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Finnish report on nuclear safety

Finnish 4th national report as referred to in Article 5 of the Convention on Nuclear Safety

Säteilyturvakeskus
Strålsäkerhetscentralen
Radiation and Nuclear Safety Authority

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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. This report is the Finnish National Report for the Fourth Review Meeting in April 2008.

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. In addition, a new nuclear power plant unit is being constructed at the Olkiluoto site. At both sites there are interim storages for spent fuel as well as final repositories for medium and low level radioactive wastes. Furthermore, Triga Mark II research reactor is operated in Espoo by Technical Research Centre of Finland.

In the report, latest large safety reviews and plant modernization programmes are explained in detail including safety assessment methods and key results. 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 including some performance indicators.

Major developments in Finland since the Third Review Meeting are as follows: relicensing of the Loviisa nuclear power plant in 2005–2007, development of regulatory practices such as development and updating of safety guides, and construction of the 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.

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, the following features stressing Finnish safety management practices in the field of nuclear safety can be concluded:

- The Finnish regulatory infrastructure including nuclear and radiation regulations is in compliance with the Convention obligations. During the recent years Finnish legislation and regulatory guidance have been further developed and the work is still going on taking into account international guidance such as IAEA standards. This work is important since the new nuclear power plant unit is under construction and also new units are considered in Finland.

- The licensee practices in provision of good safety performance and in modernization of operating nuclear power plant units comply with the Convention obligations. The licensees have shown good safety performance and rigorous safety management practices in carrying out their safety related responsibilities in the operation and modernization of existing NPP's. Periodic Safety Reviews of the Loviisa plant was carried out in 2005–2007 in connection of relicensing, and the periodic review will be completed at the Olkiluoto plant by the end 2008. During recent years, only minor operational events have been reported and analyzed and no major safety problems have appeared. The Operating License of the Loviisa NPP was extended in 2007 to correspond the current goal for the plant's lifetime, which is 50 years.
- Safety assessment practices are continuous and living probabilistic safety assessment (PSA) practices are effectively used for the further development of safety. New risks such as oil transports in the Gulf of Finland have been identified and responded via the analysis and the corresponding safety related improvements are under planning in the Loviisa plant. The methods for qualification of non-destructive testing and management of ageing have been developed further for responding to the needs of continuous safety development. The operating practices were reviewed at the Loviisa plant in 2007 by IAEA OSART mission.
- The regulatory practices comply with the Convention obligations. The resources of regulatory body have been increased to correspond the construction of the new plant in Finland. The Construction License for the new plant unit in Olkiluoto was granted in 2005. The regulatory guidance and practices have been further developed. The Finnish Technical Support organization, VTT, supports effectively regulatory body in the safety assessment work providing safety analysis capabilities and tools e.g. via the regulatory research programmes, and performing safety analyses.
- There are some issues requiring further development to enhance safety as discussed in the report. The issues are covered in Chapter 3 of the report, including provision for plant ageing, qualification of non-destructive testing (NDT), reliability of digital automation and risk informed regulation as well as management of competence taking into account of retirement of large age groups. Other important issues cover new technologies, security arrangements and the growing need for new research and development programmes. However, these issues require international attention in all countries using nuclear energy.

The Third Review Meeting in 2005 identified some challenges and recorded some planned measures to improve safety in Finland. On request of the Review Meeting these issues are included and responded in this fourth national report of Finland. These items were (in brackets the articles, in which the issues are addressed):

- ageing of regulatory staff (see Article 8)
- maintaining competence during extended retirement (see Articles 8 and 11)
- developing risk informed regulation (see Articles 7 and 8 and chapter 3)
- regulatory control of construction of the new Olkiluoto plant unit (see Article 7)
- replacement of I&C at Loviisa NPP (see Annex 2)
- maintaining and enhancing safety culture (see Article 10)
- completing the NDT qualification programme (see Article 14 and chapter 3)
- ageing management at Finnish NPPs (see Article 14 and chapter 3)
- renewal of operating licenses for Loviisa plant units 1 and 2 (see Article 6)
- Periodic Safety Review (PSR) for Olkiluoto NPP units 1 and 2 (see Article 6).

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

Contents

(continued)

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. This report is the Finnish National Report for the Fourth Review Meeting in April 2008.

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 (Fortum), and the Olkiluoto plant two BWR units, operated by Teollisuuden Voima Oy (TVO). 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. A Construction License of the new plant unit was granted by the Government in 2005 to Teollisuuden Voima Oy for constructing a Pressurized Water Reactor (EPR) 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 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 2004. Finnish Parliament endorsed in 2001 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 the use of a 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. 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.

Major developments in Finland since the Third Review Meeting are as follows: relicensing of the Loviisa nuclear power plant in 2005–2007, development of regulatory practices such as development and updating of safety guides, and construction of the 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 explained.

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- completing the NDT qualification programme (see Article 14 and chapter 3)
- ageing management at Finnish NPPs (see Article 14 and chapter 3)
- renewal of operating licenses for Loviisa plant units 1 and 2 (see Article 6)
- Periodic Safety Review (PSR) for Olkiluoto NPP units 1 and 2 (see Article 6).

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.

The fourth National Report is selfstanding and does not require familiarization with the earlier reports. The text is based directly on the third report. The latest development is indicated in the report with clear time references where some reportable development has taken place since the Third Review Meeting. The time period for the detailed description of the nuclear power plant and regulatory issues covers the latest ten year period that gives a clear picture on the nuclear safety related activities in Finland during one Periodic Safety Review timeframe.

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 Government 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 three 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 (Decision 395/1991). This fourth report concentrates on the activities of licensees to fulfil the obligations of the Convention.

The time period for the description of the nuclear power plant and regulatory issues covers the last ten year period that gives a clear picture on the nuclear safety development in Finland during one Periodic Safety Review timeframe.

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 1998. The Operating Licenses of the units are valid until the end of 2027 (unit 1) and 2030 (unit 2). According to the conditions of the licenses, two intermediate safety assessments are required to be carried out by the licensee (by the end of the year 2015 and 2023).

The nominal thermal power of both Olkiluoto units is 2500 MW, which was licensed in 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 1998.

In 2005, the gross production of Loviisa 1 was 4260 GWh (gross) and the load factor was 95.4%. The annual refuelling and maintenance outage lasted 17 days. The gross production of Loviisa 2 was 4275 GWh, the load factor 95.7% and the length of the refuelling and maintenance outage was 16 days. The annual collective radiation doses were 0.47 manSv and 0.34 manSv for Loviisa 1 and Loviisa 2, respectively.

In 2006, Loviisa 1 produced 4166 GWh (gross), the load factor was 93.3% and the refuelling and maintenance outage lasted 26 days. In 2006 the gross production of Loviisa 2 was 3958 GWh, the load factor was 88.6%, and the refuelling and maintenance outage lasted 36.5 days. The collective radiation doses in 2006 were 0.68 manSv for Loviisa 1 and 0.98 manSv for Loviisa 2.

In 2005, net production at Olkiluoto 1 was 7221 GWh and the load factor 98,3%. The annual refuelling and maintenance outage of Olkiluoto 1 lasted 7 days. The net production of Olkiluoto 2 was 6997 GWh and the load factor was 94,0%. The annual refuelling and maintenance outage of Olkiluoto 2 lasted 21 days. The collective radiation doses in 2005 were 0,36 manSv for Olkiluoto 1 and 1,74 manSv for Olkiluoto 2.

In 2006, net production at Olkiluoto 1 was 6973 GWh and the load factor was 93,8%. The annual refuelling and maintenance outage of Olkiluoto 1 and lasted 22 days. The net production of Olkiluoto 2 was 7294 GWh and the load factor was 96,9%. The annual refuelling and maintenance outage of Olkiluoto 2 lasted 8 days. The collective radiation doses in 2006 were 1,74 manSv for Olkiluoto 1 and 0,23 manSv for Olkiluoto 2.

Figure 1 shows the load factors of Loviisa and Olkiluoto NPP's during the last twelve year period. Load factor describes the energy produced in comparison to the energy that could have been

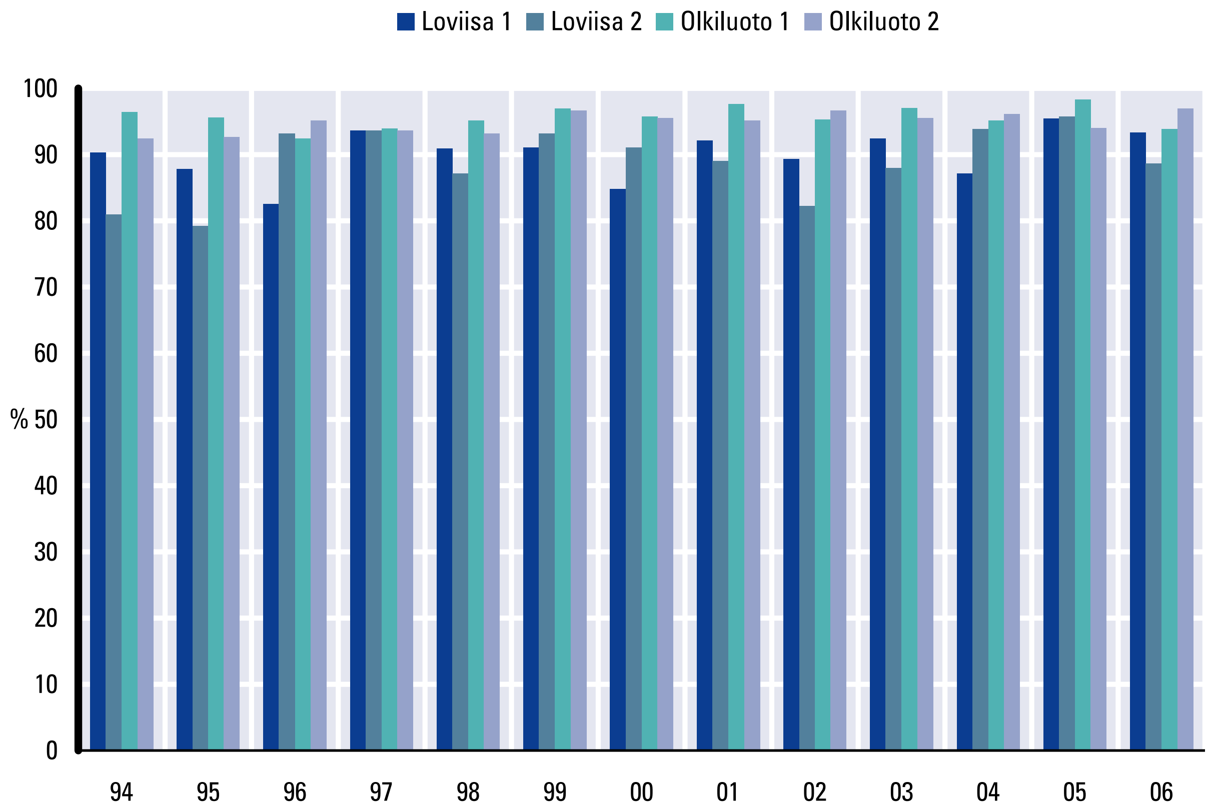


Figure 1. Load factors of the Loviisa and Olkiluoto plant units.

produced if the unit had operated at the nominal power during the whole period.

Construction License application was submitted by TVO in January 2004 for constructing the fifth nuclear power plant unit in Finland on the Olkiluoto site. The new unit, Olkiluoto 3 is a 1600 MWe European Pressurized Water Reactor (EPR), the design of which is based on the French N4 and German Konvoi type PWR's. A turn key delivery is provided by the Consortium Areva NP and Siemens. The technical requirements for Olkiluoto 3 unit were specified by using the European Utility Requirements (EUR) document as a reference. TVO's specifications complemented the EUR mainly in those points where Finnish requirements are more stringent. STUK gave its statement on nuclear safety in January 2005 and the Government issued the Construction License on February 2005. Construction work is going on and the commercial operation is expected to be started in 2011.

During the years 1996–1998 the overall safety reviews of the Loviisa and Olkiluoto plants were carried out by the licensees and independently by STUK in connection to the renewal of operating 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 latest overall safety review of the Loviisa plant took place in 2005–2007 in connection of the relicensing of the operation of the plant (see chapter 2.2.2). As regards the Olkiluoto plant, the comprehensive periodic safety review will be completed by the licensee by the end of 2008 (see chapter 2.2.3).

In Finland, the continuous safety assessment and enhancement approach is presented in the nuclear legislation. Decision (395/1991) states 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.

The large plant modernization and power uprating projects in the Finnish nuclear power plants at the end of 90'ies are described in Annex 2. Also plant modifications carried out during recent years are included in the Annex 2.

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 been organized at both of the Finnish nuclear power plants, at Olkiluoto in March 1986 and at Loviisa in November 1990. The IAEA OSART visited Loviisa NPP again during 3–21 March 2007 (see chapter 2.6.2). The WANO safety reviews at both Finnish nuclear power plants have been carried out at the Olkiluoto nuclear power plant at the end of 1999 and during the year 2006 as well as at the Loviisa nuclear power plant at the beginning of 2001.

2.2.2 Extension of Operating License of Loviisa NPP in 2007

The Finnish Government granted in July 2007 to Fortum new licenses for the following:

- Operating licence until 31 December 2027 for reactor unit Loviisa 1
- Operating licence until 31 December 2030 for reactor unit Loviisa 2
- Operating licence for other buildings and facilities and their extensions in the plant area necessary for the operation of the plant until 31 December 2030
- Licence for the possession of maximum 1100 tonnes of uranium in spent nuclear fuel, 3000 cubic meters of solid low and intermediate level nuclear waste and 2400 cubic meters of low and intermediate level liquid nuclear waste.

The length of the operating licences corresponds to the current goal for the plant's lifetime, which is 50 years. The contents of the operating license application were:

- Operating licence application including 12 appendices (13 documents, 200 pages)
- Documentation for STUK according to Nuclear Energy Decree (10 documents, 70 pages)
- Periodic Safety Review of the plant for STUK (43 documents, 700 pages).

The application was addressed to the Government and was handled by the Ministry of Trade and Industry. Fortum filed the application to the Ministry of Trade and Industry in November 2006.

Legislative and regulative requirements for the application of the operating licence are described in the Nuclear Energy Decree (161/1988) Sections 33, 34, 36 and in the Guide YVL 1.1 Regulatory control of safety at nuclear facilities.

The Loviisa plant is reaching its original design age in 2007-2010, but the technical and economical lifetime of the plant is estimated to be at least 50 years according to the current knowledge of the plant ageing. Due to consistent plant improvements, the safety level of the plant has been increased as shown by the probabilistic safety analysis (PSA).

For continued safe operation, plant improvement projects are still necessary. The largest ongoing investment is the complete renewal of the plant automation system, which is scheduled to be completed by 2014. Plant lifetime management includes credible procedures for following the plant ageing. The conditions of components which are practically impossible to be replaced by new ones (pressure vessel, steam generators, etc.) are monitored most actively.

Based on application, STUK carried out a comprehensive review of the safety of the Loviisa plant. The review was completed in July 2007 when STUK provided the Ministry of Trade and Industry with it's statement on the safety of the plant.

2.2.3 Periodic safety review at Olkiluoto NPP in 2008

The operating licence for Olkiluoto 1 and Olkiluoto 2, requires that a comprehensive safety review (PSR) shall be carried out by the end of 2008. The operating licence also covers the interim storage facilities for spent fuel and medium and low activity operational waste, so these facilities are included in the PSR. The PSR will be submitted to STUK for approval. TVO started preparations for the PSR in 2004.

Regulatory guide YVL 1.1 specifies the contents of the PSR. For a separate periodic safety review, STUK shall be provided with similar safety-related reports as in applying for the operating licence. The PSR is mainly based on the documents referred to in Section 36 of the Nuclear Energy Decree. These documents shall be continuously updated, and the updated versions shall be submitted to STUK. The PSR will include a summary of the most significant changes to the documents after the granting of the operating licence and a description of the documents' updating status.

The PSR shall also contain an assessment of the safety status of the nuclear facilities, potential areas of development and maintenance of safety. This assessment shall include the following documents:

- with respect to nuclear power plants, a report on the fulfilment of the requirements laid down in the Decisions 395–397/1991 and in the relevant regulatory guides, and, correspondingly, with regard to other nuclear facilities, a report on fulfilment of the requirements set in the regulatory guides concerning the nuclear facility in question. Work is going on to replace the Decisions by corresponding Government Decrees. These will be taken into account in the PSR.
- a summary of the renewed safety analyses and conclusions drawn from their results. Several analyses in the FSAR will be updated.
- experience of the facility ageing and ageing management
- a description of the licensee's safety culture and safety management
- with respect to nuclear power plants, a report on the actions required in Section 27 of Decision 395/1991 and on the consequent plant improvements. Here operating experiences in Finland and abroad and results of safety research are taken into account.
- a report on compliance with any terms of the operating licence
- a summary of fulfilment of the requirements laid down in Section 20 of the Nuclear Energy Act.

The report on the safety culture will include the assessment methods, conclusions from the current status and effects within the operating licence period, and the measures aimed to upgrade the safety culture. In assessing and upgrading the safety culture, the expertise acquired in both organizational studies and practical nuclear safety shall be put to good use.

When making the PSR, TVO will verify that the safety factors proposed in the IAEA's PSR guide NS-G-2.10 have been taken into account to a sufficient degree.

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 Government 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 Government Decision (478/1999) was issued to give the "Regulations for the Safety of Disposal of Spent Fuel".

The Nuclear Energy Act was amended in 2003 to establish funding for nuclear safety research. The objective of this arrangement is to ensure the high level of national safety research and to maintain the national competence in the long run. The amendment established funding for nuclear waste safety research, respectively. In addition to the national research programmes funded mainly by the above arrangement, the nuclear utilities and the nuclear waste management company Posiva Oy carry out and finance R&D programmes to support their own activities. More than half of the industry's R&D efforts are devoted to nuclear waste management. Furthermore, STUK orders contracted research to support their independent reviews of licensing applications.

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.

It is assumed that the amendment will set in force in the beginning of 2008. Based on the amendment also the Nuclear Energy Decree and all above mentioned General regulations of the Government will be revised.

An amendment to the Nuclear Act is under preparation. The main purpose is to present the principal safety regulations at the level of Act.

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. The financial provisions to cover the possible harms of a nuclear accident have been arranged according to the Paris and Brussels Conventions. A remarkable increase in the sum available for compensation of nuclear damages is expected in the near future since international negotiations about the revision of the Paris/Brussels agreements on nuclear liability were completed in 2004. In addition, Finland has decided to enact unlimited licensee liability by law. This means, that insurance coverage will be required for a minimum amount of EUR 700 million and the liability of Finnish operators shall be unlimited in cases where nuclear damage has occurred in Finland and the third tier of the Brussels Supplementary Convention (providing cover up to EUR 1.5 billion) has been exhausted. The revised law will also have some other improvements, like extending the claiming period up to 30 years for victims of nuclear accidents. The law amendment (2005) has not taken effect yet. It will enter into force at a later date as determined by government decree. The entering into force of the amending act will take place as the 2004 Protocols amending the Paris and Brussels Conventions will enter into force.

2.3.2 Provision of regulatory guidance

Detailed safety requirements are provided by STUK in the YVL Guides. YVL Guides also provide administrative procedures for regulation of the use of nuclear energy. 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.

The regulatory guides 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. Publication of new updates is described in Figure 2. Most of the planned YVL Guide updates were issued during 2002–2003 prior the Construction License application. The current list of regulations and regulatory guides is provided in Annex 1.

Relating to the next amendment of the Nuclear Energy Act (see chapter 2.3.1), the regulatory guide system will be reviewed. This project has been scheduled to be completed in 2011.

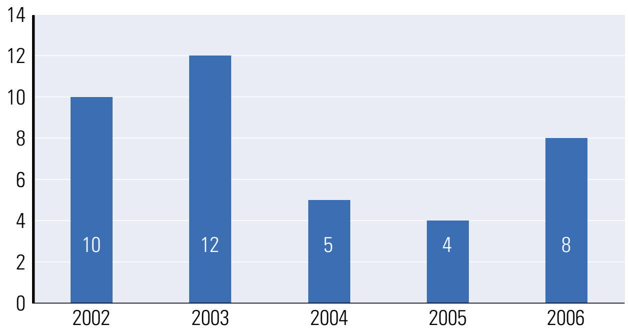


Figure 2. Recently published new updates of regulatory YVL Guides

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 Government. The conditions for granting a license are prescribed in the Nuclear Energy Act.

Before a Construction License for a nuclear power plant, nuclear waste disposal facility, or other significant nuclear facility can be applied, a Decision-in-principle by the Government 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 3. This procedure was applied 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 Government approved it and the Parliament confirmed the approval (see chapter 2.13.1).

Teollisuuden Voima Oy has filed an application for Construction License to the Ministry of Trade and Industry in January 2004. Construction License documents to be submitted to STUK for approval in this phase are defined in Nuclear Energy Decree § 35. After receiving all statements for the Construction License application, the Government made its decision in February 2005.

In accordance with Section 108 of the Nuclear Energy Decree, the different phases of construction of a nuclear facility may be begun only after STUK has, on the basis of the Construction License documents and other detailed plans and documents it requires, verified in respect of each phase that the safety-related factors and safety regulations have been given sufficient consideration.

Review of the designs of structures and equipment can be begun after STUK has found that the

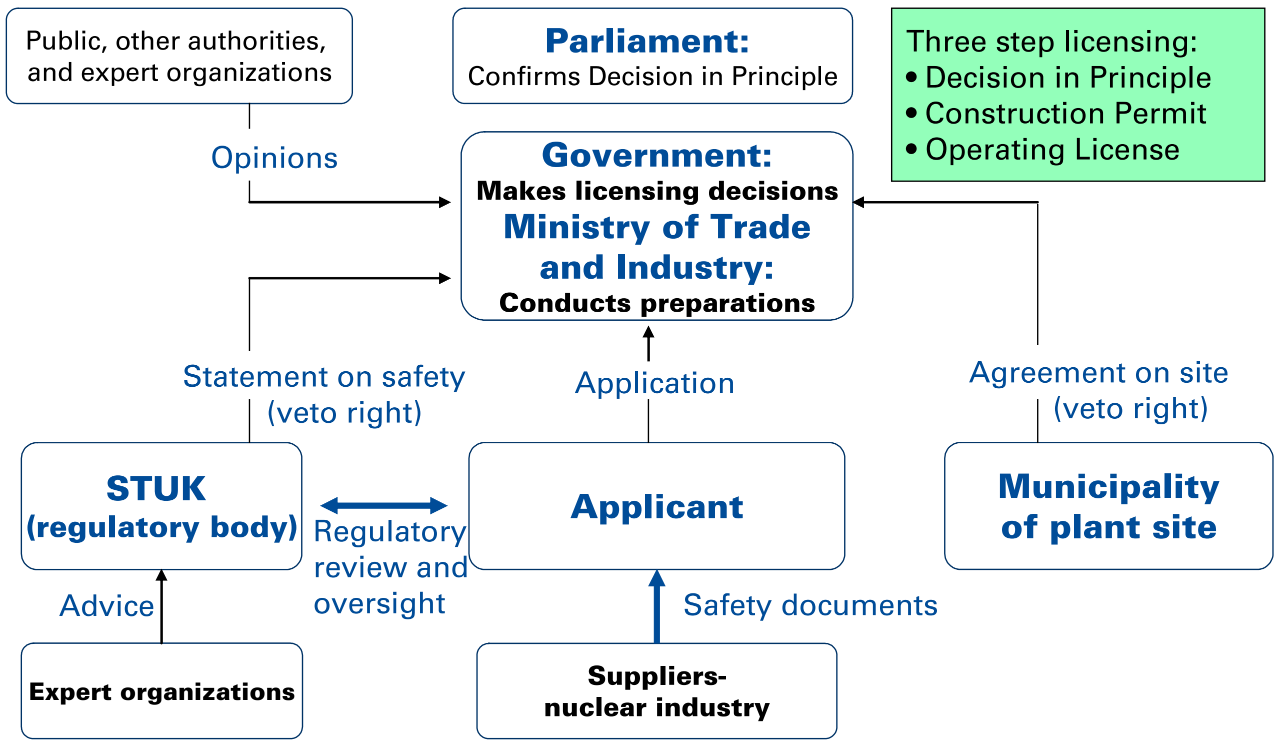


Figure 3. Licensing of nuclear facilities in Finland.

system-level design data of the system concerned are sufficient and acceptable. This assessment may take place as part of the review of the Preliminary Safety Analysis Report or separate system-specific descriptions, which are subsequently added to the Final Safety Analysis Report.

In accordance with Section 109 of the Nuclear Energy Decree, STUK oversees the construction of the facility in detail. The purpose is to ensure that the safety requirements, regulations for pressure equipment and approved plans are complied with and that the nuclear facility is constructed in other respects in accordance with the regulations. In particular, the oversigth is aimed to verify that working methods ensuring high quality are employed for the construction.

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 Decree § 36. After receiving all statements for the Operating License, the Government will make its decision.

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 Loviisa and Olkiluoto units are valid for about 20 years, but intermediate safety assessments are required as a condition of the licenses.

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.

Oversight during operation

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 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 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 International Regulatory Review Team (IRRT) mission to Finland in 2003. 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 programmes, 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 they have been carried out 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 filing 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 through STUK's plant performance indicator system. Risk significance of operational events is followed by PSA based indicators. The third 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 an investigation team to investigate a number of events together in order to look for possible generic issues associated with the events. In addition, investigations may relate to domestic or international events. These inspections are usually conducted by a leadership of the event investigation manager, and an investigation team includes normally 2–3 experts from STUK nominated on case-by-case basis.

E.g. 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 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 relations and communication between different parts of the organisation. The other investigation in 2002 addressed 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. During the period 2003–2006 there has been no investigations concerning the operating power plant units. In 2006, one investigation was carried out relating to Olkiluoto 3 (see below).

Oversight during construction

In accordance with Section 109 of the Nuclear Energy Decree, STUK oversees the construction of the facility in detail. Oversight consists of inspections within the frame of Construction Inspection Programme and inspections on manufacturing and construction of systems, structures and components important to safety. In addition, STUK has two resident inspectors overseeing the construction, installations and commissioning work at the Olkiluoto site.

To oversee the licensee's performance during construction, STUK has established a Construction Inspection Programme. The purpose of STUK's Construction Inspection Programme is to verify that the operations of the licensee ensure high-quality construction and implementation in accordance with the approved designs while complying with the regulations and official decisions. The Construction Inspection Programme is divided into two main levels: the upper level assesses the licensee's general operations to construct the facility, such as project management and resources management, organisation, dealing with safety matters and consideration of safety in management procedures, the licensee's expertise and use of expertise and project quality management. The next level, known as the operation level, assesses e.g. project quality assurance, training of the operating personnel, inspection procedures, utilization of the PSA, document management, radiation safety, and system, structure and component-specific reviews and inspections in the various fields of technology. Furthermore, the emergency response arrangements during construction, physical protection, fire protection and nuclear waste treatment are subjects of the Construction Inspection Programme as far as the scope STUK considers necessary. In addition to the above-mentioned inspections, of which the licensee is informed in advance, STUK carries out inspections without prior notice at its discretion.

STUK performs inspections on manufacturing and construction of buildings, concrete and steel structures, and components as specified in YVL Guides. In addition, STUK performs inspections on installation and commissioning of systems, structures and components. The safety class of systems, structures and components is taken into account when determining the scope of inspections. On the licensee's application, STUK may approve a separate testing and inspection organization to carry out specified control duties.

In March, 2006, STUK appointed an investigation team to assess compliance with safety requirements in the construction of Olkiluoto 3. STUK had noticed that the management of organisations participating in the construction did not fully comply with STUK's expectations concerning good safety culture. The objective of the investigation team was to make an evaluation of the practices of TVO and the Turn Key Supplier in the light of three case studies selected as examples. The example cases were the concreting of the base slab, the manufacturing of the steel liner for the reactor inner containment, and the selection of the manufacturer as well as the start of the design process for the polar crane and the material hatch in the containment. Furthermore, the investigation team examined why the regulatory oversight of STUK had not prevented the observed problems. In its report (July 2006), the investigation team stated that the major problems involved project management, in particular with regard to construction work, but not nuclear safety. The power plant vendor had selected subcontractors with no prior experience in nuclear power plant construction. These subcontractors had not received sufficient guidance and supervision to ensure smooth progress of their work. In its report, the investigation team emphasised working practises that would comply with good safety culture. It is important what kind of attitude to the safety is taken and how it is implemented in working practices. The investigation team provided recommendations both to TVO (10) and the Turn Key Supplier (11). Furthermore, there was also room for recommendations (7) for improvement in the practices of the regulatory body. TVO and the Turn Key Supplier prepared a detailed action plan in response to the recommendations. It was sent for STUK's approval in fall 2006. Particular attention was paid to identify corrective measures to address the problems experienced in subcontractors' guidance and supervision. The action plan aimed for making the project-related responsibilities clearer, increasing the level of supervision, and improving the guidance and instructions provided. The action plan was approved by STUK. In its decision, STUK emphasised that the project management expertise is a major issue, and that continued attention must be paid to it.

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.***

STUK in the regulatory framework

According to the Nuclear Energy Act, the overall authority in the field of nuclear energy is the Ministry of Trade and Industry. The Ministry prepares matters concerning nuclear energy to the Government 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-making a matter that has been defined by law to STUK. The current Act on STUK was given in 1983 and the Decree in 1997. 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 4. It is emphasised that the regulatory control of the safe use of radiation and nuclear energy is independently carried out by STUK. STUK has no responsibilities or duties which would be in conflict with regulatory control.

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 a plant 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.

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 Government.

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 site is an important tool in communication. It is important that the web pages are

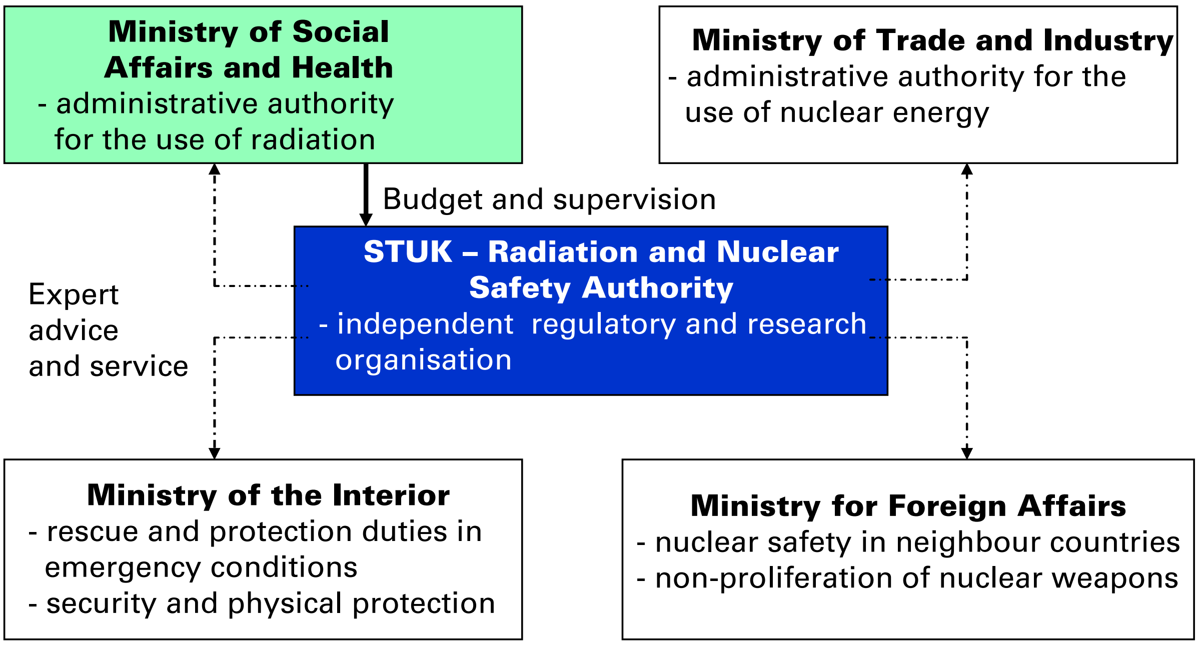


Figure 4. Co-operation and interfaces between STUK and Ministries.

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.

Finance and resources of STUK

The organisational structure and the responsibilities within STUK are provided in the Quality Manuals of STUK. Also processes for regulatory control and other activities of STUK are presented in the Manuals. The organisation of STUK is described in the Figure 5.

STUK receives about 40 % of its financial resources through the government budget. The costs of regulatory control are charged in full to the licensees. The strategy of financing the regulatory control work was changed in 2000 to 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. The tentative amount of budget for regulatory control is annually agreed with the Ministry. The change in the financing procedure has not changed the actual costs of regulatory control activities.

In 2006, the costs of the regulatory control of nuclear safety were 10.1 million €. The total costs of nuclear safety regulation were 11.1 million €. Thus the share of activities subject to a charge was 91 %.

STUK has adequate resources to fulfil its responsibilities. At the moment 95 professionals are working in the field of nuclear safety. This is 15 experts more than during the time of the third review meeting. The expertise of STUK covers all the essential areas needed in the safety control of the use of nuclear energy. As needed STUK orders independent analysis from technical support organizations to complement its own review and assessment work. The main technical support organisation of STUK is the Technical Research Centre of Finland (VTT). 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 (LUT) of Technology in

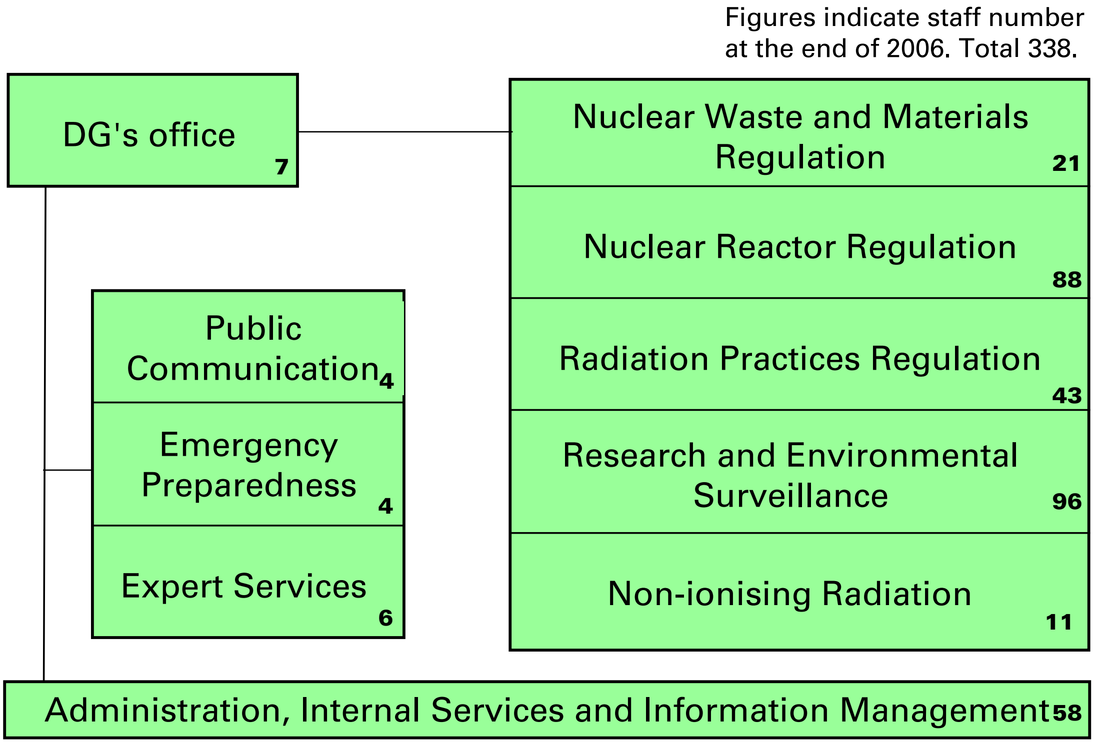


Figure 5. Organisation of STUK. Numbers indicate the number of staff in the organizational unit.

the field of nuclear research. Also international technical support organizations and experts have been used.

New personnel have been recruited since 2003 mainly for the safety review and assessment and inspection activities related to the new power plant unit Olkiluoto 3. First batch of the licensing documentation was submitted to STUK at the beginning of the year 2004 and the Construction License was granted at the beginning of 2005. The overall manpower needed for the review and assessment of the Construction License application documents was about 35 manyears; about 70 % was STUK review work and 30 % Technical Support Organizations review work. Since that the annual volume of the oversight of the construction has been about 25 manyears.

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 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.

Ensuring competence

The nuclear safety competence has been in the focus of the management at STUK. The strategy work of STUK includes the definition of the core competences needed for the oversight. Implementation of the strategy is reflected into the annual training programmes, on the job training and new recruitments. The national nuclear safety and waste management research programmes have an important role in the competence building of all essential organizations involved in nuclear energy. These research programmes have two roles: for the first ensuring the availability of experts and for the second ensuring the on-line transfer of the research results to the organizations participating to the steering of the programmes and fostering the expertise. STUK has an important role in the steering of these programmes.

Most of the professional staff of STUK conducting safety assessments and inspections has a degree of university level. The average experience of the staff is about 15 years in the nuclear field. For the first time during the years 2002 and 2003 a competence analysis was made at STUK. This analysis is periodically updated. The results of these analyses are used as the basis for the training programmes and the new recruitments. The training programme includes internal courses as well as courses organized by external organizations. On an average 5 % of the annual working hours has been used to enhance the competence. During 2005 and 2006 the focus of the internal training programme has been on the EPR safety systems.

STUK has participated in the preparation and execution of a basic professional training course on nuclear safety with other organisations in the field. The first 6-week course commenced in September 2003 and continued in 2004. The fifth basic professional training course is organized in autumn 2007. At the moment, about 200 junior experts and newcomers, of whom about 40 have been from STUK, have participated in these courses. The content and structure of the course has been enhanced according to the feedback received from the participants. The evaluation of the course was made by senior experts in 2007.

In Finland, VTT is the largest research organization in the field of nuclear energy. At VTT, about 200 experts are working in the field of nuclear energy. The total volume of the nuclear energy research in the year 2006 was 28.5 million €. This figure includes also research made by GTK, LUT and Helsinki University of Technology (TKK).

The Nuclear Energy Act was amended in 2003 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. 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 for the future waste management activities 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 programme (SAFIR2010) 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 2007 has been 2.7 million € for nuclear safety research. The research projects have also additional funding from other sources. The total volume of the programme in 2007 is 6 million €. Similarly a national research programme in the area of nuclear waste management (KYT2010) to support the authorities is underway. The annual volume of KYT2010 programme is 1.0 million €. STUK participates in the steering of the programmes. In 2006, the share of the national publicly funded reactor safety research programme was 17 % of the total volume of the research and correspondingly the share of the national publicly funded nuclear waste management programme was 4% of the total volume. All the important technical support organizations participate in the research programmes.

International co-operation

In addition to the government review of regulatory activities, there have been independent regulatory reviews conducted by International Atomic Energy Agency, IAEA. The IAEA IRRT's (International Regulatory Review Team) have visited STUK providing full-scope IRRT mission in 2000 and IRRT Follow-up Mission in 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 good practices worth pointing out to other authorities. STUK has found the IAEA IRRT mission as a fruitful tool in developing its own functions.

STUK participates actively in 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. The experience of the small regulators is shared in the Network of Regulators of Countries with Small Nuclear Programmes (NERS). STUK also participates in the work of European Commission through Atomic Questions Group, Working Party on Nuclear safety (WPNS), and RAMG-related PHARE-, TACIS- and INSC-programmes, and of EBRD as well as European regulators' association WENRA.

STUK has close connections with foreign regulatory bodies for exchanging information on important safety issues. There is regulatory co-operation through Nordic co-operation programmes and VVER Regulators Forum. STUK also co-operates actively with Russian Rostechnadzor, as well as with Kola and Leningrad NPP's concerning nuclear safety of these plants close to the Finnish borders. Finnish government finances this co-operation. Bilateral co-operation with several regulatory organizations concerning the European Pressurized Water Reactor (EPR) safety issues has been very active since the beginning of the licensing of the new plant unit (Olkiluoto 3). STUK is an active member in a Multinational Design Evaluation programme (MDEP) in which a model is developed for a multinational safety assessment of a new reactor.

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 prescribed in the Nuclear Energy Act. According to Section 9 of the Act 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. To ensure that the financial liability for the future management and disposal of nuclear wastes and for the decommissioning of nuclear facilities is covered, the nuclear power companies are each year obliged to present estimates for future costs of these operations and take care that the required amount of money is set aside to the State Nuclear Waste Management Fund. In order to provide for the insolvency of the nuclear utilities, they shall provide securities to the Ministry of Trade and Industry for the part of financial liability which is not yet covered by the Fund. At the end of the year 2006 the funded money (1 510 million euros) covered most part of whole liability and only about 75 million euros were covered by securities.

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 damages to third parties caused by a nuclear accident have been arranged in Finland according to the Paris and Brussels Conventions. Related to the revision of Paris and Brussels agreements in 2004, Finland has decided to enact unlimited licensee liability by law (see Article 7). The revised law will also have some other improvements, like extending the claiming period up to 30 years for victims of nuclear accidents.

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 2003. The Quality Policy includes also STUK's values that are engaged to every day work giving the highest priority to keeping the radiation exposure of people as low as reasonable achievable and preventing radiation and nuclear accidents. 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 licensees. The top level inspection of the periodic inspection programme, called "Safety Management", includes an assessment of safety culture issues and quality management. In addition, safety culture issues are included in quality assurance audits and event analyses. Findings related to safety culture from different inspections are analysed in STUK and discussed in annual meetings 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 high level safety culture, and to further develop it. E.g. the rate of annual investment (Figure 6, see Article 11) 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 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 and development 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 operating 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. Current safety and quality policies for Fortum's nuclear power operations and for the plant address advanced 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. The state of safety culture has been 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. Safety culture in the Loviisa Power Plant was observed during the WANO Peer Review in 2001 and during the IAEA OSART mission in 2007.

At the request of the Government of Finland, an IAEA Operational Safety Review Team (OSART) of international experts visited Loviisa Nuclear Power Plant (NPP) during 3-21 March 2007. The purpose of the mission was to review operational safety practices and to exchange technical experience and knowledge between the experts and their plant counterparts on how the common goal of excellence in operational safety could be further pursued. Emphasis was placed on assessing the effectiveness of operational safety rather than simply the content of programmes. The conclusions of the OSART team were based on the plant's performance compared with IAEA Safety Standards and good international practices. The OSART team concluded that the managers of Loviisa NPP are committed to improving the operational safety and reliability of their plant. The team found good areas of performance, including the following: A long term commitment to ongoing investment in equipment and system upgrades that have significantly reduced overall plant risk for core damage and release of radioactivity; Developed a high quality and a comprehensive Probabilistic Safety Analysis with state-of-the-art methods and tools and its use by the plant in several areas; Use of an analysis programme for estimating accidental releases in advance to support the on and off-site emergency organizations with recommendations for protective actions; Direct information exchanges with other VVER plants has contributed for sharing operating experience through twinning and personnel exchange. The OSART team also made recommendations and suggestions related to areas where operational safety of Loviisa NPP could be improved. Recommendations and suggestions include: Operators' performance could be improved by a more rigorous approach in their work practices, including shift turnover, control room conduct and field operations; The operating experience feedback programme is not comprehensive regarding reporting and analyzing operating experience, identifying and tracking corrective actions, using operating experience, and monitoring it by performance indicators; The methods currently employed by the plant for the containment and reduction of radioactive materials are not fully effective. The OSART team recognised that the radioactive waste and the decontamination processing areas will be relocated under the impending plant upgrade, which will create better conditions for improving the handling and storage issues.

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, Legal Affairs; 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 Document.

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 1999 and a Follow-up in 2001. WANO conducted a new Peer Review in Olkiluoto in 2006.

In order to maintain a high safety culture and good operational results, TVO made a self-assessment of the safety culture to enhance safety culture and safety management in 2004. The self-assessment and the enhancement programme were conducted with the help of the IAEA.

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.

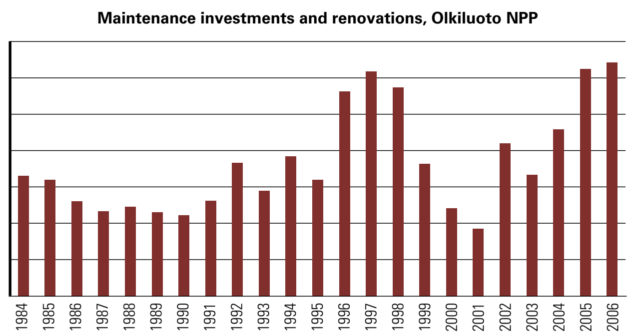
For example according to the Nuclear Energy Act, the licensee shall have adequate financial resources to take care of the safety of the plant. Nuclear Energy Act provides detailed regulations for the financial arrangements for taking care of nuclear waste management. The Act on Third Party Liability 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 provide financial information on the utilities. Both utilities have annually invested typically about 10–20 M€ for maintaining and improving safety. Figure 6 provides 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.

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 20 persons and full-scope plant-specific training simulators.

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 2005–2006 two five weeks training courses on nuclear safety technology were provided to train newcomers in the nuclear field as a specific co-operation of all nuclear related organizations. About 60 young experts and newcomers were trained during one course. The intention is to continue with the training



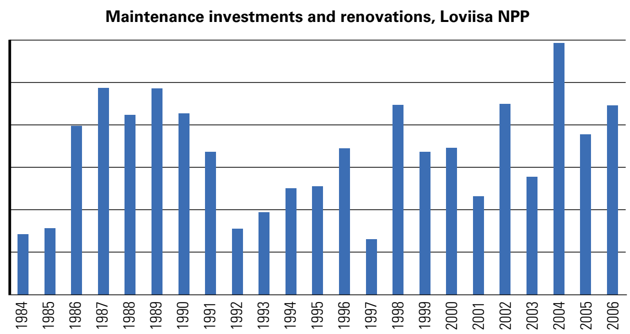


Figure 6. The annual relative rate of investments at the Olkiluoto and Loviisa NPP's.

course on annual basis as long as there are enough participants who need the training. Training materials have been developed and 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 maximum of 4 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 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 threefold 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.

In connection to bigger modification or renewal of plant equipment, i.e. renewal of the automation systems (LARA-project) separate training programme is made to ensure that the personnel is well trained in the use of the new equipment.

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 Olkiluoto 3. 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 10 weeks as a part of the basic training. 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 programme, which is conducted in a three-year period, is available for the plant operators. The programme 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.

The initial training of personnel of 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 unit. 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 at least 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 2010. 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.

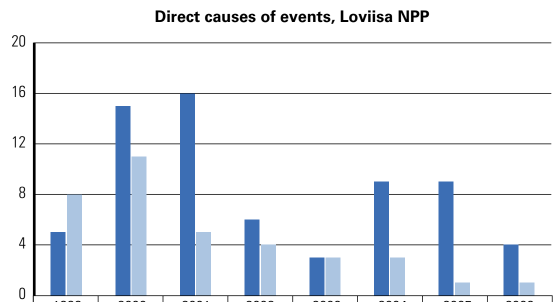
As regards the operation of the facility, the influence of human factors and the respective need for corrective measures are assessed by the licensees and STUK, when evaluating abnormal events and their lessons learnt. Each operating organisation has established a systematic procedure for making event evaluations. Figure 7 shows the share of technical and human related causes for the latest incidents at the Finnish nuclear power plants. E.g. during 2006, Loviisa NPP reported 5 events from which 1 contained human root causes and Olkiluoto NPP reported 9 events from which 6 contained human root causes.

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

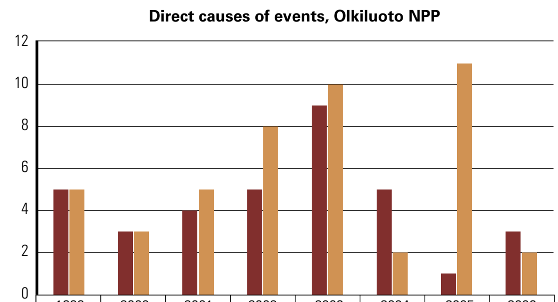
2.8.2 Monitoring and control of the Loviisa nuclear power plant

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



	1999	2000	2001	2002	2003	2004	2005	2006
Technical	5	15	16	6	3	9	9	4
Human	8	11	5	4	3	3	1	1



	1999	2000	2001	2002	2003	2004	2005	2006
Technical	5	3	4	5	9	5	1	3
Human	5	3	5	8	10	2	11	2

Figure 7. Number of technical and / or human direct causes identified in the event analysis at the Loviisa and Olkiluoto NPP's.

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. For severe accidents there is a dedicated control room shared by the both units.

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 stage of design and implementation of the first phase at the unit 1. The renewal project will be discussed under Article 18.

Human factors

Human errors can not be entirely avoided. However, the possibility of errors can be made smaller with proper procedures, 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 different types of duties performed 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 procedures. 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 the interim spent fuel storage are conducted 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 as well as with several computer display units. Conventional and computer aided alarm systems are used to facilitate the management of main processes and other sub and auxiliary processes. During the renewal of turbine automation system several new computerized operator workstations and a large screen display system were installed into the main control room. 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, is in 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 posts. 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 posts. TVO has studied the independence of the control room and the emergency control posts 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. However TVO is evaluating possibilities to improve and centralize the emergency controls to better apply the present requirements. Any modifications are planned to be carried out in connections of modernization of reactor protection automation system.

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 I&C modernization projects, some 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 I&C modernisation projects started in 90's encompass several systems the latest of which are mentioned in Annex 2. TVO plans to continue the modernization of systems during the forthcoming years.

A new programmable technology was taken into use, in connection with the conducted modernisations. The latest modernization of the turbine plant automation introduced the soft key controls to the power plant. 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.

Human Factor issues are taken into account in all events. Lessons learned from the events are taken into account in the corrective actions plans and lessons learned are used in internal training and organizational develoment. TVO cooperates in human factors with national specialists from research organizations and also specialists from other industries. TVO also cooperates with foreign nuclear companies and organizations in the area of human factors. TVO has had human factor specialist since 2004.

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 a 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 nuclear fuel 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 further assessment of the quality management system for the design and construction of the new Olkiluoto unit is underway.

STUK has a Quality Manual that includes 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 quality policy. In the quality management system, the process oriented approach has been implemented through out the whole organization in 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 through bilateral contracts.

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. Another important 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.

Since the third National Report the Loviisa Power Plant Quality Management system has been developed continuously on the bases of internal and independent assessments and audits, management system reviews and on non-conformance control and corrective action program. New procedures have been established in following areas:

- New emergency procedures
- Laboratory quality manual and procedures based on standard SFS-EN ISO/IEC 17025
- Inspection Body Loviisa YVL procedures based on standard SFS-EN ISO/IEC 17020:2004
- Management self assessment
- Industrial safety procedures and instructions.

All these new procedures are part of Loviisa Nuclear Power Plant Quality Management System. The management system processes have been defined and process descriptions implemented in 2006. The Industrial Safety System will be certified in 2007.

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's company-level policies are grouped under four headings. TVO bases its company-level policies on its values and business concept. TVO's company-level policies are: nuclear safety and quality policy, social responsibility policy, production policy and corporate security policy.

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 organization units. The Administrative Rules have been approved by STUK as a part of the Technical Specifications Document.

The documentation and procedures are controlled by a software based system as well as the management of deviations and corrective actions. TVO's quality management system and quality management system for Olkiluoto 3 construction phase are certified to fulfill ISO 9001:2000 requirements. For the Olkiluoto 3 construction phase STUK has approved "The Quality Manual for Olkiluoto 3 Project". The review of 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 Construction and 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 Licenses. 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 justified 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. According to Guide YVL 2.2, the accidents are classified based on the frequency of initiating events in Category 1 and 2. Additional criteria are presented in the Guides YVL 6.2 and YVL 7.1 concerning nuclear 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. 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 relicensing of the Loviisa nuclear power plant took place in 2006–2007 and new operating license was granted in July 2007. The latest comprehensive safety assessment of Olkiluoto nuclear power plant was carried out in connection with the relicensing in 1996–1997. The license applications included the documents required by the Nuclear Energy Decree (see above). E.g. Final Safety Analysis Reports were updated. The updates of the accident analyses and PSAs including Level 1 and 2 PSA analyses were made in this connection. They involved calculations of most transients and accidents with advanced computer codes. The results of the analyses are discussed in detail below. The licensees also provided assessment how the regulations have been complied with, including the fulfilment of YVL Guides. The licensees 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, 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 management at the utilities as well as regulatory body. 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 is done according to the Finnish regulations and YVL Guides. 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 395/1991 and with all YVL Guides is assessed by the plant designer. 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 models 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

The aim of transient and accident analyses is to demonstrate the capability of the plant to cope with various transient and accident situations so that regulatory requirements are fulfilled. According to regulatory requirements, the analyses shall be focused to events, which by nature and severity cover different kind of transient and accident situations.

In connection with the relicensing of the Loviisa 1 and 2 units during 2005–2007, Fortum has revised the Final Safety Analysis Report, including the transient and accident analyses, taking into account plant modifications implemented at both Loviisa 1 and 2 as well as new regulatory requirements. For the assessment of normal operating conditions, transients and class 1 and 2 accidents Fortum has used primarily calculation methods which have been developed and validated in Finland. The main tool in the analysis has been APROS code that has been developed in co-operation between Fortum and VTT.

The analyses presented in the Safety Analysis Report cover anticipated operational transients, Category 1 and 2 accidents used as a design basis of safety systems and severe reactor accidents. 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 analyses have been carried out for full power, low power and zero power conditions.

Fortum has separately made accident analyses for the storages of spent fuel and reactor waste. 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.

STUK has assessed 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 the applicability of analysis methods to the description of different transients, the sensitivity of analysis results to the parameters describing the plant status, and course of an accident or functioning of the models have been clarified. STUK concluded 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 Loviisa plant.

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 (SAR), related Topical Reports and other reference reports of SAR.

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 renewed during the modernisation project in 1994–1998. The renewal of analyses for periodic safety review (PSR) in 2008 is in progress.

STUK has assessed 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 have 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 the 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 (Design Basis Conditions) 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 pressure 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 accepted the PSAR and its analyses for the construction license of Olkiluoto 3 in January 2005.

2.10.3 Probabilistic safety analysis

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 1990 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.

A description of the results of PSA performed during the period 1990–2003 including the modernization programme is presented in Annex 2. Thereafter the plant modifications have further improved the plant safety and at the end of year 2007 the calculated estimate for the total probability of reactor core damage is about 8.2×10^{-5} 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 total probability of a large release to the environment is about 2.7×10^{-5} a year. The implemented modifications of the Loviisa plant to fulfil the strategy against severe accidents have been included in the estimate. 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. The estimate for a large release includes a detailed level 2 PSA study for internal events, floods and severe weather conditions in at-power states, whereas the remaining areas (fire, seismic and outages) are based on a rough estimate on the consequences of the accident sequences from level 1 analyses.

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.

Probabilistic safety analysis in the Olkiluoto NPP

STUK required in 1984 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 containment 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).

Detailed description of the results of PSA performed 2007 including the modernization programme is presented in Annex 2. At the 2007 the overall core damage frequency of Olkiluoto 1 and 2 is according to the living PSA approximately 1.5×10^{-5} per reactor year, when all analyses described in Annex 2 are taken into account.

In 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. 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.

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. STUK accepted the Olkiluoto 3 PSA for the construction license of Olkiluoto 3 in January 2005.

2.10.5 Verification

Verification programmes

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 in 2005–2007 and Teollisuuden Voima Oy in 1996–1998. These activities were controlled by STUK. The new periodic safety review of Olkiluoto plant will be completed by the end of 2008.

Inspection qualification

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) shall also be followed. The application of the documents has been described now by Guide YVL 3.8. The licensees have drawn up a strategy for qualification including general guidelines and guides to the practical qualification work. Licensees have also nominated a steering committee, which has nominated a technical support group, and independent qualification body has been established. Several qualification cases have been completed.

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 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. In the content of licensees guidelines the requirements presented in YVL 3.8, in the European Methodology for Qualification (EUR 17299) and in its recommendations have been taken into account.

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 testing bodies and a qualification body. On the basis of Sections 19 and 20 of the Nuclear Energy Act, the licensee shall have available the necessary expertise and economic resources.

The licensee has a qualification body for qualification management, implementation, control and assessment as well as the issuing of qualification certificates. The qualification body is 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 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. The nuclear licensees have established the Steering Committee and nominate its members. The Steering Committee is formed by the representatives of Fortum, TVO, VTT, vendors performing nuclear power plant inspections and STUK. The representative of the qualification body, Inspecta Certification, is the secretary of the Steering Committee. The members of the Steering Committee are nominated on annual basis. Nominated qualification body (Inspecta Certification) is responsible for the practical arrangement of qualification. When needed Inspecta Certification uses also experts outside of its own organisation for individual qualifications.

Qualification of UT inspection personnel is now organised and realised. In addition to SFS-EN 473 qualifications, an additional personnel qualification is required and established for in-service inspections. Additional personnel qualifications are based on theoretical and practical trials using qualified inspection procedures and test pieces with cracks for detection and sizing, and covering the data analysts and manual inspectors. The qualification for sizing of cracks manually is realised for the most experienced inspectors. Several qualifications of inspection systems are completed successfully and approved by STUK.

In-service inspections in 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 plans are submitted to STUK for approval before each individual inservice inspections. 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 kinds 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 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. Several inspection systems are already qualified. New qualification cases have been started and reasonable amount of qualification cases are in progress. Inspection systems are qualified or in progress for the new phased array technique. Several new qualification cases are under design phase. Implementation of input data for qualification and design of relevant test pieces is going on. STUK follows the development and implementation of the plans closely.

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.

In-service inspections in 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 programmes are supplied to STUK for approval before each inspection. The programmes 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, three or two years and for items susceptible to thermal fatigue, respectively, three years.

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

Olkiluoto NPP has qualified most of the entire NDT-system; equipment, software, procedures and personnel according Guide YVL 3.8. In the near future, focus is to maintain all the qualifications and complement qualifications with new techniques. Main focus is also to verify that all the in-service inspection items are covered with qualified inspection techniques. In addition to the aforementioned inspections, physical inspections that concern the condition and reliability of pressure equipment are performed at regular intervals according to the Finnish pressure equipment legislation.

Ageing management

The Finnish regulatory approach to ageing of systems, structures and components (SSCs) is laid down in the YVL Guides. Further dedicated regulation is expected from their renewals and the ongoing review of the Decision of the 395/1991. The current YVL 1.0 underlines ageing consideration in the design stage and in provision for the associated surveillance, repair and replacement activities. In the context of operating licence application, YVL 1.1 requires an ageing management plan which identifies all significant ageing and wearout mechanisms and incorporates the design and qualification of the components, their operation and operating experience, as well as in-service inspections, tests and maintenance in a comprehensive programme. The detailed technical requirements have been issued in the relevant guidelines for pressure equipment, concrete structures, and electric and I&C systems and components.

The regulatory oversight of ageing in operating plants focuses on operating licence renewals and Periodic Safety Reviews (PSRs) where the conformance to the relevant regulations and YVL Guides, including experiences with ageing and its management, will be investigated. STUK's findings from other regulatory control practices stipulated in YVL 1.1, particularly the periodic inspection programme, are used as verification. The periodic inspections are done on plant site according to annual schedules and tackle both the technical aspects of each discipline and the process of ageing management. Regular analysis of the results gives feedback to further planning of the programme. STUK also receives from each unit annual reports on ageing management activities within each technical discipline.

Ageing management in Loviisa NPP

Radiation embrittlement of the reactor pressure vessel (RPV) has dominated the ageing related activities in the Loviisa NPP since the early years of operation. For details, see section ”Ensuring primary circuit integrity” in ANNEX 3. The current ageing management programme, known as LO-PLIM -process, was established in the mid-1990's. This process controls operation and maintenance with procedures like long-term planning, modification proposals and annual audits. The Plant Technology unit has nominated system responsibles to take care of the SSCs belonging to the programme. The SSCs have been assigned to categories A through D based on their technoeconomical replacebility. SSC failures in category A would limit plant lifetime and thus deserve a part-assembly-wise breakdown of ageing related remedies. Data indicative of plant status and trends are collected with operation, maintenance and inspection IT systems, R&D activities and via experience exchange in the WANO and NUMEX Groups. The consequent ratings of operability, remaining service life and necessary actions for each SSC are stored on the plant computer.

In 2006, the operating utility Fortum Power and Heat Oy submitted to the Government an application to continue the operation of unit 1 and 2 until the end of 2027 and 2030, respectively, meaning a 20-year extension to the original design life-time. The permits to operate the RPVs until 2012 and 2010, respectively, would stay in effect and would have to be continued via approved updating of the current RPV safety analyses. The rationale of this application had become obvious in LO-PLIM project clarifications, including fatigue analyses covering the whole 50 years' life span with due account of the environmental effects.

Technical justification was submitted to STUK, including the updated fatigue analyses and documents on In-Service Inspection Summary Programme, Ageing Management Programme Principles and Implementation, and SSC Status and Service Life Extensibility. The SSCs assigned to category A, i.e. the RPV, main coolant pump, steam generator, pressurizer, containment and reactor building, were addressed in detail while RPV internals and electical and I&C components were dropped to a lower category due to their replacebility. Projects are underway to replace cables in containment due to its detected ambient temperature rise, and for plant-wide replacing of protection and plant automation systems and components. Safety is thus adequately implemented in the programme though it is not among the direct attributes of SSC categorization.

In its review, STUK made a general point that the state-of-the-art permitted a quantitative lifetime evaluation only in case of ageing by fatigue. Uncertainties exist e.g. with corrosion phenomena. However, the potential mechanisms of each part assembly have been identified, and the utility relies on its resources to monitor, inspect, mitigate and repair as needed. Further positive arguments were found from the organisation's well demonstrated capability to surpass forthcoming ageing issues in the past: investigations leading to more reliable direct fracture toughness determination from irradiated RPV material with the Master Curve method, successful recovery of Loviisa 1 RPV critical weld properties by annealing in 1996, unanticipated primary circuit thermal mixing and stratification management with instrumentation developed by the utility, and ageing management R&D enabling the plant modernisation and power uprating in 1997–98. The review of the electric and I&C systems and components prompted a request to clarify the coverage of their ageing surveillance, and to improve their annual reporting.

Ageing management in Olkiluoto NPP

The ageing management activities in Olkiluoto NPP arose from a struggle against wide-spread inter-granular stress corrosion cracking (ISCC) in reactor auxiliary system piping. Early replacement of entire piping systems, achievable with modest doses to maintenance staff, considerably mitigated IGSCC and led the way to the utility's current strategy of seeing to the critical SSCs so that a remaining plant life-time of 40 years (design life-time) could be always demonstrated.

Since 1991, a Working Group of Lifetime Management has taken care of these activities by gathering information of possibly needed future actions from several sources and by preparing and updating a table of recommended major modifications, replacements, repairs and overhauls. The modernization and power uprating of both units by 16% in 1994–96 evolved from these recommendations and was completely undertaken by the utility's technical support organization residing on plant site. Maintenance planning also plays an important part in Olkiluoto NPP's ageing management implementation. The SSCs are assigned based on their availability requirements and preventive maintenance needs to four equipment groups, each characterized by a common type or location (e.g. all containment isolation valves) while the systems typically differ. Denominated equipment group owners and their technical support persons analyse the entire maintenance programme and its experiences with regard to the anticipated ageing phenomena and induced failure potential, and assist in selection of the most effective maintenance works according to established guidelines. The findings from each equipment group are documented annually and stored into a relational data base on the plant computer, and a summary report is sent to STUK for information.

STUK reviewed TVO's clarification on the actual condition and ageing implications of the main SSCs in its statement to support the current operating licences, expiring in 2018. In context of the next PSR, scheduled for 2008, a similar review is expected. STUK has additionally required that a pilot project be undertaken for updating the fatigue analyses to incorporate the environmental effect. The organizational processes were the subject of periodic inspection on plant site in 2005. In spite of the staff's good involvement and good records in terms of load factor, STUK found that, compared to international guidelines, the ageing management still consists of separate routines and thus misses a description as a programmatic entity where the responsibilities, SSC selection, ageing mechanisms and means of their management are clearly defined. The utility's response is underway and will be evaluated in the course of next PSR. The recent technical reviews have centred around ageing mechanisms, surveillance and replacements specific to each discipline and have produced no major comments.

The implemented modernizations of the electrical and I&C systems have, except the improvement of the plant monitoring and control, replaced the out of date equipment with more modern technology. The ageing of the cam material of the safety relays and the observer zink whiskers have caused relay changing campaing during the years 2004–2006. Some types of relays and other components are under ageing consideration and will propably be replaced.

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). Government 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 and monitoring as regards the design and operation of nuclear power plants, e.g. YVL 1.0, YVL 7.1 (revised in 2006), YVL 7.6 (revised in 2006), YVL 7.9, YVL 7.10, YVL 7.11 (revised in 2004) and YVL 7.18. The changes in the revised Guides YVL 7.1 and 7.6 concern e.g. the requirement of BAT (best available technologies) in radioactive effluent purification. The major changes of the Guide YVL 7.11 implied more in depth requirements e.g. on the requirement specifications, suitability analysis and the whole regulatory process.

STUK carries out regulatory control and inspections for ensuring that the radiation protection requirements are complied with during the operation of nuclear facilities. Experience gained from the 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 the 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 constructional structure and maintenance activities of a plant as well as on radiation protection measures in connection with works. The factors affecting safety at the plant are partly the same as for the safety of the surrounding 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 developed and 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 reassesment of the factors of the operational radiation protection in 2006. They have recruited additional radiation protection staff in 2006 and 2007.

Olkiluoto nuclear power plant has outsourced the TL dosimetry service as a whole. Preparation and detailed plans of the renewal of installed radiation monitoring systems were done in 2006 and 2007. Based on approval of STUK first installation and commissioning of these new equipment started successfully in 2007 at unit 2.

The Finnish nuclear power plants run a joint annual training of contractor's key radiation protection experts as well as basic radiation protection training for all workers accessing the nuclear power plant. STUK is observing also international development to give further instructions of enhancing this educational system.

In 2006, there was a change of the Radiation Act concerning a periodic approval of the personal dosimetry services in Finland. The approval can be granted by STUK for a time period which shall not exceed 5 years. TVO dosimetry service already got the approval until 2011. Fortum has submitted additional substantiation based on the STUK requirements for their application.

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. This practice and the results are assessed annually. The radiation doses received in other countries than Finland and Sweden are

Table 1. Radiation doses at Loviisa NPP in 2004–2006.

Year	Collective dose [manSv]	Maximum personal dose [mSv]	Average dose*) [mSv]
2004	2.49	15.8	3.49
2005	0.81	13.5	1.65
2006	1.66	13.6	2.39

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

Table 2. Radiation doses at Olkiluoto NPP in 2004–2006.

Year	Collective dose [manSv]	Maximum personal dose [mSv]	Average dose*) [mSv]
2004	1.51	13.0	1.26
2005	2.29	11.9	1.53
2006	2.20	12.2	1.46

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

reported to STUK with a specific dose record, the use of which is also imposed by the regulations of European Union.

2.11.2 Radiation exposure of workers at the Loviisa NPP

According to Guide YVL 7.9 the objective for the limitation of the collective radiation exposure of operating 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 2005, this was mainly because of the influence of the previous year maintenance activities. The utility has clarified the situation and basic reasons. Some further actions are requested by STUK aiming to improve the effectiveness of radiation protection measures in the vicinity of the primary piping and steam generators during outages. The collective dose depends also on the extent and nature of works in annual outages.

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 2002–2006 was received during working at Loviisa nuclear power plant, and it was 70,4 mSv.

The radiation dose statistics are presented in Table 1 and Figure 8.

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 are to 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 2 and Figure 9.

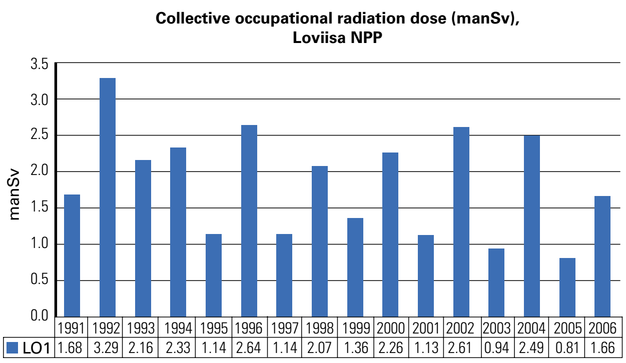


Figure 8. Collective occupational doses and distribution of individual annual worker doses at the Loviisa nuclear power plant.

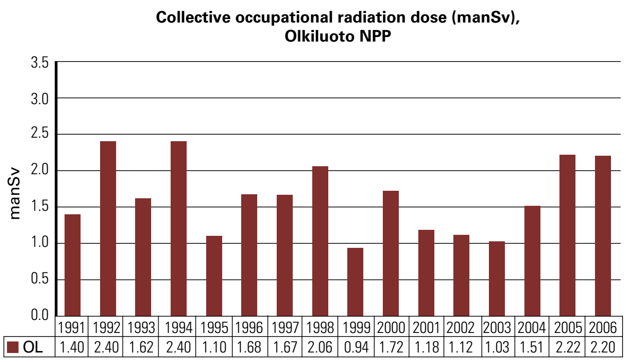


Figure 9. Collective occupational doses and distribution of individual annual worker doses at the Olkiluoto nuclear power plant.

Table 3. Radioactive effluents from the Loviisa NPP. Between brackets is presented the %-proportion of the release limit.

Year	Airborne effluents Noble gases Kr-87 ekv. [Bq]	Iodine I-131 ekv. [Bq]	Aerosols [Bq]	Liquid effluents excluding tritium [Bq]
2004	6,58E+12 (0.03%)	1,11E+07 (0.005%)	1,16E+08	1,34E+09 (0.2%)
2005	6,61E+12 (0.03%)	6,22E+04 (0.00003%)	1,07E+08	8,75E+08 (0.1%)
2006	5,78E+12 (0.03%)	3,00E+05 (0.0001%)	1,06E+08	6,49E+08 (0.1%)

Table 4. Radioactive effluents from Olkiluoto NPP. Between brackets is presented the %-proportion of the release limit.

Year	Airborne effluents Noble gases Kr-87 ekv. [Bq]	Iodine I-131 ekv. [Bq]	Aerosols [Bq]	Liquid effluents excluding tritium [Bq]
2004	under MDA	under MDA	2,14E+07	4,87E+08 (0,2%)
2005	1,52E+11 (0.0009%)	6,88E+07 (0,06%)	4,08E+07	6,80E+08 (0,2%)
2006	6,49E+11 (0.004 %)	1,56E+08 (0,1%)	3,11E+07	6,27E+08 (0,2%)

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 2,15 manSv a year for one reactor unit. The collective doses of the Olkiluoto plant is in general clearly smaller compared to the average values gained from the boiling water reactor plants of the same vintage. Extensive outage works in 2005 and 2006 have increased these from the base line.

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 are to 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 0–2 observed leakages during one annual operational period of the Olkiluoto reactors during the period 2004–2006. There were no observed leakages at Loviisa NPP during 2004–2006. Purification and waste systems of the both plants have operated 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 on the requirements of Guides YVL 7.1, YVL 7.2, YVL 7.3 and YVL 7.6). The radioactive effluents in 2004–2006 are shown in Tables 3 and 4.

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 (Decision 395/1991). Calculated radiation exposures to the individual of the critical group living in the environment of the nuclear power plants are shown in Figure 10. Doses have been clearly under the limit.

2.11.5 Environmental radiation monitoring

Environmental radiation monitoring in the vicinity of nuclear power plants has been very comprehensive and implemented according to the requirements of YVL Guide 7.7. The experience from the surveillance was taken into account when the nuclear power utilities proposed and STUK approved new monitoring programmes to be implemented 2003–2007. Changes were minor; in addition a trial of carbon-14 measurements from indicator samples in the vicinity of the sites is to be done during this 5-years period.

An outside contracted laboratory collects and analyzes about 350 samples (air, fallout, sediment,

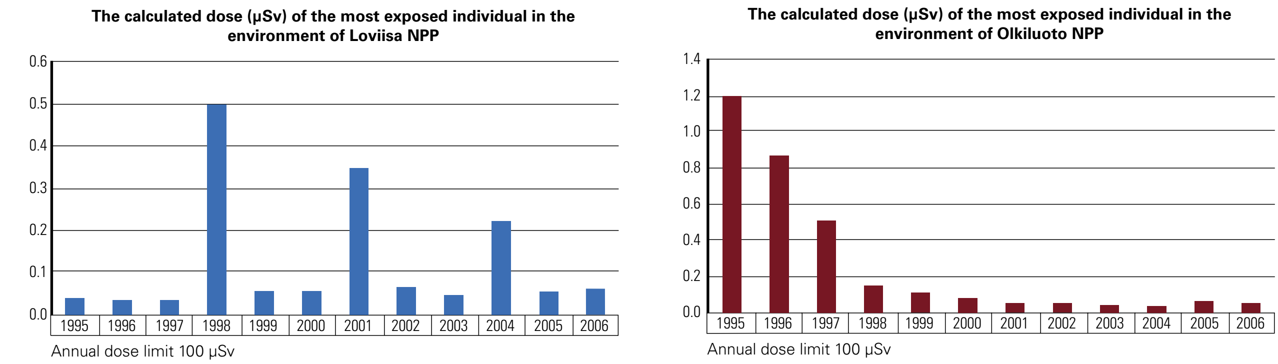


Figure 10. Calculated annual radiation exposures to the members of critical groups in the environment of the Finnish nuclear power plants. Doses have been clearly under the limit 100 microSv.

indicator organisms, milk etc) per year from the environment of each NPP. Very small quantities of radioactive substances of local origin were detected in 2004–2006 on some samples from the environment of each nuclear power plant. 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.

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.***

On-site arrangements

The basic regulations for on-site emergency planning are given in the Nuclear Energy Act and in Decision 397/1991. Rewriting of YVL Guide 7.4 (revision 2002) belongs to a pilot project of a major revision of YVL guides under preparation in 2007. 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 Third 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 have concerned new equipment and methods for keeping logbook and changing information, instructions for emergency situation, annual and long-term training.

For the new unit under construction at Olkiluoto site, the utility has provided STUK with a preliminary emergency plan. STUK also verifies in the inspections the emergency arrangement for the whole site, training for construction workers and co-operation arrangements with local rescue 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. The 2005 exercise was a typical annual emergency exercise in Loviisa NPP including notification and communications, assessment of accident situation and interactions with off-site organisations. In 2006 the Olkiluoto exercise was a table-top exercise focusing on the decision making and changing situation review between the emergency organisations of NPP and authorities. Full-scale emergency exercises with the participation of local authorities were carried out in Loviisa NPP in 2006 and in Olkiluoto NPP in 2005.

On 9 January 2005 an exceptional increase in the sea water level in the Gulf of Finland brought about an emergency standby situation at Loviisa NPP. The plant sent STUK the relevant notices and started up the operation of its own emergency stand-by organisation in order to ensure the safety level of the plant. STUK's organisation was partly summoned at STUK's emergency centre to follow the situation and communicate with Loviisa NPP as well as key authorities and partners of co-operation. The see water level increase of 1,73 m higher than the average caused no leaks into the plant's rooms or other corresponding phenomena that would endanger the plant's safety; both reactor units were in normal operation. The event was later classified as INES Level 0.

Off-site arrangements

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. The requirements for off-site plans and activities in a radiation emergency are provided in the Decree of the Ministry of Interior (774/2001). STUK is an expert body to support the Ministry of Interior in the emergency response in the case of nuclear and radiological accidents. STUK publishes VAL Guides for emergency response. Guide VAL 1.1 (2001) "Protective Actions in Nuclear or Radiological Emergency" provides detailed guidance. In the case of an accident the local authorities are alerted by the operating organisation of the plant. In the beginning of 2004 all over in Finland the counties took over the rescue obligation which was formerly a responsibility of municipalities. In this way there is a larger pool with well trained resources available.

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.

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.

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 2005 based on the Olkiluoto nuclear power plant accident scenario. In 2006 the national exercise concerned the Loviisa nuclear power plant. The rescue manager with his staff was for the first time located in the provincial capital Porvoo. This emergency operations facility had been newly planned and the off-site emergency plan totally revised. This progress and successful emergency management was noted generally very positively with numerous detailed comments concerning maintaining the preparedness continuously and further improvements.

International co-operation

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.

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 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 and 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 of 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).

In the design of a nuclear plant, site-related external events have to be taken into account. Decision 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 in 2001 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.

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

In connection with the construction of the Loviisa and Olkiluoto plants in the 1970s, principal safety requirements were defined for the siting of nuclear power plants and for the population density and human activities in the surrounding area. These requirements include also 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 licence renewal and Periodic Safety Review, 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, shall 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 of information on the design and operation of nuclear facilities.

In 1998, Teollisuuden Voima Oy and Fortum Power and Heat Oy launched the Environmental Impact Assessment procedure (EIA) of a 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. 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 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 at the existing sites either in Olkiluoto or in Loviisa. The application was reviewed by all stakeholders. STUK made a preliminary safety assessment in early 2001. After September 11, 2001, STUK updated the definitions for external threats to better reflect the change in international experience base. This update was formulated as an Addendum to the preliminary safety assessment of the new unit, and specifies as aircraft crash design requirement both a military aircraft and a large passenger aircraft. 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 a new nuclear power plant unit were given by the two candidate site municipalities. Ministry of Trade and Industry prepared the issue for the decision of the Government. The Government 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. TVO decided that the new power plant will be constructed at Olkiluoto site and applied for the construction licence early in 2004. STUK prepared the safety assessment of the new unit in early 2005. The construction licence was issued by the Government in February 2005 and the construction works started in full.

In 2007, initiatives of building one more nuclear power plant were taken. Environmental Impact Assessment programs of TVO for a possible Olkiluoto 4 unit and at the same time of Fortum for a possible Loviisa 3 unit were prepared and launched for a review. STUK will give its statement to the Ministry of Trade and Industry in September 2007. Altogether nine countries near the Baltic See have been requested for comments by the Finnish Environmental Ministry.

A new nuclear power company Fennovoima has been founded in 2007. The company has also started a preliminary site survey process, mainly in the area of the North West cost of the Gulf of

Bothnia (Baltic See northern gulf). Revision of Regional Plans of land use surrounding Olkiluoto and Loviisa NPP sites are also underway by the regional authorities and the municipalities concerned.

2.13.2 Protection against external events 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 and human activities such as oil transports have been later reviewed by Fortum as part of the Probabilistic Safety Analysis (PSA). Several modifications of plant systems and procedures have been implemented based on the PSA results. 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. Aircraft crashes are under re-evaluation in 2007.

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 direct connection to the Ahvenkoski hydro power station to ensure the power supply.

In the recent years special attention has been paid to the risks arising from oil spills in the Gulf of Finland (eastern bay of the Baltic Sea). Though no major oil accidents have so far taken place in the Gulf of Finland, the accident risk has been estimated significant in this area with busy sea traffic. An increasing part of the Russian oil exports is nowadays transported through routes passing the Loviisa NPP. Fortum has done pioneering work on oil risk analysis, including studies of oil accident frequencies and simulations of oil spill trajectories. At the Loviisa NPP, modifications of plant systems and operating procedures have been implemented to ensure residual heat removal in case of blockage of the seawater intake due to oil slick or organic material in seawater.

2.13.3 Protection against external events in the Olkiluoto NPP

Usual natural phenomena in Finland such as snow and wind loads and annual temperature changes were taken into account, when the structures of the existing Olkiluoto plant were designed. Unusual natural phenomena, from the standpoint of plant cooling systems were especially studied when the weather risk analysis was conducted by the TVO during 1990's as part of the Probabilistic Safety Analysis. 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 were studied. 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 the capacity of the shutdown service water systems is increased.

Large air plane crashes or some 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 the 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 factors 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.

Olkiluoto 3

Protection against external events and fires in Olkiluoto 3 were presented and analysed in Olkiluoto 3 PSAR and PSA documents. Documents were accepted by STUK as part of OL3 Construction License documentation. Olkiluoto 3 design copes with all Olkiluoto 1/2 external hazard aspects. In addition, Olkiluoto 3 airplane crash is addressed as a design feature from the very beginning. STUK also performed additional analyses with respect to aircraft protection by technical support organisations during the Construction License process.

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 plant units was reassessed by STUK in 2006-2007 and Olkiluoto plant units in 1997-1998. The design of Olkiluoto plant units will be reassessed by STUK again in connection with the Periodic Safety Review which will be completed by 2008.

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.

Modernisation of the Loviisa and Olkiluoto plants is 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.

In addition, aircraft crash design requirements for both a military aircraft and a large passenger aircraft are to be taken into account.

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 Government Decision 395/1991 requirements. The application of Defence in Depth principle of the new reactor follows the principles laid down in the design of existing reactors and in some cases even further enhanced Defence in Depth principles. Technical principal solutions presented in the design follow the design of the reference reactors.

2.14.2 Proven technology

The requirement to use proven or otherwise qualified technology is stated in 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.

At the Loviisa plant, the automation systems are currently being renewed. The project began in 2002 with basic conceptual design; implementation begun in 2004 with construction of new buildings to accommodate the new systems. The project is intended to be completed in 2014. The renewal is proceeding in carefully designed phases such that automation systems are renewed piecemeal, allowing each renewed system to be taken into operation during normal refueling outages. Old systems remain in use until replaced by the new; hence there is need for separate space for new systems. Control room facilities are also renewed in phases with the system renewal. For example, large screen display devices were installed in the control rooms in 2006 and 2007. Between 2004 and 2007 STUK has reviewed the licensing documents related to the project, such as Conceptual Design (including Defence-in-Depth and Diversity assessment), System pre-inspection documents for various systems, and also Preliminary Suitability documents pertaining to the qualification of the digital I&C platforms being used in the project. The first safety related phase of the project will consist of implementing preventive protection systems at both units in 2008.

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 on a way to modernise their control rooms. At the Loviisa plant this is included in a large automation modernisation project. At the Olkiluoto plant changes in the control room are made gradually. Digital instrumentation and control technology has already been implemented in modernised systems. The safety systems man-machine-interface is still of conventional technology. 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 in the 1990's

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 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 Loviisa 1
- 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 Loviisa 1; 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. The increase of the power level was licensed in 1998.

Trial tests in the Olkiluoto NPP for power uprate in the 1990's

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 after the reactor power uprate to 105% level from the nominal power of 2160 MW. In 1997 the test operation was continued at Olkiluoto unit 1and 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. The increase of the power level was licensed in 1998.

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 are also 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. The 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.

Olkiluoto NPP

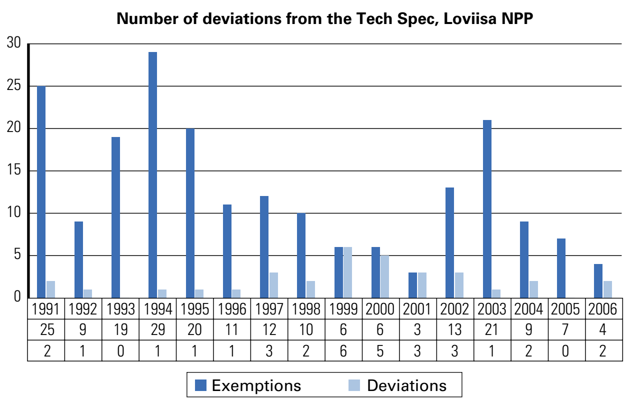
The Technical Specifications determine the limits of process parameters that affect the plant safety, for different operating modes, set the provisions for operating limits caused by component inoperability and set forth the requirements for the tests that are conducted regularly for components important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

The Technical Specifications have to be supplied to the 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.

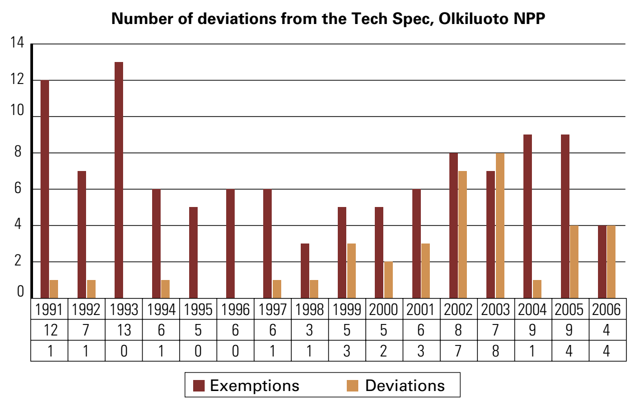
Figure 11 presents the number of exemptions and deviations from the Operational Limits and Conditions. Since 1993–1994 the number of exemptions and deviations from the Operational Limits and Conditions has been decreasing except the years 2002–2003. The main reason for the large number of exemptions at the Loviisa NPP was the project to renew the radiation monitors that required exemptions in all operational states. The peak in 1993–1995 relates to the modification of ventilation systems that needed several exemptions. In the case of the Olkiluoto NPP the main reason for the exemptions has been the conduct of maintenance and repair works.

2.15.3 Operation and maintenance in accordance with approved procedures

Requirements related to procedures are provided in 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,



	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Exemptions	25	9	19	29	20	11	12	10	6	6	3	13	21	9	7	4
Deviations	2	1	0	1	1	1	3	2	6	5	3	3	1	2	0	2



	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Exemptions	12	7	13	6	5	6	6	3	5	5	6	8	7	9	9	4
Deviations	1	1	0	1	0	0	1	1	3	2	3	7	8	1	4	4

Figure 11. Number of exemptions and deviations from the Operational Limits and Conditions in the Loviisa and Olkiluoto NPP's.

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. Regulatory requirements for maintenance are given in Guide YVL 1.8.

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.

Loviisa NPP

Operating activities of Loviisa 1 and 2 are based on written procedures 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. The operating procedures of the Loviisa plant are covered by the quality assurance programme. The most important procedure types are:

- Administrative procedures including Organisational Manual and Administrative Rules
- Operating procedures and testing procedures
- Procedures for emergency and transient situations
- Fuel handling procedures
- Radiation protection procedures
- Maintenance procedures.

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 procedures. The procedures 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 procedures 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.

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

The maintenance activities of Loviisa 1 and 2 cover preventive, predictive and repairing maintenance as well as implementation of modification works, spare part maintenance and activities during outages. The Maintenance Group of the plant takes part into the annual maintenance outages planning together with the Technology and Operation Units and prepares the annual maintenance outages together with the Operating Group. 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 that perform inspection activities and the technical competence of organisations that carry out various duties. In addition to the normal monitoring activities, the preventive and predictive maintenance programme include continuous measuring methods, such as 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

Proper planning and scheduling are the key factors in modification management. 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. The Loviisa plant has completed an extensive training course on project management in 2000 for the staff members involved with modifications in the operating organisation. Participation in the projects for plant modernisation and power uprating was important for competence development. 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 is 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 or Fuel 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 fuel handling in the reactor. The Fuel Order is drawn up on fuel handling activities in fuel pools. The Operating Notice, on the other hand, is drawn up on unusual procedures that will not be permanent.

The administrative and technical procedures needed in the 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 programme. Furthermore, other procedures that relate to the topic of inspection are reviewed in all inspections of the STUK's program.

The Work Request System ensures that the operators of the plant are aware of the plant 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 Supervisor 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.

Maintenance

The maintenance of Olkiluoto 1 and 2 covers preventive and corrective maintenance as well as the design and execution of modifications, spare part service, outage actions and the related quality control. The Maintenance Department plans and builds up the annual maintenance outages together with the Operation Department and Technical Support Department. 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 programme is assessed on the basis of observations made in connection with operational experience and preventive maintenance. As far as the spare part service is concerned, it has been made sure that completely assembled components, which can be easily used to replace the failed component, exist for as many safety-significant systems as possible.

In addition to the measures listed in the preventive maintenance programme, 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.

STUK controls the condition monitoring and maintenance as well as the modification and repair work by regularly repeated inspections. The inspections aim 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 at the Olkiluoto plant has been under continuous development since the early 1980's. After the modernisation programme 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 current procedures and comments collected from the internal, external and regulatory audit results of TVO's working methods as well as experiences from the modernisation programme of Olkiluoto 1and 2. As a result, 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 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 unit 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 ensure 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. Plant specific symptom based EOPs (Emergency Operating Procedures) have been available at the Olkiluoto units since late 80's.

The Loviisa specific EOP-project 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 was based on French approach of combined event and symptom based procedures. The development was carried out together with EdF, Framatome ANP and Fortum Nuclear Services. French consortium was 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 finalized the procedures as well as carried out the validation and verification routines. The project was finalized in early 2006. The EOP development continues now as normal routine at the Loviisa plant. Fortum Nuclear Services is responsible for the strategies and the Loviisa plant for the validation, training and procedure layout. Framatome is used frequently for reviewing.

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.

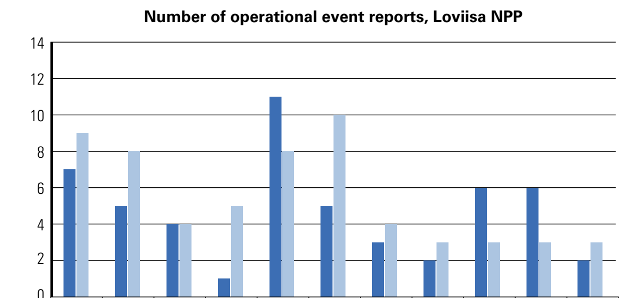
Some concern was related to the adequacy of engineering and technical support available to TVO when its Operating License was renewed in 1998. This was due to the fact that, TVO had quite independently designed and implemented some safety modifications at the plant, and the tendency was expected to continue. 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, TVO 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.

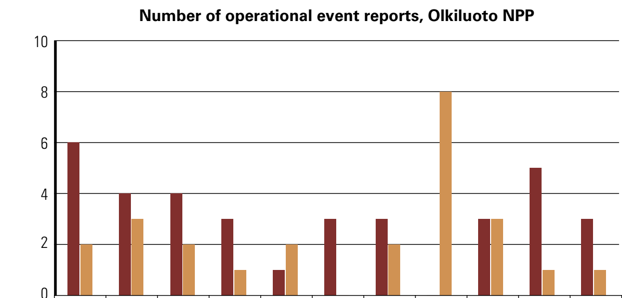
2.15.6 Reporting of incidents

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 1) 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 12 and 13 present the number of events and INES classified events at the Finnish nuclear power plants. The total number of event reports has varied typically between 15 and 25 annually during the last ten year period. At the same time



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
LO1	7	5	4	1	11	5	3	2	6	6	2
LO2	9	8	4	5	8	10	4	3	3	3	3



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
OL1	6	4	4	3	1	3	3	0	3	5	3
OL2	2	3	2	1	2	0	2	8	3	1	1

Figure 12. Annual total number of event reports (operational transient reports) submitted by Loviisa and Olkiluoto nuclear power plants.

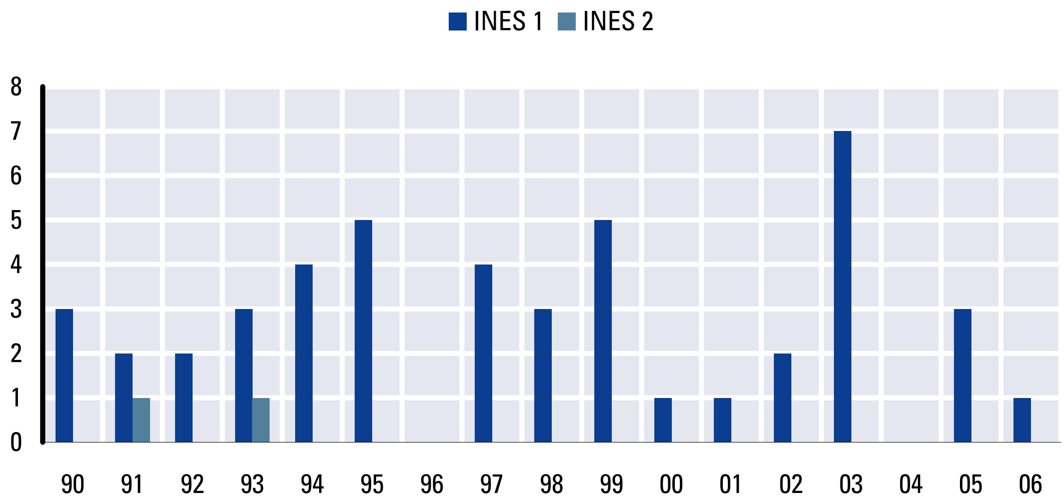


Figure 13. Annual total number of events at INES Level 1 and above at the Finnish nuclear power plants.

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. Recently one IRS report has been produced annually.

INES-classified events

Loviisa NPP

Three events in 2004, one event in 2005 and 3 events in 2006 were classified on the International Nuclear Event Scale (INES). In 2006 there was one level 1 event and the classification of the other events was 0. The level 1 event was a contamination spread incident at Loviisa 2 during the annual refuelling outage. Piping of a reactor cleaning tool was decontaminated externally and transported unpacked, which lead to spreading some contamination on the floor from inside the piping. Some contamination spread outside the plant by transport vehicles tires. New procedures have been taken into use after the incident.

Olkiluoto NPP

In 2005 six events and in 2006 four events were classified on the International Event Scale (INES). In 2005 there were three events rated at level 1. These events are described below:

A setting error was detected in the relay protection of the electrical power supply circuit breakers shared by Olkiluoto 1 and 2, which could have brought about disturbances in the power supply connections between the units in case of need. Electric cable connections have been established between the diesel-backed 660 V switchgears of Olkiluoto 1 and 2 to feed diesel-backed electrical power from one unit to the other, if necessary. The cable connections are equipped with eight identical supply circuit breakers to implement electrical power supply. The set values of all circuit breakers were checked and incorrect values were replaced with design values. In addition, the appropriateness of the preventive maintenance and relay testing programmes for equivalent circuit breakers has been ascertained.

During the annual maintenance of Olkiluoto 2 a power failure occurred that stopped the operation of some plant unit components ensuring nuclear safety, such as pumps ensuring decay heat removal during the outage, until the back-up diesel generators started up. The power failure was due to an electrical couplings isolation error made during electrical systems modifications. Due to the event, the work in question was discontinued and the plans were reviewed for the safety couplings of the modifications and the timetables were verified. In addition, improvements were planned in the co-ordination of the testing of systems important to safety.

At Olkiluoto 1 and 2 the alarm testing of the carbon-dioxide fire suppression system for the diesel generator rooms were not done once a week as required in the Technical Specifications. The system is intended for the automatic or manual suppression of a possible fire in the waste building or in the back-up diesel generator rooms. Due to the incident, the Technical Specifications was updated and document uniformity was reviewed.

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, which 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 Rostechnadzor and STUK on the operation of the Kola and Leningrad nuclear power plants and of Finnish nuclear power plants takes place semiannually.

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 (World Association of Nuclear Operators) 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. The Loviisa 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 the Loviisa plant.

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

TVO's operating experience feedback group consists of 9 members. 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 (1992). Activities started in 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. 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 Olkiluoto 1 and 2. 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 programmes 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 will be commissioned in late 2007. 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 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 failures, which also contributes to the limitation of activity accumulation in waste from reactor water cleanup systems.

Guide YVL 8.3 also 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.

In 2004–2006 one of the objectives to minimise the waste production at Olkiluoto has been the reduction of ion exchange resin consumption in the water purification systems. Resin qualities have been optimised regarding good separating capacities and long duty cycles. To minimise the volume of disposed metallic waste, a crusher was taken in use at the Olkiluoto site in 2004. Disposal containers can be filled more effectively, when crushed metal is placed to unused spaces of containers. Surface contaminated metal scraps are decontaminated in the new deco-box by blasting with glass marbles. Decontaminated metals are released from control, if the activity levels of clearance are reached.The average accumulation of low and medium level waste at the Olkiluoto NPP has been about 85 cubic meters per reactor year. In addition, a total of 1000 cubic meters of metallic waste was formed due to the replacement of the reheaters in 2005 and 2006.

At the Loviisa NPP, conditioning and disposal of liquid low and intermediate leval waste will start in 2007 through commissioning of the cementation plant and the extension of the repository for solidified waste. The management of solid low and intermediate level waste will be developed by building new facilities for the treatment, activity monitoring and interim storage of waste. A plan for upgrading the management system has prepared and will be implemented in 2006–2009.

By the end of the year 2006, 6010 cubic meters of low and medium level operating waste has accumulated at the Olkiluoto NPP and 2990 cubic meters at the Loviisa NPP. About 76% of the Olkiluoto waste and 46 % of the Loviisa waste has been disposed of in the on-site repositories. Low and medium level waste not yet disposed of is stored inside the plants.

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. By the end of the year 2006 the spent fuel accumulation at the Olkiluoto NPP was about 1147 tons of uranium and that at the Loviisa NPP about 402 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 Decision-in-principle on the spent fuel disposal facility was made by the Government in 2000. The facility 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.

Safety regulation for spent fuel disposal is included in 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 2006 the funded money covered almost the whole liability, about 1 500 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 243, October 2005).

In conclusion, Finnish regulations and practices, presented in subchapters 2.15.1-8, 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

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 safety assessment in Finland are presented.

3.1 Achievements in safety related activities since preparation of previous report

Qualification of non-destructive testing

The organisation of qualifications 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). During the period 2004–2006 the qualification organisation has been established and nine guidelines for qualification practice have been published. The licensees have established the Steering Committee for Qualification and nominate its members on annual basis. The Steering Committee for Qualification is guiding and supervising the practical qualification work with the help of a separate Technical Support Group, which has been nominated and supervised by The Steering Committee.

Based on a contract with the licensees, Inspecta Certification is responsible for the practical arrangement of qualification as the Qualification Body. The tasks of Inspecta Certification are specified in the contract. When needed Inspecta Certification uses also experts outside of its own organisation for individual qualifications. Those experts can also be outside of Finland. Inspecta Certification prepares a proposal of composition of Qualification Body to the Technical Support Group. The composition of Qualification Body is in accordance with the recommendations of ENIQ Recommended Practice 7. The Qualification Body has adequate

- expert knowledge on inspection method (including equipment and inspection procedures)
    - at least one qualified level 3 expert
    - practical inspection experience and training
    - previous qualification experience
- expert knowledge necessary for evaluation of inspection procedures and data
- expert knowledge necessary for evaluation of technical justification and used modelling
- knowledge necessary for designing test pieces with intended defects and understanding on the difficulties of manufacturing test blocks.

Qualification Body has a chairman and at least two members. One of these is from Inspecta Certification. Member of Inspecta Certification is responsible for quality assurance and confidentiality. Members of the Qualification Body are independent from procedures and personnel, which have to be qualified and they are familiar with the documents and the operating principles applied in qualification. If necessary, the Qualification Body may invite also other experts to the meetings. These experts can be specialized on questions related to materials, strength analysis or operation of nuclear power plants.

The system applied in Finland to the qualification of non-destructive in-service inspections of nuclear power plants is described in the document "The Finnish Qualification Practise for nuclear power plant inspections. General principles, SP-1". More detailed guidelines "The Finnish Qualification Practise for nuclear power plant inspections, SP-

2…SP-9" are given in order to guide the practical qualification work based on YVL 3.8. In the content of these guidelines the requirements presented in YVL 3.8, in the European Methodology for Qualification (EUR 17299) and in its recommendations have been taken into account. The purpose of the guideline "The Finnish Qualification Practise for nuclear power plant inspections. Qualification body, SP-2" is to describe the formation, activities and operation modes of the qualification body. The Steering Committee for Qualification is responsible for updating the document "General principles, SP-1". Inspecta Certification is responsible for reviewing and updating the guidelines used in qualification. It will assess annually the guidelines and their needs for up-dating. The changes proposed to the guidelines are approved by the Technical Support Group. The guidelines have been finally approved by STUK.

About 15 qualifications have been totally approved by STUK until now.

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 in the design of the new nuclear power plant 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.

The major digital automation projects in Finland have advanced steadily between 2005 and 2007. With accumulating experience on the technology and its licensing, the practical implementation of guidance developed earlier (in Guide YVL 5.5, published in 2002) is now maturing. The volume and time span of such projects is in the order of 5 to 10 years, whence the current evolution is likely to go on for some time to come. Significant effort has been devoted by the regulator and utilities involved in the assessment of modern control room concepts. Existing plants are moving towards so-called hybrid control rooms, where normal operation is based on digital controls and video screens, but safety backups are still implemented also using traditional mosaic displays, analog indicators and switches. Olkiluoto 3 will also have a hybrid control room.

Provision for plant ageing

Ageing management programmes in operating Finnish NPPs largely developed from their experiences with emerging ageing issues: radiation embrittlement, inter-granular stress corrosion cracking, erosion corrosion, thermal fatigue, ageing of cables and obsolescence of I&C components. STUK has recognized the growing importance of ageing management and, since preparation of previous report, updated the general Guide YVL 1.1 on STUK's regulatory control to include e.g. requirements concerning a comprehensive ageing management programme and ageing evaluation as part of the periodical safety review. Ageing related requirements in the recently updated guides YVL 5.2 and 5.5 on electric and I&C components, and in the new guide YVL 3.5 on mechanical components, have been also under implementation. A new Guide on Maintenance, condition monitoring and ageing management in a NPP is under development.

Implementation of YVL 3.5, entitled Ensuring the strength of NPP pressure equipment, imposed a requirement for updating of the fatigue analyses to incorporate the environmental effects. For the Loviisa plant this was already completed for the primary circuit components as part of the recent operating licence renewal with acceptable results, largely thanks to the conservative design fatigue curves of the originally applied Soviet design standard. A second requirement dealt with establishing a data base of valid strength analysis reports to ensure knowledge management of the original strength related design bases, which has proved to be a challenge in some important modifications. Knowledge management has also coincidentally become an issue in the area of in-service inspections.

In 2004, STUK approved the utility's application to continue the service of reactor pressure vessel of Loviisa Unit 1 until 2012. The approval was based on a revised safety analysis pertaining to the radiation embrittlement. As described in Annex 3, considerable efforts have been expended on this issue until successful annealing of the critical weld in 1996. The current activities deal with the re-embrittlement rate and refining the nonductile failure analysis methodology. In the plant licence renewal in 2007, even more attention was given to steam generators whose replaceability is questioned for lay-out reasons. After primary and feedwater collector modifications since 1994, the overall steam generator performance has been good and the tube pluggings, now totalling 55 in unit 1 and 28 in unit 2, have been well below VVER plant averages. An abrupt rising trend since mid-1990's is of interest, though, considering that the secondary circuit water chemistry was changed from neutral to alkaline in 1994–95 and the power upratings took place in 1997–98. How much of this increase is explained by the upgraded in-service inspections, using eddy current techniques, is as yet uncertain.

Thermal fatigue susceptibility in the primary circuit mixing and stratification points requires continuous attention in both NPPs. Permanent and transferable thermocouples have been installed to sensitive locations, serving multiple purposes: operating practice improvements, in-service inspection targeting, transient book-keeping and fatigue analysis validity evaluation. The programmes and the resulting documentation have been keenly followed in STUKs recent periodic inspections, attended by the utility's operation, system, material and stress analysis specialists.

STUK's recent regulatory inspection of the design documents concerning a dissimilar transition weld between the reactor pressure vessel nozzle and the safe end of Olkiluoto 3 led to a requirement for a 10-year long ageing surveillance programme. A unique combination of weld material (Alloy 52) and technology (narrow-gap TIG without buttering) has been introduced here, mainly to improve resistance against stress-corrosion cracking. However, preliminary tests indicate unexpected fracture behaviour in low temperatures, featuring a crack propagation jump from the heat-affected zone of the ferritic vessel material to the fusion line, which results in a reduced fracture toughness at low temperatures. The required surveillance aims to verify that the heat treatments of manufacturing and the operation will not cause significant further embrittlement due to thermal ageing.

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. Chapters 2.4 Ensuring competence and 2.7.2 Human resources provide description on the recent development in the regulatory body and in the operating organization of NPP's.

Risk informed regulation

In Finland, the regulatory authority (STUK) and licensees have introduced probabilistic safety analysis (PSA) as a widely used method in the nuclear safety regulation and safety management. Risk-informed regulation means an approach where both the PSA results and the deterministic criteria combined with engineering judgment are considered and they complement each other in the regulatory decision-making. The general aim of the risk informed methods is to use the available resources in the most efficient way to maintain and increase the nuclear safety.

The essence of the risk informed regulation and safety management is that the Living PSA works as an interactive communication platform between the licensee and STUK. Accordingly a PSA model, performed by the licensee and reviewed by STUK, is used for resolution of safety issues by both parties. For this purpose the licensees provide STUK with the PSA model in electronic form and regularly maintain and update it. In the regulatory process the deterministic and probabilistic approaches work in parallel and interact. The results of deterministic assessment provide necessary input for models and data used in PSA. Secondly PSA provides insights on adequacy of design requirements and design basis and thirdly PSA provides assessment on the need to improve the reliability of safety functions and plant systems.

The risk-informing of regulatory and risk management activities is a step by step process. STUK has introduced the PSA in regulation and safety management of NPPs since 1987 when the regulatory guide YVL 2.8 was issued. Accordingly the PSA is formally integrated in the regulatory process of NPPs already in the early design phase and it is to run through the construction and operation phases all through the plant service time. STUK will review the PSAs and makes an assessment of the acceptability of the design phase PSA/ construction phase PSA prior to giving a statement about the construction licence/operating licence application. This approach is used in the licensing process of Olkiluoto 3.

Living PSA models have been developed for both the Olkiluoto and Loviisa plants. The PSA studies include level 1 and level 2 models. Level 1 comprises the calculation of severe core damage frequency (probability per year) and level 2 the determination of the size and frequency of the release of radioactive substances to the environment. At the moment, level 1 studies for full power operation cover internal events, area events (fires, floods), and external events such as harsh weather conditions, and seismic events. The shutdown and low power states of level 1 PSA cover internal events and some area and external events. The Level 2 studies include all power states and initiating events of Level 1. In order to achieve the full scope PSAs the analyses of a few lacking initiators are in progress both at the level 1 and 2.

PSA has got an important role in the evaluation of needs for plants modifications of operating plant units. The licensee has to provide STUK with the assessment of safety significance of each proposed modification. The risk assessment is to be submitted to STUK independent of the safety class of the systems to be changed. Thanks to the plant modifications performed the core damage frequency of the Loviisa plant has decreased with a factor of ten, in the course of past several years.

In the area of operational events, PSA is a standard tool to assess the safety significance of component failures and incidents. Today risk follow-up studies are a common practice at STUK. Since 1995 STUK has performed systematic risk follow-up studies on the annual basis for each Finnish nuclear power plant unit.

A risk informed approach has been used to analyse the Allowed Outage Times (AOT). Certain inconsistency of AOTs in comparison with the respective risk impact has been identified between various safety systems. Risk assessment has also questioned the traditional conclusion that in all faulted states the shutdown of the plant would be the safest course of action. If systems used for decay heat removal are seriously degraded (CCF), it may be safer to continue operation than to shut down the plant immediately, although shutdown may be required by the current Technical Specifications. Hence the licensees has to re-evaluate the relevance of allowed outage times (AOT) of most important safety systems and to figure out those failure states of the plant where it is safer to continue operation than to shut down the plant immediately.

If a licensee applies for an exemption from Technical Specifications the licensee has to submit a risk analysis to STUK and indicate that the risk resulted from the exemption is tiny. STUK reviews the licensees' analysis and makes its own risk assessment for comparison as necessary.

STUK allows on-line preventive maintenance during power operation provided that the deterministic safety criteria are fulfilled (e.g. single failure criterion) and the risk contribution is small. According to the first Olkiluoto PSA study in 1989, the risk contribution of on-line preventive maintenance was about 5 % of the total core damage frequency. Since the maintenance schedule was optimised with PSA, the risk contribution of on-line preventive maintenance could be reduced approximately to 1 % of the total core damage frequency.

Pilot projects on Risk-Informed In-service Inspections (RI-ISI) of piping both in the Loviisa and Olkiluoto have been completed by STUK in cooperation with the licensees. STUK's risk-informed procedure combines both the plant specific PSA information and the traditional insights in support of the system specific detailed in-service inspection programme planning. Finnish licensees are running RI-ISI projects for risk-informing their in-service inspection programmes. RI-ISI approach is used also at Olkiluoto 3.

STUK is in progress of effecting the regulatory inspection programmes and conducting the inspections at site. A special PSA Info system has been developed in order to use the insights of PSA for training the inspectors, to upgrade their risk perception and to demonstrate the importance of most significant accident sequences.

3.2 Challenges for future work

The role of nuclear power in energy policies is being discussed both in Finland and elsewhere in the world. In Finland, activities in relation to the siting and construction of new nuclear power plants seem to be increasing. One new unit, Olkiluoto 3, is under construction. For the second new unit, environmental impact assessment is going on. A new company with the aim to construct a nuclear power plant in Finland has been established, and it has started to survey the site for an additional power plant. Countries considering nuclear power expansion strive to create harmonised safety requirements and uniform procedures for safety regulation during construction. Olkiluoto 3 project is the first new-generation nuclear power plant, whose safety requirements and regulatory process may serve as reference for national and international development efforts.

The European Commission has proposed that the general requirements for nuclear power plant safety and nuclear waste management be harmonised in the EU. In Finland, the safety regulations that are within the scope of the Nuclear Energy Act will also be updated early in the current strategy period. The structure of the detailed safety requirements (YVL Guides) published by STUK will also be updated.

New technologies appear that require new approach and revision of existing regulatory guidance and operating practices. Old nuclear power plants increase their lifetime that requires renewal of systems and components and modernization of technologies. The regulation of existing nuclear power plants emphasises the management of ageing and the quality of plant operations. The automation and other systems at the Loviisa and Olkiluoto plants are undergoing modernization, and extra care is needed to ensure operational safety during this work. STUK emphasises the importance of meticulous planning and controlled implementation of changes in its regulatory inspections. International cooperation for learning lessons from experiences in nuclear power plant operation must be improved so that risks identified anywhere can be controlled efficiently everywhere. STUK actively participates in the development of a network and interaction between different countries and ensures on its own part that essential information is transmitted between nuclear power plants in Finland and other countries.

Security arrangements in nuclear power production and the use of high-activity radiation sources also call for efficient supervision. One must be prepared for the possibility that nuclear materials or other radioactive substances are used in international terrorism. The procedures, preparations and information exchange involved in antiterrorism activities will be enhanced worldwide. As concerns nuclear material control in Finland, this will mean a stronger focus on security arrangements, border control, import and export control, security arrangements for other radioactive materials and research in the field. Development is carried out in cooperation with other authorities.

In a public discussion about uranium exploration, STUK is frequently asked to provide information on radiation safety of this activity. The need for more intensive cooperation with other authorities is also becoming obvious. STUK must enhance its knowledge and develop analysis methods in order to be well prepared for evaluating potential mining projects at the investigation stage.

Final disposal of spent fuel in the Olkiluoto bedrock is a major task in nuclear waste management. Posiva Oy is a company established for this purpose, and it is preparing for the construction of the final disposal facilities and repository. STUK invests in its processes and resources during the strategy period to ensure that the related regulatory tasks are correctly scheduled and of high quality.

The European Commission promotes worldwide co-operation to further develop nuclear, radiation and waste safety through its INSC- and former TACIS- and PHARE-programmes. STUK has been and will be a supporter of this European development and involvement. Currently, three fourths of STUK's service volume comprises promotion of radiation and nuclear safety in Eastern European countries.

The current development requires new research and development programmes and more resources. To develop and maintain Finnish competence in nuclear safety, STUK provides guidance to the national research programme on nuclear and waste safety. Research on the health effects of ionising radiation carried out in STUK's laboratory will be used to support the reassessment of radiation risks. Topical research themes during the current strategy period include low radiation doses, non-targeted effects of radiation, non-cancer diseases and individual susceptibility. One of the permanent duties of STUK is to survey our living conditions from the point of radiation safety. Analyses of environmental samples provide information about the occurrence of radioactive substances in the environment, drinking water, foodstuffs and humans. A national network of measurement stations provides real-time information about the dose rate of external radiation in Finland. Environmental monitoring also functions as an alarm system for potential radiation accidents. All abnormal observations are investigated and their reasons are determined and reported.

The retirement of large age groups will affect public administration throughout, including STUK. The above activities require additional manpower and efforts from the nuclear power companies and regulatory body for strengthening their activies. Ageing manpower and organizations optimized for operation and control of current nuclear facilities require further development in organizational arrangements and activities. Human resources will have to be allocated with great care in the future. STUK's resources are to be developed in such a way that the key tasks in radiation and nuclear safety can be taken care of at all times. Education and training programmes are emphasised.

Communication will become an increasingly important success factor for STUK and power companies. Interest in radiation and nuclear safety topics will continue to increase. The media plays an important role in communication.

4 Conclusions on benefits from the previous 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 obligations 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 publicly available through the Internet, but also others could be encouraged to do the same.
- 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 Review Meeting, the following list of items requiring further actions was prepared by STUK 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 knowhow 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 were addressed in the second 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 were wished to be addressed in the third National Report. These issues were 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).

The Third Review Meeting in 2005 identified some challenges and recorded some planned measures to improve safety in Finland. On request of the Review Meeting these issues are included in this fourth national report of Finland.

These items are (given in brackets the articles, in which the issues are addressed):

- Ageing of regulatory staff (see article 8)
- Maintaining competence during extended retirement (see articles 8 and 11)
- Developing risk informed regulation (see articles 7 and 8 and chapter 3)
- Regulatory control of construction of new Olkiluoto NPP unit 3 (see article 7)
- Replacement of I&C at Loviisa NPP (see Annex 2)
- Maintaining and enhancing safety culture (see article 10)
- Completing the NDT qualification programme (see article 14 and chapter 3)
- Ageing management at Finnish NPPs (see article 14 and chapter 3)
- Renewal of operating licenses for Loviisa NPP units 1 and 2 (see article 6)
- Periodic Safety Review (PSR) for Olkiluoto NPP units 1 and 2 (see article 6).

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

ANNEX 1 List of main regulations

Legislation (as of 21.9.2007)

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 21.9.2007)

General guides

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

YVL 1.1 Regulatory control of safety at nuclear facilities 10 Feb 2006

YVL 1.2 Documents pertaining to safety control of nuclear facilities 11 Sep 1995

YVL 1.3 Mechanical components and structures of nuclear facilities. Approval of testing and inspection organizations 17 Mar 2003

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 Sep 2003

YVL 1.6 Nuclear power plant operator competence (available in Finnish only) 5 Oct 2006

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 Jul 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

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 (available in Finnish only) 19 Dec 1995

YVL 1.16 Regulatory control of nuclear liability insurances 22 Mar 2000

Systems

YVL 2.0 Systems design for nuclear power plants 1 Jul 2002

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

YVL 2.2 Transient and accident analyses for justification of technical solutions at nuclear power plants 26 Aug 2003

YVL 2.4 Primary and secondary circuit pressure control at a nuclear power plant (available in Finnish only) 24 Mar 2006

YVL 2.5 The commissioning of a nuclear power plant 29 Sep 2003

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 28 May 2003

Pressure equipment

YVL 3.0 Pressure equipment of nuclear facilities 9 Apr 2002

YVL 3.1 Nuclear facility pressure vessels (available in Finnish only) 1 Jul 2005

YVL 3.3 Pipings at nuclear facilities (available in Finnish only) 26 Jun 2006

YVL 3.4 Approval of the manufacturer of nuclear pressure equipment 14 Jan 2004

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

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 Sep 2003

YVL 3.9 Nuclear power plant pressure equipment. Construction and welding filler materials (available in Finnish only) 5 Nov 2004

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

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 (available in Finnish only) 23 Jan 1997

YVL 5.2 Electrical power systems and components at nuclear facilities 24 Jun 2004

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 (available in Finnish only) 6 Apr 1995

YVL 5.5 Instrumentation systems and components at nuclear facilities 13 Sep 2002

YVL 5.6 Air-conditioning and ventilation systems and components of nuclear facilities 25 Nov 2004

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 Jun 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

YVL 6.4 Transport packages and packagings for radioactive material 4 Apr 2005

YVL 6.5 Transport of nuclear material and nuclear waste 4 Apr 2005

YVL 6.7 Quality management of nuclear fuel 17 Mar 2003

YVL 6.8 Storage and handling of nuclear fuel 27 Oct 2003

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

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

Guide YVL 6.11 Physical protection of nuclear power plants, 13.7.1992 (not publicly available)

Guide YVL 6.21 Physical protection of nuclear fuel transports, 15.2.1988 (not publicly available)

Radiation protection

YVL 7.1 Limitation of public exposure in the environment of and limitation of radioactive releases from a nuclear power plant (in Finnish and in Swedish) 22 Mar 2006

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

YVL 7.5 Meteorological measurements of a nuclear power plant 28 May 2003

YVL 7.6 Monitoring of discharges of radioactive substances from a nuclear power plant (available in Finnish only) 22 Mar 2006

YVL 7.7 Radiation monitoring in the environment of a nuclear power plant (available in Finnish only) 22 Mar 2006

YVL 7.8 Environmental radiation safety reports of a nuclear power plant (available in Finnish only) 22 Mar 2006

YVL 7.9 Radiation protection of workers at nuclear facilities 21 Jan 2002

YVL 7.10 Monitoring of occupational exposure at nuclear facilities 29 Jan 2002

YVL 7.11 Radiation monitoring systems and equipment of a nuclear power plant 13 Jul 2004

YVL 7.18 Radiation safety aspects in the design of a nuclear power plant 26 Sep 2003

Radioactive waste management

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

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

YVL 8.3 Treatment and storage of low and intermediate level waste at a nuclear power plant 29 Jun 2005

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.edilex.fi/stuklex/en/

ANNEX 2 The latest large plant modernization and power uprating projects in the Finnish nuclear power plants

Loviisa NPP

Modernization and power uprating of Loviisa NPP in 1994–97

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 50 years, which corresponds to the additional 20 years of operation applied for both units of the Loviisa NPP in 2006.

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 Government 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 latest plant modifications in the Loviisa Nuclear Power Plant (2005–2007)

Construction of a back-up decay heat removal system

A new reactor decay heat removal system has been constructed at Loviisa plant. It is designed for use during the unavailability of the normal decay heat removal system. It takes care of the decay heat removal when the reactor has cooled down enough to facilitate decay heat removal by cooling down the water recirculated on the steam generator secondary side. The pumps and heat exchangers of the system normally used for this purpose are located in the plant unit's turbine hall and could be lost in a turbine hall fire. Before the completion of the new system, it would have been impossible to bring the reactor into a cold shutdown state in such a situation; instead, it would have been necessary to release decay heat as steam into the atmosphere through the relief valves of the steam generator. In such a situation, the temperature of the primary circuit would have exceeded 100°C.

The pumps and heat exchangers of the new system are located in a separate building (external to the turbine hall). Piping and their connections to the steam lines and the feed water lines are in a section of the turbine hall that is protected against fires. Power supply for the system is ascertained such that it can be connected to the emergency diesel generators of both Loviisa 1 and Loviisa 2 as well as to a bus supplied electrical power by the nearby Ahvenkoski hydropower station. The system is shared by both Loviisa plant units and it can, where necessary, bring either one or both of the two reactors into cold shutdown. The system's heat exchangers can be cooled using the service water systems of either plant unit. The service water systems are modified, too, to improve the reliability of decay heat removal in the event of the occurrence of frazil ice, algae and flooding.

The construction of the system started in the spring of 2002 and the piping modifications were made in the winter of 2004. Test operation began in the 2004 outages and was completed during a shutdown relating to a 2005 outage. The service water circuit installations are completed in 2007.

The emergency operating procedures were revised

The emergency operating procedures of Loviisa nuclear power plant were revised in the so called HOKE project, launched in 2000. The project encompassed the drawing up of diagnosis procedures for transients and emergencies arising from primary and secondary leaks, procedures for operators and the safety engineer as well as action sheets for onsite measures. Some old procedures have been removed and the rest have been revised as appropriate i.a. as regards transition between old and new procedures.

In accordance with the new procedures, nuclear power plant operators follow their own separate procedures and initiate the necessary actions in their fields of responsibility in the event of an emergency or a transient. The shift manager co-ordinates these actions and reviews the main actions and parameters using his own procedures. The safety engineer in parallel with the operators independently oversees safety functions using separate procedures to ensure that plant behaviour is as planned.

The revised procedures consist of guidelines and instructions presented as flow charts. The guidelines define strategy and give grounds for operator actions during emergencies and transients. It serves as a basis for actual control room procedures containing operator procedures. The guidelines are used for training purposes as well.

The revised control room procedures of the Loviisa plant are based on French nuclear power plant procedures. The project's French experts also participated in the validation and verification of the procedures and their background material in co-operation with the plant's own personnel. Validation ascertains authenticity of the procedures i.a. by comparison with the plant and by simulator tests. Verification authenticates i.a. correlation and functioning of the new procedures with other plant procedures. The project included training given to the control room personnel of the Loviisa plant in the use of the new procedures. Due to the revision's significance, both structurally and contents-wise, STUK required that shift supervisors and operators working in the control room have given shift-specific proof of workmanship prior to the introduction into use of the revised procedures.

In December 2005, STUK authorised the introduction into service of the revised emergency operating procedures.

Replacement of high pressure emergency cooling system pumps

Pumps of the high pressure emergency cooling system are replaced with a new type of pump at both Loviisa units. The new type of pump was introduced because of the reduced availability of spare parts for the old pumps, and to improve system reliability. At Loviisa 2 annual maintenance in 2006, two out of four pumps were replaced, one for each redundant system section, and the necessary piping modifications were made. Corresponding work at Loviisa 1 will be done in the 2008 annual maintenance outage.

Protection against fires in the Loviisa NPP

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. In Loviisa decay heat removal systems are in turbine hall. That´s why there is the separate building for additional decay heat removal system outside turbine hall (built in 2005). The new system is needed for cooling the plant to cold shutdown, if normal systems are not operable.

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 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.

Results of PSA

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 1994–2007. At the end of 2007 the results of the risk analyses are the following:

- internal initiating events, 1.0×10^{-5} a year
- fires and earthquakes, 1.9×10^{-5} a year
- floods, 0.4×10^{-5} a year
- severe weather conditions, 0.8×10^{-5} a year
- outages, 4.1×10^{-5} a year, internal initiating events, floods and severe weather conditions.

The calculated estimate for the total frequency of reactor core damage is about 8.2×10^{-5} a year. This estimate takes into account all the factors presented above.

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.
- An automatic PCP seal water intake from make-up system was installed for the case of loss of normal seal water cooling.
- The risks of containment outside leakages have been decreased with several plant modifications, e.g. by installing an automatic isolation system of certain leakages outside containment.
- The previously mentioned latest plant modifications (2005–2007).

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.
- The ultimate heat sink was secured (see above the modifications in 2005–2007)

Level 1 PSA – Outages

The probability of reactor core damage caused by internal initiating events during refuelling outages was estimated to be about $2{,}8 \times 10^{-5}$ 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.

Level 2 PSA

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. In 1997 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 PSA level 2 study in 2007 includes internal initiating events, floods and severe weather conditions in at power states. The total frequency of of large release in these categories is estimated to be 8.3×10^{-6} a year:

- internal initiating events, 5.8×10^{-6} a year
- floods, 0.5×10^{-6} a year
- severe weather conditions, 2.0×10^{-6} a year.

The biggest part of the calculated risk in the categories above result from containment bypass sequences in internal events, high wind velocities and failure of the containment external spray in severe weather conditions.

The calculated estimate for the total frequency of large release is about 2.7×10^{-5} a year, which includes a rough estimate of yet unfinished work with the following studies:

- fires and earthquakes, 2.9×10^{-6} a year
- outages, 1.6×10^{-5} a year, internal initiating events, floods and severe weather conditions.

The calculated risk estimate takes 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.

Olkiluoto NPP

Enhanced safety and improved production through modernization at Olkiluoto NPP in 1994–98

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. TVO's policy has been to keep the plant continuously up–to–date.

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 three.

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. Renewal of steam dryers has reduced the occupational doses remarkably, because the moisture of the steam has been reduced.

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 Government 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 was continued with replacement of steam reheater moisture separators (MSR). They were replaced with modern two stage MSR's. This replacement required modernization of HP-turbine as well. These replacements were performed in outages 2005 and 2006. In the same outages the automation system of the turbine plant process was be replaced with a modern digital one.

The latest plant modifications in the Olkiluoto nuclear power plant (2005-2007)

Condensate purification system modifications

The condensate system of the Olkiluoto plant units has been modified to improve the operational conditions of the ion-exchange resins of the system's filters. The system of Olkiluoto 1 was modified during the 2004 annual maintenance outage and that of Olkiluoto 2 in 2003.

The condensate system pre-heats the condensate coming from turbine condensers and transfers it to the feed water system, which injects it to the reactor. Prior to entering the reactor, it passes through the filters of a purification system. The condensate purification systems of the Olkiluoto plant units comprise seven ion-exchange filters.

Reactor water sulphate concentrations above target value water have been a problem at both plant units. Sulphate significantly contributes to stress corrosion under certain circumstances. The sulphate concentrations have been low enough, however, not to have essentially contributed to corrosion. The sulphate in reactor water comes from sulphate released from the ion-exchange resins of the condensate purification filters. The service life of strong cationic ion-exchange resins has been restricted to decrease the sulphate concentrations. In addition, sulphate-free ion-exchange resins have been used.

Temperature is one of the factors contributing to the release of sulphate from ion-exchange resins. The temperature of condensate passing through the filters has been adjusted to 60 °C previously by partially bypassing the pre-heater. In modifications made at the plant units in 2003 and 2004, the temperature of water passing through the condensate purification filters was lowered by moving the pre-heater of the condensation system such that it is now after the filters when it was formerly before them in the process. The temperature of condensate passing through the filters was thus reduced to approx. 50°C.

After the modifiction filter resins have stayed operational for considerably longer periods with no significant increase in the sulphate concentration of the reactor water. The longer service life of the resins reduces the volume of medium-level waste at the plant.

Rectifiers replaced

At the 2004 annual maintenance outage of Olkiluoto plant, a modification project was started to replace rectifiers in the 110 V, 48 V, 24 V and ±24 V DC power systems with new ones carrying out corresponding functions. Replace is due to the ageing of the rectifiers currently in use, the decreasing availability of spare parts and increasing maintenance costs. In normal operational conditions the rectifiers feed DC power to components that need it and, simultaneously, maintain batteries on float charge. A total of 18 rectifiers were replaced at both plant units by 2007.

Modification of the turbine/reactor power monitoring system

In the 2004 annual maintenance outage of Olkiluoto 1, the plant's monitoring system for turbine/reactor power was modified by adding a function which, in the event of a turbine/reactor power disequilibrium, partially trips the reactor and limits reactor power to a level consistent with the turbine plant.

The designing of the monitoring system began in early 2002 with the objective of finding a way of preventing a reactor/turbine power disequilibrium independently of the trip signal. The importance of the modification was accentuated by a disturbance in the 400 kV network of Olkiluoto 1 on 20 April 2002. The event is described in the 2002 annual report (STUK-B-YTO 224).

The modified system detects a break in the power supplied by the 400 kV network without the help of an external signal; it is also capable of switching the plant unit over to internal power supply in case of the loss of external power supply, whether it be caused by human error or by a purely technical fault.

The monitoring system was implemented by digital technology programmed into the turbine pressure control system. Olkiluoto 2 has been similarly modified.

Sealing changes in the expansion joints of the containment building intermediate level and the transportation shaft

The sealings of the expansion joints of the containment building intermediate level and the transportation shaft were replaced in the 2005 annual maintenance outage. The intermediate level separates the upper drywell and wetwell. Systems containing high pressure water and steam are housed in the upper drywell. The wetwell is the water-filled part of the containment to which steam discharging from the reactor is channelled during accidents. The sealing, installed in the expansion joint between the reinforced-concrete intermediate level and the containment building, is required to withstand dislocations, pressure differences and heat loads during accidents. The transportation shaft between the containment upper and lower drywell is rigidly attached to the concrete casing at both ends. A construction joint is fitted to it to accommodate for thermal and other constrained motion.

The original rubber sealings of the expansion joints have exceeded their design service life. In addition, the original design did not consider severe accident conditions, which makes the sealing of the intermediate level expansion joint and that of the transportation shaft a hazard to the pressure suppression function.

A new intermediate level expansion joint sealing was installed on top of the old operational sealing. Old transport shaft sealing was removed and a new one was installed in the existing flange. The new sealing material withstands severe accident conditions better than the old one. Post-installation leakage tests showed the trasportation shaft to be leaktight. The leaktightness of the new intermediate level sealing was satisfactory.

Containment sampling system modification
The sampling system at Olkiluoto 2 was improved to facilitate gas sampling in the containment gas space during an accident. The evaluation of radionuclide concentrations in the containment gas space must be possible by sampling, or some other method, even during severe accidents. A sample can be used to assess a release time and the necessary protective measures.

The new system samples gas from the gas space of the containment upper drywell by a sampling tube connected to the containment filtered venting system. It determines the concentration of noble gases and iodine in the containment gas space. The volumes of aerosols released cannot be determined but they are rather effectively adsorbed onto the system's filter. Measurements enable the evaluation of the magnitude and environmental impact of a possible release through the filters of the filtered venting system during a severe accident.

The sampling system is normally in stand-by mode and requires no electrical power to function. Gas sampled from the system is analysed in the laboratory. The system complements and backs up other monitoring systems as well as the radiation monitoring system for rooms, which is coupled to the battery-backed system. The sampling system was installed in the 2005 annual maintenance.

Feed water distributors were reinstalled
In the 2005 annual maintenance outage at Olkiluoto 2, new feedwater distributors, repaired in the winter of 2005, were reinstalled in place of the old ones. The new distributors were first installed in the 2003 outage but were replaced with the old ones in the 2004 annual maintenance outage, since cracks had been found in them (see Annual Report 2004).

The new distributors are designed to handle feed water flow after a power uprating and their design takes into account the thermal stresses to which the emergency cooling system riser pipes, located inside the reactor pressure vessel, are subjected. The riser pipes are located directly where the feed water distributors are. A thermal stress hazard arises when cold feed water mixes with the hot water returning from the steam separators. The new distributors are intended to bring the flow mixing point further away from metal surfaces and to thus restrict riser pipe thermal stress.

No cracks were detected in the new feed water distributors replaced at Olkiluoto 1 in 2004. The distributors of Olkiluoto 1 and 2 are due for inspection in future outages.

The steam dryers were replaced
The steam dryer was replaced in the 2005 annual maintenance outage at Olkiluoto 2. The moisture content of the reactor–to–turbine steam at Olkiluoto 1 and 2 increased after a power uprating in 1998. The moisture content was approx. 0.1% before the power uprating. After it, the annual average moisture content has been 0.27–0.33% at Olkiluoto 1 and 0.31–0.34% at Olkiluoto 2. The moisture in steam has not been ascertained to have increased erosion-corrosion in turbine systems. The steam from the reactor at Olkiluoto 1 and 2 is channelled direct to the turbine plant. Thus, along with the moisture, radioactive substances dissolved in water are transported to the turbine plant, causing elevated radiation levels there. The dose rates measured at the turbine plant have been 2–10 fold compared with those measured before the power uprating. An increase in the steam moisture content essentially increases occupational doses when working with or around systems having to do with steam. Collective occupational doses at Olkiluoto 1 and 2 have been below the limit established by STUK.

Teollisuuden Voima Oy ordered new steam dryers to reduce the steam moisture content. The more effective design of their dryer panels aims at reducing steam moisture below 0.1%. The new dryer was installed at Olkiluoto 2 in the 2005 annual maintenance outage and at Olkiluoto 1 in the 2006 annual maintenance outage. A steam moisture content of 0.009% was measured after the annual maintenance with Olkiluoto 2 operating at full power. With continued operation, the moisture values have been 0.007%.

A high pressure turbine and steam reheaters were replaced
A high pressure turbine and steam reheaters were replaced at the 2005 annual maintenance of Olkiluoto 2 to increase the turbine power output

and reduce the moisture content of steam. The efficiency of the high pressure turbine had significantly deteriorated in consequence of modifications made over the years, one of which was the removal of two blading stages. The power uprates accomplished in 1998 had increased the loading on the reheaters. Some of their tubes have been plugged, which has restricted their service life. Equivalent replacement of high pressure turbine and steam reheater was preformed at Olkiluoto 1 in 2006.

The utility replaced one-stage steam reheating with two-stage steam reheating to improve turbine efficiency. With two-stage steam reheating, a new high pressure turbine extraction point was required to lead steam to the first-stage piping group of the new two-stage reheater. Live steam is directed from the reactor to the other reheater piping group. The high pressure turbine blading were improved, which increased the turbine output.

Turbine plant process automation system renewal

A new automation system was installed in the Olkiluoto 2 turbine plant control system in 2005 annual maintenance outage (equivalent modification was performed at Olkiluoto 1 in 2006). One reason was the need to switch from analogue to programmable technology because spare parts procurement for the old system was getting difficult. In addition, the modifications made in the turbine plant process in 2005, and in 2006, required some additional modifications to the automation system. The new system facilitates component maintenance. Another system renewal objective is increased reliability and reduced susceptibility to malfunctions.

The new automation system is implemented by programmable technology. This allows an increased number of process status measurements. As regards turbine automation, it facilitates for turbine operators more versatile information management, process control at operating work stations, trend monitoring and setting of safety limits. Safety limit settings enable turbine operator reaction to even minor process changes. The control desk for the turbine side in the control room was replaced with a safety systems control desk and a turbine systems control and monitoring board and the control room was fitted with a giant screen display. In addition, the process computer system capacity had to be upgraded in connection with the control system renewal to handle the large volume of data yielded by the turbine automation. The automation interface was introduced at the Olkiluoto 1 and 2 training simulator in September 2004, which made possible the training of operating personnel in its use.

Modernisation of medium voltage switchgears

In the 2005 annual maintenance outage at Olkiluoto 2, the 6.6 kV medium voltage switchgears of the internal power supply system, which distributes most of the internal electrical power required by the unit, were modernised. This was done mainly because of the ageing of the original switchgears, the reduced availability of spare parts and to bring the switchgears up to modern requirements. During this REMES project, a total of over 60 medium voltage switchgear cubicles were modernised. The project included several significant modifications and replacements as regards i.a. the control, relay protection and auxiliary voltage systems, cabling and structural work. The modernisation improved the availability, protection, control and resistance to malfunctions of the switchgears. The same modifications were implemented at Olkiluoto 1 in 2006.

Protection against fires in the Olkiluoto NPP

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. 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.

Results of PSA

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.

At the beginning of 2007 the overall core damage frequency of Olkiluoto 1 and 2 is according to the living PSA approximately 1.5×10^{-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, 6×10^{-6} a year
- internal initiating events, refuelling outage, 2×10^{-7} a year
- internal hazards, fires, power operation, 3×10^{-7} a year
- internal hazards, fires, refuelling outage, 8×10^{-9} a year
- internal hazards, floods, power operation, 1×10^{-7} a year
- external hazards, natural, earthquakes, power operation 6×10^{-6} a year
- external hazards, natural, other, power operation, 1×10^{-6} 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. However, reduction of conservatism in the assumptions has in the year 2006 decreased the core damage frequency due to outage to 2×10^{-7} per reactor year.

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 2007 the core damage frequency due to fires – including power operation and outage – at the Olkiluoto plant units 1 and 2 is 3×10^{-7} per reactor year. The contribution of the fires during the refuelling outage is small, 8×10^{-9} 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 floods in 1997 and 2004.

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 1×10^{-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.

By the means of modifications the core damage frequency due to external hazards has been reduced, and it is in 2007 1×10^{-6} 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 6×10^{-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.

The renewal process of safety documentation of for periodic safety review (PSR)

In addition of the continuous updating process of safety documentation e.g. SAR and classification documents TVO emphasizes special effort to the development of safety documentation for periodic safety review (PSR) in 2008. TVO has already combined the separate SAR system description reports of Olkiluoto 1 and 2 to one updated common system description part of SAR. The work for renewal of general parts and combined analyses reports of SAR for PSR is going on. Also the links between SAR and Topical reports and other design basis reference reports will be defined more precisely.

ANNEX 3 Application of Defence in Depth Concept in Finnish NPPs

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

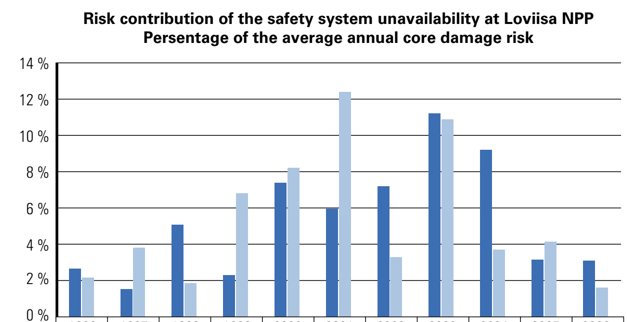
Levels of protection in the Loviisa NPP

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 A1 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, 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.



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
LO1	2.66	1.54	5.09	2.30	7.39	5.96	7.20	11.21	9.20	3.15	3.10
LO2	2.17	3.80	1.87	6.80	8.23	12.39	3.30	10.90	3.70	4.14	1.60

Figure A1. Share of the accident risk caused by the unavailability of equipment at the Loviisa NPP.

The present 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 has started. 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 is difficult. The systems have become obsolete and the availability of spare parts is poor. The renewal will cover nearly the whole automation; including control rooms, safety automation, operational automation and training simulator. Valve actuators and part of field instrumentation and cabling will remain. There will be only minor changes in the functions of automation. The new automation will be based on digital technology.

The installation of the new automation will be realized during normal maintenance outages of the units. For this reason the renewal will be divided into four stages. In stage one mainly operational automation will be renewed. In stage two safety automation like reactor protection and plant protection systems are renewed. In stage three the automation of the primary side systems are renewed. The automation of the turbine plant is renewed in the fourth stage. The installation work will start in summer 2007 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 by the 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 A2). 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.

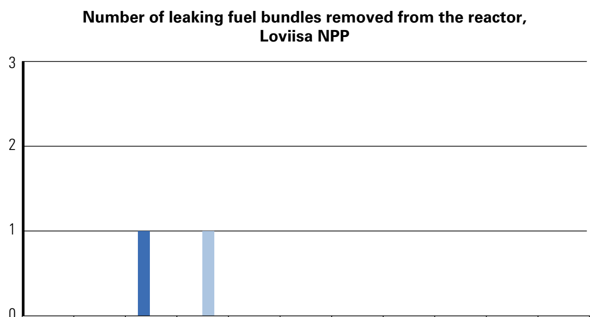
Several fuel assemblies were clogged at Loviisa 2 during 1994–1995 after the decontamination of the primary circuit. Some of the assemblies were consequently damaged due to fretting failures caused by clogging induced vibrations. After this incident the fuel failure rate has been almost non-existent.

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 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.



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
LO1	0	0	1	0	0	0	0	0	0	0	0
LO2	0	0	0	1	0	0	0	0	0	0	0

Figure A2. Number of leaking fuel bundles at the Loviisa NPP.

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.

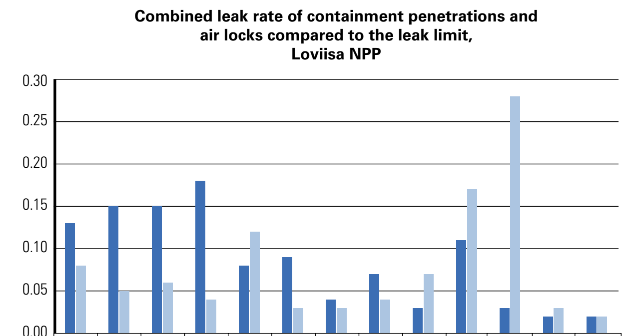
The Loviisa 1 and 2 units are provided with the containment in which the increase of the inner pressure caused by steam is limited by ice condensers. The inner spray system of the containment and the treatment systems for hydrogen are an essential part in the provision for mitigating accident situations. 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 A3 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. Severe accident management strategy for Loviisa NPP is described later on in this document.

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



	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
LO1	0.13	0.15	0.15	0.18	0.08	0.09	0.04	0.07	0.03	0.11	0.03	0.02	0.02
LO2	0.08	0.05	0.06	0.04	0.12	0.03	0.03	0.04	0.07	0.17	0.28	0.03	0.02

Figure A3. The total leakage rate through the isolation valves and penetrations at the Loviisa NPP compared to the leakage limit.

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 installation 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 (primary to secondary leakage accidents and auxiliary system LOCAs), 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 non-condensable 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. Fortum has treated the main phenomenological, Loviisa-specific questions along the lines of the ROAAM (Risk Oriented Accident Analysis Methodology) approach. Besides this Fortum has also made traditional PSA level 2 type of approach for Loviisa NPP.

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 passively 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 installation of 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 system 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 (primary system cooling by feed and bleed). 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 high capacity 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.

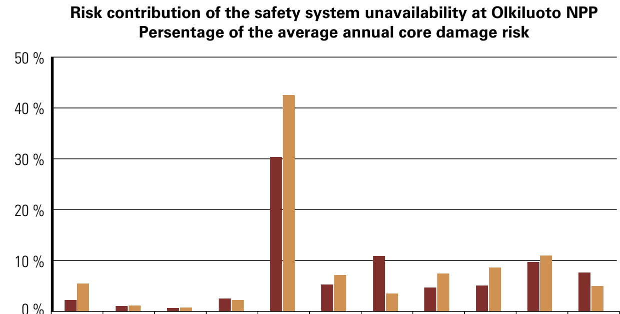
Defence in Depth concept and severe accident management in the Olkiluoto NPP

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 A4 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



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
OL1	2.17	1.05	0.65	2.47	30.30	5.28	10.90	4.68	5.10	9.64	7.60
OL2	5.46	1.14	0.72	2.26	42.50	7.17	3.50	7.39	8.60	10.95	5.00

Figure A4. Share of the accident risk caused by the unavailability of equipment at the Olkiluoto NPP.

use programmable automation has been installed at the plant units in connection with the modernisation and plant uprating project during the years 1995–1998 and subsequent turbine plant modernizations. Special attention has been paid to the design and testing of the modified 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 in systems important to nuclear safety have also 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.

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 judgement 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.

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 has beenwas 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 technical support centre 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 judgement 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.

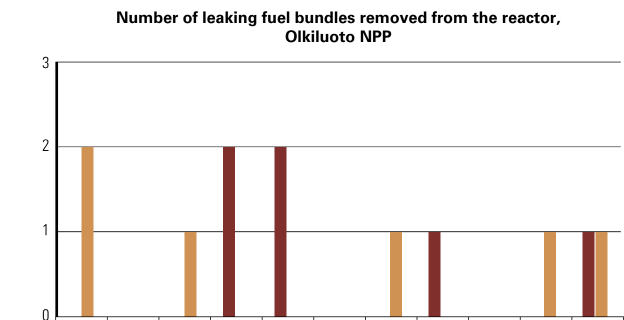
The next barrier, after the fuel (uranium dioxide matrix and the surrounding gas tight cladding), against the dispersion of radioactive materials is the pressure retaining boundary of the primary circuit. The reactor pressure vessel is manufactured from the low alloyed steel generally used in western 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 A5 presents the number of leaking fuel bundles at the Olkiluoto NPP.

The preservation of fuel integrity, under power



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
OL1	0	0	0	2	2	0	0	1	0	0	1
OL2	2	0	1	0	0	0	1	0	0	1	1

Figure A5. Number of leaking fuel bundles at the Olkiluoto NPP.

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 other BWR units.

Measures have been taken to eliminate the two transients that originally 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 pump drive control 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 originally 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 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.

After the implementation of a new, single failure tolerant pressure controller system, 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 elimination of these two transients has made the plant uprating possible without too much toll on the fuel economy.

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 the present modernized design of the plant. 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.

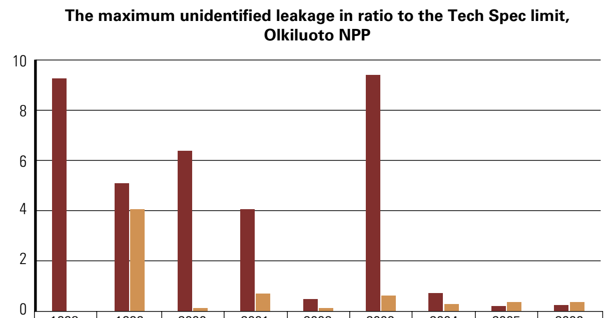
The objective is to keep the probability of a criticality accident adequately low during the outages and the refuelling by strict technical and administrative limits. The prevention of inadvertent criticality has also been taken into account in the fuel storage and handling systems at the plant.

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 A6 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 shut-downs 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



	1998	1999	2000	2001	2002	2003	2004	2005	2006
OL1	9.26	5.09	6.37	4.05	0.46	9.40	0.70	0.18	0.23
OL2	0.00	4.05	0.12	0.69	0.12	0.60	0.27	0.35	0.35

Figure A6. 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.

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.

There are two different types of valves in the relief system, which adds diversity and makes 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 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.

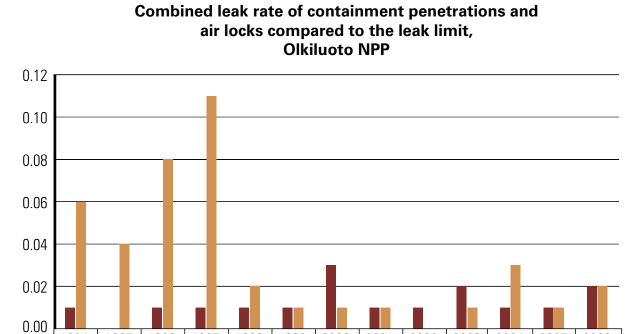
Ensuring containment building integrity

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 condense the exiting 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 to the containment during an accident, 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 correct operation of the suppression pool as a steam condenser (the pressure suppression principle) is a precondition for retaining the containment integrity in connection with accidents involving rupture of the reactor coolant pressure boundary.

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 A7 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



	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
OL1	0.01	0.00	0.01	0.01	0.01	0.01	0.03	0.01	0.01	0.02	0.01	0.01	0.02
OL2	0.06	0.04	0.08	0.11	0.02	0.01	0.01	0.01	0.00	0.01	0.03	0.01	0.02

Figure A7. The total leakage rate through the isolation valves and penetrations at the Olkiluoto NPP compared to the leakage budget.

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 means of scalculation, and according to the conducted clarifications the temperature rise doesn't significantly increase the risk of loosing the containment leak tightness during an accident.

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. To assure the functionality of the pressure suppression principle, the original seal of the expansion joint between the drywell and wetwell has been complemented with a new seal structure, which practically eliminates the risk for condensation pool bypass in connection with 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 relief 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. To improve the possibilities for retaining organic iodine in the filtered venting system, chemicals have been added to the water in the scrubber tank of the system. To minimize the formation of organic iodine, it is also possible to control the pH of the containment water volume.

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 assuring the correct and reliable operation of the reactor water level monitoring. 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.

Severe Accident Management in the Olkiluoto NPP

The main 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 development of the accident management proceduresand additional minor plant modifications at Olkiluoto plant have taken place during the years when new aspects on the issue have emerged.

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 implemented a system for controlling the pH of the containment as part of severe accident management. The function of the system is based on addition of NaOH to the fire fighting water reservoir which is used for filling of the containment in post-accident conditions.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.

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.

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.