APPENDIX 1 STUK’s safety performance indicators for NPPs in 2008

SUMMARY OF THE SAFETY PERFORMANCE INDICATORS
FOR THE NUCLEAR POWER PLANTS

Background and objectives of the indicator system 88
Results for the safety performance indicators for the nuclear power plants in 2008 89

Lovisa NPP 89
Olkiluoto NPP 92

SAFETY PERFORMANCE INDICATORS 96

A.I Safety and quality culture 96
A.I.1 Failures and their repairs 96
A.I.2 Exemptions and deviations from the Technical Specifications 103
A.I.3 Unavailability of safety systems 105
A.I.4 Occupational radiation doses 108
A.I.5 Radioactive releases 111
A.I.6 Investments in facilities 113

A.II Operational events 114
A.II.1 Number of events 114
A.II.2 Direct causes of events 116
A.II.3 Risk-significance of events 117
A.II.4 Accident risk of nuclear facilities 121
A.II.5 Number of fire alarms 123

A.III Structural integrity 124
A.III.1 Fuel integrity 124
A.III.2 Primary circuit integrity 126
A.III.3 Containment integrity 131
Summary of the safety performance indicators for the 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 status of the plant and on any changes to the safety status. 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 indicator system divides nuclear safety into three sectors: 1) safety and quality culture, 2) operational events, and 3) structural integrity. These three sectors are divided into a total of 14 sub-areas to be interpreted (see the table below). The objective of the indicator system is to recognize changes in plant safety as early as possible. If indicators weaken, the factors behind the development are defined, and changes to plant operation and STUK oversight of the area are considered. Indicators can also be used to monitor the efficiency and effectiveness of corrective measures. The information yielded by the indicators is also used when communicating nuclear safety.

STUK began the development of its own indicator system in 1995. In 2003, the nuclear safety indicators were first included in STUK's strategy and reported as part of the regulatory oversight of nuclear safety. Indicators monitor the implementation and success of the strategy. The following is a list of STUK's long-term safety objectives concerning nuclear power plants:

- No accidents or serious incidents occur at Finnish nuclear power plants.
- Releases of radioactive substances into the environment are minor and their calculated annual dose for a critical individual is less than 1% of the 100 μSv limit defined in Government Decision 395/1991.
- The radiation dose of each nuclear power plant employee is below the limit defined for individuals.

<table>
<thead>
<tr>
<th>Nuclear safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.I Safety and quality culture</td>
</tr>
<tr>
<td>1. Failures and their repairs</td>
</tr>
<tr>
<td>2. Exemptions and deviations from the Technical Specifications</td>
</tr>
<tr>
<td>4. Occupational radiation doses</td>
</tr>
<tr>
<td>5. Radioactive releases</td>
</tr>
<tr>
<td>6. Investments in facilities</td>
</tr>
<tr>
<td>A.III Structural integrity</td>
</tr>
<tr>
<td>1. Fuel integrity</td>
</tr>
<tr>
<td>2. Primary and secondary circuits integrity</td>
</tr>
<tr>
<td>3. Containment integrity</td>
</tr>
</tbody>
</table>
• The collective radiation dose for all employees of a nuclear power plant remains low in international comparisons, staying below the maximum limit defined in Guide YVL 7.9 when figures from both nuclear power plants are included.

• Risks related to a nuclear power plant are managed to decrease or stabilise the accident risk at the plants.

Since 2006, indicator information has been managed in STUK’s INDI (INdicator DIisplay) information system. In 2008, minor changes were made to the indicators. For example, the indicator describing the maintenance of plant documentation was discarded. 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.

Results for the safety performance indicators for the nuclear power plants in 2008

Lovisa NPP

Summary

The structural radioactivity confinement barriers are in good condition. Three safety significant events and some operational transients were reported relating to plant operation. Based on these events, procedures such as the plant modification management have been revised. Occupational radiation doses and releases into the environment remained low in 2008. The plant’s load factors were high, and equipment failures only caused minor production losses. Long-term investments have been made in the improvement of the plant. In 2008, several projects with significance for nuclear safety were in progress, including the renewal of the I&C systems and the waste, storage and decontamination facilities. Plant maintenance has been appropriate. However, attention must still be paid to spare parts management and adequate human resources for maintenance operations. Below, the results of the nuclear safety indicators are described by indicator area.

Safety and quality culture

Safety and quality culture is assessed on the basis of information concerning the radiation protection and the operation and maintenance of the plant. The operation and maintenance of the plant is monitored using the failure and maintenance data for the components with an effect on the safe operation of the plant, as well as by monitoring compliance with the Technical Specifications. The success of radiation protection is monitored on the basis of the employees’ radiation doses and radioactive releases into the environment. When assessing the safety and quality culture, attention is also paid to investments to improve the plant and to the currency of the plant documentation.

Plant maintenance was appropriate

The number of safety-significant component failures was small, and load factors were high. In 2008, Lovisa plant units had a total of eight component failures leading to production losses. The number of failures and the resulted production losses were low even compared to the previous years. No reactor trips occurred.

The plant’s maintenance plan aims to keep the number and effects of failures at an acceptable level. In 2008, the number of component failures remained low and even decreased slightly compared to previous years. The power company applied for permission from STUK for five planned deviations from the Technical Specifications. These were related to the repair of a failed component, inspections, and the modification of Lovisa’s I&C facilities, as well as its storage, waste material and workshop facilities. Since the planned deviations had no significant safety implications, STUK approved the applications.

Maintenance work includes both repairs and preventive maintenance. The total number of failures in 2008 was clearly lower than the average of the four previous years. No signs of aging can be detected in the indicators or the failure data behind the indicator, which proves that component life-cycle management and maintenance are successful.
The average repair times of failures causing unavailability of components have remained stable at the Loviisa plant for several years. In 2008, the average repair time for the plant units was 27.7 h, while the average of the four previous years was 33.9 h. In 2008, the average repair time of Tech Spec component failures that had an allowed repair time of 72 hours or less was 22.1 hours at Loviisa 1, and 27.8 hours at Loviisa 2.

On the basis of the 2008 indicators and the data behind them, it can be stated that the plant’s maintenance operations meet the requirements. The plant must continue to pay attention to adequate resources and the management of operations so that faults are repaired without undue delay, even if the allowed repair time is long.

**Plant safety systems were in good order**

As in previous years, the high-pressure safety injection system (TJ), auxiliary feed water systems (RL92/93, 94/97) and emergency diesels (EY01-04) were in good condition. No safety-significant faults were detected in components, and any failures with minor safety significance were caused by normal aging of components.

**Occupational radiation doses and releases into the environment remained low**

In 2008, the 4-year annual maintenance took place at Loviisa 1, and a short annual maintenance at Loviisa 2. The time used for outages was long, and there was a high amount of work with significance for radiation protection, which resulted in a total collective dose that was higher than that of the previous year. Still, the collective dose was lower than in corresponding earlier years. The low dose accumulated during the 4-year maintenance can be explained by better targeting of non-destructive inspections, the new introduction training, and the improved planning and monitoring of radiation protection.

The radiation doses for nuclear power plant workers were below the personal dose limits. The trend for the average of the ten highest doses has been declining in recent years. **In 2008, the average was higher than in the previous year, but still lower than the average dose level of recent years.** Furthermore, the threshold set for the collective occupational dose was not exceeded in 2008.

Radioactive releases into the environment from the Loviisa nuclear power plant were small. They were well below the set limits.

**Long-term investments in plant improvement**

At the Loviisa power plant, special attention has been paid to life-cycle management. From 1997 to 2000, significant power upgrade and modernisation projects were carried out at the plant.

Loviisa power plant’s accident risk has continued to decrease over the last ten years, and new risk factors discovered as the scope of the risk analysis has been extended have been efficiently removed. **The annual probability of a severe reactor accident calculated for the Loviisa plant units is small (approximately 6.0 x 10^{-5}).** For the Loviisa power plant, the most significant factors affecting the overall accident risk include internal plant events during outages (such as falling of heavy loads or a power surge caused by sudden dilution of the boron used to adjust reactor operation), fire, high levels of seawater during power operation and oil releases into the sea in front of the Loviisa plant during refuelling outages.

At the Loviisa power plant, the most significant investment in 2008 was the I&C renewal. Other major investments in 2008 included the replacement of stators, the basic renovation of waste, storage and decontamination facilities, refuelling machine renovation, replacement of bolts in the reactor support cage, basic servicing of emergency diesels and generators, the improvement of secondary circuit safety, and the renewal of high pressure safety injection pumps.
Operational events

The indicators concerning operational events are used to monitor special situations and significant disturbances at the plant. Special situations include events with an effect on the safety of the plant, the personnel or the environment. A special report is required for any special situations. Correspondingly, a disturbance report must be prepared for any significant disturbances occurring at the plant unit. Such disturbances include reactor and turbine trips, and other operational transients leading to a forced reduction of more than 5% in the reactor power or average gross power.

Risk indicators are used to monitor the safety effect of the equipment’s unavailability periods and the development of the plant’s risk level. The results provide insight into the operational activities at the plant and the efficiency of the operating experience feedback system.

The number of events was low and their risk significance minor

The number of safety significant events has remained low at the Loviisa power plant. In 2008, three events were reported: vagueness of testing instructions concerning the containment ice condenser door control system valves at Loviisa 1 and Loviisa 2, the absence of an uninterrupted power supply in a substation at the Loviisa plant, and incorrect simulations in the reactor protection system of Loviisa 2. The events had no substantial safety significance. The power company responded to these events by deciding to take corrective action in order to prevent similar events. The procedural flaws resulting in the incorrect simulation were so significant that the power company decided to carry out a root cause analysis regarding the event. The analysis will be reviewed by STUK.

The number of operational transients affecting plant production has remained at a reasonable level since 2002. Five to nine transients have been reported annually. The number of failures and the resulting production losses were low compared to previous years, which also shows in the plant’s load factors. No reactor trips occurred in 2005–2008.

Reactor trips have been generally rare in Loviisa partly because there are two turbines; the reactor remains operational even if one turbine trips due to a transient.

The impact on the annual accident risk of unavailability resulting from component failures, preventive maintenance and other events was very low, rating about 1.5% at Loviisa 1 and about 2.4% at Loviisa 2. A few individual component failures and the preventive maintenance of the subsystems of the auxiliary feed water system were most significant in terms of risk.

Two events constituting non-compliance with the Technical Specifications occurred at the Loviisa plant: an incorrect testing interval in an instruction, and an incorrect simulation in the reactor protection system. The safety significance of the event concerning testing intervals was minor. The safety significance of the incorrect simulation was also low, but deficiencies in the procedure made it significant. The power company will prepare a root cause analysis on the event in 2009, and STUK will review the analysis.

Fire safety has remained stable

The fire safety of the Loviisa plant has remained at the same level. At the Loviisa power plant, one event classified as a fire occurred in 2008. When a pump of a drains system (RN) belonging to turbine systems of Loviisa 1 and Loviisa 2, the absence of an uninterrupted power supply in a substation at the Loviisa plant, and incorrect simulations in the reactor protection system of Loviisa 2. The events had no substantial safety significance. The power company responded to these events by deciding to take corrective action in order to prevent similar events. The procedural flaws resulting in the incorrect simulation were so significant that the power company decided to carry out a root cause analysis regarding the event. The analysis will be reviewed by STUK.

Even though the number of actual fires did not increase, correct alarms from detectors did increase. Detector alarms were mainly triggered by dust, smoke or humidity. The number of alarms is affected by factors such as the amount of maintenance work (in 2008, long annual maintenance outages, above-average workload and the construction of new I&C buildings), disconnection of detectors in an adequately large area, and more reliable operation of the fire detector system. At Loviisa power plant, detection system errors have remained at the previous years’ level.
Structural integrity

*Structural integrity* is assessed on the basis of the leak-tightness of the multiple radioactivity confinement barriers – the fuel, primary and secondary circuits, and the containment. **The integrity must meet the set objectives, and the indicators must show no significant deterioration.**

Fuel integrity is monitored on the basis of the radioactivity of the primary coolant and the number of leaking fuel bundles. 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 integrity of the containment is monitored by testing the leak-tightness of isolation valves, penetrations and airlocks.

Radioactivity confinement barriers are in good condition

Based on the water chemistry indicators, the primary circuit integrity of Loviisa plant units has remained good. A minor fuel leak was detected at Loviisa 2 late in 2008. The leaking fuel bundle will be removed from the reactor in the 2009 annual maintenance outage at the latest. The previous fuel leak occurred at Loviisa in 1999.

Leaks from the containment isolation valves, penetrations and personnel airlocks were minor for both plant units. Most of the isolation valves passed the leakage test at the first attempt, even though the overall as-found leakage has increased slightly since last year.

Olkiluoto NPP

Summary

At the Olkiluoto plant units, more safety-significant events occurred than in recent years, on average. The most important events in terms of safety were the common cause failure of diesel generator starter motors at both plant units, a reactor trip and unavailability of the electrical flywheel system of reactor coolant pumps ensuring proper cooling of fuel at Olkiluoto 1 due to a failure of a voltage regulator of the generator, and the reactor trip at Olkiluoto 2 in the beginning of January, when frazil ice blocked sea water screens.

In addition to these events, a major deficiency was detected in the plant safety structures. During the operating cycle, it was found that part of the pipe penetrations with significance for nuclear and fire safety were in poor condition. There were also deficiencies in the design basis of the penetrations.

The structural radioactivity confinement barriers for the Olkiluoto power plant are in good condition. The employees’ radiation doses remained low, as in previous years. The load factors for the plant units were high, and failures only caused minor production losses, although the production losses caused by failures at both plant units were slightly more significant than in the previous year. **Otherwise, life-cycle management and maintenance of the plants were appropriate.**

Of major investments, 2008 saw the completion of the feed connection from the gas turbine plant to both plant units. Below, the results of the nuclear safety indicators are described by indicator area.
Safety and quality culture

Safety and quality culture is assessed on the basis of information concerning the radiation protection and the operation and maintenance of the plant. The operation and maintenance of the plant is monitored using the failure and maintenance data for the components with an effect on the safe operation of the plant, as well as by monitoring compliance with the Technical Specifications. The success of radiation protection is monitored on the basis of the employees’ radiation doses and radioactive releases into the environment. When assessing the safety and quality culture, attention is also paid to investments to improve the plant and to the currency of the plant documentation.

Safety equipment has been well maintained

The number of defects in components subject to Technical Specifications has remained low since 2004. The indicators concerning failures and maintenance of components subject to the Technical Specifications show that the life-cycle management and maintenance operations of the plant are appropriate.

Maintenance work includes repair of defects and preventive maintenance. The amount of preventive maintenance varies from year to year based on the work chosen for outages and preventive maintenance packages. Based on the development of the amount of preventive maintenance work and fault repairs and the assessment of the work behind the figures, the maintenance strategy can be considered appropriate.

In 2008, the average repair time of failures causing unavailability of components subject to the Technical Specifications was swift for both plant units. Based on the 2008 indicators and the data behind them, the plant’s maintenance operations can be considered successful.

Plant safety systems were in good condition

The condition of the containment spray system and the auxiliary feed water system has remained good. The increase in the unavailability of emergency diesels was a result of starter motor failures that were caused by the exclusion of these motors from appropriate preventive maintenance. In other regards, the condition of the diesel engines has remained good.

Occupational radiation doses and releases into the environment remained low

In 2008, the collective dose at Olkiluoto was the lowest since 1983. In addition, the average of the ten largest doses was clearly lower than in previous years. Emissions Releases of radioactive substances into the environment from the Olkiluoto power plant were minor and remained clearly under the set limits.

Long-term investments in plant life-cycle management

Significant investments have been made in the power upgrades and renewals of the plant units in 1997–2000 and in 2004–2006. The most significant accident risk factors for the Olkiluoto power plant include internal events during power operation (component failures and pipe ruptures leading to an operational transient) and relay failures caused by earthquakes deemed possible in Finland. The annual probability of a severe reactor accident calculated for both Olkiluoto plant units is very low (approximately $1.0 \times 10^{-5}$). Small improvements at the plant have caused a slight decrease in this indicator in recent years. Last year, the indicator value decreased clearly, due to a more detailed earthquake analysis and plant modifications. Component failures caused a slight increase in the production losses for Olkiluoto 2, compared to previous years.

Continuing major changes include the renewal of radiation measurement systems for both plant units, replacement of shutdown cooling system valves with a new valve type, replacement of DC power system batteries, repair of fine screening units in the sea water screening system, and the replacement of epoxy powder-coated circulating water pipes with ebonite pipes. A feed connection to both plant units was built from the new gas turbine plant. At the turbine plant, erosion repairs were carried out for the piping.
Operational events

The indicators concerning operational events are used to monitor special situations and significant disturbances at the plant. Special situations include events with an effect on the safety of the plant, the personnel or the environment. A special report is required for any special situations. Correspondingly, a disturbance report must be prepared for any significant disturbances occurring at the plant unit. Such disturbances include reactor and turbine trips, and other operational transients leading to a forced reduction of more than 5% in the reactor power or average gross power.

Risk indicators are used to monitor the safety effect of the equipment’s unavailability periods and the development of the plant’s risk level. The results provide insight into the operational activities at the plant and the efficiency of the operating experience feedback system.

Safety-significant events and deficiencies affecting plant safety

At the Olkiluoto plant units, more safety-significant events occurred than in recent years, on average. The most important events in terms of safety were the common cause failure of diesel generator starter motors at both plant units, a reactor trip and unavailability of the electrical flywheel system of reactor coolant pumps ensuring proper cooling of fuel at Olkiluoto 1 due to a failure of a voltage regulator of the generator, and the reactor trip at Olkiluoto 2 in the beginning of January, when frazil ice blocked sea water screens.

In addition to these events, a major deficiency was detected in the plant safety structures. During the operating cycle, it was found that part of the pipe penetrations with significance for nuclear and fire safety were in poor condition. There were also deficiencies in the design basis of the penetrations.

Based on data from the last ten years, the average number of annual events warranting a special report or an operational transient report is five. The number of events warranting a special report in 2008 (seven) is higher than average. Five of these events occurred during annual maintenance. Due to these events, TVO had a safety culture assessment carried out in 2008.

The events reported in special reports and their immediate causes were very different, but contributory factors were to some extent similar. The common factors are related to the management of the state of the plant and design information, particularly in connection with changes. The same was also observed in 2007; then, TVO launched several development measures to ensure that components to be installed at the plant conform to the plans, and that their condition and instructions meet the requirements. The management of the design basis and plant condition must be further improved in the power company.

Operational activities conformed well to the Technical Specifications, even though deviations were slightly more common in 2008 than in the previous year. In 2008, TVO applied for STUK’s approval for six deviations from the Technical Specifications. Three of these deviations concerned measures ensuring safety at work during the construction of Olkiluoto 3. STUK approved all applications.

Olkiluoto 1 experienced higher production losses from component failures in 2008 than in the previous years. Approximately 90% of production losses caused by failures resulted from a power restriction period lasting several days following a voltage regulator malfunction of the generator at the end of the annual outage on 30 May 2008. For Olkiluoto 2, production was affected by frazil ice in the beginning of January. As a result of the failure on 30 May at Olkiluoto 1, the flywheel generators of Olkiluoto 2 reactor coolant pumps were also found to be inoperable and, for approximately 11 days, the plant unit was brought to the 80–85% power level allowed by the fuel margins.

No events classified as fire occurred in the Olkiluoto 1 and Olkiluoto 2 area in 2008.

Events had significance for nuclear safety

Risks arising from operational activities were significantly above average in 2008 for Olkiluoto 1. The impact of unavailability resulting from component failures, preventive maintenance and other events on the annual accident risk was approximately 26% at Olkiluoto 1, and 1.3% at Olkiluoto 2. For Olkiluoto 2, the risk has remained at the same level as in previous years.

The risk arising from events at Olkiluoto 1
mainly consisted of the generator overvoltage leading to a reactor trip, and the common cause failure of diesel generators. The events will lead or have already led to changes in either the plant or operations.

**Structural integrity**

*Structural integrity* is assessed on the basis of the leak tightness of the multiple radioactivity confinement barriers – the fuel, the primary circuit, and the containment. The integrity must meet the set objectives, and the indicators must show no significant deterioration.

Fuel integrity is monitored on the basis of the radioactivity of the primary coolant and the number of leaking fuel bundles.

Water chemistry indicators are used to monitor and control the integrity of the primary circuit. The monitoring is done by indices depicting water chemistry control, and by following selected corrosive impurities and corrosion products.

The integrity of the containment is monitored by testing the leak tightness of isolation valves, penetrations and air locks.

**Radioactivity confinement barriers were in good working order**

There were no essential changes in the indicators describing the integrity of the fuel or the primary circuit in 2008. Based on the indicators, the structural integrity of the barriers limiting the dispersion of radioactive substances has remained good.

Olkiluoto plant units had no leaking fuel in 2008, so the I-131 activity concentrations have remained the same or decreased. Similarly, the maximum activities resulting from shutdown of the plant have also shown a declining trend. Based on the indicator, fuel integrity has been good at Olkiluoto plant units. The water chemistry index, which yields an overview of the water chemistry conditions, was at the best possible level for both plant units.

The primary circuit has been leak-proof in the operating cycle 2007–2008. Identified and unidentified leaks from the primary circuit into the containment have remained small, and the ratio of the largest daily leak volume within the containment to the maximum leakage allowed in Technical Specifications was low for both plant units. This was the fifth consecutive operating cycle with hardly any leaks from the primary circuit into the containment atmosphere.

Leaks from the containment penetrations and personnel airlocks were minor for both plant units. Most of the isolation valves passed the leakage test at the first attempt. Leaks from the outer isolation valves of Olkiluoto 2 were minor. However, the sum of the leakage test results for the outer isolation valves of Olkiluoto 1 exceeded the limit specified in the Technical Specifications. More than half of the total leakage came from one valve. After repairs, the total leakage met the requirements of the Technical Specifications.
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 Technical Specifications

Definition
The number of failures causing unavailability of components defined in the Technical Specifications (Tech Spec 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 indicator
The indicator is used to assess the plant life-cycle management and the development of the condition of components.

Responsible units/persons
Organisations and Operations (OKA), resident inspectors
Pauli Kopoloff (Loviisa nuclear power plant)
Jarmo Konsi (Olkiluoto nuclear power plant)

Interpretation of indicator

Loviisa
The total number of failures in equipment subject to Technical Specifications causing a restriction to plant use decreased from 194 in the previous year to 180 in 2008. The decrease was nearly identical for both plant units. The total number of failures in 2008 was clearly lower than the average of the four previous years, 229.

In recent years, the annual failure volumes have remained relatively stable; the variation therein is largely due to the random occurrence of failures which are difficult to predict, such occurrences being normal when the number of components is
large. The number of failures causing operation restrictions decreased in 2008. This is good for the plant maintenance result, but no certain conclusions can be made about life-cycle management and the condition of the components based on these figures. Failure detection and anticipation have been continuously improved in plant maintenance operations at Loviisa, and components have been replaced. Due to these measures, the number of component failures with an effect on the safe operation of the plant has remained under control and continues to decrease.

Based on the above, it can be stated that the indicator or the failure data behind it do not show the potentially negative effects associated with the ageing of the facilities, which indicates functional component life-cycle management and successful maintenance.

**Interpretation of indicator**

**Olkiluoto**

The number of failures occurring during power operation and causing the unavailability of components subject to Technical Specifications has been decreasing since 2004, with the exception of an increase occurring in 2007. **In 2008, the number decreased to the level of 2006.** Based on the number of failures, maintenance work has been successful.

The emergency diesel generator of one subsystem failed to start in the periodic test carried out in connection with the start-up of the Ol1 plant unit on 28 May 2008. The failure was caused by a leak in the seals of both compressed air motors of the diesel engine. In inspections, similar leaks were found in the seals of the compressed air motors of several diesel generators in both plant units. Thus, the failure was a common cause failure endangering the availability of a Safety Class 2 system. The event was classified as an anomaly, rated as INES 1 according to the International Nuclear Event Scale. **The compressed air motor seals for the diesel engines for both OL1 and OL2 were inspected and replaced in connection with the inspections.** Diesel generators were isolated one subsystem at a time. The isolation time for each diesel was, however, short. The inspection and repairs were carried out swiftly.

Capacity measurements of the plate heat exchanger of shutdown secondary cooling system 721 are regular. In 2007, several measurements indicated values below the required capacity for both plant units. In such cases, the heat exchanger was cleaned. In the second quarter of 2008, values still remained below the required capacity on several occasions, particularly for OL1. **The necessary isolation then causes an operation restriction, and the cleaning of one heat exchanger takes nearly ten hours.** The issue has been discussed with TVO representatives. TVO has changed the detergent used for cleaning the heat exchanger, and the cleaning results have improved significantly. For this reason, adding plates to the plate heat exchangers is not necessary at the moment.
A.1.1b Maintenance of components subject to the Technical Specifications

Definition
As the indicator, the number of failure repairs and preventive maintenance work orders for components defined in the Tech Specs 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 failure repairs are retrieved.

Purpose of indicator
The indicator describes the volumes of failure 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
Organisations and Operations (OKA), resident inspectors
Pauli Kopiloff (Loviisa nuclear power plant)
Jarmo Konsi (Olkiluoto nuclear power plant)

Interpretation of indicator

Loviisa
In 2006, the Loviisa power plant adopted the LOMAX information system, replacing the previous LOTI system. As a result, the scope of the indicator for the maintenance of components subject to the Technical Specifications has been extended so that future maintenance work will also include such work on Tech Spec components that did not cause an operation restriction. In connection with this period of change, changes and corrections have been made to the figures for 2006 and 2007, already presented earlier, to avoid future interpretation problems created by the information system change. Since 2006, preventive maintenance figures include, according to the information system’s classification, the scheduled maintenance, in-service inspection, periodic testing and condition monitoring for components, as well as inspection/shift rounds. Similarly, repair work figures include overhauls and repairs of component failures. Due to the information system change and the extension and further specification of the scope of the figures described above, the maintenance figures for 2008 are only fully comparable for the last three years.
When considering the variation found in the number of fault repairs and particularly of preventive maintenance measures, the many types of annual maintenance included in the maintenance strategy must be observed (refuelling outage, four-year annual maintenance, brief annual maintenance and eight-year annual maintenance). The four-year cycle may have a significant impact on the annual figures. In 2008, a major increase could be observed in the amount of maintenance work for equipment subject to Technical Specifications. The increase is mainly due to the annual maintenance cycles explained above.

Judging by the data behind the indicator, 2008 was not markedly different from the previous years as concerns preventive maintenance. The ratio of the number of preventive maintenance works to the number of fault repairs was 4.30 in 2008, compared to 4.06 in 2007. The relative increase in 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 stability of the indicator value, with changes being mainly attributable to variation due to the scheduling of annual maintenance, may be regarded as an indication of a functional maintenance strategy.

**Interpretation of 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 as of 1 January 2006, the data is not comparable with the figures for earlier years. Class 3 data (systems subject to the Technical Specifications (Tech Specs) has been removed from the work order classification, since the Class 3 category covers all systems specified in the Tech Specs. Thus this indicator is used to monitor the ratio of the number of preventive maintenance works causing unavailability of components to the number of failure repairs.

The number of maintenance works causing unavailability of components, included in the indicator, has been decreasing since 2006 due to the decreasing amount of fault repairs. The amount of work causing unavailability of components included in the so-called preventive maintenance packages,
carried out for OL2 in the first part of the year and for OL1 in the latter part of the year, dropped approximately 30% in 2007 compared to 2006. The number for 2008 was nearly equal to that of 2007.

The ratio of preventive maintenance work to fault repairs was 1.64 in 2006 and 1.2 in 2007. In 2008, the ratio was 1.34.

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.I.1c Repair time of components subject to the Technical Specifications

Definition
As the indicator, the average repair time of failures causing unavailability of components defined in the Tech Specs is monitored. With each repair, the time recorded is the time of unavailability. It is calculated from the detection of the failure to the end of 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 indicator
The indicator shows how quickly failed Tech Spec components are repaired in relation to the repair time allowed in the Tech Specs. The indicator is used to assess the strategy, resources and effectiveness of plant maintenance.

Responsible units/persons
Organisations and Operations (OKA), resident inspectors
Pauli Kopiloff (Loviisa nuclear power plant)
Jarmo Konsi (Olkiluoto nuclear power plant)

Interpretation of indicator

Loviisa
The Technical Specifications define the maximum allowed repair times for components based on the components’ safety significance. The times vary between 4 hours and 21 days. Failures in Tech Spec 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 of failures causing unavailability of components have remained stable at the Loviisa plant for several years. In 2008, the average repair time for the plant units was 27.7 hours, while the average of the four previous years was 33.9. In 2008, the average repair time of Tech Spec component failures that had an allowed repair time of 72 hours or less was 22.1 hours at LO1 and 27.8 hours at LO2.

On the basis of the 2008 indicators and the data behind them, the plant’s maintenance operations meet the requirements. The plant must continue to pay attention to adequate resources and the management of operations so that faults are repaired without undue delay, even if the allowed repair time is long.

![Average of real repair times of Tech Spec component failures, Loviisa NPP](image-url)
**Interpretation of indicator**

**Olkiluoto**

The indicator is used to monitor the repair times of components subject to the Technical Specifications. The repair time allowed in the Technical Specifications 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 Technical Specifications.

In the long term, the average repair time has varied between 5 to 8 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 2008, the average repair time of failures causing unavailability of components defined in the Technical Specifications was low for both plant units, approximately 5.5 hours. On the basis of the 2008 indicators and the data behind them, the plant’s maintenance operations meet the requirements.

![Graph](image-url)

**A.I.1d Common cause failures**

**Definition**

As the indicator, the number of common cause failures of components or systems defined in the Tech Specs 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 indicator**

The indicator is used to follow the quality of maintenance.

**Responsible unit/person**

Organisations and Operations (OKA)

Tomi Koskiniemi (Loviiisa)

Suvi Ristonmaa (Olkiluoto)

**Interpretation of indicator**

**Loviiisa**

In 2008, no safety-significant common cause failures were identified at the Loviiisa power plant. The situation is good.

**Olkiluoto**

Two common cause failures were identified at Olkiluoto. The flywheel generators of reactor coolant pumps were found inoperable in connection with a voltage regulator failure at Olkiluoto 1 in May. The other common cause failure related to seal failures in the compressed air motors of diesel generators, also observed in May.
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 followed.

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

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

Responsible unit/person
Organisations and Operations (OKA)
Tomi Koskiniemi (Lovisa)
Suvi Ristonmaa (Olkiluoto)

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

Lovisa
In 2008, Lovisa plant units had a total of five failures leading to production losses. No reactor trips occurred. Failures caused the plant to go to low load, which allowed repair work. The number of failures and the resulting production losses were low compared to previous years. The figure itself has been at a good level since 2004, which also shows in the plant’s load factors.

At Lovisa 1, there were two such failures: the leak in the drains line of the high-pressure heaters in June, and the oil leak in a reactor coolant pump motor in October. In connection with the latter, an N bearing was replaced in the pump motor. At Lovisa 2, the number of such failures was three: the dropping of a control rod due to a failure of a low-frequency transformer in May, a reactor coolant pump trip caused by a faulty differential pressure protection signal in July, and the opening of an SP50 generator breaker of the turbine generator caused by the faulted operation of a regulator.

Lovisa’s 2003 abnormal indicator value was caused by the replacement of the stator in one of the generators. The work took approximately 41 days and caused a production loss of 2.6%.

Olkiluoto
Olkiluoto 1 experienced higher production losses from component failures in 2008 than in the previous years. Approximately 90% of the production losses from component failures were caused by a voltage regulator failure at the end of the annual maintenance outage on 30 May 2008, the inoperability of the flywheel generators of the reactor coolant pumps observed in connection with the said failure, and the several days’ power restriction period following the inoperability.

At Olkiluoto 2, two major failures with an effect on production occurred. A reactor trip occurred at the beginning of January, when ice chips blocked circulating water band screens. The plant unit was disconnected from the national grid for approximately 19 hours to assess the situation and repair faults. As a result of the failure on 30 May at Olkiluoto 1, the flywheel generators of Olkiluoto 2 reactor coolant pumps were also found to be inoperable, and for approximately 11 days the plant unit was brought to the 80–85% power level allowed by the fuel margins.
A1.2 Exemptions and deviations from the Technical Specifications

Definition
As indicators, the number of non-compliances with the Technical Specifications, as well as the number of exemptions granted by STUK, are followed.

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

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

Responsible unit/person
Organisations and Operations (OKA)
Tomi Koskiniemi (Loviisa)
Suvi Ristonmaa (Olkiluoto)

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

Non-compliance with the Tech Specs 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 Technical Specifications. The objective is for no events with non-compliance to the Technical Specifications to occur at the plants. The licensee always prepares a special report on the non-compliance and any corrective action, and submits the report to STUK for decision.

Loviisa

Exemptions
STUK approved five exemptions in 2008. One application concerned repair of a component failure, one inspections, two the changes in Loviisa I&C facilities (LARA) and one the changes in the storage, waste and repair shop (VAJAKO) facilities. The number remained similar to that of the previous years. The number of failure-related exemptions decreased, which is good.

The large number of exemptions granted in 2003 can be explained by the replacement of the fixed measurement system (the MONU project); work related to this project required an exemption in any operating state.

Non-compliances with the Tech Specs
The number of non-compliances with the Technical Specifications has remained low for Loviisa in recent years.

In 2008, two events occurred at the Loviisa plant resulting in non-compliance with the Technical Specifications. One of these concerned testing intervals, and the other incorrect simulation in the reactor protection system. The safety significance of the event concerning testing intervals was low but, as a result, actions to improve safety were initiated. The safety significance of the incorrect simulation was low, but deficiencies in the procedure made it significant. The power company will prepare a root cause analysis on the event in 2009, and STUK will inspect the analysis.

In addition, a third event was reported. The event concerned fuses that were missing from the severe accident power supply subsystem’s second uninterruptable power supply system. This event was not interpreted as a non-compliance with the Technical Specifications. The Tech Specs requirement only applies to the SAM power supply, which was functional as a whole (both diesel generators and the batteries). The missing fuses were, however, against the spirit of the Tech Specs, according to which all components must be in working order. The safety significance of the event is minor.

---

Number of deviations from the Tech Spec, Loviisa NPP

<table>
<thead>
<tr>
<th>Year</th>
<th>Exemptions</th>
<th>Deviations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>2000</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>2001</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>2002</td>
<td>13</td>
<td>11</td>
</tr>
<tr>
<td>2003</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>2004</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>2005</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2006</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>2007</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>2008</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

---
**Olkiluoto**

The number of events related to Technical Specifications does not deviate from the average. Based on the results of the last ten years, Olkiluoto nuclear power plant applies for STUK's approval for non-compliance with the Tech Specs six times per year on average. In addition, the plant has an average of four events in which operations are non-compliant with the Tech Specs. In 2004 and 2005, the number of exemptions was increased by work and installations related to the modernisation of OL1 and OL2 and the construction of OL3.

**Exemptions**

In 2008, TVO applied for permission for six planned exemptions from the Technical Specifications. STUK approved all the applications. One was to do with replacing the battery bank of Olkiluoto 2 during power operation, one with investigating an incident in reactor level measurement at Olkiluoto 2, and three with the disconnection of the power supply for the duration of excavation work and Olkiluoto 3-related work in order to ensure safety at work. One application is for permission to open an isolation valve at Olkiluoto 2 during the next shutdown. In addition to these, STUK approved an extension for three permissions based on TVO's application.

**Non-compliances with the Tech Specs**

In 2008, there were four situations at the Olkiluoto plant in which the Technical Specifications were violated. Two were concerned with neglect to carry out periodic radiation measurement testing, one with the withdrawal of a control rod during annual maintenance, and one with the start-up of a plant unit after annual maintenance while one containment isolation valve was inoperable.
A.1.3 Unavailability of safety systems

Definition
As the indicators, the unavailability of safety systems is followed by the plant unit. The systems followed at 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 is calculated as the indicator. Unavailability hours are the combined unavailability time of redundant sub-systems divided by the number of sub-systems.

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 utilities. Licensee representatives submit the necessary data to the relevant person in charge at STUK.

Purpose of 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
Organisations and Operations (OKA), resident inspectors
Pauli Kopiloff (Loviisa nuclear power plant)
Jarmo Konsi (Olkiluoto nuclear power plant)
Interpretation of indicator

Lovisa

*TJ system*

The unavailability of the plant units’ high pressure safety injection systems (TJ) returned to a normal low level from the peak value of 2007.

For LO1, the total unavailability time was 26 hours, consisting of the repairs of three failures of minor significance. For LO2, the unavailability time was 29 hours, caused by the replacement of a shaft seal in a TJ pump.

The unavailability of the high pressure safety injection systems was low in 2008, i.e. their condition and availability were good.

*RL system*

In 2008, the unavailability of the auxiliary feed water systems remained at the previous years’ level.

For LO1, the total unavailability time was 479 hours, which was exclusively caused by the annual maintenance of RL84. For LO2, the total unavailability time was 362 hours, 297 hours of which were RL97 maintenance repairs performed during the annual outage. The total unavailability during LO2 power operation was 65 hours, resulting from the repairs of 4 failures. Of these, the most significant source of unavailability was the repair of the RL93D01 pump shaft’s free end seal, taking 33 hours.

The unavailability of the auxiliary feed water systems was low in 2008, i.e. their condition and availability were good.

*EY system*

The unavailability of the emergency diesels (EY) increased in 2008 compared to the previous year’s level, but still remained low, i.e. their availability was good.

In 2008, the total unavailability for all eight diesel generators was 270 hours, consisting of the repair times of 16 failures. The failures were due to normal component ageing. The failures were not serious.

Based on the indicators and the failures behind them, the condition of the emergency diesels can be regarded as good.
Interpretation of indicator

**Olkiluoto**

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

The unavailability of the auxiliary feed water system increased significantly after 2004, when the unavailability was practically at 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 will be installed for other such OL1 and OL2 lines in 2009 and 2010. There were no significant failures in 2007 or 2008, and the unavailability of the auxiliary feed water system decreased to nearly zero for both plant units.

The unavailability of the diesel generators has decreased since 2004, and was very low in 2006 and 2007. In 2008, the value increased 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. The diesel generator of one subsystem did not start in connection with a periodic test at OL1 plant unit on 28 May 2008. The failure was caused by a leak in the seals of both compressed air motors of the diesel engine. In inspections, similar leaks were found in the seals of the compressed air motors of several diesel generators in both plant units. Thus, the failure was a common cause failure endangering the availability of a Safety Class 2 system. The event was classified as an anomaly, rated as INES 1 according to the International Nuclear Event Scale. The compressed air motor seals for the diesel engines for both OL1 and OL2 were inspected and replaced in connection with the inspections. The diesel generators were isolated one subsystem at a time. The isolation time for each diesel was, however, short. The inspection and repairs were carried out swiftly.

The condition of the containment spray system and the auxiliary feed water system has remained good. The increase in the unavailability of emergency diesels was a result of starter motor failures that were caused by the exclusion of these motors from appropriate preventive maintenance. In other regards, the condition of the diesel engines has remained good.
A.I.4 Occupational radiation doses

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

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

**Purpose of indicator**
The indicators are used to control the radiation exposure of employees. In addition, compliance with the YVL Guide’s calculatory threshold for one plant unit’s collective dose averaged over two successive years is followed. The threshold value, 2.5 manSv per one gigawatt of net electrical power, means a radiation dose of 1.22 manSv for one Loviisa plant unit and 2.15 manSv for one Olkiluoto plant unit. The collective radiation doses describe the success of the plant’s ALARA programme. The average of the ten 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 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 major 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. In the previous years, major outages have been held in even years and normal outages in odd years. The effect of annual outages on collective doses can be clearly observed in the Collective radiation dose, Loviisa graph. In 2008, a four-year annual maintenance took place at Loviisa 1, and a short annual maintenance at Loviisa 2. The time used for annual maintenance outages was long, and there was a high amount of work with significance for radiation protection, which resulted in a total collective dose that was higher than that of the previous year. Still, the collective dose was lower than in other similar major annual maintenance years. The low dose for the four-year maintenance can be explained by better targeting of materials inspections, the new induction training, and the improved planning and monitoring of radiation protection.

The radiation doses for nuclear power plant workers were below the personal dose limits. The trend for the average of the ten highest doses has been declining in recent years. In 2008, the average was higher than in the previous year, but still lower than the average dose level of recent years. The average for 2007 was the lowest of all time.
The Radiation Decree (1512/1991) stipulates that the effective dose for a worker from radiation work must not exceed the 20 mSv/year average over any period of five years, or 50 mSv in any one year.

Furthermore, the threshold set for the collective occupational dose was not exceeded in 2008. 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).

Collective dose per 1 GW of net electrical capacity averaged over two succesive years

Reporting threshold 2.5 manSv/GW according to the Guide YVL 7.9

Collective occupational radiation dose (manSv), Loviisa NPP

Average of the ten highest doses (mSv), Loviisa NPP


Average of the ten highest doses (mSv) in 2005–2006, Loviisa NPP
Interpretation of 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 2005 and 2006, the collective doses for the workers were high due to turbine work with considerable significance for radiation protection. In 2008, the collective dose in Olkiluoto was the lowest since 1983. In addition, the average of the ten highest doses was decidedly lower than in the previous years, and the set dose limits (YVL Guide 7.9, the 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 followed, 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 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.

A.I.5a Releases into the atmosphere

Interpretation of indicator
Radioactive releases into the atmosphere from the Lovisa and Olkiluoto nuclear power plants were of the same magnitude as in previous years. In Lovisa, only the releases of iodine isotopes saw a slight increase. The total releases from Olkiluoto have decreased, and releases of noble gas activities remained below the detection limit. Radioactive releases into the environment from the Lovisa and Olkiluoto nuclear power plants were small. They are well below the set limits.

Gaseous fission products, noble gases and iodine isotopes originate in leaking fuel rods, in
the minute amounts of uranium left on the outer surfaces of fuel cladding during fuel fabrication, and in reactor surface contamination from earlier fuel leaks. At both Loviisa and Olkiluoto, fuel leaks have been very small. **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 indicator**
The releases of radioactive substances with gamma activity have been decreasing since 2004, when the plant carried out a planned discharge of low-activity evaporation residue into the sea. The releases of substances with gamma activity into the sea from Olkiluoto have been decreasing in recent years, reaching their lowest value in 2008.

![Graph of gamma activity of liquid effluents (Bq).](image)

### A.I.5c Population exposure

**Interpretation of indicator**
The calculated radiation dose for the most exposed individual in the vicinity of each power plant was of the same magnitude as in the previous years. The doses for the most exposed individual for both Loviisa and Olkiluoto were low in 2008. The Loviisa graph shows how the dose for the most exposed individual is affected by the controlled discharge of low-activity evaporation residues into the sea. The previous controlled discharge was made in 2004.

The calculated doses of the most exposed individual in the vicinity of both plants are less than 0.1% of the 100 microSv limit established in the Government Decision (395/1991).
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 indicator
The indicator is used to follow the amount of investments in plant maintenance and their fluctuations.

Responsible unit/person
Organisations and Operations (OKA)
Tomi Koskiniemi

Interpretation of indicator
The variation in the indicator distinctly shows the investments related to power upgrades and modernisation projects of the plants. Both plants have paid much 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. At the moment, the situation is good at both plants.

Loviisa
At the Loviisa power plant, the most significant investment in 2008 was the I&C renewal (LARA). LARA's share of the total investments was approximately 50% in 2007 and 2008. Other investments have remained at the previous years’ level.

In addition to LARA, major investments in 2008 included the replacement of stators, the basic renovation of waste, storage and decontamination facilities, refuelling machine renovation (LAMO), replacement of bolts in the reactor support cage, basic servicing of emergency diesels and generators, the improvement of secondary circuit safety (LARA/SETU), and the renewal of high pressure safety injection pumps (TJ pumps).

Olkiluoto
The investments remained at the previous years’ level in Olkiluoto in 2008. The largest investments include the gas turbine plant completed in 2008, the modernisation of the external radiation measuring system, and the continuing electricity production and aging management-related low pressure turbine renewal project and the acquisition of new generators in OL1 and OL2.
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 followed. (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 (YTD).

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

Responsible unit/person
Organisations and Operations (OKA)
Tomi Koskiniemi (Loviisa)
Suvi Ristonmaa (Olkiluoto)

Interpretation of indicator

Loviisa
The number of events warranting a special report has not changed markedly in the long term. The numbers have remained reasonably low. In the last year, three events warranting a special report (two of which were non-compliances with the Tech Specs, see section A.I.2) were observed.

The first of these was related to differences specified for valve testing intervals in the Technical Specifications and in guides. The safety significance of the event was very minor. The second event concerned an incorrect simulation in the reactor protection system. The simulation would have prevented a reactor trip resulting from the stopping of four reactor coolant pumps. The safety significance of the incorrect simulation was low, but deficiencies in the procedure made the event significant. The power company will prepare a root cause analysis on the event in 2009, and STUK will inspect the analysis.

The third event concerned fuses that were missing from the severe accident power supply subsystem’s second uninterrupted power supply system. The fuses had been absent since the annual maintenance of 2008. The safety significance of the event was very minor.

In the first case, corrective measures were targeted at the improvement of testing programmes and instructions, as well as cross-checking of the Tech Specs and improving the inspection procedures for the guidelines. For the second event, incorrect simulations were removed as an immediate corrective measure. Actual corrective measures will be defined in connection with the root cause analysis. For the event concerning the UPS fuses, corrective measures are targeted at developing record entries and more extensive inspections at plant start-up.

The number of reported operational transients has remained reasonably good since 2002, at between five and nine transients per year. At Loviisa 1, the transients concerned a short-circuit in a condensate pump motor at start-up, bypass of

<table>
<thead>
<tr>
<th>Year</th>
<th>LO1</th>
<th>LO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>2000</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>2001</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>2002</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>2003</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>2004</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>2005</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>2006</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>2007</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>2008</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>

Number of Special Reports, Loviisa NPP

<table>
<thead>
<tr>
<th>Year</th>
<th>LO1</th>
<th>LO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>2000</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>2001</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>2002</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>2003</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>2004</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>2005</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>2006</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>2007</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>2008</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Number of reactor scrams, Loviisa NPP
low pressure heaters, and the low pressure heater bypass and main coolant pump start-up problems observed in connection with the LARA main coolant pump shutdown test. At Loviisa 2, transients concerned the failure of one control rod, resulting in the rod’s entry into the reactor, a spurious trip of a main coolant pump and a spurious opening of an excitation field breaker. The plant operated as planned during the transients.

The number of reactor trips has been low at Loviisa, partly due to the two turbines. These guarantee that if one turbine trips due to a malfunction or other cause, the reactor remains operational. No reactor trips occurred in 2005–2008.

Olkiluoto

Based on the data from the last ten years, an average of one reactor trip per year occurs at Olkiluoto nuclear power plant. In 2008, two reactor trips occurred, one at both plant units. Seawater cooled rapidly in front of the Olkiluoto nuclear power plant on the morning of 5 January 2008. The ice chips created as a result of this cooling blocked the circulating water screening filters of Olkiluoto 2 and weakened the flow of the seawater used as coolant in the plant. As a result, a turbine trip occurred at the plant unit, leading to a reactor trip. Following an incorrect function in the new voltage regulator installed during the annual maintenance in 2008, generator voltage began to increase at the start-up of Olkiluoto 1 on 30 May 2008. Reactor power was 60%. The protective devices of the electrical network disconnected the generator and power plant’s main connection to the national 400 kV grid. The back-up connection from the 110 kV grid connected automatically after two seconds to supply power to the plant systems. The overvoltage peak caused by the opening of a plant breaker shut down all six main coolant pumps circulating cooling water within the reactor pressure vessel, as well as the flywheels that were supposed to slow down the stopping of the pumps, and damaged parts of the control electronics of the main coolant pumps and flywheels. As a result of the transient, a turbine trip and partial reactor trip occurred at Olkiluoto 1, with an immediate reactor trip following as the actuator oil pumps of turbine valves stopped and the direct dumping of steam into the turbine condenser was prevented.

Based on the data from the last ten years, the average number of annual events warranting a special report or an operational transient report is five. The number of events warranting a special report in 2008 (seven) is higher than average. Five of these events occurred during annual maintenance. Due to the latest events, TVO had a safety culture assessment done in 2008. TVO presented the results of the assessment to STUK in the safety management A1 inspection in January 2009.

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 2008, one event warranting an operational transient report and two warranting a special report concerned both plant units.

![Number of Special Reports, Olkiluoto NPP](chart1)

![Number of reactor scrams, Olkiluoto NPP](chart2)
A.II.2 Direct causes of events

**Definition**
As the indicators, the direct causes of events reported in accordance with Guide YVL 1.5 are followed. The causes of the events are divided into technical failures and erroneous operational and maintenance actions (non-technical, human errors).

**Source of data**
Data for the indicators are collected from special reports, reports on reactor trips and operational transient reports, and are entered into an event follow-up table maintained by OKA.

**Purpose of indicator**
The indicator is used to follow the division of the causes of reported events into technical and non-technical causes. “Non-technical causes” denote failures caused by erroneous operational and maintenance actions. The indicator may be indicative of an organisation’s operation.

**Responsible unit/person**
Organisations and Operations (OKA)
Suvi Ristonmaa and Tomi Koskiniemi

**Interpretation of indicator**
The indicators do not give cause for any particular conclusions concerning either utility.

Both technical and non-technical causes can be identified behind many events. In such cases, classification is done based on the most significant cause of the event.
A.II.3 Risk-significance of events

Definition
As the indicators, the risk-significance of events caused by component unavailability is followed. As the risk measure, 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 ($1E-8 \leq$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 Tech Specs are in category 1, if they can be utilised for this indicator. Non-compliances with the Tech Specs are also dealt with under indicator A.I.2.

N.B! Calculations for the Loviisa plant are based on a somewhat outdated internal-initiating-event model, making them indicative only of a trend.

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

Purpose of 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 systematically identify signs of a deteriorating organisational and safety culture.

Responsible unit/person
Risk assessment (RIS), Jorma Rantakivi (PSA computation)
Organisations and Operations (OKA) (failure data)

Interpretation of indicator

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

Loviisa 1:
1) Component failure: Change in the route of a pneumatic tube of the ventilation UV20 damper control on the outlet side for the distribution rooms of the control room building. The change was necessary as the tube hindered free passage. During the change (4.4 h), UV20 was not available to replace the UV25 system. CCDP = 2.1E-7.
2) Component failure: A diesel generator did not start during a test drive. The alarm remained active. The fault was latent for approximately 13 days. CCDP = 3.7E-7.
3) Component failure: One (B03) of the two cooling machines of the cooling system UV25 of the control room building’s instrumentation facility failed (oil pressure and high pressure alarms). CCDP = 1.1E-7.
4) Component failure: The frequency of diesel EY02 was too high in the periodic testing. The diesel was not synchronised with the network until the frequency was lowered. The failure had been latent for approximately 8 days. CCDP = 3.2E-7.
5) Preventive maintenance: The preventive maintenance of auxiliary feed water system RL97 during LO2 revision increased the probability of a severe accident at LO1, as the auxiliary feed water systems RL 94/97 can be connected to either plant unit. CCDP = 8.6E-7.

Loviisa 2:
1) Component failure: The water cooling machine of the control room building’s instrumentation facility cooling system UV45 made a rattling noise. UV45 was not available during repair. CCDP = 4.9E-7.
2) Component failure: The back-up auxiliary feed water pump RL97 was inoperative due to a low surface level in the diesel engine fuel tank. The failure had been latent for approximately 15 days. CCDP = 1.1E-6.
3) Component failure: The temperature measurement of the switchgear and cable space ventilation system did not start up the second pair of inlet and outlet fans (in calculations, the unavailability of the system is replaced with its own square root). CCDP = 2.7E-7.

4) Component failure: The hot safety injection system accumulator of the first redundancy and the cold safety injection system accumulator of the second redundancy were inoperative during the outage for the time of the inspection. The calculation was performed as if the event had occurred during power operation. CCDP = 4.0E-7.

5) Preventive maintenance: The preventive maintenance of auxiliary feed water system RL94 during LO1 revision increased the probability of a severe accident at LO1, as the auxiliary feed water systems RL 94/97 can be connected to either plant unit. CCDP = 8.6E-7.

At Loviisa, the risk arising from events consists of a few single device failures and the preventive maintenance of the auxiliary feed water system redundancies. 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:

Olkiluoto1:

1) Component failure (common cause failure of the diesels): The diesel engine of subsystem C did not start in the reactor protection system test, when all diesel engines were supposed to start. The fault was located in the compressed air motors of the component (two motors per diesel generator). The seals of the check valves of both motors (one valve per motor) were found to be damaged, and air leaked out. All seals for all diesel generators were inspected.

For Olkiluoto 1, six of eight seals were damaged. For Olkiluoto 2, one of eight seals was damaged. PSA computation was performed with diesel C as damaged, and diesel D with unavailability set to 0.5. The result was CCDP = 2.7E-6, which is approximately 19% of the annual risk.

2) Initial event: On 30 May 2008 a transient occurred at Olkiluoto 1 plant unit, in which the unit experienced a turbine trip and a reactor trip as a result of a generator overvoltage. In connection with the trips, the reactor coolant pumps stopped. As a result of an overvoltage in the 6.6 kV bus bars, damage occurred in the control systems of the reactor coolant pumps.
and the flywheel generators securing their deceleration ramp. At the moment of the event, the plant unit was in the middle of start-up after annual maintenance. Reactor power was approximately 60%, and the plant was synchronised to the national grid. In PSA computation, the initial event ‘loss of condenser’ was used, and the resulting CCDP was 2.1E-6.

3) Preventive maintenance: The diesel package DIP-A took approximately 17 days. CCDP = 3.8E-7.

4) Preventive maintenance: Pump P3 of shutdown secondary cooling system 721 was unavailable due to inspection of a check valve. CCDP = 1.1E-7.

Olkiluoto2:

1) Initial event: Rapid decrease of seawater temperature caused the creation of ice chips in band screens. Partial blockage of the band screens (frazil ice) hindered the flow of the water and caused a decline in the water level on the suction side of the circulating water pumps. The turbine trip resulted from high pressure in the condenser. A partial trip followed, and dumping began. This lead to a bypass trip and a reactor trip. In PRA, the case was modelled as a loss of feed water and condenser. The result was CCDP = 3.6E-6.

2) Component failure: In an inspection, the second starter motor of the subsystem B diesel generator was found to be inoperative due to a leaking seal. The fault had been latent for approximately 7 days. CCDP = 1.1E-7.

At Olkiluoto, the risk caused by these events consisted of two initial events leading to a reactor trip (OL2: frazil ice and OL1: generator overvoltage), a common cause failure of diesel generators, a few individual component failures and the long duration of diesel package A at OL1. The initial events and the common cause failure of the diesels have led to additional reports and will lead (or have already led) to changes at the plant or in the maintenance procedures. Other analysed 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 at the target level on average for several years, the annual fluctuation does not warrant particular attention.

Risks arising from operational activities have remained substantially at the same level as in previous years for all plant units except OL1. The higher value of OL1 was caused by the common cause failure of the diesel generators at the end of May.
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 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 (PSA computation)
Organisations and Operations (OKA) (failure data)

Interpretation of 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 of 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 for the last ten 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 renewing of the operating licence, as well as changes at the plant planned to be carried out earlier or in connection with the licence renewal.
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 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. 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).
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 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)
Heikki Saarikoski

**Interpretation of indicator**
At the Loviisa power plant, one event classified as a fire occurred in 2008. When starting up a pump of a drains system (RN) belonging to the turbine systems of Loviisa 1 on 19 September 2008, the motor short-circuited, which caused a powerful arc flame and smoke in the pump. The smoke stopped without any measures being taken. The plant’s fire brigade inspected the target and the environment. At Loviisa power plant, detection system errors have remained at the level of 2008. Correct alarms from the detectors have, however, increased, partially due to the large amount of work included in the long annual maintenance outages, and the construction of the new I&C buildings.

No events classified as fires occurred in the Olkiluoto plant area (OL1/2) in 2008. Outside the plant area, however, three events classified as fires occurred. All of these were minor and had no effect on plant safety. No detection system failures were observed at Olkiluoto power plant in 2008. The situation was the same as in 2007. The nine device failures shown in the table are failures of the sprinkler system, indicated by the fire alarm system. These failures did not, however, cause inoperability of the sprinkler system. Correct alarms from fire detectors have decreased since 2007, partially due to the shorter annual maintenance outages of 2008 and the smaller amount of work included in them.

The fire alarm system was renewed in 2000 at Loviisa power plant and in 2001 at Olkiluoto power plant. After the renewal of the fire alarm systems, the number of alarms increased at both plants due to 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 Loviisa and Olkiluoto plants has remained at the earlier level, as no events classified as fires have occurred, with the exception of the minor event of smoke being emitted from an electric motor at the Loviisa power plant. 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, as well as construction work done in the plant area.
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. As the indicator for the Loviisa plant, the activity level of the primary coolant calculated as I-131 equivalent concentrations, as well as the maximum activity as the sum of iodine isotopes, were followed until the end of 2006. Late in 2006, the Technical Specifications limit concerning the iodine activities in primary coolant was defined as an I-131 activity concentration, instead of the sum of iodine isotopes used until then. At the same time, I-131 activity concentrations were adopted for the monitoring of the maximum activity level. Loviisa power plant delivered the values for I-131 activity concentrations retrospectively from 1997–2006.

The maximum activity concentration of I-131 during depressurisation while entering shutdown or after a reactor trip, 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 indicator
The indicators describe fuel integrity and the fuel leakage volume during the operating cycle. The indicators for 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)
At Loviisa 2, an increase in the activity of gases released from process systems was detected on 28 November 2008. The activity concentration of the iodine isotopes in the primary coolant and the gaseous fission products dissolved into the primary coolant also increased. On 1 December 2008, the observation was confirmed as a fuel leak. After the initial stages of the leak, activity levels did not increase further, and no essential changes had occurred in the activity concentration by the end of the year. By the end of 2008, the maximum I-131 activity concentration was 1.3E+05 kBq/m³. Based on the gases released from the fuel rod and the activity concentrations of the iodine isotopes released into the primary coolant, it was estimated that a minor leak of one fuel rod had occurred. The power company continues to monitor the status and development of the leak using on-line monitoring,
as well as radioactivity measurements carried out at the laboratory. The leaking fuel bundle will be removed from the reactor in the 2009 annual maintenance outage at the latest. The previous fuel leak at Loviisa 2 took place in 1999.

The reactor of Loviisa 1 has had no leaking fuel for several years, so no essential changes have occurred in the I-131 activity concentrations.

At Loviisa plant units, the I-131 activity concentrations have shown no essential changes when the plant units have been brought to shutdown. After the fuel leak at Loviisa 2, no shutdowns had taken place at the plant unit by the end of 2008. The maximum concentrations have been detected in situations in which the plant units were being shut down for annual maintenance.

Based on the indicator, fuel integrity has been good at Loviisa 1. At Loviisa 2, fuel integrity was weakened by a minor fuel leak.

**Interpretation of indicators (Olkiluoto)**

The Olkiluoto plant units had no leaking fuel in 2008, so the I-131 activity concentrations have remained the same or decreased. Similarly, the maximum activities resulting from shutdown have also shown a declining trend. Based on the indicator, fuel integrity has been good at Olkiluoto plant units.

**A.III.1b Number of leaking fuel bundles**

**Interpretation of indicators (Loviisa)**

A minor fuel leak was detected at Loviisa 2 late in 2008. The leaking fuel bundle will be removed from the reactor in the 2009 annual maintenance outage at the latest. The previous fuel leak occurred at Loviisa in 1999.

**Interpretation of indicators (Olkiluoto)**

In recent years, fuel leaks have occurred at Olkiluoto plant units nearly every year. Leaks have been small and the leaking bundles have been removed in annual maintenance outages following leak detection. In 2008, Olkiluoto plant units had no leaking fuel. The last leaking fuel bundle was removed from the reactor of Olkiluoto 1 in the annual maintenance outage of 2006, and from the reactor of Olkiluoto 2 in the outage of 2007.
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 utilities, depicting the effectiveness of water chemistry control in the secondary circuits of PWRs and in the reactor circuits of BWRs. The indicator for Olkiluoto is the international index used by the plant. 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. This index observes corrosive factors and the concentrations of corrosion products in steam generator blow-down and the feedwater. For steam generator blow-down, the calculation includes the chloride, sulphate and sodium concentrations and acid conductivity; for feedwater, it includes the iron, copper and oxygen concentrations. The new index has been used as an indicator since 2002. 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 values during power operation.

- The maximum chloride concentration of the steam generator blow-down (Loviisa) and the reactor water (Olkiluoto) during operation compared with the Tech Spec limit in the monitoring period. At the Olkiluoto plant, the maximum sulphate content of reactor water on even, steady-state operation is followed as well.

- 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 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 and the success of the water chemistry control and the shutdown procedures. In addition to the parameters described here, the power companies 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 the Technical Specifications for the secondary circuit, the normal state value for the steam generator blowdown water chloride content was changed. The new normal state limit is $< 100 \mu g/l$, while the earlier value was $< 500 \mu g/l$. The new limit was already included in the new chemistry guidelines applied since 2006. The cation conductivity of the steam generator blowdown water during power operation was also added to the Technical Specifications of secondary circuit chemistry.

At Loviisa 2, the chloride content in the blowdown water of all steam generators exceeded the Tech Specs limit when the plant unit was brought back to power operation after the annual maintenance outage. The content was brought to within the limit in less than 24 hours. At Loviisa 1, the cation conductivity of the steam generator blowdown water exceeded the Tech Specs limit when power operation began. The high conductivity was due to organic impurities. The conductivity values were brought to within Tech Specs limits in approximately 24 hours. The limits were only exceeded for a short period of time and therefore had no substantial effect on the plant units’ chemistry indices.

The iron contents of the primary coolant and the secondary circuit feed water have complied with the power company’s guidelines. Co-60 activity concentrations measured while bringing the plant units to shutdown showed no deviation from the values of previous years.

Based on the water chemistry indicators, the primary circuit integrity of Loviisa plant units has remained good.
Interpretation of indicators (Olkiluoto)
In previous years, Olkiluoto plant units have experienced problems with the reactor coolant sulphate content exceeding the guideline set by the power company. The sulphate in the reactor coolant originates in the sulphate released from the ion-exchange resins of the condensate cleaning filters. Temperature is one of the factors in the release of sulphate from the filter resins. Changes have been made at the plant units to reduce the temperature of the water entering the condensate cleaning filters by changing the location of the condensate system pre-heater. The relocation was carried out at OL2 in 2003 and at OL1 in 2004. In addition to temperature, the replacement interval of filter resins also has an effect on the sulphate concentration. The guideline for the reactor coolant sulphate content was not exceeded in 2008. With the exception of individual deviations, the reactor coolant sulphate content has, in recent years, remained in compliance with the guideline (< 5 µg/l) set by the power company. Thus, STUK approved the power company's suggestion to the effect that annual reports concerning the cleaning of condensate will no longer be required by STUK.

In one analysis, the iron content of the reactor coolant (1.1 µg/l) exceeded the target value (< 1 µg/l) set by the power company.
The chemistry index has remained steady at the best possible value (1).

The maximum concentrations of Co-60 activity during shutdown represent concentrations that were measured when plant units were brought to shutdown for annual maintenance. Olkiluoto 1 also had a short hot shutdown and a reactor trip immediately after the annual maintenance outage, but the Co-60 activity concentrations were, in these situations, lower than when the plant unit was brought to shutdown for annual maintenance. The average Co-60 activity concentration of Olkiluoto 2 reactor coolant during power operation has seen an increase in recent years. In 2007, the concentration began to decrease, which also shows as a decrease in the maximum concentrations during shutdown in 2008. The Co-60 activity concentration of Olkiluoto 1 reactor coolant was slightly above normal before the 2008 annual maintenance outage, which could explain the concentration being a little higher than in the previous year. Year-on-year variation in the concentration has been, however, small. Variation can be created even by small differences in the conditions that prevail when a plant unit is brought to shutdown.

Based on the water chemistry indicators, the primary circuit integrity of Olkiluoto plant units has remained good.
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, and
- highest daily containment internal leakage volume during the operating cycle in relation to the allowed leakage volume in the Tech Specs (outflow water volume of water condensing in the air coolers of the containment cooling system 725/Tech Specs 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 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**
Organisations and Operations (OKA), Jarmo Konsi

**Interpretation of indicator**
One of the purposes of controlled leakage drain system 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. In the operating cycle of 2007–2008, the number of identified leaks within the containment decreased to some extent compared to the previous operating cycle.

At the lowest point of the containment dry-well, there is drain water pit T33, which collects the drain water from the containment dry-well floor drains and any leakage from the control rod actuator seals. The number of unidentified leaks from the primary circuit has been small for three consecutive operating cycles.

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 2007–2008, the containment’s largest internal daily leak volume’s ratio to the maximum allowable volume, as specified in the Technical Specifications, was low for both plant units. This was the fifth consecutive operating cycle with hardly any leaks from the primary circuit into the containment atmosphere.

The primary circuit was leak-proof in the operating cycle of 2007–2008.

---

**Identified leakages of primary circuit (352T1, m³), Olkiluoto NPP**

<table>
<thead>
<tr>
<th>Year</th>
<th>OL1</th>
<th>OL2</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>3694</td>
<td>3094</td>
</tr>
<tr>
<td>2001</td>
<td>3443</td>
<td>2877</td>
</tr>
<tr>
<td>2002</td>
<td>2678</td>
<td>3272</td>
</tr>
<tr>
<td>2003</td>
<td>2481</td>
<td>3258</td>
</tr>
<tr>
<td>2004</td>
<td>3716</td>
<td>2211</td>
</tr>
<tr>
<td>2005</td>
<td>3300</td>
<td>2792</td>
</tr>
<tr>
<td>2006</td>
<td>3004</td>
<td>3582</td>
</tr>
<tr>
<td>2007</td>
<td>4058</td>
<td>3502</td>
</tr>
<tr>
<td>2008</td>
<td>3805</td>
<td>3055</td>
</tr>
</tbody>
</table>

**Unidentified leakages of primary circuit (345T33, m³), Olkiluoto NPP**

<table>
<thead>
<tr>
<th>Year</th>
<th>OL1</th>
<th>OL2</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>100.8</td>
<td>13.4</td>
</tr>
<tr>
<td>2001</td>
<td>79.6</td>
<td>9.4</td>
</tr>
<tr>
<td>2002</td>
<td>1.8</td>
<td>1.8</td>
</tr>
<tr>
<td>2003</td>
<td>196.0</td>
<td>14.0</td>
</tr>
<tr>
<td>2004</td>
<td>9.2</td>
<td>0.69</td>
</tr>
<tr>
<td>2005</td>
<td>1.1</td>
<td>0.12</td>
</tr>
<tr>
<td>2006</td>
<td>2.5</td>
<td>0.12</td>
</tr>
<tr>
<td>2007</td>
<td>1.6</td>
<td>0.48</td>
</tr>
<tr>
<td>2008</td>
<td>2.2</td>
<td>0.69</td>
</tr>
</tbody>
</table>

**The maximum unidentified leakage in ratio to the Tech Spec limit, Olkiluoto NPP**

<table>
<thead>
<tr>
<th>Year</th>
<th>OL1</th>
<th>OL2</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>6.37</td>
<td>4.05</td>
</tr>
<tr>
<td>2001</td>
<td>4.06</td>
<td>0.46</td>
</tr>
<tr>
<td>2002</td>
<td>0.40</td>
<td>0.30</td>
</tr>
<tr>
<td>2003</td>
<td>0.30</td>
<td>0.18</td>
</tr>
<tr>
<td>2004</td>
<td>0.22</td>
<td>0.23</td>
</tr>
<tr>
<td>2005</td>
<td>0.21</td>
<td>0.21</td>
</tr>
<tr>
<td>2006</td>
<td>0.13</td>
<td>0.09</td>
</tr>
<tr>
<td>2007</td>
<td>0.25</td>
<td>0.06</td>
</tr>
<tr>
<td>2008</td>
<td>0.21</td>
<td>0.18</td>
</tr>
</tbody>
</table>
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 at the first attempt (i.e. as-found leakage smaller than acceptance criteria of valve and no consecutive exceeding of the so-called attention criteria of a valve without repair); 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. In Loviisa, the combined leakage rate is comprised of the leakage test results of 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, as well as the seals of the blind-flanged penetrations of ice-filling pipes.

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 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 indicator

Loviisa
The overall as-found leakages of the outer isolation valves have increased for both plant units, but both remained below the overall leakage limit defined in the Technical Specifications. For Loviisa 1, the largest leaks came via the ice condenser cooling system valve (approximately 25%) and the special active canalisation system valve (approximately 16%). At Loviisa 2, the largest leaks came via the four valves of the emergency core cooling system (approximately 40%). These four valves will be tested together, and the result will be calculated four-fold in the overall as-found leakage.

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 bellows seals (RA, RL, TL23), is small at both plant units.

**Olkiluoto**

The overall as-found leakage found in the first integrity tests of the OL1 outer isolation valves exceeded the overall as-found leakage limit set in the Tech Specs. The largest leak (approximately 61.4% of the overall as-found leakage) came via one valve in the controlled leakage drain system. The leak was caused by a maintenance error. After repairs, the total leakage met the requirements of the Technical Specifications.

At OL2, the sum of the first integrity test results for outer isolation valves was within the limit set in the Technical Specifications. The largest leaks came via the flange cooling system valve (approximately 20%), the scram system valve (approximately 17%) and the main steam valve (approximately 14%).

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.