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Safety assessment of Olkiluoto NPP units 1 and 2

Decision of the Radiation and Nuclear Safety Authority regarding the periodic safety review of the Olkiluoto NPP

Säteilyturvakeskus
Strålsäkerhetscentralen
Radiation and Nuclear Safety Authority

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Executive summary

In this safety assessment the Radiation and Nuclear Safety Authority (STUK) has evaluated the safety of the Olkiluoto Nuclear Power Plant units 1 and 2 in connection with the periodic safety review. This safety assessment provides a summary of the reviews, inspections and continuous oversight carried out by STUK.

The issues addressed in the assessment and the related evaluation criteria are set forth in the nuclear energy and radiation safety legislation and the regulations issued thereunder. The provisions of the Nuclear Energy Act concerning the safe use of nuclear energy, security and emergency preparedness arrangements, and waste management are specified in more detail in the Government Decrees and Regulatory Guides issued by STUK.

Based on the assessment, STUK consideres that the Olkiluoto Nuclear Power Plant units 1 and 2 meet the set safety requirements for operational nuclear power plants, the emergency preparedness arrangements are sufficient and the necessary control to prevent the proliferation of nuclear weapons has been appropriately arranged. The physical protection of the Olkiluoto nuclear power plant is not yet completely in compliance with the requirements of Government Decree 734/2008, which came into force in December 2008. Further requirements concerning this issue based also on the principle of continuous improvement were included in the decision relating to the periodic safety review.

The safety of the Olkiluoto nuclear power plant was assessed in compliance with the Government Decree on the Safety of Nuclear Power Plants (733/2008), which came into force in 2008. The decree notes that existing nuclear power plants need not meet all the requirements set out for new plants. Most of the design bases pertaining to the Olkiluoto 1 and 2 nuclear power plant units were set in the 1970s. Substantial modernisations have been carried out at the Olkiluoto 1 and 2 nuclear power plant units since their commissioning to improve safety. This is in line with the principle of continuous improvement of safety provided in section 7 a of the Nuclear Energy Act.The safety of the plant will be further improved during the current operating licence period. Based on the periodic safety review, TVO has submitted to STUK action plans for the observed points requiring improvement. STUK included also some additional requirements in the decision relating to the periodic safety review. Action plans and additional requirements were for example related to diversification of the safety related systems, development of the lifecycle management of electronic and I&C equipment qualified for demanding conditions and ensuring the competence of personnel.

As a summary of the review of the issues and documentation pertaining to the periodic safety review and the continuous oversight results, STUK notes that the safety of the Olkiluoto nuclear power plant units 1 and 2 is sufficient and the licensee utilises the necessary arrangements to continue the safe operation of the plants.

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(continued)

1 Introduction

The Government has granted Teollisuuden Voima Oy (from 1 January 2008 Teollisuuden Voima Oyj) a licence for operating the Olkiluoto 1 and 2 nuclear power plant units to generate electricity and for utilising the interim storage for spent fuel, interim storage for intermediate-level waste and storage for low-level waste, located at the plant site and forming part of the operations in Olkiluoto, for intermediate storage of waste generated by the operation of the Olkiluoto power plant until 31 December 2018. According to licence condition 2, the licensee must carry out a safety review covering the Olkiluoto NPP by the end of 2008.

According to section 7 e of the Nuclear Energy Act (990/1987), *"the overall safety of the facility shall be assessed at regular intervals"*. If the operating licence for the nuclear power plant has been granted for a period substantially longer than ten years, the Radiation and Nuclear Safety Authority (STUK) requires, in line with guideline YVL 1.1, the licensee to carry out a periodic safety review of the plant and seek the approval of STUK for it approximately ten years after the operating licence was granted or the previous periodic safety review was carried out. The equivalent safety reports as required for renewal of the operating licence are also submitted to STUK for the separate periodic safety review.

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

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

According to section 36 of the Nuclear Energy Decree, *"When the application for an operating licence is made for a nuclear facility that has already been in operation, the documents mentioned in subsection 1 need be submitted to STUK only to the extent that they have not been submitted before. In addition, the applicant must provide STUK with any other information considered necessary by the Radiation and Nuclear Safety Authority."*

The documents referred to in section 36 of the Nuclear Energy Decree must be continuously updated, and the updated versions must be regularly submitted to STUK. According to Guide YVL 1.1, when applying for renewal of the operating licence (or in case of a periodic safety review), the documents may be submitted to STUK only insofar as they have been amended since the previous updates. The licensee must also submit a periodic safety review of its own concerning the safety status of the nuclear facility, potential areas of development and maintenance of the safety. According to Guide YVL 1.1, this review must include:

- *a report on fulfilment of the requirements laid down in Government Decisions 395–397/1991* [currently, Government Decrees 733–735/2008] *and in the relevant YVL Guides*
- *a summary of the renewed safety analyses and conclusions drawn from their results*
- *experience of the facility ageing and ageing management*
- *a description of the licensee's safety culture and safety management*
- *a report on the actions required in section 27 of Government Decision 395/1991* [operating experience and safety research, section 24 of Government Decree 733/2008] *and on the consequent plant improvements*
- *a report on compliance with any terms of the operating licence*
- *a summary of fulfilment of the requirements laid down in section 20 of the Nuclear Energy Act.*

The International Atomic Energy Agency (IAEA) has published the safety guide NS-G-2.10, "Periodic Safety Review of Nuclear Power Plants", 2003, concerning periodic safety reviews. The guide lists the following 14 safety factors that are assessed in the safety review:

- plant design
- physical condition of the nuclear power plant
- qualification of equipment and structures
- ageing management
- deterministic safety analyses
- probabilistic safety analyses
- protection against external and internal hazards
- plant operating experience in terms of safety
- operating experience obtained from other plants and safety research findings
- organisation and administration
- plant procedures
- factors contributing to the work performance of people
- emergency planning
- radiological impact on the environment.

According to Guide YVL 1.1, *In making its own periodic safety review, the licensee shall verify that the safety factors proposed in the IAEA's guide [17]* [NS-G-2.10, "Periodic Safety Review of Nuclear Power Plants", 2003] *have been taken into account to a sufficient degree in the safety review and other licence application documents.*

Teollisuuden Voima Oyj (TVO) submitted the documentation related to the periodic safety review to STUK by letter 0-7/3/33 dated 30 December 2008 (Record No. C213/55) and asked STUK to approve it as a safety review referred to in licence condition 2 and Guide YVL 1.1. The submitted reports include a summary memorandum and ten appendices containing the documents required in Guide YVL 1.1. TVO updated and supplemented the documentation during the spring and summer 2009 in line with STUK's requests for further clarifications (STUK decisions C213/57 dated 27 February 2009 and C213/59 dated 1 April 2009 as well as further clarifications by TVO, submitted in letters C213/60, C213/61, C213/63 and 1/C42213/2009).

In compliance with Guide YVL 1.1, STUK makes an approval decision regarding the periodic safety review required of the licensee and appends its own safety assessment to it. The safety assessment is a summary of the inspections carried out by STUK on matters and documents related to the periodic safety review as well as of the results of continuous regulatory oversight.

1.1 Safety-related regulations

Sections 5 to 7 of the Nuclear Energy Act contain the following safety provisions:

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

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

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

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

This safety assessment covers all the aspects of the operation of the Olkiluoto 1 and 2 nuclear power plant units that fall within STUK's mandate. The issues to be addressed in the Safety Assessment and the related evaluation criteria are set out in the nuclear and radiation safety legislation and the regulations issued thereunder. In conjunction with the reform of the Nuclear Energy Act in 2008, more detailed safety-related requirements were added to sections 7 a–p of the Act. The provisions of the Nuclear Energy Act concerning the safe use of nuclear energy, physical protection and emergency preparedness arrangements, and waste management are specified in more detail in the Government Decrees applicable to each field of activity and issued under section 7 q of the Nuclear Energy Act. The decrees concern:

- the safety of nuclear power plants (733/2008);
- physical protection regarding the use of nuclear energy (734/2008);
- emergency planning for nuclear power plants (735/2008);
- safety of final disposal of nuclear waste (736/2008).

In the spring of 2006, the Ministry of Employment and the Economy (formerly the Ministry of Trade and Industry) initiated a project for revising the nuclear energy legislation in cooperation with STUK. The objective of and assignment for the project was to amend the nuclear energy legislation so that it fulfils the requirements laid down in the Finnish Constitution reformed in 2000. In particular, the regulation level of certain regulations relating to nuclear safety and the authorisation provisions of the Nuclear Energy Act were under consideration. The regulations relating to the export and import of nuclear products and goods and the decommissioning of nuclear facilities were reviewed and supplemented as required in the course of the project. The legislation was also technically updated in other relevant respects. The Government proposals to amend the Nuclear Energy Act, as well as the Government decrees on the amendment of the Nuclear Energy Decree and on the safety of a nuclear power plant, physical protection concerning the use of nuclear energy, emergency preparedness arrangements at nuclear power plants and the safety of the disposal of nuclear waste, entered into force in 2008. The assessment regarding the periodic safety review of the Olkiluoto 1 and 2 NPP units must be carried out on the basis of the currently valid legislation.

According to the transitional provision of section 32 of the Government decree 733/2008, *The following shall not be applicable to a nuclear power plant for which an operating licence was issued prior to entry of this Decree: section 10(2-4), paragraph 3 of section 13(3), section 14, section 17 and section 19(3), unless their applicability is justified with respect to the technical solutions of the nuclear power plant in question, under the principle laid down in section 7 of the Nuclear Eneregy Act.* The fulfilment of these provisions is assessed in sections 3.4, 4.3.4, 4.4, 4.6 and 4.8 of this safety review.

Pursuant to section 55, paragraph 2, point 3 of the Nuclear Energy Act, STUK specifies the more detailed safety requirements concerning the implementation of safety level stipulated in the Nuclear Energy Act and publishes them in its regulatory database (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 procedure or solution by which the safety level set forth is achieved.*

STUK continually evaluates the currency of nuclear safety regulations in relation to current international developments, particularly within the framework of the International Atomic Energy Association (IAEA) and the Western European Nuclear Regulators' Association (WENRA). The currency of the YVL guides is checked regularly at about five-year intervals. When updating the guides, STUK takes into account the advancement of nuclear and radiation safety technology and research as well as operating experience from Finland and abroad in a manner referred to in section 24 of the Government Decree 733/2008.

When preparing the YVL guides, one starting point is to attempt to continuously raise the level of safety. Consequently, when setting the safety targets specified in the guides, the highest level internationally achieved is considered the model to be followed. In some regards, the targeted level is that which is considered achievable, at least in new nuclear power plants. For this reason, it is not possible, or even feasible, to consider the new YVL guides as binding on nuclear power plants in operation in all respects.

For the purpose of clarifying the scope of applicability, a decision concerning nuclear facilities in operation or under construction is prepared for each new or revised YVL guide, defining the applicability of the guide with regard to nuclear facilities in operation or under construction. The measures to be taken by, for example, the licensee due to a guide are specified in implementation decisions. A guide does not change the decisions issued by STUK prior to the guide entering into force unless it is separately announced by STUK. On the other hand, STUK requires that the need and opportunities for increasing the level of safety are re-assessed on the basis of new YVL guides. Measures to increase safety may be required on the basis of the assessment when deemed justified. The systematic preparation of implementation decisions for YVL guides began in 2000.

The design bases concerning the structures, systems and components of the Olkiluoto 1 and 2 NPP units were mostly established during the 1970s. Although the plant units have been considerably modernised since the commissioning and modifications were implemented in several systems to improve safety, the plant does not quite meet the requirements of the currently valid YVL guides in all respects. The deviations from the YVL guides are discussed under the respective sections of Government resolutions concerning the subject in question.

1.2 Structure of the safety assessment

In this safety assessment, the matters relating to nuclear safety are discussed in the same order as they are presented in Government Decree 733/2008. The matters pertaining to nuclear waste management are presented in a separate chapter. In addition, matters relating to Government Decrees 734/2008 (physical protection) and 735/2008 (emergency planning) are also discussed, as well as compliance with the terms of the plant's current operating licence. This safety assessment also discusses those preconditions laid down in section 20 of the Nuclear Energy Act that have not been separately included in the current Government decrees but the assessment of which nevertheless falls within STUK's mandate.

The relevant text from the Government decree is quoted at the beginning of each section in *italics*. Direct quotations from other regulations are likewise presented in italics. If necessary, a brief description of the practical applications of the requirements in the Government decrees and the more detailed criteria presented in the YVL guides is provided. Each section includes an evaluation of how the related requirements are implemented at the Olkiluoto 1 and 2 nuclear power plant units. Special attention will be paid to the question of whether *"…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, subsection 2, paragraph 1). A summary of the results of the review is presented at the end of the Safety Assessment.

2 General safety (Government Decree 733/2008)

2.1 Section 3: Assessment and verification of safety

The safety of a nuclear power plant shall be assessed when applying for a construction licence and operating licence, in connection with plant modifications, and at regular intervals during the operation of the plant.

Unless compliance with safety regulations can be directly verified on the basis of the nuclear power plant's design solution, compliance must be demonstrated. Nuclear power plant safety and the technical solutions of its safety systems shall be substantiated by using experimental and calculational methods. These include analyses of operational occurrences and accidents, strength analyses, failure mode and effect analyses, and probabilistic risk assessments. Analyses shall be maintained and revised if necessary, taking into account operating experience, the results of experimental research and the advancement of calculating methods.

The calculation methods employed for demonstrating compliance with safety regulations shall be reliable and well qualified for the purpose. They shall be applied so that the resulting system design bases meet the acceptance criteria with high certainty. Any uncertainty in the results shall be assessed and considered when defining safety margins.

2.1.1 Transient and accident analyses

Analyses are intended to prove the ability of the plant unit to safely overcome various transients and accidents. According to Guide YVL 2.2, the analyses shall focus on events that, by their nature and severity, cover various types of incidents and accidents as well as possible. The course of accidents shall be analysed as a function of time, starting from the initiating event and ending in a safe and stable state.

Accident analyses describing the operation of Olkiluoto 1 and 2 NPP units, as well as the analysis methods, have been updated and developed throughout the operation of the plant. TVO completely revised the accident analyses in conjunction with renewing its operating licence in 1995–1998 following the power upgrades and modernisation work carried out. The analyses were at that time carried out for nuclear fuel that is no longer being used at the NPP units. Consequently, TVO updated the accident analyses in conjunction with the periodic safety review, and they are based on the new fuel to be introduced to the plant, SVEA-96 Optima 2. The plant modifications carried out after the renewal of the operating licence were also taken into account in the update. The updated analyses use 50 MWd/kgU as the value for discharge burnup. The currently approved maximal bundle average of discharge burnup is 45 MWd/kgU.

The revised Guides YVL 2.2 and YVL 6.2 have entered into force since the operating licence was renewed. In these guides, the classification of initiating events has been amended so that the postulated accidents are divided into two categories on the basis of their frequency of occurrence. Guide YVL 6.2 sets specific acceptance criteria for events in both categories. The requirement regarding analyses of design extension conditions has been introduced as a new event category. When updating its analyses, TVO has taken into account the above regulatory amendments.

The calculation methods used for analysing the plant's normal operating condition, transients and postulated accidents were developed by the supplier of the plant unit. The methods have been qualified to an extent corresponding to a good level from the international perspective. Due to uncertainty relating to the accuracy of calculation methods, it is essential that sufficiently large safety margins be applied when assessing the fulfilment of the analysis acceptance criteria.

Chapter 9 of the Final Safety Analysis Report and its associated topical reports describe the analyses carried out and the analysis methods used. The analyses are divided into categories containing physically similar events (for example, events associated with an increase in reactor pressure or loss of coolant). In conjunction with the periodic safety review, TVO updated the topical reports describing the analysis methods for all categories. At least the analyses of events used as a basis for dimensioning were updated for each category.

STUK has reviewed the updated analyses and the calculation methods used. Analyses regarding the adequacy of the emergency cooling system were last updated in conjunction with the operating licence renewal. The analyses carried out at that time indicated that the Olkiluoto 1 and 2 NPP units have large safety margins in primary circuit leakage situations. The analyses have not been updated in this respect in conjunction with the periodic safety review. When renewing the operating licence, the assumption was made in analyses related to loss of coolant accidents that at least two emergency cooling system trains are always available in all situations to secure the cooling of the reactor. When reviewing the analyses updated in conjunction with the periodic safety review, STUK noticed that the above assumption is not in all situations compliant with Guide YVL 2.2. This is why TVO presented a plan where the analyses related to loss of coolant accidents are updated to comply with Guide YVL 2.2 by 31 December 2009.

The accident analyses assessing the operability of safety systems are discussed in more detail in section 4.3 in terms of reactor core and fuel, and in sections 3.3 and 3.4 in terms of radiation safety.

The conclusion is that the review of safety of the Olkiluoto 1 and 2 NPP units has, with regard to the analyses of transients and accidents, been implemented in the manner referred to in section 3 of Government Decree 733/2008. TVO will submit the loss of coolant accident analyses to STUK for inspection in line with the schedule discussed above.

2.1.2 Strength analyses

As a rule, strength analyses are carried out for pressure equipment in Safety Class 1 and presented in connection with the construction plans for such equipment. The purpose of these analyses is to demonstrate that the pressure component complies with the approval limits set by the applicable standard regarding different failure mechanisms in loading situations used as the design basis.

The original strength analyses for the Olkiluoto 1 and 2 NPP units are primarily based on ASME Boiler and Pressure Vessel Code Section III, Division 1 which was also applied to the updates submitted for approval in conjunction with power upgrades and modernisation projects. The increased loads resulting from higher flow rates due to power upgrades and increased bleed capacity were also taken into account in the updates.

Guide YVL 3.5 published in 2005 set out further requirements regarding ASME III, and the implementation decision of the guide required TVO to assess its compliance with them. STUK found the reports on quality management regarding strength engineering and fulfilment of the strength engineering criteria for the new NPP to be acceptable. Quality management includes the qualification of calculation methods applied as well as ensuring the competence of the person carrying out the calculation and the adequacy of the input data. In the implementation of Guide YVL 3.5, the requirement regarding fatigue analyses remained an open question; it concerned taking into account the actual process conditions by applying fatigue test results representing them. Attempts have been made to describe this so-called ambient effect in fatigue analyses using safety coefficients required by the applicable standard, but the information currently available suggests that they are not sufficient for all transient situations.

STUK required that the question of taking the ambient effect into account in a more closely defined manner should be investigated in conjunction with the periodic safety review as a pilot project. TVO implemented the requested pilot project using VTT for expert consultancy. The F_{en} method according to the US guideline NUREG 1.207, so far only intended for licensing new NPPs, was applied to the selected objects, the main feedwater pipeline and certain associated auxiliary systems. STUK took the view that the document complied with the requirements set for periodic safety reviews in the implementation stage of Guide YVL 3.5. However, the documentation shows that the realistic modelling of ambient effects leads, in conjunction with a traditional pipeline fatigue analysis including several simplifications, to an outcome that does not comply with the approval limits of the applicable standard. In the periodic safety review submitted by TVO, a plan for updating the fatigue analyses to correspond to a service life of 60 years was presented. The ambient effects will be taken into account in conjunction with the update, but the analyses will also be further specified in other respects while ensuring that the approval limits are met. This specification work will make use of, among other things, the data on the actual progress of pressure and temperature transients, acquired through operating experience, as well as the actual material properties and geometry data established during manufacture and installation. TVO has collected this data during the current operating licence period into a pipeline database.

The conclusion is that the review of the safety of the Olkiluoto 1 and 2 NPP units has, with regard to the strength analyses, been implemented in the manner referred to in section 3 of Government Decree 733/2008. The analysis of fatigue induced by ambient conditions, carried out in deviation to Guide YVL 3.5, can be deemed sufficient for the remaining term of the operating licence period provided that the actions for updating the fatigue analyses, presented by TVO in conjunction with the periodic safety review, are initiated on schedule. STUK will monitor the work for updating the analyses in connection with its regulatory oversight.

2.1.3 Probabilistic risk analyses

In this connection, Probabilistic Risk Analyses (PRAs) refer to the probabilistic risk analyses complying with the requirements of section 3 of Government Decree 733/2008. PRAs are used for systematically analysing the occurrence of transients and the succession of safety functions required for stopping their progress, while taking into account the possibilities for faults and errors, as well as their probabilities, in each system. Event sequences describing accident propagation resulting in reactor core damage are analysed in the PRA, and the probability for their occurrence is estimated. The PRA can be used for identifying such dependencies between systems that may otherwise remain unnoticed.

The timing and probabilities of accident sequences resulting in reactor core damage are defined on level 1 of the PRA; the quantity, time and probability of the release of radioactive material into the environment is estimated on level 2 of the PRA.

In the PRA, an initiating event is a single event that causes a transient and requires the start of the plant safety functions. The initiating event can be an internal or external event. Internal initiating events are transients arising from component failures, loss of off-site power and human errors made by plant personnel. The initiating events also include floods occurring inside the plant due to ruptures in piping or pressure vessels causing a transient and loss of components important to safety, as well as initiating events in the form of fires that result in plant operational transients. External initiating events include transients caused by, among other things exceptional weather conditions, seismic phenomena and other factors stemming from the plant environment or human activity.

The PRA is used for plant safety management in the manner prescribed by YVL guides in, among other things, identifying the needs for plant modifications, assessing the technical specifications and targeting the in-service inspections of pipelines in a risk-informed manner.

Level 1 PRA – Most significant initiating events

The initiating events most significant for core damage frequency in the Olkiluoto 1 and 2 NPP units are loss of offsite power (47%), loss of feedwater (19%), loss of coolant accidents (11%) and loss of condensate system (10%). The initiating events may be caused by internal factors (such as fires and floods) or by external factors (such as weather phenomena or earthquakes). An initiating event may also occur when the plant is being brought to a scheduled shutdown for repairs or annual maintenance. The initiating events occurring in conjunction with scheduled shutdowns contribute 12% to the core damage frequency. The initiating events occurring in conjunction with annual maintenance outages have little effect on the core damage frequency (2%).

The most significant systems in loss of off-site power occurrences are the load reconnection system (system ID 684), DC systems (672 and 679), reactor level measurement system (211), reactor pro-

Table 1. Contributing shares of initiating events to the core damage frequency of 1.01E-05 /a (2008).

	Internal	Seismic	Fires	Floods	Weather	Missiles	Total
LOCAs (pipe ruptures)	11.0%						11.0%
Loss of feedwater	8.7%	1.1%	3.7%	0.6%	4.5%	0.0%	18.6%
Loss of offsite power	39.1%	0.3%	0.0%		7.0%	0.1%	46.6%
Loss of condensate system	9.9%						9.9%
Valve 314 remaining open*	0.4%						0.4%
Shutdown	11.7%		0.0%	0.0%	0.0%		11.8%
Outage	1.7%		0.1%				1.8%
Total	82.5%	1.5%	3.8%	0.6%	11.5%	0.2%	100.0%

*) if relief valve 314 remains open, the primary circuit coolant is lost.

tection system (516) and connection of emergency power from the neighbouring NPP unit (662).

The contributing shares of initiating events of the core damage frequency are shown in Table 1. As a result of plant modifications and more detailed analyses, the core damage frequency has decreased (1.4E-05 /a → 1.0E-05 /a) even though new risk factors have also been identified.

Level 1 PRA – Flood risks (internal flooding)

During the current operating licence period, TVO has developed and supplemented the analysis of flood risk at Olkiluoto 1 and 2 NPP units by, for example, modelling major flooding of seawater systems in the turbine hall and in the coolant water intake building. The most significant risk of flooding is caused by major leaks in the seawater system in case the seawater pumps are not stopped and the leak isolated quickly enough. During the current operating licence period, TVO implemented plant modifications that will ensure the quick detection of floods and shutdown of seawater pumps. The required procedures were also produced. After the plant modifications, the flood risks contribute about 0.6% to the core damage frequency.

Level 1 PRA – Fire risks

The work for updating the fire risk analysis for the Olkiluoto 1 and 2 NPP units began during the current operating licence period. TVO has drawn up a plan for updating the analysis. The plan pays special attention to the assessment of fire frequencies and risk analyses regarding the spread of fire in spaces accommodating cables and electrical equipment where two parallel safety systems have been located.

In cable spaces, the risk of fire spreading will be mitigated by the modifications in progress where the nozzles of the sprinkler system are replaced with new, faster operating nozzles. The efficiency of the fire extinguishing system will also be improved by revising the layout of the nozzles.

Level 1 PRA – Weather phenomena and other external events

The analyses indicate that the most significant external events include a storm with a simultaneous loss of off-site power, mussels breaking off the internal walls of the seawater tunnels, deposits of algae (blockage of seawater intake channels) as well as simultaneous high levels of seawater and ambient temperature.

The risks resulting from oil spillage accidents occurring at sea have not been assessed in conjunction with the PRA for the Olkiluoto 1 and 2 NPP units. Although there is little ship traffic near the plant, the PRA must include quantitative analyses that can be used as the basis for assessing the risk caused by oil and the adequacy of preparedness measures. TVO shall produce a plan for supplementing the PRA with an assessment of risk caused by oil spillage accidents.

During the operating licence period, a new potential risk to safety was identified: the impulse lines, important to safety, may freeze if the ventilation intake air heating fails when the outside temperature is well below freezing point. The risk of impulse lines freezing was substantially reduced through modifications to the plant and procedures.

Level 1 PRA – Earthquakes

Earthquakes were not taken into account in the original design of the Olkiluoto 1 and 2 NPP units. The earthquake risk analysis later carried out for the plant revealed certain flaws in the design – these were eliminated through plant modifications.

For example, certain safety critical electrical equipment was not sufficiently supported to withstand earthquake-induced loads. In addition, an earthquake may cause malfunctions in the control system relays that result in protection functions being unnecessarily activated. Examples of these include the unnecessary opening of pressure relief valves in the primary circuit and an unnecessary isolation of the containment that stops cooling of the reactor. The most significant plant modification during the current operating licence period was that the main control room was provided with capabilities to cancel unnecessary protection functions activated as a result of earthquakes. As a result of the plant modifications carried out, the risk caused by earthquakes is no longer significant.

Level 2 PRA

The level 2 PRA for the Olkiluoto 1 and 2 NPP units has been updated twice (in 2001 and 2003) during the current operating licence period. A new update of the level 2 PRA was scheduled to be released in conjunction with the other reports concerning the periodic safety review, but TVO was unable to complete it in time. However, since the current analyses are free of any essential flaws, the situation can be deemed satisfactory. The analysis covers the external and internal initiating events during both power operation and refuelling outages.

During the current operating licence period, TVO has, in the context of management of severe accidents, provided all working shifts with training on the flooding of the lower drywell and reinforced the access opening of the lower drywell for the eventuality of a steam explosion. These modification needs were identified in the level 2 PRA, and they have significantly reduced the frequency of major releases. In addition, modifications reducing the probability of severe accidents have been carried out, such as reducing the risk of dropping heavy loads during lifts taking place above the fuel pools or the reactor.

The most significant transient situation resulting in a major release (> 100 TBq Cesium-137) is one where the primary circuit pressure is successfully reduced but residual heat removal fails. Transients of this type account for 79% of accidents resulting in major releases. The second most significant sequence of events resulting in a major release is one where both the reduction of primary circuit pressure and residual heat removal fail. Transients of this type account for 13% of accidents resulting in major releases. The transient is most probably initiated by a loss of off-site power after which the connection of emergency generators fails as a result of a common cause failure in the DC battery banks.

The most significant event in accidents resulting in major releases is the loss of off-site power during power operation or a scheduled shutdown (approx. 85%).

Summary

PRA has been used for systematically identifying and eliminating risk factors during the current operating licence period. In order to ensure the availability of offsite power, a gas turbine plant has been built at the Olkiluoto plant site in conjunction with the Olkiluoto 3 plant project, and it also secures the power supply to the Olkiluoto 1 and 2 NPP units. In spite of this, the loss of off-site power remains the most significant initiating event from the perspective of risk. STUK required TVO to submit, in conjunction with the periodic safety review, a report of possibilities for reducing the risk caused by the loss of off-site power, as well as an action plan required for reducing this risk. In its reply, TVO presented the most significant risk factors, but not a plan for reducing them. In its decision C30-7/106 dated 30 April 2009, STUK required TVO to submit a plan regarding the diversification of systems that are important in situations of loss of off-site power, and TVO submitted this plan to STUK in September 2009.

The initiating events occurring in conjunction with scheduled shutdowns contribute significantly to the core damage frequency. This is why STUK required TVO to submit, in conjunction with the periodic safety review, a report of factors affecting the risk associated with shutdowns, as well as an action plan required for reducing this risk. In its reply, TVO presented that the shutdown analysis will be updated by the end of 2010, and the actions possibly required for reducing the risk will be assessed after this update.

The risk caused by oil spillage accidents has so far not been evaluated in conjunction with the PRA. TVO shall present a plan for assessing oil-related risks.

The open issues discussed above are part of the normal risk analysis updating process that includes the identification, assessment and possible elimination of risk factors. The conclusion is that TVO has justified the plant safety and safety engineering solutions in accordance with the requirements concerning probabilistic safety analyses presented in section 3 of Government Decree 733/2008.

2.2 Section 4: Safety classification

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.

Systems, structures and components important to safety shall be designed, manufactured, installed and used so that their quality level, and the assessments, inspections and tests, including environmental qualification, required to verify their quality level, are sufficient considering the safety significance of the item in question.

Detailed requirements relating to section 4 of the decree are set out in Guide YVL 2.1.

The purpose of safety classification is to ensure that the quality level complied with in the design, manufacture, installation, commissioning and operation of systems, structures and components important to safety, as well as required assessments, inspections and tests, are in correct proportion to the safety significance of the item. STUK uses the safety classification when defining its regulatory control activities.

The systems, structures and components have been classified into four safety classes: Safety Classes 1–4, as well as Class EYT (non-nuclear classification). The subjects most critical to safety are in Safety Class 1. Safety classification of the most important systems, structures and components at the Olkiluoto 1 and 2 NPP units is shown in the classification document, while the detailed component-specific classification is shown in the plant database. The safety classification is presented separately for mechanical and electrical components. The document regarding the classification of electrical components specifies the functions implemented by each system and the safety class of these functions, as well as the components or equipment groups participating in each function. The safety class (SC) of a component is determined on the basis of the SC of the most demanding of the functions that it participates in or that its failure can inhibit.

In 2005, TVO initiated a development programme for the classification document of the Olkiluoto 1 and 2 NPP units. The primary objective of the programme is to further specify the component classification and classification information contained in the plant database. The table of contents of the classification document has been totally revised, and the contents have been updated to better correspond to the requirements of Guide YVL 2.1. The work for further developing the classification document continues, and TVO intends to, among other things, supplement the component location-specific safety classification contained in the classification document and in the plant database before the automation renewal to be carried out at the plant unit. In conjunction with the classification document development project, TVO has announced the principal for supplementing the safety classification with component location-based safety classification in conjunction with major modifications.

The challenging task in planning automation renewal is that of documenting the defence in depth approach implemented at the Olkiluoto 1 and 2 NPP units. The objective is to identify and differentiate, in line with the defence in depth approach, the functions belonging to functional levels backing each other up as well as the I&C systems and components implementing them, and to ensure that the functional safety classification supports the defence in depth design approach.

The conclusion is that the safety classification at the Olkiluoto 1 and 2 NPP units has, in general, been implemented in the manner referred to in section 4 of Government Decree 733/2008. TVO's classification document development project will continue, and STUK will monitor its progress.

2.3 Section 5: Ageing management

The design and construction of a nuclear power plant shall include provision for the ageing of systems, structures and components important to safety. The condition of systems, structures and components shall be monitored to ensure that they retain their operability and conformity in design basis conditions. Their replacement by new or similar technology, as well as repairs and modifica-

tions, shall be carried out in a systematic manner.

According to Guide YVL 1.1, a nuclear power plant shall have an ageing management programme comprising the design and qualification of components and structures, their operation and operating experience, in-service inspections and periodic tests, and maintenance. The programme shall identify all significant ageing and wear mechanisms, and potential degradation owing to ageing. The periodic safety review shall assess the experience of the facility ageing and ageing management.

The ageing management related activities at the Olkiluoto NPP were prompted when intergranular stress corrosion cracking (IGSCC) was detected in the pipelines of auxiliary reactor systems after just a few years of service. This problem, common in boiling water reactors, was not sufficiently foreseen during the design stage even though the material specifications had been made more stringent. It was brought under control by introducing an extensive programme of early replacement of pipeline materials. The practice of maintaining the plants in an as new condition through actions eliminating the ageing effects of critical plant components was gradually established as a service life management strategy at TVO, and in 1991 TVO set up a Service Life Team to identify the future needs of major repairs, modifications, replacements and maintenance operations at the plant. Utilising the team's recommendations, an extensive modernisation project, planned using in-house resources, was implemented at the plant during 1994–1998. It involved a power upgrade of 16% for both plant units, and with regard to ageing management it created the right conditions for the current operating licence, which is valid until 2018. In conjunction with the modernisation project, the electrical and I&C systems were upgraded, and the systematic maintenance of design basis data was initiated.

During the same years, systematic maintenance planning (maintenance analysis process) was started at the plant. For that purpose, the plant was divided into component responsibility areas consisting of components of a similar type and/or installed in the same location. TVO appointed persons responsible for each area. A four-grade maintenance classification was specified for the components as the basis for maintenance operations that were decided on the basis of, among other things, the ageing phenomena in the components. A summary report is produced every year for the observations and actions in different component responsibility areas, and the report is sent to STUK for information.

Extensive modification works have continued at the Olkiluoto 1 and 2 NPP units during the current operating licence period. The general objective has been to improve the operability, reliability and performance of plant components as well as to ensure the availability of product support and spare parts from equipment suppliers. Examples of this work were the VT/KP, REMES, TARMO and KUIVAIN projects, where the reheaters, 6.6 kV switchgear, I&C equipment of the turbine plant and the reactor steam driers were replaced, respectively.

According to current procedures, the matters related to ageing management are processed at TVO by the Plant Meeting, Technical Meeting and Annual Maintenance Team. In the line organisation, the responsibility for preventive maintenance, also with regard to ageing, lies with different persons who work at the Power Plant Technology Department and are responsible for different areas of technology and equipment, respectively. In practice, the most significant role is that of the teams, some of which are defined in the organisation manual. The expert teams, established in different areas of technology, deal with matters related to ageing and report them to the IKÄ Team controlling these activities, as well as to the line organisation. An extensive network of plant suppliers, equipment manufacturers, research institutes and other utility companies is also available for support. In conjunction with its inspection of the periodic inspection programme, STUK has recommended that attention should be paid to the status and processes of the teams.

Olkiluoto's ageing management programme covers all systems at the plant. When determining the monitoring procedures, the factors taken into account include the requirements of YVL guides, safety class, maintenance class, PRA, known ageing phenomena, operating experience, replaceability, repairability and study results. The monitoring procedures include leak tests and monitoring during operation as well as periodic inspections and tests and preventive maintenance programmes. The contents of these activities regarding each area of technology are shown in operation and maintenance manuals. The monitoring procedures are annually reported to STUK through separate procedures in compliance with YVL guides.

During the current operating licence period, STUK has assessed the ageing management programme of the Olkiluoto 1 and 2 NPP units in several periodic inspections conducted at the plant site. They have dealt with the implementation of this programme and its targeting of individual plant components in different areas of technology. The technical observations have mainly concentrated on identifying ageing phenomena. This is particularly true in the areas of electrical and automation engineering. The assessment of the entire programme, carried out in 2005, highlighted the fact that in spite of its extent and good results, the ageing management programme appeared to consist of separate routines that had not been described as a single entity as required by the YVL guides and applicable international guidelines. Consequently, TVO supplemented its procedures and produced a report of its activities as part of the periodic safety review.

Mechanical engineering

STUK's detailed requirements relating to the ageing of mechanical equipment are specified in Guides YVL 3.0, YVL 3.5, YVL 3.8 and YVL 3.9.

The mechanical components monitoring procedures at the Olkiluoto 1 and 2 NPP units include temperature, pressure, flow rate and vibration measurements, water sampling for chemical analyses as well as a monitoring programme for the reactor pressure vessel. Periodic tests are carried out for valves and their actuators, safety valves, pumps and heat exchangers. The pressure equipment monitoring procedures, important from the point of service life, include periodic inspections, particularly inspections using non-destructive methods and erosion corrosion inspections carried out in line with Guide YVL 3.8, as well as the monitoring of pressure and temperature transients. Non-destructive inspection programmes have been extended because of IGSCC and thermally-induced fatigue, and this programme is currently being revised to make it risk-informed. The foreseeable damage mechanisms are systematically analysed, and the inspection methods are qualified in compliance with Guide YVL 3.8. The results of pressure and temperature transient monitoring have been compiled into a database that will be used as the basis for updating the fatigue analyses during the current operating licence period to correspond to a service life of 60 years so that the impact of the operating environment is taken into account. The results of these monitoring procedures are discussed in sections 2.1.2, 4.3.2 and 5.4.2. The safety-critical monitoring procedures and actions due to ageing take place under the control of STUK. The allocation of responsibilities and division or inspection areas regarding pressure equipment is discussed in Appendix 1 to Guide YVL 3.0. The programmes for and results of periodic inspections are submitted annually to STUK for approval.

The reactor pressure vessels of the Olkiluoto 1 and 2 NPP units are, generally speaking, in good condition. The fault indications of pipeline fittings and the presence of IGSCC are discussed in section 4.3.2. Austenitic stainless steel materials and predominantly nickel-based alloys have also been used in the interior parts of the pressure vessel and for welding them. Irradiation-Assisted Stress Corrosion Cracking (IASCC) may also cause ageing in these conditions. TVO has systematically analysed the factors affecting cracking, and the major actions resulting from this work are the replacement of moderator vessel covers in 1992 and 1994. The major actions during the current operating licence period include the replacement of steam dryers during 2005–2006 in order to reduce the humidity content and the resulting dispersion of radioactivity, as well as the replacement of feedwater manifolds displaying thermally-induced cracking in 2004–2005 to cope with the flow rates increased by the power upgrade. The mixing of hot reflux water and cold feedwater, taking place at the feedwater fitting, is also suspected to be the reason behind the small cracks found in the lifting lugs of the moderator vessel cover.

The most significant project initiated with respect to functional equipment is the replacement of inner isolation valves in the main steam line to correspond to the increased flow rate of steam brought about by the power upgrade. One of the valves currently in use closed in 2006 at the Olkiluoto 1 NPP unit as a result of a higher than normal flow rate after the other isolation valve had closed by itself after the permanent magnet keeping it open had grown weaker. The decision has also been taken to replace the low-pressure turbines and main seawater pumps, and the replacement or complete overhaul of emergency diesel generators is under consideration. Cracks have been discovered in the attachment grooves and stems of the blade sections of low-pressure turbines. They have most likely been caused by stress-induced corrosion and blade vibration. In its inspection of the periodic inspection programme, STUK has required TVO to ensure that the cracks will not cause a risk of missiles.

The erosion corrosion present in the turbine plant pipelines of the Olkiluoto 1 and 2 NPP units has been controlled through annual inspections and, from the 1980s onwards, through extensive material selection operations where carbon steel was replaced with austenitic stainless steel. The most important areas for material replacement were the extraction steam lines, several pressure vessels and heat exchangers linked to the low-pressure preheater.

Electrical and I&C systems

STUK's detailed requirements concerning electrical and I&C systems regarding the monitoring and reporting of ageing are specified in Guides YVL 5.2 and YVL 5.5.

The electrical and I&C systems of the Olkiluoto 1 and 2 NPP units have their own ageing management programme with related procedures. The procedures for ageing management of electrical and I&C systems present the key methods that TVO deems sufficient for managing the impacts resulting from the ageing of electrical and I&C systems in its nuclear facilities.

The ageing management of electrical and I&C systems is based on monitoring their condition. Condition monitoring is performed in order to ensure that the condition of electrical and I&C equipment and cables complies with the requirements and that they are capable of operating in the planned situations. In conjunction with the power upgrade, the TVO Service Life Team updated the ageing forecasts; for example, with respect to the containment cabling. The most important electrical and I&C systems are located in separate electrical and I&C facilities outside the containment and process facilities. The equipment located in the containment and required for the detection or control of accidents is qualified to withstand the conditions during operation and accidents. Its condition is regularly monitored. The ageing of cables located inside the containment is monitored through sampling carried out at five-year intervals. So far, no such ageing has been observed in the cables that would indicate a need to replace them. It is expected that the electrical and I&C systems will be replaced at least once during the service life of the plant.

The follow-up of feedback information from repairs and replacements of electrical and I&C systems is one source of information utilised for the monitoring and management of ageing. The actual condition and operation in compliance with the design basis of electrical and I&C systems, equipment and cables is also monitored through periodic inspections and condition monitoring as well as through the periodic inspections under the preventive maintenance programme. The major modification works regarding the electrical systems carried out at the Olkiluoto 1 and 2 NPP units during the current operating licence period included the basic overhaul of a 400 kV switchgear (OLA), upgrades of 6.6 kV equipment (system 642), drawing of cable connections for the new gas turbine plant, replacement of RPM control equipment of the diesel generators, replacements of aged contactor output contacts (system 662), the commissioning of new UPS equipment (system 664) as well as the commissioning of new rectifiers (systems 672, 673, 677, 678 and 679). Significant modification work planned for the electrical equipment includes the replacement of low-voltage switchgear, improvement of the overvoltage protection of electrical drives of reactor coolant pumps, as well as the possible replacement of these electrical drives over the longer term and the replacement of cabling inside the containment.

Certain I&C systems of the Olkiluoto 1 and 2 NPP units have been replaced during the current operating licence period. These include the computerised metering system, the control and position indication systems of reactor control and shutdown elements, the process measurement data logging system as well as the process automation system of the turbine plant. The computer system for process control and certain other monitoring systems have been upgraded. One reason for these upgrades was outdated technology. In order to ensure the operability and operational reliability of the protection I&C, TVO has joined other nuclear power companies in initiating actions for ensuring the future supply of spare parts.

Replacements related to the changes in design requirements were carried out at the Olkiluoto 1 and 2 NPP units in conjunction with the modernisation work during the previous operating licence period. The most recent of these was that ATWS (Anticipated Transient Without Scram) situations are now taken into account as supplementary functions to the reactor protection system.

The preliminary planning for the project aimed at upgrading the reactor and protection automation has been initiated, and gradual modernisation of protection automation is expected to start during 2015–2016. The analogue technology currently in use will be largely replaced with programmable equipment. A task significant for safety, to be carried out during the current operating licence period, will be the design and implementation of I&C systems diversification. In its decision C30-10/42, 39, 40, 41, 43, STUK required that TVO must submit a principal plan for the diversification of programmable equipment by February 2010 at the latest.

Operating experience shows that the ageing phenomena in electrical equipment and cables can be adequately managed through enhanced maintenance of problem areas and through basic improvements of replaceable components. The fact that equipment technologies also become outdated will be taken into account regarding I&C systems.

Construction engineering

STUK's detailed requirements relating to the ageing of concrete and steel structures are specified in Guides YVL 4.1 and YVL 4.2.

The state of repair of buildings in the Olkiluoto 1 and 2 NPP units is monitored through periodic inspections. TVO has produced separate preventive maintenance procedures for certain building elements, such as the seawater channels and doors. The areas monitored for ageing in the containment include the deformations and long-term durability of concrete structures, the ambient conditions for steel structures and expansion joints. The conditions for structures susceptible to corrosion are monitored through temperature and humidity measurements. The condition of penetrations, the partition floor, gasket face plate and pool structures is monitored through leak tests and leak detection. The cracks in concrete are monitored by taking measurements. STUK's requirements relating to the periodic inspections as well as to the repairs and modifications of buildings are specified in Guides YVL 4.1 and YVL 4.2. STUK also monitors these activities during periodic inspections.

The significant modifications carried out due to ageing for the buildings in the Olkiluoto 1 and 2 NPP units during the current operating licence period included the following: repair of a leak in the condensate pool lining of the Olkiluoto 1 NPP unit in 2006, replacement of expansion joint gaskets in the containment partition floor during 2005–2006, reopening of the expansion joint between the containment and reactor building of the Olkiluoto 2 NPP unit after it had come into contact with the concrete as a result of concrete creep and relaxation of pre-stressed steel reinforcements, as well as the cathode protection of seawater structures against chloride-induced corrosion.

Summary

STUK's assessment is that ageing management in the Olkiluoto 1 and 2 NPP units is appropriately organised. The ageing management of plant units is one of the focal areas for TVO. The goal is to keep the plants up-to-date and in good condition at all times, with respect to both safety and production capability. The early detection of dominant ageing phenomena and plant components allows making long-term predictions regarding the significant improvements and maintenance operations that will be required.

The conclusion is that ageing management at the Olkiluoto 1 and 2 NPP units has been implemented in the manner referred to in section 5 of Government Decree 733/2008. However, certain plant events have come to light in recent years where the ageing of equipment or structures has been the cause or a contributing factor. STUK will monitor the trend regarding the factors behind the events during the remaining term of the operating licence in conjunction with its regulatory oversight.

2.4 Qualification of structures, systems and components

According to the IAEA guide NS-G-2.10 “Periodic Safety Review of Nuclear Power Plants”, a nuclear power plant shall have systematic procedures for qualifying equipment and structures important to safety and for maintaining the documentation demonstrating qualification. The qualification is to ensure that equipment and structures are capable of performing their functions in design basis operating conditions and accidents with a sufficient margin while taking into account the loads and environmental conditions arising during them. Most essential in connection with periodic safety reviews is to review those factors that may have changed the qualification requirements since the previous safety review or may do so during the subsequent review period.

Mechanical components

The design parameters for the original mechanical equipment of the Olkiluoto 1 and 2 NPP units were presented in the plan specification. The equipment was qualified through testing and inspections and in some cases by calculations. As a rule, the ambient conditions were taken into account by choosing materials suitable for these conditions.

TVO updated the loading specifications of mechanical components in conjunction with the modernisation and power upgrade of the plant units during 1995–1998, and they are still up-to-date. The power upgrade increased the primary circuit flow rates and required an increase in the capacity of the relief system. These effects were taken into account by updating the stress analyses of Safety Class 1 pressure equipment and by submitting them to STUK for approval. The plan is to update the fatigue analyses of these components before the expiry of the current operating licence to correspond to the service life of 60 years.

During the current operating licence period, TVO has carried out component-specific qualification tests for the new inner isolation valves in the main steam lines. Model tests have been carried out as part of the plans for replacing seawater pumps. The changes caused by the dose of fast neutrons in the materials of the reactor pressure vessel and the moderator vessel are monitored with the help of sample pieces located in the reactor. Samples are taken out of the reactor for inspection in accordance with a schedule based on the projected service life.

Electrical and I&C systems and components

According to the guides YVL 5.2 and YVL 5.5 concerning electrical and I&C systems and components, the systems, equipment and cables at a nuclear facility shall be qualified for their intended use. Qualification verifies the conformity of the systems and their components with the requirements so that their ability to fulfil their intended purpose in all planned operational conditions is ensured. The applicability of qualification of equipment and cables must be assessed in compliance with the YVL guides, decrees and internationally accepted standards. Since the components must be able to fulfil their intended purpose throughout their entire service life, the monitoring of equipment ageing can also be deemed to be part of the continuous qualification process.

Demanding qualification requirements regarding ambient conditions mainly apply to components and cables located inside the containment since the conditions in accident situations outside the containment will be less severe. The electrical and I&C systems located in the containment buildings of the Olkiluoto 1 and 2 NPP units are divided into three environment classes on the basis of the qualification requirements regarding ambient conditions applicable to each class. The environment classification was made on a function-specific basis so that all components required for carrying out a certain function belong to the environment class specified for that function. In addition, a functional seismic classification of electrical and I&C systems has been made for the plant units; it is presented in the common classification document for the plant units.

Earthquakes were not taken into account in the original design work for the Olkiluoto 1 and 2 NPP units, which is why the electrical and I&C systems of plant units do not, as a rule, comply with the current requirements regarding earthquake resistance. However, according to the plant's seismic risk analysis, the risks arising from earthquakes are relatively minor. The seismic classification in accordance with Guide YVL 2.6, demonstrating that the plant's earthquake resistance is not impaired, is to be applied in connection with major modifications being performed at the plant units. TVO has carried out modifications at both plant units in order to improve the earthquake resistance of safety-classified electrical cabinets and battery banks by upgrading their mechanical supports.

The details of qualification tests carried out for electrical and I&C equipment regarding ambient conditions are presented in many different documents forming part of the plant documentation. The ambient conditions-related qualifications of components and cables related to later modification and modernisation operations at the plant units have been assessed in conjunction with processing the applicability assessments regarding the modification operations.

Since the beginning of 1997, STUK has required that the environmental qualification of electrical and I&C components must also include the demonstration of electromagnetic compatibility. All electrical equipment currently in use at the Olkiluoto 1 and 2 NPP units has not been tested for compliance with the EMC (Electromagnetic Compatibility) requirements. The requirements are nowadays taken into account when modernising and replacing equipment at the plant units. TVO is now applying procedures that ensure that the adequate electromagnetic compatibility of electrical and I&C equipment is installed. The procedures are based on the EMC measurements and analyses carried out in Olkiluoto during 2003 and 2004. The measurements carried out indicated that there was no need for improvements as the components currently in use are electromagnetically compatible with each other.

The design work and approval procedures regarding the electromagnetic compatibility of electrical and I&C systems and components are based on procedures that take into account, among others, the following requirements: the intended operating conditions, storage, transportation, seismic conditions, radiation and EMC. The original versions of procedures were produced by the plant supplier, but TVO has supplemented and updated their contents – for example, with regard to EMC. The type tests of equipment and cables include, among other things, ageing by radiation and heat. The procedures have been updated with regard to testing temperature requirements, taking into account the effects of modernisation and power upgrading work completed in 1998 as well as the study carried out regarding the radiation doses inside the containment in accident situations.

Service life management at the Olkiluoto NPP is discussed in section 2.3 of the safety assessment. The remaining service life must, in particular, be known for the components qualified for accident conditions. The remaining service life of cables will be ensured by tests performed on samples. As to the replaced components, the remaining qualification life is under control, provided that the construction of components a well as the environmental conditions and functional requirements have remained within the original limits. As to the other components, the validity of the qualification cannot usually be as clearly verified, which requires continuous development of the qualification methods.

In conjunction with processing the periodic safety review, STUK required TVO to present a plan regarding the development of their qualification procedure to make it more systematic, taking into account the traceability of the qualification of the most safety-important systems, structures and components to the original qualification requirements, the possible changes in loads, as well as changes in operational and environmental conditions occurring during the service life of the plant, updates to the safety analyses, and the changing of qualification requirements due to the advancement of technology, monitoring of the validity of qualification as well as monitoring of the remaining service life.

TVO submitted the requested plan regarding the development of qualification maintenance to STUK at the end of April 2009. TVO has established a working group to develop the management of service life with regard to electrical and I&C equipment qualified for demanding conditions (such as loss of coolant accidents). In accordance with the action plan submitted to STUK, the working group will begin its work with the components located inside the containment, after which it will be extended to components outside the containment. The plans to be completed by the end of 2009 regarding how the component requirements that have changed during the service life of the plant units are to be specified in the design bases and how the qualified service lives of components required for different functions are established using the different sources available to TVO. In addition, TVO will produce a plan for future component qualifications. The studies regarding tools suitable for service life management and the required information, as well as the need for and possible methods of individual monitoring and the plan for further actions and their timing will be completed by the end of 2010. In addition to actual electrical and I&C equipment, there are other components (such as pneumatic actuators) that have operational requirements in special conditions, such as during or after transients and accidents. In its studies set out in the action plan, TVO must also explain how such components are to be listed and handled regarding qualification maintenance. These reports must be sent to STUK for information in accordance with their planned schedule of completion. The plant supplier's report referred to in the action plan must also be submitted in the first delivery of documents.

The Guidelines YVL 5.2 and YVL 5.5 regarding electrical and I&C systems, which entered into force in 2004 and in 2003, respectively, require system modifications and new systems to be qualified. To this end, the licensee shall draw up a special qualification plan to demonstrate the suitability of Safety Class 2 and 3 electrical power and I&C systems, components and cables for their intended use. A system's safety significance and the reliability requirements placed on it shall be considered in the drawing up of the qualification plan. In its guidelines, TVO has set out the requirements for qualification plans and their results data.

TVO has developed the software qualification procedure, associated with systems qualification, in a separate project entitled KETTU3. The procedure is based on international standards on software quality management and nuclear technology, such as ISO 15504, IEC 62138 and IEC 61508. Among other things, the procedure includes an analysis of the fault mechanisms of the object to be qualified, as well as an analysis of their criticality and an assessment of the SIL (Safety Integrity Level). The qualification may concern application software or basic equipment software (firmware). Qualification procedures for software in Safety Class 2 equipment have been studied in a project for the SAFIR 2010 research programme which TVO participated in.

TVO has presented plans for systems qualification in conjunction with the preliminary inspection materials for new system modifications. In addition, equipment qualification proceedings have been described in the suitability assessments of components. The qualification of components belonging to Safety Class 2 and to the so-called essential accident instrumentation requires a type approval in compliance with nuclear qualification standards. TVO has taken these requirements into account in its new equipment purchases.

Summary

STUK's assessment is that no such issues are known that may have impaired the qualification since the previous safety review or may do so during the subsequent review period.

The conclusion is that the qualification procedures at the Olkiluoto NPP, with the development measures presented in TVO's action plan, are sufficient for the periodic safety review. In addition to actual electrical and I&C equipment, there are other components (such as pneumatic actuators) that have operational requirements in special conditions, such as those created during or after transients and accidents. In its studies, TVO must also explain how such components are to be listed and handled regarding qualification maintenance. The reports set out in the action plan must be sent to STUK for information in accordance with their planned schedule of completion. The plant supplier's report referred to in the action plan must also be submitted in the first delivery of documents. STUK will monitor the development of qualification procedures by inspecting the reports submitted by TVO, and also in the course of its periodic inspection programme.

2.5 Section 6: Management of human factors

Special attention shall be paid to the avoidance, detection and correction of any human error during design, construction, operation and maintenance. The possibility of human error shall be taken into account in the design of the nuclear power plant and in the planning of its operation and maintenance, so that human error and deviations from normal plant operations due to human error do not endanger plant safety. The impacts of human error shall be reduced by using various safety design methods, including defence-in-depth, redundancy, diversity and separation.

The protection systems of the Olkiluoto 1 and 2 NPP units have been designed on the basis of the so-called 30-minute rule. In practice, this means that in transient or accident situations, the operating personnel do not have to take any controlling action within the first 30 minutes because plant automation takes care of bringing the plant to a safe state. This prevents any human errors made under time pressure and stress.

Human errors cannot be completely avoided, but the possibilities for errors can be reduced by appropriate planning, instructions and procedures for which continuous training is in progress at the Olkiluoto 1 and 2 NPP units. TVO's practices for the avoidance of human errors include assignment kick-off meetings, verification of work carried out by another person, the STAA (Stop, Think, Act, Assess) approach and assignment sign-off meetings. In order to put the methods into practice, the Human Performance 2012 programme was devised in 2008, and its implementation has started with the training of contact persons. The kick-off meeting practice is quite widespread: a total of 307 kick-off meetings were held in 2007, and the Maintenance Department had held some 250 kick-off meetings by September 2008. When starting the plant after outage, tests and inspections are carried out for safety-critical systems, and also for the purpose of detecting any errors.

In order to minimise the possibility of human error, it is essential that efficient event reporting and processing practices are in place regarding both actual errors and close calls so that the experience thus gained is utilised as thoroughly as possible. It is important that plant operating experience is systematically studied in order to avoid human errors and procedures or the plants are developed as required for avoiding the repetition of similar mistakes. The operating experience feedback activities of TVO are discussed in more detail in section 5.2.2. TVO has been able to use the services of an expert in behavioural sciences since 2004, and this expertise is utilised for analysing operating events.

Ensuring competence is one element of human factors management. The Olkiluoto NPP has good facilities for providing the training necessary for avoiding human errors. They have a simulator for training operators to cope with transient and accident situations. The expertise present in TVO's organisation is discussed in more detail in section 6.3.

In its periodic safety assessment, TVO states that the influence of human factors during the operating phase can be divided into three categories: management of plant modifications, maintenance operations and plant operation. The importance of accurately documenting and maintaining the design bases as well as only carrying out one modification at at time is highlighted in safe modification work of high quality. In addition, the modification work planning at TVO includes inspections carried out by several independent parties. In conjunction with the inspection of safety management carried out in 2007 as part of the periodic inspection programme, TVO stated that minor flaws in documentation regarding original installations still surface every year in connection with modification works. This opinion was also reinforced by the events in 2008 and 2009 where the underlying reasons were either poor planning or implementation of modification work which in part was due to a failure to fully comprehend the design bases and their incomplete documentation. Following the events, TVO has promised to assess its modification work process during 2009. The company seeks to take human factors into account when implementing modification operations by providing precise procedures and by carrying out independent inspections and ensuring operability after the work has been completed. TVO also seeks long-term co-operation with its subcontractors so that they can be trained in and familiarised with TVO's special requirements.

The company strives to reduce the occurrences of human error in maintenance operations by using the work order system to limit any actions to a certain number of trains, in addition to which simultaneous work in several trains has to an extent been prevented by limiting the availability of keys, for example. In the inspection of safety management carried out by STUK in 2009 as part of the periodic inspection programme, TVO presented results of the assessment of safety culture, carried out in 2008. In its report, the team responsible for the assessment stated, among other things, that up-to-date maintenance procedures of a good standard are not available for all components, which is why the team recommended that TVO should investigate how comprehensive and up-to-date the maintenance procedures are – particularly those for safety-critical components. STUK stated in the inspection protocol that in the next inspection covering this subject, TVO must present a progress report regarding the recommendations and development issues raised in the assessment of safety culture. Maintenance activities are described in more detail in section 5.4.1.

TVO is constantly seeking to develop its control room operations, and the operating personnel always participate in this development work. The control room personnel submitted an initiative for moving to a system of 12-hour working shifts, and TVO took this system up following STUK's approval at the beginning of 2006. Before adopting the new shift rotation, TVO commissioned the Finnish Institute of Occupational Health to carry out a study regarding states of mental alertness.

Fatigue has been identified as a significant human risk factor. STUK investigated fatigue management at TVO in its inspection of human resources, carried out as part of the periodic inspection programme in2008. The results of the inspection led to the conclusion that TVO has procedures in place for determining the basic parameters of working hours and that the management and operating personnel have been trained in fatigue management. For certain annual maintenance operations, TVO has adopted a working shifts regime that makes it easier to control the length of working days of individual employees. However, during the inspection STUK made the request that the importance of the state of alertness in safety-critical jobs must be communicated to all levels of personnel participating in annual maintenance operations. TVO has submitted its communications plan to STUK for information.

In conjunction with the probabilistic risk analysis, TVO has strived to systematically identify potential human errors and to reduce their probability. The work for identifying these errors has not been limited to operating experience; instead, the goal has been to comprehensively study the key systems and safety functions so that even fewer common human errors could be prevented. During the current operating licence period, the method of analysing major operations during annual maintenance outages and their timing at different stages of the outage has been further specified. Human activities have a specially pronounced significance during annual maintenance outages when a very large number of different maintenance, testing and operating activities take place at the plant.

The conclusion is that the management of human factors at the Olkiluoto 1 and 2 NPP units has been implemented in the manner referred to in section 6 of Government Decree 733/2008. TVO is further committed to continuously developing its operations regarding the management of human factors. STUK oversees the implementation of actions both through its periodic inspection programme and other control activities.

3 Limitation of radiation exposure and releases of radioactive materials (Government Decree 733/2008)

Pursuant to section 2 of the Radiation Act (592/1991), *The use of radiation and practices involving exposure to radiation shall, in order to be acceptable, meet the following criteria:*

1) *the benefits derived from the practice shall exceed the detriment it causes (principle of justification);*
2) *the practice shall be so arranged that the resulting radiation exposure hazardous to health is kept as low as reasonably achievable (principle of optimization);*
3) *no person shall be exposed to radiation exceeding the maximum values prescribed by Decree (principle of limitation).*

According to section 7 c of the Nuclear Energy Act, *Releases of radioactive materials caused by the use of nuclear energy shall be limited in compliance with the principle laid down in paragraph 2, section 2 of the Radiation Act (592/1991). The maximum values of radiation exposure caused by a nuclear facility or any other use of nuclear energy on any member of the public will be provided for by Government decree.*

Limits on releases of radioactive materials from a nuclear facility, in order that they do not exceed the maximum values for radiation exposure provided by Government decree, shall be confirmed by the Radiation and Nuclear Safety Authority (STUK). Supervision of releases of radioactive materials shall be arranged so that compliance with limits as referred to in this section can be reliably established.

According to section 7 d of the Nuclear Energy Act, *The design of a nuclear facility shall provide for the possibility of operational occurrences and accidents. The probability of an accident must be lower, the more severe the consequences of such an accident would prove for people, the environment or property.*

The primary objective shall be the prevention of accidents. Any practical measures required shall be taken to manage accidents and mitigate the consequences thereof.

Maximum values for radiation exposure, to be used as a basis for safety design in case of operational occurrences and accidents, will be provided by Government decree.

The principles of justification, optimization and limitation recommended by the International Commission on Radiation Protection (ICRP) are used in radiation protection. The optimization principle is commonly known as the As Low As Reasonably Achievable (ALARA) principle. ICRP has recently revised the basic philosophy related to radiation protection. The revision will not, however, require any substantial changes to the existing European Basic Safety Standards or national radiation protection regulations regarding NPPs. For example, the dose limits prescribed in the Radiation Decree (1512/1991) will remain unchanged.

The radiation safety of the Olkiluoto Nuclear Power Plant workers and the population in the plant vicinity is discussed in more detail in sections 3.1–3.4. The control of radioactive releases and the monitoring of radioactive substances and radiation in the environment are discussed in section 5.5.

Detailed requirements relating to sections 7–10 of Government Decree 733/2008 are set out in Guides YVL 7.1 and YVL 7.9. In addition, the detailed requirements regarding the limitation of radiation exposure of employees and the general public are specified in Guides YVL 7.2, YVL 7.3, YVL 7.6, YVL 7.7, YVL 7.10, YVL 7.11 and YVL 7.18.

3.1 Section 7: Radiation safety of nuclear power plant workers

Occupational radiation exposure of nuclear power plant workers shall be kept as low as reasonably achievable. Furthermore, the design and operation of nuclear power plants shall be implemented so that the radiation exposure of workers can be restricted in compliance with the provisions of the Radiation Act (592/1991) and Radiation Decree (1512/1991).

The regulations governing the radiation exposure of employees are the Radiation Act 592/1991, the Radiation Decree 1512/1991, and the Series 7 YVL guides and certain ST guides issued by STUK. Section 3 of the Radiation Decree stipulates that 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 single year.

TVO's ALARA programme contains a compilation of all major objectives and procedures regarding the radiation protection and reduction of doses of employees. The ALARA programme is an procedure set included in TVO's radiation protection manual, and it is regularly updated. The most recent update was completed in 2006. The ALARA programme includes the goal that no employee at the Olkiluoto NPP should receive a radiation dose exceeding 10 mSv per year, nor should the dose caused by internal contamination exceed 0.5 mSv per year. These dose limits are tight, even on the international scale, and setting them is part of the process for fulfilling the requirement of Guide YVL 7.9 stating that the radiation dose should be kept small. In conjunction with the operational events occurring at the Olkiluoto plant units after the 2009 annual maintenance, STUK made the request that TVO should supplement the procedures concerning radiation protection so that they also take into account repair work that causes exposure to radiation and may have to be carried out during power operation. Planning the work is easier when general procedures are in place regarding the limitation of radiation doses and the necessary limitations to power operation.

STUK has inspected radiation protection measures during annual maintenance operations and found that there is a need to further ensure the careful implementation of all operational routines. In the coming years, it will also be necessary to assess whether the current level of permanent staffing is sufficient in this regard.

The highest individual radiation dose received by any employee at the Olkiluoto NPP in 2008 was 8.1 mSv. The collective radiation dose of all employees in 2008 was 935.8 mmanSv. In 2008, a total of 2,116 persons were under dosimetric surveillance. During the past five years (2004–2008) the highest radiation dose received by a Finnish nuclear power plant worker, 62.3 mSv, was accumulated while working at Swedish nuclear power plants and at the two nuclear power plants in Finland. The highest radiation dose accumulated during 2004–2008 while working exclusively at the Olkiluoto Nuclear Power Plant was 40.3 mSv.

In international comparison (e.g. the ISOE dose database of the NEA, the Nuclear Energy Association of OECD countries), the Olkiluoto 1 and 2 NPP units have been among the best boiling water plants when comparing both individual and collective radiation doses. The plant has managed to efficiently implement radiation protection and plan it well. The long-term planning of annual maintenance operations has made it possible to keep their duration short, which usually reduces the amount of work carried out and hence also the exposure to radiation.

TVO has commissioned an independent assessment for its periodic safety review, comparing the operating experience of radiation protection in Olkiluoto plant units and in equivalent Swedish BWRs. The results indicate that the standard of radiation protection is the same in all the plant units surveyed. However, some procedural differences do exist. For example, the Swedish plants have carried out more system decontamination (cleaning) operations than Olkiluoto. The report states that the decontamination of components works well in Olkiluoto. Regarding radiation sources, the primary coolant in Olkiluoto has, from time to time, contained more antimony than in the Swedish plants. As a result, TVO will replace antimony-containing components in the primary circuit with new ones with a low antimony content.

The reduction in moisture content of primary steam with the equipment upgrades during 2005–2007 (new steam dryers) substantially reduced the radiation dose rates at the turbine plant. If this situation is maintained, the radiation dose rates from the main steam line can be expected to further fall during annual maintenance operations. The risk-informed procedure will be deployed to target material inspections in pipelines from 2010 onwards. This will also contribute towards reducing the amount of work carried out in most active areas, thus reducing the radiation exposure of employees.

The approval of the dosimetric service is valid until 1 April 2011. The annually conducted quality control tests targeted at the dosimetric service have indicated that the measurement accuracy has remained in accordance with the accuracy requirements set out in international standards. The monitoring of occupational exposure at the Olkiluoto Nuclear Power Plant and the reporting of measurement data to the Dose Register maintained by STUK has been developed during the operation of the plant in accordance with Guides YVL 7.9 and YVL 7.10. The way in which employees' radiation doses were reported to the Dose Register was revised in 2008. TVO had been estimating the radiation doses using the dose reading obtained from the electronic meters backing up the official metering, although there were no grounds for doing so. The radiation doses entered using the anomalous procedure have been corrected in the Dose Register. STUK has audited the dose monitoring at the plant and the operations of Doseco Oy, the company responsible for implementing it.

TVO has modernised and extended the real-time monitoring system of employees' radiation doses in 2009. STUK has processed the respective system and equipment documentation. STUK has received the report on the transient situations in the system during the 2008 annual maintenance, and the corrective actions for eliminating the transients have been taken.

TVO also revised the access arrangements for annual maintenance personnel in 2009. STUK carried out a commissioning inspection for the modifications in the controlled area and the associated contamination control.

The conclusion is that employees' radiation protection and dose monitoring at the Olkiluoto NPP has been implemented in the manner referred to in section 7 of Government Decree 733/2008. STUK will assess the resources available for radiation protection and the procedures deployed in annual maintenance operations during the next annual maintenance operations and in the course of the periodic inspection programme.

3.2 Section 8: Limit for normal operation

The limit for the annual dose of an individual in the population, arising from the normal operation of a nuclear power plant, is 0.1 millisievert (mSv). Based on this limit, the Radiation and Nuclear Safety Authority (STUK) shall confirm release limits for radioactive materials during the normal operation of a nuclear power plant.

The prescription concerning individual protection contained in section 8 of the decree must be implemented together with the ALARA requirement concerning the limitation of radiation exposure. Guide YVL 7.1 prescribes that the releases of radioactive materials and the radiation levels in the environment must further be limited by applying the best available technology (the BAT requirement). Detailed requirements concerning the calculation methods used for assessing the radiation exposure of the population are specified in Guides YVL 7.2 and YVL 7.3.

The Olkiluoto NPP deploys efficient systems for processing liquid and gaseous effluents so that releases into the environment during normal operations are very small. The impact of radioactive releases on the radiation exposure of people living in the vicinity of the plant is so small that it can only be estimated using computational methods. As an example, the computational radiation exposure to the population of approximately 500,000 living within a radius of 100 km from the plant is theoretically of the order of less than 0.01 manSv, which is about one hundred thousandth of the radiation exposure caused to population of this size during the same time by naturally occurring background radiation and medical use of radiation sources. The increase in long-term background contamination of long-lived radioactive substances caused by effluents is non-existent, which is why the effluents will not increase the doses received from the plant surroundings even in the long run.

STUK has approved the effluent monitoring procedure included in the Olkiluoto operational procedures and the method used for calculating the radiation dose of the population. TVO has revised its calculation methods concerning the radiation exposure of the surrounding population arising from the normal operation of the Olkiluoto Nuclear Power Plant during the current operating licence period. TVO annually submits a summary of radioactive releases and computationally calculated doses to STUK, and also reports the results of radioactivity measurements carried out in the surrounding environment. STUK verifies the reliability of TVO's activities through regular on-site inspections. Section 5.5 discusses the monitoring of radioactive releases in more detail.

The release limits for radioactive materials for the Olkiluoto Nuclear Power Plant are defined in the Technical Specifications concerning the operation of the plant units, as approved by STUK. Limits have been separately defined for atmospheric noble gas and iodine releases, and, on the other hand, for water releases into the sea. A separate nuclide-specific release limit has been defined for radioactive tritium in water releases. The purpose of the release limits is to retain the individual annual radiation exposure in the surrounding population of the plant units clearly below the threshold value of 0.1 mSv set out in section 8 of the Government decree. The licensee shall continuously monitor the releases and radioactive substances present in the environment, reporting any abnormal conditions to STUK without delay.

When calculating the radiation dose of an individual of the population caused by releases of radioactive materials, the analysis is based on the average radiation exposure of the most exposed group. This group represents a hypothetical group of individuals in the population who, based on their residence and life style, are estimated to receive the highest radiation exposure arising from releases according to calculations.

The highest theoretical dose commitment received by an individual of the population most exposed to radiation in the vicinity of the Olkiluoto Nuclear Power Plant, calculated from the releases in 2008, was, as reported by TVO, 0.00026 mSv (in Finland, the average annual individual dose resulting from natural radiation is above 1 mSv). The comparative calculation performed by STUK resulted in a value lower than that reported by TVO. The calculated radiation dose has remained within this order of magnitude during the past few years since the implementation of the measures for reducing radioactive water releases into the sea at the Olkiluoto plant. The radioactive releases from the Olkiluoto 1 and 2 NPP units have been clearly below the release limits set out in the Technical Specifications.

In 2007 STUK requested a report from TVO on the implementation of Guide YVL 7.1 concerning the availability of practical solutions for further reducing the radioactive releases from the Olkiluoto NPP. The plant had earlier carried out improvements on water treatment and purification of discharge waters, and no new solutions have been presented now. TVO has commissioned an independent assessment for the periodic safety review, comparing the emissions and operating experience in the Olkiluoto plant units and in equivalent Swedish BWRs. The results indicate that the standard of radiation protection is also in this respect the same in all the plant units surveyed.

The oxygen in reactor water is activated by the neutron radiation as it passes through the reactor core, producing the short-lived but strongly radiating nitrogen-16 isotope. In boiling water reactors, this activity is in part transported by steam to the turbines, which increases the radiation levels in the building and its surroundings. This radiation can be clearly detected within the Olkiluoto power plant site. When the reactors operate at full power, this increases the radiation level at the power plant site between turbine plants by about 1 µSv/h, and this is taken into account so that the dose received will not exceed the dose corresponding to radiation work. A few hundred metres away from the turbine buildings the radiation level no longer differs from that caused by naturally occurring background radiation.

The conclusion to the above is that the operation of the Olkiluoto Nuclear Power Plant has not resulted in such radioactive releases or radiation exposure that the limit of 0.1 mSv set out in section 8 of the Government Decree 733/2008 has been exceeded. It can be expected that the calculated dose to an individual in the most exposed group of the population arising from annual normal radioactive releases of the Olkiluoto Nuclear Power Plant will remain low and well below limit set out in section 8.

3.3 Section 9: Limit for an anticipated operational occurrence

The limit for the annual dose of an individual in the population arising as the result of an anticipated operational occurrence is 0.1 mSv.

The term "anticipated operational occurrence" (or transient) refers to a deviation less serious than an accident from normal operational conditions and which can be expected to occur once or several times during any period of one hundred operating years. The detailed requirements concerning the analyses of anticipated operating transients are specified in Guide YVL 2.2. If an operational transient could cause a release of radioactive substances, the radiation doses caused by the releases must be identified. Detailed requirements concerning the calculation methods used for assessing the radiation exposure of the population are specified in Guides YVL 7.2 and YVL 7.3.

The descriptions of the analyses concerning anticipated operating transients are presented in the safety analysis report for the Olkiluoto 1 and 2 NPP units. These analyses regarding plant behaviour are discussed in section 2.1.1. of the safety assessment. The results of analyses indicate that the anticipated operational transients will not cause damage to the fuel.

The operational transients are not expected to cause significant releases of radioactive substances because the fuel will not be damaged and any releases into the environment would only consist of the radioactive substances normally present in the primary circuit water or purification systems. The plant systems are capable of efficiently containing these radioactive substances. The radiation doses to an individual in the population arising from anticipated operational transients are therefore not assessed by means of calculations.

No such operating transients have occurred at the Olkiluoto Nuclear Power Plant in which increases in radioactive releases compared with the normal conditions had occurred.

The conclusion to the above is that the anticipated operating transients of the Olkiluoto Nuclear Power Plant do not result in a release as a consequence of which the radiation doses of an individual in the population would exceed the limit value of 0.1 mSv set out in section 9 of Government Decree 733/2008.

3.4 Section 10: Limits for accident

A postulated accident and a design extension condition shall not result in such high releases of radioactive materials that extensive measures should have to be taken in the vicinity of the facility in order to limit the radiation exposure of the population.

The limit for the annual dose of an individual in the population arising as the result of an accident is:

- *1 mSv for Class 1 postulated accidents;*
- *5 mSv for Class 2 postulated accidents; and*
- *20 mSv for a design extension condition.*

The limit for the release of radioactive materials arising from a severe accident is a release which causes neither acute harmful health effects to the population in the vicinity of the nuclear power plant nor any long-term restrictions on the use of extensive areas of land and water.
The requirement applied to long-term effects will be satisfied if there is only an extremely small possibility that, as the result of a severe accident, atmospheric release of cesium-137 will exceed the limit of 100 terabecquerel (TBq).

The provisions concerning the application of section 10 of the decree to the existing nuclear power plants are set out in section 32. The detailed requirements regarding analyses on postulated accidents and severe accidents are specified in Guides YVL 2.2, YVL 2.8, YVL 7.2 and YVL 7.3. STUK has set out the requirements regarding analyses on design extension conditions for new nuclear power plants in its decision Y255/3 dated 8 April 2009.

The accident analyses and their calculation methods are subject to continuous updating and development throughout the operating life of the nuclear power plant. The Safety Analysis Report concerning the Olkiluoto 1 and 2 NPP units includes descriptions of the accident analyses of plant units (discussed in more detail in section 2.1.1 of the safety assessment). The methods of analysis for radiation exposure employed by TVO have been developed over several years and are in accordance with the requirements specified in Guides YVL 7.2 and 7.3. The methods contain unlikely assumptions that, in reality, result in overestimating the radiation doses calculated as a consequential effect. Safety-enhancing measures are taken as required on the basis of the analyses.

According to the definition in Government Decree 733/2008, Class 1 postulated accidents can be assumed to occur less frequently than once during any period of one hundred operating years, but at least once during any period of one thousand operating years. Of the postulated Class 1 accidents analysed for the Olkiluoto 1 and 2 NPP units, the most significant releases are caused by a fire involving solid waste, ion exchange resin, in the waste building of the plant unit. It is estimated to cause a maximum dose of 0.024 mSv to individuals outside the plant area; this value is clearly below the 1 mSv limit set out in the decree.

Postulated accidents in Class 2 are assumed to occur less frequently than once during any period of one thousand operating years. Of the postulated Class 2 accidents, the most significant releases are caused at the Olkiluoto 1 and 2 NPP units by a scenario where a transfer vessel full of fuel is dropped in the reactor building and one where a fuel channel in the reactor becomes totally blocked. The dropping of a transfer vessel is estimated to result in mechanical damage to the cladding of fuel bundles so that 3% of the noble gases, iodine and cesium are released. Most of the released iodine and cesium is estimated to be filtered before release into the environment occurs. The accident is estimated to cause a maximum dose of 2.2 mSv to an individual of the population outside the plant area. The complete blockage of a fuel channel is estimated to result in the partial meltdown of one fuel bundle. The assumption is made in the analysis that all of the noble gases are released from the damaged bundles to the primary circuit and that about 30% of the iodine and 25% of the cesium is released. It is assumed that the containment function will operate as planned, but that a part of the released radioactive substances will nevertheless escape from the containment via the main steam lines before their isolation valves close. Most of the iodine and cesium escaping outside the containment is estimated to be caught in the turbine systems before release into the environment occurs. The accident is estimated to cause a maximum dose of 2.0 mSv to an individual of the population outside the plant area. The estimated doses resulting from both accidents are below the 5 mSv limit set out in the decree.

The term “design extension condition” refers to a situation caused by a rare external event, or a situation where the initiating event of an anticipated operational occurrence or Class 1 postulated accident involves a common-cause failure in the safety systems, or a complex combination of failures, and which the facility is required to withstand without severe fuel damage. No such scenario has been identified regarding the design extension conditions of postulated accidents that would result in fuel damage at the Olkiluoto 1 and 2 NPP units. Therefore, the releases caused by the design extension conditions of postulated accidents are assumed be of the same order of magnitude as those resulting from a loss of reactor coolant accident analysed as a postulated accident; that is estimated to cause a maximum dose of 0.00021 mSv to individuals outside the plant area (conservative scenario). This is well below the 20 mSv limit set out in the decree.

At the time the Olkiluoto 1 and 2 NPP units were built, it was considered sufficient to have a level of safety that is achieved by designing the plants in such a manner that they can cope with the anticipated operational transients and postulated accidents without extensive damage to fuel in the reactor. The requirement to also limit releases in cases of severe accidents where the reactor core totally or partially melts down was only introduced after the plants had been built. It has been necessary to upgrade the plant units by changing the way certain systems are used and by installing some totally new systems, equipment and structures. TVO implemented the most significant plant modifications in 1988 and 1989 when, among other things, new blowdown lines fitted with filters were installed in both plant units for blowing out steam and non-condensed gases from the containment, thus preventing its uncontrolled overpressurization. Plant modifications improving the management of severe accidents have also been carried out during the current operating licence period and are discussed in more detail in section 4.3.4.

The progress of a severe accident in a situation where the accident management systems operate as planned has been considered in the accident analyses presented in the Final Safety Analysis Report. These analyses describe the operation of the containment in different accident situations. The analyses regarding radioactive releases have been made for six scenarios of severe accidents used as the design basis. An accident where the reactor feedwater line ruptures and the plant loses electrical power is assumed to result in core damage in the shortest time of all these scenarios. In turn, total loss of electrical power can be considered as the most probable scenario resulting in core damage. When the containment remains leak proof, the pressure inside it increases until the blowout of steam and non-condensed gases begins. The blowout is led through a filter that efficiently captures all other radioactive substances except noble gases and organic iodine. As a result, the long-term effects of the release will be limited and the releases of cesium-137 isotope will be well below the set limit of 100 TBq. The release will not cause any acute harmful health effects either, although the results of calculations carried out using the most conservative assumptions indicate that the effective radiation doses near the plant site are considerable, although below the dose of 0.5 Sv which will cause immediate health effects. Most of this radiation dose will be caused by the external dose from noble gas emissions.

The reliability of accident management systems has been analysed in the probabilistic risk analysis carried out by TVO. For the analysis, the mechanisms that can potentially result in damage to the containment were established, and the extent of the damage caused by each mechanism was estimated. The analysis contains both an estimate of the probability of the above mechanisms and the extent of leaks caused by the possible damage. The releases caused by the failure of containment isolation and their probability have also been estimated. The probabilistic risk analysis is discussed in more detail in section 2.1.3.

The results of the probabilistic risk analysis indicate that the frequency of an accident where a considerable part of the reactor core melts down and the integrity of the containment is lost so that the resulting cesium release exceeds the limit of 100 TBq is small but nevertheless above the design target set for new reactors in Guide YVL 2.8. The results of the analysis indicate that the biggest risk is caused by situations where an early filtered emission takes place at the upper drywell of the containment, an early emission results from damage to the drywell, or the flooding of the lower drywell is delayed.

The conclusion to the above is that postulated accidents of Class 1 or 2 or design extension conditions at the Olkiluoto Nuclear Power Plant do not result in a release as a consequence of which the radiation doses of an individual in the population would exceed the limit values set out in section 10 of Government Decree 733/2008. The release caused by a severe accident does not exceed the limit set for it in section 10 either, and the probability that the limit for cesium-137 releases is exceeded is extremely small, as prescribed in the section of the decree.

4 Nuclear safety (Government Decree 733/2008)

4.1 Section 11: Siting of a nuclear power plant

The safety impact of local conditions, as well as the security and emergency preparedness 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 facility to its environment remain extremely minor and heat removal from the plant to the environment can be reliably implemented.

Detailed requirements relating to section 11 of the decree are set out in Guides YVL 1.10 and YVL 7.4.

The normal operation of or anticipated operational transients in a nuclear power plant do not pose any limitations to land use outside the plant area. This matter is discussed in more detail in section 5.5. However, plans must be drawn up regarding land use and protection of the population in the surroundings of the nuclear power plant for preparedness for a potential severe accident. This means, among other things, that there must be no facilities or population centres in the plant's vicinity where any necessary protective measures, such as sheltering indoors or evacuation, would be difficult to implement. Further, activities that might externally cause a hazardous situation in a nuclear power plant must not take place in its vicinity.

The emergency preparedness arrangements at nuclear power plants and co-operation with public authorities are also discussed in Chapter 8 of this Appendix, as well as in Chapter 9 of Appendix 2.

The general principle regarding the location of a nuclear power plant is that it should be in a sparsely populated area, well away from any major population centres. When this is the case, the emergency preparedness arrangements are targeted at a small group of people, making them easier to implement. The major population centres nearest to the Olkiluoto NPP are the centre of Eurajoki municipality some 16 kilometres from the plant, and the City of Rauma, which has its city centre about 13 kilometres away. These population centres are clearly outside Olkiluoto's emergency planning zone and are not considered within the immediate vicinity of the power plant.

Further, there are no industrial plants, warehouses, transport routes or other activities in the vicinity of Olkiluoto that might cause a hazardous situation in the plant. The Olkiluoto power plant site has its own harbour, and the Tankokari industrial harbour is located some 3 kilometres from the plant in the northern part of the Olkiluoto island. The nearest harbour with plenty of traffic is the Rauma deep harbour some 13 kilometres away. That harbour is also the location of the nearest railway terminal. Highway 8 is some 14 kilometres away. The nearest airport is in Pori, approximately 32 kilometres from the Olkiluoto NPP, and the nearest flight routes are about ten kilometres from the power plant.

The nearest major industrial plants are the Rauma pulp mill, the Rauma paper mill belonging to UPM, and the Rauma shipyard belonging to STX Europe (formerly Aker Yards) (at distances ranging from 12 to 14 kilometres). The Raikka Oy explosives factory manufactures explosive charges, detonators and pyrotechnical products in Eurajoki and is about 11 kilometres from the power plant.

The current local detailed plan defines the current power plant site of Olkiluoto as an area for blocks of industrial and warehouse buildings. There are no permanent dwellings or holiday homes in the area, nor does any traffic route run through it. There is an accommodation village for employees at the power plant site, but most of the accommodation, about 75%, is located in the new accommodation village at a distance of about 3 km from the power plant.

The Satakunta regional plan, confirmed in 1999 by the Ministry of Environment, is in force in Eurajoki. The plan includes a protective zone extending 5–7 km from the Olkiluoto power plant. There are three permanent dwellings and some 30 holiday houses on the Olkiluoto island. The entire protective zone contains 33 permanent dwellings and about 550 holiday homes. About 40% of the holiday homes are on the mainland, in the villages of Ilavainen and Orjasaari, while the rest are on nearby islands. The vicinity of Olkiluoto can be considered to be sparsely populated in the manner referred to in Guide YVL 1.10.

The emergency planning zone extending to some 20 kilometres from the Olkiluoto NPP has a rescue plan prepared by the Satakunta Rescue Services in compliance with the Rescue Act for the eventuality of a radiation accident occurring at the nuclear power plant of Teollisuuden Voima Oyj (covering the surroundings of the plant). The adequacy of the plan and the related training are monitored by the Provincial State Office. The emergency planning zone includes the following municipalities: Eurajoki, Rauma and Luvia. The emergency planning zone has about 46,000 inhabitants. About 500,000 persons live within a one-hundred-kilometre radius of the plant.

Alerting the population and providing it with protection instructions is described in the rescue plan for surrounding areas, and these actions are the responsibility of Satakunta Rescue Services and the Rescue Management Team of the Rauma operational area, which will be assisted by the Rauma Police Station of Satakunta Police Department and the Archipelago Sea Coastguard. The actions concern the isolation of the danger zone, sheltering indoors, the use, storage and distribution of iodine tablets, as well as evacuation of the population from the power plant's protective zone. The rescue plan sets out the evacuation-related arrangements for transportation, accommodation, catering and healthcare. In an accident situation, the licensee must participate in alerting the population under immediate threat. This includes people living in the new accommodation village. The challenges associated with the rescue arrangements include the rescue operations for holiday dwellers in the archipelago and sparsely populated coastal areas, as well as those for the construction site and the accommodation village during the construction phase.

About 60% of the approximately 550 holiday homes in the protective zone of the power plant are located on islands. The conditions in the archipelago may slow down the process of warning and possibly evacuating holidaymakers. In addition, the coastline of the emergency planning zone is rather fragmented, particularly north of the power plant site, which makes alerting the people living in sparsely populated areas more difficult. The vessels of the coastguard can be used for alerting people in the archipelago and fragmented coastal areas. The development of alerting and rescue arrangements is part of the co-operation with public authorities and, in the future, the alerting procedures can also be developed by using the possibilities of modern communications technology. However, STUK is of the opinion that the alerting and rescue arrangements regarding the population living in the plant surroundings can nevertheless be implemented in the manner required by relevant regulations.

STUK's assessment is that emergency planning at the Olkiluoto NPP is up-to-date and adequate, and that TVO is further developing its preparedness for emergency situations, particularly with respect to the extensive construction site of the Olkiluoto 3 NPP unit and the accommodation village. The impacts of the plant on its environment during normal operation are described in section 5.5, while the impacts of transient and accident situations are described in sections 3.3 and 3.4. The impacts of weather phenomena on the safety of the Olkiluoto NPP and on the availability of cooling water are discussed in sections 2.1.3 and 4.6. The physical protection arrangements are described in Chapter 7.

The conclusion is that the siting of the Olkiluoto nuclear power plant complies with the requirements of section 11 of Government Decree 733/2008.

4.2 Section 12: Prevention of accidents and mitigation of consequences

In order to prevent operational occurrences and accidents, and to mitigate the consequences thereof, the operational principle of defence-indepth shall be implemented in the manner laid down in this section.

Proven or otherwise carefully examined high-quality technology shall be employed in the design, construction and operation of a nuclear power plant. When arranging the operations of the li-

censee's organisation, the aim shall be to ensure reliable prevention of operational occurrences and accidents (prevention).

A nuclear power plant shall encompass systems that facilitate the quick and reliable detection of operational occurrences and accidents and prevent the aggravation of any event. Accidents leading to extensive releases of radioactive materials must be highly unlikely (control of operational occurrences and accidents).

Effective technical and administrative measures shall be taken to mitigate the consequences of any accident. Counter-measures for bringing an accident under control and preventing radiation hazards shall be planned in advance (mitigation of consequences).

The Olkiluoto 1 and 2 NPP units have operated reliably, and the number of safety-significant transients has remained small. The plant units have constantly utilised the experience and knowledge obtained by the plant supplier in the design, construction and operation of Swedish plants. The solutions implemented by TVO have largely been similar to those carried out in corresponding Swedish plants. This has made it possible to use the Swedish plants as reference even after the construction phase of the plant. When making plant modifications, TVO strives to first implement the modifications in one unit and then gather operating experience before implementing the modifications in the other plant unit. TVO seeks to prevent human errors and the resulting transients and accidents in planning the modifications and in plant operation and maintenance by keeping documents and procedures up-to-date, by administrative measures and by training.

The Olkiluoto 1 and 2 NPP units have measuring systems monitoring the state of the process in place for detecting transient and accident situations. If the value of a process parameter important to safety significantly deviates from its normal value, the reactor protection system quickly initiates the safety functions required for controlling the situation. The main functions are reactor shutdown, starting of the emergency cooling system and the residual heat removal, as well as isolation of the containment in order to prevent the spread of radioactivity. The reactor protection system is implemented as four redundant trains in order to improve its reliability. The required function is initiated if two of the four trains are operable. The reactor protection system is based on conventional relay technology. TVO has started the planning process for modernising the reactor protection system.

Major releases of radioactive substances into the environment may occur mainly in severe accidents. The provisions made for severe accidents are discussed in more detail in section 4.3.4.

The Olkiluoto 1 and 2 NPP units have systems in place to implement safety functions for the purpose of mitigating the consequences of postulated accident situations. The plant unit operators have been provided with procedures for emergency and transient situations. Emergency preparedness arrangements are discussed in more detail in section 8 of the safety assessment.

The conclusion is that the prevention of accidents and mitigation of their consequences at the Olkiluoto 1 and 2 NPP units has been implemented in the manner referred to in section 12 of Government Decree 733/2008.

4.3 Section 13: Engineered barriers for preventing the dispersion of radioactive materials

In order to prevent the dispersion of radioactive materials, the structural defence-in-depth safety principle shall be implemented in the manner laid down in this section.

Dispersion of radioactive materials from the fuel of the nuclear reactor into the environment shall be prevented by means of successive barriers which are the fuel and its cladding, the reactor cooling circuit (primary circuit) and the containment building.

The fuel and reactor, the primary circuit of a nuclear power plant and the secondary circuit of a pressurised water reactor power plant, their water chemistry, the containment building and safety functions shall be designed so as to meet the following safety objectives:

1) In order to assure the integrity of fuel

- *the probability of fuel failure shall be low during normal operational conditions and anticipated operational occurrences;*
- *during postulated accidents, the rate of fuel failures shall remain low and fuel coolability shall not be endangered; and*
- *the possibility of a criticality accident shall be extremely low.*

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

- *the primary circuit 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;*
- *the primary circuit shall, with sufficient margins, withstand the stresses arising in normal operational conditions, anticipated operational occurrences, postulated accidents and design extension conditions;*
- *the primary circuit 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; and*
- *in order to detect leakages, the facility shall be equipped with sufficient monitoring systems.*

3) In order to ensure containment building integrity,

- *the containment building shall be designed so as to maintain its integrity during anticipated operational occurrences and, with a high degree of certainty, during all accident scenarios;*
- *pressure, radiation and temperature loads, combustible gases, impacts of missiles and shortterm high energy phenomena resulting of an accident shall be considered in the design of the containment building; and*
- *the possibility of fracturing of the reactor pressure vessel in a severe accident so that the leaktightness of the containment building would be endangered shall be extremely small. The nuclear power plant shall be equipped with systems that 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.*

4.3.1 Assuring the integrity of fuel

The fuel cladding in the Olkiluoto 1 and 2 NPP units is made of Zircaloy. The fuel suppliers have extensive experience, spanning several decades, of the use of this zirconium alloy as the cladding material for fuel rods.

In order to ensure the correct properties of fuel, maximum limits have been set for different parameters, including fuel burnup and the quantity of fission gases released from fuel pellets inside the rod. The limits have been set in such a manner that their fulfilment can be already demonstrated during the design phase through the measurements and computational analyses carried out by the fuel supplier.

Maintenance of fuel integrity during power level changes associated with the normal operation of the reactor is ensured by limitations regarding the rate at which reactor power can be adjusted. These are primarily based on research work carried out using test reactors and on operational experience gained in similar Swedish reactors and elsewhere. In addition, limits have been set during normal operation for the linear power of fuel rods and the so-called dryout factor describing the ratio of fuel bundle power to coolant flow.

The number of fuel damage occurrences during normal operation has remained small at the Olkiluoto plant units, which is an indication of compatibility between the design limits and the manner in which the reactor is operated.

The maintenance of fuel integrity during anticipated operational transients and postulated accident situations is demonstrated using computational analyses and the safety-critical limit values for normal operation (mainly the linear loading of rods and the dryout factor) derived from them. In conjunction with the periodic safety review, TVO has revised the analyses for operational transient and accident situations at the Olkiluoto 1 and 2 NPP units taking into account the plant modifications carried out during the operating licence period and the development of programs used for the calculations. The safety margin required during normal operation in relation to substantial impairment of fuel cooling (dryout margin) is currently determined for each refuelling period by analysing the most limiting initial events. The events to be analysed are the unnecessary closure of turbine control valves, loss of offsite power and failure in switching to house load operation, as well as the unnecessary triggering of reactor protection system condition XT6 (shutdown of primary coolant pumps).

Of the events included in the analyses regarding Class 2 accidents, those where an anticipated operational transient is associated with a failure of reactor scram were revised in conjunction with the periodic safety review. The analyses indicate that the probability of fuel damage in these events is small.

In addition to the analyses supporting fuel layout design, the behaviour of fuel material is monitored through on-site investigations in accordance with the spent fuel inspection programme. These investigations have confirmed the opinion that the fuel complies with the safety criteria set out in Guide YVL 6.2 up to the maximum burnup values currently in use.

The aim is to minimise the probability of a criticality accident during outages and reloading by imposing technical and administrative restraints. The prevention of inadvertent criticality has also been taken into account in the fuel storage and handling systems of the plant that are discussed in more detail in section 4.5.

The conclusion is that the integrity of fuel at the Olkiluoto 1 and 2 NPP units has been ensured in the manner referred to in section 13 of Government Decree 733/2008.

4.3.2 Ensuring the primary circuit integrity

The primary circuits of the Olkiluoto 1 and 2 NPP units include the reactor pressure vessel and its associated internal main cooling pumps and heat exchangers as well as the pipelines and fittings associated with the reactor pressure vessel up to the outer containment isolation valves. These components were designed and manufactured in accordance with the requirements of standards applicable to Safety Class 1 pressure vessels. The main standard applied was the US standard ASME Boiler and Pressure Vessel Code.

When selecting materials, provisions were made for possible ageing phenomena occurring in primary circuit conditions in accordance with the best knowledge available at the time. The reactor pressure vessel is manufactured of low-alloy MnMoNi steel and clad, with the exception of pump chambers, with austenitic stainless steel welded on the inside. The coolant pump heat exchangers and main steam lines of the reactor are made of carbon steel. Other components are made of austenitic stainless steel. The risk of brittle fracture of the reactor pressure vessel is considerably smaller than in pressurised water reactor plants because the greater distance between the reactor core and pressure vessel wall reduces the dose of fast neutrons hitting the wall. In spite of their low degree of alloying, carbon steel components are not exposed to general corrosion eroding the wall thinner, because the operating temperature is low and the steam is dry. In these conditions the erosion rate of the main steam lines is low; this has also been confirmed with measurements after the power upgrade.

In strength dimensioning, the loads caused by temperature differences of joining water flows, typical of BWRs, were minimised. In the feedwater fitting, this is done by utilising the ejector principle that causes a backflow from the reactor through the slot between the fitting and the manifold. TVO monitors the functioning of the ejector principle by continuous temperature measurements at the feedwater fitting. After commissioning, it has been discovered that loads are also caused by the additions of feedwater required for reactor start-ups and shutdowns. The adjustment of feedwater at low flow rates has been made more accurate to reduce these loads.

The strength analyses appended to the original structural plans indicated that the safety margins were sufficient in all load situations belonging to the design bases, including anticipated operational transients and postulated accidents. The updates of strength analyses and the current situation are discussed in section 2.1.2. The analysed damage mechanisms included brittle fracture of the reactor pressure vessel and the fatigue of most heavily loaded points in the primary circuit under the strain of pressure and temperature transients foreseen for the entire duration of the service life. Provisions have been made for ruptures of the reactor coolant pipe by providing anti-rupture supports and by carrying out the necessary dynamic analyses. The so-called leak before rupture criterion has not been applied. However, the containment has a leak detection system that complies with the current requirements – it allows small leaks to be reliably detected. The provisions made for pipeline ruptures are discussed in section 4.7.

The work for ensuring the integrity of the primary circuit has continued during the operation of the Olkiluoto 1 and 2 NPP units in the form of TVO procedures being part of the ageing management programme. These procedures are discussed in section 2.3. The most significant modifications have been associated with intergranular stress corrosion cracking (IGSCC). Occurrences of IGSCC were observed after a few years of operation in the base material transition zone next to the welds in pipes manufactured from austenitic stainless steel. This has been a common problem in BWR plants since the 1980s. One prerequisite for IGSCC is that material sensitizes as a result of the carbon, present as an impurity, and the detrimental thermal effect of welding. The additional requirement of carbon content below 0.05% set in the original design work did not prove a sufficient measure. Other prerequisites include the high tensile stress caused by residual welding stresses and the aggressive ambient conditions where the oxygen dissolved in the coolant as a result of radiolysis is a contributing factor in BWR plants. In order to eliminate IGSCC, pipeline sections of over 200 metres in length have, since 1987, been replaced in both plant units with pipes made of low-carbon Nuclear Grade steel.

An increasing number of indications of the presence of IGSCC in predominantly nickel-based alloys has been observed during the current operating licence period. These materials have been used in the Olkiluoto 1 and 2 NPP units in the safe-end pieces of reactor pressure vessel fittings and their weld joints as well as in the weld joints of consoles supporting the interior parts. A fault indication of about 12 mm in length and 9 mm in depth was found in the weld between the reactor pressure vessel and the feedwater pipeline of the Olkiluoto 2 NPP unit in 2003. The weld material is Inconel 182, and one of the suspected causes of the fault is a hot crack occurring during manufacture. TVO will monitor the magnitude of the fault with more frequent inspections, and preparations have been made for the repair work that may prove necessary. Faults under similar monitoring, suspected to be caused by IGSCC, have also been found in the welds of fittings in the shutdown cooling system and the reactor core spray system. In its assessments, STUK has requested that attention also be paid to thermal embrittlement that reduces the ductility of material and may be present in the dissimilar material joint of the feedwater fitting.

In the course of thermal fatigue monitoring during the current operating licence period, temperature measurements have revealed isolation valves through which water may leak into an area under lower pressure but higher temperature, causing harmful thermal stratification. The branching points susceptible to thermal mixing phenomena are included in periodic inspection programmes. The branching point of the main and auxiliary feedwater systems at the Olkiluoto 1 NPP unit was replaced because of a fault indication presumably caused my a manufacturing fault. The accumulation of pressure and temperature transient occurrences have developed steadily during the current operating licence period, and it can be assumed that most of these will, at the end of the current operating licence period, be well below the number originally foreseen for 40 years of operation.

Accident and reliability analyses indicate that at the Olkiluoto 1 and 2 -NPP units, the control of primary circuit pressure is implemented so that the primary circuit pressure remains, by a sufficient margin, below the acceptance criteria during anticipated operational transients, postulated accidents and design extension conditions.

In situations leading to an increase in primary circuit pressure, the primary circuit and systems directly connected to it are protected from overpressure by safety valves. These valves included in the overpressure protection system (system 314) of the Olkiluoto 1 and 2 NPP units blow directly into the condensate pool in the containment where the steam condenses into water. The overpressure protection system implements the diversity principle, i.e. it contains two types of valves with different operating principles. In addition to the overpressure protection system, the reactor protection and trip system also participate in limiting the primary circuit pressure.

The conclusion is that the integrity of primary circuits at the Olkiluoto 1 and 2 NPP units has been ensured in the manner referred to in section 13 of Government Decree 733/2008.

4.3.3 Water chemistry of the primary circuit

The water chemistry of reactor circuits at the Olkiluoto 1 and 2 NPP units is referred to as Normal Water Chemistry (NWC), based on the Water Chemistry Guidelines issued by the Electric Power Research Institute (EPRI). The parameters describing water chemical conditions are divided into control parameters and supplementary parameters. The control parameters affect corrosion and the condition of fuel, and they are measured and monitored in order to maintain the operability of the plant and to secure its operation. The control parameters include conductivity, corrosion-inducing anions, pH, oxygen and impurities. The supplementary parameters provide additional information on the system status. The supplementary parameters include metal concentrations. Trigger levels have been defined for the control parameters with associated time limits for restoring normal conditions. In addition to the limit values associated with the trigger levels, target levels are also specified for the control parameters; these levels are normally achieved – or at least they should be achieved. The supplementary parameters only have target values specified for them.

The control parameters, with their respective limit values and trigger levels for the Olkiluoto 1 and 2 NPP units, are specified in the Technical Specifications and Chemical Procedures. The supplementary parameters and their target values are only specified in the Chemical Procedures. TVO monitors the chemical parameters using both continuous measurements and laboratory analyses. The chemical laboratory uses an information system where the analysis results are recorded and which can be used for monitoring compliance with the set limit values and for studying the long-term trends of chemical parameters.

During the current operating licence period, the water chemistry at the Olkiluoto 1 and 2 NPP units has largely remained within the target values. The condensation of sulphates, anions causing stress-induced corrosion, was regularly above the target value for reactor coolant during the early years of the operating licence period. The sulphate in the reactor coolant originates from the sulphate released from the ion-exchange resins of the condensate cleaning filters. TVO managed to reduce the sulphate condensations in the early 2000s by choosing different filter masses, using inert mass and by limiting the times when the filter masses were used. Neither plant unit had any occurrences of exceeding the target value during 2002 or 2003, but the running times of filters had to be limited. Temperature is one factor contributing to the decomposition of condensate filters. In order to reduce its detrimental effects, the temperature of water entering the condensate cleaning filters was reduced by changing the location of the condensate system pre-heater. The modification took place at the Olkiluoto 2 NPP unit in 2003 and at the Olkiluoto 1 NPP unit in 2004. After the plant modifications, the sulphate content of reactor coolant has been in keeping with the target value, with the exception of some isolated deviations. The deviations were caused by an increase in condensate temperature, which in turn was caused by the warm cooling water in late summer. After the plant modifications, it has been possible to use the filters up to the pressure differential limit, with the exception of the situations in late summer where the filter masses had to be changed before their capacity was exhausted.

The concentration of chlorides – another anion causing stress corrosion – in reactor coolant has, during the current operating licence period, been in line with the target value set by TVO, with the exception of the turbine condenser leak occurring at the Olkiluoto 2 NPP unit in 2004. The leak allowed sea water to enter the reactor circuit, resulting in a temporary increase in the chloride concentration above the target limit, but the chloride concentration did not exceed the action-triggering limit specified in the Technical Specifications.

The chemistry index, describing the effectiveness of measures for maintaining the water chemistry conditions of the reactor circuit and affected by the chloride and sulphate content or reactor coolant and the iron content of feedwater during power operation, has constantly been close to the best possible value at both plant units ever since the sulphate content of the reactor coolant has been in line with the target value.

The iron content of feedwater is a water chemistry parameter that is essential from the point of fuel cladding. Iron may cause additional deposits on the fuel. The iron content of feedwater at the Olkiluoto 1 and 2 NPP units has, during the current operating licence period, been in line with the target value set by TVO, with the exception of a few isolated deviations. Investigations into irradiated fuel bundles have not revealed any significant changes in the quantity or composition of solid deposits accumulated on bundle surfaces.

During the current operating period, there have been five occurrences of a leaking fuel bundle at the Olkiluoto 1 NPP unit and six at the Olkiluoto 2 NPP unit. The leaks have been minor – the iodine-131 activity content of reactor coolant has been less then one per cent of the limit set out in the Technical Specifications for taking action. The leaky bundles have been removed during the next refuelling outage following detection of the leak. A fuel leak is often created when a small loose part, such as a metallic chip carried by the reactor coolant, gets stuck to the fuel assembly. The coolant flow may make the loose part vibrate and break the fuel cladding. Loose parts may enter the reactor in work carried out during outages, when the reactor and primary circuit are open. TVO has investigated the needs for developing working methods in order to prevent loose parts getting into the reactor. As a result, the licensee improved, for example, procedures and the work order and procurement procedures. In addition, information on dangers related to loose parts is given in induction training and at various meetings to both internal and contractor personnel. Personnel are also reminded of the need for a careful and attentive attitude when working with open components. These actions were deployed for the first time during the annual maintenance outages of 2006. Since then, the plant units have had one fuel leak.

In conclusion, it can be stated that during the current operating licence period, the water chemistry at the Olkiluoto 1 and 2 NPP units has remained good. The sulphate content in rector coolant, which at the beginning of the current operating licence period was above the target value, has also been in line with the target value after the modification to the condensate purification system, save a few isolated deviations. During the current operating period, there have been a total of 11 occurrences of a leaking fuel bundle at the Olkiluoto 1 and 2 NPP units. However, the leaks have been small and the leaked radioactive substances have been treated in the plant's internal systems. The leaking bundles have been removed during the next refuelling outage following the leak. The water chemistry of reactor coolant has remained good from the point of fuel cladding.

The conclusion is that the water chemistry at the Olkiluoto 1 and 2 NPP units has been implemented in the manner referred to in section 13 of Government Decree 733/2008.

4.3.4 Ensuring the integrity of containment building

The containment buildings of the Olkiluoto 1 and 2 NPP units are of steel reinforced concrete construction. In addition, the external walls of the containment are prestressed structures. The containment integrity has been ensured by installing a sealing plate of steel inside the containment. All parts of the sealing plate are protected against jet forces and missiles possibly occurring during accidents. In order to minimise the potential releases caused by leaks in penetration seals, the containment building is located inside the reactor building. The reactor building is equipped with air conditioning that allows the reactor building to be underpressurised in relation to its surroundings and to collect and filter any radioactive substances possibly leaking from the containment building.

The design requirements for the containment building with regard to the anticipated operational transients and postulated accidents have not changed since the Olkiluoto plant was built. The anticipated operational transients and postulated accidents have been taken into account in the design of the containment buildings of the Olkiluoto 1 and 2 NPP units by dimensioning the structures on the basis of loads resulting from a sudden and complete rupture of the largest pipe in the primary circuit. The functioning of the containment in a situation where a pipe rupture occurs in the primary circuit is based on the pressure reduction principle where the increase in containment pressure is limited by directing the steam discharged from the ruptured pipe to the condensation pool located at the lower part of the containment. The functionality of pressure reduction requires that the wet well and dry well of the containment have been isolated from each other in a leak proof manner.

The containment spraying system starts automatically in an accident situation. The residual heat released from the reactor core during an accident is transferred to the final heat sink, the sea, through the containment spraying system, the component cooling system and the seawater circuit.

In postulated accidents, part of the fuel cladding material may become oxidised, which releases hydrogen into the containment. Hydrogen may also be generated over longer periods in the water pools through radiolysis. In order to eliminate the fire and explosion risk caused by hydrogen, the Olkiluoto containments have an inert nitrogen atmosphere during normal power operation, except for short periods during start-up and shutdown. The containment building is also equipped with a separate hydrogen removal system that allows for the controlled burning of hydrogen released in an accident back into water.

So far, the ageing effects on the containment building and its systems have been relatively minor. TVO has replaced the expansion joint gaskets in the containment partition floor during 2005–2006. At that time, the construction and material of the gaskets was also altered so that they can withstand larger movements and higher temperatures. In the same connection, the rubber bellow of the expansion joint of the transport shaft was replaced for one with better material properties. These modifications enhance the functionality of the pressure reduction principle. The periodic leakage tests on the containment buildings have not indicated any increase in leaks that would be a sign of deterioration in the materials of the containment penetration seals.

Severe accidents were not taken into account in the original design work for the containments of Olkiluoto 1 and 2 NPP units. TVO has made modifications at the plant units to improve the possibilities for controlling severe accidents. Most of the modifications were made prior to 1998 when the operating licence for the plant units was renewed. In its statement of 1998 regarding the operating licence, STUK stated that there are still needs for research and development associated with the consequences of severe accidents and preparations made for them. Of these, steam explosions and the behaviour of iodine in the containment were deemed key issues for the Olkiluoto plant units.

The control of severe accidents at the Olkiluoto 1 and 2 NPP units is based on primary circuit pressure reduction, flooding of the lower dry well of the containment building, cooling of core melt in the lower dry well, controlled reduction of containment pressure as well as the detention of radionuclides.

The reduction of primary circuit pressure prevents the high-pressure eruption of core melt from the pressure vessel. The pressure reduction is accomplished by a forced blowout from the primary circuit relief system valves. A modification was made to the system in 1999 to allow keeping two valves open with pressurized nitrogen through actions taken from outside the containment building. The modification ensures that the reactor pressure remains low even in accident situations associated with a long-lasting loss of electrical power.

In a severe accident, the lower part of the containment below the pressure vessel (lower dry well) is flooded in order to protect the containment penetrations there from the thermal effects of core melt. The flooding has to take place early enough during the course of the accident so that the core melt possibly penetrating the pressure vessel drops into a deep pool of water. When the melt drops into the pool of water, a steam explosion may occur, resulting in a quickly travelling, strong pressure wave in the pool. For the eventuality of a steam explosion, during 2001–2002 TVO reinforced the lower personnel airlocks of the containment buildings of Olkiluoto 1 and 2 NPP units so that they can withstand higher pressures and pressure shocks.

TVO has commissioned a new study for its periodic safety review where the pressure and impulse loads generated by a steam explosion occurring in the lower dry well are estimated. In case of a severe accident at the Olkiluoto 1 or 2 NPP unit, the pressure vessel is most likely to rupture at the instrumentation tube penetrating the bottom of the pressure vessel. The mass flow of core melt discharging through the instrumentation tube is so small that calculations indicate it to be incapable of causing a steam explosion. In calculations regarding the pressure shock caused by a steam explosion, the shock has only exceeded the strength of the lower personnel airlocks of the containment buildings of Olkiluoto 1 and 2 NPP units when unlikely assumptions regarding the discharge of core melt have been used. STUK has commissioned comparison analyses using a more detailed calculation program. The results of these calculations are consistent with TVO's analyses: the core melt discharged through the instrumentation tube cools down as it travels through the pool of water and cannot create a steam explosion. Most of the results of comparison analyses calculated using the same parameters have shown smaller loading values than the results shown in TVO's study.

The core material discharged from the reactor pressure vessels of the Olkiluoto 1 and 2 NPP units is cooled down in the flooded lower dry wells of the containment buildings. As it drops through the water, the core melt cools down and disintegrates into particles. The coolability of core material in particle form has been empirically tested in Finland as part of the SAFIR research programme. The test results indicate that the heap of particles can be cooled under the pressure prevailing during an accident situation. Coolability may be compromised if plenty of fine-grained material collects on top of the heap of particles – for example, as a result of a steam explosion. A steam explosion of these proportions is unlikely due to the most probable mechanism of pressure vessel failure at the Olkiluoto 1 and 2 NPP units. STUK has commissioned comparison analyses with the same results: the heap of particles most probably forming in an accident situation can be cooled. However, there are situations where coolability is jeopardised. TVO has commissioned an independent assessment regarding the coolability tests conducted by VTT. The assessment considered the test results to be conservative with regard to the geometry of the heap of particles. The assessment recommended that further investigations should be carried out regarding the particle size distribution and shape of the particle heap. A new test programme is starting in 2009 with regard to the latter.

The lower part of the containment below the pressure vessel can be flooded with water in order to protect the penetrations from the thermal effects of core melt. Some penetrations of the containment are also structurally protected from the direct effects of core melt. In order to ensure the cooling of reactor remnants, the plant is also equipped with an external water filling system that allows bringing the water level in the containment building up to the top edge of the reactor core.

The small size of the containment buildings of the Olkiluoto 1 and 2 NPP units is one of the most significant flaws regarding the control of severe accidents. Pressure in the building increases during an accident as a result of the release of hydrogen, steam and other gases. The containment is equipped with a pressure reduction system that allows gases increasing its pressure to be removed through a purpose-built filter.

Iodine is mainly present in the containment building in the form of aerosols that are effectively captured in the condensation pool of the containment and in the filter of the relief train. In acidic conditions, iodine may also form organic compounds that are not readily captured in the containment or the relief line filter. Increasing the pH of water pools in the containment increases the absorption of iodine and reduces the formation of organic iodine compounds. In 2001, TVO installed a lye container in the fire water pumping station of the plant that allows the pH of water pools to be increased. The lye injection system was expanded in 2007–2008 when the fire water pumping station was upgraded.

TVO has supplemented the containment sampling system with a facility for taking a sample of the containment atmosphere during a severe accident. Sampling allows the composition of gases in the containment atmosphere and its organic iodine content to be established.

The conclusion is that the integrity of the containment building at the Olkiluoto 1 and 2 NPP units has been ensured in the manner referred to in section 13 of Government Decree 733/2008.

4.4 Section 14: Safety functions and provisions for ensuring them

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 feedbacks shall be such that it mitigates the increase in reactor power.

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

In order to prevent accidents and mitigate the consequences thereof, a nuclear power plant shall be provided with systems for shutting down the reactor and maintaining it in a sub-critical state, for removing decay heat generated in the reactor, and for retaining radioactive materials within the plant. Principles ensuring the implementation of these safety functions even in the event of a malfunction must be applied in designing the systems in question. Such principles are redundancy, separation and diversity. The most important systems necessary for transferring to, and remaining in, a controlled state must be capable of fulfilling their function even if any individual system component is inoperable and even if any other component of the same system or of a supporting or auxiliary system *necessary for its operation is simultaneously out of use due to required repair or maintenance..*

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

A nuclear power plant shall have on-site and offsite electrical power supply systems. The execution of safety functions shall be possible by using either of the two electrical power supply systems.

The plant shall be provided with systems, structures and components for controlling and monitoring severe accidents. These shall be independent of the systems designed for operational conditions and postulated accidents. Systems necessary for ensuring the integrity of the containment building in a severe accident shall be capable of performing their safety functions, even in the case of a single failure. The plant shall be designed so that it can be brought into a safe state after a severe accident.

The most important safety functions of a nuclear power plant are: 1) reactor shutdown, 2) residual heat removal from the reactor to the ultimate heat sink, and 3) the functioning of the containment building. These functions shall be operable in normal operational conditions, anticipated operational transients and postulated accidents.

Inherent reactor-physical feedbacks are made use of in the reactor design of the Olkiluoto 1 and 2 NPP units and in their fuel loading plans so that each physical feedback separately, and thus their combined effect collectively, mitigates the increase of reactor power in transient and accident conditions. This is demonstrated both analytically and empirically in the start-up of the plant following refuelling outages.

Control rods are the primary means of shutting down the reactor and keeping it in a shutdown state at the Olkiluoto 1 and 2 NPP units. Control rods may be moved by either driving them by means of electric motors or by pushing them down into the reactor by means of nitrogen tanks forming part of the reactor trip system. The fuel loading of the Olkiluoto 1 and 2 NPP units is designed to enable reactor scram during normal operation, anticipated operational transients and postulated accidents by means of control rods even in the event of a malfunction of the most effective control rod group. In addition to the control rods, the reactors can be shut down using the boron system equipped with an emergency diesel power supply.

Residual heat is removed from the reactor using either the shutdown cooling system or by blowing steam from the reactor through the pressure control system into the condensate pool located in the containment. The auxiliary and emergency feedwater systems maintain a sufficient flow of coolant in the reactor. The heat energy can be further transferred from the condensate pool to the sea via the secondary cooling system and the seawater systems, both consisting of four redundant trains. These systems require active equipment that receive their driving power from diesel-backed power supply sources.

The residual heat removal systems of the Olkiluoto 1 and 2 plant units were not designed in compliance with the diversity principle. There are no alternative systems for back-up in situations where the ultimate heat sink is lost or where a common mode failure occurs in the systems used for removal of residual heat. TVO has investigated the possibilities for devising a method for removal of residual heat that would be seawater-independent, but in its report submitted for the periodic safety review the company states that it does not consider the investigated system technically feasible as such. However, STUK considers it important that application of the diversity principle is systematically assessed at the plant and developed in line with the principles set out in section 7 of the Nuclear Energy Act. Instead of looking at the diversification of an individual function, TVO should consider the plant as a whole. By the end of 2010, TVO must send to STUK, for its approval, a report regarding the adequacy of the diversification at the Olkiluoto 1 and 2 NPP units, accompanied with an action plan for developing the same.

In an accident situation, the containment building must be sealed and leak proof so as to prevent any releases of radioactive substances into the environment. As a rule, the pipelines penetrating containment walls have two isolation valves, one outside the containment and one on the inside. In an accident situation, the reactor protection system closes the isolation valves when necessary.

The Olkiluoto 1 and 2 NPP units have offsite power supply systems connected to both the 400 kV and 110 kV grids. If connections to both power transfer networks are lost, both plant units have four emergency diesel sets for on-site power supply. The safety functions can be executed by using either of the two electrical power supply systems.

In addition, the plant units also have a new gas turbine plant, completed in 2008, at their disposal. It can operate virtually independently of other sources of AC power designed for different operational conditions and postulated accidents.

In 2008, one significant event related to electrical systems occurred at the Olkiluoto 1 NPP unit during start-up after annual maintenance. A malfunction occurred in the exciter system of the main generator when the plant power was at 60%. This resulted in the generator exciter current reaching its maximum value. The large exciter current increased the voltage at the generator and in the on-site power network, first to 125% of nominal voltage and then to 150% when the connection to the national grid was cut. This major overvoltage condition lasted for 150 milliseconds until the protective relays opened the generator switch. The power supply was restored to the on-site power network after a downtime of two seconds when the supply switching system automatically switched the plant supply to the 110 kV grid.

The overvoltage transient resulted in all six reactor coolant pumps stopping when the frequency converters driving the pump motors supplied an overvoltage. The frequency converters are fitted with a generator acting as a flywheel motor that is designed to generate electricity for the pump motors in a power cut situation so that they can be slowed down to minimum speed in a controlled manner through a shutdown ramp. This function did not operate because the overvoltage protection switching off the frequency converters had been triggered. The purpose of the reactor coolant pump shutdown ramp is to reduce the flow of coolant in the reactor core gradually so that the sufficient cooling of fuel is not endangered. If the flow of coolant stops abruptly, there is a risk of deterioration of cooling (heat transfer crisis). When the event started at 60% reactor power, the reactor coolant pumps were running at minimum speed so there was no risk of loss of fuel cooling ability. The analyses made after the event indicate that a similar pump stoppage occurring at full power would have resulted in a heat transfer crisis in parts of the fuel with possible fuel damage.

After the event, modifications were carried out at the Olkiluoto 1 and 2 NPP units to the triggering conditions of overvoltage protection relays and the opening conditions of power supply switches in order to protect the reactor coolant pumps from overvoltage. The modifications had the desired effect of reducing the risk of reactor coolant pumps stopping as a result of overvoltage. However, the repairs carried out are not yet sufficient from the deterministic point of view. The current arrangements mean that the controlled shutdown of reactor coolant pumps (a Safety Class 2 function) is protected by equipment in Safety Classes 4 and EYT. For this reason, STUK submitted in its decisions C542/35 dated 8 June 2008 and C30-7/106 dated 30 April 2009 that TVO must produce a plan regarding the necessary modifications to be carried out in the long run in order to improve the overvoltage resistance of reactor coolant pumps. TVO delivered the plan to STUK in September 2009.

Severe accidents were not taken into account in the original design work for the containments of Olkiluoto 1 and 2 NPP units. TVO has made modifications at the plant units to improve the possibilities for controlling severe accidents. The key safety functions in place regarding severe accidents at the Olkiluoto 1 and 2 NPP units are primary circuit pressure reduction, cooling of core melt in the lower dry well, and the controlled reduction of containment pressure. During severe accidents, the same relief system is used for reducing the pressure as is used for protecting the reactor coolant circuit against overpressure and for reducing pressure during postulated accidents. The requirement set out in section 14 of Government Decree 733/2008 regarding the independence of systems deployed in severe accidents is not met in this respect.

The cooling of core melt in the lower dry well of the containment requires that the well is flooded. The flooding is effected through the containment spraying system by manually opening the valves in the pipelines leading from the condensation pool to the lower dry well. The requirements set out in the Government decree are met because the action only utilises passive components of the spraying system and the system is single-failure tolerant.

During severe accidents, the filtered venting system is used for the controlled reduction of containment pressure. There are two redundant lines leading to the filter; the isolation valves of these lines are opened manually. Therefore, the filtered venting function of the containment building complies with the requirement set out in section 14 of Government Decree 733/2008 regarding the independence and fault tolerance of systems deployed in severe accidents. The management of severe accidents at the Olkiluoto 1 and 2 NPP units and the modifications carried out during the current operating licence period are described in more detail in section 4.3.4.

The conclusion is that the Olkiluoto 1 and 2 NPP units can be deemed to comply with the requirements set out in 14 of Government Decree 733/2008 regarding the measures to ensure safety functions when section 32 of the decree, applicable to plants in operation, is taken into account. However, the application of the diversity principle at the plant units must be systematically assessed and developed in line with the principles set out in section 7 of the Nuclear Energy Act. TVO has also submitted a plan for improving the overvoltage tolerance of the electrical drives of reactor coolant pumps. STUK will oversee the implementation of these requirements and plans.

4.5 Section 15: Fuel handling and storage

In the handling and storing of nuclear fuel, adequate cooling and radiation protection shall be ensured. Damage to fuel cladding during handling and storage must be prevented with a high degree of certainty. The possibility of a criticality accident shall be extremely low. Fuel storage conditions shall be maintained such that the leaktightness or mechanical endurance of a fuel assembly is not substantially degraded during the planned storage period.

In addition, section 114 of the Nuclear Energy Decree states that *The Radiation and Nuclear Safety Authority (STUK) shall see to it that nuclear fuel is designed, fabricated, stored, handled and used pursuant to the relevant instructions and regulations. Nuclear fuel cannot be placed in the reactor until STUK has accepted the fuel for use.*

The general design bases for nuclear fuel have been defined in the Guides YVL 1.0 and YVL 6.2. The design objective is that the probability of fuel failure is low during normal operational conditions and anticipated operational transients, and that during a postulated accident the rate of fuel failures remains low and the fuel remains in a coolable state. The measures for ensuring the integrity of fuel during the operation of the Olkiluoto 1 and 2 NPP units is discussed in more detail in section 4.3.1.

Detailed requirements for the design, quality management and control, handling, storage and transport of fuel are specified in the Guides YVL 6.2, YVL 6.3, YVL 6.4, YVL 6.5, YVL 6.7 and YVL 6.8. The following companies have supplied and produced fuel for the Olkiluoto 1 and 2 NPP units: Westinghouse Electric Sweden AB, AREVA NP GmbH, GNF ENUSA Nuclear Fuel S.A., Global Nuclear Fuel - Americas LLC and ENUSA Industrias Avazadas S.A. STUK has granted TVO permissions to use fuel types ATRIUM 10B, ATRIUM 10XM, GE12, GE14, SVEA-96 Optima and SVEA-96 Optima2. The preliminary inspection procedures prescribed in the YVL guides have primarily been observed in the licensing process.

According to the requirements set out in STUK's Guide YVL 6.3, the manufacture of nuclear fuel or control rods must not commence before STUK has approved the respective preliminary inspection material. In its decision 9/C43261/2009 dated 8 October 2009, STUK pointed out a deviation regarding the submission of preliminary inspection materials. TVO had submitted, contrary to the requirements of Guide YVL 6.3, preliminary inspection materials for approval by STUK at the stage the manufacture of fuel was already in progress. The decision set out the requirement that TVO must take the actions required in its operations management system and its associated procedures for bringing the activities to compliance with the requirements. The decision also requires that a report of the reasons for the situation and a summary of corrective actions with the respective time schedule are to be delivered to STUK by 15 January 2010.

TVO and the consultants hired by it oversee the manufacture of fuel at the fuel factory. The purpose of STUK's regulatory control is to ensure that the activities of the licensee are adequate. TVO performs an acceptance inspection for each fuel batch arriving at the Olkiluoto Nuclear Power Plant in which the fuel bundles and channels are inspected in compliance with the procedures. The quality assurance operations concerning the procurement of nuclear fuel are also described in section 6.2.

The criticality safety of the fuel racks in the Olkiluoto 1 and 2 NPP units as well as those in the intermediate fuel storage is based on the use of so-called compact racks. Compact racks have neutron-absorbing elements fitted between the fuel bundles so that a decrease in the density of water between the bundles will not compromise the criticality safety of fuel. The analyses take into account the impact of water density and temperature on the stockpile growth factor as one uncertainty factor to be considered.

The criticality safety of fuel storage racks is ensured through criticality safety analyses performed in conjunction with the fuel licensing procedure. The purpose of these analyses is to demonstrate that all fuel racks used at the plant site comply with the criticality requirement set out in Guide YVL 6.8, even allowing for the uncertainties associated with the calculation system, the storage conditions and the storage history of the fuel. The acceptance criteria for analysis results is that the the safety requirement is met even if the rack is filled up with as much reactive fuel as is possible.

In order to verify criticality safety during refuelling operations, TVO submits to STUK, for its approval, a reactor refuelling application in compliance with Guide YVL 1.13, showing, among other things, the layout of fuel rods in the reactor (loading pattern) and the analyses to be performed during the refuelling operation for the purpose of demonstrating criticality safety. These analyses take into account the possibility of individual human errors (incorrect placement of a bundle or control rod into the reactor). In addition, the neutron flux of the reactor core is monitored during the refuelling operation with the neutron flux monitoring system (SIRM) prescribed in the Technical Specifications.

The conclusion is that fuel management at the Olkiluoto 1 and 2 NPP units has been organised in the manner referred to in section 15 of Government Decree 733/2008 and in section 114 of the Nuclear Energy Decree. STUK has required TVO to take corrective actions regarding the submission of preliminary inspection materials of nuclear fuel in compliance with the requirements of Guide YVL 6.3. The handling, storage and final disposal of spent fuel is also discussed in section 9.2.

4.6 Section 17: Protection against external events

The design of a nuclear power plant shall take account of external events that may challenge safety functions. Systems, structures and components are to be designed, located and protected so that the impacts of external events on plant safety remain minor. External events to be accounted for include at least exceptional weather conditions, seismic events and other factors resulting from the environment or human activity. Design must also take account of illegal activities undertaken to damage the plant, and a large airliner crash.

Detailed requirements relating to section 17 of the decree are set out in Guides YVL 1.0, YVL 2.6, YVL 4.1 and YVL 4.2, among others.

The loads exerted and conditions caused by natural phenomena have been taken into account in the design of the structures of the Olkiluoto 1 and 2 NPP units as prescribed by Finnish building regulations. The most important natural phenomena, as well as their combinations, have also been considered in the functional design of systems. The safety margins used in the original design are not as wide as those currently required when designing new nuclear power plants.

TVO has studied the risks arising from external events as part of the probabilistic risk analysis. The events analysed include, among others, harsh weather conditions, high seawater temperature, exceptionally high seawater level, and phenomena causing a clogging risk in the seawater systems, such as frazil ice, mussels and algae. The analyses indicate that the most significant external events include a storm with a simultaneous loss of offsite power, mussels breaking off the internal walls of the seawater channels, deposits of algae (blockage of seawater intake channels) as well as simultaneous high levels of seawater and ambient temperature.

During the operating licence period, a new potential risk to safety was identified: the impulse lines, important to safety, may freeze if the ventilation intake air heating fails during winter conditions. The risk of impulse lines freezing was substantially reduced through modifications carried out by TVO to the plant and procedures. Provisions have been made at the Olkiluoto NPP for the eventuality of seawater systems becoming blocked. They consist of alternative water supply arrangements. The plant also seeks to prevent the formation of frazil ice as a result of supercooled seawater suddenly freezing by channeling warm condensate water into the seawater intake opening. In its decision C551/276 dated 26 August 2009, STUK requested TVO to assess, by 30 November

2009, the sufficiency of warm water pumped from the Olkiluoto 2 NPP unit to the Olkiluoto 1 NPP unit in a situation involving a longer outage at the Olkiluoto 2 NPP unit.

There is little ship traffic in the vicinity of the plant, and the risks resulting from oil spillage accidents have not been assessed in conjunction with the PRA for Olkiluoto 1 and 2 NPP units. TVO has drawn up a plan for enhancing the oil spillage combating arrangements, and in 2009 the company procured new oil booms and agreed with the Satakunta Emergency Response Centre on informing the Olkiluoto NPP of hazardous situations regarding oil spillages.

There are no industrial plants in the vicinity of the NPP that would pose a risk to its safety.

The aircraft crashes considered in the plant design are less severe than those required for new nuclear power plants.

The loads resulting from earthquakes were not separately analysed in the original design work for the Olkiluoto 1 and 2 NPP units. Certain safety-critical electrical equipment was not sufficiently supported to withstand earthquake-induced loads. Many electrical components, among others, have since been better supported. An earthquake may also cause malfunctions in the control system relays that result in protection functions being unnecessarily activated. Examples of these include the unnecessary opening of pressure relief valves in the primary circuit and an unnecessary isolation of the containment that stops cooling of the reactor. The most significant plant modification during the current operating licence period was that the main control room was provided with capabilities to cancel unnecessary protection functions activated as a result of earthquakes. As a result of the plant modifications carried out, the risk caused by earthquakes is no longer significant.

In conclusion, it may be stated that the plant and procedure modifications implemented during the current operating licence period reduce the risk imposed on the plant by natural phenomena and other external events. The Olkiluoto NPP is sufficiently protected against external events in the manner referred to in section 17 of Government Decree 733/2008. However, TVO still needs to present a plan for assessing risks related to oil spillage.

4.7 Section 18: Protection against internal events

The design of a nuclear power plant shall take account of any internal events that may challenge safety functions. Systems, structures and components shall be designed, located and protected so that the probability of internal events remains low and impacts on plant safety minor. Internal events to be considered include at least fire, flood, explosion, pipe breaks, container breakages, missiles, falling of heavy objects and component failures.

Detailed requirements relating to section 18 of the decree are set out in Guides YVL 1.0, YVL 4.1, YVL 4.2 and YVL 4.3, among others.

Provisions have been made in the design of structures and systems of the Olkiluoto 1 and 2 NPP units for the possibility of fires and the resulting accident risks. However, the fire compartmentalisation does not comply with the relevant requirements of Guide YVL 4.3. As a result of the deficiencies in the original design, it has been important to develop fire detection and fire extinguishing systems and structural fire protection.

TVO has upgraded sprinkler systems in many parts of the plant, including the turbine hall and cable tunnels. The fire detection system has been renewed and made location-based, as a result of which fires can be detected, located and automatically extinguished faster than previously. A new fire station has been commissioned, and operative fire protection equipment has been renewed.

STUK's assessment is that fire safety at the Olkiluoto 1 and 2 NPP units has been improved during the current operating licence period. Due to deficiencies in the compartmentalisation of safety systems and insufficient structural fire resistance, which are due to the basic design of the plant, the fire safety is not capable of fulfilling all of the requirements laid down in the Guide YVL 4.3. To this end, the fire safety of cable rooms in particular will be improved with the help of fast-acting nozzles having an improved layout in order to mitigate the risks caused by the flaws in compartmentalisation.

The risks associated with internal flood events at the plant have been assessed in flood analyses. The occurrence of a major leak in the cooling water intake building or turbine building was found to be such a major risk that TVO made modifications to the plant in order to prevent such a flood. These modifications will ensure that a flood is detected early and the seawater pumps stopped.

Provisions were made for the eventuality of dropping heavy loads the basic design work for the Olkiluoto 1 and 2 NPP units. In the outage risk analysis, the consequences of dropping heavy loads and possible initial event risks associated with them were analysed. The risk of dropping loads has little effect on the outage risk.

The conclusion is that the Olkiluoto NPP is protected against internal events in the manner referred to in section 18 of Government Decree 733/2008. The requirements of section 14 of Government Decree 733/2008 regarding compartmentalisation are met when section 32, applicable to plants in operation, is taken into account. The fire safety of the plant will be further improved in order to mitigate the risks caused by the flaws in compartmentalisation.

4.8 Section 19: Monitoring and control of a nuclear power plant

The control room of a nuclear power plant shall contain equipment that provides information on the operational state of the nuclear reactor and any deviations from normal operation. Furthermore, a nuclear power plant shall contain automatic systems that actuate safety functions whenever required and control and supervise their functioning during operational occurrences and accidents.

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 an emergency control post independent of the control room, and the necessary local control systems for shutting down and cooling the nuclear reactor, and for removing residual heat from the nuclear reactor and spent fuel stored at the plant.

According to TVO, the duties and role of the control room have remained unchanged during the current operating licence period, although the control room has become a so-called hybrid control room that also has control interfaces based on display and data bus technology in addition to the conventional hard-wired control interface. This development was contributed to by the I&C systems modernisation work undertaken during the latter half of the 1990s and the gradual development of data logging, processing and interface systems associated with the process control computer system. A substantial change took place in 2005 and 2006 when the display-based control of components was introduced in conjunction with the process automation system of the new turbine plant. Until then, the process equipment had almost exclusively been controlled by hard-wired connections from the control room to the respective control units of the process automation system. The ceilings of the main control rooms have also been upgraded during the current operating licence period taking into account the requirements regarding earthquakes. At the same time, the floors and most of the furniture in the control rooms were also upgraded.

The observance of standards and internationally recognised best practices regarding control room designs has led to the development of particular Human-Machine Interface (HMI, HFE) engineering. This is associated with the development of design processes for both control rooms and for interfaces in general. In 2000, TVO drew up a general plan entitled “Valvomon visio” regarding the development of control rooms at the Olkiluoto 1 and 2 NPP units. This plan, together with the design basis of the control rooms, have been further specified and developed during the past decade.

In conjunction with the preliminary safety review, STUK found that the procedures associated with the planning and implementation of control room modification work should be further specified and updated with regard to the design/planning process and procedures for organisation. In April 2009, TVO submitted a plan to STUK with a view to improving the procedures.

There have not been any significant changes during the current operating licence period in functions of the Olkiluoto 1 and 2 NPP units associated with actuation, control and supervision of safety functions. The reactor water level measurement system consists of four redundant trains, the operation of any two of them being sufficient to implement the safety function. Each train is based on pressure differential measurements. STUK has required that the diversity principle should be applied to the design of reactor water level measurements in compliance with the principles of section 7 of the Nuclear Energy Act. The requirement of section 14 of Government Decree 733/2008 can be deemed to be met when section 32, applicable to plants in operation, is taken into account. During the current operating licence period, TVO has, in its reports submitted to STUK, discussed the possibilities for backing up the currently used level measurement system by a measurement facility utilising some other principle for implementing the protection function. On the basis of these studies, STUK required, in its related decision, that the main alternative set out in TVO's plan is put into operation starting from the annual maintenance in 2012. STUK further required TVO to analyse, by the end of 2010, the reactor water level measurement diversification needs related to the flashing of the water surface.

In conjunction with the periodic safety review, STUK required TVO to submit a report regarding the risks associated with the current shutdown and start-up procedures with regard to reactor water level swelling and entry of water into the steam pipes. STUK further required an analysis regarding the need for modifying the plant or the shutdown and start-up procedures so that the risks caused by the swelling phenomenon are minimised. The risk of water level swelling is not only associated with scheduled start-ups and shutdowns but also with repairs carried out at reduced power. It is also possible in these situations that the unnecessary opening of the bypass valve occurs so quickly that flash boiling cannot be prevented by operator actions.

Should water rise into the steam pipes, it might endanger the integrity of the reactor coolant circuit and the containment building. The rising of water into the steam pipes is currently prevented so that when the water level is high, the steam pipe is automatically closed, stopping the rise in the water level. However, the protection required for preventing the phenomenon (a signal of a high water level in the reactor) was not designed in compliance with the diversity principle, as already discussed above. The report submitted by TVO states that analyses indicate that water will not rise into the steam pipes if the isolation valve closing command comes following a high reactor water level as planned. If this signal is absent, water will rise up to the steam pipes. In its report, TVO did not consider it necessary to change the shutdown and start-up procedures of the plant, nor did it see any need for plant modifications.

STUK takes the view that with respect to the water level swelling phenomenon, the Olkiluoto 1 and 2 NPP units do not comply with the level of safety required of new reactors in Government Decree 733/2008 because ensuring the primary circuit and containment integrity is not diversified regarding the scram and isolation signal of a high water level in the reactor. TVO must, pursuant to the principle of continuous improvement set out in section 7 of the Nuclear Energy Act, implement the plant modifications for improving the safety of the Olkiluoto 1 and 2 NPP units in a situation where the turbine bypass valves suddenly and unneccessarily open. Before the plant modifications are implemented, TVO must ensure, through administrative measures, that the plant units are not operated, without a particular reason and in addition to short durations during start-ups and shutdowns, with the isolation valves open at power levels where a sudden opening of the turbine bypass valve would increase the risk of water rising up into the steam lines.

During the current operating licence period, TVO has initiated the work for improving the Safety Analysis Report so that it would comply with the requirements of Guide YVL 2.0. The work has also began in this context for further specifying the descriptions of safety functions, starting with the reactor protection system. The further definition of safety functions and design bases is also an important part of the preliminary planning work aimed at upgrading the reactor and protection automation (see section 2.3 on ageing management). The purpose of this work is the gradual modernisation of protection automation. The project is expected to begin during 2015–2016.

The requirement set out in section 19 of Government Decree 733/2008 is not met with regard to the emergency control post. The application of section 19 to nuclear power plants already in operation is stipulated in section 32, which states *"The following shall not be applicable to a nuclear power plant for which an operating licence was issued prior to the entry into force of this Decree: [...] and section 19(3), unless their application is justified with respect to the technical solutions of the nuclear power plant in question, under the principle laid down in section 7 a of the Nuclear Energy Act."*

In December 2007, TVO submitted a preliminary plan regarding the implementation of an emergency control room to STUK in keeping with the implementation decision of Guide YVL 5.5. In conjunction with the periodic safety review, STUK required TVO to revise and assess its action plans so that it would be possible to implement a limited emergency control room function during the current operating licence period. It may not necessarily be possible to implement the functionality of such an emergency control room in its full extent to respond to all required threats. However, achieving a preliminary functionality will improve the current implementation of emergency control by concentrating functions to one location. It may also be possible to implement structural modifications early in the schedule. These monitoring and control functions can be later transferred to the final emergency control room, and at that time, the level of protection and functionality will also have to be brought to the current level requirements for emergency control rooms to the extent possible at the Olkiluoto 1 and 2 NPP units.

In its response, TVO submitted that the emergency control room would be implemented in two stages. In the first stage, the functions available in the current emergency control room are to be implemented in the new, separate emergency control room. The preliminary planning for the implementation will be completed during 2009, and the requirements will be specified and the principal plan produced during 2010. Modification of the facilities for emergency control room use and the equipment installations required for the functions would be completed during 2011–2014. The second stage of implementation of the emergency control room will be related to the upgrade of reactor operation and protection automation. In conjunction with this upgrading work, the implementation of additional functions enabled by the new equipment will be planned for the emergency control room. This would take place during 2016–2019.

The conclusion is that the supervision and control functions of the Olkiluoto 1 and 2 NPP units can be deemed to comply with the requirements set out in section 19 of Government Decree 733/2008 when section 32 of the decree, applicable to plants in operation, is taken into account. STUK will monitor the emergency control room implementation project and the diversification of reactor water level measurements in the course of its regulatory oversight. TVO must also implement the plant modifications for improving the safety of the Olkiluoto 1 and 2 NPP units in a situation where the turbine bypass valves suddenly and unnecessarily open.

5 Operation of the nuclear power plant (Government Decree 733/2008)

According to section 7 f of the Nuclear Energy Act, *safety shall take priority during the construction and operation of a nuclear facility. The holder of a construction licence […] shall be responsible for the nuclear facility's construction in accordance with safety requirements. Moreover, the condition and operating experiences of any nuclear facility shall be systematically monitored and assessed.*

5.1 Section 23, Operating

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

For operational occurrences and accidents, instructions suitable 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.

TVO has specified the minimum staffing of the control room in the Technical Specifications (Tech Spec). The shift supervisor carries the responsibility for following the regulations. The Guide YVL 1.6 refers to the qualifications of nuclear power plant operators. The Radiation and Nuclear Safety Authority (STUK) participates in oral hearings of operators arranged in compliance with the guide. The tasks of shift personnel are specified in the operating manual.

The shift personnel monitor the control room's incoming information on the operating state of systems and equipment as well as the conditions of rooms and any deviations in them. Furthermore, the shift personnel regularly perform inspection rounds of the plant. The plant's surveillance camera system is used in monitoring facilities which cannot be accessed during load operation or to which access is restricted. Such facilities include, for example, the containment and turbine buildings.

The Tech Spec specify the conditions pertaining to the operability of structures, equipment and systems important to safety, the highest allowed limit values and periodic tests. Any deviations observed will be handled in the manner specified in the Tech Spec and required by the operating and emergency procedures. Reports on failures and corrective measures are included in the work order system. STUK monitors the functionality of the work order system and supervises compliance with the Tech Spec by using local inspectors, performing inspections of the plant and supervising reports submitted to STUK.

The procedures used in operations are based on written guidelines as well as in operation orders and operating instructions drawn up when necessary. The Tech Spec are dealt with in more detail in chapter 5.3. TVO has compiled the guides into manuals, such as operating manuals and maintenance manuals. Updating and inspection methods and responsibilities for the guides have been defined. Manuals and updates significant for nuclear and radiation safety are also submitted to STUK. STUK reviews the manuals to ensure that they are up-to-date and sufficient in connection with document updates and during inspections complying with the periodic inspection programme. An operation order is prepared when, for example, changing the operating state or power level of the plant are necessary, or when actions relating to the reactor and nuclear fuel are performed. An operation instruction is prepared for deviating procedures that will not become permanent procedures.

There is an emergency operating procedure for identifying and managing transient operating conditions and accidents. TVO has drawn up three new emergency operating procedures after the modernisation of the Olkiluoto 1 and 2 nuclear power plant units modernisation project (MODE) implemented in the late 1990s. Furthermore, an emergency operating procedure for partial scram and its recovery is being prepared. No new emergency operating procedures have been drawn up during the current operating license period because there has been no need for such new procedures.

Since the power upgrades of the plants, TVO has not implemented any systematic procedure validation. STUK is of the opinion that the current best practices require procedure-specific justification documentation for emergency operating procedures that include the procedure strategy, assumptions used when drawing up the technical features of procedure, references to analyses made when drawing up the procedure and other background information related to the procedure. Procedure verification and validation must be implemented in a systematic and comprehensive manner. The validation must be documented and assessed to ensure that the procedures are functional. TVO must take action in order to correct the status of the procedures.

Operations and events with safety implications must be documented in compliance with the operating manual in the control room operating manual, the reactor manual and shift reports. TVO has been using an electronic control room record since 2009. The control room personnel collect all data related to transients in the operational transient report form and submit the data to the operational section's manager, who will draw up an operational transient report. Guide YVL 1.5 includes instructions on event reporting. The requirements of this guide are included in the TVO operating manual.

STUK' resident inspector supervises the operations of plant units. Furthermore, STUK reviews operations in periodic inspections, for example. TVO submits regular and transient-specific reports to STUK.

The conclusion to the above is that the operations of the Olkiluoto 1 and 2 nuclear power plant units have been implemented in the manner referred to in section 733 of the Government Decree 733/2008. However, STUK requires the justification documentation for emergency operating procedures and an assessment of the sufficiency of the validation of procedures.

5.2 Section 24 Operational experience feedback and safety research

Nuclear power plant operational experience feedback shall be collected and safety research results monitored, and both assessed for the purpose of enhancing safety. Safety-significant operational events shall be investigated for the purpose of identifying the root causes as well as defining and implementing the corrective measures. Improvements in technical safety, resulting from safety research, shall be taken into account to the extent justified on the basis of the principles laid down in Section 7 a of the Nuclear Energy Act.

According to section 7 a of the Nuclear Energy Act, *the safety of nuclear energy use shall 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 and safety research and advances in science and technology.*

5.2.1 Operating experience from the current operating licence period

In accordance with Guide YVL 1.5, a licensee must provide a special report for any events, failures, deficiencies or problems that will essentially influence the nuclear power plant's safety, the safety of the plant's staff or radiation safety in the plant environment. Other event reports to be submitted to STUK include operational transient reports, event reports and root cause reports. TVO has taken into account the requirements of Guide YVL 1.5 by drawing up operating manual procedures on reports to be submitted during the operation of the Olkiluoto nuclear power plant. During 1999–2008, a total of 49 events requiring special reports took place in the Olkiluoto 1 and 2 nuclear power plant units.

TVO enters all events in an operating experience database (Opex). The reports pertaining to an event include, for example, the cause of the event and the corrective measures. TVO monitors the implementation of corrective measures with a management and reporting system (Kelpo). STUK assesses the correctness of corrective measures based on reports submitted by TVO and supervises the progress of such measures in operations-related inspections complying with the periodic inspection programme.

The safety implications of nuclear power plant events are illustrated using the **I**nternational **N**uclear **E**vent **S**cale (INES). The scale includes seven levels, the lowermost of which (1–3) describe events that have deteriorated safety and the uppermost (4–7) describe accidents. In addition, level 0 is used for indicating that the event has no nuclear or radiation safety significance. The Olkiluoto 1 and 2 nuclear power plant units did not experience any events exceeding INES level 1 during 1999–2008 (23 events). Figure 1 includes the number of INES level 1 events, and Figure 2 includes the annual number of events requiring special reports during the current operating licence period.

Based on the number of events, the years 2003 and 2008 stand out from the current operating licence period. The significant issues in 2003 were the common issues influencing the events, such as failures to comply with procedures, errors in management of periodic testing, errors in monitoring of the plant facility and errors in identifying the requirements of the Technical Specifications. In 2008, embrittlement by ageing was detected in some emergency diesel seals. If allowed to continue, this could have prevented the simultaneous start-up of several diesel generators. The seals in question were not included in the regular maintenance programme; instead, the problem was detected in connection with periodic start-up testing. A power failure also occurred at Olkiluoto, proving that changes carried out during the latest reactor power increase did not result in the desired reliability of electrical systems. TVO ordered an evaluation by outside experts on the company decision-making process, the causes of the events and the safety culture for both of these years. The evaluators gave recommendations on measures to improve the situation, and TVO took these recommendations in account in its activities. Some of the measures are still being implemented.

The status of several factors affecting safety, operability and quality of operations are monitored at the Olkiluoto nuclear power plant using indicators. The load factors of the plant units have been good in international comparison. From 1999 to 2008 the load factor was 93.7–98.3% for the Olkiluoto 1 nuclear power plant unit and 93.7–96.9% for the Olkiluoto 2 nuclear power plant unit. Relatively few reactor fast closures have occurred; during the current operating licence period, there have been a total of twelve fast closures due to different reasons (six for each plant unit).

On the basis of the indicators describing the inoperability of safety systems, the operation of the Olkiluoto nuclear power plant has been controlled and safe. Safety systems have not been inoperable to any significant extent due to faults, maintenance or other similar reasons. The indicators also provide follow-up data on occupational safety, fires and common cause failures, among other things.

In summary, it can be stated that none of the operational events at the Olkiluoto nuclear power plant has essentially impaired plant safety or caused significant radioactive releases out of the ordinary into the environment. TVO has initiated measures to develop the safety culture due to the events in 2007 and 2008.

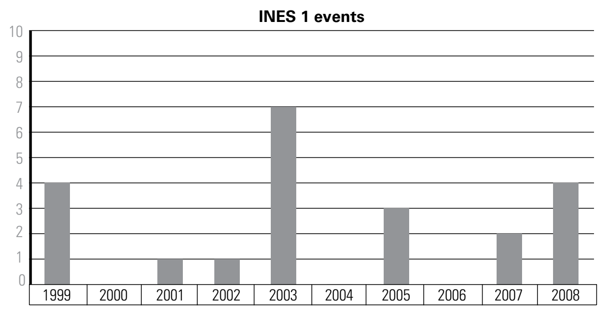

Figure 1. Annual number of INES level 1 events in the Olkiluoto 1 and 2 nuclear power plant units during the current operating licence period.

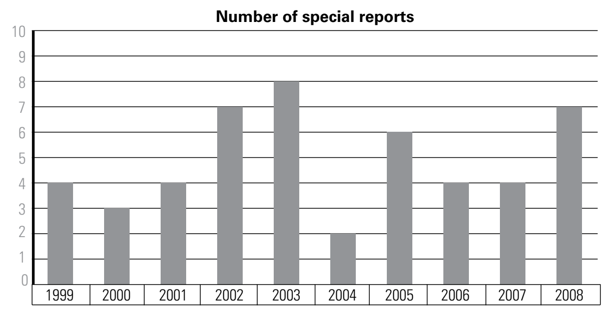

Figure 2. The annual number of special reports submitted for the Olkiluoto 1 and 2 nuclear power plant units during the current operating licence period.

5.2.2 Operatingl experience feedback

Guide YVL 1.11 includes requirements on the utilisation of operating experience feedback from nuclear power plants. TVO has taken these requirements into account by drawing up operating manual procedures on handling operational experience feedback at the Olkiluoto nuclear power plant. STUK verifies the compliance with these requirements in periodic inspection programme inspections of operation and international operating experience feedback. Furthermore, STUK assesses TVO's operational experience feedback activities when inspecting event reports. STUK has required that TVO pays more attention in specifying the schedules for corrective measures and responsibilities as well as more systematic monitoring of event recurrence.

The general objective of operating experience feedback is to create and maintain procedures that enable learning from experience obtained. TVO's operating experience feedback activities cover experiences obtained at TVO's own plants and other plants, as well as systematic utilisation of the lessons learned. TVO has an operating experience feedback team (KÄKRY) which collects information on events and observations from several sources and assesses their significance for different technical sectors. The team meets every two weeks.

The most important sources of information for events of other plants are the owners group for Nordic BWR operators ERFATOM, which screens, analyses and provides to its members operating experience feedback data as well as the reports of WANO (the World Association of Nuclear Operators), KSU (Kärnkraftsäkerhet och Utbildning AB) and the Loviisa nuclear power plant.

The conclusion to the above is that the operating experience feedback activities of the Olkiluoto 1 and 2 nuclear power plant units has been implemented in the manner referred to in section 24 of the Government Decree 733/2008.

5.2.3 Safety research

TVO monitors safety research results by means of participating in the activities of support groups for different research areas of the national SAFIR2010 research programme on nuclear power plant safety. TVO also uses the SAFIR2010 research programme to monitor the results of international research programmes. Cooperation between Nordic nuclear power plant operators is organised through the Nordic Owners Group (NOG). The plant supplier (Westinghouse Electric Sweden Ab) is strongly involved in this cooperation, which aims to find solutions especially for problems or defects connected with the boiling water reactors designed by ASEA. TVO has funded research activities also through Nordic reactor safety research (Nordisk kärnsäkerhetsforskning, NKS).

Research and participation in research projects is coordinated by the research and development office of the TVO Nuclear Technology Unit. Furthermore, the safety office of the Nuclear Technology Unit, which keeps the design bases of the Olkiluoto 1 and 2 nuclear power plant units up-to-date, monitors R&D and assesses the results achieved in the TVO plant units.

The conclusion to the above is that the safety research result monitoring of the Olkiluoto 1 and 2 nuclear power plant units has been implemented in the manner referred to in section 24 of Government Decree 733/2008.

5.3 Section 25, Technical Specifications

The Technical Specifications 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 operability of systems, structures and components important to safety, as well as the limitations that are to be observed in the event of equipment failure, shall also be presented in the Technical Specifications. The plant shall be operated in compliance with these requirements and restrictions, and compliance with them shall be monitored and any deviations reported.

Taken together, the Technical Specifications and plant procedures define the limits and operating procedures for the safe operation of the nuclear power plant in different operational conditions.

TVO has Technical Specifications (Tech Spec) for the Olkiluoto 1 and 2 nuclear power plant units as well as the interim storage for spent fuel (KPA storage). These documents are maintained to comply with any changes occurring at the plants, in the organisation or based on operating experience. The Tech Spec specify limits for different operating states by means of process parameters, provide operation restrictions for a variety of failures and include the requirements for periodic testing in compliance with the Tech Spec. The compliance with the Tech Spec is monitored, and deviations are reported in compliance with Guide YVL 1.5.

TVO systematically maintains the Tech Spec. Furthermore, the requirements included in the Tech Spec have been assessed using a probabilistic risk analysis. TVO has submitted more than 70 change proposals to STUK for approval during the current operating licence period. STUK has approved most of the change proposals, although it has required specifications or posed further requirements in the proposed Tech Spec changes in some cases.

Based on its inspections and observations, STUK has stated that the Tech Spec need to be developed in order to ensure the document justification, clarity and unambiguousness. In connection with its periodic safety review, TVO submitted a Tech Spec development plan to STUK (memorandum 130845, "Development of OL1/OL2 Technical Specifications – status review and further planning"). In accordance with the development plan, TVO will review, supplement and harmonise all the Tech Spec requirement and justification chapters by the end of 2009. The plan is to have the Tech Spec draft version assessed by the operational shifts and finalised by the persons in charge and the development team by the end of 2010. The plan is to initiate official processing of the Tech Spec at the beginning of 2011. STUK will monitor planned progress of the development work in connection with, for example, its inspection programme.

The conclusion to the above is that the Technical Specifications of the Olkiluoto 1 and 2 nuclear power plant units and the interim storage for spent fuel have been implemented in the manner referred to in section 25 of Government Decree 733/2008. Based on its assessment, STUK states that the Technical Specifications are up-to-date, and the Tech Spec contents are acceptable from a safety viewpoint. STUK has approved the Tech Spec development plan and will monitor implementation of the plan.

5.4 Section 26, Condition monitoring and maintenance

The nuclear power plant shall have a condition monitoring and maintenance programme for ensuring the integrity and reliable operation of systems, structures and components. This programme shall define inspections, testing, maintenance, replacements and other procedures for controlling operability and the impacts of the operating environment.

5.4.1 Maintenance

The maintenance of the Olkiluoto 1 and 2 nuclear power plant units covers preventive and corrective maintenance as well as the planning and implementation of modifications, spare part maintenance, shutdown activities and related quality control. Preventive maintenance aims at promoting the safety of the plant units, preventing any component malfunctions threatening availability, improving operating reliability of the components and scheduling the necessary maintenance measures. Corrective maintenance restores components into operational condition after a fault.

Guides YVL 1.8, YVL 2.0, YVL 5.2 and YVL 5.5 include the requirements for modifications, repairs and preventive maintenance which TVO has included, for example, in its maintenance and modification manuals. In addition to the procedures, TVO uses IT systems to manage and control maintenance. Such IT systems include, for example, the preventive maintenance data system, the modification management system and the work order system. The Technical Specifications define conditions and limitations for safety-critical systems, devices and structures as well as their periodic testing schedule.

In addition to the measures included in the preventive maintenance programme, TVO monitors systems, components and facilities during regular operation and daily inspections. Some of the most critical components, such as reactor coolant pumps and the turbine, are equipped with continuously operating condition monitoring systems. Inspections concerning the operability and condition of components are also carried out as required on the basis of the accumulated operating experience and advancement of technological knowledge. The most important sources of operating experience in this respect are Swedish boiling water plants and global communication systems.

Maintenance activities are prioritised using, among other things, the maintenance classification of equipment units and modifications. For example, equipment units are divided into four maintenance categories on the basis of the significance of faults in the components. Category 1 units are retained in operational order at all times, category 2 units are allowed some limited unavailability, category 3 units are allowed financially justifiable preventive maintenance activities, and category 4 units are not included within the scope of planned preventive maintenance. TVO has specified unit responsibility areas and persons in charge for each area. These persons collect operational experience data on the units and assess the necessary development measures. Annual unit responsibility reports are compiled, and a summary report of these is submitted to STUK.

During the current operating licence period, TVO has assessed and developed its maintenance. The equipment units were divided into the above-mentioned four maintenance categories during 1990–2000. A maintenance development project (KUTEVA) was implemented during 2002–2004. The project consisted of analysing and documenting the preventive maintenance tasks and programmes for the category 1, 2 and 3 units in a maintenance analysis IT system created for this purpose. An additional project implemented in 2005 consisted of specifying the analysis of maintenance category 3 units.

STUK supervises condition monitoring and maintenance as well as modifications and repairs in regular inspections. The inspections aim at ensuring that the power company has sufficient resources, such as competent personnel, instructions, a spare part and material storage and tools, required for sufficiently effective implementation of condition monitoring and maintenance measures.

In 2001, STUK performed a study of the Olkiluoto 1 and 2 nuclear power plant units regarding measures connected with the LP steam turbine control and shut-off valves. The STUK study report gave TVO several recommendations on improving the management system, such as procedures in place for modifications. In 2008, TVO performed a safety culture survey, and the survey team gave additional proposals regarding the modification procedures. The assessment team stated that the significance of plant design bases must be stressed in modifications, and that ensuring operability and the scope of test programmes in the case of plant modifications require more attention. Furthermore, the team stated that there are no up-to-date high-quality maintenance procedures for some components, and thus the team recommended that TVO should study the scope and currency of maintenance procedures, particularly those for equipment critical to plant safety.

IEC standards on automation design that entered into force at the beginning of the decade and Guide YVL 5.5 require a staged design model with stage-by-stage verification and validation of different requirement levels. It has been observed that the reconciliation of the design process traditionally used for power plant modifications and the more recent automation requirements still requires development. In its periodic inspection programme review, STUK required that TVO submits a plan for updating the automation design and automation modification management procedure by the end of 2009.

The measurement accuracy maintenance systems of the Olkiluoto 1 and 2 nuclear power plant units that are included in the scope of the periodic preventive maintenance procedure include separate measuring instruments, most of the process measuring instruments as well as other measuring systems, such as mechanical, chemical and radiation parameter measuring systems. The procedures in place for comprehensive management of the measuring accuracy maintenance system still require development. In its inspection programme review, STUK required that TVO include procedures to ensure and maintain the accuracy of measuring instruments in its operations manual. STUK has requested TVO to implement the change by the end of 2009.

Defects in modification planning and implementation as well as the management of design bases were observed in connection with the operational events that occurred in the Olkiluoto 1 and 2 nuclear power plant units in 2007 and 2008. Examples of such defects include defects observed in the sealing of pipework penetrations in the emergency injection system's pump rooms in 2008, nitrogen leaks due to damage to the sealing material of the fast closure system valves in 2007, and recurrence of such leaks in 2009, unqualified rectifier fuses installed during a director upgrading project connected to the DC power systems in the new millennium, and problems with the applicability of LED indicator lamps that were used to replace glow lamps in the 2008 preventive maintenance package.

The conclusion to the above is that the maintenance of the Olkiluoto 1 and 2 nuclear power plant units has been implemented in the manner referred to in section 26 of Government Decree 733/2008. Several areas requiring development have been observed during the current operating licence period. STUK supervises the implementation of TVO's measures in connection with its oversight.

5.4.2 In-service inspections

The condition of the pressure-bearing components of the Olkiluoto 1 and 2 nuclear power plant units is ensured by means of in-service inspections. Primary circuit components are subjected to in-service inspections performed during outages at regular intervals using non-destructive testing methods in accordance with Guide YVL 3.8. The results of the in-service inspections are compared with the results of earlier inspections and pre-service inspections performed prior to commissioning.

The in-service inspection programmes are submitted to STUK for approval prior to each round of inspections. The programmes and the related inspection procedures are modified when necessary, taking into account the development of industry requirements and standards, the development of inspection techniques, inspection experience, and operating experience from nuclear power plants in Finland and elsewhere.

Attempts have been made to focus the inspections on areas where faults are most likely to emerge. These include, for example, items susceptible to fatigue due to temperature variations or items susceptible to stress corrosion cracking. The selection of inspection items is under continuous development. For this purpose, a risk-informed in-service inspection procedure is being developed for the Olkiluoto 1 and 2 nuclear power plant units. Inspections and inspection schedules will be optimised on the basis of risk-informed methods when the next inspection period programmes are drawn up.

The frequency of the non-destructive examinations performed at regular intervals is usually ten years. The inspection frequency for items susceptible to thermal fatigue is three years, and the inspection frequency for items susceptible to stress corrosion cracking is three or five years.

Guide YVL 3.8 and the latest edition of the ASME Code, Section XI are used as the acceptance criteria for in-service inspection programmes and procedures. A qualification system complying with European practice has been developed for in-service inspections. All ultrasound and eddy current inspection systems to be used in in-service inspections complying with Guide YVL 3.8 will be qualified. Most of the qualifications have already been performed and approved by STUK.

In addition to the aforementioned inspections, physical inspections that concern the condition and reliability of pressure equipment are performed at regular intervals in accordance with Finnish pressure equipment legislation. These inspections are the full inspection, internal inspection and operational inspection, and they include non-destructive testing as well as pressure and leak tests. Inspections concerning pipelines have been defined in the system-specific condition monitoring programmes. These in-service inspections are discussed in Guides YVL 3.0, YVL 3.3, YVL 5.3, YVL 5.4 and YVL 5.7. The in-service inspection programmes of the Olkiluoto 1 and 2 nuclear power plant units fulfil the requirements specified in the YVL guides with regard to the number of inspections and inspection technique.

The reliability of the non-destructive examination methods for primary circuit pipelines and components has been essentially improved since the commissioning of the Olkiluoto 1 and 2 nuclear power plant units. The implementation of the qualification system for in-service inspections and the introduction of the risk-informed in-service inspection programme are significant development targets for operations.

The in-service inspection procedure for safety-critical electrical equipment and systems is based on statutory regulations and guidelines, recommendations of the plant supplier and equipment manufacturers as well as operational experiences from the equipment and systems. The in-service inspection procedure is controlled by means of the plant's administrative procedures and IT systems (such as the work order system). The tasks to be performed on each item and the applicable work, procedures and approval criteria are specified in the maintenance procedures. The procedures are updated every four years or whenever required.

The in-service inspection of safety-important items, as well as the frequency of these inspections, is defined in the Technical Specifications, which TVO inspects every four years.

A considerable part of the safety-critical in-service inspections of the Olkiluoto 1 and 2 nuclear power plant units is performed in connection with annual maintenance outages, at which point STUK oversees the tests by inspecting the testing protocols, the comprehensiveness of the tests and the appropriateness of the testing procedures. STUK also oversees the status of the test procedures in connection with inspections complying with the periodic inspection programme.

The conclusion to the above is that the in-service inspections of the Olkiluoto nuclear power plant have been implemented in the manner referred to in section 26 of Government Decree 733/2008.

5.5 Section 27, Radiation monitoring and control of releases of radioactive materials

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 materials from the plant monitored, and concentrations in the environment controlled.

Detailed requirements relating to section 27 of the Government decree are set out in Guides YVL 5.5, YVL 7.6, YVL 7.7 and YVL 7.11.

The Olkiluoto 1 and 2 nuclear power plant units have in place systems for collecting and storing the majority of radioactive materials released into and residing in the plant's process systems. Only a minor part of the radioactive materials are released into the environment. The radioactive releases occur in gaseous or particulate form through the vent stack into the atmosphere, as well as in the form of particles dissolved or mixed in water entering the seawater tunnel and further into the sea environment.

The Olkiluoto nuclear power plant includes continuously operating radiation monitoring systems for external radiation of the rooms as well as for processes, releases and the environment. In addition to fixed installed radiation and radioactivity measuring systems, there is a large number of portable radiation monitoring devices. Sampling and laboratory measurements are also used as control measures.

Projects in which the radiation monitoring systems are modernised have been and will be implemented at the Olkiluoto 1 and 2 nuclear power plant units. The largest project that was started in 2006 consists of the modernisation of the plant units' fixed installed 550 radiation monitoring system. As part of the project, the radiation monitoring systems are also assessed and modernised into a digital I&C system, if necessary. This will improve the reactor scram function and the containment isolation function in the case of significant nuclear fuel damage. The project has been implemented more slowly than planned because supplements to the reports pertaining to the equipment functions have been necessary.

When the continuously operated radioactivity monitors are replaced, the release measuring system will be made redundant to prepare for a severe accident. In accordance with new requirements from STUK, stack iodine and particle monitoring will be implemented, after the upgrade, by using continuously operated radiation monitoring in addition to sampling and laboratory analyses.

There are efficient modern gate monitors and double limit arrangements at the staff exit.

STUK has inspected the procedures regarding radiation monitoring, sampling and laboratory analyses, and it regularly supervises these functions.

An extensive environmental radiation monitoring programme, approved by STUK, is being implemented in the vicinity of the Olkiluoto nuclear power plant. According to this programme, the potential migration of radioactive materials is being continuously monitored by analysing the radionuclide concentrations in foodstuffs produced in the area surrounding the plant and in other samples indicating the migration of releases. The results obtained from the monitoring of the environment corroborate the monitoring of radioactive releases carried out at the Olkiluoto nuclear power plant. The monitoring programme has been updated for 2008–2011.

The monitoring programme comprises approximately 300 samples per year. Samples include milk, meat, fish, crops and vegetables, as well as water and airborne aerosols. Samples are also taken from the land and water from such indicator organisms that very effectively accumulate radioactive materials from their living environment. The nuclides that are most important in terms of human radiation exposure are analysed when studying the samples: gamma emitters, such as ^{60}Co, ^{131}I and ^{137}Cs, beta emitters ^{3}H and ^{90}Sr and alpha emitters, such as ^{238}Pu, ^{239}Pu and ^{240}Pu.

The radioactive releases from the Olkiluoto nuclear power plant have been clearly below the release limits set out (Chapter 3.2). For airborne releases, the predominant releases, expressed in terms of activity, are those of noble gases, ^{14}C and tritium, and tritium for marine releases. The released nuclides observed in the environment have been activated corrosion products (such as ^{60}Co) and tritium. Radioactive materials originating from the nuclear power plant have been observed in the soil environment mainly during annual outages in air, fallout and rainwater samples as well as regularly in indicator samples taken from the water environment. The contents are very low and insignificant in terms of the surrounding population or the environment. Radioactive materials originating from the Chernobyl accident have also been predominant in the environmental samples of the Olkiluoto nuclear power plant. Although the radioactivity concentrations in the environmental samples are small, the measurement results for the marine environment indicator organisms and sinking matter show a decreasing trend of ^{60}Co concentrations.

An automatic monitoring system for external radiation in the environment is located in the area surrounding the Olkiluoto nuclear power plant, the purpose of which is to rapidly provide information about the possible changes in the environment occurring in a potential abnormal condition. The system equipment and data communication system were completely upgraded in 2008. Furthermore, three external radiation dose rate meters will be implemented in the power plant area before commissioning of the Olkiluoto 3 nuclear power plant unit. The instrumentation of the weather measurement system located near the plant and used for assessing the spread of a radioactive release in the atmosphere was upgraded in 2008.

Radioactive release monitoring results and the results of the environmental radiation monitoring programme are reported to STUK in the quarterly and annual reports in compliance with Guide YVL 7.8.

The conclusion on the above is that the releases of radioactive materials and their concentrations within the plant and in the environment are effectively monitored at the Olkiluoto nuclear power plant in the manner referred to in section 27 of Government Decree 733/2008.

6 Organisation and personnel (Government Decree 733/2008)

6.1 Section 28, Safety culture

When designing, constructing, operating and decommissioning a nuclear power plant, a good safety culture shall be maintained. The decisions and activities of the management of all organisations participating in the abovementioned activities shall reflect its commitment to safety-promoting operating methods and solutions. Personnel shall be motivated to perform responsible work and an open working atmosphere shall be promoted in the working community to encourage the identification, reporting and elimination of factors endangering safety. Personnel shall be given the opportunity to contribute to the continuous enhancement of safety.

The significance of a safety culture as an important factor affecting safety has been widely acknowledged since the 1990s. The concept of safety culture was introduced shortly after the Chernobyl accident by the IAEA International Nuclear Safety Advisory Group (INSAG). The development of a safety culture is a continuous learning process. The safety culture prevailing in organisations does not remain unchanged but is constantly changing for internal and external reasons. Thus, proper procedures for continuous assessment and development of the safety culture must be used. In compliance with the safety culture principles, it is important that all organisations which influence safety sufficiently stress all factors influencing safety in all of their activities. An advanced safety culture shares many goals with quality assurance programmes, management practices and development of the atmosphere at work.

TVO defines safety culture in compliance with the INSAG 4 document of the IAEA:

"Safety culture is that assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance."

TVO has documented its high level of commitment to safety culture in the general section of its management system.

TVO plans to retain the Olkiluoto 1 and 2 nuclear power plant units in operation for a minimum of 60 years. In order to achieve this objective, the plants must be retained in good condition, which requires staff alertness in reacting to signs of ageing and any risks observed as well as in preventing such risks.

During the current operating licence period, TVO has assessed its safety culture through several methods. The safety culture has been regularly discussed in safety group meetings. Furthermore, personnel surveys and the Peer Review method and Early Warning survey of the World Association of Nuclear Operators (WANO) have been utilised. After these measures were implemented, TVO developed, in cooperation with the IAEA, a safety culture self-assessment procedure and tool.

TVO implemented a safety culture self-assessment in compliance with the IAEA model in 2004 and 2007. The self-assessment results show that TVO's safety culture is of a good level based on the IAEA scale. At present, TVO has two focus areas in safety culture development: learning organisation and zero tolerance, meaning that no deviations from safety-related requirements are allowed. A learning organisation is at the third and most advanced level of the IAEA safety culture assessment scale.

Another safety culture survey was implemented in the autumn of 2008 on the basis of a STUK initiative. In this survey, external experts were used. Based on the survey results, TVO states that the status of most of the safety culture aspects is as required from a nuclear power company. The most important aspects requiring development are ensuring competence, developing the handling process of safety-related issues, and encouragement of safety reporting. Furthermore, the survey team stated that the internal and external resources for abnormal conditions are insufficient in some places. The survey team also stated in its recommendations that project management of modifications requires extensive competence and TVO should study the sufficiency of its available competence, particularly in terms of the design bases, as well as take action to ensure competence in these areas. STUK already addressed the same issue when the operating licence was renewed in 1998. STUK supervises the implementation of the measures in the periodic inspection programme inspections, for example. The results of the safety culture surveys are also discussed in chapters 2.5, 5.2.1, 5.4.1 and 6.3.

TVO also regularly implements job satisfaction surveys. According to the results of these surveys, the atmosphere at TVO is good when compared with the national comparison data collected by the party that performed the survey.

During the operational licence period, TVO has arranged several safety culture events and training sessions for its staff, and the safety culture is addressed in introductory training provided to all persons who receive an access permit and also later during the induction process. Training for contractors' supervisors relating to annual outages also addresses safety culture issues.

TVO uses an application called Kelpo which personnel can use anonymously to report close call situations. Deviation reports are submitted using the application, and it is also used to monitor the implementation of repairs and corrective measures. An event report is drawn up for all safety-critical events or events significant for the operation. The report is used internally to observe any procedures that need to be revised. TVO studies the potential impact of human and organisational factors on operational events. Several procedural and organisational changes have been implemented on the basis of defects observed during the study of operational events.

TVO utilises a performance-based bonus scheme in which part of the bonus is specified on the basis of how well safety culture development measures have been implemented. In a safety management inspection in 2009, STUK imposed a requirement pertaining to the TVO bonus scheme which stated that TVO must continue the development of the bonus scheme to make the importance of safety more clearly visible to personnel. STUK will study the implementation of the measures based on this requirement in the next safety management inspection.

TVO regularly assesses, maintains and develops safety culture. TVO plans to implement the next safety culture self-assessments in compliance with the IAEA model in 2010 and 2013, and implement the necessary development measures based on the assessment results.

TVO addresses safety culture in surveys pertaining to the periodic safety review mainly as an internal organisation issue. One interpretation of section 28 of the Government decree is that the suppliers of a nuclear power plant have a central role in the development of safety culture. The most recent STUK guide, YVL 1.4, also promotes the significance of the supplier safety culture level. In the implementation decision of Guide YVL 1.4, STUK imposes requirements for the supervision of outsourced processes and functions as well as acquisition procedures. STUK supervises the development of the TVO management system in compliance with Guide YVL 1.4 utilising the implementation decision process.

The conclusion to the above is that TVO has implemented systematic procedures through which personnel are motivated in responsible working and that the safety culture development of the Olkiluoto 1 and 2 power plant units has been implemented in the manner referred to in section 28 of Government Decree 733/2008. TVO is committed to continuous development of its safety culture and STUK supervises the implementation of these measures in the scope of its periodic inspection programme and in its continuous oversight.

6.2 Section 29, Safety and quality management

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 safety is prioritised without exception, and that *quality management requirements correspond to the safety significance of the function. The management system shall be systematically assessed and further developed.*

Safety and quality management shall cover all functions influencing nuclear power plant safety. For each function, requirements significant in safety terms shall be identified, and the planned measures described in order to ensure compliance with requirements. The processes and operating methods shall be systematic and based on instructions.

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

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

Furthermore, as specified in section 7 j of the Nuclear Energy Act, *the management system of a nuclear facility shall pay particular attention to the impact of safety related opinions and the attitudes of the management and personnel towards the maintenance and development of safety, alongside systematic operating methods and their regular assessment and development.*

The TVO quality management system is described in the TVO management system. TVO has developed its quality management system during the operational licence term. During 1998–2001, the TVO quality assurance procedures were described in an operating quality assurance manual. After STUK's approval, TVO started using a comprehensive management system in 2001.

The purpose of the TVO management system is to provide every TVO employee with procedures to be used to ensure safe, competitive, high-quality and environmentally friendly electrical production. TVO has specified values and related ethical principles, and strict adherence to these is required in order to ensure the safety of production activities. In its management system, TVO requires personnel to follow the management system procedures and supervisors to ensure that their organisation follows the given procedures and regulations.

There are requirements for products and activities based on their safety implications. Tasks, responsibilities and authorisations important for nuclear and radiation safety are included in the Olkiluoto 1 and 2 nuclear power plant units' administrative rules.

TVO's management system consists of a general part and an activity part. In the general part of the management system, TVO describes the company policies, general business principles and requirements for safety and quality management. The activity part includes descriptions of activity processes as well as manuals and procedures guiding activities. The management system covers all issues influencing safety as specified in Guide YVL 1.9.

The quality assurance requirements and procedures to be adhered to when procuring nuclear fuel and planning its use at the Olkiluoto nuclear power plant are defined in a nuclear fuel procurement quality manual approved by STUK. According to STUK's assessment, most of the requirements included in Guide YVL 6.7 are met but TVO has failed to implement the audits of the quality management system of most important fuel suppliers' subcontractors as specified in the guide. The realisation of some of the requirements of Guide YVL 6.7, particularly those related to procurement included in Section 3 of the guide, has not been systematically verified. This is due, first of all, to document safety issues, which the guide does not directly oblige the licensee to take action on to verify these issues. Secondly, this is due to the fact that the entire issue is not clearly covered in STUK's periodic inspection programme. In the future, STUK will pay more attention to verification of these issues, and it will address this issue in its inspections. TVO submitted to STUK for approval the most recent update to the nuclear fuel procurement quality manual in October 2008. The decision regarding the update will also address the fulfilment of the YVL 6.7 requirements.

The TVO operational quality management system and its implementation are regularly monitored by TVO and STUK. TVO's assessment methods include TVO's internal audits, management reviews and safety culture self-assessments (see Chapter 6.1). The internal audits are implemented annually in accordance with a planned schedule. Approximately fifteen audits per year have been implemented during the current operational licence period.

TVO also uses external assessments, such as the Peer Review method of the World Association of Nuclear Operators (WANO) and third party assessments of its management system, which are based on international standards such as ISO 9001:2000 and ISO 14001:2004. TVO has several quality management certificates. In 2008, the following were in force: ISO 9001:2000, ISO 14001:2004 and OHSAS 18001:2007, among others.

WANO has assessed TVO's activities in 1999, 2001, 2006 and 2009. Based on the 1999 assessment, strengths (such as a monthly internal bulletin, a wireless telephone network, short annual outages as well as high availability and reliability levels) and a total of 20 issues requiring development (such as effectiveness of management and employees' behaviour related to safety at work, chemistry and radiation protection) were identified. The WANO follow-up report of 2001 stated that 69% of the development areas specified by WANO had been improved. The assessment in 2006 identified several good practices and a total of 29 development areas (such as risk management related to the health of individuals, addressing attitudes and promoting good practices in the field). Measures to develop the areas requiring development have been initiated, and according to TVO's own assessment, approximately 80% of these issues have been improved. The WANO follow-up report in 2009 stated that 53% of the development areas specified by WANO had been improved.

Since the operating licence was granted, TVO has implemented a system of management reviews. The reviews are conducted twice per year. In compliance with international standards, the management reviews deal with the status and applicability of the management system, focusing on quality management, environmental management, management of occupational health and safety as well as nuclear safety.

The general section of the TVO operations manual includes procedural guidelines for handling deviations. TVO utilises the Kelpo application in handling deviations. Deviation reports are submitted using the application, and it is also used to monitor the implementation of repairs and corrective measures. The status of measures correcting deviations is monitored in the management reviews. During the operational licence period, the time it takes to correct deviations has decreased.

TVO aims to control the commitment of its cooperation partners to a high safety and quality culture by means of an agreement and supplier assessment procedure. However, STUK imposed new requirements in this area in the implementation decision of the new Guide YVL 1.4.

The TVO management system is mostly consistent with the requirements of the new Guide YVL 1.4, except for some issues. STUK has imposed requirements regarding these issues in the implementation decision for the new Guide YVL 1.4. TVO submitted a development plan for the deviation handling process to STUK in February 2009. STUK approved the development plan with some remarks.

STUK has regularly inspected the quality management of TVO's Olkiluoto 1 and 2 nuclear power plant units. During the current operating licence period, no such deficiencies relating to the fundamentals or structures of quality management that would have an essential significance to safety or operations affecting quality have been observed. TVO has appropriately processed and rectified the single deficiencies observed in the implementation of quality management.

In 2008, TVO included an organisation-specific self-assessment in the activity planning process. TVO will further develop the organisation-specific self-assessment procedures. TVO has annually implemented assessments of the functionality and scope of the quality assurance activities in compliance with Guide YVL 1.9, except for the years 1999, 2006 and 2007. TVO has requested the approval of STUK for development of the quality assurance functionality and scope assessment procedure. STUK approved the TVO application with some remarks and required TVO to submit the specified procedure description for information. For the time being, TVO will implement the quality assurance functionality and scope assessments at least three times per year so that the assessments will cover all the aspects of the system important for nuclear and radiation safety. TVO will implement the first assessment of the functionality and scope of its management system in compliance with the new procedure by the end of 2009. STUK supervises the development utilising the implementation decision process of Guide YVL 1.4, inspections included in the periodic inspection programme and document inspection activities. Furthermore, STUK will supervise TVO's measures related to the recommendations of the safety culture survey team implemented in 2008 regarding modification practices, for example.

The conclusion to the above is that the safety and quality management of the Olkiluoto 1 and 2 nuclear power plant units has been implemented in the manner referred to in section 29 of Government Decree 733/2008. TVO has presented a plan for developing safety and quality management, and STUK will supervise the implementation of the measures using its periodic inspection programme and in connection with its continuous oversight.

6.3 Section 30, Lines of management, responsibilities and expertise

The lines of management in the organisation of a nuclear power plant, alongside the positions and related responsibilities of employees, shall be defined and documented. Furthermore, the operations of the organisation shall be monitored and continuously developed.

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

The organisation shall have access to professional expertise and technical knowledge required for the safe operation of the plant, the maintenance of equipment important to safety, and the management of accidents.

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

Furthermore, in compliance with section 7 i of the Nuclear Energy Act, *the holder of the licence granting the right to use nuclear energy (licensee) shall have a sufficient number of qualified personnel suitable for the related tasks. Only a person approved by the Radiation and Nuclear Safety Authority (STUK) for the position in question may act as a nuclear facility operator in the control room of the facility. The licensee shall appoint persons responsible for ensuring emergency response arrangements, security and the control of nuclear material. Only persons approved by the Radiation and Nuclear Safety Authority (STUK) specifically for each position can be appointed. The licensee shall ensure that the persons referred to above occupy the positions required for the task, while possessing adequate authority and the genuine prerequisites for bearing the responsibility vested in them.*

According to section 7 k of the Nuclear Energy Act, *the licensee shall appoint a responsible manager and his or her deputy:*
[…] 2) for the operation of a nuclear facility; […]

It is the responsible manager's task to ensure that the provisions, licence conditions and regulations issued by the Radiation and Nuclear Safety Authority (STUK) concerning the safe use of nuclear energy, the arrangements for security and emergencies, and the control of nuclear materials are complied with. The licensee shall ensure that the responsible manager occupies the position required by the task and possesses adequate authority and the actual prerequisites required for bearing the responsibility vested in him or her.[…]

According to section 119 of the Nuclear Energy Decree, *the Radiation and Nuclear Safety Authority (STUK) sees to it that the organisation available to the licensee is adequate and serves its purpose, that the persons participating in the use of nuclear energy meet the qualification requirements set, and that proper training has been arranged for them.*

Detailed requirements regarding the organisation and expertise related to section 30 of the Government Decree are included in Guide YVL 1.7, and procedures related to the approval of operators are included in Guide YVL 1.6.

The TVO management system specifies lines of management, responsibilities and important issues related to expertise in the administrative rules, the organisation manual and the training manual. The administrative rules specify tasks, responsibilities and authorisations important for nuclear and radiation safety. The rest of the organisation and its tasks are specified in the organisation manual. These documents have been drawn up in compliance with the requirements of Guide YVL 1.7. Organisational issues pertaining to emergency planning and preparedness are discussed in Chapter 8.

Representatives of TVO's shareholders participate in the management of the company in the meeting of shareholders as well as through the board of directors and committees named by the board. TVO's business is managed by the President and CEO who is responsible for the business and profit of the company and who reports to the board. Persons working directly under the President and CEO include the Executive Vice President, the directors of the Production, Engineering, Nuclear Safety, Corporate Resources, Finance, Corporate Relations and OL3 project departments, corporate advisers and the manager of the OL4 project. The President and CEO is assisted by the steering committee, whose members are the department directors and a personnel representative. In addition to the steering committee, TVO has an operative committee which only includes the directors.

The responsible director is the director of the Production department. TVO has named two deputies for the responsible director from the Production department. The Production department director and the Production department the director manages are responsible for all activities at the Olkiluoto 1 and 2 nuclear power plant units.

The TVO organisation aims to arrange personnel in such a manner that the set objectives are reached. The departments are divided into activities and offices whose tasks and responsibilities are described in the organisation manual. Furthermore, auxiliary staff units consisting of the corporate advisers work under the management of the directors. In addition to the standard organisation, TVO utilises a variety of project teams and other working groups.

There are committees for handling tasks involving several organisational units. These committees include representatives of the different units. Examples of these are the safety team, plant meeting, information security team, annual outage team, operational experience feedback team and ageing management team. The assemblages and tasks of the working groups are described in the organisation manual, except for the safety team, whose rules are specified in the administrative rules of the Olkiluoto 1 and 2 nuclear power plant units. Most of the safety team members are representatives from units other than the operational and project unit. The safety team may also include external experts. When handling the operational licence application in 1998, STUK stated in its assessment: *"Since the role of the safety team has changed after the establishment of the plant meeting more into a body monitoring principles and procedures, the requirements for improving the team's objectiveness should be reassessed. Expertise could be obtained from the Swedish sister plants, for example. This issue should be studied in more detail as a cooperation issue between similar plants, for example."* At present, the TVO safety team has a professor of the Helsinki University of Technology as a member from outside TVO. A representative of Fortum also has the right to participate in the safety team meetings. In practice, the safety team still mainly convenes as a TVO internal body, and thus the remark included in the operating licence statement is still valid. The safety team is a body providing recommendations and statements concerning nuclear safety and quality management issues. The chairperson of the safety team is the director of the Nuclear Safety department who also draws up an annual review of safety issues and safety culture for the TVO board of directors. The safety team convenes at least every three months.

The plant meeting is an advisory body for the Production department director. The plant meeting convenes once per month, with the aim of ensuring communication between the units. When convening to discuss an operating transient, the plant meeting is also a steering committee in charge of troubleshooting.

TVO has specified plant unit-specific main control room and plant area minimum staffing as well as shift personnel working hour regulations in the Technical Specifications. There are six shifts for each of the plants and a shared shift that rotates between the plant units.

TVO has an operating staff training team that has worked in 2003, 2004, 2006 and 2007 (four to eight people per team). The members of the team can be licensed as operators after approximately two years of training. The current practice is that a new training team is recruited approximately every two years. TVO follows Guide YVL 1.6 in operating staff recruitment, training and operator licensing. Operational experience feedback from the TVO plants and other plants is continuously used in operator training. Operators are trained for approximately fifteen days per year. There is a training simulator for operator training, and it is used to train plant engineering staff and also control room communication staff, for example.

The company has approximately 710 permanent employees of whom approximately 75% have a technical educational background or a natural sciences background, and approximately 20% have a Master-level degree. TVO's employee turnover rate is low, and most employees leave the company when they retire. TVO is currently undergoing a generational change. The employment contracts of approximately 250 employees have been in force for less than five years and the employment contracts of approximately 230 employees for more than 25 years. In 2008, TVO prepared procedures on strategic human resource planning that was submitted to STUK for information. The number of permanent TVO employees increased by 224 people between 1998 and 2008. The main increase occurred after 2004, mainly because of the Olkiluoto 3 project. The number of personnel employed by the Production department (called the Department of Operation between 2003 and 2007) for the Olkiluoto 1 and 2 nuclear power plant units has remained fairly stable during the entire current operating licence period. The number of people employed by auxiliary maintenance and operation functions has increased by approximately 20%, mainly because of the Olkiluoto 3 nuclear power plant unit project and the increased number of activities occurring at different parts of Olkiluoto (such as Posiva Oy).

In the TVO safety culture survey final report of 2008, the survey team provided its observations regarding human resources. The survey team stated that the internal and external resources for abnormal conditions are insufficient in some places, and that TVO should study the sufficiency of its available competence, particularly in terms of the design bases, as well as take action to ensure competence in these areas. Attention must still be paid to strategic HR planning and the sufficiency of personnel. STUK reviews the strategic HR planning guideline records and implementation of the guidelines in connection with its inspection programme.

TVO is preparing for the change of generation by maintaining comprehensive documentation in manuals, by recruiting replacements for all employees about to retire, two to three years before the retirement time, and by continuously developing the competence of personnel. HR development is guided by key competencies derived on the basis of the company strategy and competence requirements specified for employees. TVO utilises an IT system for monitoring these activities. The TVO training manual specifies procedures used to maintain and develop personnel competence. Each employee attends approximately ten training days each year. The events of the past few years, and particularly the events during annual outages at the Olkiluoto 1 and 2 nuclear power plant units, suggest that TVO needs to invest more in the development of personnel competence and in ensuring the competence of the personnel. In September 2009, STUK focused in a periodic inspection programme inspection on TVO HR planning and allocation, maintenance and development of personnel competence as well as supervisory work. STUK included in the inspection record a requirement that TVO must assess the competence assurance activities as a whole and draw up a development plan to make the activities more systematic and to improve quality. STUK requested TVO to submit the development plan, including a schedule and persons in charge, by 30 April 2010.

TVO also utilises external expertise whenever necessary. TVO aims to sign long-term cooperation agreements as long-term cooperation provides better preconditions for ensuring sufficient supplier competence. Supplier competence is studied in regular assessments, and external personnel are provided with introductory training and also other training if necessary.

The activities of the organisation are monitored by means of the TVO activity indicators (balanced scorecard and benchmarks) as well as a variety of assessments – for example, a job satisfaction and atmosphere survey performed by an outside expert. If necessary, the organisation is revised. In such cases, the safety implication assessment for the organisational change is carried out in compliance with the procedures included in the general part of the TVO operations manual.

TVO finds that the current procedures and their development will ensure clarity of the lines of management and the competence of the personnel during the remaining operating licence period.Furthermore, STUK will supervise TVO's measures related to the recommendations of the safety culture survey team implemented in 2008 regarding sufficiency of HR resources under abnormal conditions and in modification projects, for example.

The conclusion to the above is that the lines of management, responsibilities and expertise of the Olkiluoto 1 and 2 nuclear power plant units have been defined, described and implemented in the manner referred to in section 30 of Government Decree 733/2008. TVO is committed to continuous development of its management activities and organisation. As a result of the challenges imposed by the change of generation and the plant events in the past few years, ensuring personnel competence needs to be stressed more than before, in addition to the development of personnel competence. STUK will supervise the implementation of the measures using its periodic inspection programme and in connection with its continuous oversight.

7 Physical protection (Government Decree 734/2008)

7.1 Regulations and the related requirements

According to section 7 l of the Nuclear Energy Act, *arrangements for security during the use of nuclear energy shall be based on threat scenarios involved, 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.

The regulations for physical protection are defined in the Nuclear Energy Act, Nuclear Energy Decree, and Government Decree 734/2008. Detailed application procedures for the requirements and STUK's oversight are described in the classified Guide YVL 6.11, "Physical protection at nuclear power plants", and YVL 6.21, "Physical protection of nuclear fuel transports". Moreover, some YVL guides, such as YVL 1.0, YVL 2.0, YVL 5.5 and YVL 5.6, contain requirements where the need to consider unlawful actions against the nuclear power plant shall be taken into account.

Relating to new plant projects and significant modification projects concerning the existing plants, it has been observed that requirements concerning physical protection should be further specified in certain respects. These specifications have been presented to licensees in STUK's classified decisions in 2002. The events of 11 September 2001 in the United States were taken into account in the preparation of these decisions. New requirements concerning the specification decisions are mainly related to so-called external threats. In this context, external threats refer to such intentional or negligent external actions against a nuclear power plant which, without provisions against such actions, could endanger nuclear power plant safety. The requirements aim to take into account the long operating life of the plant units as well as the difficulties related to predicting the future as regards, for example, various disorders and crises in society. However, actual military operations have not been taken into account in the design basis. International agreements concerning military operations prohibit attacks on targets containing large amounts of energy, such as power plants.

7.2 Responsibility and control

According to law, the licensee is unambiguously responsible for the safety of the nuclear power plant. However, the licensee's means and authorisations are not adequate as such in, for example, a situation resulting from terrorism. Even then it must be possible to dimension the applicable countermeasures, both as regards the extent and timing of the verified threat. In addition to the licensee, the police and other authorities providing executive assistance to the licensee as required also have legal obligations to secure safety in the event of various unlawful circumstances. Therefore, the significance of cooperation between the safety authorities and the various parties should be emphasised in cases relating to threat situations and the provisions made for them at nuclear power plants. No acts classified as serious aimed at damaging nuclear power plants have occurred in Finland.

STUK also acts as the regulatory authority for physical protection in cases relating to the use of nuclear energy. The Council of State has summoned a separate expert team to provide safety precautions against unlawful action, and whose task is to regularly follow and assess threat scenarios and any changes to them, to develop operational preparedness and communication, to define guidelines pertaining to nuclear sector physical protection and to submit initiatives concerning them. In addition to STUK and experts from power companies, the team includes representatives from the main Finnish police and safety authorities. The member organisations of the team have an extensive international cooperation network through which information and opinions concerning international developments are forwarded to the team.

7.3 Physical protection arrangements and the assessment

STUK has assessed the currency and sufficiency of the physical protection of the Olkiluoto nuclear power plant on the basis of the requirements laid down in the Nuclear Energy Act, Government Decree 734/2008 and Guides YVL 6.11 and YVL 6.21, as well as on the basis of the specification decision concerning the guides, focusing on the changes in the national and international security situation during the past ten years and the impact of these factors on physical protection at nuclear power plants. In compliance with section 37 of the Nuclear Energy Decree, STUK has requested a statement from the Ministry of the Interior Police Department regarding TVO's physical protection. The issues included in the statement have been taken into account when preparing the decision on the periodic safety review and the safety assessment.

The safety plan of the Olkiluoto nuclear power plant describes the procedures used to prevent unlawful actions against the Olkiluoto 1 and 2 nuclear power plant units. The plan covers the structural and technical protection of the plant as well as administrative procedures. The plan and certain other documents concerning physical protection are handled as confidential documents. This is due to the fact that should they come into the possession of those planning unlawful actions, it could compromise the achievement of the objective of the security arrangements (Act on the Openness of Government Activities 621/1999, section 24, subsection 7).

According to STUK's assessment, the Olkiluoto nuclear power plant safety plan should be further developed. The safety plan must show by which means the licensee will implement the nuclear power plant's physical protection. The plan must be more comprehensive and detailed. A detailed example of the issues that must be included in the safety plan, pointed out in connection with a statement requested by STUK from the Ministry of the Interior, are TVO's procedures pertaining to protecting confidential information and the disposal of materials containing such confidential information.

TVO must submit the plan on the development of the safety plan to STUK for information.

The safety instruction rules submitted by TVO to STUK in August 2009 must also be supplemented. According to section 7 n of the Nuclear Energy Act, the licensee is obliged to document the operative main issues of the prevention of unlawful activities in the form of safety instruction rules. Issues to be included in the safety instruction rules include, for example, management of the safety organisation and arrangement of its operations, which in practice means definition of the basic activities of the safety organisation, such as safety organisation management and lines of management, staffing, on-call staffing, deputy arrangements, monitoring and supervision tasks and operational tactics. Furthermore, the safety instruction rules must also include the outfitting of the safety organisation: monitoring tools and technology, communication tools as well as other tools and accessories, also including the uniforms of those included in the safety organisation, and its protective equipment and forcible means equipment available as required for the tasks. TVO must submit the supplemented safety instruction plan to STUK for approval.

TVO has announced that it will periodically – every three years – arrange a comprehensive review of physical protection in compliance with Guide YVL 6.11, performed by a separately convened team in order to "ensure the correct level of physical protection". In the opinion of STUK, such reviews have not been performed. The most recent review was scheduled for 2009 but TVO failed to submit to STUK a plan regarding the review. The plan must be drawn up and submitted to STUK for approval.

A decision of STUK regarding physical protection, issued in 2002, included requirements that are currently also included in the Government Decree 734/2008. TVO submitted a report in connection with the periodic safety review including a statement of position regarding the implementation of the design bases presented in the abovementioned specification decision. STUK considers the submitted report insufficient. TVO must submit a plan on the development of these issues to STUK for approval.

TVO must assess the so-called plant area limitation of the Olkiluoto 1, 2 and 3 nuclear power plant units and the related plans. The assessment must be drawn up and submitted to STUK for approval.

The Ministry of Employment and the Economy (TEM) has ordered an IPPAS assessment (International Physical Protection Advisory Service) from the International Atomic Energy Agency (IAEA) pertaining to physical protection in Finland. The objective was to obtain an independent assessment of the planning, implementation and statutory supervision of the physical protection of nuclear power plants and radioactive sources by comparing them with Finnish regulations, international treaties, the IAEA recommendations and good practices.

The assessment team observed several good practices in Finland and compiled several recommendations and proposals based on its observations to further improve physical protection and its supervision. Positive observations included, for example, functional cooperation between nuclear power plants, the police and the Finnish Border Guard as well as a specific nuclear source registration system. The recommendations included, for example, supplementing regulatory guidelines based on the reformed legislation and increasing the number of regulatory inspections, including unplanned inspections.

The assessment was performed by a global team consisting of seven experts. The assessment was carried out by studying documentation, interviewing involved experts and observing the implementation of physical protection in Helsinki and at the nuclear power plant sites in Loviisa and Olkiluoto from 22 June to 3 July 2009. The results will be used when planning and implementing the Finnish physical protection infrastructure and the planning of physical protection for new nuclear power plants in particular. The IAEA final report on the assessment was completed in September 2009. TVO must submit to STUK a response pertaining to the IPPAS report recommendations and proposals on Olkiluoto.

Implementation of requirements by virtue of reformed legislation and the construction of the Olkiluoto 3 nuclear power plant unit will require additional physical protection resources. TVO must ensure the sufficiency of its physical protection staff and maintain their competence.

According to STUK's view, the arrangements for physical protection of the Olkiluoto nuclear power plant have been planned and implemented in a manner that makes it possible to prevent unlawful actions against the plant. According to STUK's assessment, the Olkiluoto nuclear power plant is not fully in compliance with the requirements of Government Decree 734/2008, which came into force in December 2008. STUK requires that TVO updates the safety plan and safety instruction plan as well as submits plans on the development of the above-mentioned issues. Furthermore, attention must be paid to the sufficiency of physical protection staff resources.

8 Emergency response arrangements (Government Decree 735/2008)

8.1 Regulations and the related requirements

According 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 9(2) of the Rescue Act (468/2003).

Emergency response arrangement regulations are included in the Nuclear Energy Act, the Nuclear Energy Decree and the Government Decree on Emergency Response Arrangements at Nuclear Power Plants (735/2008). Detailed application instructions for the requirements and the monitoring procedures of STUK are included in Guide YVL 7.4. Other YVL guides also include requirements pertaining to emergency response arrangements, including assessment of the environmental radiation condition, radiation and release monitoring as well as meteorological monitoring.

8.2 Planning emergency response arrangements and the emergency response organisation

TVO has analysed accident and safety-impairing events, and these are specified in the safety analysis reports for the Olkiluoto 1 and 2 nuclear power plant units and the interim storage for spent fuel (see Chapter 2.1.1 of the safety assessment). These analyses have been used as the basis for planning the Olkiluoto nuclear power plant emergency response arrangements. Emergencies are classified and described in the plant's emergency plan. The notifications and alarms to plant personnel and authorities required by different classes of emergencies, as well as the scope of operations of the emergency response organisation pertaining to the type of emergency, are described in the emergency procedures. A more specific description of the emergency response plan and its contents is included in Chapter 9 of Appendix 2.

Emergency response arrangements and procedures ensure the safety of personnel by planning on how they will be warned and extra personnel will be evacuated from the power plant area, including the Olkiluoto 3 power plant unit construction site.

The emergency response arrangements of the Olkiluoto nuclear power plant have been coordinated with the management of operation and the arrangements for physical protection. The emergency response plan includes separate guidelines for the fire brigade as well as descriptions on the activities and authority in the case of a fire and separately in the case of an emergency including a fire and in the case of an emergency not including a fire. The emergency response plan and the procedures have been reconciled with the rescue plan and procedures of the Olkiluoto 3 nuclear power plant unit that is currently under construction. The changes resulting from the regional restructuring of rescue operations and the initiation of emergency response centre operations have been updated into the emergency response plan.

A person responsible for emergency response arrangements and his deputy have been appointed for the Olkiluoto nuclear power plant. The emergency response organisation has been described in the emergency plan and procedures, updated with regard to personnel changes and contact information approximately once a year. The more limited staffing of the emergency response organisation required for emergency standby state is defined in the shift supervisor guide for the emergency response plan.

8.3 Preparedness

Provisions have been made at the Olkiluoto nuclear power plant for performing the measures required in an emergency and for analysing its effects and assessing its development. There are procedures on the activities of the emergency response organisation in the emergency response plan. The facilities of the emergency response organisation at the Olkiluoto nuclear power plant include procedures for operating transients and emergencies as well as a large amount of plant process and radiation status data in the process computer, some of which is automatically transmitted to the STUK emergency response centre. The data communication connections of the Olkiluoto 1 and 2 nuclear power plant units will also be upgraded in connection with the commissioning of the Olkiluoto 3 nuclear power plant unit.

Preparations have been made at the Olkiluoto nuclear power plant for assessing the radiation condition and dispersion of radioactive materials in accidents. Systems were developed by upgrading the external radiation dose rate monitoring network in the power plant area and at a five-kilometre range around the power plant area in the summer of 2008. Furthermore, three new radiation dose rate meters will be implemented in the power plant area in connection with the commissioning of the Olkiluoto 3 nuclear power plant unit. Instrumentation of the weather mast monitoring system was upgraded in the autumn of 2008. The ROSA application is used in calculating the dispersion of releases and environmental radiation exposure in the emergency response area.

The management of the Olkiluoto nuclear power plant emergency response organisation has facilities in both plant units in the nuclear power plant area. A backup facility is located in the plant's air raid shelter in premises renovated in 2005. All the facilities are equipped with a filtered emergency ventilation system. The facilities contain the equipment and software required for analysing the plant and radiation condition and for maintaining an overall picture of an accident, as well as the required software and background materials. There are assembly points for personnel in the power plant, protective equipment readily available for emergencies and facilities for personnel contamination monitoring and decontamination. TVO has stocked iodine tablets for personnel in the power plant area and in the new accommodation village.

The plant communications and alarm systems were developed during the current operating licence period by replacing the dedicated DigiPower dial connection with other redundant phone connections and by deploying a computer-based alarm system for alerting the emergency response organisation. This is also used for testing the availability of the emergency response organisation at regular intervals. Personnel will be alerted using a high power alarm, acoustic and light alarms indoors as well as speaker and telephone systems. Accident procedures for the residents of the accommodation village were reviewed in the spring of 2009.

Written procedures have been planned and drawn up for informing the media and the public, and these are regularly tested in emergency exercises.

8.4 Maintenance of preparedness

Emergency response training and exercises are annually arranged for the emergency response organisation of the Olkiluoto nuclear power plant. TVO has submitted the annual plans for emergency response training to STUK, as well as reports on their implementation. Further, STUK has also been provided with a longer-term plan for emergency response training and exercises. The emergency response training has included classroom and action group-specific practical training as well as special training, such as first aid, fire and radiation protection training. In addition to severe accidents, the emergencies covered by the emergency response exercises also included conditions classified as emergency standby. The content and scope of the training as well as feedback obtained for the training are assessed in the inspections of the STUK operational inspection programme. For several years, the Olkiluoto nuclear power plant has used double staffing in emergency response training, meaning that a more senior emergency response team guides a junior employee with the same tasks.

In addition to emergency response organisation training, attention has been paid to the emergency response training of others working at the plant site. Special attention has been paid to introductory training for the personnel of the Olkiluoto 3 nuclear power plant unit and the related activities of the Olkiluoto 1 and 2 nuclear power plant units in the event of an accident occurring when personnel are working in the power plant area.

The emergency response facilities and systems are maintained in operational order by utilising the preventive maintenance system. The emergency response plan is updated whenever necessary but at least once per year.

8.5 Action in an emergency situation

The control rooms of the Olkiluoto nuclear power plant are in constant readiness to initiate emergency operations. The shift supervisor serves as the emergency manager until the emergency manager appointed from within the emergency response organisation assumes responsibility for managing the situation. The emergency response plan contains a description of the emergency response organisation at the initial stage of its operation, as well as of the actual emergency organisation along with the related job descriptions. The procedures concerning notifications and alarms to the authorities have been updated with regard to emergency response centre operations. The means of communicating the overall picture of the situation have been developed by introducing procedures on communicating release data to STUK during an emergency situation.

The plant emergency manager's command responsibilities in an emergency situation have been revised due to amendments implemented in rescue legislation, and the related updates have been made in the emergency response plan and procedures. The plant emergency manager's procedures include procedures on providing recommendations on rescue measures to the rescue activity manager until STUK assumes responsibility for this. During the past few years, attention has been paid to the termination of emergency situations and debriefing measures. This has been instructed in the emergency manager's emergency procedures, and the activities concerning it have been tested in emergency exercises where the further measures required by the situation have been briefly assessed at the end of the exercise.

8.6 Measures relating to rescue operations

Section 9 of the Rescue Act includes planning obligations required for catastrophes for both nuclear power plants and their surroundings. The regional rescue authorities have procedures in place for accidents, and the environmental rescue plan for a Teollisuuden Voima Oy nuclear power plant radiation accident was updated on 25 July 2007. TVO has taken care of cooperation with the Satakunta Fire and Rescue Services for emergencies in joint meetings and when updating the rescue plan drawn up by the rescue services. On 25 April 2006, the Provincial State Office of Western Finland appointed an external safety cooperation committee for the Olkiluoto nuclear power plant, including representatives of TVO, STUK, the Finnish Meteorological Institute, the Provincial Police Command and the Rescue Department of the Provincial State Office of Western Finland, the Rauma Unit of the Satakunta Fire and Rescue Services, the Satakunta Emergency Response Centre and the Emergency Services College. The committee periodically prepares emergency response exercises implemented under the management of the Provincial State Office, monitors the implementation of development areas observed in the exercises in different organisations as well as prepares and implements joint training events. An emergency response exercise arranged in the autumn of 2008 tested the functionality of the procedures and the practical cooperation between the power company and the authorities. If necessary, TVO will participate in warning residents in the neighbouring areas using the high power alarm located in the nuclear power plant area.

Emergency operating procedures have been distributed to the population in the emergency planning zone, and iodine tablets were distributed to the population in the protective zone in 2009.

8.7 Summary

According to STUK's assessment, the emergency response arrangements of the Olkiluoto nuclear power plant are up-to-date and sufficient, and TVO is further developing preparedness for emergencies. The most important change in the next few years will be commissioning of the Olkiluoto 3 nuclear power plant unit that is currently under construction. The commissioning will require updating of the emergency response plan and other background materials as well as a review of the emergency response organisation assembly. The emergency response organisation facilities must be properly equipped, personnel must be trained and an emergency exercise must be arranged.

STUK has requested a statement of the Olkiluoto nuclear power plant emergency response arrangements from the Rescue Services Department of the Ministry of the Interior in compliance with section 37 of the Nuclear Energy Decree in connection with a periodic safety review of the Olkiluoto 1 and 2 nuclear power plant units. In the statement, the Rescue Services Department of the Ministry of the Interior finds that the TVO report has been appropriately drawn up, and the Rescue Services Department of the Ministry of the Interior does not have anything to comment on in the scope of its sector.

The conclusion to the above is that the emergency response arrangements of the Olkiluoto nuclear power plant have been implemented in the manner referred to in Government Decree 735/2008.

9 Nuclear waste management

According to section 20, paragraph 1, point 2 of the Nuclear Energy Act, a prerequisite for granting a construction permit for a nuclear facility is that *the methods available to the applicant for arranging nuclear waste management, including the final disposal of nuclear waste and the decommissioning of the facility, are sufficient and appropriate.*

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

9.1 Handling, storage and disposal of radioactive waste

According to section 16 of Government Decree 733/2008, *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 final disposal, and stored safely.* Furthermore, Government Decree 736/2008 includes more detailed requirements for the safety of final disposal of radioactive waste.

The starting point of the management of reactor waste by TVO is that the waste is taken care of at the Olkiluoto plant site, including its final disposal. No significant safety-related problems have emerged in the management of intermediate and low-level waste generated during the operation of the Olkiluoto nuclear power plant during the current operating licence period.

At the end of 2008, there was approximately 6,240 m^3 of intermediate and low-level waste. Approximately 80% of the waste has been finally disposed of. The total activity, excluding activated metal waste, was approximately 73 TBq. The accumulated waste volumes and activities were below average in international comparison when not taking into account the large equipment removed when modernising the Olkiluoto 1 and 2 nuclear power plant units.

Processing of low-level and intermediate level waste has been developed at the Olkiluoto nuclear power plant during the current operational licence period. The most important projects were an upgrade of bituminisation equipment used in the solidification of intermediate level waste, an expansion of the interim storage capacity to retain the large equipment removed during the modernisation of the plant units and the acquisition of a waste shredder for the intermediate level waste storage.

TVO is studying alternative methods of processing currently stored scrap metal and large equipment. Available alternatives include delivery to be melted, in which case some of the metal may possibly be released from the monitoring scope for recycling, or cutting up, packaging and final disposal of the scrap metal and equipment.

The final repository for radioactive waste was commissioned in 1992, and it has a separate operating licence that is valid until the end of 2055. A periodic safety review took place in 2006 in compliance with the operating licence condition.

STUK submitted a statement of the review to the Ministry of Employment and the Economy. A periodic safety review of the final repository will take place every fifteen years.

According to STUK's view, the methods for managing radioactive waste employed by TVO are appropriate and sufficient for managing the waste in a safe manner. The conclusion to the above is that the handling, storage and disposal of radioactive waste have been implemented in the manner referred to in section 16 of Government Decree 733/2008.

9.2 Processing, storage and disposal of spent nuclear fuel

According to section 15 of Government Decree 733/2008, *in the handling and storing of nuclear fuel, adequate cooling and radiation protection shall be ensured. Damage to fuel cladding during handling and storage must be prevented with a high degree of certainty. The possibility of a criticality accident shall be extremely low. Fuel storage conditions shall be maintained such that the leaktightness or mechanical endurance of a fuel assembly is not substantially degraded during the planned storage period.* Furthermore, Government Decree 736/2008 includes more detailed requirements for the safety of final disposal of radioactive waste.

Spent fuel from the Olkiluoto 1 and 2 nuclear power plant units is retained in water pools in the interim storage for spent fuel in the plant area until it can be disposed of in the disposal facility constructed by Posiva Oy. No significant problems have emerged in the storage of spent fuel during the current operating licence period.

At the end of 2008, there was approximately 1,225 tU of spent nuclear fuel at the Olkiluoto nuclear power plant. This amount does not include the fuel inside the nuclear power plant units' reactors. The interim storage contained approximately 995 tU of spent fuel. The interim storage is dimensioned for the amount of spent fuel the plant units will generate during thirty years of operation. According to TVO's estimate, the interim storage will have to be expanded by 2014. The currently valid operating licence allows expansion of the interim storage up to 1,800 tonnes of uranium by virtue of a plant change to be approved by STUK as specified in section 112 of the Nuclear Energy Decree.

TVO assessed the safety of the spent nuclear fuel interim storage in 2002. The assessment included observations and recommendations which TVO has taken into account in its operation. The most important of these included preparing a condition monitoring programme for the roof girders of the interim storage for spent fuel, a revision of the spent fuel transport cask handling procedures and improving the flood prevention system. Some improvements in the fuel transfer machine's operation have been implemented but according to the plan, the actual modernisation of the machine will take place at the end of the current operating licence period.

During this operating licence period, cracks were observed at the bottom surface of the reinforced concrete roof girders of the interim storage for spent fuel during TVO's in-service inspections. In order to ensure the durability of the roof structures, TVO performed a structural analysis that verified that the roof structures meet the durability requirements set for them. Nevertheless, TVO decided to support the roof by installing steel trusses above it in 2004. The steel trusses were installed in order to ensure that concrete will not fall from the cracks of the reinforced concrete roof girders into the spent fuel storage pools when the foundation of the Olkiluoto 3 nuclear power plant unit is quarried.

There are also spent fuel condition monitoring programmes for the Olkiluoto nuclear power plant. The purpose of these programmes is to ensure safe storage and processing as well as the fuel's sufficiently good condition for final disposal. In its current form, the Olkiluoto nuclear power plant spent fuel condition monitoring programme has been in force since 1988. According to the programme, the three selected fuel assemblies are visually inspected and two assemblies are inspected by means of oxide layer thickness measuring every ten years. During the current operating licence period, STUK approved updates of the condition monitoring programmes with its decisions C634/120, dated 24 May 2004, and C634/131, dated 20 January 2005.

The spent nuclear fuel disposal plan for the Olkiluoto nuclear power plant is based on the final disposal project of Posiva Oy, for which the related Government decision-in-principle was ratified by Parliament in 2001. STUK performed a preliminary safety assessment of the disposal project in 2000 based on Government Decree 478/1999. According to the present schedule, Posiva Oy will apply for a construction licence for the encapsulation and disposal facility in 2012 and an operating licence in 2018. The disposal of spent nuclear fuel could thus be commenced in 2020.

STUK oversees the spent nuclear fuel disposal project prepared by Posiva Oy in accordance with the Nuclear Energy Act. Monitoring of the underground research facility to be constructed in Olkiluoto is based on the principles outlined in STUK's letter Y819/22, dated 26 October 2001. By virtue of the decision issued by the Ministry of Trade and Industry (KTM) in 2002, Posiva Oy published an extensive report on the status of the final disposal project and the related research, development and design at the end of 2006. STUK has performed an expert review of the report, which was also submitted to the Ministry of Trade and Industry for information in late June 2007.

According to STUK's assessment, the methods for managing spent nuclear fuel employed by TVO, as well as the plans for their future improvement, are appropriate and sufficient for managing spent nuclear fuel in a safe manner. For more information on compliance of nuclear fuel processing and storage with the requirements of section 15 of Government Decree 733/2008, see Chapter 4.5.

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 related decommissioning plan being kept up to date as provided in section 28 herein. When the operation of a nuclear facility has been terminated, the facility shall be decommissioned in accordance with a plan approved by the Radiation and Nuclear Safety Authority (STUK). Dismantling the facility and other measures taken for the decommissioning of the facility may not be postponed without due cause.*

According to section 20 of Government Decree 733/2008, *the design of a nuclear power plant shall take account of decommissioning of the facility so as to limit the volume of waste destined for final disposal, accumulating during the dismantling of the plant, and the radiation exposure of workers due to the dismantling of the plant, and to prevent radioactive materials from spreading into the environment.*

According to a decision issued by the Ministry of Trade and Industry (7/815/91, KTM 19 March 1991), the plan concerning the decommissioning of a nuclear power plant must be updated every five years. TVO last updated the decommissioning plan for the Olkiluoto nuclear power plant in 2008. The Ministry of Employment and the Economy has requested a statement from STUK regarding this update (4363/815/2008, 9 January 2009).

The starting point of the decommissioning plan for the Olkiluoto nuclear power plant decommissioning plan is the decommissioning of the plant approximately 30 years after the termination of the monitored storage. According to the plan, all structures and components exceeding the limits for the removal of regulatory control will be disassembled from the plant and packed for disposal. The waste packages will be disposed of in facilities constructed in the close vicinity of the disposal facility. Reactor pressure vessels will be disposed of as such in separate shafts. The interim storage for spent fuel will not be disassembled until the disposal of spent fuel is implemented.

According to a STUK statement pertaining to the decommissioning plan (C822/287, 30 June 2009), the decommissioning plan for the Olkiluoto nuclear power plant is sufficiently comprehensive and detailed at this point. The decommissioning of the power plant and preparation for decommissioning can be implemented as specified in the plan. The conclusion to the above is that the decommissioning preparations of the Olkiluoto nuclear power plant have been implemented in the manner referred to in section 20 of Government Decree 733/2008.

10 Nuclear material safeguards

According to section 118 of the Nuclear Energy Decree, *the Radiation and Nuclear Safety Authority (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 party. 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 abovementioned supervision in accordance with the pertinent regulations.*

According 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 the control of nuclear material, as provided and defined in the Nuclear Energy Act and provisions issued thereunder, and in the Euratom Treaty and provisions issued thereunder, are met. The facility shall not contain premises, materials or functions, relevant to the control of nuclear materials, which are not included in the design information. The licensee shall have an accounting and reporting system for nuclear material and other nuclear commodity which ensures the correctness, scope and consistency of information in order to implement the supervision necessary for the non-proliferation of nuclear weapons.*

The nuclear safeguards are based on the Non-Proliferation Treaty (NPT) and the subsequent Safeguards Agreement signed by the IAEA, the EU Commission and the non-nuclear weapon states of the EU (INFCIRC/193), in addition to the national Nuclear Energy Act and Decree. The EU Commission also has its own safeguards system that is based on the European Atomic Energy Community (Euratom) Treaty. As regards safeguards arrangements, the relevant changes during the current operating licence period include the EU regulation concerning the control of dual-use items (Council Regulation EC No 1334/2000), the Commission Regulation on the application of safeguards (302/2005, 28 February 2005), and the additional protocol (INFCIRC/193a8, 30 April 2004) relating to the Safeguards Agreement signed by the non-nuclear weapon states of the EU, Euratom and the IAEA. Finland started implementing the improved safeguarding on 15 October 2008. Improved safeguarding refers to reconciling the Safeguards Agreement and the monitoring methods specified in its additional protocol, which means that the total number of IAEA inspections in Finland will somewhat reduce.

As regards the Olkiluoto nuclear power plant, TVO is obliged to comply with the nuclear material accounting and control manual approved by STUK and the applicable EU regulations. Furthermore, TVO is obliged to follow the accounting and monitoring manual for international nuclear material transfers, as approved by STUK.

STUK approved the most recent update of the Olkiluoto nuclear power plant nuclear material manual on 7 April 2009. In its decision, STUK required TVO to specify some parts of the manual, and TVO submitted the revised chapters to STUK on 1 July 2009. STUK approved TVO's accounting and monitoring manual for international nuclear material transfers on 4 May 2006.

TVO has submitted all reports and announcements required by the EU Council Regulation for the Olkiluoto nuclear power plant on time. The reports relating to the Olkiluoto nuclear power plant required by the additional protocol have been submitted to the IAEA and partly to the EU Commission within the time limits specified in the agreement.

STUK has supervised nuclear material activities at the Olkiluoto nuclear power plant. No major defects have been observed in the inspections, and TVO has properly corrected all defects observed. Furthermore, it has been observed in the inspections that TVO's own nuclear material monitoring system has been properly implemented and complies with the regulations. No remarks pertaining to the Olkiluoto nuclear power plants have been submitted in inspections performed by the International Atomic Energy Agency (IAEA) and the European Atomic Energy Community (Euratom) or the annual conclusions drafted on the basis of the monitoring of IAEA and Euratom. However, safeguarding nuclear materials has become more comprehensive with improved safeguarding after monitoring activities by virtue of the Safeguards Agreement and its additional protocol were combined. Improved safeguarding includes not only traditional monitoring activities but also other activities related to nuclear materials in the entire power plant area as well as inspections and inspection visits at short notice. This requires continuous readiness of the plant's own monitoring arrangements. The TVO organisation handling nuclear material safeguarding at the Olkiluoto nuclear power plant is not extensive enough for this purpose. Even if the person in charge of nuclear material safeguarding is absent, the plant must be able to completely handle its nuclear material safeguarding obligations.

In summary, it can be stated that the necessary controls to prevent the proliferation of nuclear weapons have been arranged in compliance with sections 118 and 118 b of the Nuclear Energy Decree at the Olkiluoto nuclear power plant. However, more attention must be paid to the sufficiency of the organisation handling nuclear material safeguarding due to the more extensive safeguarding practices.

11 Other requirements

In addition to the safety requirements specified in the Government decrees, a few other requirements relating to the safety of a nuclear facility are laid down in the Nuclear Energy Act. This chapter discusses the applicant's financial and other prerequisites to engage in safe operations and in accordance with Finland's international treaty obligations (section 20, subsection 1, paragraph 4 of the Nuclear Energy Act) to the extent falling within STUK's mandate. Furthermore, compliance with the conditions of the current operating licence of the Olkiluoto 1 and 2 nuclear power plant units is assessed.

11.1 The licensee's financial prerequisites to engage in operations

A licence to operate a nuclear facility may be granted if *the applicant is otherwise considered to have the financial and other prerequisites to engage in operations safely…* (section 20, subsection 1, item 4 of the Nuclear Energy Act). The financial preconditions are primarily assessed by authorities other than STUK (mainly the Ministry of Employment and the Economy). The licensee has financial obligations to, for example, make provisions for the costs of nuclear waste management (for the related technical aspects, see Chapter 9) and to cover the nuclear liability (see Chapter 11.2). The financial position and business environment of the licensee also affect the safety of plants, and STUK therefore keeps track of the trends in investments made in Finnish nuclear power plants to improve safety, as well as organisational reforms, the number of employees and the competence of personnel.

As the Finnish electricity market was deregulated more than ten years ago, there is relatively long practical experience of the operations of nuclear power companies in the deregulated market in Finland. TVO has adhered to a policy whereby the financial performance of operations is ensured by maintaining a high utilisation rate at the plant, meaning that even minor disturbances are to be avoided, which, in turn, requires that the plant units be kept in good condition. This requires investments that, for their part, contribute to the improvement of safety; proactive prevention of disturbances is always the primary goal in safety planning.

In the reports submitted to STUK in connection with the periodic safety review, TVO undertakes to continuously improve the safety of the Olkiluoto nuclear power plant in the future.

11.2 International treaties

The international treaties concerning nuclear material safeguards and matters pertaining to nuclear liability, nuclear safety and nuclear waste fall within STUK's mandate. In addition, Finland is bound by the treaty establishing the European Atomic Energy Community (Euratom) as well as by the obligations of the regulations and directives issued by virtue of it. These treaties have been incorporated into Finnish national legislation.

Nuclear liability – that is, the liabilities and obligations arising from nuclear damage – is prescribed by the Nuclear Liability Act (484/1972). The Nuclear Liability Act takes into account international treaties concerning Finland, which mainly set the minimum limits on the liabilities for nuclear damage. Raised liabilities can be enacted nationally, as is done in some countries.

The Nuclear Liability Act was last amended by legislation (493/2005) in which the amendments concerning, for example, the extent of liability of the operator of a nuclear facility, provided in section 18, required by the Protocol amending the Paris Convention and the Protocol supplementing the Brussels Supplementary Convention were incorporated into the Nuclear Liability Act. In the amendment, the extent of the licensee's liability to be covered by insurance is substantially increased to EUR 700 million (the present requirement is EUR 175 million Special Drawing Rights, which translates into approximately EUR 200 million). In addition, the revised agreements provide EUR 500 million from the host country and EUR 300 million from the states participating in an international convention to be used for compensation, which amounts to EUR 1.5 billion being available for compensating for the consequences of an accident in the new contractual arrangement. Finland's amended Nuclear Liability Act also imposes unlimited liability on the licensee to compensate for damage arising from an accident occurring in Finland.

The Nuclear Liability Act amended by legislation (493/2005) will enter into force by virtue of a Government decree to be issued at a later date. The entry into force of the new Nuclear Liability Act is connected with the entry into force of international treaties. As the progress of the national ratification of the treaties has been slow, the revised legislation is not yet in force.

TVO's liability insurance covers the separate nuclear power plants at the plant site, i.e. the Olkiluoto 1 and 2 nuclear power plant units as well as their nuclear waste management structures and the separate final repository for operating waste. The amounts insured currently fulfil the requirements laid down in section 18 of the Nuclear Liability Act. The Insurance Supervision Authority has assessed the liability insurance policies taken out by TVO and stated, by virtue of decision 22/499/2003, dated 30 December 2003, that they are acceptable. According to section 20, subsection 2 of the Nuclear Energy Act, the operation of a nuclear facility is subject to the licensee of the nuclear facility having arranged indemnification regarding liability in the case of nuclear damage as prescribed.

STUK assesses the liability insurance policies relating to transports in connection with each transport. The insurance has been appropriately arranged. In the case of TVO, the insurance cover has been provided by TVO agreeing with the necessary insurance on a case-by-case basis with the sending party.

The International Nuclear Safety Convention, Treaty Series 74/1996 (INFCIRC/449), a collection of top-level nuclear safety principles legally binding the states that have joined the Convention, was signed in 1994. Finland joined the Convention from the beginning, and it has been in force since 1996.

Furthermore, the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (the so-called Nuclear Waste Convention, Treaty Series 36/2001, INFCIRC/546) was signed in 1997. It is a collection of nuclear waste management principles legally binding the states that have joined the Convention. Finland joined the Convention from the beginning, and it has been in force since 2001.

The matters regulated by the International Nuclear Safety Convention and the International Nuclear Waste Convention are covered by Finnish legislation, Government decrees and regulations. The implementation of the conventions is reviewed at the meetings organised by the International Atomic Energy Agency (IAEA) every three years, for the purpose of which each Member State must submit a report on its actions. The previous international review meeting in which the implementation of the International Nuclear Safety Convention was assessed was held in April 2008, and the latest review meeting of the Nuclear Waste Convention took place in May 2009.

International treaties relating to nuclear material safeguards were discussed in section 10 above.

11.3 Compliance with the conditions of the plant's current operating licence

The Council of State granted Teollisuuden Voima Oy (from 1 January 2008, Teollisuuden Voima Oyj) an operating licence concerning the Olkiluoto nuclear power plant by virtue of resolution 31/812/96 on 20 August 1998. The operating licence for the Olkiluoto 1 and 2 nuclear power plant units and related buildings required for nuclear fuel and nuclear waste management is valid until 31 December 2018. The following licence conditions are presented in the operating licence.

By virtue of the licence issued with this decision, the licensee is allowed to possess, fabricate, handle, use and store nuclear waste and nuclear material as well as other nuclear substances as follows:

- *Spent nuclear fuel produced in connection with the operation of the Olkiluoto nuclear power plant in plant unit Olkiluoto 1 a total of 280* *tons of uranium, and in plant unit Olkiluoto 2 a total of 450 tons of uranium as well as a total of 1,800 tons of uranium in the interim storage for spent fuel. Increase of the capacity of the interim storage for spent fuel to 1,800 tons of uranium requires the Radiation and Nuclear Safety Authority's approval of the storage capacity increase in compliance with Section 112 of the Nuclear Energy Decree.*

- *Spent nuclear fuel produced in connection with the operation of the Olkiluoto nuclear power plant 400 m³ at both the Olkiluoto 1 and the Olkiluoto 2 nuclear power plant units, a total of 5,000 m³ at the interim storage for intermediate-level waste as well as a total of 3,000 m³ at the interim storage for low level waste. Increase of the capacity of the interim storage for intermediate-level and low level waste the amounts mentioned above requires the Radiation and Nuclear Safety Authority's approval of the storage capacity increase in compliance with Section 112 of the Nuclear Energy Decree.*
- *New nuclear fuel needed for the operation of the Olkiluoto nuclear power plant for which the regulations provided by the Nuclear Energy Act and Nuclear Energy Decree have been complied with.*
- *Other nuclear materials required in the operation of the Olkiluoto nuclear power plant as follows: nuclear material already existing at the plant site, as well as other substances, components and equipment mentioned in Section 2, Subsection 1, Point 4 of the Nuclear Energy Act in the import of which the regulations provided by the Nuclear Energy Act and Nuclear Energy Decree have been complied with.*

The licensee must carry out an intermediate safety assessment covering the Olkiluoto nuclear power plant by the end of 2008. The Radiation and Nuclear Safety Authority will issue a separate decision including specific regulations on the scope of the assessment.

Only the spent fuel produced in connection with the operation of the plant itself is owned, handled, used and stored at the Olkiluoto nuclear power plant. All spent fuel produced at the plant during the operating licence period is retained at the Olkiluoto 1 and 2 nuclear power plant units or stored in the spent fuel storage facility. The amount of spent fuel at the plant site has remained below the limit values specified in the operating licence conditions throughout the entire operating licence period. At the end of 2008, the Olkiluoto 1 nuclear power plant unit contained 192 tons of uranium, the Olkiluoto 2 nuclear power plant unit 191 tons of uranium and the interim storage for spent fuel contained 995 tons of uranium.

TVO has assessed the current maximum storage capacity of the interim storage for spent fuel as approximately 1,200 tons of uranium. TVO is planning to expand the storage within the next few years in compliance with the operating licence conditions of the Olkiluoto 1 and 2 nuclear power plant units as well as the construction licence for the Olkiluoto 3 nuclear power plant unit. STUK has established a separate project for the oversight of the expansion project.

Only the radioactive waste produced in connection with the operation of the plant itself is being possessed, handled, used and stored at the Olkiluoto nuclear power plant. The amount of radioactive waste in the plant units and the intermediate storage has remained below the limit values specified in the operating licence conditions throughout the entire operating licence period. Since 1998, the maximum amounts of waste in storage at the Olkiluoto 1 nuclear power plant unit has been 161 m³, at the Olkiluoto 2 nuclear power plant unit 207 m³, at the intermediate level waste storage 96 m³ and at the low-level waste storage 1,040 m³. Part of the waste produced at the plant is disposed of in the radioactive waste repository, at which point it falls within the operating licence conditions of the repository. The operating licence for the repository is valid until 31 December 2051.

Only the new fuel needed for the operation of the plant itself is owned, handled, used and stored at the Olkiluoto nuclear power plant. The regulations laid down in the Nuclear Energy Act and Decree have been complied with in the import of all nuclear materials, components and equipment present on the plant site.

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

12 Summary

Sections 5–7 of the Nuclear Energy Act (990/1987) contain the following provisions on the safe use of nuclear energy:

5§, *the use of nuclear energy, taking into account its various effects, shall be in line with the overall good of society;*

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

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.*

A licence is required for the use of nuclear energy (section 8 of the Nuclear Energy Act). According to section 20 of the Nuclear Energy Act, the licence to operate a nuclear facility may be granted if:

1. *the operation of the nuclear facility has been arranged so that the protection of workers, the population's safety and environmental protection have been taken into account appropriately* (sections 4 and 4.6 of the safety assessment);
2. *the methods available to the applicant for arranging nuclear waste management, including the final disposal of nuclear waste and the decommissioning of the facility, are sufficient and appropriate* (section 10);
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* (section 6.3.2);
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* (sections 12 and 13); *and*

the nuclear facility and its operation otherwise fulfil 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* (sections 3–13)*; 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 section 7.*

In this safety assessment, STUK has evaluated the realisation of those points that fall within its mandate as part of its periodic safety review.

With regard to section 20, subsection 1, paragraphs 1–3 of the Nuclear Energy Act, the arrangements for the Olkiluoto 1 and 2 nuclear power plant units, and the related buildings and storage facilities required for nuclear fuel and nuclear waste management are sufficient and adequate in respect of safety.

With regard to section 20 of the Nuclear Energy Act, STUK states that the Finnish electricity market has already been open to competition for ten years with no adverse effects in respect of the investments relating to the safety of the Olkiluoto nuclear power plant having been observed. The Finnish legislation and the practices of the licensee concerning it are, to the extent falling within

STUK's mandate, in accordance with international treaties.

No such factors on the basis of which the Olkiluoto nuclear power plant could be deemed not to comply with the principles laid down in sections 5–7 of the Nuclear Energy Act have arisen in the course of regulatory oversight carried out by STUK.

Relating to section 20, subsection 2, paragraph 1 of the Nuclear Energy Act, STUK states that the Olkiluoto nuclear power plant meets the safety requirements for operational nuclear power plants, the emergency preparedness arrangements are sufficient and the necessary control to prevent the proliferation of nuclear weapons has been appropriately arranged, with the reservations presented below. STUK also notes that the licensee of the nuclear facility has, as provided, arranged indemnification regarding liability in the case of nuclear damage. The physical protection of the Olkiluoto nuclear power plant is not yet completely in compliance with the requirements of Government Decree 734/2008, which came into force in December 2008. Further requirements concerning this issue are included in the decision relating to the periodic safety review.

12.1 Development areas relating to the safety of the nuclear power plant

The safety of the Olkiluoto nuclear power plant has been assessed in compliance with the Government Decree on the Safety of Nuclear Power Plants (733/2008), which came into force in 2008. The decree notes that existing nuclear power plants need not meet all the requirements set out for new plants (section 32 of Government Decree 733/2008). According to the principles set out in section 7 a of the Nuclear Energy Act, *the safety of nuclear energy use shall 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 and safety research and advances in science and technology.*

Most of the design bases pertaining to the Olkiluoto 1 and 2 nuclear power plant units were set in the 1970s. The objective during the operation of the plant units has been to continuously improve plant safety. Substantial modernisations have been carried out at the Olkiluoto 1 and 2 nuclear power plant units since their commissioning, and extensive modifications have been implemented in several systems in order to improve safety. The safety of the plant will be further improved during the current operating licence period. Based on the periodic safety review, TVO has submitted to STUK action plans for the observed points requiring improvement. These will be discussed next.

Risk factors have been systematically identified and eliminated using probabilistic risk analysis (PRA) during the current operating licence period. Examples of such plant changes at the Olkiluoto 1 and 2 nuclear power plant units include adding the possibility to eliminate possible spurious protection functions arising, as a result of an earthquake, in the main control room, reinforcing the lower access opening of the containment building's lower drywell and constructing a gas turbine plant at the plant site. However, it will be necessary to further continue the development of the PRA and the safety improvement measures at the plant units during the current operating licence period.

In order to ensure the electricity supply, a gas turbine plant was constructed at the Olkiluoto plant site in connection with the Olkiluoto 3 construction project. The turbine plant will also ensure the electricity supply for the Olkiluoto 1 and 2 power plant units. Nevertheless, the loss of off-site power is the most important initiating event in terms of core melt frequency. The core melt frequency and the most important initiating events are discussed in more detail in Chapter 2.1.3. In connection with the periodic safety review, STUK required TVO to submit a report on the possibilities to reduce the risk arising from the loss of off-site power and a plan on the measures needed to reduce the risk. In its reply, TVO listed the most important risk factors but not a plan for reducing the risks. In its decision C30-7/106, dated 30 April 2009, STUK required TVO to submit a plan on the diversification of systems important in a loss of power event. TVO submitted such a plan to STUK in September 2009. STUK will review the adequacy of the measures proposed by TVO to reduce the risk from common cause failures.

TVO has not submitted quantitative reviews on the basis of which it would be possible to assess the risk caused by oil leaking into the sea and the adequacy of the preparedness for oil releases. TVO shall submit a plan on supplementing the PRA with a risk assessment for oil releases.

The share of initiating events occurring during planned outages of the core damage frequency is significant. TVO has proposed to update the outage analysis by the end of 2010. After the update, possible changes required to reduce the risk will be assessed. Furthermore, TVO shall continue to develop the fire risk analysis in compliance with the update plan. STUK will oversee the implementation of the plans.

Analyses pertaining to the adequacy of the emergency cooling system capacity were last updated when the operating licence was renewed. At that time, the analyses showed that the safety margins of the Olkiluoto 1 and 2 power plant units in case of a primary circuit leak are large. These parts of the analyses were not updated in connection with the periodic safety review. When the operating licence was renewed, the analyses pertaining to loss of coolant accidents were performed on the presumption that the volume of water in the reactor under all conditions will be secured by a minimum of two subsystems of the emergency cooling systems. When reviewing the analyses that were updated in connection with the periodic safety review, STUK observed that the above-mentioned presumption does not comply with Guide YVL 2.2 under all conditions. As a result, TVO submitted a plan to update the analyses pertaining to the loss of coolant accidents in compliance with Guide YVL 2.2 by 31 December 2009. STUK will review the analyses when they are completed.

Nuclear power plants must maintain systematic procedures for the qualification of safety-critical equipment and structures, and to maintain documentation proving qualification. The qualification is to ensure that equipment and structures are capable of performing their functions in design basis operating conditions and accidents with sufficient margin while taking into account the loads and environmental conditions arising during them. In connection with the handling of the periodic safety review, STUK required TVO to submit a plan on developing the qualification follow-up system. TVO has established a working group to develop the lifecycle management of electronic and I&C equipment qualified for demanding conditions (such as a coolant loss accident).

With the development measures proposed by TVO, the qualification procedures of the Olkiluoto nuclear power plant are sufficient from the viewpoint of the periodic safety review. In addition to actual electronic and I&C equipment, there are other pieces of equipment (such as pneumatic actuators) for which operational requirements are imposed in case of special conditions arising due to an operating transient or an accident or after them. In the reports referred to in the action plan, TVO shall also establish how such components are listed and handled for the purposes of follow-up of qualification. The reports specified in the plan of action must be submitted to STUK for information in compliance with the planned completion schedule. Furthermore, the Westinghouse survey specified in the plan of action must also be submitted in connection with the first delivery. STUK will oversee the development of the qualification procedures as part of its periodic inspection programme and by reviewing the reports submitted to STUK.

The residual heat removal systems of the Olkiluoto 1 and 2 nuclear power plant units have not been designed in compliance with the diversity principle. As a result, there are no diverse systems in case of a loss of ultimate heat sink or a common cause failure in the systems used to remove residual heat. TVO has assessed the possibilities to construct a residual heat removal method independent on seawater. However, in its report submitted for the periodic safety review, TVO notes that implementing the studied system as such is not technically feasible. Nevertheless, STUK considers it important to systematically assess the application of the diversity principle at the plant and to develop it in compliance with the principles laid down in section 7 a of the Nuclear Energy Act. Instead of concentrating into separate safety functions, TVO must consider the plant as a whole. TVO shall submit to STUK for approval a comprehensive survey on the sufficiency of diversification at the Olkiluoto 1 and 2 nuclear power plant units and a plan on measures to develop diversification by the end of 2010.

The reactor level measurement system of the Olkiluoto 1 and 2 nuclear power plant units consists of four separate subsystems, two of which are sufficient for implementing the protection function. Both subsystems are based on differential pressure measuring. STUK has required application of the diversity principle in compliance with the principles set out in section 7 a of the Nuclear Energy Act in the design of the reactor level measurement system. The requirement set out in section 19 of Government Decree 733/2008 can be considered met when section 32 pertaining to operational plants has been taken into account. During the current operating licence period, TVO has presented in reports submitted to STUK the possibilities to supplement the currently used level measurement system with another system based on a different measuring principle. Based on these reports, STUK required in its decision C259/94, dated 13 October 2008, implementation of the main alternative proposed by TVO starting at the annual outages in 2012. Furthermore, STUK required TVO to study the reactor level measurement diversification needs pertaining to water level swelling by the end of 2010. STUK will oversee the implementation of the water level measurement system diversification.

In connection with the periodic safety review, STUK required TVO to submit reports on the risks inherent to the currently used shutdown and start-up method due to swelling of the reactor water level and the access of water into the steam pipes. If water were able to rise into the steam pipes, it could endanger the integrity of the primary circuit and the containment building. The access of water into the steam pipes is currently prevented by a system that automatically closes the steam pipe when the reactor pressure vessel water level is high with an isolation valve in order to stop the water level from rising. However, the swelling phenomena of the Olkiluoto 1 and 2 nuclear power plant units does not comply with the safety level required for new reactors in section 14 of Government Decree 733/2008 because the system used to secure the primary circuit and containment integrity does not comply with the diversity principle in the case of the fast closure and isolation signal in case of a high reactor water level. Based on the continuous improvement principle laid down in section 7 a of the Nuclear Energy Act, TVO shall implement plant modifications that will improve the safety of the Olkiluoto 1 and 2 nuclear power plant units in cases where the turbine by-pass valves suddenly open without cause. Prior to implementing the plant modifications, TVO must ensure by administrative means that the plant units will not be operated without a special reason with the isolation valves open at a power level where sudden opening of the turbine by-pass valves would cause the risk of water accessing the steam pipes due to the increased water level, except for a short time during shutdown or start-up.

In 2008, a significant event relating to the electrical systems occurred at the Olkiluoto 1 nuclear power plant unit. After the event, the trip conditions of the over-voltage protection relays and the opening conditions of the incoming feeders at the Olkiluoto 1 and 2 nuclear power plant units were modified in order to protect the main coolant pump drives from surges. The modifications lowered the risk of the main coolant pump drives triggering due to a surge but the repair measures are not sufficient from a deterministic viewpoint. In its decisions C542/35, dated 8 June 2008, and C30-7/106, dated 30 April 2009, STUK required TVO to draw up a plan on modification needs in the long-term in order to improve the surge protection of the main coolant pump drives. TVO submitted a plan to STUK in September 2009 and STUK has initiated the document review process.

In December 2007, TVO submitted to STUK a preliminary plan for the implementation of an emergency control room in compliance with the implementation decision of Guide YVL 5.5. In connection with the periodic safety review, STUK required TVO to assess its action plans so that the limited emergency control room function can be implemented during the current operating licence period. TVO proposed to implement the emergency control room in two stages. The first stage will consist of implementing the functions of the current emergency control post in a new separate emergency control room. The preliminary planning related to the implementation will be finished by the end of 2009, with a conceptual design plan by the end of 2010. According to the plan, the modification of the facilities for emergency control room use and installation of the equipment required will take place in 2011–2014. The second stage of the emergency control room implementation process will be related to the planned modernisation of the reactor operational and protection I&C. The implementation of additional functions provided by the new equipment in the emergency control room will be assessed and planned in connection with the modernisation. According to the plan, this will be done in 2016–2019. STUK will oversee the progress of the emergency control room implementation project.

In connection with its periodic safety review, STUK required clarification and updating of the procedures pertaining to the control room modification planning and implementation. TVO submitted a plan on improving the procedures to STUK. STUK will oversee the implementation of the plan.

STUK is of the opinion that the current best practices require procedure-specific justifying documentation for emergency operating procedures that include the procedure strategy, assumptions used when drawing up the technical features of procedure, references to analyses made when drawing up the procedure and other background information related to the procedure. Procedure verification and validation must be implemented in a systematic and comprehensive manner. The validation must be documented and assessed to ensure that the procedures are functional.

TVO shall submit to STUK for information by 30 November 2009 the comparison of the guides for the Olkiluoto 1 and 2 nuclear power plant units and the Olkiluoto 3 nuclear power plant unit included in TVO's memorandum 130694, "Action plan for developing emergency operating procedures". According to the action plan submitted to STUK, TVO has decided to divide the isolation procedures A, I, M and Y into operator-specific procedures. TVO shall prepare guide-specific strategy/justification documentation for the isolation procedures A, I, M and Y as well as assess the adequacy of the validation of the procedures and, if necessary, systematically validate the procedures before their implementation. The strategy/justification documentation for the procedures, a report on adequacy of validation and any plan on validating the procedures shall be submitted to STUK for information by 31 October 2010. Validation reports shall be submitted to STUK for information when they are completed. Procedure validation must be performed separately from the regular refresher training done with a simulator.

Based on the work specified above, TVO shall assess the need to develop other emergency operating procedures (including design extension conditions, severe accidents and shutdown states) as well as draw up further plans for developing the procedures by the end of 2011. This summary and the further measures specified on the basis of the summary shall be submitted to STUK for information. TVO shall continue the work with the procedures in compliance with the plan in such a manner, however, that the general emergency operating procedure, the related procedures, the strategy/justification documentation for outage procedures and validation of the procedures will be finished by the end of 2012. STUK will oversee the compliance with the requirements.

Based on its inspections and observations, STUK has stated that the Tech Spec need to be developed in order to ensure the document justification, clarity and unambiguousness. In connection with its periodic safety review, TVO submitted to STUK a plan on the development of the Tech Spec, according to which TVO plans to review, supplement and harmonise all the Tech Spec requirement and justification chapters by the end of 2009. The plan is to have the Tech Spec draft version assessed by the operational shifts and finalised by the persons in charge and the development team by the end of 2010. The plan is to initiate the regulatory review of the Tech Spec at the beginning of 2011. STUK has approved the Tech Spec development plan and will oversee the implementation of the plan.

TVO is preparing for the change of generation of workers by maintaining comprehensive documentation in manuals, by recruiting replacements for all employees about to retire, two to three years before the retirement time, and by continuously developing the competence of personnel. As a result of the challenges posed by the change of generation and the events that have occurred in the Olkiluoto 1 and 2 nuclear power plant units in the past few years, ensuring the competence of personnel needs to be stressed more than before in addition to the development of personnel competence. In September 2009, STUK focused in a periodic inspection programme inspection on TVO HR planning and allocation, maintenance and development of personnel competence as well as supervisory work. STUK included in the inspection memorandum a requirement that TVO shall assess the competence assurance activities as a whole and draw up a development plan to make the activities more systematic and to improve quality. STUK requested TVO to submit the development plan, including a schedule and the persons in charge, by 30 April 2010.

On the basis of the Safeguards Agreement and its additional protocol drawn up on the basis of the Nuclear Non-Proliferation Treaty, safeguarding nuclear materials has become more comprehensive that includes not only traditional monitoring activities but also other activities related to nuclear materials in the entire power plant area as well as inspections and inspection visits at short notice. This requires the continuous readiness on the plant's own safeguards arrangements. The TVO organisation handling nuclear material safeguarding at the Olkiluoto nuclear power plant is not extensive enough for this purpose. Even if the person in charge of nuclear material safeguarding is absent, the plant must be able to completely handle its nuclear material safeguarding obligations. More attention shall be paid to the sufficiency of the organisation handling nuclear material safeguarding due to the more extensive safeguarding.

12.2 Compliance with physical protection requirements

Physical protection issues included in the periodic safety review are handled using separate documentation and STUK's decisions. In compliance with section 37 of the Nuclear Energy Decree, STUK has requested a statement from the Ministry of the Interior Police Department regarding TVO's physical protection arrangements. The issues included in the statement have been taken into account when preparing the decision on the periodic safety review and the safety assessment.

According to STUK's view, the arrangements for physical protection of the Olkiluoto nuclear power plant have been planned and implemented in a manner that makes it possible to prevent unlawful actions against the plant. According to STUK's assessment, the Olkiluoto nuclear power plant is not fully in compliance with the requirements of Government Decree 734/2008, which came into force in December 2008. Furthermore, development needs in physical protection arrangements have been recognised in connection with the periodic safety review regarding continuous improvement of safety in compliance with the principles laid down in section 7 a of the Nuclear Energy Act.

TVO's current physical protection plan shall be updated. The physical protection plan must show by which means the licensee will implement the nuclear power plant's physical protection. The plan must be more comprehensive and detailed. A detailed example of the issues that must be included in the physical protection plan, pointed out in connection with a statement requested by STUK from the Ministry of the Interior, are TVO's procedures pertaining to protecting confidential information and the disposal of materials containing such confidential information. TVO must submit the plan on the development of the physical protection plan to STUK for information by 30 November 2009.

The security standing order submitted by TVO to STUK in August 2009 must be supplemented. According to the Nuclear Energy Act, the licensee is obliged to document the operative main issues of the prevention of unlawful activities in the form of security standing order. Issues to be included in the security standing order include, for example, management of the physical protection organisation and the arrangement of its operations, which in practice means definition of the basic activities of the physical protection organisation, such as physical protection organisation management and lines of management, staffing, on-call staffing, deputy arrangements, monitoring and supervision tasks and operational tactics. Furthermore, the security standing order must also include the outfitting of the physical protection organisation – monitoring tools and technology, communication tools as well as other tools and accessories, also including the uniforms of those included in the safety organisation – and its protective equipment and use-of-force equipment. TVO shall submit the supplemented security standing order to STUK for approval by 31 January 2010.

TVO has notified that it will periodically – every three years – arrange a comprehensive review of physical protection arrangements in compliance with Guide YVL 6.11, performed by a separately convened team in order to "ensure the correct level of physical protection". In the opinion of STUK, such reviews have not been performed. The most recent review was scheduled for 2009 but TVO failed to submit a plan regarding the review to STUK. The plan must be drawn up and submitted to STUK for approval by 30 November 2009.

A decision of STUK regarding physical protection, issued in 2002, included requirements that are currently also included in Government Decree 734/2008. TVO submitted a report in connection with the periodic safety review, including a statement of position regarding the implementation of the design bases presented in the above-mentioned decision. STUK does not consider the provided report sufficient, and TVO shall supplement its assessment on the compliance with the requirements of Government Decree 734/2008. TVO shall submit a plan on development of these issues to STUK for approval.

TVO shall assess the so-called plant area delimitation of the Olkiluoto 1, 2 and 3 nuclear power plant units and the related plans. The assessment shall be drawn up and submitted to STUK for approval by 31 December 2009. Changes pertaining to area delimitations cannot be implemented before STUK's approval.

The Ministry of Employment and the Economy (TEM) has ordered an IPPAS assessment (International Physical Protection Advisory Service) from the International Atomic Energy Agency (IAEA) pertaining to physical protection arrangements in Finland. The assessment was carried out by studying documentation, interviewing the experts involved and observing the implementation of physical protection in Helsinki and at the nuclear power plant sites in Loviisa and Olkiluoto from 22 June to 3 July 2009. The assessment team observed several good practices in Finland and compiled several recommendations and suggestions on the basis of its observations to further improve the physical protection and its supervision. The results will be used when planning and implementing the Finnish physical protection infrastructure and the planning of physical protection for new nuclear power plants in particular. TVO shall submit to STUK a response pertaining to the IPPAS report recommendations and suggestions on Olkiluoto NPP by 31 December 2009.

Implementation of requirements by virtue of reformed legislation and the construction of the Olkiluoto 3 nuclear power plant unit will require additional resources for physical protection arrangements. TVO shall take care of the sufficiency of its physical protection personnel and maintain their competence.

12.3 Conclusion

In conclusion, STUK's overall evaluation is that, with regard to matters falling within its mandate, the prerequisites of section 5–7 and section 20, subsection 1 of the Nuclear Energy Act for granting an operating licence for the Olkiluoto 1 and 2 nuclear power plant units and the related buildings and storage facilities required for nuclear fuel and nuclear waste management are still met. In connection with the preparation of this safety assessment, STUK has noted that the issues and arrangements referred to in section 20, subsection 2, paragraph 1 of the Nuclear Energy Act are in order.

Based on its review, STUK imposes requirements related to compliance with the requirements of the Government decrees that were revised in 2008 on nuclear plant safety and physical protection. STUK provides a reasonable time to take into account the requirements on physical protection in the operation of the plant and in the operations of TVO because the requirements did not enter into force until at the end of 2008. In the case of compliance with the decree on nuclear plant safety, STUK is of the opinion that the Olkiluoto nuclear power plant complies with the requirements set out for already existing plants and that the requirements specified above are given in order to ensure the continuous improvement of safety by virtue of section 7 a of the Nuclear Energy Act.

As a summary of the review of the issues and documentation pertaining to the periodic safety review and the continuous oversight results, STUK notes that the safety of the Olkiluoto 1 and 2 nuclear power plant units is sufficient and the licensee utilises the necessary arrangements to continue the safe operation of the plants.

TVO has prepared its own periodic safety review on the status of the Olkiluoto 1 and 2 nuclear power plant units as well as the interim storage for spent fuel, intermediate level waste and low-level waste, possible development areas and the maintenance of safety in compliance with Guide YVL 1.1.