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FINNISH REPORT ON NUCLEAR SAFETY

Finnish 3rd national report as referred to in Article 5 of the Convention on Nuclear Safety

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Executive summary

Finland signed on 20 September 1994 the Convention on Nuclear Safety which was adopted on 17 June 1994 in the Vienna Diplomatic Conference. The Convention was ratified on 5 January 1996, and it came into force in Finland on 24 October 1996. The first two review meetings were organized in 1999 and 2002. This report is the Finnish National Report for the Third Review Meeting in April 2005.

There are two nuclear power plants in Finland: the Loviisa and Olkiluoto plants. The Loviisa plant comprises of two VVER units, operated by Fortum Power and Heat Oy, and the Olkiluoto plant two BWR units, operated by Teollisuuden Voima Oy. The Loviisa units were connected to the electrical network in 1977 (unit 1) and 1980 (unit 2) and the Olkiluoto units 1 and 2 in 1978 and 1980, respectively. The nominal reactor thermal power of the Loviisa units is 1500 MW and of the Olkiluoto units 2500 MW. At both sites there are interim storages for spent fuel as well as final repositories for medium and low level radioactive wastes.

In the report, latest large safety reviews and plant modernization programmes are explained in detail including safety assessment methods and key results based on the Articles of Convention and related Finnish regulatory requirements. Safety performance of the Finnish nuclear power plants is also presented by using representative indicators. Finnish regulatory practices in licensing, provision of regulatory guidance, safety assessment, inspection and enforcement are also covered in detail. The Summary Report of the Second Review Meeting presents a list of topics where additional information is wished. These wishes have been taken into account in the report.

The major developments in Finland since the Second Review Meeting are as follows: continuation of safety assessment and enhancement of Loviisa and Olkiluoto nuclear power plant units after the large modernization programmes at the end of 90'ies, development of regulatory practices such as development and updating of safety guides, and Decision-in-principle for a new nuclear power plant unit, Olkiluoto 3. The report also reflects operational safety issues and the recent developments in design, such as defence in depth and severe accident management issues. Latest development in the various topics of the Convention on Nuclear Safety is described.

The issues requiring further development to enhance safety have been covered in Chapter 3 of the report including provision for plant ageing, qualification of non-destructive testing, and reliability of digital automation and management of competence.

In the report, the implementation of each of the Articles 4 and 6 to 19 of the Convention is separately evaluated. Based on the evaluation it can be concluded that

- The Finnish regulatory infrastructure including nuclear and radiation regulations is in compliance with the Convention obligations.
- The regulatory practices comply with the Convention obligations.
- The licensee practices in provision of good safety performance and in modernization of old nuclear power plant units comply with the Convention obligations.
- There are some issues requiring further development to enhance safety as discussed in the report.

In conclusion, Finland has implemented the obligations of the Convention and also / therefore the objectives of the Convention are complied with.

Contents

References 3–6 are not included in this report; they are however provided together with the Finnish national report.

1 Introduction

Finland signed on 20 September 1994 the Convention on Nuclear Safety which was adopted on 17 June 1994 in the Vienna Diplomatic Conference. The Convention was ratified on 5 January 1996, and it came into force in Finland on 24 October 1996. The first two review meetings were organized in 1999 and 2002 and respective national reports have been provided. This report is the Finnish National Report for the Third Review Meeting in April 2005.

The fulfilment of the obligations of the Convention is evaluated in this report. The evaluation is based on the Finnish legislation and regulations as well as on the situation at the Finnish nuclear power plants. The reference is made to the IAEA Safety Requirements and other safety standards as appropriate.

Finland is a Member State of the European Union. The regulations of the Union are in force in Finland. The EU regulations relate e.g. to radiation protection, but there are no regulations pertaining directly to nuclear safety. When necessary, the Finnish legislation is modified to take into account the EU Directives.

In Finland, there are two nuclear power plants: the Loviisa and Olkiluoto plants. The Loviisa plant comprises of two VVER units, operated by Fortum Power and Heat Oy, and the Olkiluoto plant two BWR units, operated by Teollisuuden Voima Oy. The Loviisa units were connected to the electrical network in 1977 (unit 1) and 1980 (unit 2) and the Olkiluoto units 1 and 2 in 1978 and 1980, respectively. The nominal reactor thermal power of the Loviisa units is 1500 MW and of the Olkiluoto units 2500 MW. The booklet Nuclear Energy in Finland, Reference 4, provides an overview on the use of nuclear energy in Finland.

A Decision-in-principle to construct a new NPP unit was made by the Council of State and confirmed by the Parliament in 2002. Teollisuuden Voima Oy has filed an application for a Construction License at the beginning of 2004 to construct a Pressurized Water Reactor (PWR) unit of nominal reactor thermal power 4300 MW at the Olkiluoto site (Olkiluoto 3).

There are intermediate spent fuel storage facilities and final disposal facilities for low and medium level radioactive waste at the Olkiluoto and Loviisa plant sites. The disposal facility at Olkiluoto was taken into operation in 1992 and at Loviisa in 1998.

For taking care of the spent fuel final disposal, a joint company Posiva Oy has been established by Fortum and Teollisuuden Voima Oy. Research, development and planning work for spent fuel disposal is in progress and the disposal facility is envisaged to be operational in early 2020. The repository will be constructed in the vicinity of the Olkiluoto NPP site. To confirm the suitability of the site, construction of an underground rock characterisation facility was commenced in mid-2004. Finnish Parliament has endorsed a Decision-in-principle made by the Government for the implementation of Finnish Disposal Facility to the Olkiluoto site.

Finland observes the principles of the Convention, when applicable, also in other uses of nuclear energy than nuclear power plants, e.g. in research reactor. In Finland, there is one TRIGA Mark II research reactor (250 kW) situated in Espoo. The reactor was taken into operation in 1962.

In the report, latest safety reviews and plant modernization programmes are explained in detail including safety assessment methods and key results based on the Articles of Convention and related Finnish regulatory requirements. Safety performance of Finnish nuclear power plants is also presented by using representative indicators. Finnish regulatory practices in licensing, provision of regulatory guidance, safety assessment, inspection and enforcement are also covered in detail. The Summary Report of the Second Review Meeting presents a list of topics where additional information is wished. These wishes have been taken into account in the report.

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In Chapter 2 of this report, the implementation of each of the Articles 4 and 6 to 19 of the Convention is separately evaluated. At the end of Chapter 2, a concluding summary on the fulfilment of the obligations of the Convention is presented. Main issues requiring further measures to enhance safety are discussed in Chapter 3.

2 Compliance with Articles 4 and 6 to 19 – Article–by–article review

2.1 Article 4. Implementing measures

Each Contracting Party shall take, within the framework of its national law, the legislative, regulatory and administrative measures and other steps necessary for implementing its obligations under this Convention.

Main regulations in the field of nuclear energy are the Nuclear Energy Act and Decree, the Radiation Act and Decree, and the Decisions of the Council of State as well as the Regulatory Guides (YVL Guides) issued by the Radiation and Nuclear Safety Authority (STUK). The most essential safety regulations and guides are listed in Annex 1.

The legislative and regulatory measures to fulfil the obligations of the Convention were discussed in detail in the first and second reports. It was concluded that the Finnish regulatory framework fulfils the obligations of the Convention, and also the objectives of the Convention are complied with. The approach in Finland is a continuous fulfilment of the criteria presented in the Articles of the Convention. Also, the approach of a continuous improvement of safety is manifested in the Finnish nuclear legislation (VNP 395/1991). This third report concentrates on the activities of licensees to fulfil the obligations of the Convention.

2.2 Article 6. Existing nuclear installations

Each Contracting Party shall take the appropriate steps to ensure that the safety of nuclear installations existing at the time the Convention enters into force for that Contracting Party is reviewed as soon as possible. When necessary in the context of this Convention, the Contracting Party shall ensure that all reasonably practicable improvements are made as a matter of urgency to upgrade the safety of the nuclear installation. If such upgrading cannot be achieved, plans should be implemented to shut down the nuclear installation as soon as practically possible. The timing of the shut-down may take into account the whole energy context and possible alternatives as well as the social, environmental and economic impact.

2.2.1 Nuclear installations in Finland

In Finland, there are two nuclear power plants: the Loviisa and Olkiluoto plants. The Loviisa plant comprises of two VVER units that are operated by Fortum Power and Heat Oy, and the Olkiluoto plant comprises of two BWR units that are operated by Teollisuuden Voima Oy.

The Loviisa and Olkiluoto nuclear power plant units were connected to the electrical network as follows: Loviisa 1, February 8, 1977; Loviisa 2, November 4, 1980; Olkiluoto 1, September 2, 1978; and Olkiluoto 2, February 18, 1980.

The nominal thermal power of both of the Loviisa units is 1500 MW (109% as compared to the original 1375 MW). The increase of the power level was licensed in April 1998. The Operating Licenses of the units are valid until the end of 2007.

The nominal thermal power of both Olkiluoto units is 2500 MW, which was licensed in August 1998. The new power level is 115,7% as compared to the earlier nominal power 2160 MW licensed in 1983. The original power level of both units was 2000 MW. The Operating Licenses of the units are valid until the end of 2018. According to the conditions of the licenses, the licensee shall carry out an intermediate safety assessment by the end of 2008.

At both sites there are fresh and spent fuel storage facilities, and facilities for storage and treatment of low and medium level radioactive wastes. Other existing nuclear installations in Finland are the final disposal facilities for low and medium level radioactive waste at the Olkiluoto and Loviisa plant sites. The disposal facility at Olkiluoto was taken into operation in 1992 and at Loviisa in 1999.

In 2002 the gross production of Loviisa 1 was 3988 GWh (gross) and the load factor was 89.3%. The annual refuelling and maintenance outage lasted 26 days. The gross production of Loviisa 2 was 3674 GWh, the load factor 82.2% and the length of the refuelling outage was 49.5 days. Loviisa 2 had an extended inspection outage, which is performed every eighth year. The annual collective radiation doses were 1.04 manSv and 1.57 manSv for Loviisa 1 and Loviisa 2 respectively.

In the year 2003 Loviisa 1 produced 4129 GWh (gross), the load factor was 92.4% and the refuelling and maintenance outage lasted 23.5 days. In 2003 the gross production of Loviisa 2 was 3929 GWh, the load factor was 87.9%, and the refuelling outage lasted 16.5 days. The collective radiation doses in 2003 were 0.61 manSv for Loviisa 1 and 0.33 manSv for Loviisa 2.

In 2002 net production at Olkiluoto 1 was 6998 GWh and the load factor 95,3%. The annual outage and refuelling of Olkiluoto 1 was performed in May and lasted 13 days. The net production of Olkiluoto 2 was 7109 GWh and the load factor was 96,6%. The annual outage and refuelling of Olkiluoto 2 was in May and lasted 7 days. The collective radiation doses in 2002 were 0,81 manSv for Olkiluoto 1 and 0,31 manSv for Olkiluoto 2.

In 2003 net production at Olkiluoto 1 was 7127 GWh and the load factor was 97,0%. The annual outage and refuelling of Olkiluoto 1 was performed in May–June and lasted 10 days. The net production of Olkiluoto 2 was 7027 GWh and the load factor was 95,5%. The annual outage and refuelling of Olkiluoto 2 was in May and lasted 15 days. Inspections made during the annual outages showed that the plant units are in good condition and that any faults or defects were minimal. The company policy is to keep the plant units as good as new. The collective radiation doses in 2003 were 0,27 manSv for Olkiluoto 1 and 0,76 manSv for Olkiluoto 2.

Figure 1 shows the load factors of Loviisa and Olkiluoto NPP's during the last ten year period. Load factor describes the energy produced in comparison to the energy that could have been produced if the unit had operated at the nominal power during the whole period.

The latest comprehensive overall safety reviews of the Loviisa and Olkiluoto plants were carried out by the licensees and independently by STUK in 1996–1998 in connection to the renewal of op-

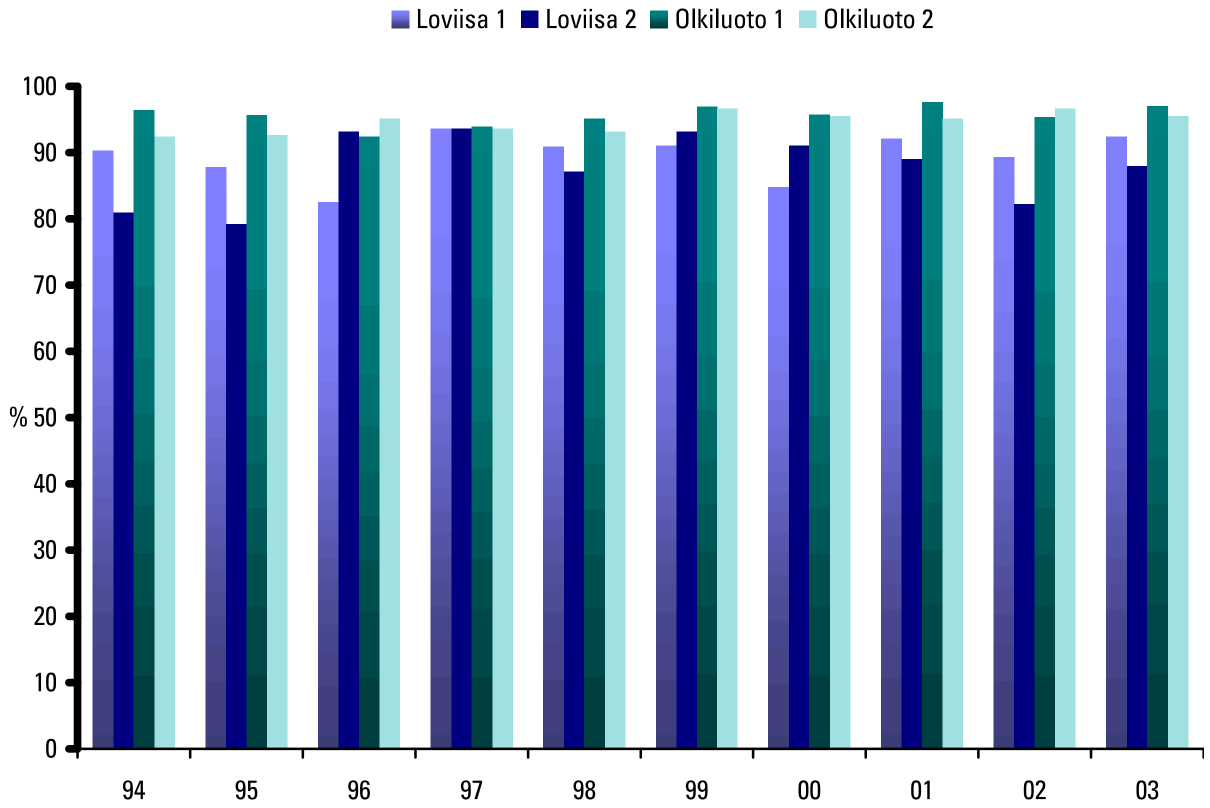


Figure 1. Load factors of the Loviisa and Olkiluoto plant units.

erating licenses of nuclear power plant units. The safety documentation, including safety assessments done by both licensees, was submitted to STUK at the end of 1996. In addition to the review of the licensing documents such as Final Safety Analysis Report, STUK also made an independent safety assessment. The statements of STUK were given to the Ministry of Trade and Industry in March 1998 (Loviisa) and in June 1998 (Olkiluoto). As regards radiation and nuclear safety, the main conclusions in the statements were that the conditions of the Finnish nuclear energy legislation are complied with. The next periodical safety reviews will be carried out 2006-2008 when the Loviisa NPP applies for a renewal of operating license and Olkiluoto NPP provides an intermediate safety review report for STUK evaluation.

In Finland, the continuous safety assessment and enhancement approach is presented in the nuclear legislation (Council of State Decision (395/1991) where it is stated that *operating experience from nuclear power plants as well as results of safety research shall be systematically followed and assessed. For further safety enhancement, actions shall be taken which can be regarded as justified considering operating experience and the results of safety research as well as the advancement of science and technology*. The implementation of safety improvements has been a continuing process at both Finnish nuclear power plants since their commissioning and there exists no urgent need to upgrade the safety of these plants in the context of the Convention. Recently implemented and ongoing safety upgrading measures, mostly related to the mitigation of severe accidents at the nuclear power plants, are described in this report.

In addition to the regulatory safety assessment, there have been independent safety reviews conducted by International organizations such as IAEA and WANO. IAEA OSART (Operational Safety Review Team) missions have visited both of the Finnish nuclear power plants, Olkiluoto in March 1986 and Loviisa in November 1990. WANO safety reviews at both Finnish nuclear power plants were carried out at the Olkiluoto nuclear power plant at the end of 1999 and Loviisa nuclear power plant at the beginning of 2001.

In the following, the latest large plant modernization and power uprating projects in the Finnish nuclear power plants are described.

2.2.2 Modernization and power uprating of Loviisa NPP

The project for the modernization and power uprating of Loviisa NPPs gave an excellent possibility to take advantage of the latest development in the nuclear power plant technology. The key aspects were to verify the plant safety, to improve production capacity and to give a good basis for the extension of the plant's lifetime to at least 45 years (later strategic goal is at least 50 years).

Feasibility study and project objectives

In the first phase, before starting the project, a feasibility study for uprating of the reactor thermal power was carried out. The main result was in short that no technical or licensing issues could be found which would prevent the raising of the reactor thermal output up to 1500 MW from the original level of 1375 MW.

The carefully prepared feasibility study gave a good picture of the necessary plant modifications as well as essential areas in the analysis work, which was of use in planning the critical works and the time schedule of the project. The feasibility study focused on the following tasks:

- the optimisation of the power level and definition of the new parameters of the main process
- reactor core and fuel studies, including RPV irradiation embrittlement
- safety analyses and licensing
- the main components and systems
- project planning and risk assessment.

The main objectives for the project were based on the feasibility study:

(1) Plant safety level as a whole will be checked and, if needed, improvements will be made.
(2) Plant units will be licensed for 1500 MW reactor thermal output.
(3) Gross electric output of the plant units will be raised to about 510 MW.
(4) Assistance to the life time extension of the plant units.
(5) The long-term availability of the plant is not impaired.
(6) Increase in the expert knowledge of staff.

Time schedule and project organisation

The feasibility study concerning the reactor power upgrading and improvements of the turbine efficiency was started in spring 1994. After good results from the study, the preparation of the project plan began in summer 1995. Critical works in the time schedule, such as the revision of the Final Safety Analysis Report and the preparation of certain plant modifications, were started immediately.

The first step of the trial run at 103% reactor power could be started in January 1997. Test runs continued step by step during the year, and the last transient test at final reactor power 109% was completed successfully in December 1997. Measures to improve the efficiency of the steam turbines continued in the annual maintenance outages until the year 2002.

The implementation of the project was carried out in co-operation between Loviisa NPP and Fortum Nuclear Services (former Fortum Engineering). In addition, many other organisations such as the Technical Research Centre of Finland (VTT) participated in the work. Special attention was paid to the QA routines in the project as well as to the co-ordination of the work in several organisations. One example of this was the particular subject-specific specialist groups which were established to overview essential sections such as nuclear safety and commissioning.

The work was divided into the following ten sub-projects each having a responsible person from the organisations of both Loviisa NPP and Fortum Engineering:

(1) Operating licenses
(2) Other licenses
(3) Safety analyses and basic data management
(4) FSAR revision and comparison of the plant with regulatory body guidelines
(5) PSA (including level 2 PSA)
(6) Modification of the turbines
(7) Electricity systems
(8) Reactor and fuel
(9) Process systems and automation
(10)Commissioning and revision of instructions.

Technical implementation and experience of the trial operation

Increasing the electrical output by about 50 MW at each unit was part of the Loviisa modernisation programme. After completing the uprating of the reactor thermal output in April 1998, more than 80% of the total increase in the electrical output was fulfilled. The rest of the power increase was available when the measures to improve the steam turbines were completed in 2002.

The reactor power uprating from 1375 MW to 1500 MW was planned on the basis of optimising the need for major plant modifications. In the primary side and the sea water cooling system, the mass flow rates were not affected, but the temperature difference has been increased in proportion to the power upgrading. In the turbine side, the live steam and the feedwater flow rate were increased by about 10%; the live steam pressure was not changed.

The reactor fuel loading was considered on the basis of the previous limits set for the maximum fuel linear power and fuel burn-up. The increase in the reactor thermal output was carried out by optimising the power distribution in the core and the power of any single fuel bundle was not increased above the maximum level before power upgrading. In parallel with this work, more advanced options related to the mixing rate of the cooling water in the fuel subchannels and the increasing of fuel enrichment were investigated. The dummy elements installed on the periphery of the core in Loviisa 1 and 2 were preserved to minimise irradiation embrittlement of the reactor pressure vessel.

The VVER 440 design margins in the primary side are rather large and the hardware modifications needed there were quite limited. Replacement of the pressuriser safety valves was indicated already during the feasibility study as a necessary measure because of the power upgrading. Most of the other substantial measures in the primary side were carried out on the basis of the continuing effort to maintain and raise the safety level of the plant, and they were not directly included in the power upgrading.

It was necessary to carry out more extensive measures in the turbine plant and to the electrical components. Steam turbines were modified to a higher steam flow rate. Because of these measures, also the efficiency and operation reliability has improved. Certain modifications were carried out in the electrical generators and the main transformers to ensure reliability in continuous operation with the upgraded power output.

The last step in the process to uprate the reactor thermal power was the long-term trial run to verify the main process parameters as well as plant operation in both steady state and transient situations. The trial run was carried out at gradually uprated reactor power with a power level of 103%, 105%, 107% and finally 109%. Transient tests defined in the test programme were performed with a reactor thermal power of 105% and 109%. The test results correspond very well with all analyses and calculations. All the acceptance criteria for the tests were fulfilled.

Licensing procedure and safety analyses

The modernization programme as a whole was started from the basis of the positive safety progress. This was applied by taking advantage of the latest development in calculation codes and technology as well as feedback of the operating experience, expertise in the ageing processes and safety reassessment coupled with the evolution of safety standards.

STUK was closely involved at every stage of the project, from the early planning of the concept to the evaluation of the results from the test runs. STUK examined all the modification plans that might be expected to have an impact on plant safety. Individual permits were granted stage by stage, based on the successful implementation of previous work.

The renewal of the operating license for the increased reactor power was carried out in the following steps:

- permission from the Ministry of Trade and Industry to make plant modifications and test runs with upgraded reactor power under the existing operating license and under the control of STUK
- assessment of the environmental impact (EIA-procedure) of the project
- STUK's approval of the Final Safety Analyses Report (FSAR), the safety-related plant modifications, test programmes and results.
- the Ministry of Trade and Industry, the responsible authority for the NPP operating licenses, received a statement from several local and national organisations
- The operating license was prepared by the Ministry of Trade and Industry, and the Council of State awarded the license in their session on 2 April 1998. The license is awarded to 1500 MW nominal reactor thermal power until the end of the year 2007.

The environmental impact has been assessed in the EIA Report, which was completed in December 1996. This was the first time in Finland (parallel with TVO plant having a corresponding modernisation programme) the EIA Procedure has been applied to a nuclear power plant. The law and the decree set certain procedures, including a public hearing for screening, scoping and the EIA statement, which are the stages of this procedure.

The result was that the reactor thermal power uprating has no other considerable environmental impact than a slight increase in the outlet temperature of the cooling water. This means that the maximum temperature increase of the cooling water in the main condenser, before released back to the sea, is about 1°C higher than the previous temperature increase, which was typically close to 10°C.

An extensive safety review and comparison of the plant with the latest national regulatory body guidelines (YVL guides) have been carried out. This work was performed taking into account many international standards, such as the IAEA report “A Common Basis for Judging the Safety of Nuclear Power Plants Built to the Earlier Standards INSAG-8”. As a result of the work, a particular safety review report has been completed.

A part of the safety review and the licensing process of the reactor power uprating was the renewal of the Final Safety Analysis Report. New accident analyses were made concerning the containment pressure, loss of coolant accident (LOCA) and main steam line break (MSLB), for example. In addition to the accident analyses, there are a large number of transient situations that were also analysed. The risk for a radioactive release to the environment was probabilistically considered (PSA level 2) for the first time for Loviisa NPP. The analysis work carried out is described in more detail under Article 14.

2.2.3 Enhanced safety and improved production through modernization at Olkiluoto NPP

Olkiluoto 1 and Olkiluoto 2 units have been in operation about 25 years. The performance indicators have been favourable. For instance, the average capacity factor for the last ten years is well above 90%.

Already before modernization the plant design was reasonably modern due to the following advanced features included in the original design:

- internal main circulation pumps
- fine motion control rod drives
- 4 × 50% redundant safety systems
- inerted pre-stressed concrete containment, back fitted against severe accidents.

Numerous design modifications have been implemented since the commissioning of the units. For instance, the containments were back fitted against severe accidents at the end of the 80's. TVO's policy has been to keep the plant continuously up-to-date.

It would be imprudent to take favourable performance for granted. Therefore, TVO started pro-actively a modernization program in 1994. It was recognised that there were many modifications to be implemented in the next years and a decision was made to include them in a program called "modernization".

The operating licences of Olkiluoto 1 and 2 were renewed in 1998. The time schedule of the modernisation was established so that the outcome of the program could be utilised in the operating licence renewal.

Principles and goals

From the beginning, the following principles were followed in the program:

- technical development was exploited
- new safety requirements
- advanced design solutions
- operational experiences were utilised
- own experiences
- experiences from other plants
- own staff was used as much as possible
- losses in electricity production were avoided
- plant modifications presupposing shutdown were implemented during normal refuelling and maintenance outages
- cost/benefit approach was applied.

The main goals of the modernisation were as follows:

- reviewing safety features and enhancing safety, when feasible
- improving the production related performance,
- finding factors limiting the plant lifetime and eliminating them, when feasible
- enhancing the expertise of the own staff and improving productivity.

The goals supported each other. For instance, it is easier to license the reactor uprating if safety is simultaneously enhanced. On the other hand, the cost of safety improvements can be compensated for by the additional output working for lower production cost.

Safety enhancement

In order to achieve the safety goal, the existing plant design has been reviewed and compared by the TVO to the present and foreseeable safety requirements. The most important requirements are included in the YVL Guides issued by STUK for new nuclear power plants. Compliance with the European Utility Requirements (EUR) has also been reviewed.

The feasibility of fulfilling new requirements set for the new nuclear power plants has been considered case by case. The living PSA model of the plant has been utilised in this context.

The most important safety related modifications included in the modernisation program are listed below:

- Reactor pressure relief system has been diversified by installing two additional relief valves.
- ATWS behaviour has been improved by modifying some trip signals and making boron injection automatic and more effective.
- Additional severe accident mitigation measures have been implemented.
- Earthquake resistance of the plant has been checked and related modifications have been made.
- Partial scram function has been strengthened.
- Generator breaker was replaced with a new one, which is able to break also short circuit current.
- Protection against frazil ice at the seawater intake has been improved.
- Protection against snowstorms at the air intake of the emergency diesels has been improved.

The modernization program as a whole reduced the severe core damage frequency estimate by a factor of seven.

The radiation exposure of the population was reduced in accordance with the ALARA principle.

Liquid releases have been reduced by a factor of ten by improving the liquid waste handling systems. Also occupational doses have been reduced. In practice, this means minimising the cobalt content in the primary circuit.

Production improvement

Four ways were followed to increase the electricity production:

Reducing the unplanned capacity loss factor

There have not been many operational disturbances until now, but there will be more due to the ageing of equipment and components. Replacement of the components helps in itself. In addition to that, favourable system solutions have been realised that tolerate more component failures without an adverse impact on the plant operation. For instance, the original one out of two turbine protection and control systems have been replaced by new two out of three systems.

Shortening refuelling and maintenance outages

Olkiluoto outages have not been very long in the past. However, there is still room for improvement. For instance, the refuelling machine has been speeded up by modernising its instrumentation.

Improving thermal efficiency

The low pressure turbines have been replaced and in that way about 30 MW additional production capacity in each unit has been achieved.

Uprating the reactor thermal power

The following facts made power uprating possible:

- development of the BWR technology
- margins revealed by operational experience
- plant modifications due to other reasons.

The most important development in this respect has taken place in fuel technology. The operation was started with 8×8 bundles and now 10×10 bundles are used. The new bundles have 40 percent lower average linear heat rating than the old ones.

The reactor uprating is a sensitive matter that must be treated with extreme care. The following criteria have been applied:

- safety level after the modernisation program at least the same as before
- no adverse effect on long-term availability
- no shortening of plant life-time
- additional electricity production economically justified.

The thermal power was uprated from 2160 MW to 2500 MW (15.7 percent). Some design changes implemented due to the uprating are listed below:

- 10×10 fuel bundles are used instead of the original 8×8 bundles.
- Inertia of the main circulation pumps has been increased electrically.
- Steam separators have been replaced.
- High-pressure turbine was modified.
- High-pressure turbine valves were replaced.
- Feed water system has been modified.
- Capacity of the decay heat removal system has been increased.
- Generator has been replaced.
- Main transformers have been replaced.

Enhancing staff expertise

The modernization program continues TVO's policy to maintain and enhance the expertise of the own staff by having challenging projects always in progress. The most important projects since the plant commissioning have been the previous reactor uprating, severe accident mitigation, training simulator, PSA, interim storage for spent fuel, repository for reactor waste, investigation program for disposal of spent fuel, preparation of the specifications and evaluation of the bids for a new nuclear power plant in the beginning of the 1990's and again in the beginning of the 2000's.

Implementation

The modernisation program of the Olkiluoto plant was started in 1994 and completed in 1998. Some later installations were realised during outages in 1999. The modernization program consisted of about 40 separate projects. The installations were performed during the refuelling outages of the years 1996–1998. In spite of large modifications the refuelling outage times were reasonable, between 15 and 20 days. The test program was quite the same as in the case of a new plant. In addition, the capacity factors of the power plant units have been satisfactory (well above 90%) during and after the modernisation. The total cost of the modernisation program was EUR 135 million.

Licensing

Licensing steps related to the modernisation program were as follows:

- An uprated Safety Analysis Report (PSAR, for example) and an uprated Probabilistic Safety Assessment (level 1 PSA) were submitted to and reviewed by STUK.
- Design modifications and test runs were accepted by STUK before implementation.
- The Final Safety Analysis Report (FSAR) and the related Topical Reports were rewritten. It means also that almost all transient and accident analyses were redone taking into account the uprated power level and modified plant design. The FSAR and Topical Reports were submitted to STUK at the end of 1996.
- An operating license renewal application, covering design modifications and the power uprating, was submitted to the Council of State at the end of 1996. The license was granted in 1998.
- The power uprating has been reviewed also according to the Environmental Impact Legislation.

Results

The results were: ensured safety, additional production capacity (over 260 MW in total), extended plant life time, and more competent and motivated staff.

After modernization

Modernization of Olkiluoto 1 and 2 is a continuous process. Modernization and power uprating during years 1996–1998 in Olkiluoto 1 and 2 contained several safety, ageing and efficiency remedies. Mostly influences of modifications have been positive. A negative finding has been a slight increase of steam moisture. To improve this in both units steam dryers will be replaced in outages 2005 and 2006. Another slightly negative finding was increase of condensate clean up temperature, which decreased the life cycle of clean up resins. To avoid this problem the location of condensate clean up system has been changed in the process. In this connection even the first LP-preheaters were replaced and modernized.

The modernization of turbine plant will continue with replacement of steam reheater moisture separators (MSR). They will be replaced with modern two stage MSR's. This replacement requires even modernization of HP-turbine. These replacements will be performed in outages 2005 and 2006. In the same outages the control system of the turbine will be replaced with a modern one.

In conclusion, Finnish regulations and practices are in compliance with Article 6.

2.3 Article 7. Legislative and regulatory framework

1. Each Contracting Party shall establish and maintain a legislative and regulatory framework to govern the safety of nuclear installations.

2. The legislative and regulatory framework shall provide for:

i. the establishment of applicable national safety requirements and regulations;

ii. a system of licensing with regard to nuclear installations and the prohibition of the operation of a nuclear installation without a licence;

iii. a system of regulatory inspection and assessment of nuclear installations to ascertain compliance with applicable regulations and the terms of licences;

iv. the enforcement of applicable regulations and of the terms of licences, including suspension, modification or revocation.

2.3.1 Legislative and regulatory framework

In Finland, current nuclear legislation is based on the Nuclear Energy Act from 1987, together with a supporting Nuclear Energy Decree from 1988. The scope of this legislation covers e.g.

- the construction and operation of nuclear facilities; nuclear facilities refer to facilities for producing nuclear energy, including research reactors, facilities for extensive disposal of nuclear wastes, and facilities used for extensive fabrication, production, use, handling or storage of nuclear materials or nuclear wastes
- the possession, fabrication, production, transfer, handling, use, storage, transport, export and import of nuclear materials and nuclear wastes as well as the export and import of ores and ore concentrates containing uranium or thorium.

The current radiation legislation is based on the Radiation Act and Decree, both of which are from 1991 and take into account the ICRP Publication

60 (1990 Recommendations of the International Commission on Radiological Protection). Section 2, General principles, and Chapter 9, Radiation work, of the Act are applied to the use of nuclear energy.

Based on the Nuclear Energy Act, the Council of State issued in 1991 the following regulations:

- General regulations for the Safety of Nuclear Power Plants (395/1991)
- General regulations for Physical Protection of Nuclear Power Plants (396/1991)
- General regulations for Emergency Response Arrangements at Nuclear Power Plants (397/1991)
- General regulations for the Safety of a Disposal Facility for Reactor Waste (398/1991).

The Decisions 395/1991, 396/1991 and 397/1991 are applied to a nuclear power plant which is defined to be a nuclear facility equipped with a nuclear reactor and intended for electricity generation, or if such or other nuclear facilities have been placed on the same site, the entity of facilities formed by them. The regulations are also applied to other nuclear facilities to the extent applicable. In 1999, a further Council of State Decision (478/1999) was issued to give the "Regulations for the Safety of Disposal of Spent Fuel".

2.3.2 Provision of regulatory guidance

Detailed safety requirements are provided in YVL Guides. YVL Guides also provide administrative procedures for regulation of the use of nuclear energy. YVL Guides are issued by STUK, as stipulated in the Nuclear Energy Act. YVL Guides are rules an individual licensee or any other organisations concerned shall comply with, unless some other acceptable procedure or solution has been presented to STUK by which the safety level laid down in an YVL Guide is achieved. The procedure to apply new guides to existing nuclear facilities is such that the publication of an YVL guide does not, as such, alter any previous decisions made by STUK.

After having heard those concerned, STUK makes a separate decision on how a new or revised YVL guide applies to operating nuclear power plants, or to those under construction, and to licensee's operational activities. To new nuclear facilities, however, the guides apply as such.

Development in 2002–2004

- The earlier Amendment of Nuclear Energy Act has been set in force to implement the new additional protocols of the IAEA Safeguards Agreements under the International Treaty on the Non-Proliferation of Nuclear Weapons (NPT) for expanding the safeguards control.
- The Nuclear Energy Act was amended to establish The Nuclear Safety Research Fund. The objective of this Fund is to ensure the high level of national safety research and to maintain the national competence in the long run. A Fund for Nuclear Waste Safety Research was also established, respectively.

Some other minor amendments were also made in nuclear and radiation legislation to reflect changes of other legislation (labour safety, criminal code). Amendments in other national legislation have not caused essential changes to the regulatory control of NPPs nor to the safety requirements set for them.

As a result of the successful international negotiations to update the Paris and Brussels Conventions on Nuclear Liability also the Finnish Nuclear Liability Act has been under review by a special governmental committee. It is foreseen, that in near future the Act will be updated to reflect the modified conventions. Also setting an unlimited financial liability to licensees is under consideration. At the hierarchical level of regulations (e.g. Council of State Decisions) no changes are to be reported.

The regulatory guides prepared and issued by STUK are being continuously re-evaluated for updating. After the Decision-in-principle was made in 2002 for the new unit, STUK established a special plan to update the most relevant guides related to the design and construction of a new reactor. In 2002 10 new or revised guides were issued, in 2003 12 guides were issued and in 2004, the same magnitude of over 10 revised guides are expected to be issued. Most of the planned YVL guide updates were issued during 2003 prior construction license application. The current list of regulations and regulatory guides is provided in Annex 1.

2.3.3 System of licensing

The licensing process is defined in the legislation. The construction and operation of a nuclear facility is not allowed without a license. The licenses are granted by the Council of State. The conditions for granting a license are prescribed in the Nuclear Energy Act. The Operating Licenses are granted for a limited period of time. This period has been at the beginning five years and then about ten years. The periodic re-licensing has allowed good opportunities for a comprehensive, periodic safety review. Current operating licenses of the Olkiluoto units are valid for about 20 years, but an intermediate safety assessment is required as a condition of the licenses after 10 years.

Before a Construction License for a nuclear power plant, a nuclear waste disposal facility, or other significant nuclear facility can be applied, a Decision-in-principle by the Council of State is needed. A condition for granting the Decision-in-principle is that the operation of the facility in question is in line with the overall good for society. Further conditions are as follows:

- the municipality of the intended site of the nuclear facility is in favour of constructing the facility
- no factors indicate a lack of sufficient prerequisites for constructing the facility according to the Nuclear Energy Act: the use of nuclear energy shall be safe; it shall not cause injury to people, or damage to the environment or property.

The coming into force of the Decision-in-principle further requires that it will be confirmed by the simple majority of the Parliament. The Parliament can not make any changes to the Decision, it can only approve it or to reject it as it is. The parties involved in the Decision-in-principle process and their tasks are described in Figure 2. This procedure was applied for the first time during the period November 2000 – May 2002 when Teollisuuden Voima Oy applied a Decision-in-principle for the fifth NPP unit in Finland and the Council of State approved it and the Parliament confirmed the approval. This political process provided a thorough debate and review and the result was accepted as a democratic parliamentary decision. Since then Teollisuuden Voima Oy has filed an application for Construction License to the Ministry of Trade and Industry in January 2004 for a 4300 MWth PWR unit, Olkiluoto 3, to be located at the existing Olkiluoto NPP site.

For the Construction License application of Olkiluoto 3, the Ministry of Trade and Industry asked STUK's statement on safety by the end of 2004, if possible. Construction License documents to be submitted to STUK for approval in this phase are defined in Nuclear Energy Degree § 35. After receiving all statements for the Construction License application, the Council of State will make its decision.

Before loading fuel into the reactor, an Operating License has to be granted. For the Operating License application, the Ministry of Trade and Industry asks STUK's statement on safety. Operating License documents to be submitted to STUK for approval in this phase are defined in Nuclear Energy Degree § 36. After receiving all statements for the Operating License, the Council of State will make its decision.

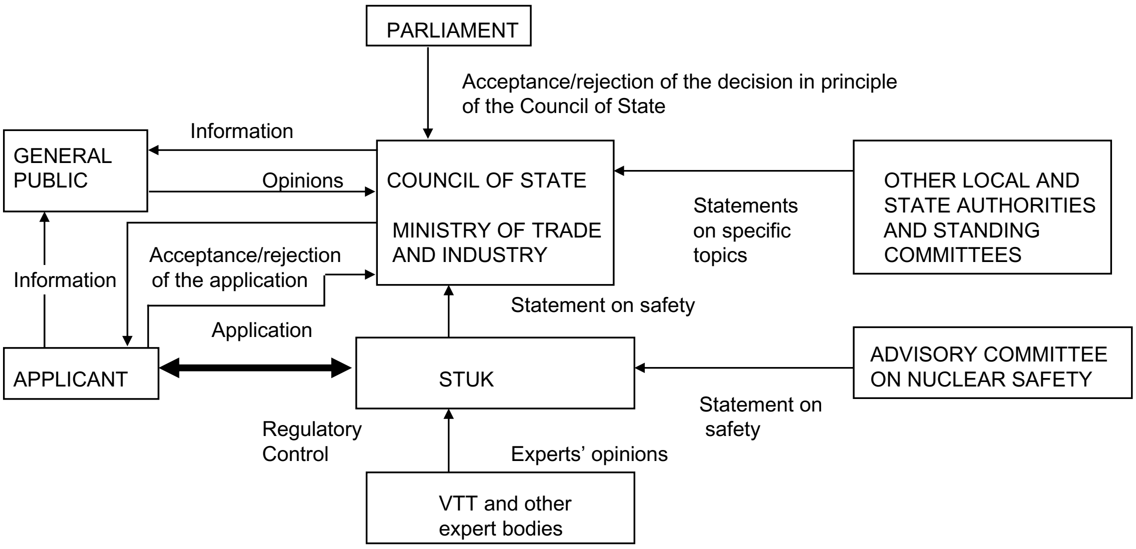


Figure 2. Licensing of nuclear power plants in Finland.

2.3.4 System of regulatory inspection and assessment

The legislation also provides the regulatory control system for the use of nuclear energy. According to Nuclear Energy Act, STUK is responsible for the regulatory control of the safety of the use of nuclear energy. The rights and responsibilities of STUK are provided in the Nuclear Energy Act. Safety review and assessment as well as inspection activities are covered by the regulatory control.

The current periodic inspection programme of STUK for operating nuclear power plants was established in 1998 and consists of altogether 30 separate inspections. This programme replaced the former programme that had been in place for about 10 years. The current programme is focused on licensee main working processes and is considered to cover the most relevant areas of nuclear power plant safety. The new programme has three levels: safety management, main working processes and activities in different organisational and technical areas. The objective of the inspection process is to assess the safety level at the plants as well as the safety management. Possible problems at the plants and in procedures of the operating organisations are to be recognised. Special emphasis has been put on the management of the entire inspection programme, including the timely conduct and accurate reporting of results. The experience of the current programme has been good. Some development areas such as enhancement of the longterm planning and reporting of the inspection programme were identified during the IRRT mission 2003 and by self-assessment. STUK is also developing Risk Informed Regulation practices. These include among others use of PSA for planning regulatory inspections to focus inspections on risk significant areas. It also includes assessment of inspection findings by PSA.

In addition to the periodic inspection programme, STUK conducts ad-hoc inspections if seen necessary. In the past, these have mainly related to operating event investigations (both domestic and international events), but also on the consequences of the development of science and technology.

Review of operational events by STUK is done basically at three different levels. First step is to perform a general review of all operational events, transients and reactor scram reports, which the licensees submit for information to STUK. The second level activities are related the clarification of events at site and entering of events' specific data into the event register database of STUK. This is done for the events which meet the set criteria for the operator to submit a special report to STUK for approval. Numbers of operational events in different categories are followed by STUK's plant performance indicator system. Risk significance of operational events is followed by PSA based indicators. The final step in operational event assessment performed by STUK is to assign STUK's own investigation team for events deemed to have special importance, especially when the licensee's organisation has not operated as planned. It is also possible to nominate investigation team to investigate a number of events together in order to look for possible generic issues associated with the events. In addition, investigations can be related to domestic events and international events. These inspections are usually conducted by a leadership of the event investigation manager and an investigation team including 2–3 experts from STUK nominated on case-by-case basis. STUK has launched its own investigation once a year, on average.

In 2002, STUK investigated two events. At the beginning of 2002 STUK launched its own investigation team to address the course of events and the utility actions in connection with degradation of turbine control and fast shutdown valves at Olkiluoto 2. During this event the utility made also a temporary turbine protection system modification at full power, which raised a concern by STUK. The investigation of the event was mainly targeted on the safety culture of the utility, including decision making and the relations and communication between different parts of the organisation. In October 2002 STUK started its investigation to address the course of events and the utility procedures and actions in connection with neglected license applications for non-destructive testing organisations and their personnel, and non-compliances in approval applications for in service inspection programs as well as qualification of inspection systems. In 2003, STUK did not start any new investigation into Loviisa or Olkiluoto plants.

2.3.5 Enforcement

The Nuclear Energy Act defines the enforcement system and rules for suspension, modification or revocation of a licence. The enforcement system includes provisions for executive assistance if needed and for sanctions in case the law is violated. The enforcement tools and procedures of regulators are considered to fully meet the needs. The repertoire of these tools together with some practical examples for implementing them has been presented in an internal policy document as part of STUK's Quality System (2003).

In conclusion, Finnish regulations and practices are in compliance with Article 7.

2.4 Article 8. Regulatory body

1. ***Each Contracting Party shall establish or designate a regulatory body entrusted with the implementation of the legislative and regulatory framework referred to in Article 7, and provided with adequate authority, competence and financial and human resources to fulfil its assigned responsibilities.***
2. ***Each Contracting Party shall take the appropriate steps to ensure an effective separation between the functions of the regulatory body and those of any other body or organization concerned with the promotion or utilization of nuclear energy.***

According to the Nuclear Energy Act, the overall authority in the field of nuclear energy is the responsibility of the Ministry of Trade and Industry. The Ministry prepares matters concerning nuclear energy to the Council of State for decision-making and, to some extent, grants import and export licences for nuclear equipment and materials. Among other duties, the Ministry of Trade and Industry is responsible for the formulation of a national energy policy.

STUK is an independent governmental organisation for the regulatory control of radiation and nuclear safety. No Ministry can take for its decision a matter that has been defined by law to STUK. The current Act on STUK was given in 1983. According to the Decree on STUK, STUK has the following duties:

- regulatory control of safety of the use of nuclear energy, emergency preparedness, physical security and nuclear materials
- regulatory control of the use of radiation and other radiation practices
- monitoring of the radiation situation in Finland, and maintaining of preparedness for abnormal radiation situations
- maintaining of national metrological standards in the field
- research and development work for enhancing radiation and nuclear safety
- informing on radiation and nuclear safety issues, and participating in training activities in the field
- producing expert services in the field
- making proposals for developing the legislation in the field, and issuing general guides concerning radiation and nuclear safety
- participating in international co-operation in the field, and taking care of international control, contact or reporting activities as enacted or defined.

STUK is administratively under the Ministry of Social Affairs and Health. Connections to ministries and governmental organisations are described in Figure 3. It is emphasised that the regulatory control of the safe use of nuclear energy is independently carried out by STUK. STUK has no responsibilities or duties which would be in conflict with regulatory control.

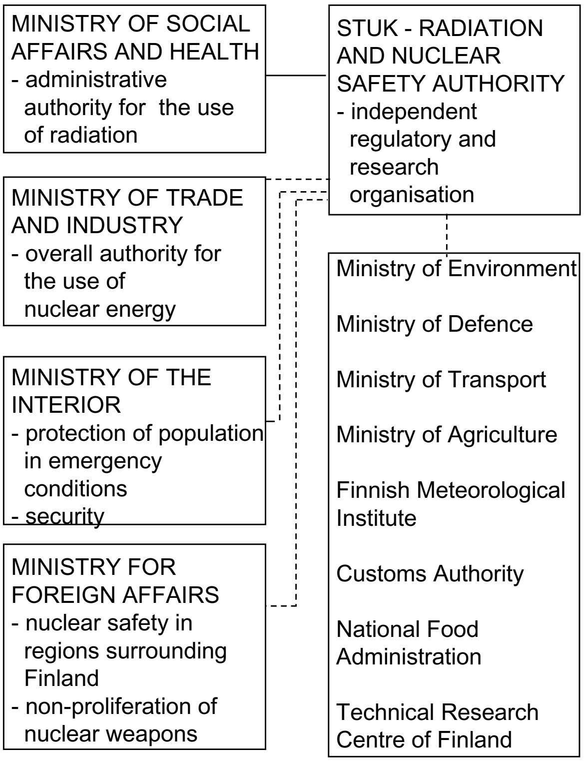


Figure 3. Co-operation / Interfaces between STUK and Ministries and other governmental organisations.

STUK has the legal authority to carry out regulatory control. The responsibilities and rights of STUK, as regards the regulation of the use of nuclear energy, are provided in the Nuclear Energy Act. They cover the safety review and assessment of licence applications, and the regulatory control of the construction and operation of a nuclear facility. The regulatory control of nuclear power plants is described in detail in Guide YVL 1.1. STUK has e.g. legal rights to require modifications to nuclear power plants, to limit the power of plants and to require shutdown of plants when necessary for safety reasons.

STUK does not grant any construction or operating licences for nuclear facilities. However, in practice no such licence would be issued without STUK's statement where the fulfilment of the safety regulations is confirmed.

STUK has adequate resources to fulfil its responsibilities. About 80 professionals are working in the field of nuclear safety. The expertise of STUK covers all the essential areas needed in the safety control of the use of nuclear energy. New personnel have been recruited during 2003 and 2004 for the review and assessment of the construction license application of the new power plant unit Olkiluoto 3. First batch of the licensing documentation was submitted to STUK at the beginning of the year 2004.

Most of the professional staff of STUK conducting safety assessments and inspections has a degree of university level. During the years 2002 and 2003 a competence analysis was made at STUK. This analysis is used as the basis for the training programmes. Preparedness and competence relating specifically to the new nuclear power plant in planning were developed. With this in mind STUK participated in the preparation and execution of a basic professional training course on nuclear safety with other organisations in the field. The 6-week course commenced in September 2003 and continued in 2004. About 50 junior experts and new comers in the nuclear field from various organisations participated, eleven of which were from STUK. STUK has close connections with foreign regulatory bodies for exchanging information on important safety issues. The average experience of the staff is about 15 years in the nuclear field.

The organisational structure and the responsibilities within STUK are provided in the Quality Manuals of STUK. Also procedures for regulatory control and other activities of STUK are presented in the Manuals. The organisation of STUK is described in the Figure 4.

STUK receives the main part of its financial resources through the government budget. The costs of regulatory control are charged in full to the licensees. In the area of regulatory control, the strategy of financing the work has been changed to

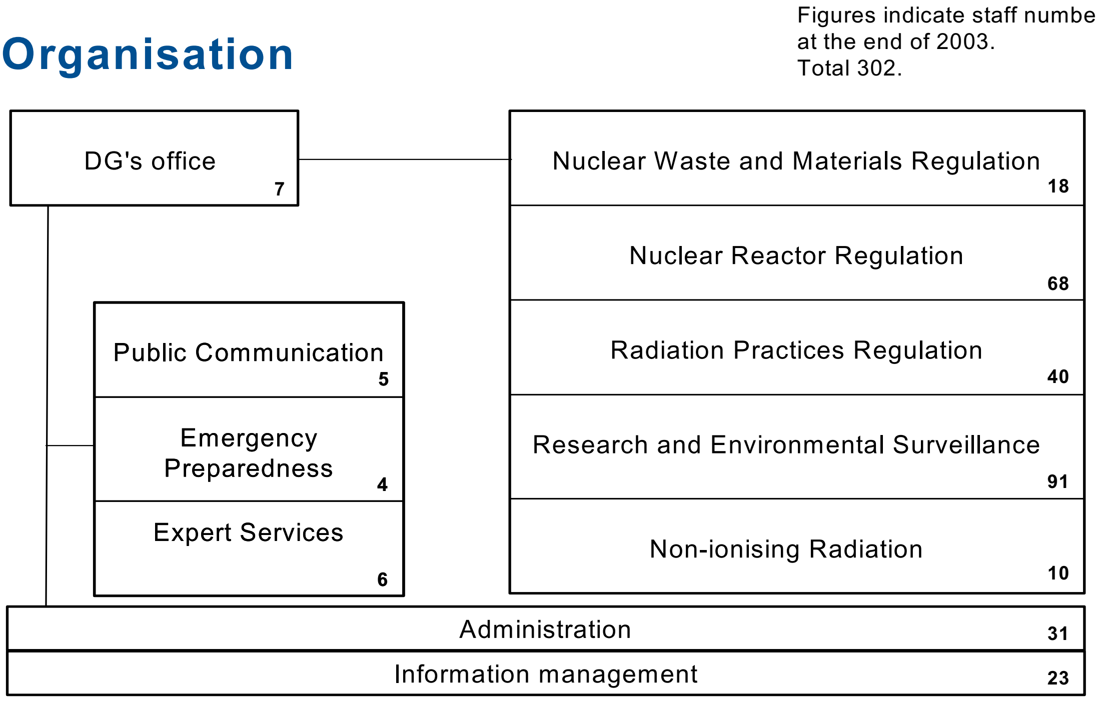


Figure 4. Organisation of STUK. Numbers indicate the number of staff in the organizational unit.

so call net-budgeting model. This means that the licensees pay the regulatory control fees directly to STUK. This approach to finance governmental regulatory activities became a common practice in Finland in the 1990's. The change was carefully analysed and discussed among the parties involved. The conclusion was that considering the long traditions and stability of the amount of regulatory control no concern of loosing the required objectivity was foreseen. Also it was clearly recognised that the amounts charged would continuously be under the control of the Ministry of Social Affairs and Health. Annually beforehand, tentative maximum amount of budget is authorized by the Ministry in the Result Agreement. The change in the financing procedure has not changed the actual costs of regulatory control activities.

The annual report on the regulatory control of nuclear safety for 2003 is attached to this document, Reference 3. In 2003, the costs of the regulatory control of nuclear safety subject to a charge were 7.2 M€. The total costs of nuclear safety regulation were 8.7 M€. Thus the share of activities subject to a charge was 83%.

An Advisory Committee on Nuclear Safety has been established by a decree. This Committee gives advice to STUK on important safety issues and regulations. In addition, an Advisory Committee on Radiation Safety has been established for advising the Ministry for Health and Social Affairs. The members of these Committees are nominated by the Council of State.

The main technical support organisation of STUK is the Technical Research Centre of Finland (VTT). At VTT, about 200 experts are working in the field of nuclear energy. There are research programmes related to the safety of nuclear power plants and waste management. The total volume of the research in this area in the year 2003 was 16 M€. New funds have been established to finance the national research programmes on operational safety of nuclear power plants and nuclear waste management. Also the Geological Survey (GTK) of Finland and University of Helsinki are important technical support organizations in the field of nuclear waste research and, respectively, Lappeenranta University, in the field of nuclear research.

The Nuclear Energy Act has been changed at the beginning of the year 2004 to ensure funding for a long term nuclear safety and nuclear waste management research in Finland. Money is collected annually from the licence holders to a special fund devoted to this purpose. The amount of money is proportional to the thermal power of the licensed plant or the thermal power presented in the Decision-in-principle. For the waste research, the payments are proportional to the payments to the Nuclear Waste Fund. The research projects are selected so that they support and develop the competences in nuclear safety. The key topics of the recent research program (SAFIR) are the behaviour of the reactor, the properties of the containment and the ageing management of the nuclear power plant. There are also research projects in the field of the assessment of the safety culture of an organization. The amount of money collected in year 2004 has been 2.7 M€ for nuclear safety research. Similarly a national research programme in the area of nuclear waste management (KYT) to support the authorities is underway. The annual volume of KYT programme is 1.0 M€. The research projects have also additional funding from other sources. STUK participates to the steering of the programmes.

In addition to above mentioned research STUK finance independent analysis made by VTT or other technical support organizations related to ongoing licensing projects. The independence of STUK's technical support has been evaluated in 2000. The evaluation included quality audits to the five research units of the Technical Research Centre of Finland, VTT, the main technical support organisation of STUK. The audits were performed by Qualitas Fennica Ltd. The audits concentrated on activities and work processes that are essential to nuclear safety and safety related research. Independence problems were not discovered in these audits. On the other hand, one essential element in this respect is STUK's in-house expertise providing independence when drawing conclusions from research results. However, based on the audit results, the quality systems of these research units have been further enhanced taking into account STUK's point of view concerning the required independence from utility driven research projects. Two follow-up audits conducted in October 2001. A similar quality audit carried out at the Geological Survey of Finland, GTK, at the end of 2001. This means that all main support organisations of STUK have been evaluated.

In addition to the government review of regulatory activities, there have been independent regulatory reviews conducted by International Atomic Energy Agency, IAEA. IAEA IRRT's (International Regulatory Review Team) have visited STUK providing full-scope IRRT mission in 2000 and IRRT Follow-up Mission in September 2003. The Review Team established that the majority of recommendations it had given in 2000 had lead to improved operations. The Team gave STUK two more recommendations and some proposals to consider whether certain matters could be taken care of better, using the alternative method proposed. The team identified also some procedures worth pointing out to other authorities. STUK has found IAEA IRRT mission as an fruitful tool in developing its own functions.

STUK's public communication is proactive, open, timely and understandable. Communication is a privilege and duty of all employees. Good cooperation with the media is emphasized in all communication. The general public and media can reach STUK's experts any time, including nights, weekends and holidays. A prerequisite for successful communication is that STUK is known among media and general public and the information given by STUK is regarded as truthful. Communication is always based on best available information. Even sensitive matters are openly communicated. STUK's web page is an important tool in communication. It is very important that the web pages are professionally edited and updated regularly. The information on web pages must be easy to find and understandable. Internal communication provides the personnel information about STUK's activities and supports its capability in participating in the external communication.

STUK participates actively European and international co-operation in the field of nuclear and radiation safety. STUK directors have memberships and chairmanships in the OECD / NEA, IAEA and IRPA. STUK experts participate actively in the working groups of these organisations. STUK also participates in the work of European Commission through Atomic Questions Group, NRWG, CONCERT and RAMG-related PHARE- and TACIS- programmes, EBRD as well as through European regulators' association WENRA. In addition, there are regulatory co-operation through Nordic co-operation programmes and VVER Regulators Forum. STUK also co-operates actively with Russian FNRA, Kola and Leningrad NPP's concerning nuclear safety close to the Finnish borders. Finnish government finances this co-operation.

In conclusion, Finnish regulations and practices are in compliance with Article 8.

2.5 Article 9. Responsibility of the licence holder

Each Contracting Party shall ensure that prime responsibility for the safety of a nuclear installation rests with the holder of the relevant licence and shall take the appropriate steps to ensure that each such licence holder meets its responsibility.

The responsibility for the safety rests with the licensee as manifested in the Nuclear Energy Act according to which each licensee is responsible for the safety of his use of nuclear energy. Furthermore, the licensee is responsible for such physical protection and emergency preparedness arrangements and other necessary arrangements for limitation of nuclear damages, which do not belong to the authorities. The licensee, whose operations generates or has generated nuclear waste, is responsible for all nuclear waste management measures and their appropriate preparation. The licensee is furthermore responsible for depositing in advance for the costs of nuclear waste management in a special nuclear waste fund being operated under the Ministry of Trade and Industry.

It is the responsibility of the regulatory body to verify that the licensees fulfil the regulations. This verification is carried out through safety review and assessment as well as inspection programmes established by STUK. In its activities, STUK emphasizes the commitment to the strong safety culture.

The financial provisions to cover the possible harms of a nuclear accident have been arranged according to the Paris and Brussels Conventions. Finland has supported the international efforts to revise the Paris and Brussels Conventions for Nuclear Third Party Liability in order to raise the funds made available by the Contract Parties in case of accidents. Accordingly, the Finnish Nuclear Third Party Liability Act is currently under revision process.

In conclusion, Finnish regulations and practices are in compliance with Article 9.

2.6 Article 10. Priority to safety

Each Contracting Party shall take the appropriate steps to ensure that all organizations engaged in activities directly related to nuclear installations shall establish policies that give due priority to nuclear safety.

2.6.1 Regulatory approach to safety culture

Safety is emphasised in the general principles of the Nuclear Energy Act: the use of nuclear energy shall be safe; it shall not cause injury to people, or damage to the environment or property. Decision 395/1991 provides that, an advanced safety culture shall be maintained when designing, constructing and operating a nuclear power plant. It shall be based on the safety emphasising attitude of the management of the organisation in question, and on motivation of the personnel for responsible work. This presupposes well organised working conditions and an open working atmosphere as well as the encouragement of alertness and initiative in order to detect and eliminate factors which endanger safety.

Safety is also emphasised in the Quality Manuals of STUK as well as in the framework contract between STUK and its technical support organisation VTT. STUK has updated its own Quality Policy in 1999. The Quality Policy includes also STUK's values that are engaged to every day work giving the highest priority to the prevention and mitigation of the harmful effects of radiation. STUK has taken an active role in this area and both developed its own culture and taken the initiative in the assessment and development of the culture of the utility organisations. STUK has indicators in its indicator system to detect the development in plant safety.

Safety culture has also been an essential topic in STUK's continuous interaction with the power plants. The top level inspection of the periodic inspection programme, called "Safety Management", includes an assessment of safety culture issues and quality management. In addition, STUK has emphasised that the strengths and shortcomings of safety culture are determined in quality assurance audits and event analyses. Findings related to safety culture from different inspections are analysed in STUK and discussed in a yearly meeting between the senior managers of the nuclear power plant and the regulatory body. Attention has been paid to safety culture in the operation and maintenance of Finnish nuclear power plants. At the Loviisa and Olkiluoto nuclear power plants, actions have been taken to emphasise a high level of safety culture, and to further develop it. E.g. the rate of annual investment (Figures 5 and 6) shows a trend towards safety.

According to the Nuclear Energy Act, a responsible director approved by STUK has to be appointed for the construction and operation of a nuclear power plant. The responsible director has a duty to see that the provisions of the Nuclear Energy Act, the rules and regulations issued by virtue of it and the licence conditions concerning the safe use of nuclear energy, the arrangements for physical protection and emergencies and the safeguards control are complied with. The responsible director shall have real possibilities to take effectively care of this duty.

Organisational units for safety exist at the Loviisa and Olkiluoto plants. These units are independent of those units which are directly responsible for the operation of the plants. In addition, independent advisory bodies for safety issues have been established by both licensees. The licensees have also established written quality and safety policies.

2.6.2 Priority to safety at the Loviisa NPP

The Loviisa plant is headed by a General Manager (responsible director). The operating organisation is comprised of four units: Operation, Safety, Technology and Maintenance Units. The operating organisation is supported by the Nuclear Safety Committee of the Loviisa plant. Its members are experts in different fields. The majority of the members work at the headquarters of Fortum Power and Heat Oy. In addition, other organisation units of Fortum outside the plant also participate in the evaluation of safety and in the technical support to the plant. The duties, responsibilities and authorities of the various units of the plant operating organisation and of Fortum's internal support organisation are presented in the Administrative Rules and Organisational Manual of the Loviisa plant.

The Loviisa plant and Fortum Nuclear Services, its supporting organisation, have made a co-operation agreement that is annually updated. One aim of the agreement is to assure that all the know-how within Fortum Group is utilised in connection with the design of the plant modifications, as well as to the utilisation of modification work experiences for the development of activities.

The minimum staffing of the main control room and the plant site is presented in the Technical Specifications of the Loviisa plant. According to the plant duty system a person outside the shifts is continuously reachable for the control room staff. The person has the highest level operator competence (the level of shift supervisor). The system is aimed to ensure safety, when operator actions are made during emergency situations.

In addition to the normal operating organisation, an emergency preparedness organisation has been defined to the plant for accident situations. The emergency preparedness organisation has been described in the Emergency Plan. The activities of the emergency organisation are trained during annual emergency exercises. A security organisation has been defined to the plant in the Security Plan. This organisation is responsible for the planning and maintaining of physical protection arrangements.

Developing safety culture

Fortum has a long tradition in power production. That has influenced on the development of the company's organisational culture and reflected positively to the design, construction and operation of the Loviisa plant. A factor that has influenced on the development of safety culture at the Loviisa plant has been the inadequacy of operation procedures received from the plant supplier. It caused a need to put effort in the design of the plant and to develop the functions of the operating organisation. This development process has given to the plant and the whole Fortum a strong expertise in several issues.

In the 1990's Fortum internationalised in a strong way and with the acquisitions and incorporation Fortum has become a Group organisation. In the Group it has been considered appropriate that each independent company or unit develops its organisational culture from its own starting points, taking into account the principles of the Group management on common visions and values. It has been evaluated in Fortum that the attitude in the Group on the continuous development of activities gives a solid frame for maintaining an advanced safety culture in the operation of the Loviisa plant.

The concept of the advanced safety culture was added in the Administrative Rules of the Loviisa plant in 1991. The quality policy of the plant written in 1996 brings up the meaning of safety expressing good safety culture. Present quality and safety policies for Fortum's nuclear power operations and for the plant address developed safety culture. Several measures have been implemented at the Loviisa plant for maintaining and developing safety culture. Related to this Fortum carried out a self-evaluation in 1994 using an interview method based on the IAEA-guidance. During the preparation of the application for the operating licence the state of safety culture was evaluated using mainly the IAEA-guidance as a point of comparison. Based on the evaluation the procedures for maintaining safety and availability have been noted to be comprehensive and relatively well operative.

In the evaluation many good characteristics of safety culture were noted. Respectively, the most important areas have been identified, to which the development measures should be focused in the future for the continuous development of safety culture. By nature these issues are related to the activities of organisations and people. In 2002 safety culture in Loviisa Power Plant was observed during WANO Peer Review.

2.6.3 Priority to safety at the Olkiluoto NPP

TVO is headed by the President and CEO with the assistance of the Management Group. In addition to the President and CEO, the following members belong to the Management Group: Senior Vice President, Operation; Senior Vice President, Nuclear Engineering; Senior Vice President, Power Plant Engineering; Senior Vice President, Project; Executive Vice President, Corporate Resources; Senior Vice President, Finance and Senior Vice President, Corporate Social Responsibility. The activities of the company are divided into areas of responsibility that belong to the aforementioned directors. TVO has a Safety Committee that is composed of experts from different technical areas. The tasks, responsibilities and duties of units are clarified in the TVO Administrative Rules and in the Organisational Manual. The Administrative Rules have been approved by STUK as a part of the Technical Specifications.

The minimum crew required for the main control room and the plant area has been presented in the Administrative Rules of the Olkiluoto plant.

According to the duty system of the plant a person of the Shift Supervisor level has to be reachable for the control room personnel at all times, for a case of possible special situations at the plant.

In addition to the operating organisation, an emergency preparedness organisation has been defined for the plant to prepare for accident situations. The emergency preparedness organisation is described in the Emergency Plan and its operation is exercised annually in emergency drills. To design and maintain security arrangements, a security organisation of the plant is defined in the Security Plan.

Developing safety culture

An in-depth safety approach is essential for ensuring the safety of a nuclear power plant. It means that malfunctions must be anticipated and the preparation for them must be in the form of multiple safety systems which are able, if necessary, to stop a power plant unit and prevent the malfunction from spreading. Safety measures are always planned on a conservative assumption that equipment malfunctions can occur and people operating them can make errors. On the basis of analysing such situations, the plant is equipped with appropriate and adequate safety systems. The plant has several parallel systems that ensure its reliability.

In accordance with the safety culture, a nuclear power plant also contains a number of structural protective zones within each other. In order to achieve operational reliability, different systems are built so that they can operate normally with an ample margin of safety in every situation. Reporting of errors, nonconformities, deficiencies and “near misses” is the basis of TVO’s safety culture. The reports are analysed and the analyses form the basis for corrective measures. All observations are discussed in an open manner so that as much as possible can be learned from them and the reoccurrence of any similar nonconformities can be prevented. In the planning of preventive measures probability based safety and reliability models, operational experience, “near-misses” and the result of “early warning” questionnaires are used.

TVO was originally founded as a nuclear power company. Its corporate culture was developed from approaches that have been available since the beginning of 1970’s for producing nuclear energy in a manner that emphasises safety factors. The technical personnel who was employed to the company immediately after its foundation and who has since then had a crucial role in developing the company, received its education and prior work experience within the area of nuclear technology. This background has significantly promoted the emphasis on safety issues in all of their actions.

Asea-Atom AB (later on ABB AB), the supplier of the plant, had also a favourable impact on the improvement of the TVO’s safety culture. The responsibility for practical safety solutions in the development of nuclear technology, was clearly left to the industry in Sweden, and safety authorities set forth only general requirements. Asea-Atom AB acknowledged its responsibility for the safety, and developed many solutions that were later adopted in other countries as well. TVO received all essential approaches needed for safe operation of the plant from its plant suppliers and developed them further.

In 1995, TVO drew up a safety and quality policy document signed by the Managing Director. The document contains the principles of safe and high quality performance as well as the principles of the good safety culture. In the policy document the company management commits to create the means for maintaining and developing a high quality safety culture.

TVO and its personnel have committed themselves to a high level of safety culture. Each matter is given the treatment and attention its importance deserves. Each matter is considered on the basis of its safety impact and safety is always given priority when decisions are made. If there is a conflict between safety and economic considerations, TVO always gives priority to safety.

TVO has conducted several measures to maintain and develop its safety culture. Related to this, the safety culture was self-assessed by the company management in 1992. Review was based on the principles and questions presented in the INSAG 4 Report. Review concluded that TVO’s measures are well in-line with the measures and characteristic features, defined in the INSAG 4 Report, of a company that has a high level safety culture. TVO also assessed the results of the two comprehensive Swedish safety culture reviews in 1995 from the standpoint of its own actions. Several findings requiring development actions were made on the basis of the reviews, but no new significant issues surfaced.

TVO conducted an internal review of its actions during the year 1996 and the beginning of the year 1997 by using the objectives and criteria presented by the WANO (World Association of Nuclear Operators). In connection with the review, several issues requiring improvements were found. WANO conducted a Peer Review In Olkiluoto in the 1999 and a Follow-up in the 2001.

Currently, in order to maintain a high safety culture and good operational results, TVO has decided to make a self-assessment of the safety culture to start up a programme for enhancing safety culture and safety management. The self-assessment and the enhance programme will be conducted with the help of IAEA. Training for the self-assessment was carried out in June 2004.

In conclusion, Finnish regulations and practices are in compliance with Article 10.

2.7 Article 11. Financial and human resources

1. ***Each Contracting Party shall take the appropriate steps to ensure that adequate financial resources are available to support the safety of each nuclear installation throughout its life.***
2. ***Each Contracting Party shall take the appropriate steps to ensure that sufficient numbers of qualified staff with appropriate education, training and retraining are available for all safety-related activities in or for each nuclear installation, throughout its life.***

2.7.1 Financial resources

Nuclear Energy Act defines as a condition for granting a Construction or Operating Licence that the applicant has sufficient financial resources, necessary expertise and, in particular, that the operating organisation and the competence of the operating staff are appropriate. Decision 395/1991 requires initial, complementary and refresher training programmes for the personnel. STUK controls the necessary qualifications on the persons engaged in activities important to safety. STUK has issued requirements on staff qualification and described the respective regulatory control procedures in the Guides YVL 1.1, YVL 1.6 and YVL 1.7.

For example according to the Nuclear Energy Act, the licensee shall have adequate financial resources to enhance the safety of the facility based on operating experience and the results of safety research as well as on the advancement of science and technology. Nuclear Energy Act provides detailed regulations for the financial arrangements for taking care of nuclear waste management. The Act on Third Party Liability provides regulations on financial arrangements for nuclear accidents, taking into account that Finland is a party to the Paris and Brussels conventions.

The annual reports of Fortum Corporation and Teollisuuden Voima Oy for 2003 are attached to this document, References 5 and 6. They provide financial information on the utilities. Both utilities have annually invested typically about 10–20 M€ for maintaining and improving safety. Figures 5 and 6 provide information on plant annual rate of investments. The costs of large modernisation programmes at both nuclear power plants during 1996–2003 can be seen in these figures.

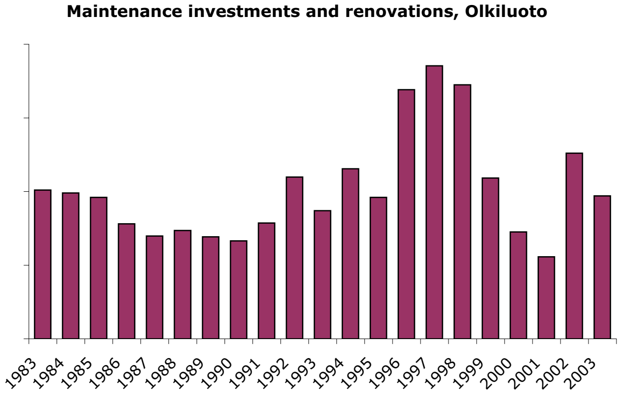


Figure 5. The annual rate of investments at Olkiluoto.

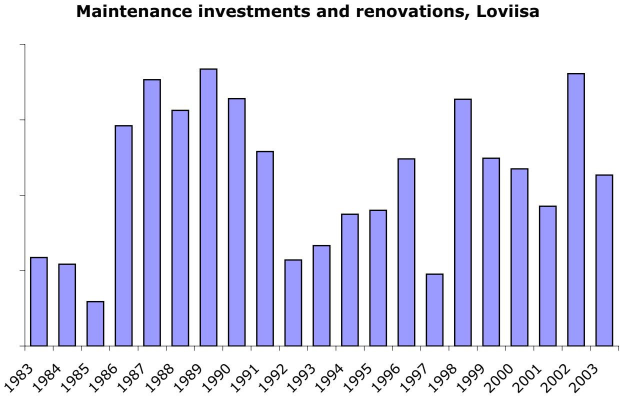


Figure 6. The annual rate of investments at Loviisa.

2.7.2 Human resources

The licensee has the prime responsibility for ensuring that his employees are qualified and authorised to their jobs. Both Finnish power companies have training organizations and training facilities at NPP sites with the training staff round ten persons and full-scope plant-specific training simulators. Training programmes, including simulator training, are further discussed in this report.

Both utilities have a systematic approach to training. However, changes in energy markets and the fast development of technology will bring new challenges to the knowledge, and this requires special emphasis of all parties. During 2003–2005 two five–six weeks training courses on nuclear safety technology are provided to train newcomers in the nuclear field as a specific co-operation of all nuclear related organizations. About 90 young experts and new comers are trained during the courses. The intention is to continue with the training course on annual basis as long as there are enough participants who need the training. Training materials are developed that can be used by the organizations in their internal training programmes as appropriate and for self-study via distance learning including text book, overhead materials, exercises and video lectures.

Certain persons, such as the responsible director and his deputies, shift supervisors and control room operators of the plant, persons taking care of physical protection, emergency preparedness and nuclear material control need an authorization from STUK for their tasks. The authorization of plant operators is valid for three years at a time. The renewal of the authorization requires e.g. that the person in question has worked continuously in the control room, has taken part in the refresher-training program and in demonstration of shift work skill as well as an oral examination.

STUK also approves the persons, who control the operation of the plant pressure vessels. Only companies approved by STUK and persons working for them may conduct repairs of pressure bearing structures and inspections of mechanical components and structures.

In spring 2000, the Ministry of Trade and Industry set up a working group to analyse the contents and scope of the know-how required to continue the safe operation of nuclear power plants. The task of the group was to identify the measures needed to compensate the retirement of many experts and train new experts. The age distribution of personnel working in organisations in the nuclear energy sector indicates that the need for new experts will increase two- or even three-fold round 2010 due to retirement. The current training capacity of universities is adequate to meet this need.

In addition to nuclear power plants, it is important to take care of the financial and human resources of technical support organizations such as research institutions and universities. In this respect, the new funding arrangement for nuclear research (see section 2.3.2) is an important prerequisite and this item needs further attention also in the future.

Loviisa NPP personnel training

The principles and organisation of the training activities of the Loviisa plant as well as detailed training instructions have been presented in the Training Manual. It has been established to ensure the systematic implementation of training activities. The training and simulator groups take care of training activities at the plant. The total manpower is 11 persons. For assisting the training group, organisation unit-specific contact persons have been appointed. They ensure that unit- and individual-specific needs are taken into account and that information is transferred to both directions. The competence requirements of the personnel are presented in the Training Manual. The competence requirements are based on the duties of each vacancy, on responsibility areas and on regulatory requirements related to the duties in question. The competence requirements define the basic education of a person and the initial and refresher training to be given at the Loviisa plant.

A full-scope training simulator identical with the plant is available for the training of the plant operators. Simulator training is given to new operator candidates during about 50 days as a part of the initial training. In addition to the simulator training, the initial training programme of the operators includes course-oriented classroom lectures and practical training at the plant and in the main control room. The initial training takes about two and a half years. Thereafter an operator can be licensed to work as a turbine or reactor operator. At the end of the training period a written and oral examinations as well as the demonstration of professional skills at the simulator are arranged for the operators. These are preconditions for the work as an operator or a shift supervisor in the main control room of the plant.

For the operators of the plant a refresher training programme has been established. It is implemented in the periods of three years. The programme includes those subjects which shall be annually gone through. In addition, the refresher training of the operators includes annually simulator training during two weeks, covering normal operational situations (e.g. start-up and shutdown situations) and plenty of training for disturbance situations. Refresher training is arranged for the plant operators during three weeks a year on average.

To ensure that all the expertise available within Fortum Group is utilised in dealing with extensive and/or many-sided principled safety issues the Loviisa plant and Fortum Nuclear Services have signed a co-operation agreement. In the agreement those expertise areas are identified within which it is the responsibility of Fortum Nuclear Services inside Fortum Group to educate and maintain sufficient number of experts to support the Loviisa plant operation.

Olkiluoto NPP personnel training

The principles and organisation of TVO's training activities as well as detailed training procedures are presented in the training manual, by the means of which a systematic implementation of the training is ensured. The training in the company has been organised so, that in addition to the existing seventeen persons in the training centre there are training contact persons at both units in operation and also in the project organization of the third unit in Olkiluoto. In addition to this, there are several committees that survey and handle the training needs of e.g. operation and maintenance as well as of the entire company and monitor training results. External or internal experts give major part of the general training and the training centre staffs gives only minor part. The training centre staffs, instead, gives all simulator training. An organisation model like this makes it possible to take unit and individual related training needs into account in an efficient manner. The training manual presents vacancy related competence requirements that have been defined for the personnel. The competence requirements are based on the tasks, areas of responsibility relating to the vacancies in question, and the related regulations of the regulatory authority. Person's basic education and the basic and refresher training given by the TVO are defined in the qualification requirements.

A training simulator, is available for the training of plant operators of Olkiluoto 1 and 2 at power plant site. The number of operating training days to new operator candidates is approximately 50 days as a part of the basic education. In addition to the simulator training, the basic training program of operators includes classroom and on-the-job training at the plant and in the main control room. The basic training takes approximately 18 months, after which the operator is allowed to work as a turbine operator. After working as a turbine operator and gaining more experience, the turbine operator is given more individual training by e.g. the simulator for the duties of a reactor operator. In the end of the training period, a written and oral examinations as well as a demonstration of operating skills at the training simulator are required before a person is allowed to start working as an operator or as a shift supervisor in the main control room of the nuclear power plant.

A refresher-training program, which is conducted in a three-year period, is available for the plant operators. The program includes the subjects that shall be repeated annually. Furthermore, the refresher training of operators includes annually two weeks of operating training at the simulator containing a considerable amount of transient situation training in addition to the training of normal operating conditions (e.g. start-ups and shutdowns). The plant operators receive approximately three weeks of refresher training annually.

Initial training of personnel of the new NPP unit Olkiluoto 3, which will be given during the construction and commissioning phases, will cover all staff members who are directly involved in plant operation, plant and systems maintenance, technical support and in power plant management. The training courses are comprised of theoretical courses such as fundamental plant technology, survey and plant courses. The training will also include practical training such as on-the-job training in factories and operating power plants as well as active hands-on training during the commissioning phase of the power plant. Olkiluoto 3 will also be equipped with a plant specific training simulator.

Shift supervisors and control room operators will have a training period at the simulator, starting one year before the first fuel loading and ending with the licensing examination just before the fuel loading, which has been planned to take place in August 2008. The length of the simulator training course is 10 weeks. During the operational period of Olkiluoto 3, the training and the refresher training of the personnel will be incorporated into the existing complementary and refresher training programmes of TVO.

In conclusion, Finnish regulations and practices are in compliance with Article 11.

2.8 Article 12. Human factors

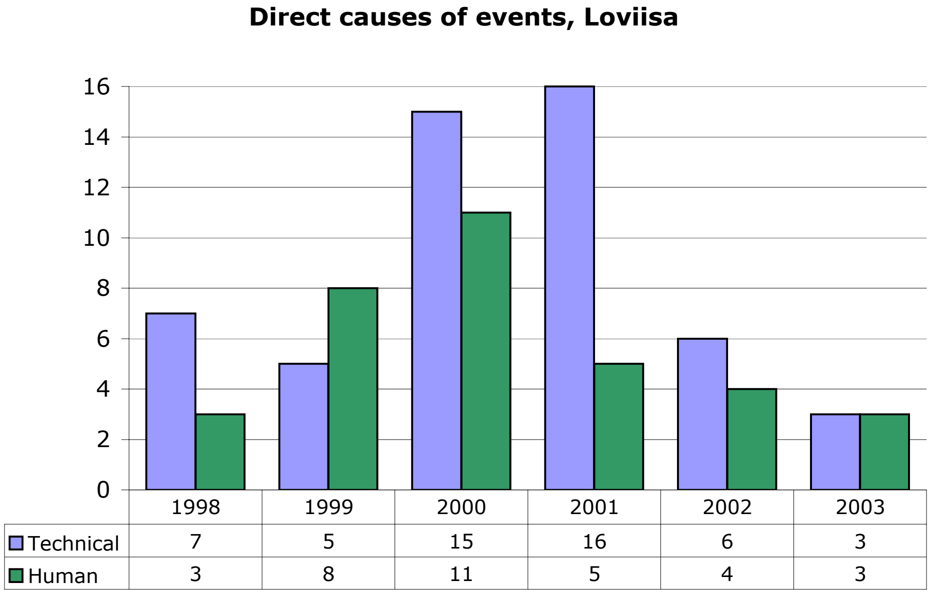
Each Contracting party shall take the appropriate steps to ensure that the capabilities and limitations of human performance are taken into account throughout the life of a nuclear installation.

2.8.1 Regulatory approach to human factors

Decision 395/1991 requires that a nuclear power plant's control rooms shall contain equipment which provide information about the plant's operational state and any deviations from normal operation as well as systems which monitor the state of the plant's safety systems during operation and their functioning during operational transients and accidents. A nuclear power plant shall contain automatic systems that maintain the plant in a safe state during transients and accidents long enough to provide the operators a sufficient time to consider and implement the correct actions. There shall be an emergency control post at a nuclear power plant which is independent of the control room and the necessary local control systems by the means of which the nuclear reactor can be shut down and cooled and residual heat from the nuclear reactor and spent fuel stored at the plant can be removed.

Decision 395/1991 requires that special attention shall be paid to the avoidance, detection and repair of human errors. The possibility of human errors shall be taken into account both in the design of the nuclear power plant and in the planning of its operation so that the plant withstands well errors and deviations from planned operational actions. Human factors have also to be taken into account in the failure analyses of plant safety systems and in probabilistic safety analyses. Such analyses have been completed for all Finnish nuclear power plants.

As regards the operation of the facility, the influence of human factors and the respective need for corrective measures are assessed by the licensees and STUK, when evaluating abnormal events and their lessons learnt. Each operating organisation has established a systematic procedure for making event evaluations. Figures 7 and 8 show the share of technical and human related causes for the latest incidents at the Finnish nuclear power plants. During 2003, Loviisa NPP reported 6 events from which 3 contained human root causes and Olkiluoto NPP reported 17 events from which 8 contained



	1998	1999	2000	2001	2002	2003
🟦 Technical	7	5	15	16	6	3
🟩 Human	3	8	11	5	4	3

Figure 7. Number of technical and / or human root causes identified in the event analyses at the Loviisa NPP.

human root causes. In two events in Olkiluoto NPP there were both technical and human root causes. (See Chapter 2.15.6)

Human resources and quality assurance are discussed under Articles 11 and 13, respectively.

2.8.2 Monitoring and control of the Loviisa nuclear power plant

The Loviisa 1 and 2 units have their own independent main control rooms. There are available the needed process information and all the needed control actions can be performed there. Alarm signals from the spent fuel storages are also available in the Loviisa 2 main control room. As regards their implementation, the main control rooms are of proven control room technology.

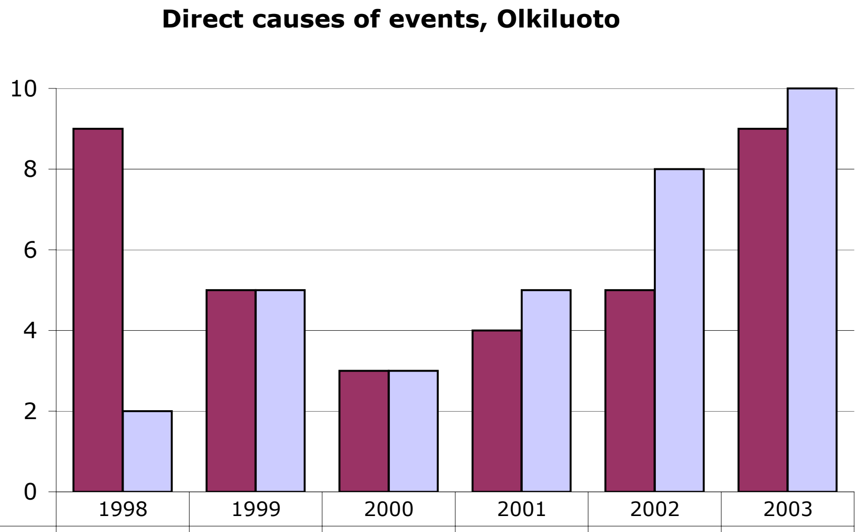
Process information is presented in the main control room with indicating meters, indicator lights and recorders as well as with the monitors of the process computer system. There are two redundant alarm systems in the main control room. These systems have been realised by using two different techniques, conventional and computer-based techniques. Indicator light fields are in the operator's consoles, and two monitors have been reserved for computer alarms. In addition, data on events and conditions as well as the exceeding of warning and alarm limits are recorded by the alarm printers. The process computer gives process information in an illustrative format for the use of the operators.

In addition to the main control room, the shutdown of the reactor as well as the control and monitoring actions necessary for safety can be performed by means of a so-called emergency control room table, located in the main control room of the other unit.

In addition to the main control room, the additional control rooms are located in the both auxiliary buildings for controlling the functioning of important auxiliary processes. Furthermore, there are the unit-specific ventilation control rooms and the diesel-specific local control posts at the plant. The alarm signals from all auxiliary control rooms are available in a combined format in the main control rooms.

The Loviisa 1 and 2 protection systems have been designed so that quick operator actions are not required for the start-up of the safety systems during transient or accident situations. Possibilities of human errors are effectively reduced by a sufficient consideration time available to the operators before control or other actions, by appropriate instructions for transient and emergency situations as well as by operator training. The process computer has been equipped with a so-called critical safety functions control system (SPDS), by means of which an operator can follow the performance of all the safety functions in a combined and clear format. An identification system for transient situations is also related to the control of the critical safety functions. An operator may use it as a support when a situation is being identified.

The renewal of plant automation is in preparatory stage and will be discussed under Article 18.



	1998	1999	2000	2001	2002	2003
■ Technical	9	5	3	4	5	9
□ Human	2	5	3	5	8	10

Figure 8. Number of technical and / or human root causes identified in the event analysis at the Olkiluoto NPP.

Human factors

Human errors can not be entirely avoided. However, the possibility of errors can be made smaller with proper instructions, procedures, and training and efficient quality assurance. For identifying human error possibilities and for clarifying their consequences Fortum has prepared an extensive evaluation concerning these issues. This evaluation is a part of the probabilistic safety analysis. For analysing hidden defects influencing the course of a possible transient or accident, Fortum has evaluated regularly performed duties of different types at the plant. In the analysis concerning human errors such operational and maintenance mistakes have been evaluated which may act as an initiating event of a transient or an accident. Different plant states and duties related to them have been evaluated in detail.

Control actions needed during an accident have been divided in the evaluation into two parts: a diagnosis and actions taken to prevent the accident. Possibilities for mistakes have been studied with the help of a simulator. Plant procedures for emergency situations have been developed and will be further developed, taking also into account the results of PSA. The progress is shortly referred in Article 19.

For preventing human errors it is important, that the operating events are carefully evaluated and, if necessary, procedures or the plant is developed to prevent similar mistakes. Fortum has developed the utilisation of operating experiences and does the root cause analyses out of every significant event.

When starting up the plant from an outage, a dedicated quality procedure is followed in order to check all required provisions for continued power operation.

The protection systems of the plant initiate the safety systems automatically when needed so that the operators will have enough time to consider actions according to operating instructions. Due to the inherent characteristics of the Loviisa plant, the operators will have usually more time for consideration in a transient situation than at other types of nuclear power plants. The Loviisa plant is well equipped concerning the needed training for preventing human errors. A simulator is at hand. It is used for training the operators to come through accident situations.

Studies on human errors until now and the development of improvement measures are also internationally focused on the activities of the plant operators and of the lowest levels of the operating organisation. In the future, also the functions of an organisation more extensively and the preventing of human errors in design activities may be significant targets for development.

2.8.3 Monitoring and control of the Olkiluoto nuclear power plant

Olkiluoto 1 and 2 have their own independent control rooms, where the necessary process information is available, and from where all necessary control measures can be conducted. The alarms covering also the spent fuel storage (KPA storage) are output to the control room of the Olkiluoto 1. The technical solutions of the main control rooms are based on the proven control room technology.

Process information is presented by the indicating measuring equipment installed in the steering desks and panels. Conventional and computer aided alarm systems are used to facilitate the management of main processes and other sub and auxiliary processes.

The alarms are indicated primarily by the alarm lamp panels. The parallel alarms received through the computer are seen on the monitors. In addition, the event and state data as well as deviations from warning/alarm limits are printed on the alarm printers.

A safety parameter display system (SPDS), which improves the performance capability of the operating personnel in controlling transient and accident situations, has been taken into use at the Olkiluoto plant units.

A so-called 30-minute rule has been the design basis for the protection system at Olkiluoto 1 and 2. Important protection measures and safety systems start up automatically so, that no actions of operating personnel are needed during the first thirty minutes after the beginning of the operational transient or postulated accident. Operators have time for consideration before entering into the control and other measures. Proper emergency and transient situation procedures as well as training of those situations reduce the possibility of human errors further.

Both Olkiluoto plant units have an emergency control post, from where the reactor can be tripped and where the main parameters of the reactor such as neutron flux, pressure, temperature and water level can be monitored. Cooling the reactor down to a cold state and removal of decay heat can be carried out after the shutdown by using local control rooms. The interim spent fuel storage has its own local control room for the monitoring of decay heat removal.

The requirement of another, independent emergency control post emerged after the TVO plants were designed. The units have been designed so that they can be shutdown in an ordinary way only from the control room or from the emergency control post.

TVO has studied the independence of the control room and the emergency control post in connection with different accident scenarios such as fires and in different initiating events of common cause failures such as earthquakes, high temperature of air and sea water, a magnetic field caused by a mobile phone and losses of electrical power. The risk of a simultaneous loss of the control room and the relay room, which functions as an emergency control post, can be considered small.

In a long-term accident situation the main process parameters as well as crucial radiation measurements and weather information can be monitored from the space preserved for the emergency preparedness supporting group. The indicating instrumentation equipment, which is one of the severe accident management systems (SAM system) and monitors the state of the containment in case of a severe accident has been placed in an easily accessible room.

The modernization of systems, conducted in connection with the power uprating, facilitated the monitoring and operation of the plant. During the projects, functions that were earlier manual have been automated and displays of the control rooms as well as other means for collecting information have been improved. The modernisation of the neutron flux measuring system and reactor pressure control can be mentioned as examples from these modifications. TVO plans to continue the modernization of systems during the forthcoming operating period.

A new programmable technology was also taken into use, in connection with the conducted modernisation, in the aforementioned neutron flux measuring system and in controlling the reactor pressure and feed water flow. The introduction of new technology sets new challenges not only for the modification design of the systems but also for personnel training and for the procedures applied at the plant during the operation. The aforementioned matters can be considered as improvements for the forthcoming operating period.

Human factors

TVO has conducted a probabilistic safety analysis (PSA) where the consequences of human errors have been studied. Latent maintenance and testing errors have been studied in connection with the system analyses related to the PSA. In addition to the human factor experts, experienced staff members from the operating and maintenance personnel have participated in assessing the possibility of errors. The identified error possibilities have been classified into groups according to their importance and the most important ones have been modelled in the PSA study to clarify the risks related to errors.

The reliability of operator actions conducted during accident conditions was assessed as a part of the PSA analysis. The diagnostic errors that may be made in connection with accidents have also been assessed. Based on the results of the analyses concerning the human errors, a few additions and modifications have been made on the emergency and operating procedures of the plant.

All the main control room related modifications are tested at the training simulator and operators are trained for managing the modified systems prior to the modifications are installed. In the development of human aspects in the operating procedures TVO has utilized operating experience and results of root causes analyses. Errors related to the maintenance actions have also been examined and measures have been developed to avoid corresponding errors.

When needed TVO has used the services of nationally well-known experts on the area of human behaviour. TVO has also participated in the research of matters related to the human behaviour and organizational culture both on national and international level. In order to enhance its knowledge further, TVO has recruited a specialist of human factors.

In conclusion, Finnish regulations and practices are in compliance with Article 12.

2.9 Article 13. Quality assurance

Each Contracting Party shall take the appropriate steps to ensure that quality assurance programmes are established and implemented with a view to providing confidence that specified requirements for all activities important to nuclear safety are satisfied throughout the life of a nuclear installation.

2.9.1 Regulatory approach to quality assurance

Nuclear Energy Decree requires that a quality management system for design and construction as well as for operation are required to be submitted to STUK when applying for the construction and operating licence of a nuclear facility, respectively. The general quality management system requirements apply to the whole life of a nuclear facility. Decision 395/1991 requires that advanced quality management system shall be employed in all activities which affect safety and relate to the design, construction and operation of a nuclear power plan. The quality management system requirements are provided in the Guides YVL 1.4 and YVL 1.9. The detailed quality management requirements for design of a nuclear facility are presented in the Guide YVL 2.0 and for the fuel are presented in the Guide YVL 6.7. The quality management requirements related to specific technical areas are presented in the corresponding technical guides.

Quality management systems of the licensees/applicants and of the main suppliers are subject to approval by STUK. Furthermore, quality management systems have to be established by all other organisations participating in activities important to safety of the use of nuclear energy. The implementation of these quality management systems is verified by STUK through inspections.

At the moment, STUK's YVL Guides that set the general requirements for quality management system are being updated. The new guides will reflect the ongoing updating of the IAEA guidelines and the recent development in the quality management in industry. In addition, both licensees have recently implemented new quality management systems. The assessment of the quality management system for the design and construction of the new unit is underway.

STUK's Quality Manual has been prepared and implemented since the First Review Meeting. It includes STUK's quality policy, description of the quality system, organisation and management, main and supporting working processes and personnel policy. The results of systematic internal audits, self-assessments and international evaluations are used as inputs for the enhancement projects of the Quality Management System at STUK. In addition to STUK's Quality Manual, all main functions of STUK have their own more detailed Quality Manuals. During 2003 STUK has updated its strategy and its quality policy. The quality management system is under revision to implement the process oriented approach through out the whole organization before the end of year 2004. The Quality Manual prepared for the regulatory control of the use of nuclear energy has been benchmarked with other regulators under the auspices of OECD/NEA working groups and bilateral agreements.

2.9.2 Development of the quality system in the Loviisa NPP

After Fortum Corporation was formed a need for an updated quality policy was obvious. In 1999 a quality statement "Fortum's Policy Commitment to Quality in the Nuclear Power Operations" was issued by the president of Fortum Power and Heat Oy. The statement has been confirmed in 2001 also by the new management of Fortum Power and Heat Oy.

The recent development of the plant quality management system is based on the principle of continuous improvement in accordance with the observations and remarks made in quality audits and quality assessments. Loviisa Power Plant adopted in 2001 a newly formulated management procedure which defines an annual planning process from strategic planning to annual reports. A first 10-year strategic plan for the power plant was developed in 2000. A second important and new procedure describes those review processes (e.g. management reviews, self assessments), which are needed in an effective quality management system.

In the internal quality audits, new efforts are directed to the evaluation of the recurrence of events. These have considerably increased the necessary background work both in the preparation and in the reporting phase of an internal audit. An evaluation of the plant quality management system against the ISO/DIS 9001, 9004:2000 standards were made in 2000 by Fortum Engineering. The work continued in 2001 - 2002 and a similar comparison with IAEA Safety Series No. 50-C/SG-Q was carried out.

The environmental management system of the plant was certified in 2002 according to the ISO 14001:1996 standard. During the preparation phase an environmental policy and a new chapter on environmental system were introduced in the Quality Manual. Numerous quality procedures were also updated. A novel environmental aspect shall be considered in internal audits and new part-time auditors have been trained for environmental evaluations.

A new tracking system for quality and safety decisions, obligations and actions has been taken into use in 2002.

2.9.3 Development of the quality system in the Olkiluoto NPP

TVO's new quality management system, Activity Based Management System, is described in the quality management manual. It takes into account the requirements from the documents YVL 1.4 (1991), YVL 1.9 (1991), IAEA Safety Series No. 50-C/SG-Q, and ISO 9001:2000. Activity Based Management System guides all TVO's operations and provides each staff member with procedures for the safe, economical, high-quality and environmentally friendly generation of electricity. The system comprises a general section and a functions section. The general section presents TVO's vision, business concept and values, company-level policies, organization and areas of responsibility, general principles governing the operations, the principles guiding quality assurance in operational processes, and a general description of the processes, their resources and the ways in which they are run. The functions section describes the operation as process models, and it also contains more detailed handbooks and instructions covering the functions.

TVO reviewed its company-level policies during the year 2003. They were grouped under four headings and approved in February 2004. TVO bases its company-level policies on its values and business concept.

TVO has approved the following as its company-level policies: nuclear safety and quality policy, social responsibility policy, production policy and corporate security policy. Also the process for plant modification has been updated during the year 2003.

The functions and responsibilities of TVO's organizations and personnel are described in detail in the TVO Administrative Rules, in the Organisational Manual and in the manuals and instructions of individual organizations. The Administrative Rules have been approved by STUK as a part of the Technical Specifications.

The documentation and instructions are controlled by a software based system as well as the management of deviations and corrective actions.

For the new reactor, one of the licensing documents submitted to STUK for approval is QA for construction, "The Quality Manual for Olkiluoto 3 Project". Review of the document as well as review of the QM systems of plant vendor and major suppliers is carried out by STUK. STUK has also asked external QM experts opinions on the QM systems.

In conclusion, Finnish regulations and practices are in compliance with Article 13.

2.10 Article 14. Assessment and verification of safety

Each Contracting Party shall take the appropriate steps to ensure that:

i. comprehensive and systematic safety assessments are carried out before the construction and commissioning of a nuclear installation and throughout its life. Such assessments shall be well documented, subsequently updated in the light of operating experience and significant new safety information, and reviewed under the authority of the regulatory body;

ii. verification by analysis, surveillance, testing and inspection is carried out to ensure that the physical state and the operation of a nuclear installation continue to be in accordance with its design, applicable national safety requirements, and operational limits and conditions.

2.10.1 Regulatory approach to safety assessment

The license applications for a new licence or for the renewal of license include the documents required by the Nuclear Energy Decree: Preliminary or Final Safety Analysis Reports; Probabilistic Safety Analysis Reports, including Level 1 and 2 PSA analyses; Quality Assurance Programmes for Operation; Safety Classification Document, Operational Limits and Conditions Document (Technical Specifications); Programmes for Periodic Inspections; Plans for Physical Security and Emergency Preparedness; Manuals for Accounting and Control of Nuclear Materials; Administrative Rules for the Facilities; Programmes for Radiation Monitoring in the Environment of the Facilities.

The design of the facility is described in the Preliminary Safety Analysis Report (PSAR) and in the Final Safety Analysis Report (FSAR). The reports are submitted, respectively, to STUK for approval in connection with the applications for Construction and Operating Licences. According to the Nuclear Energy Decree, FSAR has to be continuously updated.

Decision 395/1991 requires that nuclear power plant safety and the design of its safety systems shall be substantiated by accident analyses and probabilistic safety analyses. Analyses shall be maintained and revised if necessary, taking into account operating experience, the results of experimental research and the advancement of calculating methods. The calculating methods employed for demonstrating the meeting of the safety regulations shall be reliable and well qualified for dealing with the events in question. They shall be applied so that the calculated results are, with a good confidence, less favourable than the results which are considered best estimates. Furthermore, analyses which simulate the likely course of transients and accidents shall be conducted for the purpose of probabilistic safety analyses and for the development of emergency operating procedures. Detailed requirements concerning transient and accident analyses, including sensitivity analyses, are presented in Guide YVL 2.2, “Transient and Accident Analyses for Justification of Technical Solutions at Nuclear Power Plants” and requirements concerning reliability and risk analyses in Guide YVL 2.8. Additional criteria are presented in the Guides YVL 6.2 and YVL 7.1 concerning fuel and releases from the nuclear power plant.

Special attention has been paid to plant modification processes and documentation. Requirements concerning modifications designed by the utility and their independent assessment have been reassessed and included into appropriate YVL Guides. The new requirements mean in practice that all safety significant plant modifications have to be assessed by a unit which is independent of the design and implementation of the modification. Detailed requirements for the system modifications are presented in the Guide YVL 2.0. STUK has also established its own plant modification database, including the whole operating history of the Finnish plants. Based on this database, STUK produces reports on ongoing plant modifications biannually. These reports include all safety significant plant modifications and other important modifications.

Comprehensive and systematic safety assessment is an essential part of the licensing process and license renewal. As a condition for a license, both deterministic and probabilistic safety assessments (PSA) need to be carried out and submitted to STUK for approval. Both assessments are kept up to date throughout the operation of the nuclear facility, reflecting the advancement of science and technology. Any changes to these documents are submitted to STUK for approval. The review of these safety assessments by STUK includes independent safety analyses.

The latest comprehensive safety assessments of the Loviisa and Olkiluoto nuclear power plants were carried out in connection with the license renewal and power uprate of the plants in 1996-97. The license applications included the documents required by the Nuclear Energy Decree (see above). E.g. Final Safety Analysis Reports were updated. The update of the accident analyses and PSAs including Level 1 and 2 PSA analyses, was made in this connection. It involved calculations of most transients and accidents with advanced computer codes. The results of the analyses are discussed in detail below. Licensee also provided assessments how the regulations have been complied with, including the fulfilment of YVL Guides. Licensee also explained how an adequate safety level has been maintained. Plans for Radioactive Waste Management were presented.

Recently, the PSAs have been updated, and their scope has been extended at both nuclear power plants. Plant-specific living PSAs, including internal initiators, fires, flooding, severe weather conditions, seismic events for operation mode, and internal events, floods, and severe weather conditions for normal annual refuelling outage, have been completed for the plants. These PSA studies are used in support of decision making by the regulatory body and of safety management at the utilities. Special attention has been paid to seismic events in Finland, although Finland is not in a seismically active area. According to the PSA results, seismic events do not cause major risks in Finland. However, some modifications have been made at Olkiluoto nuclear power plant, where for example the support structures of batteries and switchgear cubicles have been improved. There has been no need to implement any specific measures regarding seismic events at Loviisa nuclear power plant.

Safety assessment of Olkiluoto 3

The design and licensing process of Olkiluoto 3 project will be done according to the detailed Finnish YVL guides and their main references. The safety approach includes a strong deterministic basis complemented by probabilistic analyses in order to improve the prevention of accidents, as well as their mitigation.

A twofold strategy is pursued for the EPR safety requirements:

- To improve the preventive measures against accidents.
- To mitigate Severe Accidents consequences, even if their probability has been further reduced. This is achieved by implementing features, which ensure containment integrity. Thus, it can be demonstrated that the need of stringent countermeasures are restricted to the immediate vicinity of the plant. The most important special safety features of Olkiluoto 3 design are as follows:
    - severe accident management (SAM) has been taken into account already in the beginning of the design process
    - plant structures are designed against a possible airplane crash so that the event does not lead to release of significant amount of radioactive substances to the environment or threaten the safety functions required to achieve safe shutdown state. The military and the large commercial aircraft are considered in the design.

The compliance of the EPR with the Decision 395/91 of the Council of State and with all YVL guides are assessed by the plant designer. The review of this assessment is going on by TVO and STUK, independently.

The deterministic as well as probabilistic safety assessment will be done by plant designer and reviewed by TVO. The deterministic approach is founded on the international defence in depth concept. The comprehensive review of STUK during the design, construction and operating phases of Olkiluoto 3 is an on-going process divided into several stage-by-stage approvals.

In addition to the review of the reports provided by TVO, STUK has asked VTT and foreign institutes to perform independent transient and accident analysis for the most limiting scenarios. VTT has developed own model and codes for the analysis. Results of these analyses will be compared to ones provided by TVO.

2.10.2 Deterministic safety assessment

Transient and accident analyses of the Loviisa NPP

By means of analyses it is aimed to demonstrate the capability of the plant to cope with various transient and accident situations safely enough. According to Guide YVL 2.2, the analyses shall be focused to events, which by nature and severity cover different kind of transient and accident situations.

Fortum has revised in connection with the modernising of the Loviisa 1 and 2 units the transient and accident analyses included the Final Safety Analysis Report, taking into account the reactor power increase. For the assessment of normal operating conditions, transients and postulated accidents Fortum has used primarily calculation methods which have been developed in Finland. The main tool in the analysis work was APROS code that is developed in co-operation between Fortum Nuclear Services and the Technical Research Centre of Finland (VTT) since 1986. In this connection a new model and input data file of the plant were developed from scratch. The plant model is very detailed modelling all six loops and the whole secondary circuit, too. So-called topical reports have also been presented on used methods. Their aim is to demonstrate the reliability and usability of the methods. Methods have been validated to the extent, which is consistent with the level recognised internationally as good, mainly by making reference calculations with various methods and by using measurement results at experimental equipment as a reference. Due to uncertainties related to the accuracy of the calculation methods it is essential that adequate safety margins are applied when evaluating the fulfilment of the acceptance criteria of analyses.

Input data and assumptions influencing on the results of the analyses as well as made sensitivity calculations have also been presented and justified in the analyses described in the Safety Analysis Report and in related topical reports.

The analyses presented in the Safety Analysis Report cover anticipated operational transients, postulated accidents used as a design basis of safety systems and so called severe reactor accidents. Analyses related to severe reactor accidents, mainly radioactive release analyses, are still partly being done. Different transient and accident types have been classified. Each category contains several different accident sequences. Specific analyses have been presented on each accident sequence. Each analysis essential to safety includes sensitivity calculations which are often considerably extensive.

The anticipated operational transients are events which can be expected to occur at least once during the lifetime of a plant. The following events have been considered as anticipated operational transients: stopping of reactor coolant pumps; uncontrollable withdrawal of control rods; stopping of a main feedwater pump; closure of isolation valves of steam generators, and loss of off-site power supply. Based on the results of the analyses concerning operational transients it can be noted that the power increase does not essentially make the transient behaviour of the plant worse.

As postulated accidents all such situations have been re-evaluated which according to Guide YVL 2.2 are postulated accidents and which begin at full reactor power. These kind of accidents are: loss of coolant accidents; breaks of a steam line; leaks from the primary to secondary circuit; ejection of a control rod; anticipated transients without scram (ATWS); and a large spectrum of disturbances in reactivity control, including false dilution of boron concentration in the primary circuit (boron is used in reactivity control).

As regards transients beginning at low or zero-power, the power increase can only be seen as small changes in the process quantities of the initial state, when compared with the earlier figures. Furthermore, transients and accident situations beginning in outage situations have been analysed.

The influence of the 9% power increase on the results of accident analyses is mainly quite small. The influence can be seen more clearly in connection with a so-called major loss of coolant accident. Due to the power increase, the maximum cladding temperature of the fuel rods exceeds during this kind of postulated accident the maximum temperature calculated using comparable assumptions and the earlier nominal power 1375MW. The mentioned exceeding is, however, only a small part of the present safety margin to the approval criterion of the maximum fuel rod cladding temperature. On the other hand, because the power increase is implemented by balancing the power distribution without changing the load of the most loaded fuel rods, the number of the most loaded fuel rods slightly increases.

In connection with the updating of the safety analyses it was noted that the original dimensioning of the intermediate cooling circuit for decay heat removal from the containment has been done on faulty basis. In accident conditions, the intermediate cooling system has two essential duties: to remove decay heat into the final heat sink, and to cool a large number of equipment and systems for various safety functions and their room spaces. Accordingly, the reliable function of the intermediate cooling system is an essential safety factor in accident situations. Fortum has implemented extensive measures for increasing the design temperature of the intermediate cooling circuit, in order to ensure the adequate reliability of the functions of the intermediate circuit on the basis of new information. Such measures are i.e. process modifications for decreasing heat load and component modifications for improving heat endurance of motors and cables.

Accident analyses for evaluating functioning capabilities of the safety systems are also discussed as regards the reactor core and nuclear fuel, and as regards radiation safety. Fortum has separately made accident analyses for the storages of spent fuel and reactor wastes. The descriptions and results of the analyses have been presented in the appropriate Chapters of the Safety Analysis Report.

Transient and accident analyses and used analytical methods have to be maintained and developed throughout the whole lifetime of a nuclear power plant. Based on the results of the analyses measures are taken for enhancing safety, when necessary. The accident analyses indicate that the process parameters of some essential safety systems can be defined more appropriately than currently done.

STUK has reviewed the analyses and the methods applied. In addition, STUK has made independent reference analyses, or such analyses have been done by order of STUK. Sensitivity calculations and reference analyses are needed for evaluating and reducing uncertainties related normally to calculation methods and assumptions.

Transient and accident analyses of the Olkiluoto NPP

The performed analyses and the methods used in them have been described in the Safety Analysis Report, related Topical Reports and in the pre-inspection documents of the systems.

Transient and accident analyses as well as analysis methods describing the operation of Olkiluoto 1 and 2 have been maintained and developed during the entire time of plant operation. The analyses concerning the operation of Olkiluoto 1 and 2 have been completely renewed during the modernisation project currently in progress. In addition to the uprated power level the analyses have taken into account e.g. the changed reactor power/flow rate area and the structural modifications of fuel rods and reactor internals. To ensure that the scope of analyses is adequate TVO has conducted a failure consequence analysis, where consequences of the transients caused by system and equipment failures have been considered from the standpoint of plant operation. Based on the review, the available transient and accident analyses cover well the transients caused by system and equipment failures that may surface in plant operation.

In connection with the modernisation project, new analysis methods for description of accident situations have also been taken into use together with the new systems. The analysis of transient situations has been improved by the means of a new computer code capable of three dimensional modelling of the reactor core, due to which e.g. the reactor stability and the course of reactivity accidents can be observed more accurately than before.

STUK has inspected the essential parts of the analyses and applied methods described in the Safety Analysis Report. STUK has also conducted or purchased comparison analyses, by the means of which both the applicability of analysis methods to the description of different transients, and the sensitivity of analysis results to the parameters describing the plant status, course of an accident or functioning of the models has been clarified. STUK's review is that the plant behaviour in different transient and accident situations has been analysed comprehensively and that the methods used in the analyses are properly validated to describe the operation of the Olkiluoto plant.

Transient and accident analyses of the Olkiluoto 3

Safety analysis rules provide a methodology to verify that safety systems are suitably designed. The degree of conservatism of these rules is sufficient to provide appropriate margins in design of the safety relevant systems.

The safety analysis rules are strictly applied when calculating the thermal-hydraulic and neutronic transients associated to the DBC incidents and accidents. They cover the initiating events of DBC 2 to 4. The "DBC accident analysis rules" are part of the conservative methodology, which supports the deterministic safety assessment of the Nuclear Power Plant.

Events are grouped according to their potential risk with regard to the main safety functions:

- reactivity and power control,
- heat removal from the fuel assemblies,
- confinement of radioactivity.

The events with potential risk are classified in Design Basis Conditions and in Design Extension Conditions. The classification of Design Basis Conditions is based upon their rough expected frequency of occurrence:

- DBC 1 events: Normal operation,
- DBC 2 events: Incident Conditions,
- DBC 3 events: Accident Conditions, Category 1 and
- DBC 4 events: Accident Conditions, Category 2.

The Design Basis Conditions contain events caused by the failure of one component or the failure of one I&C function or one operator error (e.g. spurious starting of RCP) or loss of offsite power.

The deterministic design of the safety systems is supported by the safety analysis of the Design Basis Conditions. Beyond this analysis, the design basis is extended to provide a frame for the design of additional equipment needed to meet the probabilistic objectives for core melt and large releases, and to limit radiological releases to an acceptable level in case of a postulated low pres-sure core melt. In this design extension, a limited number of representative events are analyzed in order to justify the design of this additional equipment. The representative events are considered as Design Extension Conditions.

The preliminary analyses of Olkiluoto 3 are presented in PSAR and the Topical Reports joined to PSAR. The validation process of the used calculation methods and codes is based on the operational data and experiences of the reference plants as well as model comparisons by test facilities. The validation process of codes used for design and licensing calculations is going on.

STUK is reviewing the analyses provided by plant designer and verifying the most important results by the analyses performed by technical support organisations and STUK itself.

2.10.3 Probabilistic safety analysis in the Loviisa NPP

STUK required in 1984 that Fortum makes an extensive probabilistic safety analysis concerning the Loviisa units. It was required that the objective of the study is to determine the plant-specific risk topographies of the most essential accident sequences. Another important objective was to train the plant personnel to understand more deeply than before the plant and its behaviour as a whole in different situations.

Fortum provided STUK with level 1 PSA in summer 1989. Since 1990 Fortum has extended PSA by analysing risks related to fires, floods, earthquakes, severe weather conditions and outages, as well as by making level 2 PSA (integrity of the containment and releases). Since 1991 many modifications of the Loviisa units have been implemented. By means of these modifications risks have been decreased and the risk topography of the plant has been balanced. A part of the modifications was implemented in connection with the modernisation of the plant. Technical solutions of the modifications have also been often justified with PSA. Examples of the most essential plant modifications have been presented in the following. They are classified according to initiating events.

Level 1 PSA – Internal initiating events

The 1989 analysis contained an evaluation of the risks caused by various plant transients, ruptures of the cooling pipes and disturbances in the electrical network (internal initiating events). The result of the analysis concerning the probability of reactor core damage was about 2×10^{-3} a year. Reasons for that high estimate were simplified assumptions related to event sequences which are difficult to model: some events, such as e.g. exceeding the design temperature in the rooms of electrical systems were assumed to result in a reactor core damage. For decreasing the importance of these event sequences new redundant air cooling system for instrumentation rooms were implemented, after which their probability became so small that they had no significant effect on the total risk. In the same connection other improvements such as primary coolant pumps improved antireverse control system and new stopping signal based on the low seal coolant flow were implemented to prevent seal LOCA. After the improvements of the plant in 1990 the probability of reactor core damage was estimated to be about 1.4×10^{-4} a year.

In addition, since 1991 several modifications of the plant have been made, reducing essentially the risk:

- The reliability of reducing the pressure of the primary circuit was improved by making possible the emergency spray of the pressurizer by means of the pumps of the high-pressure safety injection system. The modification makes more effective the reducing of the primary circuit pressure to the level of the secondary circuit e.g. in connection with a leak from the primary to secondary circuit (PRISE). In this way the primary-secondary leak in a steam generator can be stopped.
- A new safety injection water tank was installed in order to cool the reactor and extend the time available to operators when coolant is lost from the primary circuit due to the primary-secondary leak through an open-stuck relief valve of the steam generator.
- Radiation monitoring equipment was installed in the secondary circuit for making a more effective detection of leaks from the primary circuit to the secondary circuit in a steam generator.
- A new protection signal was installed for isolating the feedwater line and the steam line and for stopping the reactor coolant pump in the case of a high water level in a steam generator.

- The reliability of the emergency core cooling was improved. The old minimum circulation lines leading to the emergency injection water tank have been replaced with the new minimum circulation lines which lead directly from the delivery side of the safety injection pumps to the suction side of the pumps. They have also been equipped with a separate cooling system. After the modification the possibility has been eliminated for the alternate turnover of the suction source of the pumps between the tank and the containment emergency sumps. In connection of a turnover a valve failure might occur resulting in loss of emergency cooling.

Level 1 PSA – Fires

Plant fire risks were evaluated in the analysis completed in 1992. The probability of reactor core damage caused by fires was estimated to be 1×10^{-3} a year. This figure was conservative, because simplified pessimistic assumptions had to be done in the modelling of fire progress and consequences due to a lack of well established methods. For reducing fire risks several modifications of the plant were made:

- installation of sprinkler system for the main transformer area
- removal of standby transformer from the main transformer area
- permanent closing of some fire doors
- additional emergency feedwater system to back up the auxiliary feedwater system in case of turbine hall fire
- additional fire pump station
- isolation/rerouting of the most critical cables
- additional sprinklers for protection of cables important to safety
- fire protection of control and power supply cables was improved
- fire protection of important pressurised air piping was improved
- structural protection of the hydraulic oil stations of the turbine bypass valves as well as sprinkler protection of the stations was improved for preventing high pressure oil sprays.
- fire alarm system renewed.

Level 1 PSA – Floods

The probability of reactor core damage caused by floods was estimated to be about 1×10^{-5} a year in the analysis completed in 1994. The analysis resulted in many modifications of the plant for reducing the risks related to internal floods:

- A wall against floods was constructed for preventing the spreading of a flood from the turbine hall to the lower rooms of the reactor building through cable spaces. In the lower rooms a flood could cause failures in the cooling system of the reactor coolant pumps and in the emergency core cooling system.
- Drainage of the cable spaces in the control room building was improved so that the flooding water accumulating on the floor would not cause the exceeding of the design load of the floor.
- For reducing the flood risks of the control room building the cooling water pipes related to the standard ventilation units were removed from the cable spaces below the control room to more secure routes.
- Drainage on the level of the feedwater tanks was improved so that the flooding water accumulating on the floor would not cause the exceeding of the design load of the floor.
- To protect the floor of the feedwater tanks against possible high pressure jet forces, jet shelters were installed on the welded joints of the feedwater piping to control the reaction forces in leak situations. Furthermore, the pipes crossing the feedwater tank level were replaced by pipes made out of better material.

Level 1 PSA – Weather

In the analysis concerning weather risks, completed in 1994, seawater phenomena, a bad snow storm and algae were evaluated as significant risks. The probability of reactor core damage was estimated to be about 5×10^{-4} a year. The following modifications of the plant were implemented to reduce the risks:

- To reduce the breaking risk of the travelling basket screen in the sea water intake channel, a system was installed which stops sea water pumps one by one based on the increase of the pressure difference in the screen. As a result of this change the access of the algae into the sea water cooling piping and heat exchangers is prevented.
- To protect the intake air channels of the diesel generators against clogging caused by a snow storm, the type of the intake air filters has been changed. In addition, the intake air of the diesel

generators can now be taken from the interiors through the automatically opening air inlet dampers, if the intake air channel clogged.
- To protect frazil ice of causing blockage of service water system a new procedure to utilize service water and condenser water in warming up water intake at low intake water temperatures.
- To protect sea vegetation and frazil ice causing blockage of service water system a new procedure was developed to utilize siphon through the main condensers after the circulating water pumps have stopped.

After the improvements of the plant, the biggest part of the weather risk is caused by algae (sea vegetation) and frazil ice. In this case the sea water intake channel may be clogged by ice crystallising out of subcooled water.

Level 1 PSA – Outages

The probability of reactor core damage caused by internal initiating events during refuelling outages was estimated to be about 2,8 × 10^{-5} a year in the analysis completed in 1997. Heavy hoisting in containment building was to be a very important risk factor. By means of the outage risk analysis Fortum has justified following improvements:
- Changes were made in the operating and testing instructions based on the observations done in PSA.
- To reduce the risk related to the hoisting of heavy loads procedures were changed.
- To ensure the cooling of the instrument spaces important to safety, a modification was made in the change-over automation of the ventilation units. This will ensure the proper functioning also in the case of a fuse failure.

All the improvements of the plant mentioned above have been taken into account in the updated risk analyses related to the internal floods, fires, severe weather conditions and internal initiating events (level 1). Fortum provided STUK with these analyses in 1994–2003.

At the end of 2003 the results of the risk analyses were the following:
- internal initiating events, 1.9 × 10^{-5} a year
- fires, 3.4 × 10^{-5} a year
- floods, 0.6 × 10^{-5} a year
- severe weather conditions, 0.5 × 10^{-5} a year
- earthquakes, 3.6 × 10^{-6} a year
- outages, 9.7 × 10^{-5} a year, internal initiating events, floods and severe weather conditions.

The calculated estimate for the total probability of reactor core damage is about 1.7 × 10^{-4} a year. This estimate takes into account all the factors presented above.

Fortum has also provided STUK with the level 2 PSA in which the integrity of the containment and the release of radioactive materials from the plant to the environment are evaluated. It was estimated that the probability of a large release to the environment is about 5 × 10^{-6} a year, caused by the internal initiating events at power. The biggest part of the calculated risk (about 70%) is caused by leaks between the primary and secondary circuit as well as by other bypasses of the containment. The rest of the risk is caused by high-energy phenomena resulting in the damage of the containment, such as a steam explosion in the reactor vessel, the discharge of the melted core out of the pressure vessel to the reactor cavity, or a hydrogen explosion in the containment.

The calculated risk estimate mentioned above took already into account the modifications of the Loviisa plant designed for severe accidents. These are: the external cooling of the reactor pressure vessel, the measures aimed for preventing such loading situations which break the reactor cavity, the improved control of hydrogen and the new procedures for severe accident management. These modifications have been implemented by 2003.

For evaluating the current situation STUK has made a rough risk assessment related to the Loviisa plant as it was at the end of 1997. This upper limit estimate for the probability of a large release was about 9 × 10^{-6} a year, caused by the internal initiating events. Until now, the risk estimate of the level 2 PSA does not include the risk caused by the external initiating events (fires, floods, severe weather conditions).

STUK has reviewed the analyses provided by Fortum. In the reviews a PSA computer program developed by STUK has been used. The results of the review show that Fortum has applied in its analyses commonly accepted methods in modelling transient and accident situations of the plant and in collecting and handling reliability data

2.10.3 Probabilistic safety analysis in the Olkiluoto NPP

By the means of probabilistic safety analyses (PSA) the effects of different initiating events – plant transients, fires, internal floods, natural external events including harsh weather conditions and earth-quakes – to the plant safety are assessed.

PSA describes the course of the accident from the initiating event to the reactor core damage and assesses the probability of failure to manage the transient caused by the initiating event and the initiating event itself. The objective is to model plant systems and their operation so accurately that the effect of accident and transient situations, equipment failures as well as operation and maintenance errors to the plant operation can be clarified.

A so-called accident sequence is determined by the accident's initiating event and failures in the safety systems as well as failures in operator actions. The frequencies of initiating events that initiate an accident are assessed on the basis of both plant-specific and world-wide operating experience. The functions of the safety systems and the actions of the plant personnel to prevent the damage of the reactor core are analysed by the means of e.g. thermo-hydraulic analyses, system analyses as well as operation and emergency procedures. The failure probability of these actions is assessed by the means of gathered operating experience. A special attention in the analyses is paid to the dependences, which can simultaneously cause the inoperability of several safety systems, and common cause failures of identical components. When the core damage frequencies of different accident sequences are connected, the result is the core damage frequency for the entire plant, which is one of the measures describing the plant's safety level.

In 1984 STUK required that TVO shall conduct a comprehensive probabilistic safety analysis (PSA) referring to Olkiluoto plant units 1 and 2, with the objective to clarify plant related "risk topographies" and to train the personnel to understand more profoundly the plant and its behaviour as a whole in different accident situations. In the first part of the PSA, TVO was to analyse the frequencies of accident sequences leading to a reactor core damage (level 1). In the second part of the PSA, TVO was to observe the damage mechanisms of the reactor core and the course of an accident as well as to group the accident sequences to release categories according to the amount of radioactive substances released to the environment, release mode and timing of release, and to assess the occurrence probabilities of these release categories (level 2).

At the beginning of 2004 the overall core damage frequency of Olkiluoto 1 and 2 is according to the living PSA approximately 1.7×10^{-5} per reactor year, when all analyses described below are taken into account. The core damage risk is distributed according to following frequencies:

- internal initiating events, power operation, 1×10^{-5} a year
- internal initiating events, refuelling outage, 4×10^{-7} a year
- internal hazards, fires, power operation, 5×10^{-7} a year
- internal hazards, fires, refuelling outage, 3×10^{-8} a year
- internal hazards, floods, power operation, 2×10^{-7} a year
- external hazards, natural, earthquakes, power operation 5×10^{-6} a year
- external hazards, natural, other, power operation, 9×10^{-7} a year.

Level 1 PSA – Internal initiating events

TVO delivered the level 1 PSA, for the part of analysis of internal initiating events, to STUK in the summer of 1989. The analysis contained an analysis of core damage risk caused by different plant transients, ruptures of cooling water piping and disturbances of external grid. After the analysis, improvements were made e.g. on emergency and operation procedures, which endeavour to ensure the supply of excess water to the tanks of the auxiliary feed water system and to the condenser, electrical supplies from the diesel generators of the neighbouring unit as well as the manual depressurisation of the reactor conducted from the relay room. Furthermore, modifications that affect the core damage frequency were conducted in connection with the modernisation, for example

- two valves that apply to both the steam and water blow-ups were added to the reactor over pressure protection system
- turbine control and protection system was modernised

- plant's grid connections were improved by installing on each unit a parallel start-up transformer supplied by an independent transmission line from the external grid.

TVO has continuously kept the PSA model up-to-date with regard to the plant modifications and operating experience. The core damage frequency due to internal initiating events was in 1989 4 × 10^{-5} per reactor year. During the recent years it has been around 1 × 10^{-5} per reactor year.

Outage risks were assessed in an analysis completed in 1992. The core damage frequency during an outage was assessed to be approximately 3.6 × 10^{-6} per refuelling outage. The most significant outage risk proved clearly to be the bottom leakage of the reactor vessel caused by a maintenance error of main circulation pumps. To reduce the risk the instructions of maintenance work were improved and the Technical Specifications were modified in such a way that the lower personnel hatch is kept closed during the maintenance of main circulation pumps.

The modifications of procedures have reduced the core damage frequency during an outage significantly, an it has been from the year 1997 to 2004 around 4 × 10^{-7} per refuelling outage.

Level 1 PSA – Internal hazards

Fire risks at the plant were assessed in an analysis completed in 1991. According to the analysis the core damage frequency due to fires was approximately 1 × 10^{-5} p.a. To reduce the fire risks improvements were made e.g. in fire extinguishing systems and in the separation of cables important to safety. TVO has updated the fire risk analysis for power operation in 1994 and 1997. In the year 1998 the fire risk analysis was extended to the refuelling outage.

According to the living PSA results in the year 2004 the core damage frequency due to fires – including power operation and outage – at the Olkiluoto plant units 1 and 2 is 5 × 10^{-7} per reactor year. The contribution of the fires during the refuelling outage is small, 3 × 10^{-8} per reactor year.

As a part of the PSA, TVO analysed also the risks caused by internal floods. According to a study conducted in 1994 the core damage frequency caused by floods is approximately 1.4 × 10^{-6} p.a. TVO has updated the analysis of internal flood in 1997.

Recently conducted plant modifications haven't significantly affected this value. However, reduction of conservatism in the assumptions has in the year 2003 decreased the core damage frequency due to floods one order of magnitude to 2 × 10^{-7} per reactor year.

Level 1 PSA – External hazards

A limited external hazards was conducted to assess the risks caused by the most important harsh weather conditions, the severe blizzard and the frazil ice experienced in the beginning of 1995. Severe blizzard and frazil ice were found to be very significant risks. The probability of reactor core damage caused by them was at that time assessed at approximately 2 × 10^{-5} p.a. Following plant modifications were made to reduce the risks:

- To improve the reliability of emergency electrical supply, automatically opening dampers based on the pressure difference operation, were installed in the diesel generator system during the 1996 annual maintenance outage, so that the combustion air can be taken directly from the rooms.
- A system that supplies warm water, when necessary, to plant units' sea water inlet was built for the plant to reduce the risk caused by frazil ice. The system secures the supply of condenser water to the plant by preventing the blockage of the sea water canal caused by icing.

A comprehensive screening analysis of external hazards was conducted to assess the risks caused by the natural phenomena (threats from the sea, earth and air) in 1997. Detailed analyses were done for the single phenomena and combinations of phenomena that exceeded the screening limit of the core damage frequency: White frost; Frazil Ice; Storm – Blizzard; Lightning; Algae and mussels in the seawater tunnels. The analysis was extended at the end of 1998 with the detailed analyses of the high and low seawater level and the high temperature of the seawater and the air. A new extension of the analysis is going on during 2004.

By the means of modifications the core damage frequency due to external hazards has been reduced, and it is in 2004 9 × 10^{-7} per reactor year.

The risk analysis of earthquakes, was completed in 1996. Especially direct-current systems and accumulators were found to be sensitive to minor earthquakes. To reduce the risks, modifications have been made to support the accumulators in the direct-current systems that are important to safety and to anchor rectifier/inverter cabinets to the load bearing structures. After the modifications the core damage frequency due to earthquake is approximately 5 × 10^{-6} p.a.

Level 2 PSA

In the year 1996 TVO also delivered to STUK the level 2 PSA, in which the durability of the containment and the releases of radioactive materials to the plant vicinity are assessed. The analysis has been updated during 1997 and 2003. The level 2 PSA has caused or contributed following modifications:

- The isolation valves of the filtered venting line are left open after a LOCA in order to provide filtered overpressure protection of the containment.
- The primary route for containment venting is from the upper drywell through the automatic rupture disk line, because the venting from wetwell does not significantly decrease the release of radio nuclides.
- The lower drywell access locks of Olkiluoto 1 and 2 were modified in 2001 and in 2002, respectively, so that they will sustain a steam explosion.
- The basket bolts of the four containment spray system pipes penetrating the pedestal wall were changed in the 2001 refuelling outages to weaker ones to prevent the deformation of the pipes in case of ex-vessel steam explosion.
- The operator training was extended in the initiation of the lower drywell flooding, because the time available is rather short.

According to the living PSA model in 2004 the frequency of the large early release to the environment (>100 TBq Cs or undelayed release of noble gas) is 6 × 10^{-6} per reactor year, which is approximately one third of the core damage frequency. Several modifications in the plant systems and in the procedures as well as training of the control room staff have significantly decreased the size of the release, but the frequency of the release exceeding the limit has decreased only slightly. The frequency of the unfiltered release has been reduced from 8 × 10^{-6} to 3 × 10^{-6} per reactor year, while the total large early release frequency has been decreased from 8 × 10^{-6} to 6 × 10^{-6} per reactor year. The risk of release is greatest during the operation at power. The biggest threats to the integrity of the containment are caused by the

- inadvertent opening of the filtered venting line of the containment leading to undelayed release of noble gas
- early containment failure due to hydrogen detonation in shutting down the reactor for refuelling, or start up of the reactor after refuelling, when the containment is not inert.

STUK has inspected the analyses that TVO supplied by the means of a PSA-program it has developed. The inspection showed that, in its analyses, TVO applied generally approved methods in modelling the transient and accident situations of the plant as well as in obtaining and handling of the reliability data. In the level 2 PSA, the specification of results requires further development of the models describing the course of an accident.

Probabilistic safety analyses of Olkiluoto 3

The supplier of the nuclear island of Olkiluoto 3 has conducted a design phase PSA. The design phase PSA has been delivered to STUK as required by Nuclear Energy Decree 35 §. The design phase PSA includes analysis of internal initiating events, internal hazard and external hazards for power operation and refuelling outage. The document is under review of STUK in 2004.

2.10.5 Verification

Decision 395/1991 includes several requirements which concern the verification of the physical state of a nuclear power plant. For instance, In all activities affecting the operation of a nuclear power plant and the availability of components, a systematic approach shall be applied for ensuring plant operators' continuous awareness of the state of the plant and its components. The reliable operation of systems and components shall be ensured by adequate maintenance as well as by regular in-service inspections and periodic tests. General requirements on verification programmes and procedures are provided in YVL Guides (e.g. Guide YVL 1.8, YVL 1.9, YVL 3.0, YVL 3.8).

Main programmes used for verification of the state of a nuclear power plant are

- periodical testing according to the Technical Specifications

- preventive and predictive maintenance programme
- in-service inspection programme
- periodical inspections of pressure equipment and piping
- surveillance programme of reactor pressure vessel material
- programmes for evaluating the ageing of components and materials.

Activities for verifying the physical state of a power plant are carried out in connection with normal daily routines and with scheduled inspections, testing, preventive maintenance etc. Activities are performed by the licensee personnel, and in the case of certain inspections by contractors approved separately. Detailed programmes and procedures are established and approved by the licensee, and reviewed and, to some extent, approved by STUK. The results of tests and inspections are documented in a systematic way and used through a feedback process to further develop the programmes. The Operational Limits and Conditions are approved by STUK. In general, the role of STUK is to verify that the licensees follow the obligations imposed on them and carry out all activities scheduled in verification programmes.

Comprehensive evaluations related to the state and operation of the Loviisa and Olkiluoto plants were carried out by Fortum and Teollisuuden Voima Oy in 1996–1998. These evaluations also covered the trial tests of the plants at the increased power levels. These activities were controlled by STUK.

According to international experience and Guide YVL 3.8 STUK has recognised the qualification of non-destructive testing systems and procedures as an issue of high importance. This issue requires high priority at both nuclear power plants. The implementation of qualified NDT systems has been started in 1990's in Finland. STUK has decided in those days that the consensus document “Common position of European Regulators on qualification of NDT-systems for pre- and in-service inspection of light water reactor components, EUR 16802 EN” is to be followed in Finland. ENIQ documents (European Network for Inspection Qualification) can also be followed. The application of the documents has been described now by Guide YVL 3.8. A draft national strategy document for NDT qualification has been written. The most important issue is that the qualification body shall be competent and independent. Ad hoc type qualification bodies have been established by the Steering Committee of NDT Qualifications. However, this has not been an easy task due to the shortage of independent and competent personnel in Finland. A draft national strategy document for NDT qualification has been written by the Finnish utilities.

General requirements on inspection qualification are provided in Guide YVL 3.8. The document European methodology for qualification drawn up by the European Network for Inspection Qualification, shall be used as the minimum requirement level for qualification of inspection systems to be used in-service inspection, and it shall be complemented by recommended practices. The report stating the common position of European regulators on the qualification of NDT systems relates the qualification of inspection methods applied in the in-service inspection of nuclear power plant pressure equipment to nuclear safety.

Inspection qualification means the systematic assessment, by all those methods that are needed to provide reliable confirmation, of an inspection system to ensure it is capable of achieving the required performance under real inspection conditions. Each inspection system shall be qualified for in-service inspections such that it reliably detects, characterises and/or sizes defects endangering structural integrity and nuclear safety.

The licensee is responsible for organising qualification and using in its implementation the services of a testing body and a qualification body. On the basis of sections 19 and 20 of the Nuclear Energy Act (990/1987), the licensee shall have available the necessary expertise and economic resources.

The licensee shall have a qualification body for qualification management, implementation, control and assessment as well as the issuing of qualification certificates. The qualification body shall be competent and independent of the construction and operation of nuclear power plants as well as financial factors that could affect its work and decisions.

The personnel of the qualification body shall have diverse expertise and experience in the technical fields required to assess the capability of inspection systems to reliably detect, characterise and size flaws. At least one member of the personnel monitoring and assessing qualifications from the inspection technical point of view shall have Level 3 basic qualification for the inspection method in question according to a qualification system that complies with Standard SFS-EN 473 or a corresponding system; in addition, extensive practical experience is required on factors that could affect inspection reliability in the in-service inspection of nuclear power plant components and structures.

A qualification body may also be qualification-specific. The licensee is responsible for assuring the continuity of qualification by setting up a qualification steering committee and assigning to it members who have sufficient expertise in the field. Ad hoc type qualification bodies have been established by the Steering Committee of NDT Qualifications. However, this has not been an easy task due to the shortage of independent and competent personnel in Finland. Lack of plans and administration of qualification process, insufficient written plans, procedures and other qualification documents have made inspection qualification difficult. No totally qualified inspection systems have been approved by STUK until now.

In-service inspections in the Loviisa NPP

The condition of the pressure-retaining components of Loviisa 1 and 2 is ensured with regular in-service inspections. The components of the primary circuit are inspected by means of non-destructive examination methods. These regularly repeated examinations are carried out during outages according to Guide YVL 3.8. The results of the in-service inspections are compared with the results of the previous inspections and of the preservice inspections which have been carried out before the commissioning.

The in-service inspection programmes are submitted to STUK for approval before each inspection series. Programmes and related inspection procedures are changed when necessary, taking into account the development of requirements and standards in the field, the advancement of examination techniques and inspection experiences as well as operating experiences in Finland and abroad.

Those areas have been tried to select as inspection objects where defects arise most probably. These kind of areas are e.g. objects susceptible to fatigue due to temperature variations. The selection of inspection objects is subject to a continuous development.

The length of the inspection period of the regular inspections (e.g. ASME Code, Section XI) is normally ten years. Inspection programmes have been complemented with additional inspections as regards the reactor pressure vessel and the primary circuit piping, and the length of the inspection period of the reactor pressure vessel has been reduced to eight years. The length of the inspection period of the objects susceptible to thermal fatigue is often 3 years.

Guide YVL 3.8 and the latest revisions of the regulations ASME Code, Section XI are applied as approval bases for the in-service inspection programmes and procedures.

The reliability of the non-destructive examination methods for the primary circuit piping and components has been essentially improved after the commissioning of the plant. Guide YVL 3.8 calls for the qualification of the entire NDT-system; equipment, software, procedures and personnel. Improvements of the qualification are at an early stage and the plans concerning it are general in nature. STUK follows the development and implementation of the plans closely. The implementation of the qualification system will be a significant improvement issue in the future.

In addition to the inspections mentioned above, physical inspections concerning the condition and reliability of pressure equipment are carried out as regular pressure equipment inspections according to the Finnish pressure equipment legislation. Such inspections are a full inspection, an internal inspection and an operational inspection. These inspections include non-destructive examinations as well as pressure and tightness tests. The inspections of piping have been defined in the system-specific monitoring programmes. These periodic inspections are dealt with in Guides YVL 3.0, YVL 3.3, YVL 5.3, YVL 5.4, YVL 5.7. The periodic inspection programmes fulfil the requirements of YVL Guides, as regards the number and techniques of inspections.

The reliability of the non-destructive examination methods for the primary circuit piping and components has been essentially improved after the commissioning of the plant. The implementation of the qualification system of in-service inspections is an essential subject for development of activities.

Plant life management

Ageing of the systems, components and structures at Loviisa 1 and 2 is followed based on operation and maintenance experiences. A systematic plant life management, utilising reports and data systems related to inspection, testing, maintenance and repair activities, was established in 1995. Tasks were reorganized from the beginning of 2002 when plant life management was interpreted as one the key processes of the new Technology unit.

The present life time management process is based on full time system engineers with expert engineering support and system classification according to life management needs. The process includes continuous maintaining the database and updating the long term investment plan as well as semi-annual expert meetings and an annual review.

Ageing of the Loviisa 1 and 2 electric and automation equipment and systems as well as cables is systematically followed. The ageing of the plant protection automation was evaluated in a study carried out by the Technical Research Centre of Finland (VTT). According to the study there is no immediate technical need to replace the system. Ageing components have been systematically replaced at the both units with new devices and components fulfilling the current requirements. Cables have also been extensively replaced.

The renewal of plant automation is in preparatory stage and will be discussed under Article 18.

In-service inspections in the Olkiluoto NPP

The condition of pressure retaining components of Olkiluoto 1 and 2 is assured through regular in-service inspections. Periodically repeated inspections are performed during the outages to the safety-significant components by non-destructive testing methods according to the Guide YVL 3.8. Results of in-service inspections are compared with the results of earlier inspections and with the results of pre-service inspections conducted before the commissioning.

In-service inspection programs are supplied to STUK for approval before each inspection. The programs and related inspection procedures are changed when necessary, taking into account the development of requirements and standards in the area, the development of inspection techniques as well as inspection experience and operational experience from nuclear power plants in Finland and elsewhere.

The objective has been to choose areas where initiation of defects is most likely as inspection items. Such ones are the items that are susceptible to thermal fatigue and stress corrosion.

The length of an inspection period is usually ten years. The inspection periods for items susceptible to stress corrosion are five or three years and for items susceptible to thermal fatigue, respectively, three years.

Guide YVL 3.8 and the latest editions of the standard ASME Code, Section XI are used as the acceptance criteria of in-service inspection programs, procedures and results.

Guide YVL 3.8 calls for the qualification of the entire NDT-system; equipment, software, procedures and personnel. Improvements of the qualification are at an early stage and the plans concerning it are general in nature. STUK follows the development and implementation of the plans closely. The implementation of the qualification system will be a significant improvement issue in the future.

In addition to the aforementioned inspections, physical inspections that concern the condition and reliability of pressure vessels are performed at regular intervals according to the Finnish Pressure Vessel Legislation. These inspections are the full inspection, internal inspection and operational inspection and they include non-destructive testing as well as pressure and tightness tests. Inspections concerning pipelines have been defined in the system related condition monitoring programmes. These in-service inspections are handled in the Guides YVL 3.0, YVL 3.3, YVL 5.3, YVL 5.4 and YVL 5.7.

Life-time management of the plant units

The management of ageing at the Olkiluoto plant is based on predictions made by an expert group composed of experts from the areas of mechanical, electrical, instrumentation, civil, maintenance and safety engineering. By utilising the operational and maintenance experience and research results related to the ageing phenomena, the objective is to identify in an early stage those areas of the plant, that limit the operating life and require significant modification, repair and inspection work or special condition monitoring.

The predictions for necessary measures are drawn up from the estimates supplied by the experts responsible for systems, techniques and components as well as by other expert groups, and these predictions are updated annually. The unit responsible for operation takes the predictions into account when it designs the annual maintenance and assesses the comprehensiveness of preventive maintenance programs.

The updating of predictions, conducted in connection with the power uprating, was directed to e.g. components of the reactor pressure vessel and its internals susceptible to stress corrosion, valves and pipelines of the reactor plant, sea water canals as well as the containment and its cables.

In conclusion, Finnish regulations and practices are in compliance with Article 14.

2.11 Article 15. Radiation protection

Each contracting Party shall take the appropriate steps to ensure that in all operational states the radiation exposure to the workers and the public caused by a nuclear installation shall be kept as low as reasonably achievable and that no individual shall be exposed to radiation doses which exceed prescribed national dose limits.

Radiation Act includes the ALARA requirement for radiation protection. Occupational dose limits and dose limits for the general public are set forth in the Radiation Decree. These limits are in conformity with the ICRP 60 Recommendation (1990). Council of State decision 395/1991 includes regulations for limiting the radiation exposure of the general public and the releases of radioactive materials into the environment, arising from the operation of a nuclear power plant. These sections also cover design limits for releases in anticipated operational occurrences and accidents. There are several YVL Guides which deal with radiation protection as regards the design and operation of nuclear power plants, e.g. YVL 1.0, YVL 7.1, YVL 7.9 (revised in 2002), YVL 7.10 (revised in 2002) and YVL 7.18 (revised in 2004). The changes in the revised Guides YVL 7.9 and 7.10 concerned the requirements for ALARA programmes, the categorisation of radiation workers, change of work specific criteria for a detailed radiation protection plan and registration thresholds of radiation doses. Also the international development in the dosimetry QA was included. The major changes of the Guide YVL 7.18 imply more in depth requirements e.g. for radiation safety conditions within the plant during severe accident scenarios.

STUK carries out regulatory control for ensuring that the radiation protection requirements are complied with during the operation of nuclear facilities. Experience gained from operation of Finnish nuclear facilities shows that the ALARA principle has been followed and that the dose limits have not been exceeded. The results of environmental surveillance programmes show that the amount of radioactive materials originating from Finnish nuclear facilities has been very low in their environment. Radiation safety is discussed in more detail below.

2.11.1 Topical issues on the radiation safety of workers

The radiation safety of workers depends on the structure and maintenance of a plant as well as on radiation protection measures in connection with works. The factors affecting safety at the plant are partly same as for the safety of the surroundings population (integrity of nuclear fuel, materials/water chemistry, functioning of purification systems). In addition, e.g. the realisation of the work planning and permits of radiation protection as well as radiation measurements contribute to radiation safety.

Olkiluoto and Loviisa nuclear power plants have implemented plant-specific ALARA programmes. Key issues in this ALARA implementation are e.g. proper maintenance work and outage planning, real-time dosimetry, training and contamination control. The plant operators have also paid special attention to water chemistry conditions and the proper selection of materials, when changing primary circuit equipment and components. The activity levels in the primary circuit water have been reasonably low. STUK has followed the work and made also its own judgement on the results.

Loviisa nuclear power plant has carried out a project for the renewal of the installed radiation monitoring systems (area monitors, air monitors, process monitors and effluent monitors) at the plant during 2001-2003.

Olkiluoto nuclear power plant has contracted an outside company to operate the TL dosimetry service as a whole. This change in the procedures was approved by STUK in 2002. Practical transition into the contracted (outsourced) service was successful.

The Finnish nuclear plants and utilities run a joint annual training of contractor’s key radiation protection experts as well as basic radiation protec-

Table I. Radiation doses at Loviisa NPP in 2001–2003.

Year	Collective dose [manSv]	Maximum personal dose [mSv]	Average dose*) [mSv]
2001	1.13	12.4	1.8
2002	2.61	19.5	3.1
2003	0.94	11.6	1.6

*) calculated by using the registered radiation doses, which are >= 0.1 mSv/month

tion training for all workers accessing the nuclear power plant.

Monitoring of occupational radiation doses and the reporting of measurement data in the central dose register of STUK are based to YVL Guide 7.10. The Finnish and Swedish competent authorities for radiation safety agreed already in 1983 on the practice that the radiation doses of the nuclear power plant workers received in other country are reported in the central register of the home country of the workers. The radiation doses received in other countries than Finland and Sweden are reported to STUK with a specific dose record, the use of which is also imposed by the regulations of European Union.

2.11.2Radiation exposure of workers at the Loviisa NPP

According to Guide YVL 7.9 the objective for the limitation of the collective radiation exposure of nuclear power plant workers is 2.5 manSv per 1 GW of net electric power, calculated for one reactor unit and averaged over two successive years. At the preset power level of the Loviisa plant, this corresponded with the average of 1,22 manSv a year for one reactor unit. If this value is exceeded as a result of the operation for two successive years, radiation protection shall be improved at the unit in question. Exceeding of the set goal occurred at Loviisa 1 in 2001, this was because of the influence of the previous year, when collective dose was 1,7 manSv. The utility has clarified the situation and no further actions are needed. The collective dose depends on the extent and nature of works in annual outages. The radiation exposure of the workers has not essentially increased during the operation at the Loviisa NPP.

The dose limit for the exposure of a worker is 50 mSv a year. In addition it is provided, that the radiation exposure of a person engaged in radiation work is limited so that the added dose does not exceed 100 mSv for the period of 5 years. The personal radiation doses at the Loviisa NPP have remained under the set dose limits. The largest dose of a Finnish worker during a 5 years period 1999–2003 was received during working at Loviisa nuclear power plant, and it was 71,6 mSv.

The radiation dose statistics are presented in Table I and Figure 9.

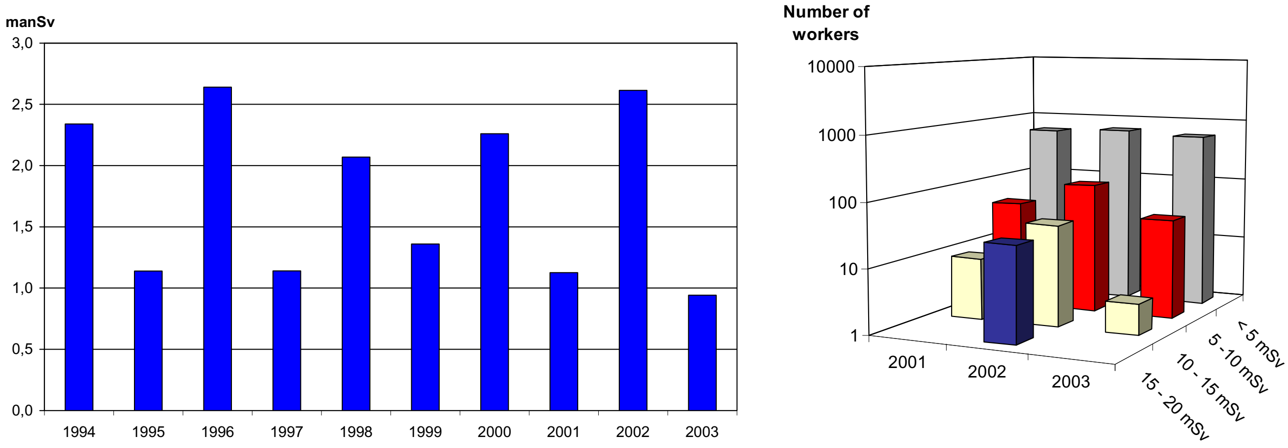


Figure 9. Collective occupational doses and distribution of individual annual worker doses at the Loviisa nuclear power plant.

Table II. Radiation doses at Olkiluoto NPP in 2001–2003.

Year	Collective dose [manSv]	Maximum personal dose [mSv]	Average dose*) [mSv]
2001	1.18	12.7	1.2
2002	1.12	10.4	1.1
2003	1.03	7.9	1.0

*) calculated by using the registered radiation doses, which are >= 0.1 mSv/month

STUK's review finding is that the limitation of personnel's radiation exposure has been arranged appropriately at the Loviisa plant. Measures for limiting radiation exposure shall be continued according to the ALARA principle.

2.11.3 Radiation exposure of workers at the Olkiluoto NPP

The occupational collective and personal radiation doses at the Olkiluoto NPP have clearly remained under the set dose limits. The radiation dose statistics are presented in Table II and Figure 10.

At the present power level of the Olkiluoto plant, the YVL 7.9 limit 2.5 manSv per 1 GW of net electric power correspond to 2,10 manSv a year for one reactor unit. The collective dose of the Olkiluoto plant is also clearly smaller compared to the average values gained from the boiling water reactor plants of the same vintage.

STUK's review finding is that the limitation of personnel's radiation exposure has been arranged appropriately at the Olkiluoto plant. Measures for limiting radiation exposure shall be continued according to the ALARA principle.

2.11.4 Radioactive effluents

In the operation of a nuclear power plant radioactive materials are produced and mainly remain within the nuclear fuel. Radioactive materials are produced also in the reactor coolant circuit, and are further transferred in water, gas and waste treatment systems. A very small part of radioactive materials is released in the air and water of the surroundings.

Fuel rods at the Olkiluoto and Loviisa nuclear power plants have had low failure rates. There has been 0–1 observed leakages during one annual operational period of the Olkiluoto reactors during the period 2001–2003. There were no observed leakages at Loviisa NPP during 2001–2003. Purification and waste systems of the both plants have been operating properly.

Both nuclear power plants have efficiently implemented measures to reduce the releases of radioactive substances into the environment. Radioactive releases into the environment from the Finnish nuclear power plants have been well below authorised limits (for important nuclides and pathways, of the order of 0.01% to 0.1% of set values based

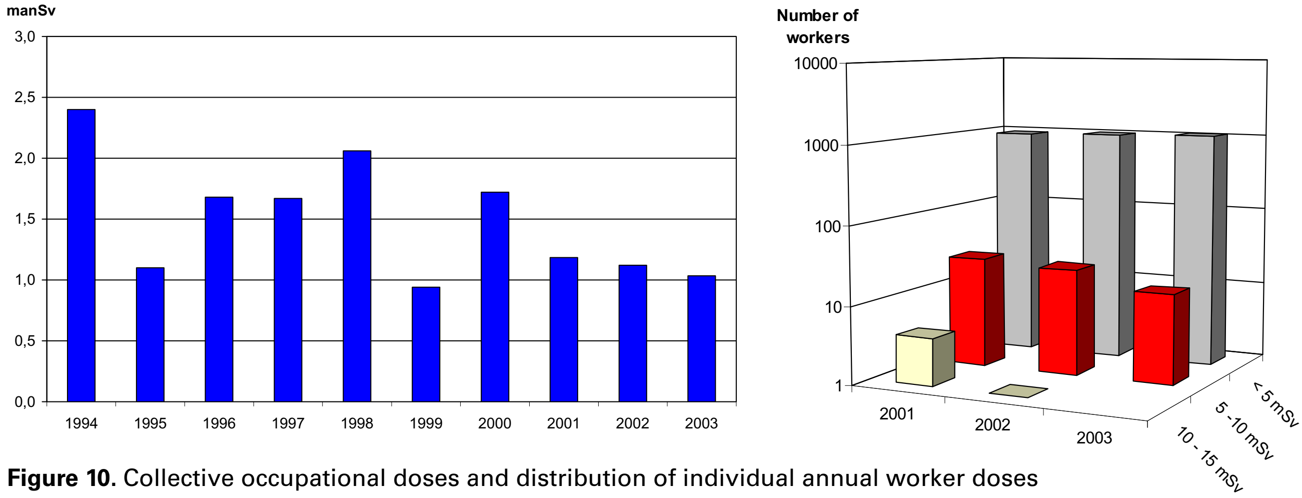


Figure 10. Collective occupational doses and distribution of individual annual worker doses at the Olkiluoto nuclear power plant.

Table III. Radioactive effluents from the Loviisa NPP. Between brackets is presented the %-proportion of the release limit.

Year	Airborne effluents					Liquid effluents excluding tritium [Bq]	
	Noble gases Kr-87 ekv. [Bq]		Iodine I-131 ekv. [Bq]		Aerosols [Bq]		
2001	4.93E+12	(0.02 %)	under MDA		4.10E+07	1.28E+09	(0.1%)
2002	4.98E+12	(0.02 %)	9.85E+05	(0.0004%)	6.69E+07	8.46E+07	(0.01%)
2003	6.49E+12	(0.03 %)	3.53E+06	(0.002 %)	7.95E+07	3.08E+08	(0.03%)

Table IV. Radioactive effluents from Olkiluoto NPP. Between brackets is presented the %-proportion of the release limit.

Year	Airborne effluents					Liquid effluents excluding tritium [Bq]	
	Noble gases Kr-87 ekv. [Bq]		Iodine I-131 ekv. [Bq]		Aerosols [Bq]		
2001	5.67E+10	(0.0003%)	under MDA		3.26E+07	8.64E+08	(0.3%)
2002	2.80E+10	(0.0002%)	9.81E+06	(0.009%)	3.03E+07	7.50E+08	(0.3%)
2003	1.35E+11	(0.0008%)	1.74E+07	(0.02%)	3.25E+07	5.88E+08	(0.2%)

on the requirements of Guides YVL 7.1, YVL 7.2, YVL 7.3 and YVL 7.6). The radioactive effluents in 2001–2003 are shown in Tables III and IV.

The limit for the dose commitment of an individual of the population, arising from the normal operation of a nuclear power plant in any period of one year, is 0.1 mSv (395/1991). Calculated radiation exposures to the person of the critical group living in the environment of the nuclear power plants are shown in Figure 11. Doses have been clearly under the limit. A new set of calculation codes of the Loviisa NPP TUULETV2004 and MERI2003 have been approved by STUK in 2004.

2.11.5 Environmental radiation monitoring

Environmental radiation monitoring in the vicinity of nuclear power plants has been comprehensive and implemented according to the requirements of Guide YVL 7.7. The experience from the surveillance was taken into account when the nuclear power utilities proposed a new monitoring programme for approval to be implemented 2004-2008. These programs were approved by STUK. Changes were minor; a trial of carbon-14 measurements from indicator samples in the vicinity of the sites will be done during this 5-years period.

An outside contracted laboratory collects and analyzes about 400 samples (air, fallout, sediment, indicator organisms, milk etc) per year from the environment of each NPP. Very small quantities of radioactive substances of local origin were detected in 2001–2003 on some samples (20–40 per year) collected from the environment of each nuclear power plant. Cobalt-60 is the most common NPP-origin nuclide detected. Also, silver-110m and manganese-54 were detected. Concentrations of the radioactive substances were very low, and health effects for the public are insignificant.

In conclusion, Finnish regulations and practices are in compliance with Article 15.

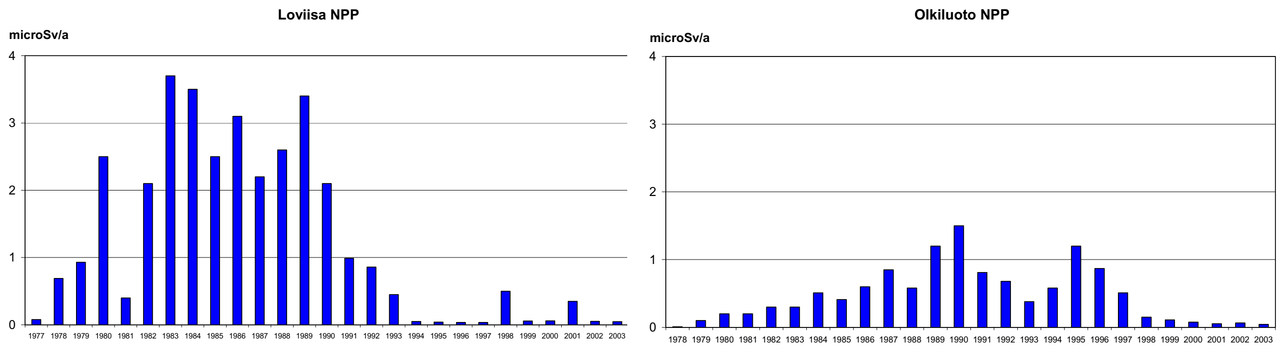


Figure 11. Calculated annual radiation exposures to the members of critical groups in the environment of the Finnish nuclear power plants. Doses have been clearly under the limit 100 microSv.

2.12 Article 16. Emergency preparedness

1. ***Each Contracting Party shall take the appropriate steps to ensure that there are on-site and off-site emergency plans that are routinely tested for nuclear installations and cover the activities to be carried out in the event of an emergency. For any new nuclear installation, such plans shall be prepared and tested before it commences operation above a low power level agreed by the regulatory body.***
2. ***Each Contracting Party shall take the appropriate steps to ensure that, insofar as they are likely to be affected by a radiological emergency, its own population and the competent authorities of the States in the vicinity of the nuclear installation are provided with appropriate information for emergency planning and response.***
3. ***Contracting Parties which do not have a nuclear installation on their territory, insofar as they are likely to be affected in the event of a radiological emergency at a nuclear installation in the vicinity, shall take the appropriate steps for the preparation and testing of emergency plans for their territory that cover the activities to be carried out in the event of such an emergency.***

The basic regulations for on-site emergency planning are given in the Nuclear Energy Act and in Decision of the Council of State (397/1991). STUK YVL Guide 7.4 has been revised in 2002 mainly because of the changes in national rescue legislation.

The licensee is responsible for the on-site emergency response arrangements. Emergency response arrangements shall also be consistent with the rescue service and emergency plans made by the authorities in provision against nuclear power plant accidents. Appropriate training and exercises shall be arranged to maintain operational preparedness.

Since the Second Review Meeting emergency response procedures at Olkiluoto and Loviisa nuclear power plants have been further developed based on the requirements of Guide YVL 7.4 and the experiences in training and exercises. These procedures have been regularly tested in annual exercises that are part of the plants' emergency preparedness training. STUK has approved major changes to the emergency plans of nuclear power plants, and carries out annual inspections to assess the emergency preparedness regime, including emergency training and exercises. Among other things, the maintenance and adequacy of emergency rooms and equipment, communication and alarm systems, computerised support systems as well as personnel training and qualifications are inspected. Main observations in the inspections concerned new equipment and computer programmes and their testing, instructions for emergency situation, annual training and exercises. In 2003 STUK organised a joint seminar about on-site emergency preparedness at Finnish nuclear power plants to share experiences and to develop further e.g. training, exercises and co-operation between the nuclear power plants and the authorities.

Annual on-site emergency exercises are conducted so that at least the licensee personnel, local off-site emergency management group and STUK participate in them. There are observers from STUK and several other organisations assessing the performance of exercising teams. In the 2002 exercise of Loviisa the exact exercise time was not announced in advance for STUK participants. In 2003 the Olkiluoto exercise was a table-top exercise focusing on the regional changes in rescue legislation and arrangements in Finland.

In addition to the on-site emergency plans established by the licensees, off-site emergency plans required by the Rescue legislation (468/2003) are prepared by local authorities. At the moment, the requirements for off-site plans and activities in a radiation emergency are provided in the Decree of the Ministry of Interior (774/2001) and the guide VAL 1.1 (2001) 'Protective Actions in Nuclear or Radiological Emergency'. In the case of an accident the local authorities are alerted by the operating organisation of the plant. The regulations and guides are tested in off-site emergency exercises conducted every third year. Full scale off-site emergency and rescue exercise was carried out in Finland in 2002 based on the Olkiluoto nuclear power plant accident scenario. In 2003 the national exercise concerned the Loviisa nuclear power plant.

The on-site and off-site plans include provisions to inform the population in the case of an accident. In addition, written instructions on radiation emergencies, emergency planning and response arrangements have been provided to the population living within the 20 km Emergency Planning Zone. Basic information on radiological emergencies and response is given in the telephone directories of Finland. The published regional directories (about the EPZ area) contain similar but more detailed instructions.

STUK has an Emergency Preparedness Manual for its own activities in the case of a nuclear accident or radiological emergency. STUK has an expert on duty for 24 hours a day, in order to be able to immediately give advice to local and governmental authorities on needed emergency response actions. These actions can include, i.e., warning the population with a message which can be heard through all radio channels. The message on an exceptional event (alarm) can be received from the operating organisations of the facilities, or automatically from the radiation monitoring network that is dense in the whole country (300 measuring stations), or from foreign authorities (Figure 12).

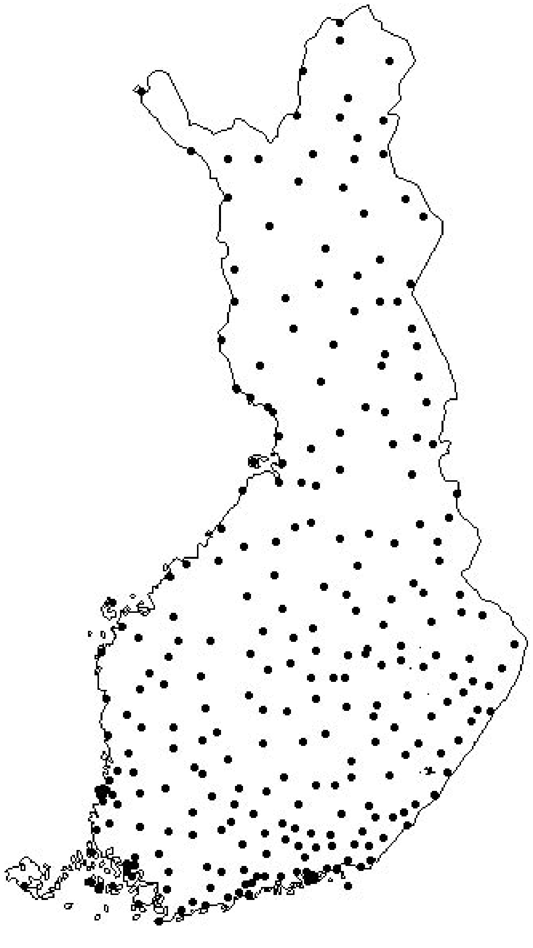


Figure 12. The automatic radiation monitoring stations of Finland.

Finland is a party to the Convention on Early Notification of a Nuclear Accident and the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency, done in Vienna in 1986. Being a member of the European Union the Council Decision (87/600/EURATOM) on Community arrangements for the early exchange of information in the event of a radiological emergency applies in Finland, too. In addition, Finland has respective bilateral agreements with Denmark, Germany, Norway, Russia, Sweden and Ukraine. Accordingly, arrangements have been agreed to directly inform the competent authorities of these countries in the case of an accident.

A new development at STUK is www-FINRI, a protected web emergency information site for Finnish and foreign counterparts. The Nordic radiation and nuclear safety authorities' expert on duty services have already earlier developed and use routinely a dedicated urgent mail - message system when exchanging information during nuclear or radiological emergencies.

In addition to the domestic nuclear emergency exercises held annually on each nuclear power plant site, STUK has taken part in international emergency exercises. STUK has also participated as a co-player in emergency exercises arranged by the Swedish nuclear power plants and authorities. Neighbouring countries have been actively invited to take part in the Finnish exercises. In 2003, all Nordic countries participated in the Loviisa exercise. A lot of efforts have been put to organise exercises focusing recovery phase of an emergency. Such exercises have been carried out e.g. with governmental organisations and with three provinces.

For the new NPP unit at Olkiluoto site the utility has already provided STUK e.g. with a preliminary emergency plan. This contains the description of the basic emergency arrangements including the principles for the site emergency rooms and data transfer from the main control room to the emergency centres of the nuclear power plant and STUK. In 2004 STUK also verifies in the inspection the emergency arrangement for the whole site, training for construction workers and co-operation arrangements with local rescue authorities.

In conclusion, Finnish regulations and practices are in compliance with Article 16.

2.13 Article 17. Siting

Each Contracting Party shall take the appropriate steps to ensure that appropriate procedures are established and implemented:

i. for evaluating all relevant site-related factors likely to affect the safety of a nuclear installation for its projected lifetime;

ii. for evaluating the likely safety impact of a proposed nuclear installation on individuals, society and the environment;

iii. for re-evaluating as necessary all relevant factors referred to in sub-paragraphs (i) and (ii) so as to ensure the continued safety acceptability of the nuclear installation; for consulting Contracting Parties in the vicinity of a proposed nuclear installation, insofar as they are likely to be affected by that installation and, upon request providing the necessary information to such Contracting Parties, in order to enable them to evaluate and make their own assessment of the likely safety impact on their own territory of the nuclear installation.

2.13.1 Regulatory approach to siting

Requirements for the siting of a nuclear power plant and for an environmental impact assessment are provided in the Nuclear Energy Act. According to the Nuclear Energy Decree, the application for a Decision-in-principle has to include e.g.:

- an outline of the ownership and occupation of the site,
- a description of settlement and other activities and town planning arrangements at the site and its vicinity,
- an evaluation of the suitability of the site and the restrictions caused by the nuclear facility on the use of surrounding areas,
- an assessment report in accordance with the Act on the Environmental Impact Assessment Procedure (468/1994) as well as a description on the design criteria the applicant will observe in order to avoid environmental damage and to restrict the burden to the environment.

More detailed requirements on the Environmental Impact Assessment are provided in the Decree (792/1994). The procedures have been applied in practice e.g. when modernising and increasing the power levels of Finnish nuclear power plants. The site selection has to be confirmed in the application for a Construction Licence. This application includes also up-to-date descriptions similar to the above.

In the design of a nuclear plant, site-related external events have to be taken into account. Regulation 395/1991 provides as follows: The most important nuclear power plant safety functions shall remain operable in spite of any natural phenomena estimated possible on site or other events external to the plant. In addition, the combined effects of accident conditions induced by internal causes and simultaneous natural phenomena shall be taken into account to the extent estimated possible. STUK issued a Guide YVL 1.10, “Safety criteria for siting a nuclear power plant”, that describes generally all requirements concerning the site and surroundings of a nuclear power plant, gives requirements on safety factors affecting site selection as well as covers regulatory control. Specific provisions against earthquakes are provided in Guide YVL 2.6.

Structures, systems and components important to safety shall be designed and located, as well as protected by means of structural fire barriers and adequate fire fighting systems so that the likelihood of fires and explosions is small and their effect on plant safety insignificant. Detailed requirements are presented in Guides YVL 1.0, YVL 2.6, YVL 4.1, YVL 4.2 and YVL 4.3.

The probabilistic safety analysis required as part of the safety review for Construction and Operating Licences provides information on risks caused by external events. As an input to PSA, deterministic analyses are made to assess the impact of various natural phenomena and other external events.

In connection with the construction of the Loviisa and Olkiluoto plants, safety requirements were defined for the siting of nuclear power plants and for the population density and human activities in the surrounding area. Currently, these requirements include also administrative restrictions for industrial facilities and air traffic. In a sparsely populated country like Finland the safety requirements were quite easily and practically achievable.

The operating licences for nuclear facilities are granted for a limited period of time. For the license renewal, a comprehensive re-assessment of safety, including the environmental safety of the nuclear facility and the effects of external events on the safety of the facility, has to be done. STUK reviews the licence application, including all site-specific safety reports. These reports deal e.g. with meteorology, hydrology, population and use of land and sea area as well as other items mentioned above. During the operation of the nuclear facility, FSAR, including the descriptions of its site-specific parts, has to be periodically reviewed and updated as needed.

Finland is a party to the Convention on Environmental Impact Assessment in a Transboundary Context, done in Espoo in 1991. The Finnish policy is (Act 468/1994), to provide full participation to all neighbouring countries, which can be affected by the nuclear facilities in question. In 1976, an agreement was done between Denmark, Finland, Norway and Sweden as regards nuclear power plants to be constructed near the borders. This agreement includes provisions for exchanging information on such plants. The bilateral agreements mentioned under Article 16 include provisions to exchange information on the design and operation of nuclear facilities.

In Teollisuuden Voima Oy, the preparation of the environmental management system based on the ISO 14001 standard was started in 1998 and accomplished at the end of 1999 when TVO was granted an international certificate based on this environmental management system. TVO's environmental management system is EMAS registered under the identifier FIN-000039. The environmental management system of Loviisa plant is also based on ISO 14001:1996 standard and was certified in 2002.

In 1998, Teollisuuden Voima Oy and Fortum Power and Heat Oy launched the Environmental Impact Assessment procedure (EIA) of the new nuclear power plant. The EIA reports were finalised in 1999. In 1999, STUK issued to the Ministry of Trade and Industry statements on the EIA reports from the radiation and nuclear safety point of view. The following issues, among others, were assessed: how the applicants fulfil current radiation safety requirements and releases of radioactive matters during normal operation and during a severe accident situation. STUK also assessed the estimated environmental impacts of fuel procurement and nuclear waste management. In the STUK statements, no factors emerged concerning environmental radiation safety that would prevent the construction of a new reactor on the existing sites of nuclear power plants: The sites are remote to population and there are no large industrial facilities or transport routes near the sites; The most significant environmental impacts of a possible new reactor would arise from cooling water discharges increasing the temperature of sea water in the vicinity of the nuclear power plant. Based on the Espoo-treaty, Finland also received statements on the EIA from the neighbouring countries. The co-ordination authority, Ministry of Trade and Industry, gave its statement on the completeness of EIA Report in 2000.

In November 2000, TVO submitted to the Ministry of Trade and Industry an application for a Decision-in-principle for the new nuclear reactor unit to be constructed in the existing sites either in Olkiluoto or in Loviisa. The application was reviewed by all stakeholders. STUK made a safety assessment in early 2001 of the siting of new reactor unit: Both sites were considered to be appropriate for the new reactor of the proposed size of 1000–1600 MW electric power. After September 11, 2001, STUK updated the definitions for external threats to better reflect to change in international experience base. This update was formulated as an Addendum to the safety assessment of the new unit, and specifies as aircraft crash design requirement both a military craft and a large passenger craft. Certain other identified malevolent external actions were also explicitly included in the design requirements. The addendum was provided to the Ministry of Trade and Industry in January 2002.

The statements in favour of the new nuclear power plant unit were given by the candidate site municipalities. In addition, based on the Espoo-Treaty between the Nordic Countries, also Sweden gave its favourable statement on the application for a Decision-in-principle. The statements were submitted to the Ministry of Trade and Industry that prepared the issue for the decision of Council of State. The Council of State decided in favour of the Decision-in-principle in February 2002, and this decision was confirmed by a vote of 107 to 92 by the Finnish Parliament in May 2002.

2.13.2 Protection against external events and fires in the Loviisa NPP

The structures of the Loviisa plant have been designed taking into account the loads caused by natural phenomena applied in Finland. The risks caused by natural phenomena have been later on reviewed in connection with the weather risk analysis, prepared by Fortum. The analysis has identified a few needs for improvement. External missiles, like aircraft crashes or other effects of events caused by human actions, have been taken into account in the plant design to a smaller extent than required for new nuclear power plants. The combinations of internal and external effects, evaluated to be possible, have not been taken into account in the Loviisa plant design as required by Guide YVL 1.0. These events are evaluated in connection with PSA.

The effects of an earthquake were evaluated to be small at the time when the Loviisa plant was designed. They were not separately taken into account in the design, but it was considered that safety factors related to structures and components are adequate for taking into account earthquakes. The fulfilment of the earthquake requirements has been assessed in the probabilistic safety analysis made by Fortum. According to its results, the risks arising from earthquakes are small as compared with other risks.

Loss of off-site electric power supply has been taken into account in the plant design. The plant is currently also equipped with a net connection to the Ahvenkoski hydro power station to ensure the power supply. The main transformers have been protected with a sprinkler system which essentially reduces the risk that a fire would spread into the surrounding buildings, especially into the turbine hall.

The possibility of fires and nuclear accident risks caused by them were not adequately taken into account initially in the functional design and the lay-out design of the Loviisa plant. Therefore, fire compartments were not implemented in many parts so that the plant safety functions could be maintained during all fire situations considered possible. For this reason the significance of an active fire fighting (fire alarm and extinguishing systems as well as operative fire fighting) is important along with structural fire protection arrangements.

Fire safety has been improved with several measures at the Loviisa plant after its commissioning. These measures have been implemented in various fields of fire protection. As a result, the plant safety against the effects of fires has been essentially improved.

For a provision against oil fires in the turbine hall several measures have been taken. Fire insulators of the load-bearing steel structures of the turbine building have been installed. The turbine hall has been equipped with an automatic sprinkler system and the significant parts of the turbines have been protected. Later on, the fire wall of the turbine hall has been built up to protect components important to reactor decay heat removal. Furthermore, the additional emergency feedwater system has been built for the case that all feedwater and emergency feedwater systems would be lost in a turbine hall fire.

The risk to lose the AC-power during transformer fires has been reduced by protecting the diesel generators against fires. The 110 kV net connection has been physically separated from the 400 kV connection so that the loss of both connections as a result of a transformer fire is improbable. Several improvements against fires have been done in off-site power supply arrangements and in diesel generators. The original fire water pumps are supplied only from the off-site electrical network. Therefore, an additional fire water pump station has been constructed at the plant. It has been equipped with diesel-driven fire water pumps and with a separate fire water tank. Fire water piping and fire extinguishing systems as well as their coverage have been improved. A new addressed fire alarm system was completed in 1999 at Loviisa 1 and in 2001 at Loviisa 2. Several structural improvements for fire safety have been done, or are under design.

The level of the operative fire protection has been improved by establishing a plant fire- fighting crew which is permanent, constantly ready to depart and has the proper equipment. As regards fire protection and fire risks also plant instructions have been complemented.

In the cable spaces, underneath the control room level of the control room building, a halon system was earlier used as a primary fire protection. Halon extinguishing systems were replaced with water extinguishing systems by the year 2000.

2.13.3 Protection against external events and fires in the Olkiluoto NPP

Usual loadings such as snow and wind loads and temperature changes that are applied in Finland and caused by natural phenomena were taken into account, when the structures of the existing Olkiluoto plant were designed. Unusual natural phenomena, from the standpoint of plant cooling systems and the cooling of other important spaces as well as the functioning of systems, were not studied especially when the plant was designed.

Risks that arise from natural phenomena such as storms, algae, fluctuation of the sea water level, warm air, warm sea water, formation of frazil ice and drifting of snow arising from snow storms have been examined later in connection with the probabilistic weather risk analysis conducted by the TVO. Risks have been reduced by improving e.g. the suction air system of the diesel generators and sea water cooling of the plant against severe weather conditions. During recent years maximum sea water temperatures have been higher than earlier. As a preparative measure for still higher temperatures, modification work is going on to increase the capacity of the shut-down service water systems.

External missiles such as large air plane crashes or other external events caused by man were not taken into account in the original plant design. Furthermore, the combined effects of external and internal events have not been taken into account in the design of Olkiluoto 1 and 2 in the manner required by the Guide YVL 1.0. These events have been examined later in connection with the probabilistic safety analysis. Air craft crash sensitivity was re-evaluated after September 2001. Immediate catastrophic consequences were found unlikely. All site buildings were included in the assessment. The assessment criteria were risk of core damage and risk of large radioactivity release. Structural response evaluations were performed for three aircraft types:

- business jet
- large passenger aircraft
- large wide-body passenger aircraft.

It was concluded that the plant design provides relatively good protection from aircraft impacts based on

- multitude of the systems that can be used to achieve the required safety functions
- the presence of four spatially separated safety trains.

The containment and the fuel pools are not breached. A key aspect of reducing the risk in the event of an aircraft strike is the location of equipment of each of the four safety trains in distinct quadrants of the buildings. Even if safety equipment is lost in some of the quadrants, but equipment of one or more of the trains survive, safe shutdown capacity is likely maintained.

The effects of earthquakes were assessed as insignificant, when the existing Olkiluoto plant was designed. The effects were not taken particularly into account during the design, but it was considered, that the safety coefficients included in the design of structures and devices were adequate for taking earthquakes into account. The risks arising from earthquakes have been examined later in connection with the probabilistic safety analysis conducted by the TVO. The analysis identified certain improvement needs such as the anchoring of direct current accumulator batteries and rectifier cabinets. After this the rectifier cabinets, some of the electronic cabinets and the cabinets next to them and the accumulator batteries of two parallel subsystems have been anchored on both plant units to prevent them from moving. The control room ceilings including lighting fixtures have been rebuilt. These improvements reduce considerably the risks arising from earthquakes. The anchoring of accumulator batteries will be continued during the next years.

Preparedness for fires and fire protection

The possibility of fires and the risks of nuclear power plant accidents arising from fires have been taken into account in the functional and layout design of the existing Olkiluoto plant. The nuclear power plant does not, however, fulfil the requirements set forth in the Guide YVL 4.3. Fire safety has been improved in different areas of the fire protection at the existing Olkiluoto plant after commissioning. Although the loss of external electrical supply has been taken into account in the plant design, the plants were provided with e.g. a new start-up transformer, based on the experience gained from the fire of the electric supply unit in 1991, to improve the independency of plant's external grid connections. Furthermore, the main transformers, in-house transformers and start-up transformers are protected with a sprinkler extinguishing system, which reduces essentially the risks arising from transformer fires.

The use of halon is forbidden in Finland after the year 1999 with the exception of some special items.

Due to this the halon extinguishing systems at the existing Olkiluoto plant were replaced with other extinguishing systems by the year 2000.

Fire risks have been assessed in a probabilistic safety analysis that concentrates on fire issues. Based on this the fire protection of cables, that are crucial to safety, have been improved at the entire plant. On the basis of the probabilistic safety analysis these improvements reduce the risks arising from fires considerably.

Olkiluoto 3

Protection against external events and fires in Olkiluoto 3 are presented and analysed in Olkiluoto 3 PSAR and PSA documents . Documents are under STUK's review. STUK is also performing additional analyses with respect to aircraft protection by technical support organisations.

In conclusion, Finnish regulations and practices are in compliance with Article 17.

2.14 Article 18. Design and construction

Each Contracting Party shall take the appropriate steps to ensure that:

i. ***the design and construction of a nuclear installation provides for several reliable levels and methods of protection (defence in depth) against the release of radioactive materials, with a view to preventing the occurrence of accidents and to mitigating their radiological consequences should they occur;***

ii. ***the technologies incorporated in the design and construction of a nuclear installation are proven by experience or qualified by testing or analysis;***

*iii.****the design of a nuclear installation allows for reliable, stable and easily manageable operation, with specific consideration of human factors and the man-machine interface.***

2.14.1 Defence in depth

According to the Decision 395/1991, several levels of protection have to be provided in the design of a nuclear power plant. The design of the nuclear facility and the technology used is assessed by STUK when reviewing the application for a Decision-in-principle, Construction License and Operating License. Design is reassessed against the advancement of science and technology, when the Operating License is renewed.

In the design, construction and operation, proven or otherwise carefully examined high quality technology shall be employed to prevent operational transients and accidents. A nuclear power plant shall encompass systems by means of which operational transients and accidents can be quickly and reliably detected and the aggravation of any event prevented. Effective technical and administrative measures shall be taken for the mitigation of the consequences of an accident. The design of a nuclear power plant shall be such that accidents leading to extensive releases of radioactive materials are highly unlikely.

Decision 395/1991 requires that dispersion of radioactive materials from the fuel of the nuclear reactor to the environment shall be prevented by means of successive barriers which are the fuel and its cladding, the cooling circuit of the nuclear reactor and the containment building. Provisions for ensuring the integrity of the fuel, primary circuit and containment are included.

Decision 395/1991 requires that in ensuring safety functions, inherent safety features attainable by design shall be made use of in the first place. If inherent safety features cannot be made use of, priority shall be given to systems and components which do not require an external power supply or which, in consequence of a loss of power supply, will settle in a state preferable from the safety point of view (passive and fail-safe functions). Systems which perform the most important safety functions shall be able to carry out their functions even though an individual component in any system would fail to operate and additionally any component affecting the safety function would be simultaneously out of operation due to repairs or maintenance. In ensuring the most important safety functions, systems based on diverse operation principles shall be used to the extent possible. Furthermore, a nuclear power plant shall have sufficient on-site and off-site electrical power supply systems. Detailed requirements are given in Guides YVL 1.0, YVL 2.0, YVL 2.4, YVL 2.7, YVL 3.0, YVL 4.3, YVL 5.2, YVL 5.5, YVL 6.2.

An assessment of the design of the facility and related technologies is made by STUK for the first time when assessing the application for a Decision-in-principle. Later on, the evaluation is continued when the Construction Licence application is reviewed. Finally, the detailed evaluation of systems and equipment is carried out through their design approval process. The design of Loviisa and Olkiluoto nuclear power plants was reassessed by STUK in 1997-1998. The results of this review are discussed in Annex 2.

Severe accidents were not taken into account in the original design of the Loviisa and Olkiluoto plants. However, since their commissioning, many improvements have been implemented in the plant structures and systems, as well as procedures to enhance safety and to mitigate the consequences of severe accidents. Improvements have been implemented to enhance the safety of the plants and to mitigate the consequences of severe accidents. Plant improvements are discussed in Annex 2.

Olkiluoto 3

Possibilities to mitigate the consequences of the severe accidents are taken into account in the early design phase of Olkiluoto 3. This is achieved by implementing features to ensure containment integrity. Thus, it can be demonstrated that the need of stringent countermeasures during the severe accident are restricted to the immediate vicinity of the plant. In line with the deterministic design targets, two categories of events for risk reduction were introduced:

- Prevention of core melt
- Prevention of large releases.

Design provisions for the reduction of the residual risk are:

- Primary system discharge into the containment in case of total loss of secondary side cooling
- Features for corium spreading and cooling, for hydrogen recombination, and for containment heat removal in case of severe accidents.

Application of the Defence in Depth principle in the design of the new reactor is presented in the PSAR. in addition to PSAR, TVO has performed a self assessment on the fulfilment of Council of State Decision 395/1991 requirements. The application of Defence in Depth principle of the new reactor seems to follow the principles laid down in the design of existing reactors. Technical principal solutions presented in the design seem to follow the design of the reference reactors. However, a detailed review is underway.

2.14.2 Proven technology

The requirement to use proven or otherwise qualified technology is stated in the Decision 395/1991 as follows: In design, construction and operation proven or otherwise carefully examined high quality technology shall be employed to prevent operational transients and accidents (preventive measures). The respective detailed requirements are provided in many YVL Guides.

2.14.3 Reliable, stable and easily manageable operation

Decision 395/1991 requires that a nuclear power plant's control room shall contain equipment which provide information about the plant's operational state and any deviations from normal operation as well as systems which monitor the state of the plant's safety systems during operation and their functioning during operational transients and accidents. Furthermore, it requires that a nuclear power plant shall contain automatic systems that maintain the plant in a safe state during transients and accidents long enough to provide the operators a sufficient time to consider and implement the correct actions. Special attention shall be paid to the avoidance, detection and repair of human errors. The possibility of human errors shall be taken into account both in the design of the nuclear power plant and in the planning of its operation so that the plant withstands well errors and deviations from planned operational actions.

Plant systems reliability and human factors are systematically considered in the probabilistic safety analyses. The analyses support the efforts to eliminate accidents or to mitigate their consequences. The probabilistic safety analyses are subject to the approval of STUK. Human factors in relation to the monitoring and control of Finnish nuclear power plants are described in 2.8.2 and 2.8.3.

Both plants are planning to modernise their control rooms. At the Loviisa nuclear power plant this is included into a large automation modernisation project. At the Olkiluoto nuclear power plant changes in the control room are made gradually.

Digital instrumentation and control technology has already been implemented in some modernised systems. The development of detailed safety requirements and procedures to ensure adequate reliability of such systems is still underway.

In conclusion, Finnish regulations and practices are in compliance with Article 18.

2.15 Article 19. Operation

Each Contracting Party shall take the appropriate steps to ensure that:

i. the initial authorization to operate a nuclear installation is based upon an appropriate safety analysis and a commissioning programme demonstrating that the installation, as constructed, is consistent with design and safety requirements;

ii. operational limits and conditions derived from the safety analysis, tests and operational experience are defined and revised as necessary for identifying safe boundaries for operation;

iii. operation, maintenance, inspection and testing of a nuclear installation are conducted in accordance with approved procedures;

iv. procedures are established for responding to anticipated operational occurrences and to accidents;

v. necessary engineering and technical support in all safety-related fields is available throughout the lifetime of a nuclear installation;

vi. incidents significant to safety are reported in a timely manner by the holder of the relevant licence to the regulatory body;

vii. programmes to collect and analyse operating experience are established, the results obtained and the conclusions drawn are acted upon and that existing mechanisms are used to share important experience with international bodies and with other operating organizations and regulatory bodies;

viii. the generation of radioactive waste resulting from the operation of a nuclear installation is kept to the minimum practicable for the process concerned, both in activity and in volume, and any necessary treatment and storage of spent fuel and waste directly related to the operation and on the same site as that of the nuclear installation take into consideration conditioning and disposal.

2.15.1 Initial authorisation based on safety analysis and a commissioning programme

The Operating Licence is needed before fuel loading into the reactor. Initial authorization for fuel loading is given by STUK after its specific inspection where readiness of the power plant and operating organization is checked. Furthermore, according to the Nuclear Energy Decree, the various steps of the commissioning, i.e. criticality, low power operation and power ascension, are subject to the approval of STUK.

Requirements for the commissioning programme are set forth in Guide YVL 2.5. According to Guide YVL 2.5, the purpose of the commissioning programme is to give evidence that the plant has been constructed and will function according to the design requirements. Through the programme possible deficiencies in design and construction can also be observed.

The commissioning programme is described in the Preliminary and Final Safety Analysis Reports. The participation of the operating staff in the commissioning programme is a requirement of Guide YVL 1.6. The commissioning programme is to be submitted to STUK for approval. The detailed commissioning test programmes for systems in safety classes 1, 2 and 3 are submitted separately to STUK for approval. STUK witnesses commissioning tests and assesses the test results before giving stepwise permits to proceed in the commissioning.

Trial tests in the Loviisa NPP for power uprate

Fortum planned and carried out a trial test programme, by which it has been made sure of the effects of the nominal power increase on the functioning of the systems and components of the plant. Normal operation and in a limited way also transient behaviour of the plant were studied in the trial tests. Studies made by means of the plant simulator and the results of transient analyses were used in the planning of the trial test programme.

Due to the small number of plant modifications required for the power increase of the Loviisa plant, a simple trial test programme supported by the simulator studies was considered as appropriate and acceptable. Trial tests and disturbance tests can not be considered only as type tests, but their purpose was to make sure of the appropriate functioning of the components of both units.

The trial operation of both units was carried out at the various reactor powers, increasing stepwise the current power level (103%, 105%, 107% and 109%). The trial operation at the power levels 103–107% continued at both units for several months. At the final target power level 109% the operation of the Loviisa 1 continued for fourteen days and the operation of the Loviisa 2 eight days. According to the trial test programme, transient tests and extensive measurements concerning the state of the plant were carried out at various power levels.

Transient tests were carried out at the power levels 105% and 109% at both units. They were selected so that by means of tests the acceptability of the functioning of the most important process and control systems of the primary and secondary circuit could be verified, the number of the tests being as small as possible. Stopping of a reactor coolant pump and stopping of a main feedwater pump (without starting up an emergency pump as well as a turbine load trip (only at the Loviisa 1) were carried out as transient tests.

Based on the trial tests it was considered that the units operate as planned also at the increased power level. However, e.g. following observations were made during the trial tests:

- in the determination of the reactor heat power a fault was noticed at the Loviisa 1 unit
- steam flow rate has from time to time exceeded the original target value 40 m/s of the steam piping at both units
- a hidden fault was detected in the protection system limiting reactor power at the Loviisa 1 unit; the system was unnecessarily launched due to the fault.

As a result of the observations mentioned the necessary corrective measures were planned and implemented.

In conclusion it was noted that the trial tests of the Loviisa plant, performed in connection with the modernisation, were carried out with acceptable results and to the extent necessary for the planned power increase.

Trial tests in the Olkiluoto NPP for power uprate

An essential part of the modernisation and power uprating projects at the Olkiluoto plant units has been the test operation. The objective of the test operation is to demonstrate planned and safe operation of modified systems and the plant integration made up of these systems in normal operating conditions and in certain probable transient conditions. Test operation has also been used as a part of design, when such modifications have been made to the systems of the plant units and set limits of the control systems that enabled the operation of the units at the uprated power level and improved their transient behaviour and mitigated sensitivity for the transients.

Test operation included system related tests, plant unit related transient tests and so-called long-term test operations, during which the reactor was operated at an uprated constant power for a longer period of time. Test operations were conducted in stages at different power levels under STUK's supervision and within the frames permitted by STUK. Before uprating the reactor power to a higher power level STUK conducted a safety review concerning the test operation for the power level in question and asked the Nuclear Safety Advisory Committee for a statement concerning the review before granting the test operating license.

Test operation programs that included the entire plant units and were drawn up by TVO, were based on the original commissioning programs that were run through during the start-up phase and that were modified taking into account the test requirements caused by the modernised systems. One principle was also to minimise the loads to structures and equipment caused by the test operation, due to which the different transient tests concerning the behaviour of the entire plant units were evenly distributed, when possible, to both plant units.

For the long-term test operation of the plant units the reactor powers were uprated step by step from the nominal power of 2160 MW to 2500 MW. The test operation begun at Olkiluoto 1 after the 1996 refuelling outage, when the reactor power was uprated to a 105% level from the nominal power of 2160 MW. In 1997 the test operation was continued at Olkiluoto 1 unit and was begun at Olkiluoto 2 unit at a 109% level on both units. The reactor powers were uprated to the final level of 115.7% (2500 MW), designed in the modernisation, after the 1998 annual maintenance outage.

The most significant plant transient tests of the test operation were the load rejection test, turbine trip test and the by-pass test of the high-pressure preheaters. Furthermore, tripping tests of condensate and feed water pumps were conducted. In addition to the plant transient tests the functioning of the most important control systems was tested in separate pressure, power and feed water transient tests. During the long-term tests the following matters, for example, have been monitored: the behaviour of the reactor core, the functioning of condensate and reactor water clean-up systems, erosion and corrosion effects, vibration levels of pipelines and turbine generator, temperatures of rooms and electric appliances, radiation levels in systems and rooms of the reactor plant.

No such matters emerged in the test operation that could have formed an obstacle to a continuous and safe operation of the plant units at the 2500 MW reactor power level. Based on the observations made during the test operation, several modifications were made to the plant systems to complement the plant and the system design that were conducted in connection with the modernisation or to repair deficiencies. Some of the observations were made only after a longer period of lower power level test operation. STUK considered it necessary to continue the test operation at the 2500 MW power level for about two months before issuing a statement in favour of continuing the operation of the plant units at the 2500 MW power level.

2.15.2 Operational Limits and Conditions

Nuclear Energy Decree requires that the applicant for an Operating License must provide STUK with the Technical Specifications (Operational Limits and Conditions). The Technical Specifications shall at least define limits for the process quantities that affect the safety of the facility in various operating states, provide regulations on operating restrictions that result from component failures, and set forth requirements for the testing of components important to safety. Technical and administrative requirements and restrictions for ensuring the safe operation of a nuclear power plant shall be set forth in the plant's Technical Specifications. Guide YVL 1.1 requires that the minimum staff availability in all operational states and the limits for the releases of radioactive substances have also to be defined in the document.

The Technical Specifications have been established for each nuclear power plant unit. The Technical Specifications are updated based on operational experiences, tests, analyses and plant modifications. The Technical Specifications are subject to the approval of STUK prior to the commissioning of a facility. Strict observance of the Technical Specifications is verified by STUK through a regular inspection programme. Technical Specifications, operating procedures and other plant documentation need to be updated after plant modifications.

Loviisa NPP

Fortum has established the Technical Specifications for the Loviisa 1 and 2, and STUK has reviewed and accepted them. The Technical Specifications are continuously updated, and all the changes need to be approved by STUK. The limitations and conditions of the reactor and plant operation, the requirements for periodic tests and the essential administrative instructions are presented in the Technical Specifications.

The operating procedures of the Loviisa plant are a part of the quality assurance programme. The most important instruction types are:

- administrative instructions of which the Organisational Manual and especially the Administrative Rules included in the Manual are essential
- instructions for emergency and transient situations
- fuel handling instructions and instructions for radiation protection
- operating instructions and testing instructions
- maintenance instructions.

The updating and coverage of the procedures are subjects to inspection in the STUK's inspection programme for the operation of the Loviisa plant. In addition, during all inspections of the programme individual instructions are evaluated.

An advanced and updated system of procedures exists at the Loviisa plant. It includes about 2300 separate instructions. The instructions cover well work processes and functions important to safety and availability.

The system of procedures is a part of the quality system of the plant. Strict requirements have been set in the Quality Assurance Manual for the coverage, responsibilities, updating and observance of the procedures. According to the Manual the evaluation of the system of procedures is included in the annual review of the coverage and effectiveness of the quality assurance programme. Among other things the requirements, adequacy and need for updating of the instructions and the fulfilment of the set requirements are considered in this review.

The state of the plant procedures is good at the Loviisa plant. Procedures are maintained, evaluated and developed systematically and in a controlled way.

Olkiluoto NPP

The Technical Specifications determine the limits of process parameters, that affect the plant safety, for different operating modes, set the provisions for operating limits caused by component inoperability and set forth the requirements for the tests that are conducted regularly for components important to safety. Furthermore, the Technical Specifications include the bases for the set provisions.

The Technical Specifications have to be supplied to the Radiation and Nuclear Safety Authority (STUK), when the operating licence is applied, and the Technical Specifications have to be kept updated during the entire time of plant operation. STUK's approval has to be applied, if any modifications are to be made to the Specifications.

The administrative and technical procedures needed in operation of Olkiluoto 1 and 2 have been gathered into the Operating Manual. The Procedures have been inspected by STUK. The checking/updating of the procedures is a continuous task.

The Operating Manual contains necessary transient and emergency procedures for unusual conditions.

The Maintenance Manual includes the administrative and technical procedures needed in maintenance. The most important procedures have been inspected by STUK. The power company checks the procedures periodically, approximately in four-year-intervals.

Updating and comprehensiveness of the procedures are among the inspection issues included in the STUK's Periodical Inspection Program. Furthermore, other procedures that relate to the topic of inspection are reviewed in all inspections of the STUK's program.

2.15.3 Operation and maintenance in accordance with approved procedures

Requirements related to the procedure approvals are provided in the Decision 395/1991: Appropriate procedures shall exist for the operation, maintenance, in-service inspections and periodic tests as well as transient and accident conditions of a nuclear power plant. Detailed guidance is given in the guides YVL 1.1, YVL 1.8 and YVL 1.9. YVL 1.9 requires that documents and operating procedures needed by the control room operators have to be defined, and that these documents and procedures shall be continuously updated. The responsibilities and administrative procedures indicating how to take care of these actions are described in the Quality Assurance Programme.

The procedures for operation, maintenance, inspection and testing have been established at both Finnish nuclear power plants. The procedures shall be approved by the licensee itself, and most of them are required to be submitted to STUK for information. Detailed requirements are presented in appropriate YVL Guides. STUK verifies by means of inspections and audits that approved procedures are followed in the operation of the facility.

Figures 13 and 14 present the number of exemptions and deviations from the Operational Limits and Conditions. Since 1994–1995 the number of exemptions from the Operational Limits and Conditions has been decreasing but during the last years the trend has changed to increasing from 21 in 2002 to 25 in 2003. The main reason for the large number of exemptions at the Loviisa NPP was the project to renew the radiation monitors that required exemptions in all operational states in 2002–2003. The peak in 1994–1995 relates to the modification of ventilation systems that needed several exemptions. In the case of Olkiluoto NPP the main reason for the exemptions was the conduct of maintenance and repair works. During 2003, there was one deviation from the Operational Limits and Conditions at the Loviisa NPP and 8 deviations at the Olkiluoto NPP; In the case of Loviisa NPP trend is decreasing and in the case of Olkiluoto NPP trend is increasing. Human errors are the main cause for deviations.

Loviisa NPP

The procedures followed in the operating activities of Loviisa 1 and 2 are based on written instructions and on operating orders prepared when needed. An operating order is prepared e.g. when the operating state or power of the unit is changed, or for measures related to the reactor or nuclear fuel.

By means of a work order system it is ensured i.e. that the plant operators are aware of the state of the unit. Fortum has developed, and develops further, its work order system based on accumulated operating experiences. In addition to the work order system the operators in the main control room of the units follow failures, repairs and preventive maintenance of the components referred to in the Technical Specifications. A shift supervisor gives a permit to start a specific work when he has evaluated the work plans specified in the work order system, taking into account the operability requirements of the systems and components set in the Technical Specifications. The main control room is provided with information on the operating states of the systems and components and on the conditions of room spaces as well as on possible deviations existing. The deviations are responded according to the procedures for operation and transients.

Maintenance

Requirements for maintenance are given in Guide YVL 1.8.

In addition to preventive, predictive and repairing maintenance, the maintenance activities of Loviisa 1 and 2 cover implementation of modification works, spare part maintenance and activities during outages.

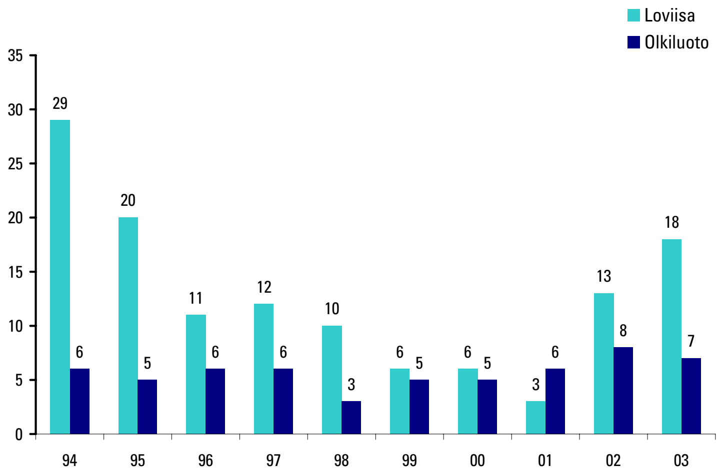


Figure 13. Number of exemptions from the Operational Limits and Conditions at Finnish NPPs.

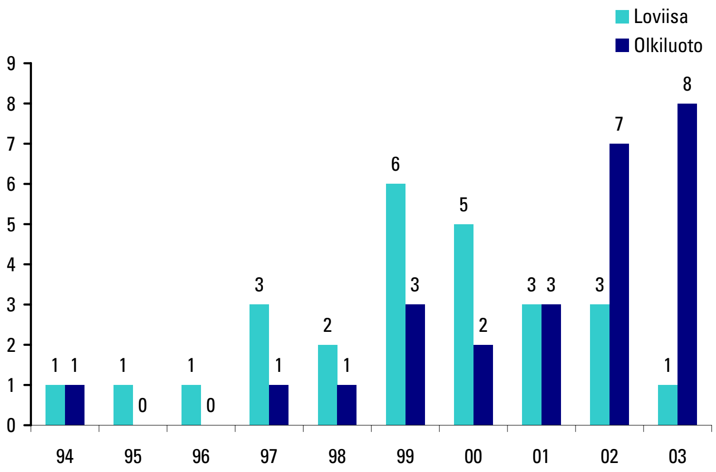


Figure 14. Number of plant events in non-compliance with the Operational Limits and Conditions at Finnish NPPs.

The maintenance organisation of the plant takes part into the annual maintenance outages planning together with the Technology and Operation Units. and prepares annual maintenance outages together with the operating organisation. Special attention has been paid to the reliable activities of subcontractors as well as to the technical competence of external human resources. Both the utility and STUK control companies performing inspection activities and the technical competence of organisations carrying out various duties. In addition to the normal monitoring activities, the preventive and predictive maintenance programme includes also continuously measuring methods, such as the vibration measurements of the control rod drive units, reactor coolant pumps and turbogenerators, the monitoring of the primary circuit loadings as well as the monitoring of leakages, water chemistry and lose parts.

The maintenance procedures at the Loviisa plant have been programmed in the plant computer according to the work order system. Some parts of the system are available to STUK for reading.

The functioning of the systems and components is ensured with regular tests. The systems and components to be tested and the time periods of the tests are presented in the Technical Specifications. At least the respective periodic tests are required after the modification and repairing works and maintenance activities requiring dismounting. The performance test programme to be carried out after an essential modification is required to be approved by STUK in advance.

In addition, inspections regarding to the functioning and condition of components are carried out when necessary based on operating experiences from other plants and on the advancement of technical knowledge. Other operating organisations of VVER-type reactors have been essential sources of operating experiences in this respect.

STUK controls monitoring and maintenance activities as well as repair and modification works with regular inspections. During inspections it is aimed to make sure that the utility has adequate resources, such as a competent staff, instructions, a spare part and material storage as well as tools for the sufficiently effective implementation of the monitoring and maintenance activities. Special subjects are the condition monitoring programmes for the carbon steel piping and their results.

Modification management development

An analysis of reported events often reveals that deficiencies of modification management have been a contributing factor. Such deficiencies include late planning, lack of co-ordination with other works, last moment changes, documentation defects, unfinished disassembling works and delayed updating of the documentation.

Proper planning and scheduling are the key factors in modification management. Loviisa Power Plant has completed an extensive project training course in 2000 for those in the operating organisation who will be involved in future modification projects. Successful projects such as the plant modernisation and power upgrading have been used as good examples. From the beginning of 2002 modification process has been managed by the Technology Unit.

The scheduling of the modification planning for the next outage is fixed in order to get enough time for preparations. Minor modifications are concentrated to every second annual maintenance outage and major works are carried out every fourth year. This is accomplished by starting from a long term investment planning which converts into a long term modification plan.

During the maintenance outage the scheduling office is now directing their efforts from the earlier control of the overall schedule to controlling the individual work packages including also the modification works. In the main schedule more time is allocated to tests related to start-up. New arrangements for handling the work orders in the main control room have been introduced The idea are to even up the work load in the main control room and decrease the disturbance of the operators.

Quality procedures for executing modifications have recently been updated. The authority to make decisions on last moment changes in the scope or schedule of the modification works has been clarified.

Olkiluoto NPP

The measures that are followed in the operation and maintenance of Olkiluoto 1 and 2 are based on written procedures and on Operating Orders and Operating Notices that are drawn up if necessary. The Operating Order is drawn up e.g. when the operating condition or power of the plant is modified or when measures are directed to the reactor or nuclear fuel. The Operating Notice, on the other hand, is drawn up on unusual procedures that will not be permanent.

The Work Request System ensures that the operators of the plant are aware of the plant unit's state. TVO has developed its Work Request System and will continue to do so on the basis of operational experience. In the main control room of the plant units, the operators follow, in addition to the Work Request System, the failures, repairs and preventive maintenance of the components specified in the Technical Specifications. The Shift Chief grants the permission to begin a single work, when he/she inspects the work plans that are in accordance with the Work Request System, by taking into account the operability requirements for the systems and components set forth in the Technical Specifications. The control room is informed from the operational conditions of systems and components as well as from the room conditions and their possible deviations. The proper response to deviations is specified in the operating and transient procedures.

TVO has available a computer-aided preventive maintenance programme, which includes all systems and components that are essential for the safety and operability. The program includes the normal preventive maintenance measures that are in accordance with the Work Request System such as calibrations of measuring systems, frequency measurements of rotating components, checks of oil levels, lubrications and greasing. The comprehensiveness of the program is assessed on the basis of observations made in connection with operational experience and preventive maintenance.

Maintenance

The requirements concerning the maintenance are clarified in the Guide YVL 1.8.

The maintenance of Olkiluoto 1 and 2 covers, in addition to the preventive and corrective maintenance, the design and execution of modifications, spare part service, outage actions and the related quality control.

The maintenance organisation plans and builds up the annual maintenance outages together with the operation organisation and technical support organisation. Special attention has been paid to the reliable work of the subcontractors and to the technical competence of the external work force. The technical expertise of testing laboratories and contractors is controlled both by the power company and STUK.

TVO has available a computer-aided preventive maintenance programme, which includes all systems and components that are essential for the safety and operability. The program includes the normal preventive maintenance measures that are in accordance with the Work Request System such as calibrations of measuring systems, frequency measurements of rotating components, checks of oil levels, lubrications and greasing. The comprehensiveness of the program is assessed on the basis of observations made in connection with operational experience and preventive maintenance.

In addition to the measures listed in the preventive maintenance program, systems, components and rooms are controlled in connection with the normal operation and daily tour routes. Some of the most important components such as the main circulation pumps and the turbine are provided with on-line monitoring equipment.

The operability of systems and components is ensured by regularly conducted tests. The systems and the components that will be tested as well as the test dates are presented in the Technical Specifications. Periodical testing that correspond at least to the aforementioned, are required after maintenance measures that require modifications, repairing or disassembling. STUK's approval is required in advance for a functional test programme that is conducted after a significant modification.

Inspections that concern the operability and condition of components are also conducted, if necessary, on the basis operational experience received from elsewhere and development of technical knowledge. The most significant sources of experience, in this sense, have been the Swedish BWR plants and international communication organs.

As far as the spare part service is concerned, it has been made sure that completely assembled components, that can be easily used to replace the failed component, exist for as many safety-significant systems as possible.

STUK controls the condition monitoring and maintenance as well as the modification and repair work by regularly repeated inspections. The inspections endeavour to ensure that the power company has adequate resources such as a competent personnel, instructions, a spare part and material storage as well as the tools for adequately efficient implementation of condition monitoring and maintenance actions. Special items are the condition monitoring programmes of the carbon steel pipelines and their results.

Modification management development

The modification handling procedure in Olkiluoto has been under continuous development since the early 1980's. After the modernisation program and several reviews of TVO's working methods, experiences have been collected in a separate development project. The project was realised during the years 1997–1999 and it had participants from operation, maintenance, quality assurance, safety, modification planning and refuelling planning. Special attention was placed also on the new modern automation and on modifications during the field installation phase.

The project started with exploring

1. The working procedure at present state
2. Comments relevant to the modification procedure collected from the internal, external and regulatory audit results of TVO's working methods
3. Experiences from the modernisation programme of Olkiluoto1 and 2.

On the basis of the results of the above mentioned studies and other experiences, about 60 remarks on the state of the modification process were collected to be taken into account in the development work. The target state was defined and it was also checked that all remarks had been taken into account. In addition, many new ideas were found by the project group itself.

In the development work, detailed procedures were defined making the decision process more exact and taking into account the opinions of all parties in TVO's organisation. Some of the most significant modifications made included:

- enhanced information flow on modifications within TVO
- procedure for surveys to use the knowledge of the whole TVO-organisation and to enable also safety organisation to analyse the safety significance already in the early stage of the project
- better commitment of personnel responsible for the work
- consideration for independent review on modifications
- establishment of a basic plan for system modifications and more exact specification for system level pre inspection material
- enable comments for the modification process in early stage
- more exact content for the modification plan pointing out environmental matters, training, commissioning, spare parts
- principle of continuous improvement
- better follow up for modification process progress
- consideration of changes to the plant documentation in an early stage.

The practice has shown that there is still need for continuous improvement to keep the personnel motivated and to take into account all aspects to guarantee safe and reliable long term operation of the power plant. General training, discussion and development seminars have been arranged to continue the modification process development and to get the working organisation committed to the new procedure.

2.15.4 Procedures for anticipated operational occurrences and accidents

Decision 395/1991 defines the levels of protection needed for ensuring nuclear safety. Together with the requirements to prevent transients and accidents by the plant system design, it is stated as follows: Effective technical and administrative measures shall be taken for the mitigation of the consequences of an accident. Counter-measures for bringing an accident under control and for preventing radiation hazards shall be planned in advance. Appropriate procedures shall exist for the operation, maintenance, in-service inspections and periodic tests as well as transient and accident conditions of a nuclear power plant.

At both Finnish nuclear power plants, procedures for anticipated operational occurrences and accidents are in use. To the extent found necessary, the procedures have been verified during operator training at the plant simulators. At both nuclear power plants there are also advanced safety panels for monitoring critical safety functions. STUK has independently evaluated the appropriateness and comprehensiveness of the procedures for anticipated operational occurrences and accidents.

The Loviisa specific EOP-project (Emergency Operating Procedures) was launched by Fortum in summer 2000. The initial aim of the project was to develop full set of accident and transient procedures for initial conditions starting at full power. Before the project, an extensive feasibility study of different approaches was carried out. The project is based on French approach of combined event and symptom based procedures. The development is carried out together with EdF, Framatome ANP and Fortum Nuclear Services. French consortium is mainly responsible for creating strategies for the set of procedures as well as transferring knowledge of the training and EOP layout. Fortum Nuclear Services together with Loviisa NPP finalizes the procedures as well as carries out the validation and verification routines. The phase 1 will be finalized at the end of 2004.

Plant specific symptom based EOPs have been available at the Olkiluoto units since late 80's.

2.15.5 Availability of engineering and technical support

The requirements in Guide YVL 1.7 also cover technical support. Competence of the engineering and technical support is supervised by the licensee. In addition, STUK carries out inspections and audits by which also the competence of the support staff is evaluated. According to the Nuclear Energy Decree, only organisations and their employees approved by STUK are allowed to carry out non-destructive testing of a nuclear power plant's structures and components. The approval procedures are described in Guide YVL 1.3.

Some concern was related to the adequacy of engineering and technical support available to Teollisuuden Voima Oy when its Operating License was renewed in 1998. This was due to the fact that, recently, Teollisuuden Voima Oy has quite independently designed and implemented some safety modifications at the plant, and the tendency is expected to continue. This issue was raised again in a preliminary safety assessment by STUK related to the Decision-in-principle for the fifth reactor in Finland. It was stated that if the Decision-in-principle is approved by the Parliament, Teollisuuden Voima Oy should in a very early phase start to develop its organisation and expertise to ensure the safety of the plant in case there is no comprehensive design service available in the market.

There has also been some concern about how to sustain the expertise of nuclear safety personnel in a deregulated environment. This concern has especially touched Fortum Engineering that was recently exposed to divestment. However, a new company, Fortum Nuclear Services Ltd, was founded and nuclear safety engineering was transferred to this company so that the divestment of Fortum Engineering has not reduced the nuclear safety expertise of the company.

2.15.6 Reporting of incidents

Guide YVL 1.5 provides in detail the reporting requirements on incidents. The Guide provides a number of examples of operational disturbances and events, which have to be reported to STUK. It also defines requirements for the contents of the reports and the administrative procedures for reporting, including time limits for submitting of various reports. STUK publishes the operational events in its quarterly reports on nuclear safety that are also available to the general public through internet or paper reports in Finnish. STUK Annual Report on nuclear safety (see Reference 3) summarizes events from the whole year and is available to the general public through internet or paper reports both in Finnish and in English.

Figures 15 and 16 present the number of events at the Finnish nuclear power plants. The total number of event reports has varied between 5 and 25 annually during the last ten year period. At the same time frame number of INES classified events (level 1 or above) have been between 0 and 7 annually. Number of IRS reports produced during the last ten year period is 16. During the period 2001-2003 one IRS report has been produced annually.

INES-classified events

Loviisa NPP

Twelve events in 2002 and one event in 2003 were classified on the International Nuclear Event Scale (INES). In 2002 there was one level 1 event and the classification of the other events was 0. The level 1 event was a boron dilution incident at Loviisa 1 during the annual refuelling outage. When reactor cavity was cleaned after reloading, more water was needed than normally. Boron concentration in the primary circuit diluted slightly under the Technical Specification limits because of inadequate surveillance and poor cleaning instructions. New procedures have been taken into use after the incident.

Olkiluoto NPP

During the year 2002 one event was classified level 1 on the International Nuclear Event Scale (INES). The incident was functional problems with two triggering limits of Start-up and Intermediate Range Monitoring (SIRM) system at Olkiluoto 1 and 2. As a corrective measure the limits were specified in a proper manner.

During the year 2003, seven events occurred that were classified level 1 on the International Nuclear Event Scale (INES). The events were:

- The isolation valve of the main steam line did not close at Olkiluoto 1. The procedures for assembling the valve and tightening the shaft seal were reviewed.
- Emergency core cooling pumps were disconnected during the annual outage of Olkiluoto 2. The instructions and procedures were reviewed.
- The rate of decrease of the temperature exceeded the reactor water temporary change rate defined in the Technical Specifications at Olkiluoto 1. Operation instructions were corrected.
- The operating test of the level switches in the controlled area floor drain system in the spent fuel storage, specified in the Technical Specifications, had not been performed on four level switches. The respective Technical Specifications were specified in more detail and training on the basics of Technical Specifications was arranged for the personnel.

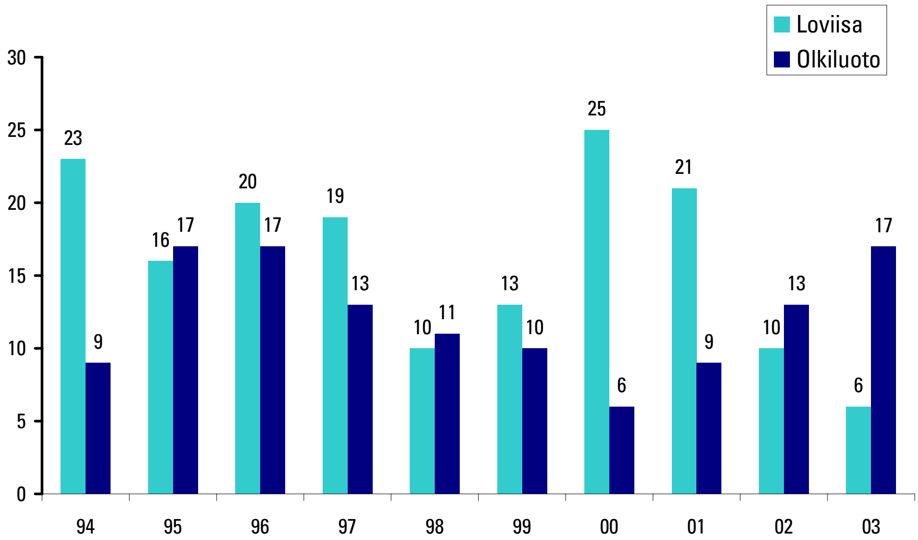


Figure 15. Number of event reports submitted by Loviisa and Olkiluoto nuclear power plants.

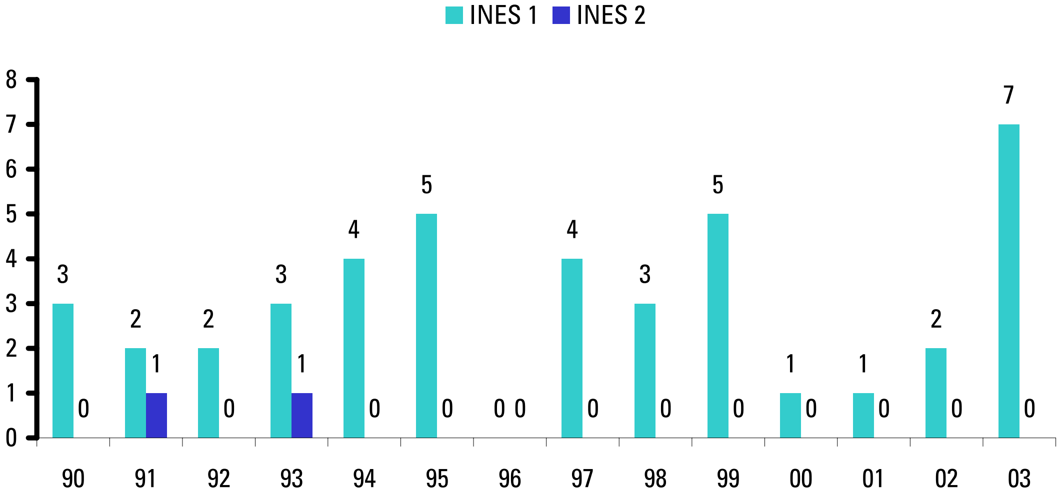


Figure 16. Number of events at INES Level 1 and above at the Finnish nuclear power plants.

- One of the three fire fighting water pumps of the plant units was not serviceable as required by the Technical Specifications after the preventive maintenance. The maintenance and sealing instructions were updated and training on the use of maintenance information systems was arranged.
- The fire damper in the stairwell of reactor building was inoperable at Olkiluoto 2. The instructions that must be specified using the Technical Specifications were surveyed and all tests and inspections specified in the Technical Specifications were reviewed.
- Vibration measurements revealed that the vibration levels of three emergency cooling system pumps at Olkiluoto 1 were too high. The steel plates below the motors were anchored to the supporting concrete slab and the empty spaces below the steel plates and the grouting were injected.

2.15.7 Programmes to collect and analyse operating experience

Decision 395/1991 requires the following: Operating experience from nuclear power plants as well as results of safety research shall be systematically followed and assessed. For further safety enhancement, actions shall be taken which can be regarded as justified considering operating experience and the results of safety research as well as the advancement of science and technology. Guide YVL 1.11 provides detailed requirements and administrative procedures for the systematic evaluation of operating experiences, and for the planning and implementation of corrective actions. Foreign operational occurrences have to be assessed as well, from the point of view of their safety significance.

The licensees have developed the required procedures for analysing operating experiences. The procedures for root cause analyses are in use. Further attention is, however, still needed to avoid recurrence of incidents.

STUK verifies by means of inspections and audits that the activities of the licensees as regards incident evaluation are effective. When necessary, a special investigation team is appointed by STUK to evaluate a certain incident. The evaluation of foreign operational occurrences and incidents is based on the reports of the IRS Reporting System (IAEA/NEA) and on the reports of other national regulatory bodies. IRS-reports are also evaluated by the licensees. Reports for the IRS System on safety-significant occurrences at Finnish nuclear power plants are written by STUK.

Special attention was paid to incident evaluation methods and operating experience in Finland in 1999. A study was conducted by the Technical Research Centre of Finland, VTT, to evaluate operating experience feedback systems and incident evaluation methods in the Finnish nuclear industry. Several development areas were identified to enhance incident evaluation and to close the operating experience loop in order to avoid recurrence of events. Implementation of these measures was included to the continuous development of quality systems.

Experiences gained from plant operations are directly shared with utilities operating similar types of plant (same NSSS vendor), and appropriate reports are also distributed through WANO. Both plants co-operate with WANO and countries having similar reactor types. This co-operation is more closely described below. STUK has also participated in co-operation between international organisations such as the IAEA, the OECD/NEA and the EU, who exchange information on safety issues and operating events. Other forums that STUK uses to obtain information are WENRA, the VVER Forum and the NERS Forum as well as some bilateral agreements. A special exchange of information between Gosatomnadzor and STUK on the operation of the Kola and Leningrad nuclear power plants and of Finnish nuclear power plants has taken place quarterly.

Exchange of operational experience with similar power plants in the Loviisa NPP

VVER reactor operating experience is collected, screened and evaluated by a dedicated operating experience feedback group composed of engineers from the plant operation organisation and from Fortum Nuclear Services. The group can give recommendations on further studies and measures to the operating organisation. The main information to be handled comes from WANO Moscow Centre which links all the VVER reactor operators. Additional reports are received from the IAEA, OECD/NEA and NRC, and naturally the activities of the operation experience feedback group are not limited only to VVER reactors.

The plant managers of VVER-440 reactors run a so-called VVER Club with periodic meetings. The plant operation problems, modernisation, back-fitting, plant life management and safety questions are handled and experiences are exchanged in these meetings and in further individual contacts.

Loviisa Power Plant participates in the WANO Peer Review Programme by sending peers to other plants including VVER plants. In February–March 2001 WANO Moscow Centre organised a Peer Review at Loviisa Power Plant. Several peers including the team leader came from other VVER plants. A follow-up review was carried out in March 2004. This co-operation between plants of the same design serves also the exchange of relevant operation experiences.

Fortum Nuclear Services has been a partner in several international and Finnish safety and quality related support programmes. Loviisa Power Plant has participated in some of these projects and has had a possibility to widen the organisation's experience on current development with other VVER operators. The same applies to a couple of direct commercial consultation projects which have been managed by Loviisa Power Plant.

Exchange of operational experience with similar power plants in the Olkiluoto NPP

TVO's operating experience feedback group consists of 7 members and 3 advisors. This onsite group gives recommendations to the line organisation that makes decisions on eventual corrective actions. The industry operating experience from similar reactor types is followed by several means. The main sources of information are ERFATOM, KSU, WANO and Forsmark. These are explained in more detail below. Information is also coming directly from several sources (IAEA and OECD/NEA (IRS), Loviisa power plant (e.g. operating experience meetings and reports), vendors (Westinghouse Atom, Alstom Power Sweden AB), component manufacturers, the WANO Network, BWROG (BWR Owners Group) and BWR Forum (FANP).

ERFATOM was founded by the Swedish utilities and TVO as a consequence of the so called Barsebäck incident (July 1992). Activities started on January 1st, 1994 in the premises of former ABB Atom (Västerås, Sweden). Nowadays ERFATOM is part of the NOG (Nordic Owners Group) and issues reports every two weeks and topical reports when needed. ERFATOM also gives recommendations. ERFATOM co-operates very closely with KSU (Swedish nuclear training and safety center). KSU concentrates on operational safety issues and they have the responsibility to screen out external (international) operating events. ERFATOM screens out internal events from Swedish Nuclear Power Plants and from Olkiluoto.

TVO is a member of WANO (World Association of Nuclear Operators). Although KSU screens out important events reported through the WANO Network, TVO reviews independently all the SOERs (Significant Operating Experience Reports) and SERs (Significant Event Reports) reported by WANO. Forsmark units 1 and 2 in Sweden can be called as "sister units" of OL1 and OL2. Reports from Forsmark 1 and 2 (e.g. licensee event reports) and minutes of the meetings of the Forsmark safety committee are reviewed regularly.

In addition to the above, TVO participates actively in WANO programs and in several international technical groups (such as valve group, reactor group and turbine group) which have regular meetings about twice a year.

2.15.8 Radioactive waste from the operation of a nuclear installation and the treatment and storage of spent fuel and radioactive waste on site

Management of low and intermediate level waste takes place at the NPP sites. At the Olkiluoto site the necessary facilities are already in place while at the Loviisa site, a solidification facility is under construction and will be commissioned in 2006. At both NPP sites, final disposal facilities of rock cavern type are in operation for low and medium level radioactive wastes. As these facilities are operated by the nuclear power plant utilities, the technical feasibility and economic motivation to minimise the generation of radioactive waste are evident. The average accumulation of low and intermediate level waste at Finnish NPPs has been about 75 cubic meters per reactor year.

The detailed requirement for radioactive waste minimisation is included in Guide YVL 8.3. It calls for a limitation of waste volumes in particular from repair and maintenance works, and segregation of wastes on the basis of activity. Clearance of wastes from regulatory control, prescribed in the Nuclear Energy Decree and in Guide YVL 8.2, aims at limiting the volumes of waste to be stored and disposed of. Guide YVL 6.2 provides for prevention of fuel damages, which also contributes to the limitation of activity accumulation in waste from reactor water cleanup systems.

Guide YVL 8.3 requires that besides the short-term radiation protection objectives, also the long-term properties of waste packages with respect to final disposal shall be taken into account in the conditioning and storage of waste. The Guide includes also more specific requirements for the conditioning and interim storage of wastes. Guide YVL 8.1 calls for a waste type description, to be approved by STUK, for each category of reactor waste to be disposed of. In the description of waste type, the most important characteristics of waste with respect to the safety of disposal are defined.

By the end of the year 2003, 7020 cubic meters of low and medium level operating waste has accumulated at the Olkiluoto and Loviisa NPPs. About

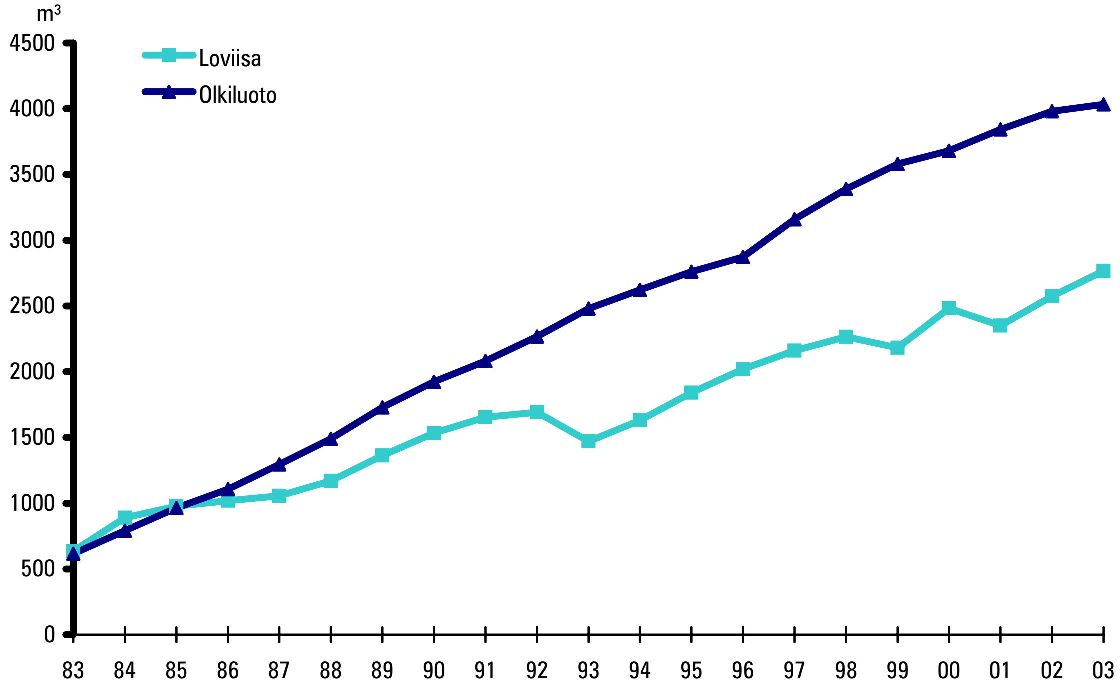


Figure 17. The volume of low and medium level waste at the Finnish NPPs.

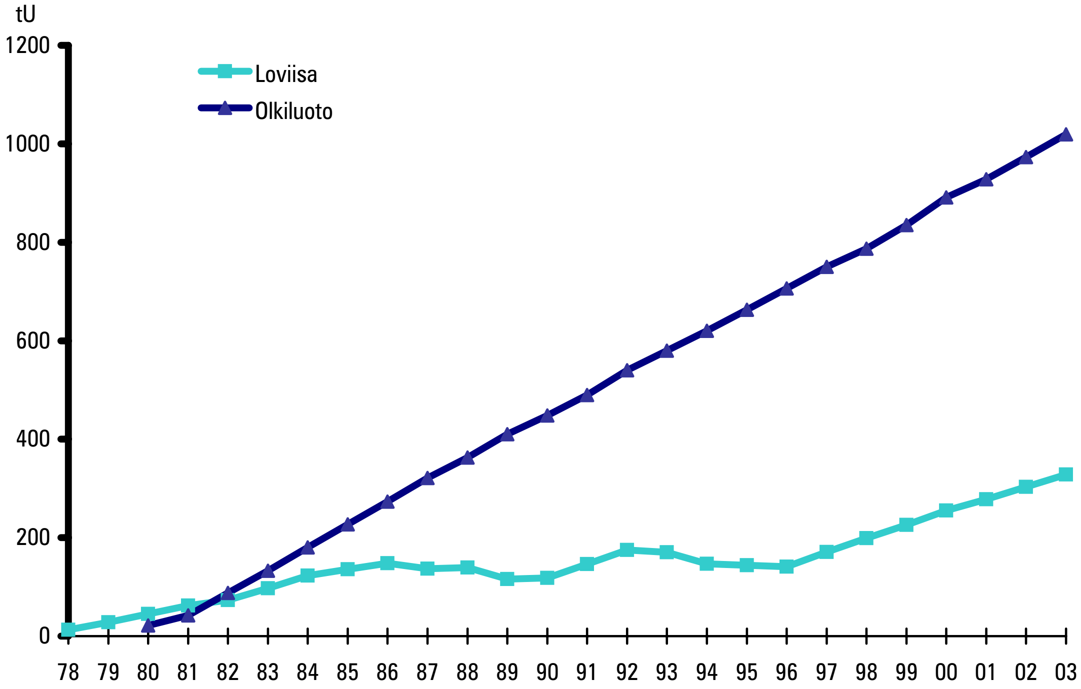


Figure 18. The accumulation of spent nuclear fuel at the Finnish NPPs.

73% of this waste has been disposed of in the on-site repositories.

Guide YVL 1.0 requires that provision for a nuclear power plant's decommissioning shall be made already during the plant's design phase. One criterion when deciding the plant's materials and structural solutions shall be that volumes of decommissioned waste are to be limited. Guide YVL 7.18 calls for selection of such construction materials that limit the degree of activation and spread of contamination and makes decontamination of surfaces feasible.

Interim storage facilities for spent fuel are available at the Loviisa and Olkiluoto sites. Both are wet-type storages. At the Loviisa plant, spent fuel was earlier transported back to Russia. Amendment of the Nuclear Energy Act issued in 1994 requires that spent fuel generated in Finland has to be treated, stored and disposed of in Finland. Accordingly, spent fuel shipments to Russia were terminated at the end of 1996, and an extension of the spent fuel storage facility was completed in 2000 at the Loviisa site. The extension part of the storage was completed in 2000. At both sites, additional storage capacity still needs to be constructed by early 2010's.

By the end of the year 2003 the spent fuel accumulation at the Finnish NPPs was about 1350 tons of uranium.

For taking care of the spent fuel final disposal, a joint company Posiva Oy has been established by Fortum and Teollisuuden Voima Oy. Research, development and planning work for spent fuel disposal is in progress and the disposal facility is envisaged to be operational in about 2020. The repository will be constructed in the vicinity of the Olkiluoto NPP site. To confirm the suitability of the site, construction of an underground rock characterisation facility was commenced in mid-2004. Finnish Parliament has endorsed a Decision-in-principle made by the Government for the implementation of Finnish Disposal Facility to the Olkiluoto site.

Safety regulation for spent fuel disposal are included in the Government Decision 478/1999 and STUK's Guides YVL 8.4 and YVL 8.5.

To ensure that the financial liability for future spent fuel and nuclear waste management and decommissioning of NPPs is covered, the utilities are obliged to set aside the required amount of money each year to the State Nuclear Waste Management Fund. At the end of 2003 the funded money covered the whole liability, 1 338 million euros.

A detailed description of spent fuel and radioactive waste management and related regulation is included in the Finnish National Report on the Safety of Spent Fuel Management and Radioactive Waste Management (STUK-B-YTO 223, April 2003).

In conclusion, Finnish regulations and practices are in compliance with Article 19.

2.16 Concluding summary on the fulfilment of the obligations

In the above the implementation of the obligations of the Convention, Articles 4 and 6 to 19, is evaluated. Based on the evaluation it can be concluded that Finnish regulations and practices continue to be in compliance with the obligations of the Convention.

Safety improvements have been annually implemented at the Loviisa and Olkiluoto plants since their commissioning. There exists no urgent need for additional improvements to upgrade the safety of these plants in the context of the Convention.

3 Planned activities to improve safety

3.1 Challenges for future work

The Finnish regulatory control system includes both periodic safety review and continuous safety review processes. Actions for safety enhancement are to be taken whenever they can be regarded as justified, considering operating experience, the results of safety research and the advancement of science and technology. In the following some specific issues and challenges for future work in Finland are presented.

Qualification of non-destructive testing

The reliability of NDT systems taking into account also the small amount of independent and competent personnel resources requires special attention in Finland. International activities and co-operation will be closely followed (see Chapter 2.10.5).

Reliability of digital automation

Practical implementation of the new safety requirements and procedures to ensure adequate reliability of digital instrumentation and control systems in the modernization project of the operating power plants and the new nuclear power plant in planning can be considered as one of the major challenges for the next ten years. This includes also the issues related to the digital control rooms.

Provision for plant ageing

Ageing issues in Finnish nuclear power plants have already been addressed. However, recent operating experience has shown that this area requires further attention. It is also recognised that ageing effects will reveal technical challenges in the future for which there need to be expertise available to cope with potential problems. The issue of ageing has also been included into the national Finnish research programme on nuclear power plant safety (FINNUS).

Maintaining competence

Based on the evaluation of human resources in the nuclear field in Finland, further measures are needed during the next 5 to 10 years in order to avoid loosing competence. Finnish organisations have started co-operation to provide professional training in nuclear safety. These measures need to be enhanced further in the specific fields where the resource basis is narrow.

4 Conclusions on benefits from the first review meetings

The Convention on Nuclear Safety is the first legally binding international instrument for nuclear safety in countries that have ratified it. The content of the Convention is consistent and covers well the safety concerns connected to the use of nuclear energy. The Convention calls for regular reporting on how its various articles have been implemented in the participating countries and communities.

In Finland the Convention was cordially welcomed, and Finland was also among the first signatories of it. Based on the experience gained during and after the First Review Meeting in 1999, it can be said that this international legal instrument can be – and it is foreseen to be case also in future – a very powerful tool for enhancing the safety of the nuclear community.

In Finland the Convention and the review mechanism included in it are considered fruitful i.e. for the following reasons:

- The preparation of the national reports requires a certain amount of self-evaluation. Some shortages and development needs of the own regulatory framework are fixed and managed before reporting the situation to the international community.
- The preparation of the review report – if prepared in co-operation with national regulators, the nuclear industry and licensees, and the technical support organisations – contributes to the establishment of a common national understanding on prioritising the important safety issues.
- The reports, as such, form a comprehensive database of nuclear programmes not only in the own country but also in the sense of providing information on other countries' frameworks and programmes. Many Contracting Parties have made their reports available through the Internet, but also others could be encouraged to do the same. In this also the IAEA could provide assistance as needed.
- The publication of reports provides for transparency, which is in today's world one of the basic requirements for gaining general acceptability for using nuclear power. Furthermore, the openness in reporting can be considered to be one expression of a well-developed safety culture.
- Confidentiality of discussions during the review meetings is essential for providing an effective and direct atmosphere for the experts to change views on the prioritisation of safety issues and regulatory policies. Also the way of public reporting of the results of review meetings without making comparisons between contracting parties and without pointing out any countries together with some country-specific needs to enhance the safety level of their nuclear facilities is a necessity for an effective review process.

Taking into account the discussions and observations in the First and Second Review Meeting, the following list of items requiring further actions was prepared and responded. The list was also published on the Internet after the First Review Meeting.

- Reassessment of the requirements for modifications planned by the power company and their independent verification (see Article 14).
- Reassessment of the procedures and requirements for the submission of documents to authorities for approval and information (see Article 7).
- Assessment of the degree of detail and control of the regulatory guides and other regulations (see Article 7).
- Incorporation of safety culture related know-how into a uniform national programme (see Article 10).
- Development of the methods for evaluating the appropriateness and functionality of the oversight of licensee organisations and strengthening the control and resources in this sector (see Articles 8 and 10).

- Enhancement of the plant modification database with adequate technical data (see Article 14).
- Training to increase awareness and consideration of seismic risks at the nuclear facilities and updating of the requirements related to the control (see Articles 14 and 17).
- Development and maintenance of STUK's Quality System and benchmarking with other regulators (see Article 13)
- Evaluation of the independence of the technical support to STUK (see Article 8).

These items are also discussed in this report under Articles 6–19, as indicated in brackets.

The Second Review Meeting did not rise any specific points to be corrected in Finland. The Summary Report of Second Review Meeting listed several specific issues that are wished to be addressed in the third National Report. These issues have been described in the report as follows (number refers to the corresponding Article):

- Information on regulatory practices such as effectiveness of quality management, regulatory guidance, adequacy of TSO support, open and proactive policy of providing information to the public, international co-operation (Art. 7, 8, 13);
- Inspection, monitoring and assessment of the operational safety of nuclear installations through the use of performance indicators, analysing important events in nuclear installations taking into account human performance and organizational issues; safety management and safety culture; trends in occupational doses and releases to the environment; periodic safety reviews, safety of on-site radioactive waste management (Art. 8, 10, 12, 13, 14, 15, 19);
- Information on maintaining competence, simulator training and plant specific simulators, as well as results of national and international emergency exercises (Art. 8, 11, 12 16);
- Further and more detailed information on the status of safety improvement programmes, back fitting of NPPs to meet the current standards, information on periodic safety reviews and operating licence renewals, role of advanced safety assessment methods such as PSA and updated safety analysis reports, measures for severe accident management and containment issues, operating procedures, including symptom based procedures, and guidelines for severe accident management (Art. 6, 14, 17, 18, 19);
- Information on provisions in place for financing safety improvement programmes; status of decommissioning plans and funds (Art. 11);
- Addressing design principles with respect to new reactor concepts (Art.17, 18).

As a conclusion, in Finland the First and Second Review Meetings were considered very fruitful and it is believed that the Third Review Meeting will also follow the same lines.

ANNEX 1 List of main regulations

Legislation (as of 1.9.2004)

1. Nuclear Energy Act (990/1987)
2. Nuclear Energy Decree (161/1988)
3. Act on Third Party Liability (484/1972)
4. Decree on Third Party Liability (486/1972)
5. Radiation Act (592/1991)
6. Radiation Decree (1512/1991)
7. Regulations for the Safety of Nuclear Power Plants (395/1991)
8. Regulations for Physical Protection of Nuclear Power Plants (396/1991)
9. Regulations for Emergency Response Arrangements at Nuclear Power Plants (397/1991)
10. Regulations for the Safety of a Disposal Facility for Reactor Waste (398/1991)
11. Regulations for Safety of Disposal of the Spent Fuel (478/1999)
12. Act and Decree on the Finnish Centre for Radiation and Nuclear Safety (1069/1983 and 1515/1991)
13. Decree on Advisory Committee on Nuclear Safety (164/1988)
14. Decree on Advisory Committee on Nuclear Energy (163/1988)

YVL Guides (per 1.9.2004)

General guides

YVL 1.0 Safety criteria for design of nuclear power plants, 12 Jan. 1996

YVL 1.1 Finnish Centre for Radiation and Nuclear Safety as the regulatory authority for the use of nuclear energy, 27 Jan. 1992

YVL 1.2 Documents pertaining to safety control of nuclear facilities, 11 Sept. 1995

YVL 1.3 Mechanical components and structures of nuclear power facilities. Approval of testing and inspection companies, 17 Mar. 2003 (available only in Finnish)

YVL 1.4 Quality assurance of nuclear power plants, 20 Sep. 1991

YVL 1.5 Reporting nuclear facility operation to the Radiation and Nuclear Safety Authority, 8 Sept. 2003 (available only in Finnish)

YVL 1.6 Nuclear power plant operator licensing, 9 Oct. 1995

YVL 1.7 Functions important to nuclear power plant safety, and training and qualification of personnel, 28 Dec. 1992

YVL 1.8 Repairs, modifications and preventive maintenance at nuclear facilities, 2 Oct. 1986

YVL 1.9 Quality assurance during operation of nuclear power plants, 13 Nov. 1991

YVL 1.10 Requirements for siting a nuclear power plant, 11 July 2000

YVL 1.11 Nuclear power plant operating experience feedback, 22 Dec. 1994

YVL 1.12 INES classification of events at nuclear facilities, 16 Jan. 2002 (available only in Finnish)

YVL 1.13 Nuclear power plant outages, 9 Jan. 1995

YVL 1.14 Mechanical equipment and structures of nuclear facilities. Control of manufacturing, 4 Oct. 1999

YVL 1.15 Mechanical components and structures in nuclear installations, Construction inspection, 19 Dec. 1995 (available only in Finnish)

YVL 1.16 Control of nuclear liability insurance policies, 22 March 2000 (available only in Finnish)

Systems

YVL 2.0 Systems design for nuclear power plants, 1 July 2002

YVL 2.1 Nuclear power plant systems, structures and components and their safety classification, 26 June 2000

YVL 2.2 Transient and accident analyses for justification of technical solutions at nuclear power plants, 26 Aug. 2003 (available only in Finnish)

YVL 2.4 Primary and secondary circuit pressure control at a nuclear power plant, 18 Jan. 1996

YVL 2.5 The commissioning of a nuclear power plant, 29 Sept. 2003 (available only in Finnish)

YVL 2.6 Seismic events and nuclear power plants, 19 Dec. 2001

YVL 2.7 Ensuring a nuclear power plant’s safety functions in provision for failures, 20 May 1996

YVL 2.8 Probabilistic safety analysis in safety management of nuclear power plants, 20 May 2003

Pressure equipment

YVL 3.0 Pressure equipment for nuclear facilities, 9 Apr. 2002 (available only in Finnish)

YVL 3.1 Construction plan for nuclear facility pressure vessels, 27 May 1997 (available only in Finnish)

YVL 3.3 Nuclear power plant pressure vessels. Control of piping, 4 Dec. 1996

YVL 3.4 Nuclear power plant pressure equipment. Acceptance of manufacturer, 14 Jan. 2004 (available only in Finnish)

YVL 3.5 Ensuring the firmness of pressure vessels of a NPP, 5 April 2002 (available only in Finnish)

YVL 3.7 Pressure vessels of nuclear facilities. Commissioning inspection, 12 Dec. 1991

YVL 3.8 Nuclear power plant pressure equipment. In-service inspection with non-destructive testing methods, 22 Sept. 2003

YVL 3.9 Nuclear power plant pressure vessels. Construction and welding filler materials, 6 April 1995 (available only in Finnish)

Buildings and structures

YVL 4.1 Concrete structures for nuclear facilities, 22 May 1992

YVL 4.2 Steel structures for nuclear facilities, 19 Dec. 2001 (available only in Finnish)

YVL 4.3 Fire protection at nuclear facilities, 1 Nov. 1999

Other structures and components

YVL 5.1 Nuclear power plant diesel generators and their auxiliary systems, 23 Jan. 1997 (available only in Finnish)

YVL 5.2 Electrical power systems and components of nuclear facilities, 24 June 2004 (available only in Finnish)

YVL 5.3 Regulatory control of nuclear facility valves and their actuators, 7 Feb. 1991

YVL 5.4 Supervision of safety relief valves in nuclear facilities, 6 April 1995 (available only in Finnish)

YVL 5.5 Instrumentation systems and components at nuclear facilities, 13 Sept. 2002

YVL 5.6 Ventilation systems and components of nuclear power plants, 23 Nov. 1993

YVL 5.7 Pumps at nuclear facilities, 23 Nov. 1993

YVL 5.8 Hoisting appliances and fuel handling equipment at nuclear facilities, 5 Jan. 1987

Nuclear materials

YVL 6.1 Control of nuclear fuel and other nuclear materials required in the operation of nuclear power plants, 19 June 1991

YVL 6.2 Design bases and general design criteria for nuclear fuel, 1 Nov. 1999

YVL 6.3 Regulatory control of nuclear fuel and control rods, 28 May 2003 (available only in Finnish)

YVL 6.4 Transport packages for nuclear material and waste, 9 October 1995

YVL 6.5 Supervision of nuclear fuel transport, 12 October 1995 (available only in Finnish)

YVL 6.7 Quality management of nuclear fuel, 17 Mar. 2003 (available only in Finnish)

YVL 6.8 Handling and storage of nuclear fuel, 27 Oct. 2003 (available only in Finnish)

YVL 6.9 The national system of accounting for and control of nuclear material, 23 Sept. 1999 (available only in Finnish)

YVL 6.10 Reports to be submitted on nuclear materials, 23 Sept. 1999 (available only in Finnish)

YVL 6.11 Physical protection of nuclear power plants, 13 July 1992 (available only in Finnish)

YVL 6.21 Physical protection of nuclear fuel transports, 15 Feb. 1988 (available only in Finnish)

Radiation protection

YVL 7.1 Limitation of public exposure in the environment of and limitation of radioactive releases from nuclear power plants, 14. Dec. 1992

YVL 7.2 Assessment of radiation doses to the population in the environment of a nuclear power plant, 23 Jan. 1997

YVL 7.3 Calculation of the dispersion of radioactive releases from a nuclear power plant, 23 Jan. 1997

YVL 7.4 Nuclear power plant emergency preparedness, 9 Jan. 2002 (available only in Finnish)

YVL 7.5 Meteorological measurements of nuclear power plants, 28 May 2003 (available only in Finnish)

YVL 7.6 Monitoring of discharges of radioactive substances from nuclear power plants, 13 July, 1992

YVL 7.7 Radiation monitoring in the environment of nuclear power plants, 11 Dec. 1995

YVL 7.8 Environmental radiation safety reports of nuclear power plants, 11 Dec. 1995 (available only in Finnish)

YVL 7.9 Radiation protection of nuclear power plant workers, 21 Jan. 2002 (available only in Finnish)

YVL 7.10 Monitoring of occupational exposure at nuclear power plants, 29 Jan. 2002 (available only in Finnish)

YVL 7.11 Radiation monitoring systems and equipment in nuclear power plant, 13.7.2004 (available only in Finnish)

YVL 7.18 Radiation protection aspects in the design of NPPs, 26 Sept. 2003 (available only in Finnish)

Radioactive waste management

YVL 8.1 Disposal of low and intermediate level waste from the operation of nuclear power plants, 10 Sept. 2003

YVL 8.2 Premises for removal of regulatory control from nuclear waste, 25 March 2002

YVL 8.3 Treatment and storage of radioactive waste at a nuclear power plant, 20 Aug. 1996

YVL 8.4 Long term safety of disposal of spent nuclear fuel, 23 May 2001

YVL 8.5 Operational safety of a disposal facility for spent nuclear fuel, 23 Dec. 2002

Only the guides without a language marking are available in English.
The guides are available on the Internet at www.stuk.fi/english.

ANNEX 2 Application of Defence in Depth Concept in Finnish NPPs

Defence in Depth concept and severe accident management in the Loviisa NPP

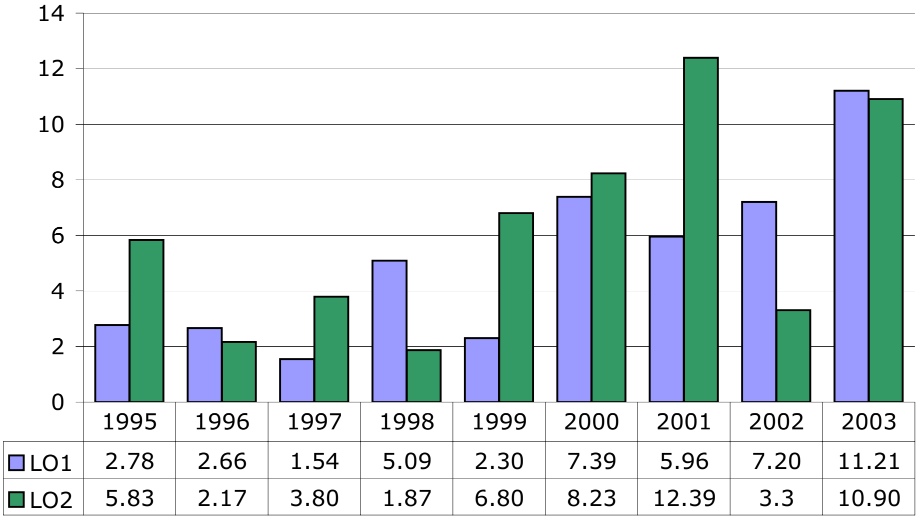
Levels of protection in the Loviisa NPP

Decision 395/1991 requires that in design, construction and operation proven or otherwise carefully examined high quality technology shall be employed to prevent operational transients and accidents (preventive measures). A nuclear power plant shall encompass systems by the means of which operational transients and accidents can be quickly and reliably detected and the aggravation of any event can be prevented. Accidents leading to extensive releases of radioactive materials shall be highly unlikely (control of transients and accidents). Effective technical and administrative measures shall be taken for the mitigation of the consequences of an accident. Counter-measures for bringing an accident under control and for preventing radiation hazards shall be planned in advance (mitigation of consequences). Detailed requirements are given in Guides YVL 1.0 and YVL 1.4.

The Loviisa 1 and 2 units have operated reliably. The number of the occurred incidents significant to safety has remained small. Incidents have been dealt with in quarterly reports issued by STUK. Important events such as failures of equipment, preventive maintenance and deviation from the Operational Limits and Conditions cause unavailability of safety important components. Figure 19 presents the effect of this unavailability to the total accident risk. STUK has set a goal value of 5% of the total accident risk to the equipment unavailability. The goal value was exceeded during 2003 because of latent failures of diesel generators and preventive maintenance of additional emergency feedwater system.

In addition to the structure of the plant, the quality of operating activities has also an essential effect on preventing transient and accidents. Quality assurance related to operating instructions,

Risk contribution of the safety system unavailability at Loviisa (percentage of the average annual core damage risk)



	1995	1996	1997	1998	1999	2000	2001	2002	2003
🟦 LO1	2.78	2.66	1.54	5.09	2.30	7.39	5.96	7.20	11.21
🟩 LO2	5.83	2.17	3.80	1.87	6.80	8.23	12.39	3.3	10.90

Figure 19. Share of the accident risk caused by the unavailability of equipment at the Loviisa NPP.

other plant instructions and operating activities has been developed by Fortum continuously in recent years. In the training of the staff, the importance of recognising the instructions and quality assurance programme has been emphasised. The inspection programme of STUK concerning the operation of a nuclear power plant includes several inspections which are concentrated on procedures and methods followed in operating activities.

Guide YVL 1.0 requires that a nuclear power plant is equipped with a protection system. Loviisa 1 and 2 are provided with the protection systems which comprise a reactor protection system and a plant protection system. The duty of the protection systems is to initiate automatically the needed safety functions, if some quantity important to safety essentially deviates from its normal value. The duty of the reactor protection system is to initiate the shutdown of the reactor. The most important of the functions initiated by the plant protection system are emergency core cooling, decay heat removal and containment functions. For these functions Loviisa 1 and 2 are equipped with the necessary safety systems.

The reactor protection system is realised by using relay techniques, and the plant protection system by using conventional electronics. The techniques employed are proven, but is already getting obsolete. The design and implementation of the reactor protection system are based on those solutions on which the plant supplier had got experiences from earlier constructed VVER-type plants. The reliability of the system has been improved based on experiences by replacing some components with more reliable ones, and by adding new components in the system to ensure the function also in the case of a common-cause failure of the redundant components. The tests and operational experiences of the plant protection system show that the solutions employed until now have been appropriate.

The renewal of the plant automation is in preparatory stage. The aim of the renewal is to ensure that automation systems will not restrict the safe and economic operation of the plant to the end of planned life time. Maintenance of the current automation systems would not be possible still more than 20 years. The systems would be over-aged and the availability of spare parts would be very difficult. The renewal will cover nearly the whole automation; including control room, safety automation, operational automation and training simulator. Valve actuators and part of sensors and field cabling will remain. There will be only minor changes in the functions of automation. The new automation will be based on digital technology.

The renewal project started in 1999 with strategic study. The invitation to tender was published in December 2002. Two candidates for the supplier were selected in June 2003. The supplier of the two first stages will be selected by the end of 2004. A new commercial competition will be arranged for stages 3 and 4.

Licensing of the renewal is an essential part of the project and it was started at early stage of the project by providing information on planned schedule and design principles to STUK. In January 2004 the conceptual design plans of the renewal developed together with both candidates were delivered to STUK. Preparation of the more detailed pre-inspection documents for STUK inspection will be started when the supplier has been selected.

The installation of the new automation will be realized during the almost normal maintenance periods of the units. For this reason there will be several stages of the renewal. The installation work will start in summer 2006 at unit 1. The renewal work at unit 2 will follow 1-2 years later. Stages 1 and 2 will be completed in summer 2010. Stages 3 and 4 are planned to be completed in summer 2014.

The protection systems fulfil the fail safe principle required by Guide YVL 1.0. It means that each subsystem settles in a state requiring protection, if any of its components fails.

For mitigating the consequences of the postulated accidents taken into account in the design of the Loviisa plant, the plant has been equipped with the appropriate safety systems. In addition, the operators of the plant have available procedures for transient and accident situations. These procedures have been evaluated by STUK. Emergency Plan is a document approved by STUK. It includes i.e. the definitions of duty and responsibility areas for accident situations. Regular exercises are carried out for testing planned emergency preparedness activities.

Major amounts of radioactive materials could be releases to the environment mainly in severe accidents.

Technical barriers for preventing the dispersion of radioactive materials in the Loviisa NPP

Decision 395/1991 requires that dispersion of radioactive materials from the fuel of the nuclear reactor to the environment shall be prevented by means of successive barriers which are the fuel and its cladding, the cooling circuit (the primary circuit) of the nuclear reactor and the containment building. Detailed provisions on the integrity of the technical barriers are also given in the Decision 395/1991.

During the operation of a nuclear power plant, radioactive materials are mainly produced as the result of uranium nuclei fissions in the fuel pellets, made from uranium dioxide. The uranium dioxide matrix creates as such the first barrier for preventing the dispersion of radioactive materials. During normal operational conditions, when the temperature of uranium dioxide does not rise abnormally high, the great majority of fission products remain inside the fuel pellets (in matrix).

As regards the Loviisa 1 and 2 nuclear fuel, the uranium dioxide pellets have been loaded in cladding tubes, the external diameter of which is about 9 mm. The cladding tubes have been hermetically plugged by welding and fabricated as fuel assemblies, each comprising of 126 fuel rods. Based on its properties the cladding material is well suited for the reactor conditions, and it also fulfils the abnormal durability requirements caused by high temperatures.

Next barrier following nuclear fuel (uranium dioxide matrix and surrounding hermetic cladding tube), for preventing the dispersion of radioactive materials, is the pressure-retaining barrier of the primary circuit. The main components of the primary circuit (the reactor pressure vessel, steam generators, pressurizer, piping) have been manufactured from stainless steel, or from carbon steel with a stainless steel cladding.

A basis for the primary circuit design was that releases to the environment would remain within the set limits, although about one percent of the fuel rods in the reactor (of about 40 000 fuel rods altogether) would lose their cladding integrity during normal operational conditions. The water treatment system of the primary circuit has been equipped with filter devices by means of which fission products released in the coolant can be filtered and removed. This concerns also corrosion products, which have been activated by neutron radiation and which are moving in the primary circuit.

Current requirements for the basic dimensioning of the primary circuit as well as of the fuel assemblies are mainly similar as in the construction stage of the plant.

The whole primary circuit is inside the hermetic containment, made from steel plates. The steel containment is surrounded by a concrete cylindrical secondary containment. The secondary containment has a light roof structure supported by a steel frame. A low pressure is held in the space between the primary and secondary containment. The space has been equipped with a filtered ventilation system for reducing possible releases of radioactive materials in accident situations.

The containment was not originally designed for severe reactor accidents. Measures to mitigate the consequences of severe accidents have been implemented later.

Ensuring fuel integrity

Decision 395/1991 requires that the probability of significant degradation of fuel cooling or of a fuel failure due to other reasons shall be low during normal operational conditions and anticipated operational transients. During postulated accidents, the rate of fuel failures shall remain low and fuel coolability shall not be endangered. The possibility of a criticality accident shall be extremely low. Detailed requirements are given in Guides YVL 1.0, YVL 2.2 and YVL 6.2.

An essential objective of the modernisation of Loviisa 1 and 2 was the increase of the reactor thermal power by 9 percent units. The increase was implemented without changing the current fuel thermal margins. This resulted in that the power increase had no essential effects on the behaviour of the fuel and reactor during normal operational conditions, anticipated transient and postulated accidents.

Fuel cladding has been fabricated from a zirconium-niobium alloy. The fuel manufacturers have a significant amount of experiences on its use as a fuel rod cladding material. The experiences extend to 1960’s. The results of operational experiences and hot cell examinations, received from the manufacturers, could be confirmed by means of spent fuel examinations carried out at the plant. The oxide layer on the fuel cladding, caused by corrosion, remains very thin, and the ductility properties of the material remain sufficient for the fuel operation life.

Measurement results on fission gas amounts, released in fuel rods from fuel pellets, have been received from the fuel manufacturer. These results have also been assessed with analytical methods. In addition, supplementary measurement results have been received on fuel assemblies irradiated at the Loviisa plant. Based on these results and analyses the release rate of fission gases can be considered to be adequately small at the current operation mode of the reactor.

The fuel integrity in transient situations related to the normal reactor operation is ensured by the limitations on power change rates. These limitations are mainly based on studies carried out at research reactors as well as on operating experiences received from Russia and other countries.

Based on the current operating experiences of the Loviisa plant, the probability of fuel failures can be considered to be very small during normal operational conditions (see Figure 20). The structure of the fuel assemblies and rods has been developed step by step based on accumulated experiences. The current upper part design of the fuel assemblies takes properly into account the elongation of fuel rods during the operation – the elongation is bigger than originally considered. The manufacturing process of fuel pellets has been changed. The inner pressure of fuel rods has been increased. The material of fuel assembly spacers is a zirconium based alloy. All these changes have had a favourable effect on the fuel integrity during normal operational conditions, anticipated transients and postulated accidents. In Figure 20, the peak value in 1995 was caused by the decontamination work carried out for the primary circuit.

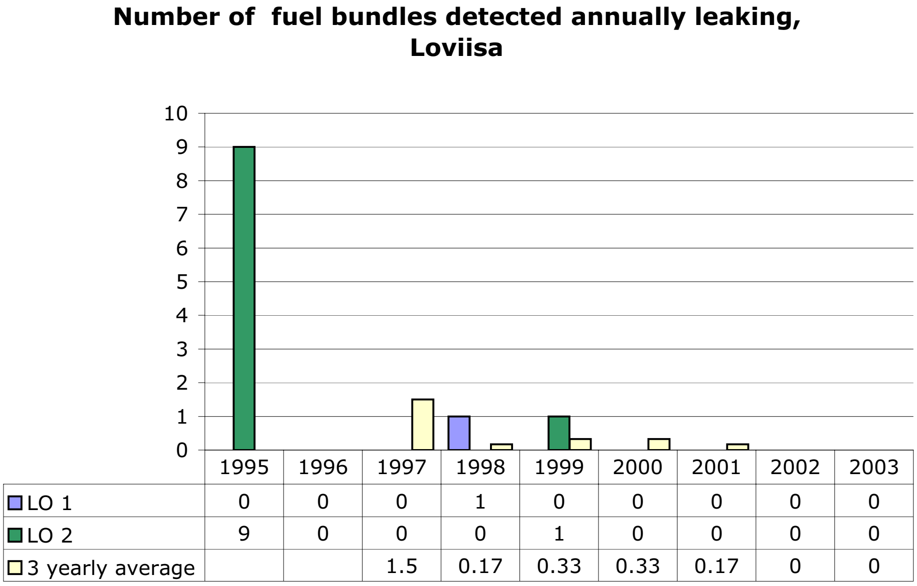
Several fuel assemblies were clogged at Loviisa 2 during 1994–1995 after the decontamination of the primary circuit. Some of the assemblies were consequently damaged due to fretting failures caused by clogging induced vibrations. After this incident the fuel failure rate has been almost non-existent.

The probability of a significant degradation of fuel cooling (heat transfer crisis) is very low at Loviisa 1 and 2. This depends mainly on the favourable relations between the fuel gross and linear power as well as the primary and secondary coolant flow rates, coolant amounts and related time constants. This is indicated e.g. by a fairly big dryout margin during a stationary state.

Based on the reasons mentioned above heat transfer crisis is very improbable during anticipated transients.

Related to the postulated accidents fuel failures would mainly be expected in loss of coolant accidents, in an accident concerning a control rod ejection and in an ATWS-accident. Related to these accidents, analyses have shown that the plant complies with the appropriate acceptance criteria.

One basic objective is to prevent transients



	1995	1996	1997	1998	1999	2000	2001	2002	2003
🟦 LO 1	0	0	0	1	0	0	0	0	0
🟩 LO 2	9	0	0	0	1	0	0	0	0
🟨 3 yearly average			1.5	0.17	0.33	0.33	0.17	0	0

Figure 20. Number of leaking fuel bundles at the Loviisa NPP.

leading to an unintended criticality of the reactor and/or to a reactivity increase. The possibility and importance of malfunctions resulting in the dilution of the boron solution – boron is used as a reactivity poison – and of the inner dilution of the boron concentration in connection with some accident types have been evaluated. Based on calculations, significant plant modifications have been done for preventing the sudden dilution of the boron content. Major modifications are described later on.

The reliability of the reactor core and containment emergency cooling systems during an accident has been improved by replacing the containment emergency sumps of the systems. Heat insulator materials, damaged in a loss of coolant accident, would have blocked the reactor emergency cooling and decay heat removal, if the material had drifted to the original sumps. The need for the modification was discovered in the analyses, which were started based on a foreign operating event.

Ensuring primary circuit integrity

Decision 395/1991 requires that the primary circuit of a nuclear reactor shall be designed so that the stresses imposed upon it remain, with sufficient confidence, below the values defined for structural materials for preventing a fast growth crack during normal operational conditions, anticipated operational transients and postulated accidents. The possibility of a primary circuit break due to other reasons shall be low, too.

The most important components of the primary circuit of Loviisa 1 and 2 are the reactor pressure vessel, pressurizer, main circulation piping, primary collector and heat transfer piping of the steam generators, reactor coolant pumps, main isolation valves and those piping which have a direct connection to the reactor pressure vessel. Requirements for the construction plan of the primary circuit components are given in Guides YVL 3.1, YVL 3.3, YVL 5.3 and YVL 5.4. According to these Guides, the components in Safety Class 1 shall be dimensioned as required by the standard ASME Boiler and Pressure Vessel Code, Section III, or in other way resulting in the same safety level. The primary circuit components of the Loviisa 1 and 2 units have been designed according to a Russian standard concerning nuclear power plants, except the reactor coolant pump, which has been designed according to ASME III. As regards brittle fracture assessments, the old Russian standard from the year 1973 included deficiencies. Otherwise these two standards do not essentially deviate from each other as regards the dimensioning.

During the manufacturing of the Loviisa 1 and 2 pressure vessels systematic quality assurance activities could not be implemented in the way required by YVL Guides. The licensee tried to ensure the quality by compensatory measures. The resulting deficiencies cause some uncertainties in the evaluation of the pressure vessels embrittlement.

The reactor pressure vessel has been manufactured from a low alloy CrMoV-steel, and it has an inner cladding made from austenitic stainless steel. After the three year operation of Loviisa 1 it was noted, based on the examinations of material samples irradiated inside the pressure vessel that the material of the circular weld joint at the level of the reactor core became brittle faster than anticipated. The observation was made before the commissioning of Loviisa 2. Neutron radiation produced in the reactor core increases the critical temperature around which the ductility of the reactor pressure vessel quickly decreases, when the temperature drops. During the normal operating temperature safety is not endangered. However, in some transient and accident conditions cold water is injected in the primary circuit, and the danger of the sudden brittle fracture of the pressure vessel increases, if there are cracks in the pressure vessel.

The integrity of the pressure vessel in the conditions mentioned above has been evaluated by means of thermo-hydraulic and fracture-mechanical calculations. For decreasing the dose rate of fast neutrons 36 fuel assemblies on the perimeter of the reactor core have been replaced by steel elements. Several modifications of the plant have been implemented for reducing loads and decreasing their probabilities. For preventing a cold pressurisation during outages, primary circuit relief valves functioning in a low pressure have been installed at the units. In addition, the best non-destructive testing methods have been used for finding out possible cracks.

Fortum has made both deterministic and probabilistic safety analyses concerning the Loviisa 1 and 2 reactor pressure vessels. Both analyses fulfil the acceptance criteria set for them.

The brittle weld joint of the Loviisa 1 reactor pressure vessel was heat-treated during the 1996 annual outage for improving the ductility properties of the welding material. In this connection the reactor pressure vessel was subject to thorough non-destructive tests. The use of the reactor pressure vessel has been accepted so far until the 2004 annual outage.

Embrittlement rate has been re-assessed based on the new surveillance programme representing the critical weld. Analysis results were given to STUK for acceptance in the beginning of 2004 and Fortum was granted a permission to use the reactor pressure vessel until 2012.

Based on the smaller contents of impurities in the critical welding material the use of the Loviisa 2 reactor pressure vessel has been accepted until 2010. So the service life of the pressure vessel is 30 years also without a heat-treatment.

Other pressure-retaining components of the primary circuits of Loviisa 1 and 2 have been manufactured from austenitic stainless steel or carbon steel which has an austenitic stainless steel cladding. A safety factor for deformations is at least 1.5. So the size of a crack resulting in a sudden break is so big that the crack can, with great confidence, be detected either as a small leakage or be found out in in-service inspections. Based on the material selections, common corrosion wearing wall thicknesses can't occur in the primary circuit.

The effect of the power increase on the primary circuit integrity is very minor, because the operating pressure isn't changed and the operating temperature is increased only by few degrees. The flow rate of the primary circuit remains almost unchanged. The power increase raises the fast neutron dose of the reactor pressure vessel, and it has been taken into account in the safety analyses.

The primary circuit over-pressure protection was made more effective in 1996 by installing new safety valves which have been demonstrated to function both with water, steam, and with a compound of water and steam.

Erosion corrosion failures were detected in the original feedwater distributors on the secondary side of the steam generators. Although the direct safety significance of these failures is minor, Fortum decided to replace the feedwater distributors. The new feedwater distributors are of a new type. They are located on the pipe assembly of the steam generator which is a different place than the original one. In this connection Fortum has extensively studied different distributors, as an objective a structure which is as undisturbed as possible. As a result of the new location of the distributor, heat fatigue may be possible in the steam generator pipes during some accident situations. This has been exactly examined. The final design was accepted, and the last new distributor was installed in 2002.

The original fatigue analyses of the components have been carried out a 30 years service life as a basic assumption. The number of different loading situations has been evaluated for the analyses based on this service life. The frequency of the occurred loadings has been essentially smaller than anticipated. The ageing control of the primary circuit components has been made more effective by adopting new plant life management system in 2002.

Ensuring containment integrity

Decision 395/1991 requires that the containment shall be designed so that it will withstand reliably pressure and temperature loads, jet forces and impacts of missiles arising from anticipated operational transients and postulated accidents. Furthermore, the containment shall be designed so that the pressure and temperature created inside the containment as a consequence of a severe accident will not result in its uncontrollable failure. The possibility of the creation of such a mixture of gases as could burn or explode in a way which endangers containment integrity shall be small in all accidents. The hazard of a containment building failure due to a core melt shall also be taken into account in other respect in designing the containment building concept. Detailed requirements are given in Guide YVL 1.0.

The Loviisa 1 and 2 units are provided with the containment in which the increase of the inner pressure caused by steam is limited by ice condensers. The inner spray system of the containment and the treatment systems for burnable gases are an essential part in the provision for mitigating accident situations. The primary, pressure-retaining tight steel containment is surrounded by a secondary building with concrete walls. The purpose of the double structure is to protect the primary containment against external effects, and to enable a low pressure in the space between the buildings with a filtered ventilation system. Releases to the environment, arising from containment leaks, can be decreased in this way in accident situations.

Figure 21 shows the results of leakage measurements of isolation valves and penetrations of the containment during the annual outage periods. The total leakage is presented as a percentage of the leakage budget.

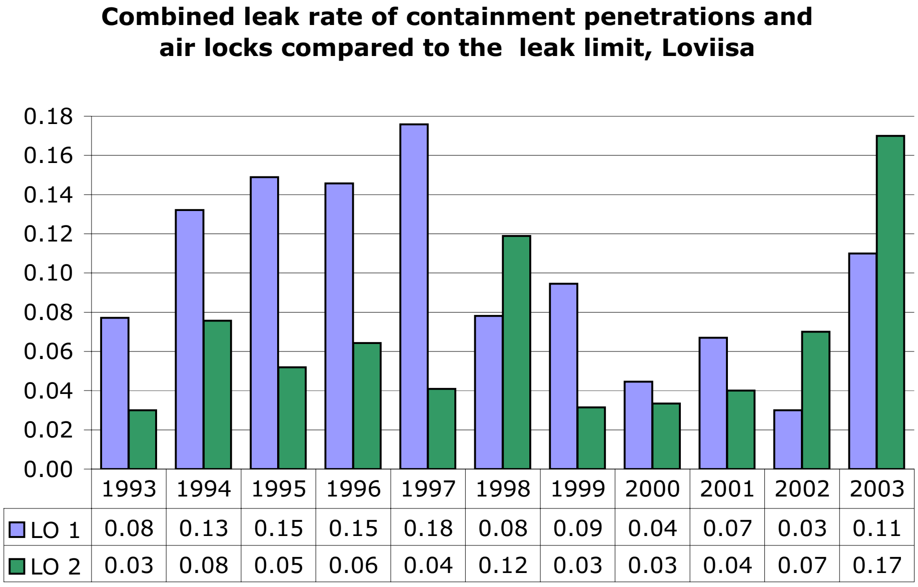
The functioning and tightness of the manholes, penetrations and process lines isolation valves of the containment are verified with regular periodic tests. The tightness of the primary steel containment is verified every forth year with tightness tests. A special periodic testing programme has been established for testing the functions of the auxiliary systems necessary for the overall containment function.

Based on what is presented above, it can be concluded that the containment and to it directly related auxiliary systems have been designed so that the containment withstands reliably pressure and temperature loads, jet forces and impacts of missiles arising from anticipated operational transients and postulated accidents.

The original design bases of the Loviisa 1 and 2 containment systems have not directly included loads arising from severe accidents. Decision 395/1991 and Guide YVL 1.0 require for a severe accident management as regards the containment of new nuclear power plants. Based on a long research and development work Fortum has established a strategy for the severe accident management which is due to the special features of the plant internationally considered unique and innovative in many respects. The essential parts of the strategy are the reliable pressure reduction of the primary circuit, the retaining of melt core in the reactor pressure vessel by cooling the pressure vessel externally, the containment decay heat removal by the external containment spray system and the prevention of a sudden pressurisation (energetic hydrogen deflagrations and detonations) by ensuring with catalytic recombiners the controlled oxidation of hydrogen released in the core meltdown process. The strategic plan also included provisions for instrumentation, automation and electrification which are needed for the implementation of these measures and which are independent from the other operation of the plant. An especially favourable aspect in the Fortum 's overall plan was the aim to take care of the retention of the containment tightness also during severe accidents.

Because the integrity and tightness of the steel containment can be retained, the safety significance of the containment bypass through the process and other systems is emphasised. This fact is also seen in the results of the level 2 PSA.

The external containment spray system was implemented in 1991. The depressurisation capability of the primary system through separate severe accident depressurization valves was implemented in 1996. The plant modifications needed to ensure the reactor pressure vessel external cooling were installed in the year 2000 for Loviisa 1, and in 2002 for Loviisa 2. For the hydrogen control, the installa-



	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
🟦 LO 1	0.08	0.13	0.15	0.15	0.18	0.08	0.09	0.04	0.07	0.03	0.11
🟩 LO 2	0.03	0.08	0.05	0.06	0.04	0.12	0.03	0.03	0.04	0.07	0.17

Figure 21. The total leakage rate through the isolation valves and penetrations at the Loviisa NPP compared to the leakage budget.

tion of passive autocatalytic recombiners has been completed in 2003. Also, the glow plug igniters system, installed originally in the early 1980's has been modified at the same time. In order to ensure efficient mixing of the containment atmosphere thereby efficient hydrogen removal, a specific pneumatic system was installed in 2002 which can be used for forcing the ice-condenser doors open in a severe accident situation.

Ensuring safety functions

Decision 395/199 requires that in ensuring safety functions, inherent safety features attainable by design shall be made use of in the first place. In particular, the combined effect of a nuclear reactor's physical feedbacks shall be such that it mitigates the increase of reactor power. If inherent safety features cannot be made use of in ensuring a safety function, priority shall be given to systems and components which do not require an off-site power supply or which, in consequence of a loss of power supply, will settle in a state preferable from the safety point of view. Systems which perform the most important safety functions shall be able to carry out their functions even though an individual component in any system would fail to operate and additionally any component affecting the safety function would be out of operation simultaneously due to repairs or maintenance. A nuclear power plant shall have on-site and off-site electrical power supply systems. The execution of the most important safety functions shall be possible by using either of the two electrical power supply systems. Safety systems which back up each other as well as parallel parts of safety systems shall be separated from each other so that their failure due to an external common cause failure is unlikely. In ensuring the most important safety functions, systems based on diverse principles of operation shall be used to the extent possible. Detailed requirements are given in Guides YVL 1.0, YVL 2.1 and YVL 2.7.

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

Inherent reactor-physical feedbacks have been made use of in the design of the Loviisa 1 and 2 reactors and their reloading so that each physical feedback separately, and thus their combined effect, mitigates the increase of reactor power during transient and accident conditions. This is demonstrated analytically as well as experimentally during the start-up of the plant after the reloading outages.

Both the control rods and the reactor boron systems are available for shutting down the reactor. The control rods can be used either by driving them into the reactor by means of a electric motor, or by dropping them into the reactor by gravitation in connection with a reactor scram. If the control rods lose the needed electrical power, they drop into the reactor and shut down it.

The reloading of the Loviisa 1 and 2 reactors have been designed so that the reactor can be shut down with the control rods during normal operational conditions, anticipated operational transient and postulated accidents, although the most effective control rod would not function.

In addition to the control rods, the reactors can be shut down with the boron systems. Boron is used in the coolant for the long-term power control of the reactor. Modifications in the systems and operation mode of the plant have been done for avoiding an unintended boron concentration dilution of the coolant. For example following modifications were implemented:

- In the beginning of the fuel cycle borated water from a dedicated tank is used to dilute primary coolant. The boron content of the water is such that a possible boron dilution transient does not result in a reactivity accident.
- The dilution of the primary coolant will be interrupted in case of primary coolant pump stopping.
- Borating of the primary coolant will be started automatically in case of stopping of 4 or more primary coolant pumps.
- Before starting of a primary coolant pump the loop will be flushed with the counter-current flow through the loop.

The risk of the boron concentration dilution arising from external reasons has been reduced to an acceptable level with these measures. The safety significance of the inner boron dilution during some accident situations has been considered small based on Fortum's extensive assessments.

Decay heat is removed from the primary to the secondary circuit by a gravitation-driven inherent circulation in six similar coolant loops. Heat transferred into the secondary circuit can be further transferred in the sea or to the atmosphere by several different systems. In these systems active components are needed. The driving power of these components is supplied either from the diesel-backed power sources or diesel generators. The additional emergency feedwater system has been equipped with own diesel-operated pumps. The system is partly common to both units. The decay heat removal by the secondary circuit is ensured in a versatile and reliable way.

After a possible break in the primary circuit, at the beginning water would be obtained in the primary circuit from the safety accumulator tanks which discharge without external driving power. Later on, decay heat should be removed by means of the active components which need electric energy as a driving power and which mainly are four- redundant.

If the decay heat removal isn't possible through the secondary circuit, there is an alternative way to remove decay heat directly from the primary circuit by a so-called feed and bleed method. In this case, water is injected in the primary circuit with high pressure safety injection cooling pumps. In the primary circuit up-heated water is discharged in the containment by opening the new safety valves of the pressurizer. The valves have a large capacity. Decay heat is removed from the containment by circulation through the sumps by means of the emergency heat transfer chain.

The emergency sump structures of the containment have been completely re-designed after a foreign operational event indicated that the original design had essential deficiencies. A sump blockage would mean the complete loss of the emergency core cooling function. A danger for a blockage occurs, when heat insulators around the primary circuit pipes are damaged during pipe breaks. Due to its characteristics, a damaged insulator material disturbs the sump function much more than previously was believed. The new strainer structures of the sumps have been designed to collect the largest possible amount of damaged insulators without disturbing the emergency core cooling function. This amount has been determined based on the best current knowledge, taking into account also other impurities released simultaneously. In addition, the new sump strainers have been equipped with an instrumentation and a purification system. In this way the build-up of a blockage can be controlled and when necessary the strainers can be purified. So the long-term function is also ensured.

As a result of the sump modification, a need has also been noted to evaluate more closely the functioning of the high pressure safety injection pumps during a sump circulation. The pumps in question have been designed only for pumping clean water, but during the sump circulation they may be exposed to impurity loads, especially at the beginning of the circulation. Fortum has examined the functioning of the pumps with water including insulator-impurities.

Additional tests were performed with a strainer element in order to investigate effects of pressure loss caused by fragmented paint debris, especially with thin fibre beds. Due to increased sump strainer area the amount of fibres penetrating the strainer system would also increase. Therefore high and low head safety injection pumps were tested with fibre concentrations higher than those used in previous tests. The tests for low pressure pumps were performed with different types of shaft seals.

The low pressure safety injection pumps were renewed in 2000–2002. In order to increase the delivery head of the low pressure safety injection system the new pumps have higher head than the original ones. The modification of the low pressure safety injection system included also an increase of the water volume and lowering the pressure of the passive safety accumulators. The goal of these modifications was to improve core cooling by increasing the feeding capacity of the system and lengthen the injection period of the accumulators.

The intermediate circuit of the emergency heat transfer chain has a function to transfer decay heat from the emergency core cooling systems to the sea water. The intermediate circuit has been re-dimensioned, because the original design included faults. According to the revised safety analyses, the sump water accumulating on the containment floor may warm up near to the saturated temperature in some primary coolant leak situations. This increases the heat load to the intermediate circuit, and together with the simultaneous high sea water temperature results in the temperature level increase of 10 degrees in the intermediate circuit. In addition to the decay heat transfer, the intermediate circuit has a function to cool almost all emergency, auxiliary and support systems important to the plant's safety, and their room spaces. The original design temperatures of the most cooling objects of this kind would be exceeded, when the temperature of the intermediate circuit rises. Fortum took immediately measures both to make the functioning of the intermediate circuit more effective and to develop the systems concerned and components to withstand the higher functioning temperature. The needed measures have been designed and mainly implemented. These safety improvements would have been made independently of the plant nominal power.

Plant modifications have been done to ensure the reactor core cooling and decay heat transfer in the case of leaks from the primary side of a steam generator to the secondary circuit. These plant modifications are the construction of a new safety injection water tank common for the both units, the spray pipelines of the pressurizer from the high pressure safety injection pumps and the increases of a protection automation. The management of the primary–secondary leaks is based on the assumption that the steam pipelines integrity is maintained. Pressure shocks endangering the integrity of the steam piping in this situation were evaluated. However, the possibility of the pressure shocks of a dangerous magnitude, in the critical location of the piping from the viewpoint of the accident management, can be evaluated to be so small that the management of the primary–secondary leaks can be considered as acceptable. Emergency operation procedures take into account that the safety valve of the steam generator may stick open in the steam generator collector break.

The functioning of active components is not required to keep the containment pressure and temperature within the design values at the beginning of any design basis accident. In situations during which large amounts of steam leak in the containment, the containment inner spray system is needed to ensure the integrity and functioning of the containment after the melting of the ice in the ice condensers. In this kind of situation decay heat released from the reactor is separately transferred through the emergency core cooling system and intermediate cooling system into the sea water circuit. The functioning of these systems is based on active components which need electric energy as their driving power. Decay heat removal from the containment is also possible to carry out with an external spray system which is directed on the outer surface of the containment. The spray pumps get their driving power from their own diesel generators which are independent of other electric systems of the plant. The tightness of the process penetrations of the containment is ensured with isolation valves, the number of which is mainly two, one is inside and the other outside the containment.

The possibility for a preventive maintenance during the operation is limited for the systems where the number of the redundant components is only two. The needed preventive maintenance requires, however, that from time to time some components are separated from the process. Maximising the operability of systems with a well planned preventive maintenance is a demanding duty. It is subject to Fortum’s continuous attention.

The external electric power supply system of the Loviisa plant comprises two 400 kV and one 110 kV connections to the Finnish base electrical network. In addition to the normal internal electric systems, there are four diesel generators per unit for the emergency supply of electric power as well as battery systems. The plant safety systems have been divided into two subsystems which are separated from each other. Each subsystem is supplied from the external electrical network or from two diesel generators. Each component is supplied from a bus bar connected to a separate diesel generator in those plant systems which comprise four redundant active components, e.g. low and high pressure safety injection pumps.

A 20 kV overhead line connection has also been built to the Loviisa plant from the Ahvenkoski hydro power station, located at the extent of 20 km from the Loviisa plant. This connection can be coupled instead of any diesel generator.

Many electric component modifications have been done at Loviisa 1 and 2 to ensure safety functions. The purpose of these modifications is to ensure the functioning of the safety systems during accident conditions, taking into account the requirements indicated by the revised safety analyses.

Detailed requirements given in the Technical Specifications guide the operation of the units in maintaining continuously the acceptable safety level and in ensuring the necessary safety functions. The requirements of the Technical Specifications are extensive as regards their number as well as very detailed as regards their content, indicating thus the need to compensate system deficiencies resulted from the design bases with strict administrative procedures.

The components needed for the safety functions of Loviisa 1 and 2 are not completely well separated physically, and so a same external cause may result in a failure of redundant components. Therefore, after the commissioning of the plant several modifications have had to be done, mainly as a result of the separation requirements for fire protection. The physical separation of the systems has been further improved based on the results of the probabilistic safety analyses concerning fire and flood risks.

In conclusion, the safety functions of the Loviisa plant have been ensured according to Decision 395/1991 except the following deviations: The functioning of the safety systems has not fully been ensured in case of an individual component is inoperable and additionally other component is out of operation simultaneously due to repairs or maintenance. In addition, the redundant parts of the safety systems have not been fully separated from each other so that their failure as a result of the same external cause would be unlikely.

After the commissioning of the plant, safety functions have been continuously improved by means of studies carried out and plant modifications implemented based on the studies. In addition, the safety systems of the Loviisa units are mainly functionally exceptionally flexible which compensates the above mentioned deficiency concerning the reliability of the safety functions.

Severe Accident Management implementation at Loviisa NPP

The Loviisa severe accident program, which includes plant modifications and severe accident management procedures, was initiated in order to meet the requirements of STUK.

Fortum's approach for severe accident assessment and management for Loviisa is based on four successive levels. The first level of the approach is to ensure that severe accidents can be prevented with high probability. The quantitative targets for the overall core damage frequency (CDF) obtained from PSA level 1, are 10^{-4} /reactor year for existing plants.

The second level is to show a very low fraction of overall CDF for those classes of accident sequences which can be assumed to directly lead to a large release. Such sequences are the ones with an impaired containment system function, high pressure core melt sequences and reactivity accidents leading to core damage. The class called sequences with impaired containment function consists of containment by-pass sequences (especially, primary to secondary leakage accidents), sequences with pre-existing openings, containment isolation failures, containment pressure suppression system by-passes and sequences with induced leakage outside the containment.

On the third level of the approach, the focus is on physical phenomena capable of threatening the containment integrity. The challenge to the containment integrity due to any physical phenomena should be excluded either by excluding the phenomenon itself as physically unreasonable or by showing that the loads caused by the phenomenon are tolerable. The phenomena considered include in-vessel and ex-vessel steam explosions, hydrogen burns, direct containment heating, missiles, slow over pressurization due to steaming and generation of noncondensable gases, core-concrete interaction, recriticality of the degraded core and core debris, and temperature loadings of the containment. It is obvious that plant specific studies are needed for proper treatment of the individual phenomena. Instead of traditional PSA level 2 type of approach, in case of Loviisa, Fortum has treated the main phenomenological, Loviisa-specific questions along the lines of the ROAAM (Risk Oriented Accident Analysis Methodology) approach.

After successful exclusion of the containment system and structural failures, the fourth and final level of the approach is to define the radioactive releases through containment leakages. The releases during the managed accident sequences should stay below the acceptable criteria concerning acute health effects and land contamination.

For Loviisa, the approach translates to ensuring the following top level safety functions:

- depressurization of the primary circuit
- absence of energetic events, i.e. hydrogen burns
- coolability and retention of molten core in the reactor vessel
- long term containment cooling
- ensuring subcriticality
- ensuring containment isolation.

The cornerstone of the SAM strategy for Loviisa is the coolability of corium inside the reactor pressure vessel (RPV) through external cooling of the vessel. Since the RPV is not penetrated, all the ex-vessel phenomena such as ex-vessel steam explosions, direct containment heating and core-concrete interactions can be excluded. The only energetic phenomena remaining which could have potential to threaten the containment integrity are hydrogen burns.

In-vessel retention of corium

Some of the design features of the Loviisa Plant make it most amenable for using the concept in-vessel retention (IVR) of corium by external cooling of the RPV as the principle means of arresting the progress of a core melt accident. Such features include

- the low power density of the core
- large water volumes both in the primary and in the secondary side
- no penetrations in the lower head of the RPV and, finally,
- ice condensers ensure a flooded cavity in most severe accident scenarios.

On the other hand, if in-vessel retention was not attempted, showing resistance to energetic steam generation and coolability of corium in the reactor cavity could be laborious for Loviisa, because of the small, water filled cavity with small floor area and tight venting paths for the steam out of the cavity.

An extensive research program regarding the thermal aspects was carried out by Fortum. The work included both experimental and analytical studies on heat transfer in a molten pool with volumetric heat generation and on heat transfer and flow behaviour at the RPV outer surface.

Based on experiments, the IVR concept for Loviisa was finalised. The conceptual design was submitted to STUK for approval and approval in principle was received in December 1995. The concept included plant modifications at four locations. The modifications were completed in 2002. The most laborious one of them was the modification of the lower neutron and thermal shield such that it can be lowered down in case of an accident to allow free passage of water in contact with the RPV bottom. Other two modifications included slight changes of thermal insulations and ventilation channels in order to ensure effective natural circulation of water in the channel surrounding the RPV. Finally a strainer facility was constructed in the reactor cavity in order to screen out possible impurities from the coolant flow and thereby prevent clogging of the narrow flow paths around the RPV.

Absence of energetic events

Based on plant-specific features, the only real concern regarding potential energetic phenomena is due to hydrogen combustion events. The Loviisa reactors are equipped with ice-condenser containments, which are relatively large in size (comparable to the volume of typical large dry containments) but have a low design pressure of 0.17 MPa. The ultimate failure pressure has been estimated to be well above 0.3 MPa. An intermediate deck divides the containment in the upper (UC) and lower compartments (LC). All the nuclear steam supply system (NSSS) components are located in the lower compartment and, therefore, any release of hydrogen will be directed into the lower compartment. In order to reach the upper compartment, which is significantly larger in volume, the hydrogen and steam have to pass through the ice-condensers.

Because of the relatively low design pressure of the containment, the hydrogen burns that can create a potential threat include not only detonations, but also all large-scale combustion events that are rapid enough to yield an essentially adiabatic behaviour. An additional concern, which is caused by the type of the containment, occurs when the steam and hydrogen mixture passes through the ice-condenser. The steam will be condensed in the ice beds, which could potentially lead to very high local hydrogen concentrations.

In the 1990's an extensive research program was carried out at Fortum to assess the reliability and adequacy of the existing igniters system. One of the focus areas in the studies was to determine the prerequisites for creating and maintaining a global convective flow loop around the containment for ensuring well mixed conditions. The global flow loop which passes from the lower compartment through an ice-condenser to the upper compartment and back to the LC through the other ice-condenser is necessary in order to bring air into the LC and thus to be able to recombine or burn hydrogen in a controlled way already in the LC. The experiments and the related numerical calculations demonstrated that the global convective loop will be created and maintained reliably provided that the ice-condenser doors will stay open.

Based on the studies a new hydrogen management strategy for Loviisa was formulated. The new strategy concentrates on two functions: ensuring air recirculation flow paths to establish a well-mixed atmosphere (opening of ice condenser doors) and effective recombination and/or controlled ignition of hydrogen. Necessary plant modifications were identified. These included autocatalytic hydrogen recombiners, modifications in the igniters system (igniters were removed from the upper compartment and left only in the lower compartment) and a dedicated system for opening the ice-condenser doors. The modifications were completed in 2003.

Prevention of long term over pressurization

The studies on prevention of long term over pressurization at Loviisa started by considering the concept of filtered venting, as was done for many European NPPs after the Chernobyl accident. However, the capability of the steel shell containment to resist subatmospheric pressures is poor. If using filtered venting, it is possible that the amount of noncondensable gases after the venting is significantly less than originally, which later – after cooldown of the containment atmosphere – may lead to subatmospheric pressures and possibly collapse of the containment. Therefore, alternative solutions were sought for.

Since the concrete used in the reactor cavity of Loviisa does not contain any CO_2, the amount of noncondensable gases (except for hydrogen) generated during core-concrete interaction would be practically zero. Therefore, the overpressure protection of the containment could be limited to condensing the steam produced. An obvious way of doing this is to spray the exterior of the containment steel shell. Later on, the concept of in-vessel retention was introduced to Loviisa (as discussed above), which excludes core-concrete interactions altogether and thus finally ensures that no noncondensable gases apart from hydrogen need to be considered.

The system was designed to remove the heat from the containment in a severe accident when other means of decay heat removal from the containment are not operable. Due to the ice condenser containment, the time delay from the onset of the accident to the start of the external spray system is long (18–36 hours). Thus the required heat removal capacity is also low, only 3 MW (fraction of decay power is still absorbed by thick concrete walls). The system is started manually when the containment pressure reaches the design pressure 1.7 bar. Autonomous operation of the system independently from plant emergency diesels is ensured with dedicated local diesel generators. The single failure criterion is applied. The active parts of the system are independent from all other containment decay heat removal systems. There are no active parts of the system inside the containment.

The both units Loviisa 1 and 2 have their own external spraying circuits and spray water storage tanks. The cooling circuit of the spraying system and the dedicated diesel generators are common for both units. The ultimate heat sink is sea water.

Primary circuit depressurization

The primary depressurization is an interface action between the preventive and mitigation parts of SAM. If the primary feed function is operable, the depressurization may prevent the core melt. If not, it sets in motion the mitigation actions and measures to protect the containment integrity and mitigate large releases.

Manual depressurization capability has been designed and implemented through motor-operated relief valves. Depressurization capacity will be sufficient for bleed & feed operation with high-pressure pumps, and for reducing the primary pressure before the molten corium degrades the reactor vessel strength. Depressurization is to be initiated from indications of superheated temperatures at core exit thermocouples. The depressurization valves were installed at the same time with the replacement of the existing pressurizer safety valves in 1996.

Implementation

The SAM-strategy described in the previous chapters has lead to a number of hardware changes at the plant as well as to new severe accident guidelines and procedures.

The containment external spray was implemented at the two units in 1990 and 1991. Primary system depressurization capability was installed at both units in 1996. The major back fittings related to external coolability of the reactor pressure vessel and to opening the ice-condenser doors are, for the most part, implemented at Loviisa 1 in 2000 and at Loviisa 2 in 2002. The modifications to ensure the hydrogen control were completed in 2003. In addition to the mechanical equipment, the implementation included also a new, dedicated, limited scope instrumentation and control system for the SAM-systems, a dedicated AC-power system and a separate SAM control room which is common to both units. These were implemented mainly in year 2000 for Loviisa 1 and 2002 for Loviisa 2.

In addition to the hardware modifications, severe accidents guidance for the operating crew has been implemented. It consists of SAM-procedures for the operators and of a so-called Severe Accident Handbook for the Technical Support Team. The SAM procedures are entered after a prolonged uncover of the reactor core indicated by highly superheated core exit temperatures. The procedures are symptom oriented and their main objective is the protection of containment integrity through ensuring the top level severe accident safety functions. The most important operator actions after the core uncover are the ensuring of containment isolation, primary circuit depressurization, opening of ice-condenser doors in order to ensure mixing of hydrogen, lowering of the neutron shield of the lower part of the RPV and, in the long term, starting of the containment external spray. The Severe Accident Handbook contains background material for the procedures and it should facilitate the support team in gaining understanding of the progress of the accident and of potential means of recovery.

Defence in Depth concept and severe accident management in the Olkiluoto NPP

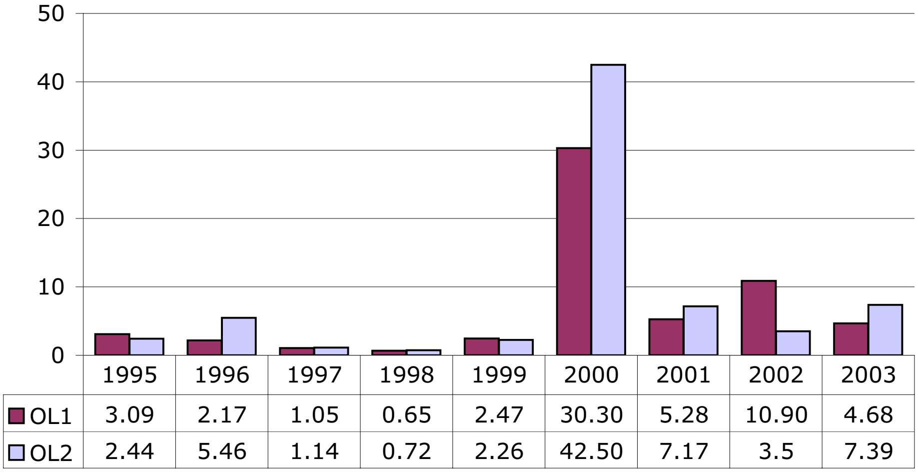
Levels of protection in the Olkiluoto NPP

Prevention

Olkiluoto plant has continuously utilised the experience and data that the plant supplier, Asea-Atom AB, gathered in connection with design, construction and operation of the Swedish plants. The solutions implemented by TVO have, for the most part, been similar to the ones in corresponding Swedish plants, which have enabled the deployment of Swedish plants as a reference also in modifications implemented after the plant construction. When different technical solutions have been assessed in connection with modifications, TVO's policy has been to take into use only such systems, whose reliability and maintenance can also be assessed on the basis of operating experience. Important events such as failures of equipment, preventive maintenance and deviation from the Operational Limits and Conditions cause unavailability of safety important components. Figure 22 presents the effect of this unavailability to the total accident risk. STUK's 5% goal value was exceeded during 2003 in the plant unit 2 because of common cause failures (material defects) in the actuators of external isolation valves of the emergency core cooling system.

New technology, such as control systems that use programmable automation and that don't come with the extensive operating experience that is usually

Risk contribution of the safety system unavailability at Olkiluoto (percentage of the average annual core damage risk)



	1995	1996	1997	1998	1999	2000	2001	2002	2003
■ OL1	3.09	2.17	1.05	0.65	2.47	30.30	5.28	10.90	4.68
□ OL2	2.44	5.46	1.14	0.72	2.26	42.50	7.17	3.5	7.39

Figure 22. Share of the accident risk caused by the unavailability of equipment at the Olkiluoto NPP.

available for modifications, has been installed at the plant units in connection with the modernisation project. Due to the relative meagreness of operating experience special attention has been paid to the design and testing of systems. The biggest modifications, such as the modernisation of the electric drives in the main circulation pumps and the modernisation of the turbine control system, have been conducted in stages at different plant units. The modifications have also, according to possibilities, been taken into use in stages and by using the traditional analogous hardwired technology as a backup. According to the experience gained from the commissioning, special attention shall be paid to the forthcoming design and validation of systems that utilise new technology.

Management of operational transients and accidents

Olkiluoto plant units are equipped with measuring systems that continuously monitor the state of the processes to detect operational transients and accidents. An alarm limit, which, when exceeded, causes a transmission of an alarm signal to the control room, has been set for a large part of the measurements. When protection limits, which have, in addition, been set for the most important measurements, are exceeded, the protection system monitoring the measurements shuts down the reactor or reduces its power. If the measurements indicate a leak in the primary circuit, the system also starts the emergency cooling of the reactor and closes the isolation valves of process pipelines penetrating the containment wall. To ensure the reliability of functions, the protection system has been realised as four independent subsystems, where the function of two subsystems is enough to initiate the needed protection functions. According to the conducted analyses the measuring systems and protection systems are adequate for detecting transients in the plant operation.

TVO has continuously developed the process computer system that is operated by the control room personnel and that is responsible for gathering information from the measuring systems and transmitting it to the control room. A big modification, from the standpoint of accident management, was implemented in 1992, when the Safety Parameter Display System (SPDS), in which the main measured variables related to different transients are grouped into their own entities, was taken into use. TVO implemented the modification so that the Display System supports the symptom based emergency operating procedures used by operators as well as possible.

To increase the efficiency of transient control, modifications, arising mainly from the changes in reactor operation at the new power level, to the protection system have been designed and implemented in connection with the modernisation project. The tightened requirements concerning the management of a faulty reactor scram (ATWS) have also caused some modifications to the protection and safety systems.

Olkiluoto is currently upgrading the turbine automation system to a programmable digital system.

To develop the management of severe accidents at the Olkiluoto plant units, a containment building monitoring system, which is independent from other monitoring systems and normal electrical supply, has been taken into use. The task of the system is to ensure that information concerning the accident course is gained even in a situation, where all normal measuring systems are lost.

STUK's review is that the Olkiluoto plant units have such systems available, by means of which both transients and accidents can be detected and their aggravation prevented. Sections 3.6 and 4.5 present an review on how TVO meets the requirements concerning the probability of a large release.

Mitigation of consequences

For mitigating the consequences of the postulated accidents taken into account in the design of the Olkiluoto plant, the plant has been equipped with the appropriate safety systems. In addition, TVO has taken steps to mitigate the consequences of an accident by planning the actions of the control room personnel in advance and by drawing up related instructions (emergency operating procedures), by ensuring the transmission of data from the control room to other parts of the organisation and to the regulatory body by the means of the process computer and by planning and exercising in advance the actions of the entire organisation for emergency preparedness situations.

The plant specific full-scope simulator was used in the preparation of emergency operating procedures and in the training of operators. The simulator provides a possibility for exercising the management of different transient and accident situations in realistic conditions. The applicability of the emergency operating procedures was also assessed in connection with the probabilistic safety analyses, when the probability and the consequences of operator errors were examined.

To ensure the transmission of data also in accident situations the process computer connection has, in addition to the control room, been arranged to the commando centre and air-raid shelter of the power plant as well as to STUK. The data transmission connection makes it possible to follow the state of the plant almost in real time also from outside the control room. The operation, by utilising the connection, has been tested in emergency preparedness exercises. Experience shows that an on-line connection facilitates the communication between the regulatory body and the power company, and reduces the risk of acting on false or insufficient information.

An emergency preparedness plan, that e.g. defines the emergency preparedness organisation with its responsibilities and duties used in accident situations and presents detailed instructions on how to organise the operation and to inform from it in accident situations, has been drawn up against accidents. Operation in accident situations shall be exercised regularly.

STUK's review is that TVO has taken proper measures to mitigate accident consequences.

Technical barriers for preventing the dispersion of radioactive materials in the Olkiluoto NPP

The operation of a nuclear power plant produces radioactive materials from fuel pellets fabricated of uranium dioxide mainly as a result of fission of uranium nuclei. Uranium dioxide matrix as such forms the first barrier against the dispersion of fission products. Under normal operating conditions, when temperature of the uranium dioxide doesn't become exceptionally high, the majority of fission products remain inside the pellet (in the matrix).

Since a small part of the fission products, produced from the fuel, drifts outside the fuel matrix even during normal operation, the excursion of fission products outside the reactor core has been prevented by enclosing the fuel pellets into a gas-tight cladding. The cladding material is, due to its properties, well suited for the conditions existing in the reactor and also meets the exceptional endurance requirements set by the high temperatures. According to the operating experience gained from the manufacturer and the results of laboratory researches, the oxide layer, arising from corrosion, on the cladding surface remains within acceptable limits and the ductility properties of the material remain adequate during the fuel's operating life. These observations were also verified in inspections, directed at spent fuel, that were conducted at the plant.

The basis for the design of the plant is that the releases to the environment shall remain within the set limits, even if approximately one percent of the fuel rods (with 500 modern 10×10 fuel assemblies there are approximately 45 000 fuel rods in the core) contained by the core lose the integrity of the cladding during normal operating conditions. The water treatment system of the reactor primary circuit is equipped with filters, which allow an controlled gathering and removal of fission products – once released into the cooling water – and corrosion products activated by the neutron radiation. Operating experience has shown that fuel leakage are rare and that systems are adequate for keeping the activity concentrations of the primary circuit within acceptable limits.

The next barrier, after the fuel (uranium dioxide matrix and the surrounding gas tight cladding), against the dispersion of radioactive materials is the pressure retaining boundary of the primary circuit. The reactor pressure vessel is manufactured from the low alloyed steel generally used in western countries and its inner surface is lined with the stainless steel. The pipelines connected to the pressure vessel are manufactured either from stainless steel or low alloyed steel. Current requirements related to the basic dimensioning of the primary circuit are for the essential parts same as during the plant construction.

The last barrier, that surrounds the reactor pressure vessel and part of the connected pipelines, is a cylindrical, gas tight containment building, built out of prestressed concrete, having bottom and upper slabs manufactured from concrete and on the top also a removable steel dome for opening the reactor pressure vessel.

Ensuring fuel integrity

A starting point in ensuring the fuel integrity is that the properties of the fuel are known accurately enough, so that the plant operation and management of transient situations can be planned with the objective that fuel does not fail in any design basis situation. To ensure the properties of the fuel, maximum limits have been set for e.g. fuel burn-up and for the quantity of fission gases released during operation from the fuel pellet inside the rods. The limits have been set so that their fulfilment can be demonstrated already in connection with the design by the means of calculation analyses and measurements conducted by the fuel manufacturer. At Olkiluoto plant the fulfilment of the set limits, for the part of fuel types used so far, has also been demonstrated by measurements performed on the spent fuel. Figure 23 presents the number of leaking fuel bundles at the Olkiluoto NPP.

The preservation of fuel integrity, under power variation situations that relate to normal operation of the reactor, is ensured by limits that concern power variation speeds and that are based on research on test reactors and on operating experience gained from the Swedish plants and elsewhere.

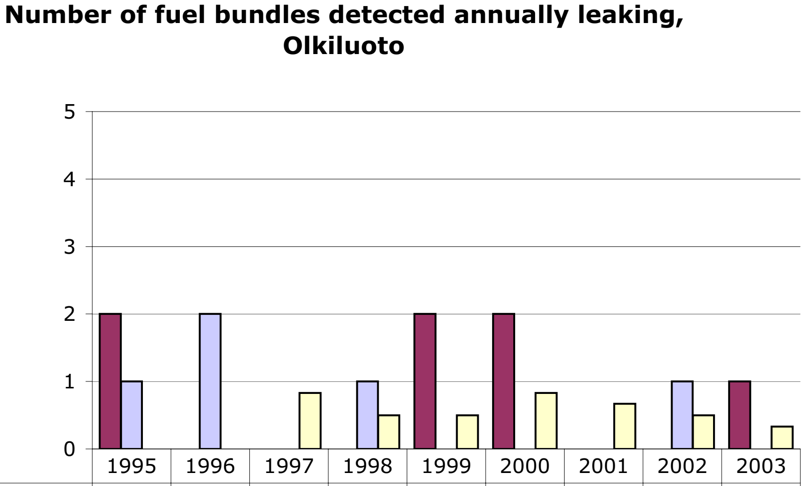
The effects of the modernisation project to fuel integrity in anticipated operational transients and accidents have been assessed by calculation analyses, which have taken into account the plant modifications conducted at the plant in connection with the power uprating. A margin that must be maintained between the power obtained from the fuel and the maximum cooling capacity that corresponds with the operating condition in question, is defined on the bases of the analysis results.

During the modernisation project, measures have been taken to eliminate the two transients that have earlier set the margins for operation: loss of electricity of the main recirculation pumps and malfunction of the turbine pressure controller.

A transient that is caused by a simultaneous tripping of the main circulation pumps – caused by a loss of electricity – is mitigated by adding a rotating mass to the electric drives, due to which the pumps can be run down in a controlled manner. This helps to avoid any degradation of the heat transfer conditions during the flow coast-down.

In the modernised system, the control of the pump coastdown is conducted by means of a programmable automation system. In addition, there is a separate protection logic unit which is based on hardwired technology.

Another transient that has before limited the power level of the plant is the malfunction of the turbine pressure controller. The pressure controller controls e.g. the steam flow to the turbine, and so the failure of the controller may cause a sudden stop in the steam flow to both the turbine and the bypass to the condenser. The pressure of the primary circuit rises when the flow stops, which results in the decrease of the void content in the reactor. As the steam void content decreases the reactor power tends to rise, and if the operational margins between the reactor power and the cooling



	1995	1996	1997	1998	1999	2000	2001	2002	2003
■ OL 1	2	0	0	0	2	2	0	0	1
□ OL 2	1	2	0	1	0	0	0	1	0
□ 3 yearly average			0.83	0.5	0.5	0.83	0.67	0.5	0.33

Figure 23. Number of leaking fuel bundles at the Olkiluoto NPP.

capacity are not adequate, local heat transfer crisis may result. Although the cooling becomes adequate as the reactor power decreases again, the transient may cause fuel failures in a limited part of the reactor.

The modernisation of the pressure controller, implemented in connection with the modernisation project, has aimed at reducing the failure frequency of the system, so that the pressure transient caused by a failure is no longer an anticipated operational transient but a so-called postulated accident, which enables the application of milder criteria in provision for the transient. The failure of the turbine pressure controller still remains, however, as the event that limits the power level, in spite of the alleviated acceptance criteria as to the fraction of fuel rods that may undergo heat transfer crisis.

The modernisation of the turbine control and protection system, which is also responsible for pressure control, has been completed on both plant units. According to the operating experience thus far, both systems have functioned as intended.

The change of the reactor operating mode may cause the stability characteristics of the reactor to weaken. Instability causes the reactor power to oscillate, possibly even with a growing amplitude. To avoid such situations and possible fuel failures resulting from them, certain modifications, that have an positive effect on the reactor stability, have been made at Olkiluoto 1 and 2. Steam separators above the reactor core have been replaced by new separators that have a smaller pressure loss. Limits have been set for the reactor operation domain in such areas of the power-flow map that are the most limiting from the standpoint of stability. Limits have also been set to the power peaking factors in the core. Stability control has also been ensured by increasing the efficiency of the partial scram . Stability is also one of the criteria applied when assessing the feasibility of new fuel types for use at the Olkiluoto plant units.

The demand that measures must be taken to prepare for a complete inoperability of the reactor scram system – a situation where control rods can't be inserted into the core by means of the hydraulic scram system nor by electric motors – has also been taken into account in connection with the modernisation project. In order to manage the complete failure of reactor scram without fuel failures, the reactor power must be quickly limited by controlling the feed water flow and main recirculation pump speed and by pumping boron solution into the reactor. To ensure the power limitation, modifications have been made in the protection system. These include automatic depressurization of the reactor and modifications in the operation of the feed water system and main recirculation and boron pumps. The capacity of the boron system has also been improved by going over to the use of enriched boron and by increasing the concentration of the boron solution and the capacity of the pumps.

The objective is to keep the probability of a criticality accident adequately low during the outages and the refuelling by strict technical and administrative limits. The prevention of inadvertent criticality has also been taken into account in the fuel storage and handling systems at the plant.

Ensuring primary circuit integrity

The primary circuit of Olkiluoto 1 and 2 includes the reactor pressure vessel, the internal main recirculation pumps with heat exchangers as well as the pipelines and their accessories from the reactor pressure vessel down to the outer isolation valves of the containment. The components that fall into the safety class 1 have been designed according to the standard ASME Boiler and Pressure Vessel Code, Section III.

The integrity of the primary circuit in the nuclear power plant may be threatened, if there is a transient that causes the circuit pressure and the loads arising from local thermal expansion of material to exceed the values used in design, or if, as a result of plant ageing, the structural materials of components degrade uncontrollably due to changes in structural properties, thinning of wall thickness, fatigue of metal or cracking. Figure 24 presents the largest uncontrolled leakage from the primary circuit during the operation of Olkiluoto 1 and 2 in comparison with the limit value of Operational Limits and Conditions.

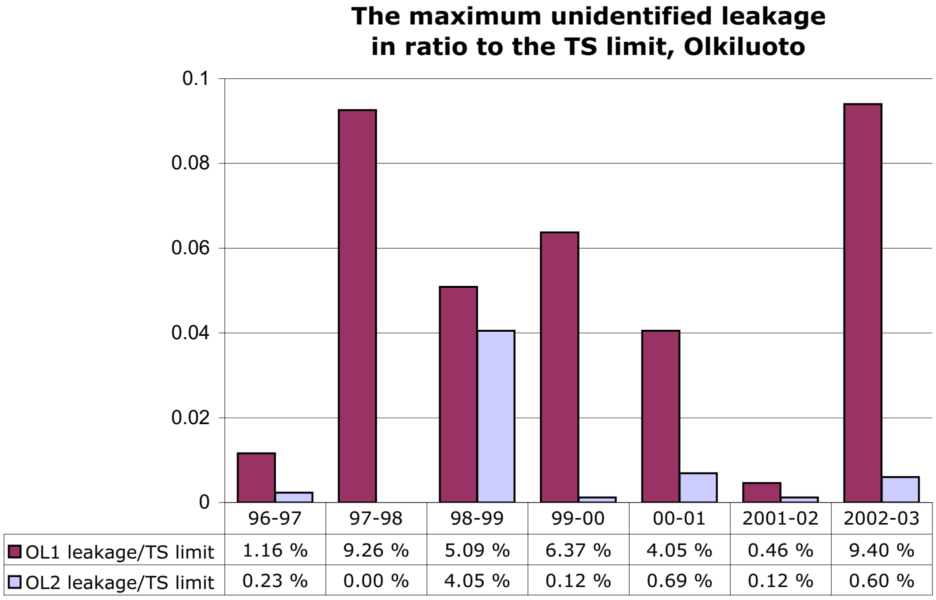
In addition to the conditions that prevail during operation, anticipated operational transients and postulated accidents have been taken into account in the design of the primary circuit. During operation, the circuit is loaded by the temperature changes that arise from the start-ups and shutdowns of the plant units as well as from operational transients that cause changes to the stress state of the structures and metal fatigue. Loads arising from plant operation are monitored continuously and cumulative loads are compared to the values used in design. The loads arising from operation thus far, have been smaller than designed, and so, making an review based on this, the accumulation of primary circuit loads does not limit the designed operating life of the plant.

Two new safety valves have been installed on both plant units to maintain the pressure loading, arising from possible operational transients and postulated accidents to the primary circuit, below the values used in design also after the power uprating conducted in connection with the modernisation project. The new valves are different from the safety valves earlier at the plant, and so the modification has also made it possible to improve the reliability of the entire system. The pressure control of the primary coolant system has been implemented according to the accident and reliability analyses in a such manner, that no significant risk of circuit rupture, resulting from over pressurisation, is related to the transient situations.

The properties of the base material and weld seams in the primary circuit may degrade during operation due to changes in the structural properties of the material that are caused by neutron radiation, thinning of wall thickness caused by corrosion or initiation and propagation of cracks resulting from e.g. thermal stresses or stress corrosion.

Embrittlement of the pressure vessel is not a similar general problem in boiling water reactors as in old pressurised water reactors, because the dose of fast neutrons directed at the wall of the reactor pressure vessel is considerably smaller in boiling water reactors than in pressurised water reactors due to a longer distance between the core and the wall. Due to the character of boiling water reactors, a parallel existence of high thermal stresses and stresses caused by pressure is also not possible. Due to these reasons the embrittlement of the reactor pressure vessel does not limit the operating life time of the Olkiluoto plant.

Effects of corrosion have been prevented already in advance by e.g. material selections during the plant construction. The reactor pressure vessel is made out of low-alloyed MnMoNi steel that has been layered with austenitic stainless steel weld except for the pump housing, which has a low operating temperature. The heat exchangers of the primary circulation pumps, and steam lines with their valves are of carbon steel while the other components are of high alloyed carbon steel or mostly of austenitic stainless steel. Due to the high alloyed steel, dry steam or low operating temperature, a general corrosion that reduces the wall thickness is either rare or non-existent. The erosion speed of steam lines is monitored by measuring the wall thickness of the lines regularly. No significant thinning has been



The maximum unidentified leakage in ratio to the TS limit, Olkiluoto

	96-97	97-98	98-99	99-00	00-01	2001-02	2002-03
■ OL1 leakage/TS limit	1.16 %	9.26 %	5.09 %	6.37 %	4.05 %	0.46 %	9.40 %
□ OL2 leakage/TS limit	0.23 %	0.00 %	4.05 %	0.12 %	0.69 %	0.12 %	0.60 %

Figure 24. The largest uncontrolled leakage from the primary circuit during operation of Olkiluoto NPP units 1 and 2 in comparison with the limit value of Operational Limits and Conditions.

observed, nor is the corrosion expected to speed up during the future operation.

Intergranular stress corrosion, which has occurred in the heat affected zone of the austenitic stainless steel base material beside the weld seam, is a problem for boiling water reactors. A narrow defect or a crack may initiate in a structure even if the thickness of the surrounding wall doesn't become any thinner. A stress corrosion mechanism like this requires the parallel existence of three factors: a high tensile stress, sensitised material and aggressive environment. Tensile stresses to material are generated by welding, which causes residual stresses that could, at the worst, be in the same magnitude with the material's yield strength. Welding arrangements can be used to affect residual stresses, and this has also been done when pipelines have been replaced with materials that have a better resistance against stress corrosion. Sensitising refers to the degradation of corrosion properties of material's grain boundaries e.g. as a result of thermal effect arising from welding. This means that a chromium poor zone liable for corrosion, is left in the vicinity of chromium carbide precipitates at the grain boundaries. The aggressive effect of the water at operating temperatures is aggravated especially by oxygen, which is always present in the water of a boiling water reactor due to radiolysis. An environmental effect can also be aggravated by other impurities in the water. Strict requirements have been set for water purity and the amount of impurities is monitored continuously.

The intention has been to design the processes in a such manner, that the lines do not become loaded uncontrollably, when flows of different temperatures get mixed. The elimination of some mixing items was not possible and they are under special monitoring. The condition of the primary circuit is monitored in periodical non-destructive inspections, which enable the detection of possible cracks already in their initiating phase. Furthermore, the material properties and the wall thickness of primary circuit lines at the Olkiluoto plant are such that instead of a fast break a rupture will probably take place gradually, so that it can be detected on the basis of measurements as a leakage from the primary circuit to the internal space of the containment.

STUK's review, based on the experience gained from the ageing of nuclear power plants, is that the risk of a primary circuit break, caused by degradation of material properties or by growth or accumulation of loads, is not likely to increase significantly in the future. Since, at the moment, there is relatively little experience at hand from the operation of boiling water plants that are over 30 years old, the effects of ageing can't be reliably assessed far to the future.

Ensuring containment building integrity

Anticipated operational transients and postulated accidents have been taken into account in the design of containments for Olkiluoto 1 and 2 by dimensioning the structures – according to the practice applied in the western countries – on the basis of loads arising from a sudden and complete break of the biggest primary circuit line. To condensate the exhausting steam from the primary circuit, the containment is provided with a condensation pool, where the steam is directed by natural mechanisms, and with a spray system that is automatically turned on in accident situations. To remove the heat that is released from the reactor core during an accident, from the containment the plant units are provided with the necessary intermediate cooling and sea water circuits, by means of which the heat can be removed to the final heat sink, the sea.

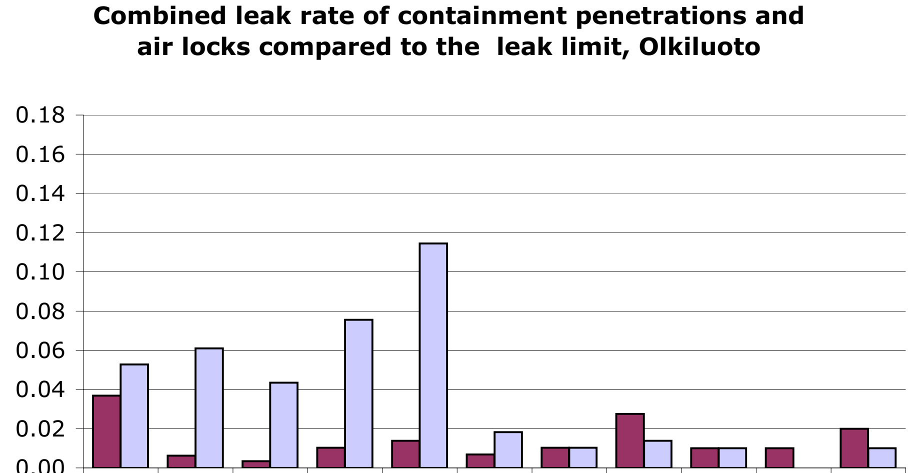
The containments of Olkiluoto 1 and 2 have a reinforced concrete structure and their outer walls, in addition, have a prestressed structure. The leak tightness of the containment in connection with a design basis accident is ensured by fitting a steel liner, which is, for all parts, protected from jet forces and flying objects considered possible in accident conditions, inside the containment wall. To minimise the releases arising from possible seal leakage of the penetrations, the containment has been placed inside the reactor building. The reactor building is provided with a ventilation system that enables the underpressurization of the reactor building in relation to its environment and thus a controlled collection and filtering of the radioactive substances leaking from the primary containment in accident conditions. Figure 25 shows the results of leakage measurements of isolation valves and penetrations of the containment during the annual outage periods. The total leakage is presented as a percentage of the leakage budget.

In postulated accidents part of the fuel cladding material may become oxidised and cause also a hydrogen release. Also the radiation inside the reactor causes the water molecules to break down into oxygen and hydrogen. To eliminate the fire and explosion risk caused by the hydrogen, the containments of the Olkiluoto plant are inerted with nitrogen during normal operation at power except for short periods of time during start ups and shutdowns. Furthermore, the containment is provided with a separate hydrogen recombination system, by the means of which the hydrogen and oxygen released by radiolysis during the accident can be controllably recombined back to water.

Design criteria that concern the containment and relate to the anticipated operational transients and postulated accidents have not changed after the construction of the Olkiluoto plant. The uprating of reactor powers at the plant units has, however, required some modifications to the containment systems. The uprating of the power level affects mostly the functioning of emergency heat transfer chain, because the magnitude of the decay heat power, to be transmitted during the accident, depends directly on the normal power level of the plant. Due to the power uprating, the capacity of the emergency heat transfer chain has been raised by increasing the capacity of heat exchangers. Nevertheless, the temperature of the condensation pool would exceed the earlier values during a pipe break accident. The effect that the temperature rise has on the functioning of the containment has been analysed by calculation means, and according to the conducted investigations the temperature rise has on the functioning of the containment has been analysed by calculation means, and according to the conducted clarifications the temperature rise doesn't significantly increase the risk of loosing the containment leak tightness during an accident.

As the power of the plant increases, also the radiation level during an accident increases in the reactor, due to which more hydrogen and oxygen is released in a design basis accident. In order to prevent the growth of hydrogen fire risks due to the accelerated generation of hydrogen and oxygen during an accident, the limit of the allowable oxygen content during normal operation has been reduced in the containment. According to the performed analyses, the modification is adequate for ensuring that the contents of oxygen and hydrogen in the containment remain below the ignition limit for 20 hours from the beginning of the accident without special measures, and that the capacity of the hydrogen recombine system is adequate for preventing the initiation of uncontrolled fires from here on.

The effects that the plant ageing has thus far had on the containment and its systems have been relatively small. In the regularly conducted tightness tests of the containment no such increase of leaks has been observed that would indicate a degradation of sealing materials. The amount of preventive maintenance work, concerning mostly the sealing of expansion joint between the dry and wet well space of the containment, has, however, been relatively big, which is why TVO is at the



	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
■ OL 1	0.04	0.01	0.00	0.01	0.01	0.01	0.01	0.03	0.01	0.01	0.02
□ OL 2	0.05	0.06	0.04	0.08	0.11	0.02	0.01	0.01	0.01	0.00	0.01

Figure 25. The total leakage rate through the isolation valves and penetrations at the Olkiluoto NPP compared to the leakage budget.

moment clarifying the possibility of a structural modification that would allow the reduction of maintenance need for the sealing of construction joint, prevention of possible tightness problems arising from ageing and possibly the improvement of sealing reliability in accidents more severe than the original design basis accident.

The starting point for design during the construction of Olkiluoto 1 and 2 was that by dimensioning the containments against pipe break accidents, their integrity could be ensured by an adequate certainty also in accidents, where the reactor core suffers substantial damage or even melts completely. The Harrisburg accident demonstrated that the loads arising from a pipe break accident on structures can't be considered commensurate with the possible loads arising from a core melt down accident especially in containments, where measures against the pipe break accidents include different steam condensing systems. The Harrisburg accident launched several new inspections, whose objective was both to clarify the character and magnitude of loads arising from a severe accident and to find means for controlling the loads. The inspections led to plant modifications, whose implementation was accelerated by the 1986 Chernobyl accident, which concretely demonstrated the importance of a functioning containment.

The most significant deficiencies at the Olkiluoto plant containments, from the standpoint of controlling severe accidents, have been the small size of the containment, which may cause the containment to pressurise due to the hydrogen and steam generation during an accident, and the location of the reactor pressure vessel inside the containment, which is such that the core melt erupting from the pressure vessel may expose the structures and penetrations that ensure the tightness of the containment, to pressure loads and thermal stresses. To eliminate these deficiencies, the containment is e.g. provided with a pressure suppression system, by the means of which gases that pressurise the containment can be removed through a filter designed for the purpose, if the pressure inside the containment threatens to increase too much. The part of the containment underneath the reactor pressure vessel can be flooded with water in order to protect the containment bottom and penetrations from the thermal effect of core melt. Some penetrations of the containment have been protected from the direct effect of core melt also by structural means. To ensure the cooling of reactor debris, the plant units are also provided with a water filling system, by the means of which the water level inside the containment can be raised all the way to the same level with the upper edge of the reactor core.

The means for managing severe accidents had to be adjusted to the existing design, and so an optimal implementation of all chosen solutions was not possible.

The cooling of reactor core melt and the protection of containment penetrations requires that the lower dry well of the containment is flooded at such an early stage of the accident that if the pressure vessel melts through, the erupting core melt falls into a deep water pool. When the core melt falls into the water a so-called steam explosion, which causes a strong and quickly propagating pressure wave in the water pool, may occur. A lot of research has been done on steam explosions, but it is still uncertain, how probable the explosion is, when the core melt and water meet, or how powerful the explosions may be. Based on inspection results and experience gained from e.g. metal industry, the possibility of a powerful explosion that causes a pressure wave strong enough to rupture the structures of containment penetrations or personnel hatches, can't be ruled out. To decrease the risk for loss of containment integrity due to loads caused by steam explosions, the structures of the lower equipment hatch have been enforced.

According to the conception that existed, when measures to manage severe accidents more effectively were designed, iodine occurs in the containment during accidents mainly as aerosols, which are effectively absorbed in the condensation pool of the containment and in the filter of the filtered venting system. The Chernobyl accident and the tests conducted after it have, however, demonstrated that in unfavourable conditions iodine may also form organic compounds that are not easily absorbed in the containment or in the filter. Such conditions may occur at the Olkiluoto plant, if the water inside the containment is acidified due to chemicals released during the accident. Organic iodine may also be generated in the primary circuit, if iodine reacts with the hydrocarbons that are released, when the boron carbide contained in the control rods becomes oxidised during the core damage. The possibilities for improving the absorption of iodine in the containment and in the filtered venting system are still being investigated.

Ensuring safety functions

Reactivity control

The Olkiluoto plant reactors and their loading, operation and control has been designed and implemented so, that the combined effects of inherent, reactor physical feedbacks are always negative or, in other words, mitigate the increase of reactor power in all operating conditions of the reactor. Due to this, disturbances in power will decay even without any functioning of active systems. The stability of the reactor has also been ensured by means of e.g. a partial scram function, which has been designed to trip early enough in circumstances in which risk for core instability might exist.

The reactor can be shutdown either by the control rods that are operated by a pressurised nitrogen/hydraulic system and by electric motors, or by the boron system, which is used to pump boron solution into the reactor. The systems function on different principles and are independent from each other. Both systems receive automatic commands from the reactor protection system, but can also be tripped by the operators.

The loading of Olkiluoto 1 and 2 has been designed and the reactors ordinarily operated so that the reactor shutdown can be carried out both hydraulically and electrically, even if the most efficient control rod group from the fourteen groups is not functioning. Furthermore, it has been demonstrated by analyses that the pressure of the hydraulic system is adequate for the shutdown of the reactor, even if none of the relief and safety valves opened.

Plant modifications, which ensure that the reactor can be shutdown by the boron system alone, have been implemented to prepare for a complete inoperability of control rods. The single failure criterion has been applied in the design of boron system as well.

The shutdown systems of the reactor have been designed so that in a situation, where electrical operating power is lost, the reactor is shutdown by the hydraulic system, which pushes the control rods into the reactor core. Control rods alone are adequate for keeping the reactor subcritical in all other operating conditions except possibly in severe accidents.

In a severe accident the control rods melt before the fuel rods, and so the reactor may return to criticality, if the core cooling during the core damage starts to function again. According to the conducted analyses, the reactor power exceeds the capacity of decay heat removal systems after the reflooding of the core in the most unfavourable conditions. To prevent this from occurring requires that the reactor is kept shutdown by pumping boron solution into it. The modifications made in the boron system, such as the increase of boron concentration and pumping capacity, improve the capability to control reactivity also in severe accidents. The capacity increase is, however, still not adequate for ensuring the reactivity control in a situation, where the reactor core is reflooded after the control rods have melted and the boron pumped into the pressure vessel escapes because of leaks or an error in adjustment of the reactor water level. It can be assumed that leaks underneath the core are produced mostly during the maintenance of the main circulation pumps. TVO has reduced the core damage risk arising from the aforementioned issues by modifying work related instructions and the Technical Specifications. The risk arising from the adjustment error of water level can, on the other hand, be reduced by ensuring the measuring of the surface level. Possibilities for improving the reliability of the reactor water level measurement are constantly being investigated.

Decay heat removal

The decay heat removal at the Olkiluoto plant has been designed so, that the decay heat released in accident conditions is transferred as water and steam from the primary circuit through the pressure relief system to the wet well of the containment, which can, at an early stage, store all the decay heat released from the fuel. Sooner or later the heat must be removed from the containment with active equipment by circulating the containment water in the spray system, from where the heat is transferred through the heat exchangers to the intermediate cooling system and sea water system and then to the final heat sink, the sea.

A controlled decay heat removal in accident conditions requires that the pressure of the primary circuit and the water level in the reactor can be controlled by means of the measurements as well as by the feed water, emergency cooling water and pressure relief systems. These systems have been designed according to a principle that it must be possible to carry out a safety function also in a situation, where any single device is inoperable and simultaneously any other device affecting safety is not in use due to repair or maintenance (so-called N+2 criterion). This requirement has been fulfilled by implementing the process and measuring systems in question as four redundant sub-systems. Electrical power is supplied to each subsystem from four separate and independent diesel-backed alternating current buses. Subsystems are ordinarily situated in different rooms to prevent common cause failures. An exception is made in certain premises of the reactor building, where two parallel subsystems are situated in a same room contrary to the requirements set forth in the Guide YVL 1.0. The objective has been to locate the systems as far from each other as possible and separate them with distinct shields in such places, where ensuring the separation has been found necessary. In order to improve especially the fire safety, TVO has also modified the sprinkler and fire alarming systems of the main transformer and plant transformers.

Systems that take part in controlling the pressure and surface level of the primary circuit have been designed mainly by following the diversity principle, according to which crucial safety functions shall be ensured by systems, whose operating principles or technical solutions differ from each other. Water level measuring system, where all measurements are realized with the same technique, is an exception. TVO follows the research and development work – done in the field – whose objective is to create a functioning and reliable water level measuring system that is based on an alternative technique.

Severe accidents were not taken into account in the original design basis for controlling the water inventory and the pressure of the primary circuit. Ensuring the pressure control in severe accidents is particularly important, in order to avoid the pressure vessel melt-through and the loads arising from it to the containment, when the pressure of the circuit is high. TVO has made modifications, which ensure that two of the valves of the overpressure protection system stay open also in connection with severe accidents.

The original design basis for the heat removal from the containment did not require the fulfilment of the diversity principle, and the Olkiluoto plant doesn't fulfil the aforementioned requirement at the moment. There are no such technical solutions in the immediate sight that would make it possible to equip the Olkiluoto plant with decay heat removal systems that are separate from the current systems and that are based on a different functioning principle. Continuous research work is, however, being done in the field to develop new-fashioned active and passive systems.

Containment

The task of the containment is to prevent the dispersion of fission products that may escape from the fuel during an accident, to the environment. The precondition for stopping the dispersion of fission products is that the containment can be isolated in an accident situation so that it forms a gas and water tight boundary between the fuel and the environment, and that the containment maintains its leak-tightness during the entire accident.

The containments of the Olkiluoto plant are designed so that in an accident the process penetrations going through the containment walls can be closed with isolation valves. There are usually two isolation valves: one outside and the other inside the containment. Certain penetrations that are not connected to the primary circuit or directly to the inner space of the containment as well as instrumentation lines, where the possibility of a leak is, in addition to the isolation valve, also limited by transmitters that can endure the pressures and temperatures generated in severe accidents, are provided with one isolation valve.

Loading mechanisms that may occur during severe accidents haven't been taken particularly into account in the original design of containments at the Olkiluoto plant units, but the containments are dimensioned based on pipe break accidents. Due to this there has been and still is, despite the performed plant modifications, some deficiencies in the design of containments at the Olkiluoto plant concerning the preparedness for severe accidents. These deficiencies have been handled already earlier in the section 4.5 in connection with the designed plant modifications.

Severe Accident Management in the Olkiluoto NPP

The provisions for severe accident management were installed in Olkiluoto 1 and 2 during the SAM project which was finished in 1989. The measures implemented were

- containment overpressure protection
- containment filtered venting
- lower drywell flooding from wetwell
- containment penetration shielding in lower drywell
- containment water filling from external source
- containment instrumentation for severe accident control
- Emergency Operating Procedures for severe accidents.

Subsequent accident management activities at Olkiluoto plant comprise both the development of accident management procedures and additional plant modifications. They were initiated mainly during the OL1 and OL2 modernisation project.

Emergency Operating Procedures for Severe Accidents

Emergency Operating Procedures for Severe Accidents have been modified in order to take into account plant modifications and to enhance severe accident management. The containment filtered venting system rupture disk line from the upper drywell will no more be closed in the beginning of an accident. This is a precaution for a possible rapid pressurisation of the containment if the generation of non-condensable gases is large. The previously manual depressurisation of the primary system in severe accidents has been replaced by an automatic actuation of the depressurisation system.

Containment filtered venting system – impact of chlorine in the filter

In a severe accident, a large amount of chlorine could be released, due to irradiation and heating, from the synthetic rubbers used as the insulation material of the electrical cables. In order to maintain the iodine retention capability, the sodium tiosulfate concentration of the filter was increased in 1999. The iodine retention capability and stability of the solution have been experimentally verified by TVO and the Technical Research Centre of Finland, VTT.

Containment pH

A large amount of chlorine, which could be converted to HCl in the containment, could reduce the pH of the water pools and wet surfaces. The chlorine originates from the synthetic rubbers used as insulation in cables. This could lead to a significant amount of elemental as well as organic iodine. Another source of organic iodine could be reactions between boron carbide in control rods, steam and iodine in the degrading core.

TVO has investigated the possibilities for enhancing the retention of iodine by a containment pH control system. The solution used would be 50% NaOH, which is already normally used by the water treatment plant. A new NaOH tank has been installed. The required NaOH volume was analysed by VTT. The required volume is about 5 m^3 according to the calculations. The solution is gravity driven into a raw water storage tank near fire water outlet nozzles, from where the solution is delivered into the containment during containment water filling.

The lower drywell will be flooded from the wetwell prior to the NaOH supply and the lower drywell water pool pH will be kept above 7. The system modifications were made in 2001.

Energetic ex-vessel fuel coolant interactions

TVO has investigated the response of concrete structures in the containment to energetic fuel coolant interactions, steam explosions, and the result is that they would withstand large steam explosion loads. The enforcement of the structures of the equipment and personnel access hatch in the lower drywell has already been mentioned.

Diaphragm floor seal

TVO investigates how the diaphragm floor seal would behave in severe accidents. The leak tightness of the seal is important in order to maintain the pressure suppression function of the containment as long as possible. The replacement of the floor seal is being planned, taking into account also the requirements set by the severe accident conditions.

Reliability of isolation valves

The piping part inside the lower drywell may be damaged because of contact with core debris. In order to ensure the isolation function in severe accidents, an additional second isolation valve was installed in 1998 in the nitrogen system piping lines from the lower drywell to the reactor building.

Primary system depressurization in severe accidents

To secure depressurisation of the reactor primary system in severe accident situations and to prevent a new pressurisation of the reactor, two valves of the relief system have been modified. It is now possible to keep the valves open with the help of nitrogen supply or water supply from outside the containment. The modification was finished in 1999.

Recriticality

The SIRM detectors will be drawn in the beginning of the accident half a meter below the active core to detect possible recriticality. Analyses were performed in 1999 to determine how to relate the reading of the SIRM monitors to actual reactor power.