APPENDIX 1 STUK’s safety performance indicators for NPPs in 2011

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Summary of the safety performance indicators for nuclear power plants

Background and objectives of the indicator system

Safety is a primary prerequisite for the operation of nuclear power plants. The power companies and STUK evaluate and oversee the safety and operation of the plants in many ways. Along with inspections and safety reviews, indicators are a method of acquiring information on the safety level of the plant and on any changes to the safety level. The STUK indicator system consists of two main groups: 1) plant safety indicators, and 2) indicators describing the efficiency of the authorities. This summary covers the indicators describing plant safety.

The objective of the indicator system is to recognise changes in plant safety as early as possible. If the indicators weaken, the factors behind the development are investigated and changes to plant operation and STUK’s oversight of the area are considered. Indicators can also be used to monitor the efficiency and effectiveness of the corrective measures. The information yielded by the indicators is also used when communicating nuclear safety.

In the indicator system, nuclear safety is divided into three sectors: 1) safety and quality culture, 2) operational events, and 3) structural integrity. STUK began the development of its own indicator system in 1995. Since 2006, indicator information has been managed in STUK’s INDI (INdicator DIisplay) information system. Nominated STUK representatives are responsible for the maintenance and analysis of the indicators. Individual indicators, their maintenance procedures and the interpretation of results are presented at the end of this summary. A brief summary of the safety situation in each plant in 2011 is presented below, followed by the detailed results by indicator.

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Results of the safety performance indicators for the nuclear power plants in 2011

Summary of indicator results for the Loviisa power plant

Structural integrity
In 2011, neither plant unit reactor in Loviisa had any leaking fuel, meaning that fuel integrity was good. The low activity values of primary coolant during shutdown of the plant units for annual maintenance outages indicated the success of the shutdowns from the perspective of radiation protection.

The indicator system values show that both plant units have enjoyed good primary circuit integrity during 2011.

The indicators show that the leak-tightness of outer containment isolation valves has improved from the previous year at both Loviisa plant units. The indicator describing the overall as-found leakage of the personnel airlock, material airlock, emergency personnel airlock, reactor pit, inward relief valves, cable penetrations and bellows seals (RA, RL, TL23), is good at both plant units.

Radiation doses and releases
The radiation doses received by employees and the releases into the environment remained small and clearly below the limits set in official regulations. The total time spent on annual maintenance outages was short, and there were few operations of significance for radiation protection. Consequently, the total collective dose of the Loviisa power plant was the lowest ever in the history of the Loviisa NPP. The releases into the environment were small, well below the set limits.

Operational events at the plant
No reactor trips occurred at the Loviisa plant units during 2011. The one event classified as an operational transient at Loviisa 1 was a turbine trip. The leaking seal in the steam generator flange was a significant operational event at Loviisa 1. The plant unit was shut down for a short outage to repair the seal. The operational events had no safety significance. The annual maintenance outages were so-called refuelling outages. For the
Lovisa power plant, the most significant factors affecting the overall accident risk include internal plant events during outages (such as falling heavy loads in the reactor hall), fire, a high level of seawater during power operation and oil spills during a refuelling outage. The annual probability of a severe reactor accident calculated for the Lovisa plant units has decreased by about 17% from the previous year. Several minor plant modifications and the improvements of computational modelling have contributed to the reduction of the risk. Lovisa power plant’s accident risk has continued to decrease over the last 10 years, and new risk factors discovered as the scope of the risk analysis has been extended, have been systematically removed.

The functionality of safety systems is monitored at the Lovisa power plant on the basis of the unavailability of the high-pressure safety injection system, the emergency feedwater system and the emergency diesel generators. The unavailability of the emergency make-up water system at Lovisa 2 increased somewhat from the previous year due to pump motor failures and the poor availability of spare parts. The indicators show that the maintenance of and fault repairs to components important to safety was otherwise appropriate.

There were no events classified as fires at the Lovisa power plant or in its immediate vicinity in 2011. The power plant’s fire detection system had a similar number of faults as in the previous year. The average fire safety of the Lovisa plant has remained at the same level.

### Summary of indicator results for the Olkiluoto power plant

#### Structural integrity

The impurity and corrosion product levels in reactor water and feedwater, followed in STUK’s indicator scheme, were in keeping with the guide values set by the license holder at both plant units almost throughout the year. The indicators show that reactor circuit integrity has been good at the Olkiluoto plant units in 2011.

In 2011, fuel integrity was good at Olkiluoto 1. Two fuel leaks were observed at Olkiluoto 2. A fuel leak was detected immediately after the 2010 annual maintenance outage, and the leaking fuel assembly was removed from the reactor during the 2011 annual maintenance outage. The leak remained very small throughout this time. A new fuel leak was detected at Olkiluoto 2 on 5 August 2011. The leak has remained small throughout the monitored period, and the leaking fuel assembly will be removed from the reactor during the 2012 annual maintenance at the latest. Several fuel leaks have occurred in the 2000s at the Olkiluoto plant units, particularly at Olkiluoto 2. The main reason for the leaks has been small loose objects entering the reactor during maintenance operations. Among other things, foreign object sieves of a new type have been designed for the fuel assemblies in order to prevent loose objects from entering the assemblies. Fuel assemblies fitted with these are to be introduced in 2012.

The total as-found leakages of outer isolation valves at the Olkiluoto 1 plant unit was extremely small, clearly below the limit set in Tech Specs. At Olkiluoto 2, the as-found leakage of the outer isolation valves was also below the limit set in the Tech Specs and has remained approximately the same as before. The percentage of isolation valves that passed the leak tightness test at first attempt has remained high for both plant units. The total as-found leakage rate of containment penetrations, in which TVO includes leakages in the upper and lower personnel airlocks, the maintenance dome and the containment dome, has remained small for both plant units.

#### Radiation doses and releases

The radiation doses received by employees and the releases into the environment remained small and clearly below the limits set in official regulations. At Olkiluoto, the radiation dose of employees was the lowest in the power plant’s operational history. The releases of substances with gamma activity into the sea from the Olkiluoto power plant have been decreasing in recent years. In 2011, the atmospheric releases of radioactive substances were of the same magnitude as in previous years.

#### Operational events at the plant

For the Olkiluoto power plant, the most important factors affecting the overall accident risk include internal events during power operation (component failures and pipe ruptures leading to an operational transient). In 2011, the annual probability of a severe reactor accident calculated for the Olkiluoto plant increased by approximately 30%
The production losses due to failures were higher than in previous years. This is particularly due to the fact that there were three maintenance outages during which inspections and repairs were carried out. The production losses due to failures at Olkiluoto 1 during 2011 were mainly (>80%) caused by the maintenance outages in June and August. In June, inner parts of the primary circuit overpressure protection and residual heat removal system valves were inspected and damaged parts were replaced. The inspections were made following the observations made during the annual maintenance outage at Olkiluoto 2. In August, the motor of one main circulation pump was replaced by an overhauled pump because the motor's vibration levels had been increasing during the operating cycle. The inspections revealed that this was caused by a damaged bearing. The production losses due to failures at Olkiluoto 2 were mainly (>70%) caused by the maintenance outages in August, in which inner parts of the primary circuit overpressure protection and residual heat removal system valves were replaced. The damage was discovered during the annual maintenance outage in May–June. Not all parts could be replaced at that time due to an insufficient inventory of spare parts. A root cause report was produced for this event.

Based on data from the last 10 years, the average number of annual events warranting a special report or a transient report is five. The number of events warranting a special report in 2011 (2) was below the average. In contrast, the number of events warranting a transient report (9) was above the average. Both special reports concerned faults in the emergency diesel generators. The events are described in greater detail in Appendix 3 to the report. The majority of transient reports (6 out of 9) concern the main circulation pumps. As a rule, operational transients do not warrant any actions on STUK's part.

A latent fault was discovered in 2011 at Olkiluoto 1 in an emergency diesel generator, making the addition or risks due to faults in 2011 larger than in previous years. In 2011, the unavailability of EDGs was over four times higher than in 2010 because of faults detected in exhaust manifolds and exhaust pipes, the highest figure ever recorded while the parameter has been monitored. However, the risk significance of events at the Olkiluoto plant in 2011 remained, on average, at the level of previous years. The number of failures occurring and preventive maintenance operations carried out during power operation and causing the unavailability of components subject to Technical Specifications increased somewhat from 2010.

Fire safety has remained at the 2010 level, i.e. no events classified as fires occurred in the Olkiluoto plant area (OL1/2) in 2011.
Safety performance indicators

A.I  Safety and quality culture

A.I.1  Failures and their repairs

A.I.1a  Failures of components subject to the Operational Limits and Conditions

Definition
The number of failures causing the unavailability of components defined in the Operational Limits and Conditions (OLC components) during power operation is monitored as an indicator. The failures are divided by plant unit into two groups: failures causing an immediate operation restriction and failures causing an operation restriction in connection with repair work.

Source of data
The data is obtained from the work order systems and the operational documents of the power plants.

Purpose of the indicator
The indicator is used to assess the plant life-cycle management and the development of the condition of components.

Responsible units/persons
Operational safety (KÄY), resident inspectors
Pauli Kopiloff (Loviisa nuclear power plant)
Jarmo Konsi (Olkiluoto nuclear power plant)

Interpretation of the indicator

Loviisa
In 2011, the number of failures in OLC components causing an operating restriction was 164, while in 2010 it was 204. The number of failures was lower than the average of the four preceding years (190). No single significant reason can be identified for the decrease.

The number of failures per year has remained stable. Any variation therein has been caused by the random occurrences of failures that occur in any large number of components. Failure detection and anticipation have been continuously improved in plant maintenance operations at Loviisa, and components have been replaced. Thanks to these
measures, the operability of components significantly affecting the safe operation of the plant has remained well under the NPP’s control.

Based on the above, it can be stated that the indicator or the failure data behind it does not show any significant negative effects associated with the ageing of facilities, which is an indication of well-functioning component life-cycle management and component maintenance.

Interpretation of the indicator

**Olkiluoto**
The number of failures occurring during power operation and causing the unavailability of components subject to Operational Limits and Conditions has been increasing since 2009. The number of failures occurring in 2011 was almost double compared to the failures in 2009. The number of failures had decreased during the period 2007–2009. The number of failures indicates that maintenance work has been successful.

The unavailability times of OLC components at OL1 were short during all quarters of 2011 except for the failure of a valve in the containment building gas treatment system that occurred during the first quarter. The failures occurring during the third quarter mainly concerned the seawater system of a shut-down reactor.

At OL2, the failures during the first quarter of 2011 mainly consisted of cases of unavailability of the diesel generator. The unavailability times of OLC components were in the main short.

Heat exchanger washing operations increased the number of operation restrictions at both plant units.
A.I.1b  Maintenance of components subject to the Operational Limits and Conditions

**Definition**
As the indicator, the number of fault repairs and preventive maintenance work orders for components defined in the OLCs are followed by plant unit.

**Source of data**
The data is obtained from the plant work order systems, from which all preventive maintenance operations and fault repairs are retrieved.

**Purpose of the indicator**
The indicator describes the volumes of fault repairs and preventive maintenance and illustrates the condition of the plant and its maintenance strategy. The indicator is used to assess the maintenance strategy executed at the plant.

**Responsible units/persons**
Operational safety (KÄY), resident inspectors Pauli Kopiloff (Loviisa nuclear power plant) Jarmo Konsi (Olkiluoto nuclear power plant)

**Interpretation of the indicator**

**Loviisa**
A new IT system was commissioned at the power plant in 2006. The scope of the indicator was changed in conjunction with the IT system revision. The annual maintenance operations also included the work for such components covered by OLCs to which no operating restriction applied. Due to the IT system change and the extension and further specification of the scope of the figures, the maintenance figures are only fully comparable for the last six years.

When considering the variation in the volume of fault repairs and particularly in the number of preventive maintenance works, the scheduling of various annual maintenance works (fuel replacement outage, four-year annual maintenance, brief annual maintenance, eight-year annual maintenance) included in the maintenance strategy of the Loviisa power plant during a four-year cycle should be considered as this can have a significant impact on the annual figures. The Loviisa plant units had short refuelling outages in 2011.

Judging by the data behind the indicator, 2011
was markedly different from the previous years as concerns the number of fault repairs and amount of preventive maintenance. The number of maintenance operations on OLC equipment reduced from the previous year by 19%, so that the reduction in preventive maintenance operations was 14%, while the reduction in fault repairs was 39%. Due to the fact that the reduction was different in the different types of work, their ratio changed significantly from 4.6 in 2010 to 6.5 in 2011.

The large share of preventive maintenance operations reflects the selected maintenance strategy, the purpose of which is to keep the number of faults and the effects of faults at a tolerable level.

The decrease in the fault repairs included in the indicator and the ratio of preventive maintenance operations to fault repairs may be regarded as an indication of a functional maintenance strategy.

Interpretation of the indicator

Olkiluoto

The data for the indicator is obtained from the plant work order system and operating documentation. Due to changes in the work order system implemented by the power company from 1 January 2006, the data is not comparable with the figures for earlier years. Class 3 data (systems subject to the Operational Limits and Conditions (OLCs)) has been removed from the work order classification, since the Class 3 category covers all systems specified in the OLCs. Nowhere near all of these systems are subject to restrictions set out in the OLCs. As a result, this indicator is used to monitor the ratio of the number of preventive maintenance works causing the unavailability of components to the number of fault repairs.

The number of maintenance works causing the inoperability of components, included in the indicator, has been decreasing during 2006–2009 due to the decreasing number of fault repairs. In 2010, the number of fault repairs increased while the number of preventive maintenance operations decreased.

In 2011, the number of fault repairs causing unavailability increased at both plant units from 2010. At the same time, the number of preventive maintenance operations increased by 30% with the result that the ratio of preventive maintenance operations to fault repairs is better than in 2010.

Based on the development of the ratio of preventive maintenance work to fault repairs and the assessment of the work behind the figures, the maintenance strategy can be considered functional.
A.1.1c Repair time for components subject to the Operational Limits and Conditions

**Definition**
As the indicator, the average repair time of failures causing the unavailability of components defined in the OLCs is monitored. With each repair, the time recorded is the time of inoperability. It is calculated from the detection of the failure to the end of the repair work, if the failure causes an immediate operation restriction. If the component is operable until the beginning of repair, only the time of the repair work is taken into account.

**Source of data**
The data is obtained from the work order systems and maintenance, and the operational documents of the power plants.

**Purpose of the indicator**
The indicator shows how quickly failed OLC components are repaired in relation to the repair time allowed in the OLCs. The indicator is used to assess the strategy, resources, and effectiveness of plant maintenance.

**Responsible units/persons**
Operational safety (KÄY), resident inspectors
Pauli Kopiloff (Loviisa nuclear power plant)
Jarmo Konsi (Olkiluoto nuclear power plant)

**Interpretation of the indicator**

**Loviisa**
The Operational Limits and Conditions define the maximum allowed repair times for components based on the components’ safety significance. The times vary between four hours and 21 days. Failures in OLC components are to be repaired within the allotted time without undue delay.

Due to the small amount of work requiring operation restrictions and the varying allowable repair times, an individual operation may have a significant effect on the indicator value even when it is performed within the allotted time. This aspect of the indicator is taken into account in the interpretation of the indicator by evaluating the significance of individual long-term failure repairs in terms of maintenance strategy, resources, and efficiency of operations.

The average repair times for failures causing the unavailability of components have remained stable at the Loviisa plant for several years. However, a decreasing trend can be seen over the last three years in these times. In 2011, the average repair time at the plant units was 23.4 hours while the average for the four preceding years was 33.0 hours. The average repair time of OLC component failures that had an allowed repair time of 72 hours or less was 11.1 hours at LO1 and 14.3 hours at LO2 in 2011.

Based on the 2011 indicators and the data behind them, the plant’s maintenance operations can be considered appropriate. In spite of the positive development in repair times, attention needs to be paid to the power plant’s maintenance on having the necessary resources available for fault repairs and on carrying out the repairs without unnecessary delays.
Interpretation of the indicator

Olkiluoto

The indicator is used to monitor the repair times of components subject to the Operational Limits and Conditions. The repair time allowed in the Operational Limits and Conditions is usually 30 days for faults concerning one subsystem and three days for faults concerning two subsystems. Depending on the system and the component, other allowed repair times may be defined in the Operational Limits and Conditions.

Over a longer period, the average repair time has varied from six to ten hours with the exception of 2007. In that year, repair times increased strongly for both plant units to 1.5 times the previous figure at OL1 and to more than six times the previous figure at OL2. For both plant units, the increase was due to a failure in a single device. In 2011, the average repair time of failures causing the unavailability of components defined in the Operational Limits and Conditions was about six hours at OL1 and about seven hours at OL2. At both plant units, the average repair time of failures causing the unavailability of components defined in the Operational Limits and Conditions was of the same order of magnitude as in 2010.

On the basis of the 2011 indicators and the data behind them, the plant's maintenance operations met the requirements.

A.I.1d Common cause failures

Definition

As the indicator, the number of common cause failures of components or systems defined in the OLCs is followed.

Source of data

Data for the indicators is collected from the reports by the utilities of works causing an operation restriction.

Purpose of the indicator

The indicator is used to follow the quality of maintenance.

Responsible unit/person

Operational safety (KÄY)
Suvi Ristonmaa

Interpretation of the indicator

Loviisa

In 2011, one safety-significant common cause failure was identified at the Loviisa power plant. The start-up problems occurring in the periodic tests of recombiners at the upper section of the reactor building were identified as such failures. Hence, the situation is almost as good as in previous years.

Olkiluoto

Less common cause failures were identified than in previous years. At Olkiluoto, six common cause failures important to safety were identified in 2011. Four of these cases concerned the EDGs. The other two were the cracks observed in the inner parts of blowdown system valves and the faults in the speed governors of the start-up and shutdown piping system. The EDG system faults were the cracks and damage observed in the exhaust pipes, generator isolation faults and impurities in the cooling water. TVO has initiated a planning process for replacing the EDGs.
**A.I.1g Production loss due to failures**

**Definition**
As the indicator, the loss of power production caused by failures in relation to rated power (gross) is monitored.

**Source of data**
Data for the indicator is obtained from the annual and quarterly reports submitted by power companies.

**Purpose of the indicator**
The indicator is used to follow the significance of failures from the point of view of production.

**Responsible unit/person**
Operational safety (KÄY)
Jouko Mononen (Loviisa)
Suvi Ristonmaa (Olkiluoto)

**Interpretation of the indicator**
Production losses due to failures have been small at both Loviisa and Olkiluoto, as is also indicated by the plants’ high load factors.

**Loviisa**
Loviisa 1 experienced higher production losses from component failures in the previous years. Most of the losses were due to a leaking steam generator flange. The plant was run down to a cold shutdown state for repairing this fault. Loviisa 2 experienced less-than-average production losses from component failures.

**Olkiluoto**
The production losses due to failures were higher than in previous years. This is particularly due to the fact that there were three maintenance outages during which inspections and repairs were carried out.

The production losses due to failures at Olkiluoto 1 during 2011 were mainly (>80%) caused by the maintenance outages in June and August. In June, inner parts of the blowdown system valves were inspected and damaged parts were replaced. Inspections were made following the observations made during the annual maintenance outage of Olkiluoto 2. In August, the motor of one main circulation pump was replaced by an overhauled motor because the motor’s vibration levels had been increasing during the operating cycle. The inspections revealed that this was caused by a damaged bearing. The production losses due to failures at Olkiluoto 2 were mainly (>70%) caused by the maintenance outages in August, when inner parts of the blowdown system valves were replaced. The damage was discovered during the annual maintenance outage in May–June. All parts could not be replaced at that time due to an insufficient inventory of spare parts.
A.1.2 Exemptions and deviations from the Operational Limits and Conditions

**Definition**
As indicators, the number of non-compliances with the Operational Limits and Conditions, as well as the number of exemptions granted by STUK, are monitored.

**Source of data**
Data for the indicators is collected from applications for exemption orders and from event reports.

**Purpose of the indicator**
The indicator is used to follow the utilities’ activities in accordance with the OLCs: compliance with the OLCs and identified situations during which it is necessary to deviate from them; of which conclusions can be made as regards the appropriateness of the OLCs.

**Responsible unit/person**
Operational safety (KÄY)
Jouko Mononen (Loviisa)
Suvi Ristonmaa (Olkiluoto)

**Interpretation of the indicator**
The main purpose of the OLCs exemption procedure is to enable alterations and maintenance promoting safety and plant availability.

Non-compliance with the OLCs refers to a situation where the plant or a system or component of the plant is not in a safe state as required by the Operational Limits and Conditions. The objective is for no events with non-compliance to the Operational Limits and Conditions to occur at the plants. The licensee always prepares a special report on the non-compliance and any corrective action, and submits it to STUK for approval.

**Loviisa**

**Exemptions**
The Loviisa power plant applied for permissions from STUK for four planned deviations from the Operational Limits and Conditions during 2011. The number of applications was slightly lower than the average of previous years (7). The number of deviations in 2011 is at the lower limit of the variation range. Two of the applications were related to fault repairs and one to tests on the new emergency diesel generator. The fourth application was related to the periodic inspection of a chemical tank. STUK approved all the applications because the deviations had no significant safety implications for the safety of the plant or the environment.

**Events non-compliant with the OLCs**
In 2011, two events took place at the plant during which the plant was not in a state compliant with the Operational Limits and Conditions. One event was a case where the hydrogen analysis had been omitted, and the other related to beginning the annual maintenance operations on the DC systems of the emergency diesel generator while the plant was in a state of power operation. The number of events is similar to that in previous years.
Olkiluoto

Based on the results of the last 10 years, the Olkiluoto nuclear power plant applies for STUK’s approval for non-compliance with the OLCs seven times per year on average. Hence, the number of applications in 2011 (7) was in line with the average. Five of the applications were related to modifications (including replacement of the plant’s radiation measurement systems) and two to periodic tests. The planned deviations had no significant safety implications, so STUK approved all the applications but imposed certain restrictions related to the deviations in a few of its decisions. They concerned, among other things, the period of validity of the permission and operations during the deviation. STUK also approved two applications for extending the validity period of two earlier approved deviations from the OLCs. TVO could not start the work according to the intended schedule before the permissions expired. In 2004 and 2005, the number of deviations was increased by work and installations related to the modernisation of OL1 and OL2 and the construction of OL3. Similarly, major modifications were carried out during 2010 and 2011.

Events non-compliant with the OLCs

The Olkiluoto power plant did not report any situations during the year in which the Operational Limits and Conditions would have been breached.

A.I.3 Unavailability of safety systems

Definition

As the indicators, the unavailability of safety systems is monitored by the plant unit. The systems monitored at the Olkiluoto nuclear power plant are the containment vessel spray system (322), the auxiliary feed water system (327) and the emergency diesel generators (651…656). Those followed at Loviisa nuclear power plant are the high-pressure safety injection system (TJ), auxiliary feed water system (RL92/93, RL94/97) and the emergency diesel generators (EY).

Essentially, the ratio of a system’s unavailability hours and its required availability hours are calculated as the indicator. Unavailability hours are the combined unavailability of redundant subsystems divided by the number of subsystems.

Annual plant criticality hours are the availability requirement for the 322, 327, TJ and RL systems. For diesels, the requirement is continuous, i.e. equal to annual operating hours.

Subsystem unavailability hours include the time required for the planned maintenance of components and unavailability due to failures. The latter includes, in addition to the time spent on repairs, the estimated unavailability time prior to failure detection. If a failure is estimated to have occurred in a previous successful test, but to have escaped detection, the time between periodic tests is added to the unavailability time. If a failure has occurred between tests such that its date of occurrence is unknown, half of the time period between tests is added to the unavailability time. Whenever the occurrence of the failure can be identified as an operational, maintenance, testing or other event, the time between the event and the fault detection is added to the unavailability time.

Source of data

Data for the indicators is collected from the power companies. Licensee representatives submit the necessary data to the relevant person in charge at STUK.

Purpose of the indicator

The indicator indicates the unavailability of safety systems. The condition and status of safety systems and their development can be monitored by means of the indicator.
Responsible units/persons
Operational safety (KÄY), resident inspectors
Pauli Koploff (Loviisa nuclear power plant)
Jarno Konsi (Olkiluoto nuclear power plant)

Interpretation of the indicator

Loviisa

**TJ system**

Analysis of the unavailability figures of the high pressure safety injection systems (TJ) of the plant units and their background information shows that the LO1 plant unit had two faults causing system unavailability amounting to 13.2 hours. Similarly, LO2 had two faults that caused 229.5 hours of unavailability; of this, 206.5 hours were spent in the inspection and complete overhaul of the motor of pump TJ11D0001 following the excess vibration observed in the motor. The failures of TJ systems were not serious. Apart from the repair on TJ11D0001, the repairs were completed within the allowed repair times. In the case of the repair of TJ11D0001, the permissible three-day operation restriction time was deviated from by exemption permit 1/B42272/2011 granted by STUK.

The significant unavailability of the high pressure safety injection systems was caused by a single fault at LO2. When that is taken into account, it can be stated that the unavailability of TJ systems was low in 2011, i.e. their condition and availability were good.

**RL system**

At LO1, the total unavailability time was 129.1 hours, of which 53.8 hours were attributable to a single fault occurring during power operation. The rest of the unavailability hours at LO2 were caused by annual maintenance of the RL94 system that took 75.3 hours.

At LO2, the total unavailability time was 74.7 hours, which was exclusively caused by the annual maintenance of the RL97 system.

The unavailability of the auxiliary feed water systems was low in 2011, i.e. their condition and availability were good.

**EY system**

In 2011, the total unavailability for all eight diesel generators was 474.4 hours, of which repairs made up 309.1 hours, and the estimated total duration of unavailability before detecting the faults was 165.3 hours. There were 18 faults in all, of which seven caused immediate operation restrictions while 11 caused operating restrictions from the beginning of the repair work. The failures detected were mainly caused by the normal ageing of components and did not have any serious implications.

The unavailability of the emergency diesels (EY) increased slightly from the previous year’s level, but still remained low, i.e. their availability was satisfactory.
Interpretation of the indicator

Olkiluoto

The unavailability times of the containment spray system have been decreasing since 2005. In 2007, 2008, 2010 and 2011, the unavailability was zero for both plant units, and almost in 2009.

The unavailability of the auxiliary feed water system increased significantly after 2004, when the unavailability was practically zero. The increased unavailability of Olkiluoto 1 in 2006 was due to faults in the recirculation and safety valves in system 327. As corrective measures, the torque settings of the recirculation line’s valve actuator motors were adjusted, and a separate safety valve testing line was installed for one of the lines leading to the reactor core in 2008. Testing lines were installed in other similar lines at OL1 and OL2 during 2009 and 2010. No significant faults occurred in 2007, 2008 or 2009, and the unavailability of the auxiliary water system was reduced to zero in 2009 at both plant units. In 2010, unavailability at OL1 was still zero but increased slightly at OL2 from the previous year, mainly as a result of the new faults discovered during the outage. In 2011, the figure for OL1 was multiplied many times over as the result of a latent fault in one auxiliary feedwater system valve that was faulty for 504 hours. Confer with Section A.II.3.

The unavailability of the diesel generators has decreased since 2004, and was very low in 2006 and 2007. In 2008, the value increased by nearly 95% compared to the previous year. The increase was due to latent faults in the compressed air motors of the diesels in both plant units. In 2009, the unavailability of diesel engines decreased considerably from the 2008 figures. In 2010, unavailability increased somewhat from the previous year as a result of failures occurring in connection with periodic tests. At OL1, the stator winding of a diesel generator failed in connection with a periodic test in August 2010, and the generator was replaced with an overhauled unit. The other similar generators were inspected at both plant units, and visual inspection did not reveal any deviations in them. The failed generator was sent for repairs. During the repairs, which lasted until early 2011, there were no spare generators available at either plant unit. In 2011, the unavailability of EDGs was over four times higher than in 2010, the highest figure ever recorded while the parameter has been monitored. The reason for the increase was the generator fault discussed above, which may have lasted as long as from August 2010 to May 2011. In addition, there were faults in exhaust manifolds and exhaust pipes.
A.I.4 Occupational radiation doses

Definition
As the indicators, collective radiation exposure by plant site and plant unit is monitored, as well as the average of the 10 highest yearly radiation exposures.

Source of data
The data on collective radiation exposure is obtained from quarterly and annual reports. The data on individual radiation doses is obtained from the national dose register.

Purpose of the indicator
The indicators are used to control the radiation exposure of employees. In addition, compliance with the YVL Guide’s calculated threshold for one plant unit’s collective dose averaged over two successive years is followed. The threshold value, 2.5 mSv per one gigawatt of net electrical power, means a radiation dose of 1.22 mSv for one Loviisa plant unit and 2.15 mSv for one Olkiluoto plant unit. The collective radiation doses describe the success of the plant’s ALARA programme. The average of the 10 highest doses indicates how close to the 20 mSv dose limit the individual occupational doses at the plants are, at the same time indicating the effectiveness of the plant’s radiation protection unit.

Responsible unit/person
Radiation protection (SÄT)
Antti Tynkkynen
Interpretation of the indicator

**Loviisa**

Most doses are incurred through work done during outages. Thus outage duration and the amount of work having significance on radiation protection affect the yearly radiation doses. Both Loviisa plant units have more extensive annual outages every four and eight years (the four-year annual maintenance and the eight-year annual maintenance) so that both plant units never have a major annual maintenance outage in the same year. The four-year and eight-year outages have been held in even years and normal annual outages in odd years. The effect of annual outages on collective doses can be seen on the Collective radiation dose, Loviisa graph. In 2011, the Loviisa 1 and 2 plant units had refuelling outages. The time used for annual maintenance outages was short, and there were few operations of significance for radiation protection, which resulted in the total collective dose of the Loviisa power plant being the lowest ever in the history of the Loviisa NPP. The previous lowest collective dose ever was recorded in 2007.

The radiation doses for nuclear power plant workers were below the individual dose limits. In 2011, the average of the 10 highest radiation doses was the lowest ever recorded at the Loviisa power plant. The trend of the 10 highest radiation doses has been a declining one with the exception of 2010 when the individual doses were higher due to the extensive eight-year maintenance. The Radiation Decree (1512/1991) stipulates that the effective dose for a worker from radiation work must not exceed the 20 manSv/year average over any period of five years, or 50 manSv in any one year.
Furthermore, the threshold set for the collective occupational dose was not exceeded in 2011. If, at one plant unit, the collective occupational radiation dose average over two successive years exceeds 2.5 manSv per one GW of net electrical power, the utility is to report the causes of this to STUK, and any measures possibly required to improve radiation safety (Guide YVL 7.9).

**Interpretation of the indicator**

**Olkiluoto**

Most doses are incurred through work done during outages. Thus outage duration and the amount of work having significance on radiation protection affect the yearly radiation doses. The annual outages for the Olkiluoto power plant units are divided into two groups: the refuelling outages and the maintenance outages. The refuelling outage is shorter in duration (approx. 7 days). The length of the maintenance outage depends on the amount of work (2–3 weeks). Annual outages are scheduled so that in the same year, one plant unit has a maintenance outage and the other a refuelling outage. In 2011, the collective radiation dose at the Olkiluoto power plant was the fourth-lowest recorded during the plant’s history, in spite of the maintenance outage of Olkiluoto 2 that was extensive both in terms of the personnel involved and the amount of work carried out. The lowest-ever collective radiation dose was recorded at the power plant in 2010. The new steam dryers installed at the plant units in 2005–2006 have reduced the radiation levels and collective doses at the turbine plant.

In 2011, the average of the 10 highest radiation doses was lower than average. The prescribed dose limits (Radiation Decree 1512/1991) were not exceeded.
A.I.5 Radioactive releases

**Definition**
As the indicators, radioactive releases into the sea and the atmosphere (TBq) from the plant are monitored, as well as the calculated dose due to releases to the most exposed individual in the vicinity of the plant.

**Source of data**
Data for the indicators is collected from the utilities’ quarterly and annual reports. From this data, the calculated radiation dose for the most exposed individual in the vicinity of the plant is defined.

**Purpose of the indicator**
The indicator is used to follow the amount and trend of radioactive releases and to assess factors having a bearing on any changes in them.

**Responsible unit/person**
Radiation protection (SÄT), Antti Tynkkynen

A.I.5a Releases into the atmosphere

**Interpretation of the indicator**
In 2011, the radioactive releases into the atmosphere from the Loviisa and Olkiluoto nuclear power plants were of the same magnitude as in previous years. The releases into the environment were small, well below the set limits.

The releases of noble gases and particulate aerosols from the Loviisa power plant were of the same magnitude as in previous years. The releases of iodine isotopes decreased markedly and were at the 2007 level. The iodine releases from the Loviisa power plant were larger than average during 2009–2010 as a result of small fuel leaks.
Of the releases from the Olkiluoto power plant, the atmospheric releases of noble gases were larger in 2011 than in previous years, while the iodine releases were smaller than in 2010. The noble gas and iodine releases were affected by the fuel leaks occurring at the Olkiluoto 2 plant unit in 2011. The atmospheric releases of particulate aerosols were smaller than previously.

Gaseous fission products, noble gases and iodine isotopes originate from leaking fuel rods, from the minute amounts of uranium left on the outer surfaces of fuel cladding during fuel fabrication, and from reactor surface contamination from earlier fuel leaks. At both Loviisa and Olkiluoto, there have been very few leaking fuel rods and the leaks have been small. One fuel rod leak was detected at the Loviisa 2 plant unit during the refuelling cycle of 2008–2009 and one at the Loviisa 1 plant unit during the refuelling cycle of 2009–2010. The leaking assemblies were replaced with fresh assemblies during the annual maintenance outages of the plant units. Both plant units at Olkiluoto also had a leak in one fuel assembly each before the annual maintenance outages in 2010, plus a leak in a fuel assembly at Olkiluoto 2 plant unit during the refuelling cycle of 2010–2011. The leaking assemblies were removed from the reactors during the annual maintenance outages of the plant units. Furthermore, a new fuel leak was detected at the Olkiluoto 2 plant unit immediately after the 2011 annual maintenance. The indicator A.III.1 describes fuel integrity. The noble gas releases from the Loviisa plant are dominated by argon-41, an activation product of argon-40, found in the airspace between the reactor pressure vessel and the main radiation shield. Aerosol nuclides (including activated corrosion products) are released during maintenance work.
A.I.5b Releases into the sea

Interpretation of the indicator
Releases of radioactive substances emitting gamma radiation into the environment from the Loviisa and Olkiluoto nuclear power plants were clearly below the set limits. During 2001, 2004 and 2009, the Loviisa power plant discharged low-activity evaporation residues into the sea as planned. Consequently, the releases of substances with gamma activity were larger than average in those years. The releases of substances with gamma activity into the sea from Olkiluoto have decreased in recent years.

A.I.5c Population exposure

Interpretation of the indicator
In 2011, the doses of the most exposed individual in the vicinity, calculated on the basis of releases from the plant, were below the set limit both at Loviisa and Olkiluoto. At Loviisa, the dose of the most exposed individual in the vicinity was lower than average, while at Olkiluoto, it was the lowest ever recorded in the plant’s history. As a result of the planned release of low-level evaporation waste to the sea at Loviisa, the dose of the most exposed individual in the vicinity of the Loviisa power plant was higher than usual in 2009.

For both plants, the calculated doses of the most exposed individual in the vicinity were less than 0.1% of the 100-microsievert limit established in the Government Decree (733/2008).
A.I.6 Investments in facilities

Definition
Investments in plant maintenance and modifications in the current value of money adjusted by the building cost index.

Source of data
The licensee submits the necessary data directly to the person responsible for the indicator.

The indicator demonstrates the relative fluctuation of investments. The amounts given in euro are the confidential information of the utilities involved, and not to be published here. Furthermore, the scales of the Loviisa and Olkiluoto power plants' investment and modernisation diagrams are not mutually comparable.

Purpose of the indicator
The indicator is used to follow the amount of investments in plant maintenance and their fluctuations.

Responsible unit/person
Operational safety (KÄY)
Suvi Ristonmaa

Interpretation of the indicator
The variation in the indicator distinctly shows the investments related to the power upgrades and modernisation projects of the plants. Both plants have paid great attention to life-cycle management, which also shows as continuous long-term investment plans. The renewal of the operation permit of the Loviisa plant in 2007 and the intermediate assessment carried out at Olkiluoto in 2008 have also had an effect on the investment plans.

Loviisa
The increase in investments, starting from 2007, is caused by the modernisation of I&C systems at Loviisa. Other major investments in 2011 included the construction of a new diesel emergency power plant, extension of the repository for low- and intermediate-level waste, modification of the pressure equalisation system, replacement of the service water system pipelines, construction of a new training simulator and the replacement of safety valves in the fresh steam pipelines. Many modification projects span over many years, which means that their total cost is also divided between several years.

Olkiluoto
The major modifications, mainly implemented during the 2010 annual maintenance outage of Olkiluoto 1 and the 2011 annual maintenance outage of Olkiluoto 2, show in the investment figures for 2010 and 2011. These modifications included the replacement of inner isolation valves of the seawater pipes, the replacement of low-pressure turbines and the replacement of main seawater pumps.
A.II Operational events

A.II.1 Number of events

Definition
As the indicators, the numbers of events reported in accordance with Guide YVL 1.5 are monitored. (Events warranting a special report, reactor trips and reports on operational events.)

Source of data
Data for the indicators is obtained from STUK's document administration system.

Purpose of the indicator
The indicator is used to follow the number of safety-significant events.

Responsible unit/person
Operational safety (KÄY)
Jouko Mononen (Loviisa)
Suvi Ristonmaa (Olkiluoto)

Interpretation of the indicator

Loviisa
No reactor trips occurred at the Loviisa power plant. The previous occurrences of reactor trips were in 2004 and 2010. The total number of reactor trips has remained small. There have been two during the last 10 years.

Based on data from the last 10 years, the average number of annual events warranting a special report or a transient report is three per year, while the average number of events warranting a transient report is seven per year. In 2011, there were fewer of both types of reportable events than in previous years.

One operational transient occurred in 2011. This was a turbine trip that occurred in connection with a planned ramp-down of power at the Loviisa 1 unit, carried out to allow maintenance work on the control rod mechanism.

The licensee reported two special situations. One was a case of the equipment not being in a condition compliant with the Operational Limits and Conditions. In the other event, the operations were not compliant with the requirements of the Operational Limits and Conditions regarding primary circuit water sampling.

The indicator shows that the plant's operations have continued to be of a good standard.

When considering the indicators, it must be noted that the number of reports does not give the correct conception of the division of events by plant unit, since, for system technical reasons, the reports for both plant units have been entered for Loviisa 1.
Olkiluoto

No reactor trips occurred at the Olkiluoto nuclear power plant. Based on the data from the last 10 years, an average of one reactor trip per year occurs at the Olkiluoto nuclear power plant. During the previous decade (1993–2001), an average of almost three to four reactor trips occurred per year. The figure is explained by the fact that it also includes reactor trips during annual maintenance outages that occurred, for example, in connection with testing the reactor protection system.

Based on data from the last 10 years, the average number of annual events warranting a special report or a transient report is five. The number of events warranting a special report in 2011 (2) was below the average. In contrast, the number of events warranting a transient report (9) was above the average. Both special reports concerned faults in the emergency diesel generators. The events are described in closer detail in Appendix 3 to the report. The majority of transient reports (6 out of 9) concern the main circulation pumps. Of these, three reports deal with the planned control of one main circulation pump at Olkiluoto 1 and Olkiluoto 2 to lower revs due to a transient in the external electricity grid. One report deals with the control of one circulation pump at Olkiluoto 1 to lower revs, caused by a damaged bearing in the pump motor. The motor was replaced during a maintenance outage (Section 4.2.2). Two reports deal with the stoppages of one main circulation pump at Olkiluoto 1 and Olkiluoto 2. As a rectifying action, TVO replaced parts of the frequency converters and sent them to the equipment manufacturer for investigation. The investigations regarding the cause of the fault are in progress. STUK has sent TVO a letter requesting it to submit the results for information to STUK before the 2012 annual maintenance outages. The other transient reports concern the errors detected during the testing of the new main generator of Olkiluoto 2 and its voltage regulator (wrong setting of the voltage regulator, error in planning the tests) and the closure of the inner isolation valve of one main steam line at Olkiluoto 2 during the operating cycle. The valve closed because the contact breaker of its control valve opened for an unknown reason. One of the most significant events during the year was the discovery of damage in the blowdown system valves at Olkiluoto 1 and Olkiluoto 2. The event is not included in these indicators because a root cause report was produced for the event.

When considering the indicators, it must be noted that the number of reports does not give the correct conception of the division of events by plant unit, since, for system technical reasons, the reports for both plant units have been entered for Olkiluoto 1. In 2011, one event warranting a transient report and three warranting a special report concerned both plant units.
A.II.3 Risk-significance of events

Definition
As the indicators, the risk-significance of events caused by component unavailability is monitored. As the measure of risk, an increase in the Conditional Core Damage Probability (CCDP) associated with each event is employed. CCDP takes the duration of each event into consideration. Events are divided into three categories: 1) unavailability due to component failures, 2) planned unavailability, and 3) initiating events. In addition, events are grouped into three categories according to their risk-significance (CCDP): the most risk-significant events (CCDP>1E-7), other significant events (1E-8≤CCDP<1E-7) and other events (CCDP<1E-8). The indicator is the number of events in each category.

Unavailability caused by work for which STUK has granted an exemption is included in category 2. Possible non-compliances with the OLCs are in category 1, if they can be utilised for this indicator. Non-compliances with the OLCs are also dealt with under indicator A.I.2.

N.B.! The calculations concerning the Olkiluoto plant were performed using FinPSA software and those concerning the Loviisa plant using RiskSpectrum software. Calculations for the Loviisa plant regarding simultaneous multiple failures are only based on the power operation model, making them indicative only. All states (17 of them) could be modelled, but the calculation time would be too long compared to the benefits.

Source of data
Data for the calculation of the indicators is collected from utility reports and applications for exemptions.

Purpose of the indicator
The indicator is used to follow the risk-significance of component unavailability and to assess risk-significant initiating events and planned unavailability. Special attention is paid to recurring events, CCFs, simultaneously occurring failures and human errors. Another objective of the event analysis is to identify systematically signs of a deteriorating organisational and safety culture.

Responsible unit/person
Risk assessment (RIS), Jorma Rantakivi (PRA computation)
Operational safety (KÄY) (failure data)

Interpretation of the indicator

Loviisa
A brief description of the most significant events regarding risk is given below:

Loviisa 1:
1. On 22 January 2011, the replacement of connecting rod bearings of diesel EY01. According to information received from the supplier, the bearing in the diesel was from an obsolete batch. Unavailability lasted for 123.5 h. CCDP: 1.20 E-7. During the replacement work, valve VF62S006, pump TF12D001 and valve RA54S003 were also broken (part of the time). If these faults are taken into account, we obtain 3.1E-7 for the CCDP of the entire fault complex.
2. On 8 November 2011, valve VC10S0001 stopped in an intermediate position when it was being closed. Seawater is discharged from VF 70/21 to VC through this valve. Unavailability lasted 7.7 h. CCDP: 2.55E-7.
3. On 24 November 2011, a bellow was torn in the suction line of blower UV20D0001, and the blower was rotating in the wrong direction. Unavailability lasted 128.8 h. CCDP: 4.6E-7.

Loviisa 2:
1. On 7 February 2011, the temperature regulator of inlet air heating element UV40W0001 was repaired and checked. Unavailability lasted 241 h. CCDP: 8.8E-7. During the fault, EY02S0204 was also broken (leaked diesel fuel) for 77.5 hours. Combined CCDP: 9.6E-7.
2. On 10 March 2011, leaky diesel fuel valves EY02S0201, 202 and 203 were repaired. The day-tank for diesel fuel could not be filled while the work was in progress. Unavailability lasted 223.6 h. CCDP: 2.8E-7.
3. On 29 August 2012, start-up air valve EY01S014 of diesel EY01 was repaired. Unavailability lasted 339.9 h. CCDP: 3.3E-7.
The analysed events are considered to be part of normal nuclear power plant operation, and no further measures were required from STUK.
Olkiluoto
A brief description of the significant events is given below:

Olkiluoto 1:
1. On 5 May 2011, the exciter of diesel generator 653G401 was repaired. The fault had demonstrated itself when the switch-over and re-switching automation of the 660 V emergency power supply was tested during annual maintenance R111. The generator switch tripped with overvoltage. TVO identified the fault in a thyristor that did not respond to controls. The fault would not have been found in normal monthly tests, which means that it could have been latent since the previous time of operation (since 18 August 2010). If 3120 h is taken as the value for unavailability, CCDP is 1.65E-6. This also takes into account other faults (327V107, 323P004, 612T291, 322V436, 655G101, 322V301, 351P001, 653G301, 327P002, 327P004, 321V305, 351P002, 712P003, 327P001, 327P003, 721P001, 721P003, 721P04, 324P001, 721P002) occurring during the time the EDG was faulty.
2. On 18 January 2011, valve 327V107 was repaired. This was a motor-actuated valve in the bypass line. The valve did not close automatically or when controlled from the MI unit. This was a latent fault with an unavailability time...
of 504 h, yielding 4.3E-7 as the value of CCDP when the fact was also taken into account that 653G401 was also faulty at that time (without the diesel vault, the CCDP would be 3.5E-7).

Olkiluoto 2:

OL1 case 1 led to additional investigations because it involved a diesel fault that was not discovered in normal tests. The other Olkiluoto events are considered to be part of normal nuclear power plant operation, and they did not give rise to any further measures by STUK.

The combined total CCDP of all three categories divided by the probability of a severe accident gives an overview of the risk-significance of operational events. To facilitate analysis, risk calculation is based on conservative assumptions and simplifications, which materially weakens the applicability of the results for trend monitoring.

If the risk-significance remains on average at the same level year after year, the annual fluctuation does not warrant particular attention.

In 2011, the risk arising from operational activities reduced slightly at the Loviisa plant compared to previous years. At Olkiluoto (OL1), the fault detected in the 2010 outage tests in the pilot valves of the pressure reduction system 314 causes alone an increase of 160% in the risk during the operational cycle of 2009–2010. Such events, causing a major increase in the risk, will inevitably occur from time to time. However, they are rare because, roughly speaking, the design principles of nuclear power plants dictate that the probability of events must be smaller, the bigger the risk increase they cause. The pilot valve fault could possibly have prevented the 314 main valves from closing, which would have caused a serious cooling transient in the primary circuit. In addition, the probability of a major coolant leak was considerably increased, because the normal operation of overpressure protection would have caused a major coolant leak that was clearly more probable than usual. The event was discovered during outage tests, which is probably why the major risk increase caused by it was inadvertently ignored when first analysing the events in 2010, and it was not included in the report for 2010. Of course, the seriousness of the event was well understood, and it gave rise to many actions, both at STUK and TVO. Leaving this one serious event aside, the results of Olkiluoto have remained roughly at the same level as in previous years. The latent fault of diesel generator 653G401, present throughout the operating cycle of 2010–2011, slightly increases the result of OL1.
A.II.4 Accident risk of nuclear facilities

Definition
As the indicator, the annual probability of an accident leading to severe damage to nuclear fuel (core damage frequency) is followed. The accident risk is presented per nuclear power plant unit.

Source of data
The data is obtained as the result of probabilistic risk analyses (PRA/PSA) of the nuclear power plants. The risk analysis is based on detailed calculation models, continuously developed and complemented. A total of 200 man-years have been used at Finnish nuclear power plants to develop the models. As the basic data of the risk analyses, the globally collected reliability information of components and operator activities, as well as the operating experience from Finnish power plants, are used.

Purpose of the indicator
The indicator is used to follow the development of the nuclear power plant’s accident risk. The objective is to operate and maintain the nuclear power plant so that the accident risk decreases or remains stable. Risk analyses can help detect a need to make modifications to the plant or change operating methods.

Responsible unit/person
Risk assessment (RIS), Jorma Rantakivi (PRA computation)
Operational safety (KÄY) (failure data)

Interpretation of the indicator
When assessing the indicator, it must be remembered that it is affected by both the development of the power plant and the development of the calculation model. Plant modifications and changes in methods, carried out to remove risk factors, will decrease the indicator value. An increase in the indicator value may be due to the model being extended to new event groups, or the identification of new risk factors. In addition, developing more detailed models or obtaining more detailed basic data may change risk estimates in either direction. For example, the increase in the Loviisa indicator in 2003 was due to the analysis being extended to cover exceptionally harsh weather conditions and oil accidents at sea during a refuelling outage. In the following year, the indicator value decreased, partly as a result of a more detailed analysis of these factors.

Loviisa power plant’s accident risk has continued to decrease over the last 10 years, and new risk factors discovered as the scope of the risk analysis has been extended, have been efficiently removed. The indicator decreased in 2007 due to the new seawater line completed during the period. The new line allows for the alternative intake of seawater from the outlet channel to cool the plant in shutdown operation. The change will decrease risks in situations where algae, frazil ice or an oil release endanger the availability of seawater through the conventional route. The decrease of the indicator in 2008 results from more detailed analyses performed in conjunction with the renewal of the operating licence, as well as changes at the plant planned to be carried out earlier or in connection with the licence renewal. Such changes include: the I&C renewal LARA; the decrease in the probability of a criticality accident using, for example, boron analysers; modernisation of the refuelling machine and the decrease in the probability of an external leak.
For the Loviisa power plant, the most important factors affecting the overall accident risk include internal plant events during outages (such as the falling of heavy loads or a power surge caused by the sudden dilution of the boron used to adjust reactor operation), fire, a high level of seawater during power operation and oil releases during a refuelling outage.

The annual probability of a severe reactor accident calculated for the Loviisa plant units was approximately $4.3 \times 10^{-5}$ in 2011. The value has decreased by about 17% from the previous year. Several minor plant modifications and the improvements of the PRA model have contributed to the reduction of the risk. The PRA modifications carried out in 2011 concerned, among other things, the modelling of replaced sump screen meshes in the recirculation pipes of emergency cooling water, new procedures for recovering the 400 kV main transformer in cold shutdown states, replacement of the old gas turbines in Hästholmen with a new diesel emergency power plant (EY07) and replacement of the EDG relays (P8 relays). For the backup system for residual heat removal, the introduction of own operating experience data and further specified assessment of human errors reduced the estimated unavailability of the system. In addition, the assessed seismic risk has decreased when the analysis has been updated and the susceptibility of components to seismic damage has been reassessed using up-to-date computational methods.

The indicator for the Olkiluoto plant decreased approximately 30% in 2008 compared to previous years’ relatively stable value. The decrease was mainly due to the more detailed modelling of earthquake events and the plant changes carried out to improve seismic qualification. The increase in 2009 was due to the fact that the heat exchanger of the screening system cannot be used for residual heat removal after all, contrary to earlier assessments. For the Olkiluoto power plant, the most important factors affecting the overall accident risk include internal events during power operation (component failures and pipe ruptures leading to an operational transient).

In 2011, the annual probability of a severe reactor accident calculated for the Olkiluoto plant was $1.33 \times 10^{-5}$. The increase of approximately 30% from 2010 is caused by supplementing the model with the risks caused by an oil spill in the sea, as well as by an update of initiating event frequencies of fires and internal transients.
A.II.5 Number of fire alarms

Definition
As the indicators, the number of fire alarms and actual fires are followed.

Source of data
Data for the indicators is collected from the power companies. The licensees submit the data needed for the indicator to the person responsible for the indicator at STUK.

Purpose of the indicator
The indicator is used to follow the effectiveness of fire protection at the nuclear power plants.

Responsible unit/person
Civil Engineering and Fire Protection (RAK)
Pekka Välikangas

Interpretation of the indicator
There were no events classified as fires at the Loviisa power plant or outside the plant area in 2011. The fire detection system faults occurring at the Loviisa power plant remained in 2011 at the same level as in 2010. The actual alarms given by the detectors at the Loviisa 1 plant unit remained in 2011 at the same level as in 2010, while they decreased slightly from the 2010 level at the Loviisa 2 plant unit.

No events classified as fires occurred in the Olkiluoto plant area (OL1/2) in 2011. Eight events classified as fires occurred outside the plant area, seven of them at the OL3 NPP unit site (a substation located outside in a container burned, there were cases of insulation panels catching fire, a heater burned, cables on the outside of the building burned), in addition to which, a chip crusher was generating smoke at the landfill site. The fire events were of a minor nature. No fire detection system failures were observed at the Olkiluoto power plant (OL1/2) in 2010. The situation was the same in 2011. The number of actual fire alarms was of the same order in 2011 as in 2010.

The automatic fire detectors were upgraded at the Loviisa power plant in 2000 and at Olkiluoto in 2001. The number of alarms increased at both units after that because of the more sensitive detectors. The distinct reduction in alarms at the Loviisa plant since 2003 and at the Olkiluoto plant since 2004 is due to pre-alarms no longer being included in the calculations.

On average, fire safety at the Loviisa and Olkiluoto plants has remained at the earlier level, as no events classified as fires have occurred. Alarms from the fire alarm system have also been at a relatively low level. Most of the alarms were caused by dust, smoke or humidity. Fire alarm systems are not always disconnected in a wide enough area for maintenance work. The number of alarms from the fire alarm system is also affected by the amount of maintenance and repair work performed at the plants.
A.III Structural integrity

A.III.1 Fuel integrity

Definition
As the indicators, the plant unit-specific maximum level and the highest maximum activity value of the iodine-131 activity concentration (I-131 activity concentration) in the primary coolant in steady-state operation (start-up operation or power operation for Loviisa and power operation for Olkiluoto) are followed. The change in activity concentration of I-131 in primary coolant due to depressurisation in conjunction with shutdowns or reactor trips, as well as the number of leaking fuel bundles removed from the reactor, are also followed as indicators.

Source of data
The licensees submit the indicator values directly to the person in charge of the indicator at STUK. The maximum activity levels are also available in the quarterly reports submitted by the utilities.

Purpose of the indicator
The indicators describe fuel integrity and the fuel leakage volume during the operating cycle. The indicators for the shutdown situations also describe the success of the shutdown concerning radiation protection.

Responsible unit/person
Reactor and Safety Systems (REA), Kirsti Tossavainen

A.III.1a Primary coolant activity

Interpretation of indicators (Loviisa)
In 2011, neither plant unit reactor at Loviisa had any leaking fuel. A leaking fuel assembly was last removed from the reactor of Loviisa 1 in 2010 and from the reactor of Loviisa 2 in 2009. The fuel leak at Loviisa 1 had been so small that the removal of the leaking fuel assembly did not affect the I-131 activity content of primary coolant. The I-131 activity content of primary coolant at Loviisa 2 has clearly decreased following the removal of the leaking fuel assembly. In 2009, the I-131 activity content of primary coolant at Loviisa 2 briefly exceeded the OLC limit value (see STUK-B 118). In 2011, the maximum values of I-131 activity content related to shutdowns occurred during shutdowns for annual maintenance outages. After removal of the leaking fuel assemblies, the maximum activity values related to shutdowns also returned to the level before the leaks.

In 2011, fuel integrity at both Loviisa plant units was good.

Interpretation of indicators (Olkiluoto)
The reactor of Olkiluoto 1 did not have leaking fuel in 2011, whereas the reactor of Olkiluoto 2 had leaking fuel almost throughout the year. A fuel leak was detected at the plant unit immediately after the 2010 annual maintenance outage. The leak remained very small, and the leaking assembly was removed from the reactor during the
2011 annual maintenance outage. A new fuel leak was detected at Olkiluoto 2 on 5 August 2011. The leak has remained small throughout the reported period. The leaking fuel assembly will be removed from the reactor during the 2012 annual maintenance outage at the latest. The maximum I-131 activity content during shutdown at Olkiluoto 2 was measured in a situation where the plant unit was shut down for a generator maintenance outage. At Olkiluoto 1, the shutdown did not affect the I-131 activity content.

In 2011, fuel integrity was good at Olkiluoto 1. The fuel integrity of Olkiluoto 2 was weakened by minor fuel leaks.

Several fuel leaks have occurred in the 2000s at the Olkiluoto plant units, particularly at Olkiluoto 2. The main reason for the leaks has been small loose objects, such as metal chippings, entering the reactor during maintenance operations, which can get caught in the fuel assembly structures. The coolant flow may make the loose objects vibrate and break the fuel cladding. In addition to enhancing administrative procedures, technical solutions are also being sought to eliminate the problem. Among other things, foreign object sieves of a new type have been designed for the fuel assemblies. Fuel assemblies fitted with these are to be introduced in 2012.

### A.III.1b Number of leaking fuel assemblies

#### Interpretation of indicators (Loviisa)

In 2011, neither plant unit reactor at Loviisa had any leaking fuel.

#### Interpretation of indicators (Olkiluoto)

In 2011, the reactor of Olkiluoto 1 had no leaking fuel. A leaking fuel assembly was removed from the reactor of Olkiluoto 2 during the annual maintenance outage. It had been leaking since 2010. Yet another fuel leak was detected at Olkiluoto 2 in August. The leaking fuel assembly will be removed from the reactor in the 2012 annual maintenance at the latest.
A.III.2 Primary circuit integrity

A.III.2a Water chemistry conditions

Definition
As the indicators, the water chemistry conditions for each plant unit are followed. The water chemistry indicators are:

• Chemistry performance indices used by the licensees, depicting the effectiveness of water chemistry control in the secondary circuits of PWRs and in the reactor circuits of BWRs. The chemical conditions in the secondary circuit of a pressurized water reactor affect the integrity of the interface between the primary and secondary circuits. The indicator for Loviisa is a new index developed at the plant to be used together with the international index. The new index describes the water chemistry conditions in the secondary circuit at Loviisa with a higher degree of sensitivity than the corresponding international index for VVER plants. The indicator for Olkiluoto is the international index used by the plant. This index observes corrosive factors and the concentrations of corrosion products in the steam generator blowdown and the feedwater. For steam generator blowdown, the calculation includes the chloride, sulphate and sodium concentrations and acid conductivity. For feedwater, it includes the iron, copper and oxygen concentrations. The chemistry index of the Olkiluoto plant consists of the chloride and sulphate concentrations of the reactor water and the iron concentration in the feedwater. The indices for both plants only cover the aforementioned parameter values during power operation.

• The maximum chloride concentration of the steam generator blowdown at the Loviisa plant units and the reactor water at the Olkiluoto plant units during operation compared with the OLC limit in the monitoring period. At the Olkiluoto plant, the maximum sulphate content of reactor water on even, steady-state operation is also followed.

• Corrosion products released from the surfaces of the reactor circuit and the secondary circuit into the coolant. For the Loviisa plant, the iron concentration of the primary coolant and the secondary circuit feedwater (maximum values for the monitoring period) are followed. For the Olkiluoto plant, the iron concentration of feedwater (maximum value for the monitoring period) is followed. In addition, the maximum Co-60 activity concentration in the reactor coolant while bringing the plant to a cold shutdown or after a reactor trip is followed for both plants.

Source of data
The licensees submit indicators describing water chemistry control to the respective responsible person at STUK. The concentration levels of corrosive substances and corrosion products can also be obtained from quarterly reports submitted by the licensees.

Purpose of the indicator
The water chemistry indicators are used to monitor and control primary and secondary circuit integrity. The monitoring is done by indices depicting water chemistry control and by following selected corrosive impurities and corrosion products. The water chemistry indices combine a number of water chemistry parameters and thus give a good overview of the water chemistry conditions. STUK indicators are also used to monitor the fluctuation of certain parameters in more detail. The corrosive substances monitored include chloride and sulphate. The corrosive products followed are iron and radioactive Co-60. The activity concentration of Co-60 isotope while bringing the plant to cold shutdown is used to describe the access of cobalt-containing structural materials into the reactor circuit, the success of the water chemistry control, and the shutdown procedures. In addition to the parameters described here, the license holders use several other parameters to monitor the plant units’ water chemistry conditions.

Responsible units/persons
Reactor and Safety Systems (REA)
Kirsti Tossavainen
Interpretation of indicators (Loviisa)

In 2011, the impurity and corrosion product levels in primary and secondary circuits, followed in STUK’s indicator scheme, were in keeping with the guide values set by the license holder at both plant units. The chemistry index of both Loviisa plant units has remained in recent years at almost the best possible value. The exceptional value of the index for Loviisa 2 in 2004 was caused by a seawater leak in the condenser, which had caused the chloride concentration of the steam generator blowdown, affecting the index, to become greater than normal. The condenser leak was repaired in the annual maintenance outage in 2004, after which the chloride concentration also decreased. The maximum Co-60 activity levels associated with shutdowns were measured during shutdowns for annual maintenance outages. In 2011, the concentrations did not deviate from previous years’ values.

The indicator shows that primary circuit integrity has been good at the Loviisa plant units in 2011.

Interpretation of indicators (Olkiluoto)

The impurity and corrosion product levels in reactor water and feedwater, followed in STUK’s indicator scheme, were in keeping with the guide values set by the license holder at both plant units almost throughout the year. Olkiluoto 1 had individual cases of exceeding the target values for reactor water iron content and sulphate content. The iron content of Olkiluoto 1 feedwater has been increasing. However, the iron content was in keeping with the licensee’s guide value apart from one sampling. Usually, the installation of new components causes an increase of iron content but, in this case, no obvious causal link to component re-
placements exists. The iron content of feedwater is affected by corrosion and the filter material used in the ion exchangers of the condensate purification system. The licensee is investigating the reason for the increase in iron content.

Olkiluoto 2 had cases of exceeding the target values for reactor water chloride content and sulphate content. The higher-than-usual chloride content was caused by a seawater leak in the condenser. The leak was repaired within two weeks of detecting it, after which the chloride content has been in line with the guide value. Exceeding the target values for sulphate content is associated with the use of the ion exchange filters of the condensate purification system, and the situation will be rectified by changing the exchanger resin, which is done from time to time in the course of normal operations.

At Olkiluoto 1, the deviations from target values were so small that they did not affect the chemistry index, which was at its optimum value. At Olkiluoto 2, the chemistry index was slightly higher than the optimum value due to the exceptional exceeding of the target value for chloride content.

At both plant units, the shutdown-related maximum value of Co-60 activity content occurred during shutdowns for annual maintenance outages. The Co-60 activity content values did not significantly change from previous years. A change in the OLCs regarding chemistry was introduced at both Olkiluoto plant units before the annual maintenance outages. The changes affecting the followed in STUK's indicator scheme were the addition of a limit value for reactor water sulphate content in the OLCs and the introduction of a stricter value for reactor water chloride content.

The indicator shows that reactor circuit integrity has been good at the Olkiluoto plant units in 2011.
A.III.2b Primary circuit leakages (Olkiluoto)

Definition
The indicators below are used to follow identified and unidentified primary circuit leakages at the Olkiluoto plant units:

- Total volume (m³) of identified (from containment to collection tank 352 T1 of the controlled leakage drain system) and unidentified (total volume of leakages into the sump of the controlled floor drainage system, 345 T33) containment internal leakages during the operating cycle.

- Highest daily containment internal leakage volume during the operating cycle in relation to the allowed leakage volume in the OLCs (outflow water volume of water condensing in the air coolers of the containment cooling system 725/OLCs limit).

Source of data
The licensee submits data on primary circuit leakages at the Olkiluoto power plant to the responsible person at STUK.

Purpose of the indicator
The indicators describing primary circuit leakages are used to follow and monitor the leak rate of the primary circuit within the containment.

Responsible units/persons
Operational safety (KÄY), Jarmo Konsi

Interpretation of the indicator, operating cycle 2010–2011
One of the purposes of controlled leakage 352 is to collect seal box leakages from valves, pumps and other such components. The drains from the seal boxes of the valves within the containment are equipped with temperature sensors to locate any leaks. Temperature sensors installed on the drains above the main lines will detect any leakage in the specific line. Other methods must then be used to locate the actual leaking object. The containment leakages identified at OL1 during the four last operating cycles have increased a little. At OL2, the identified leakages have remained almost constant. The leakage volumes do not include the drainage of process systems during annual maintenance outages and other outages. The identified leakages include sampling flows of approximately 1,000–1,500 m³ from the reactor building.

At the lowest point of the containment drywell, there is the drain water pit T33, which collects the drain water from the containment drywell floor drains and any leakage from the control rod actuator seals. The volumes of unidentified primary circuit leakages during the operating cycle 2010–2011 decreased at both plant units.

One of the purposes of containment gas cooling system 725 is to remove moisture from the containment atmosphere. Moisture may originate from steam leaking from the primary circuit. In the operating cycle of 2010–2011, the containment’s largest internal daily leak volume’s ratio to the maximum allowable volume, as specified in the Operational Limits and Conditions, was low for both plant units.

The primary circuit has been relatively leak-proof in the 2010–2011 operating cycle.
A.III.3 Containment integrity

Definition
As the indicators, the parameters below are followed: the total as-found leakage of outer isolation valves following the first integrity tests, compared with the highest allowed total leakage from the outer isolation valves; the percentage of isolation valves tested during the year in question at each plant unit that passed the leakage test on the first attempt (i.e. as-found leakage smaller than the acceptance criteria of a valve and no exceeding of the so-called attention criteria of a valve without repair in consecutive years) and the combined as-found leakage rate of containment penetrations and airlocks in relation to their highest allowed total leakage. The combined leakage rate at Olkiluoto includes leakages from personnel airlocks, the maintenance dome and the containment dome. At Loviisa, the combined leakage rate is comprised of the leakage test results from personnel airlocks, the material airlock, the cable penetrations of inspection equipment, the containment maintenance ventilation systems (TL23), the main steam piping (RA) and the feedwater system (RL) penetrations; the seals of blind-flanged penetrations of ice-filling pipes are also included.

Source of data
Data is extracted from the utilities’ leak-tightness test reports submitted by the licensee to STUK for information within three months of the completion of annual maintenance. STUK calculates the total as-found leakages, since the reports give total leakages as they are at the end of the annual maintenance outage (i.e. after the completion of repairs and re-testing).

Purpose of the indicator
This indicator is used to follow the integrity of the containment isolation valves, penetrations and airlocks.

Responsible unit/person
Reactor and Safety Systems (REA)
Päivi Salo

Interpretation of the indicator

Loviisa
The overall as-found leakages of outer containment isolation valves have decreased at both plant units.

The percentage of isolation valves which passed the leakage test at the first attempt has remained high.

The overall as-found leakage of containment penetrations, which at Loviisa includes the leakage test results for the personnel airlock, the emergency personnel airlock, the material airlock, the reactor pit, inward relief valves, cable penetrations and bellow seals (RA, RL, TL23), was small at both plant units.

Source: Data from utility leak-tightness test reports submitted to STUK within three months of the completion of annual maintenance. STUK calculates the total as-found leakage, as they are at the end of the annual maintenance outage (i.e. after completion of repairs and re-testing).

Graphs:
- Isolation valves passing the leakage test at the first attempt, Olkiluoto NPP
- Combined leak rate of containment penetrations and airlocks compared to the leak limit, Loviisa NPP
- The overall as-found leakage of outer isolation valves compared with the highest allowed overall leakage of outer isolation valves, Loviisa NPP
Olkiluoto

The total as-found leakages of outer isolation valves at the Olkiluoto 1 plant unit was extremely small, clearly below the limit set in OLCs.

At the Olkiluoto 2 plant unit, the as-found leakage of the outer isolation valves was below the limit set in the OLCs and has remained approximately the same as before.

The percentage of isolation valves that passed the leak tightness test at first attempt has remained high for both plant units.

The total as-found leakage rate of containment penetrations, in which TVO includes leakages in the upper and lower personnel airlocks, the maintenance dome and the containment dome, has remained small for both plant units.