the spent nuclear fuel storage at the Olkiluoto nuclear power plant was expanded by constructing three additional pools. STUK approved the increase of the storage capacity to 1,800 tonnes of uranium in 2015 (2/E42242/2013, 23 June 2015). STUK's decision applied to the storage of spent nuclear fuel generated at the Olkiluoto 1 and 2 nuclear power plant units. The storage of the spent fuel generated by the operation of the Olkiluoto 3 power plant unit in the spent nuclear fuel storage will be processed separately at a later time.

The Olkiluoto power plant also holds, handles, uses and stores only operational waste generated by the facility' s own operations. The amount of operational waste in the plant units and storages has remained below the limit values set in the operating licence terms for the entire duration of the operating licence period. Since 1998, the maximum waste volumes have been 161 m^3 at the Olkiluoto 1 nuclear power plant unit, 207 m^3 at the Olkiluoto 2 nuclear power plant unit, 176 m^3 in the interim storage for intermediate-level waste and 1,040 m^3 in the interim storage for low-level waste. Some of the waste created at the plant is placed in the repository for power plant waste for final disposal, at which point the waste is governed by the operating licence terms of the repository. The operating licence for the repository will remain valid until 31 December 2051.

The Olkiluoto power plant main holds, handles and stores only fresh fuel required for the facility' s own operations. The provisions of the Nuclear Energy Act and Nuclear Energy Decree have been observed in the import of all nuclear materials, devices and equipment at the plant site.

In accordance with licence term 2, TVO conducted the periodic safety review by the end of 2008 during the current operating licence period. TVO submitted the related documentation to STUK on 30 December 2008. STUK approved TVO's periodic safety review and appended the decision with its own safety assessment (C213/55, 28 October 2009). STUK stated in its decision that the state of safety at the nuclear power plants is sufficiently good and that the licensee has sufficient arrangements in place to continue safe operation.

In summary, it can be stated that the Olkiluoto nuclear power plant has fulfilled the licence terms specified in the current operating licence.

11.4 International peer reviews

In the current operating licence period, TVO's operations have been assessed by means of several peer reviews. For example, international peer reviews at Olkiluoto have been conducted by WANO's (World Association of Nuclear Operators*) experts* and IAEA's (International Atomic Energy Agency) expert group (Operational Safety Review Team, OSART).

The purpose of WANO's peer reviews is to help nuclear power companies to utilise the best practices in the field. WANO's peer reviews have been carried out at Olkiluoto in 2006, 2012 and 2016. In the interim years, WANO has conducted monitoring inspections.

The OSART reviews conducted by IAEA assess programmes and measures that are essential to the operational safety of nuclear power plants. The OSART reviews assess safety objectively based on IAEA's safety standards and, if necessary, issue suggestions for improving operational safety. A 17-day OSART review on the Olkiluoto 1 and 2 nuclear power plant units was performed in Olkiluoto in 2017. According to the international group of experts, the Olkiluoto nuclear power plant is strongly committed to safety. In addition to many good practices, the group identified needs for improvement and presented a host of recommendations for improving operational safety in its report. Among other areas, TVO's maintenance practices should be developed. TVO should also assess the efficiency of the recent organisational changes and ensure sufficient resources for safe plant operation even after the designed service life.

In order to take the recommendations presented in the peer reviews into account, TVO has established a project aimed at ensuring the development plans are prepared, development measures are monitored, preparations are made for follow-up inspections and the inspections are completed.

12 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 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.

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 Trade and Industry 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 periodic safety review for the operating licence the Olkiluoto 1 and 2 nuclear power plant units.

As regards Sections 20(1)(1-3) of the Nuclear Energy Act, the arrangements of the Olkiluoto 1 and 2 nuclear power plant units and of the buildings and storages belonging to them 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 supervisory work has not revealed any issues that would keep the licensee and the Olkiluoto 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 the Olkiluoto nuclear power plant meets the safety requirements, the security arrangements and emergency response arrangements are sufficient, and the control necessary to ensure to non-proliferation of nuclear weapons has been organised appropriately, with due consideration to the safety-related aspects presented in this safety assessment. STUK further states that the nuclear facility operator's liability for nuclear damage has been arranged according to the relevant regulations.

12.1 Safety-related development targets at the plant

STUK has assessed the safety of the Olkiluoto nuclear power plant against the STUK regulations brought into force in 2016. These include STUK's regulations on the safety of a nuclear power plant, emergency arrangements of a nuclear power plant, security in the use of nuclear energy and safety of disposal of nuclear waste. The safety regulation (STUK Y/1/2016) takes into account that operating plants do not need to meet all requirements laid down for new plants (STUK Y/1/2016, Section 27, Transitional provision). In accordance with the principles set forth in Section 7 a of the Nuclear Energy Act, the safety of nuclear energy use must be maintained at as high a level as practically possible. For the further development of safety, measures shall be implemented that can be considered justified considering operating experience, safety research and advances in science and technology.

The design bases applicable to the Olkiluoto 1 and 2 nuclear power plant units have been primarily laid down in the 1970s. The goal for the operating period of the plant has been to ensure the continuous improvement of plant safety. During the plant's operating history, TVO has updated the Olkiluoto 1 and 2 nuclear power plant units to a significant degree and carried out extensive modifications on the plant systems, structures and components to improve safety. This chapter presents a summary of the TVO's planned or on-going development projects to further improve plant safety, as mentioned in the safety review.

<u>Ageing management</u>

Pressure equipment subject to registration under the Finnish pressure equipment legislation must be subjected to a pressure test at no less than eight-year intervals using a pressure that is 1.3 times the highest allowed operating pressure. At the Olkiluoto 1 and 2 nuclear power plant units, the primary circuit's periodic pressure test has not been performed after the commissioning of the plant units. By STUK's decisions, periodic pressure tests have been replaced with tightness tests (1.02 x operating pressure) conducted at 8-year intervals, which is permitted by ASME XI for reactor plants planned and inspected in accordance with ASME requirements. When the pressure test was originally replaced with a tightness test compliant with ASME XI, it was not known that the service life of the plant units would be longer than the 40 years presumed in the ASME version effective at the time. For this reason, STUK has, based on its own periodic safety review, required that the periodic primary circuit tightness test prescribed by the current procedure must be replaced with a periodic pressure test conducted every eight year at the maximum allowable operating pressure. The purpose of the pressure test is to demonstrate through tests that the known or any possible latent ageing mechanisms have not weakened the integrity of the primary circuit once the plant units have reached their original design life span. The first pressure tests on the Olkiluoto 2 nuclear power plant must be conducted in 2019 and the first tests on the Olkiluoto 1 unit must be performed in 2020. TVO must submit the pressure test to STUK for information before the first pressure test, and STUK will monitor the performance of the pressure test as part of its control activities.

Development measures implemented due to the Fukushima incident

In order to ensure reactor water supply in accident situations, the following solutions will be implemented alongside the auxiliary feedwater systems: a high-pressure make-up water system that is independent of electrical power supply and is driven by the reactor's steam pressure, and a low-pressure make-up water system that feeds water into the reactor with the help of fire water pumps. The make-up water systems are planned to be commissioned at both plant units in 2018.

In case of seawater system failure, the reactor auxiliary feedwater system's dependence on seawater cooling will be reduced significantly by leading the system's circulation line back to the demineralised water reservoirs. The modification has already been implemented at the Olkiluoto 1 nuclear power plant unit and it is estimated to be completed at the Olkiluoto 2 unit between 2018 and 2019.

STUK controls the implementation of the plant modifications by reviewing plans and monitoring the manufacture, installation and commissioning of components.

Other on-going modernisation projects to improve the safety of the plant site

Even before the Fukushima incident, a project had been initiated to update the emergency diesel generators. In addition to the seawater cooling capability that was used before, the new generators will provide the opportunity for air cooling. This change will improve the reliability of power supply to safety systems in the content of a possible seawater system blockage due to external events. The intention is to commission the new emergency diesel generators between 2018 and 2022.

In conjunction with updating the reactor's main circulation pumps, a sufficient amount of inertia is added to their shaft. This ensures that the pump speed is reduced passively in the event of scram or power loss and the previous electrically connected and separate flywheels will no longer be required to ensure fuel integrity in the context of these transients. The main circulation pumps of the Olkiluoto 2 nuclear power plant unit were modernised in 2017. One new pump has been installed at the Olkiluoto 1 unit in 2016, and the rest of the pumps will be updated in 2018.

An alternative float chamber-based trip that meets the diversity principle has been designed for the essential function of reactor water level measurement. According to the schedule presented by TVO, the modification is intended to be implemented between 2019 and 2021. STUK finds it highly important that the planned alternative trip solution that meets the diversity principle is installed at the plant units in recent years. The activation of the reactor scram and emergency cooling when the reactor water level drops is one of the most important safety functions of the plant units.

Another possible route for decay heat removal into seawater will be implemented so that filtered containment blowdown into the atmosphere is not required outside full seawater loss. Heat is transferred with the existing systems, and the purpose of the modification work is to increase the capacity of the heat transfer chain. The modification is planned to be completed in 2019.

STUK controls the implementation of the plant modifications by reviewing plans and monitoring the manufacture, installation and commissioning of components.

Improving the reliability of the protection I&C system

In accordance with the principle of continuous improvement, TVO has significantly reduced the risk of core damage and large release at the Olkiluoto 1 and 2 nuclear power plant units over the course of the operating licence period. However, among the risk reduction opportunities, the share of a common cause failure in the protection I&C system's terminal, which is currently about 8% of the total core damage frequency, remains to be examined. Furthermore, in addition to possible component updates to the protection I&C system, TVO has not presented other plans to improve the reliability of the system during the upcoming operating licence period. STUK requires the possibility of reducing this risk to be investigated in more detail.

TVO must analyse the significance of common cause failure in the reactor protection system's terminal relays from the perspective of the reliability of the safety functions and the core damage frequency and use these analyses to determine the necessary measures to reduce the core damage risks caused by the aforementioned common cause failures. The results of the analyses and assessments must be submitted to STUK for information no later than 31 March 2019. A plan on the measures necessary to reduce the risk must be delivered to STUK for approval by 31 December 2020.

Procedures for disturbances and emergencies

The disturbance and emergency procedures are updated continuously based on operating experience, analyses conducted, plant modifications and feedback from work shifts. The updated procedures are delivered to STUK for information in accordance with Guide YVL A.6. TVO will continue the development of disturbance and emergency instructions between 2017 and 2019. The development targets identified by TVO include improving the consideration of the loss of the final heat sink or AC power, outage state events and risk significance of operator measures in the procedures. STUK will monitor the progress of the procedure development measures as part of its operational control activities.

Operating experience feedback

In its own periodic safety review, TVO presents the most important achievements and lessons learned during the assessment period as a result of the internal and external operating experience activities. TVO's proposal is a list of plant modifications implemented based on individual events. This is a narrow view of the matter As a result, TVO has identified the development need and initiated work to develop the monitoring and assessment procedures pertaining to the effects of operating experience activities. Resources have also been assigned for the task. Through its inspection efforts, STUK ensures that TVO completes the initiated development work and can continue to perform more comprehensive analyses on the efficacy of the operating experience activities and improvement needs.

TVO is also in the process of establishing and developing procedures created due to updated official requirements (Guide YVL A.10). STUK is monitoring the progress of the work as part of its inspection activities. In order ensure the continuous improvement of operations, TVO has also initiated projects to develop the processing of observations and improve the efficiency of implementing measures defined based on operational events. STUK monitors the progress of initiated measures through its inspection programme and other control activities.

Technical Specifications

In conjunction with the periodic safety review of the Olkiluoto 1 and 2 nuclear power plant units conducted in 2008, TVO initiated a development project on the requirement and justification values, with the core aim of clarifying the requirements and justifications. A further aim was to clarify the justification section to make the interpretations of the requirements more unambiguous. The requirement section was divided into clearer parts and specified where necessary. The development project was completed in the autumn of 2017. TVO has planned to continue the TechSpecs development work by reviewing the chapter on the periodic systems of TechSpecs systems in detail. The purpose of the development work is to ensure the content and timeliness of the periodic tests and the correctness of the test criteria. STUK monitors the development of the TechSpecs as parts of continuous control activities.

Security arrangements

STUK has prepared updated YVL Guides for TVO as well as implementing decision concerning the design basis threat. The current design basis threat is was not the original design basis for the Olkiluoto 1 and 2 nuclear power plant units. The improvement measures suggested by TVO or required by STUK will be monitored based on the design basis threat and the implementing decision of Guide YVL A.11. The practical implementation of the security arrangements is also otherwise developed i accordance with technological developments, for example. Measures, such as the modernisation of access control, are under way. STUK monitors the implementation of the measures through its Periodic Inspection Programme and other regulatory control efforts.

Storage of spent nuclear fuel

In the action plan to develop plant safety that it delivered in conjunction with the periodic safety review, TVO identified several measures related to the KPA storage which are intended as preparation for the increasing volume of stored fuel generated by the continued operation of the Olkiluoto 1 and 2 nuclear power plant units and, at a later time, by the need to store spent nuclear fuel from the Olkiluoto 3 nuclear power plant unit. According to current estimates, the maximum capacity of the decay heat removal systems of the KPA storage will be reached in 2026. TVO also intends to update the radiation measurement systems of the KPA storage in 2019–2020. STUK will monitor the progress of the measures as part of its control activities.

Management, organisation and safety culture

In 2015, TVO carried out an organisational change in which the TVO organisation was divided into business units and service functions. TVO has exhibited significant problems related to work atmosphere in recent years and the staff turnover has increased from previous years. Staff motivation and competence are essential in maintaining a good safety culture. TVO's work atmosphere issues and the high staff turnover in recent years at the same as the commissioning of the Olkiluoto 3 nuclear power plant unit present a challenge for high-quality and safety-informed work. Due to the challenges with work atmosphere, TVO has initiated extensive programmes aiming towards a strong safety culture, good work atmosphere and management. In 2017 and 2018, STUK has carried out intensified monitoring on the implementation and efficacy of the TVO's measures.

The implementation of development measures related to management, safety culture as well as staff resourcing and competence must be continued, and STUK will monitor their effectiveness as part of their control efforts. Based on its own periodic safety review, STUK has required TVO to provide periodic reporting on the development of the safety culture and work atmosphere. By the end of January each year, TVO must deliver to STUK for information a report on the effectiveness of the most important measures implemented to develop safety culture, work atmosphere competence and resource availability. The report must also contain an assessment from TVO's management on the current situation, the most important needs for change and development determined based on the assessment, and the resulting concrete development measures. The deadline for the first report is 31 January 2019. The annual report must be submitted to STUK for information regularly until STUK deems that the positive development of the work atmosphere and safety culture at TVO has been established as the norm.

12.2 TVO's action plan to improve plant safety

Based on its periodic safety review, TVO has presented an action plan to improve safety. Safety-related development targets include the following:

- further development of the management system and safety culture,
- completing the project to survey competence within the TVO Group,
- completing the on-going projects to improve safety (e.g. updating the emergency diesel generators, updating the main circulation pumps and their frequency converters, feeding of high- and low-pressure water into the reactor, applying the diversity principle to the reactor level measurement trips and decay heat removal, modifying the auxiliary feedwater system's circulation line as well as projects and spare parts changes in accordance with the ELMA programme),
- developing the classification document,
- updating the condensers,
- developing safety arrangements and
- planning and implementing plant modifications concerning the KPA storage.

STUK monitors the progress of the development measures and modification as part of its control activities.

12.3 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 Olkiluoto1 and 2 nuclear power plant units and the included buildings and storages required for the management of nuclear fuel and nuclear waste are met.

In connection with preparing this safety assessment, STUK has found that the matters and arrangements referred to in Section 20(2)(1) of the Nuclear Energy Act are in order, with the specifications presented in this safety assessment.

In summary with regard to the inspections and reviews of matters and documents related to the periodic safety review and the results of continuous monitoring, STUK states that TVO has ensured the safety of the Olkiluoto 1 and 2 nuclear power plant units in accordance with the effective provisions, for the parts that are applicable to operating facilities. TVO has presented measures to improve safety at the Olkiluoto 1 and 2 nuclear power plant units during the upcoming operating licence period. In STUK's assessment, the licensee has the required capabilities, procedures, competence and resources to continue safe operation. STUK will monitor the timely and compliant implementation of TVO's safety-improving methods.

TVO has prepared its own periodic safety review on the safety of the Olkiluoto 1 and 2 nuclear power plant units and the storage facilities for spent fuel, intermediate-level waste and low-level waste, and on possible development targets and continued safety in accordance with Guide YVL A.1.