SAFETY ASSESSMENT OF THE OLKILUOTO 3 NUCLEAR POWER PLANT UNIT FOR THE ISSUANCE OF CONSTRUCTION LICENSE

Table of Contents

Table of Contents ...................................................................................................................................1
1 Introduction ........................................................................................................................................3
  1.1 Safety-related regulations............................................................................................................3
  1.2 Other premises of the Safety Assessment and its structure.........................................................5
2 Premises and definitions (Decisions of the council of State 395/1991)............................................8
  2.1 Section 1: Applicability...............................................................................................................8
  2.2 Section 2: Definitions..................................................................................................................8
3 General Principles (Decision of the Council of State 395/1991).......................................................9
  3.1 Section 3: General objective .......................................................................................................9
  3.2 Section 4: Safety culture ............................................................................................................9
  3.3 Section 5: Quality assurance .....................................................................................................12
  3.4 Section 6: Demonstration of compliance with the safety regulations.......................................15
    3.4.1 Accident Analyses...............................................................................................................15
    3.4.2 DEMONSTRATION of the plant safety through EXPERIMENTS...................................20
    3.4.3 Probabilistic safety analyses (PSA)....................................................................................21
    3.4.4 Summary ............................................................................................................................26
4 Regulations concerning radiation exposure and releases of radioactive materials (Decisions of the Council of State 395/1991) .................................................................26
  4.1 Section 7: Limitation of radiation exposure..............................................................................26
  4.2 Section 8: Radiation safety of nuclear power plant workers.....................................................27
  4.3 Section 9: Limit for normal operation.......................................................................................28
  4.4. Section 10: Limit for an anticipated operational transient ........................................................29
  4.5 Section 11: Limit for a postulated accident...............................................................................30
  4.6 Section 12: Limit for a severe accident.....................................................................................31
5 Design criteria for nuclear safety (Decision of the Council of State 395/1991)..............................32
  5.1 Section 13: Levels of protection................................................................................................32
  5.2 Section 14: Technical barriers for preventing the dispersion of radioactive materials.............33
  5.3 Section 15: Ensuring fuel integrity............................................................................................36
  5.4 Section 16: Ensuring the integrity of the primary circuit ............................................................43
  5.5 Section 17: Ensuring the containment building integrity............................................................49
  5.6 Section 18: Ensuring safety functions.......................................................................................55
  5.7 Section 19: Avoiding human errors ..........................................................................................62
  5.8 Section 20: Protection against external events and fires...........................................................63
  5.9 Section 21: Safety classification ...............................................................................................68
  5.10 Section 22: Monitoring and control of a nuclear power plant................................................70
RADIATION AND NUCLEAR SAFETY AUTHORITY

SAFETY ASSESSMENT 2

21.1.2005

6 Operation of the Nuclear Power Plant (Decision of the Council of State 359/1991) ......................75
   6.1 Section 23: Technical Specifications and plant procedures.........................................................75
   6.2 Section 24: Operation and maintenance....................................................................................76
   6.3 Section 25: Personnel................................................................................................................78
   6.4 Section 26: Monitoring releases of radioactive materials ............................................................79
   6.5 Section 27: Operating experience and safety research...............................................................80
7 Miscellaneous provisions (Decisions of the Council of State 395/1991) ........................................81
   7.1 Section 28: Nuclear power plants in operation .........................................................................81
   7.2 Section 29: Detailed regulations ...............................................................................................82
8 Physical protection (Decision of the Council of State 396/1991)....................................................82
9 Emergency response arrangements (Decision of the Council of State 397/1991)............................85
10 Nuclear waste management...........................................................................................................86
   10.1 Final disposal of nuclear waste (Decision of the Council of State 398/1991) ........................87
   10.2 Final disposal of spent nuclear fuel (Decision of the Council of State 478/1999)..................88
   10.3 Decommissioning of plant units ..............................................................................................89
11 Nuclear fuel management and handling of nuclear materials........................................................90
12 Other requirements.........................................................................................................................91
   12.1 Siting in Olkiluoto in terms of environmental impact ..............................................................92
   12.2 STUK's opportunities for supervision.....................................................................................93
   12.3 Applicant's prerequisites for implementing the project ..........................................................94
   12.4 Maintaining domestic expertise ..............................................................................................97
   12.5 About factors presented in the Preliminary Safety Assessment and its supplement ............98
13 Summary ......................................................................................................................................100
1 INTRODUCTION

Teollisuuden Voima Oy (TVO) has applied for a construction licence for the Olkiluoto 3 Nuclear Power Plant Unit by a letter filed with the Finnish Ministry of Trade and Industry (KTM) on 8 January 2004. In preparation for the issuance of the licence, KTM sent letter G212/9 dated 16 January 2004 to the Radiation and Nuclear Safety Authority (STUK) requesting a statement on the application filed by TVO. This Safety Assessment presents the basis for STUK's statement.

The Olkiluoto 3 Nuclear Power Plant Unit is based on the French-German European Pressurised Water Reactor (EPR) concept that represents light water reactors. The plant unit will be delivered on a turnkey basis by a consortium consisting of the French-German Framatome ANP and the German Siemens AG; Framatome ANP will supply the reactor plant while Siemens will deliver the turbine plant. The consortium will rely on a large number of international and Finnish subcontractors for the design and implementation of the plant complex.

The most important design values for the Olkiluoto 3 Nuclear Power Plant Unit are tabulated below.

<table>
<thead>
<tr>
<th>Design Value</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated thermal power of reactor</td>
<td>4,300 MW</td>
</tr>
<tr>
<td>Net electrical output</td>
<td>approx. 1,600 MW</td>
</tr>
<tr>
<td>Primary circuit pressure</td>
<td>15.5 MPa</td>
</tr>
<tr>
<td>Secondary circuit (fresh steam) pressure</td>
<td>7.8 MPa</td>
</tr>
<tr>
<td>Seawater flow rate through condenser</td>
<td>approx. 53 m³/s</td>
</tr>
<tr>
<td>Temperature increase in seawater</td>
<td>approx. 12°C</td>
</tr>
<tr>
<td>Foreseen service life</td>
<td>60 years</td>
</tr>
<tr>
<td>Net electrical efficiency</td>
<td>approx. 37%</td>
</tr>
</tbody>
</table>

The largest nuclear power plant units built in the world to date have a net electrical output in the region of 1,450 to 1,500 MW. In accordance with the accepted Finnish practice, the thermal power of the reactor is recorded in the operating licence as the rated power, whereas the electrical output of the plant unit may vary within a range of several per cent depending on the efficiency achieved in the energy conversion process at any given time. Efficiency, in turn, will be determined by the seawater temperature, fine-tuning of the plant unit processes, etc.

1.1 Safety-related regulations

This Safety Assessment provides a summary of the reviews of the issues and documents related to the construction licence application carried out by STUK. While performing these reviews STUK has carried out and commissioned independent analyses, studies and experiments for the purpose of evaluating the technical concepts proposed in the application documents.
Sections 6 to 7 of the Nuclear Energy Act (990/1987) contain the following safety provisions: Section 6: The use of nuclear energy must be safe; it shall not cause injury to people, or damage to the environment or property; Section 6a: Nuclear waste generated in connection with or as a result of use of nuclear energy in Finland shall be handled, stored and permanently disposed of in Finland [...], and Section 7: Sufficient physical protection and emergency planning as well as other arrangements for limiting nuclear damage and for protecting nuclear energy against illegal activities shall be a prerequisite for the use of nuclear energy.

This Safety Assessment covers all the aspects of the construction of the Olkiluoto 3 Nuclear Power Plant Unit that fall within STUK's mandate. The issues to be addressed in the Safety Assessment and the related evaluation criteria are set forth in the nuclear energy and radiation safety legislation and the regulations issued there under. The provisions of the Nuclear Energy Act related to the safe use of nuclear energy, safety and emergency preparedness arrangements, and waste management are specified in more detail in the Decisions of the Council of State applicable to each field of activity and issued under Section 81 of the Nuclear Energy Act. The decisions are:
- Decision of the Council of State on the general regulations for the safety of nuclear power plants (395/91);
- physical protection of the nuclear power plant (Decision of the Council of State 396/1991);
- emergency response arrangements (Decision of the Council of State 397/1991);
- final disposal of reactor waste (Decision of the Council of State 398/91); and
- final disposal of spent nuclear fuel (Decision of the Council of State 478/1999).

The YVL Guides published by STUK set out even more detailed safety requirements. STUK continually evaluates the currency of the nuclear safety regulations relative to current international developments, particularly within the framework of the International Atomic Energy Association IAEA and the Western European Nuclear Regulators' Association WENRA. By international standards, the Finnish regulations are considered ambitious, so that compliance satisfies the policy expressed in the Government's Decision-in-Principle related to the nuclear power plant project. The currency of the YVL Guides is checked regularly at about five-year intervals; however, the Guides concerning the design of nuclear power plants were updated in view of the present project to ensure that the design criteria were known before the general contract for the delivery of the plant was signed.

The fundamental nuclear energy legal provision date back to the late 1980s and early 1990s, but despite their age, they have proven quite adequate to the evaluation of the Olkiluoto 3 Nuclear Power Plant Unit project.

In STUK’s view, the Council of State Decision 395/1991 concerning nuclear safety is still up-to-date in most respects. The main revision needs relate to severe reactor accidents and aircraft crashes, because both the technical requirements and technology in respect of these phenomena have developed greatly since the early 1990s.
The Council of State Decision 397/1991 related to emergency preparedness arrangements should be updated to reflect the amendments made to the Rescue Act.

An internal evaluation of the Council of State Decision 369/1991 concerning security arrangements was made by STUK in 2002, followed by a decision to revise its provisions to make them more specific.

STUK intends to submit proposals for the new content and format of the Council of State Decisions before the application for the operating licence for the Olkiluoto 3 Nuclear Power Plant Unit is processed.

1.2 Other premises of the Safety Assessment and its structure

This Safety Assessment follows the structure of the Council of Statement Decisions and covers the issues contained therein as well as such requirements set forth in Sections 18 and 19 of the Nuclear Energy Act that are not included in the current Council of State Decisions but that nevertheless fall within the mandate of STUK. These refer to Paragraphs 6 to 8 of Section 19 of the Nuclear Energy Act concerning the organisation of nuclear fuel management, creation of the necessary prerequisites for supervision by STUK, and the expertise of the licence applicant. Paragraph 9 of Section 19 of the Nuclear Energy Act addresses the applicant's financial resources for implementing the project, something that mostly falls within the competence of other government agencies. With reference to this provision, STUK submits its observations concerning TVO's operations in the deregulated electricity markets. The Safety Assessment will also address compliance with international conventions concerning the control of nuclear materials, nuclear safety and nuclear waste management that are binding on Finland (Paragraph 10, Section 19, of the Nuclear Energy Act).

One prerequisite for the issuance of the construction licence is that the Council of State passes a Decision-in-Principle stating that the construction of the plant unit is in the public interest. On 17 January 2002 the Council of State passed such a Decision-in-Principle on TVO's nuclear power plant project attaching a statement saying "...the Government trusts that the contemplated project is implemented in accordance with the strictest safety standards. Parliament ratified this decision (Parliament brief 8/2002 vp - M 4/2001 vp) on 24 May 2002.

As part of the process leading to the Decision-in-Principle, the Radiation and Nuclear Safety Authority issued a Preliminary Safety Assessment on 7 February 2001 and a Supplement thereto on 8 January 2002. It is indicated in the relevant sections of this Safety Assessment how the issues raised in the Preliminary Safety Assessment have been taken into account as the project progresses. When making the Decision-in-Principle, the Council of State had access to the Environmental Impact Assessment (EIA) of the Olkiluoto project prepared by the licence applicant and a related statement issued by the liaison authority. These two documents will be discussed in this Safety Assessment to the extent to which they fall within the mandate of STUK.
TVO has submitted the application for the construction licence and the attachments thereto required under Section 32 of the Nuclear Energy Decree to KTM, as well as the following documents to STUK required under Section 35 of the Nuclear Energy Decree:

1. the preliminary safety analysis report (PSAR), which shall include the general design and safety principles of the nuclear facility, a detailed description of the site and the nuclear facility, a description of the operation of the facility, a description of the behaviour of the facility during accidents, a detailed description of the effects that the operation of the facility has on the environment, and any other information considered necessary by the authorities;

2. a proposal for a classification document, which shows the classification of structures, systems and components important to the safety of the nuclear facility on the basis of their significance with respect to safety;

3. a description of quality assurance during the construction of the nuclear facility, showing the systematic measures that are applied by the organisations that take part in the design and construction of the nuclear facility in their operations affecting quality;

4. plans for physical protection and emergencies;

5. a plan for arranging the safeguards control that is necessary to prevent the proliferation of nuclear weapons; and

6. a description of the arrangements referred to in section 19, paragraph 7 of the Nuclear Energy Act. This means that STUK shall have the right to require that the nuclear fuel or the structures or components designed to be incorporated in the nuclear power plant are manufactured in a manner approved by the same. The licence applicant shall make the necessary arrangements to provide STUK access to witness the manufacture, handling, and quality assurance of the nuclear fuel or the structures or components designed to be incorporated in the nuclear facility.

Additionally, the licence applicant shall submit to the Radiation and Nuclear Safety Authority any other reports that STUK may deem necessary. TVO has also submitted to STUK a preliminary probabilistic safety analysis (design-phase PSA) of the new plant unit, and safety assessments for the entire plant unit and its systems.

The said documents and reports have been filed with STUK in several batches and updated or otherwise supplemented in the course of the application process, either in response to requests by STUK or the progress of the plant design.

The issues related to the nuclear safety of the project are addressed in this Safety Assessment in the same order as they are presented in the Council of State Decision 395/1991. The relevant text of the Council of State Decision is repeated at the beginning of the each section in italics. Direct quotes from other regulations or the Preliminary Safety Analysis are also italicized. If necessary, a brief description of the
practical applications of the requirements in the Council of State Decisions and the more detailed criteria presented in the YVL Guides is provided. Each section includes an evaluation of how the related requirements are expected to be implemented at the Olkiluoto 3 Nuclear Power Plant Unit. Special attention will be paid to the question of whether "...the plans...entail sufficient safety" (Paragraph 1, Section 19, of the Nuclear Energy Act). A summary of the results of the review is presented at the end of the Safety Assessment.

2.1 Section 1: Applicability

In this decision general regulations relating to the safety of nuclear power plants equipped with a light water reactor are given.

In terms of its basic design, the Olkiluoto 3 Nuclear Power Plant Unit is an EPR light water reactor.

2.2 Section 2: Definitions

In this decision:

1. dose (more precisely, effective dose) shall refer to the weighted sum of the equivalent doses of tissues and organs subjected to radiation, where the equivalent dose denotes the product of the mean energy imparted by radiation to tissue or organ per mass unit and of the weighting factor of radiation;

2. dose commitment shall refer to the time integral of the dose rate reaching to a separately defined period of time;

3. criticality accident shall refer to such an accident during which an uncontrolled chain reaction of fissions caused by neutrons arises;

4. quality assurance shall refer to all planned and systematic actions necessary to provide adequate confidence that a component, plant or activity will satisfy given requirements;

5. anticipated operational transient shall refer to a deviation milder than an accident from normal operational conditions which can be expected to occur once or several times during any period of a hundred operating years;

6. accident shall refer to a deviation from normal operating conditions which is not an anticipated operational transient. Accidents are grouped into two classes:

7. postulated accident means an event which serves as a design basis for the engineered safety systems of a nuclear power plant. The nuclear power plant shall withstand a postulated accident without severe fuel damages and without radioactive releases that would require extensive measures for restricting the exposure of the general public; and

8. severe accident shall refer to an emergency in which a considerable part of the fuel in the reactor is damaged;

9. probabilistic safety analysis shall refer to estimates and calculations based on experience and probabilistic methods which address the reliability of operation of nuclear power plant systems, potential accident sequences, reactor damage, accident propagation and releases of radioactive materials;

10. safety functions shall refer to functions important from the safety point of view the meaning of which is to prevent the emergence or advancement of transient and accident conditions or to mitigate the consequences of accidents; the most
21.1.2005

important safety functions are reactor shutdown, residual heat removal from the reactor to the ultimate heat sink and the functioning of the containment building; and

11. nuclear power plant shall refer to a nuclear installation equipped with a nuclear reactor which is intended for electricity generation, or, if several such or other nuclear installations have been placed on the same site, the entity of installations formed by them.

This Safety Analysis makes use of the definitions specified in the Council of State Decision 395/1991.


3.1 Section 3: General objective

The general objective is to ensure nuclear power plant safety so that nuclear power plant operation does not cause radiation hazards which could endanger the safety of workers or of the population in the vicinity or could otherwise harm the environment or property.

This is the objective stated in section 6 of the Nuclear Energy Act. More detailed requirements for measures required to ensure safety are also included in sections 6a, 7 and 19 of the Nuclear Energy Act (see chapter 13, Conclusions), Decisions of the Council of State 395/1991, 396/1991, 397/1991, 398/1991 and 478/1999, YVL Guides issued by the Radiation and Nuclear Safety Authority, and radiation safety legislation. The above-mentioned regulations form the basis of the current safety assessment.

This safety assessment gives an evaluation of the attainment of the above-mentioned general objective.

3.2 Section 4: Safety culture

When designing, constructing and operating a nuclear power plant, an advanced safety culture shall be maintained which is based on the safety-oriented attitude of the topmost management of the organisations in question and on the motivation of the personnel towards 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.

TVO has organised the preparatory work as well as the administration and supervision of the construction of the Olkiluoto 3 Nuclear Power Plant Unit under a separate project department. Experts from the company's other departments have been transferred to the project department and the organisation has been complemented with recruits from
outside the company. The project department will also make use of the expertise and services provided by other departments. The starting point was that the project would be managed and supervised according to TVO's established procedures. Accordingly, the safety culture thus developed is intended to manifest itself in the operations of the project organisation in the course of the construction project. Technical expertise has been concentrated on TVO's line organisation, whose services will be utilised by both the project and the operation if needed. In the initial stages of the project the flow of information between the project organisation and the operating organisation was somewhat slow. The flow of information has been improved by increasing the participation of the operating organisation in the project process and vice versa. In its control activities, STUK has tried to ensure that the construction of the Olkiluoto 3 Nuclear Power Plant Unit does not compromise the safety of the operational plant units.

The conclusions presented in this chapter are based on documentation provided by TVO, on STUK's experience related to the operating organisation of TVO's current plant units (Olkiluoto 1 and 2) and the state of TVO's safety culture, on the results of the three separate inspections of the project operations undertaken in the autumn of 2004, and on observations of the operation of the Olkiluoto 3 Project.

Documents of particular importance to the assessment of the organisation and its safety culture include the administrative rules, the organisation handbook, the quality management handbook, and the project plan for the construction of the Olkiluoto 3 Nuclear Power Plant Unit.

Corporate organisation and staff functions, mandate and accountability are stated in the administrative rules of the nuclear plant referred to in section 36 of the Nuclear Energy Act. The latest update to the administrative rules is under discussion within STUK. Besides the operational plant units Olkiluoto 1 and 2, the update covers the organisation related to the construction of the Olkiluoto 3 plant unit.

A more detailed description of the functions, mandate and accountability of the various organisational units than that given in the administrative rules is presented in the organisation handbook, which has also been updated to cover the construction of the Olkiluoto 3 Nuclear Power Plant Unit.

Section 35 of the Nuclear Energy Act requires that the licence applicant should submit a quality assurance report on the construction of the nuclear facility. It should show the systematic measures that are applied by the organisations that take part in the design and construction of the nuclear facility in their operations affecting quality. TVO has submitted a description of their quality management system to STUK for approval. The description presents the construction-related processes, which include a process for maintaining and developing a safety culture.

The project plan describes the procedures and plans that are essential from the viewpoint of TVO's project management and implementation, as well as the functions of the people participating in the project.
In the above-mentioned documents, sufficient importance has been given to safety and its assurance. The decision-making process related to safety issues has been clarified and specified on the basis of STUK's inspection findings. It can be expected that safety issues will be appropriately handled with the procedures presented.

In connection with the construction of the Olkiluoto 3 Nuclear Plant Unit, TVO has also asked STUK to approve the responsible manager and his deputy referred to in section 16 of the Nuclear Energy Decree, and the persons who will be in charge of the construction-related physical protection and emergency planning, and the supervision of nuclear material. On 17 January 2005 STUK approved the responsible manager and his deputy. The person in charge of the supervision of nuclear material was approved on 18 January 2005 and the person in charge of physical protection and emergency planning was approved on 15 November 2004.

The Olkiluoto 1 and 2 plant units have been operating well during their entire operational period. Operational incidents have been few and of little significance to safety. Response to faults and defects has been based on their safety significance. STUK has prepared a quarterly report on safety-related failures and defects found in the activities of the operating organisation since the start of operations. The Olkiluoto power plant has been maintained in a technically good condition and during their operating history the plants have undergone a number of significant modernisations, such as two major power upgrades and other safety improvements. TVO has endeavoured to develop the plant organisation and operation, using methods such as seeking assessments of the company's operations from national and international expert groups.

In the autumn of 2004 STUK undertook three separate inspections of TVO with the purpose of ascertaining the prerequisites for the construction of the Olkiluoto 3 Nuclear Power Plant Unit with a view to a licensing opinion. The inspections made by STUK covered TVO’s project management and human resources, handling of safety issues, project implementation, and quality management and documentation control. STUK found defects requiring correction in all of the above-mentioned areas and requested that TVO take appropriate measures to eliminate them. The most important defects have now been corrected. As far as the less important defects are concerned, STUK will inspect the adequacy of the measures underway before the commencement of construction.

STUK will make an assessment of the stage of development of TVO's safety culture during the construction process and will prepare a more detailed report on the matter in its opinion regarding the operating licence application.

In 2003 STUK took notice of the safety culture of TVO's operating organisation, because the Olkiluoto 1 and 2 units showed an exceptional number of operation-related events, which included breaches of technical specifications. In 2003 there were a total of seven operation-related events, which were classified as level 1 on the international
seven-level scale for the seriousness of events at nuclear facilities (INES). None of these events compromised the safety of the facility. What is significant, however, is the exceptionally large number of events and the common background factors, which revealed defects in the ability of the organisation to identify the causes of the events and so prevent the recurrence of similar events. Because of the events, TVO set up a separate working group, whose task was to determine what development activities were necessary. Additionally, TVO commissioned a comprehensive independent investigation of the events, which focused on practices in particular and, on a larger scale, on the organisation's cultural factors. On the basis of the investigations, TVO has implemented and started numerous development projects aimed at the organisation's operations, which is a sign of an advanced safety culture and the ability to tackle the problems that have been discovered.

The quality policy of the project for the implementation of the facility is based on a high safety and quality culture, with emphasis on risk prevention and continuous improvement of operations. The quality policy also requires that deviations and "near-miss" situations should be documented and their primary causes investigated. Safety at the construction stage should be ensured by implementing operations in accordance with health, safety and environmental objectives (HSE).

TVO and STUK have dealt with the plant supplier's safety and quality culture in audits of the plant supplier's design activities (various organisation units of the consortium). The plant supplier has corrected the deviations discovered by the audits. Signs indicating the internalisation of a safety culture are visible in the design activities as a whole. On the basis of interviews, the organisations seem to perceive that a safety culture is realised when it is emphasised in design the solution presented by the design documentation is safe for the user of the end product. This is emphasised by the fact that when the designer discovers an error, deviation or defect during the design process, he has the right and duty to bring the matter to notice. The design organisations have documented procedures for dealing with deviations that have been brought forward.

In summary, STUK states that the project partners have the prerequisites for acting according to an advanced safety culture.

3.3 Section 5: Quality assurance

Advanced quality assurance programmes shall be employed in all activities which affect safety and relate to the design, construction and operation of a nuclear power plant.

The quality control and assurance of design, equipment manufacturing and construction has been described in a separate report according to section 35 (3) of the Nuclear Energy Decree. It describes the main features of TVO's project quality policy and quality management system, which has been designed as part of the management system of the project.
TVO's quality management system states the procedures and responsibilities involved in the management and implementation of the project. A quality management system based on a process operating model has been integrated into the operating system of TVO's operational plant units. The highest document in the system is the project quality policy, to which all project participants must commit themselves.

The quality management system is based on international quality standards. The quality control and assurance requirements set in the YVL Guides and code 50-C-QA of the International Atomic Energy Agency (IAEA) have been taken into account in the establishment of the system. The quality standards, YVL Guides and the IAEA code are to be followed in the quality management systems of all the organisations that have an impact on the safety of the facility.

TVO will ascertain the quality of operations at various stages to the extent and allocation as required by the safety significance of each system, structure and item of equipment. Quality assurance will cover the assessment and supervision of the project itself, the subcontractors used in the project, the consortium, and the equipment suppliers.

TVO will also use the quality management system to ensure high quality for the operations of the consortium. Adequate design documentation inspections and approval procedures have also been created for the system. Audits performed in the premises of the consortium and the equipment suppliers are also used to ensure that the quality level set for safety-related activities is achieved.

The consortium's quality assurance is described in a preliminary safety analysis report. The report and supplementary topical reports present the principles for quality assurance operations in different technology areas. The report also defines equipment quality grades based on equipment safety classes, as well as inspection and approval procedures for design and manufacturing documentations.

The consortium has designed a general quality management programme for the Olkiluoto 3 project as guidance for its operations. The programme requires that the consortium and all project participants should commit themselves to a high quality and safety culture and to a continuous improvement of operations and the monitoring of the effect of equality management systems.

The consortium has quality management systems consisting of three-level documentation, which have been complemented with quality plans that cover the different stages of the Olkiluoto 3 project and with a project-specific quality assurance programme. The procedures, tasks and responsibilities are described in detail in the consortium's manuals dealing with this project.

Special requirements have also been placed on quality control because of the nature of the technical solutions chosen for the facility. Special attention has been paid to the use
of programmable automation technology (for more details see Chapter 5.10) and the construction of major pressure vessels and pipework based on the principle of Break Preclusion (for more details see Chapter 5.4).

TVO has evaluated the quality control methods and quality assurance operations of the design organisations through auditing the consortium and the outside design organisations used by it.

STUK has evaluated the quality control and assurance of design, equipment manufacturing and constructing by taking part in the audits of the consortium and equipment suppliers carried out by TVO. In addition, STUK has carried out inspections of the consortium’s unit that is responsible for the preparation of a probabilistic safety analysis and on planning operations related to radiation safety.

The audits and the inspections carried out by STUK discovered a number of quality-related defects in the operations of the consortium and the design organisations used by it. Four of the defects were classified as critical by TVO. Corrective action planned because of such deviations has been taken. The plant supplier has proposed corrective action for all deviations classified as significant and minor. Some corrective action has not been implemented yet. The action required is under discussion, as required by TVO's quality management system. In STUK's opinion, the deviations that are still unresolved have no harmful effect on activities related to nuclear safety. The plant supplier and the organisations used by it possess adequate capabilities for high-quality design and construction activities.

As far as the most important main components are concerned, the manufacturing of mechanical equipment was started—with a very short preparatory period—before the granting of the construction permit because of the tight construction schedule and long lead times for the equipment. The plant supplier and the equipment suppliers have not had time to complete all the pre-manufacturing measures required in the YVL Guides according to the planned schedule, which has caused distinct delays. Equipment manufacturing had to be commenced with short steps as design and preparatory action proceeded with STUK's approval of just the initial manufacturing stages. The manufacturing stages themselves, and their control, have followed the YVL Guides, but equipment dimensioning has been approved conditionally. They will be reviewed when the design principles are approved.

In connection with the inspections of the initial manufacturing stages of the main components, the plant supplier has endeavoured to ensure, with comparisons made with reference facilities, that it is possible to meet the level of requirements set for the equipment, although final results of the analysis are not available for all parts. The stepwise manufacturing approval process has provided additional time for the preparation and inspection of documents related to the later manufacturing stages. With an increase in the quantity of equipment for discussion, it will not be possible to follow a similar procedure in the future; instead, a procedure specified by the YVL Guides
must be followed. Accordingly, all essential documents related to equipment design and manufacturing must be approved before manufacturing can be started.

The quality management procedures for the future use of the Olkiluoto 3 Nuclear Power Plant Unit will be assessed in detail at the licensing stage. TVO plans to implement the operation of the Olkiluoto 3 plant unit in accordance with the instructions for the quality management system regarding the operation of the Olkiluoto 1 and 2 plant units.

In summary, STUK states that the advanced quality assurance programmes specified in YVL Guide 1.4 are being followed in the activities that are related to the design and construction of the Olkiluoto 3 Nuclear Power Plant Unit and have an impact on safety.

3.4 Section 6: Demonstration of compliance with the safety regulations

If compliance with the safety regulations cannot be directly ascertained, fulfilment shall be demonstrated by the necessary experimental and calculation methods.

Nuclear power plant safety and the design of its safety systems shall be substantiated by accident analyses and probabilistic safety analyses. Analyses shall be maintained and revised if necessary, taking into account operating experience, the results of experimental research and the advancement of calculating methods.

The calculating methods employed for demonstrating that the safety regulations are met shall be reliable and well qualified for dealing with the events in question. They shall be applied so that the calculated results are, at a confident estimate, less favourable than the results which are considered best estimates. Furthermore, analyses which depict 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.

3.4.1 ACCIDENT ANALYSES

Compliance with safety regulations is assessed, as far as possible, based directly on the design of the plant unit and its systems. Facts that are directly verifiable include system-level failure tolerance and other similar characteristics, which are logical in nature and whose implementation can be determined from design drawings that show the functional structure of the systems. In order to assess whether the structures and systems will function successfully, it is not enough to merely use logical reasoning; instead, it will be necessary to use mathematical-physical analyses which will examine the phenomena connected with each function and calculate the behaviour of a plant unit and its systems for a number of imaginable operation, failure and accident situations. This is called accident analysis.
The events under examination are divided by their estimated frequency of occurrence into the following classes: normal operation, anticipated transients, postulated accidents (Class 1 and 2), and severe accidents. In the case of the Olkiluoto 3 Nuclear Power Plant Unit, event combinations that cannot be easily classified solely on the basis of the frequency of initiating events will also be examined. These examinations are aimed to justify sufficient diversity of the safety functions and prove that no such threshold phenomena exist immediately outside the scope of the design-basis events that would endanger the safety of the plant unit. These conditions are called design extension conditions (DEC). Additionally, certain special situations, such as aircraft crashes, are treated as a unique event class.

Assumptions to be made in the analyses and acceptance criteria have been defined for each class of events. The initial and boundary conditions of the accident analyses include assumptions that change the final outcome to an unfavourable direction in terms of approval criteria, so that any uncertainties associated with the design and analyses are covered with sufficient reliability. Calculations for analyses are made using so-called best-estimate methods - i.e., calculation methods that include no built-in unfavourable assumptions. Consequently, the same methods and models can be used to calculate the most probable development of situations, provided the "most probable" initial and boundary conditions can be determined. In more complicated accident situations it is often impossible to determine in advance which combination(s) of analysis assumptions will have the most unfavourable end result. Therefore, when best-estimate calculation methods are used, a large number of sensitivity studies are made in order to determine the combined effects of various phenomena and assumptions, and to establish the most unfavourable end result in a physically reliable manner. The criteria given in YVL Guide 6.2 have been used as approval criteria for fuel in the different classes of events.

In the Preliminary Safety Assessment, the following comments were made on accident analyses: In the dimensioning of safety functions, it is necessary to choose as initial events or other design factors a larger number of events than was the case at the time when the presently used plants were originally designed. The requirements for this are presented in instruction YVL 2.2. Here are a few examples:

- Initial events to be treated as postulated accidents should include operational transients in which a reactor shutdown by means of control rods is assumed to fail completely (the so-called ATWS).
- In pressurised water reactors, a possible leak from the primary circuit to the secondary circuit must not result in coolant release into the atmosphere.
- In the analysis of initial events, indirect threats must also be identified and provisions made against them in the design of systems and equipment. Each initial event is always connected with an obvious direct threat to the integrity of a dispersion barrier; for example, coolant loss caused by a pipe break in the primary circuit always interferes directly with the cooling of the fuel cladding and thus poses an integrity threat. Besides a direct threat, an initial event may be connected with indirect threats: For example, in connection with coolant loss, materials damaged by a pipe break may clog filter structures of the emergency cooling system.
21.1.2005

that cools the fuel and thus interfere with emergency cooling. As another example, coolant loss that takes place in pressurised water reactors may be accompanied by a natural process in which the boron dissolved in the cooling water for reactor power control is enriched in the reactor core whereas pockets of diluted water are formed elsewhere in the primary circuit. Diluted water entering the reactor core at a later stage might cause reactor re-criticality, which would not be safe in the case of an accident.

The transient and accident analyses of the Olkiluoto 3 Nuclear Power Plant Unit are described in Chapter 15 of the PSAR and the related Topical Reports. The major results and an assessment of the acceptability of the facility's design and operation are presented in Chapter 5 of the present safety analysis. Safety analyses have been prepared in order to justify the technical solutions for the plant unit. The analyses will be supplemented or updated in the course of construction as necessary.

Calculation models used

In the design of the Olkiluoto 3 Nuclear Power Plant the plant supplier has used separate calculation models for analysing transients, accidents, containment behaviour and severe accidents, and for strength calculations.

Transient and accident analyses not associated with loss of coolant employ calculation methods (computer codes) in which the plant’s primary and secondary circuits are modelled in detail. In order to calculate fuel power, these models address the neutron kinetics, either by a point model, a one-dimensional model or a three-dimensional model, depending on the problem under consideration. Furthermore, the programs include a sufficient number of models associated with thermohydraulics and heat transfer in the fuel. These programs have been used to calculate fuel rod power and the margin to heat-transfer crisis. In cases of rapid changes in power, the energy gain (maximum enthalpy) of a fuel rod is calculated.

Loss of coolant accidents have been calculated using computer codes with detailed plant modelling, detailed thermohydraulic models and adequate models associated with the calculation of reactor power and heat transfer in the fuel. These codes have been used to estimate fuel coolability – that is, the maximum temperature and oxidation of the fuel cladding.

The mechanistic behaviour of the fuel has been modelled by computer programs that allow the calculation of the plastic deformation, ballooning and bursting of the fuel cladding, oxidation and hydriding of fuel and creep of the fuel cladding, as well as stresses imposed on the cladding. The thermohydraulic boundary conditions required for the calculation method have been obtained from models used for transient and accident analyses. The programs have been used to estimate the degree of damage to fuel rods in the core, taking fuel burn-up into account.
The pressure and temperature loads in the containment building during accidents have been estimated by computer programs that model the overpressure and heat transfer to structures caused by steam and water released into the containment building. The calculation methods associated with containment building behaviour model both the containment building and the systems immediately associated with it.

In the severe accident analyses the plant supplier has used both manual calculations based on test results and computer programs. Manual calculations have been used to justify molten core management and to define the quantity of materials to be eroded by the molten material (sacrificed deliberately). Detailed computer calculations have been used for purposes such as the determination of hydrogen behaviour in the containment building, and it has been shown that assumed hydrogen burns would not compromise the leaktightness of the containment building. For the purpose of comparison, STUK has performed and commissioned analytical manual calculations, MELCOR program analyses, and verification tests of its own. For severe accident phenomena, analyses have also been made of the behaviour of the primary circuit during core meltdown, the effect of molten material on the sump structures under the reactor pressure vessel, spreading of molten material, cooling of the spreading area, hydrogen management, and the removal of decay heat power from the containment building.

In analysing radiation doses caused by transients and accidents among the population, the plant supplier has used computer programs called ACARE and PRODOS to model the conveyance of radioactive materials in the containment building of the nuclear power plant and in the environment, and to estimate resulting radiation doses in the most exposed individual among the population. TVO has used the TUULET program to perform comparison calculations and STUK has commissioned VTT to carry out calculations with the ARANO program.

The plant supplier has determined the loads caused by pipe breaks for primary and secondary circuit equipment and structures using models that calculate the forces caused by pressure waves and flow fluctuations on the surrounding structures. Together with the stress analysis models, these models are used to consider the interaction between the flow and the structures.

Behaviour of the buildings during accidents has been calculated using general-purpose calculation models that represent construction engineering mechanics. These same models have also been used to calculate building responses to earthquake impulses and other dynamic loads, including aircraft crashes. Special phenomena related to aircraft crashes, such as wall penetration, fire-induced pressure changes in confined spaces, thermal effects of fireballs generated by the crash, etc., have been estimated using mainly experimental or semi-experimental correlations, and, in part, computational fluid dynamic methods.

The calculation models used in the design of the Olkiluoto 3 Nuclear Power Plant have been described with sufficient precision. The models have been qualified within the range of parameters used for the calculation models by comparing the calculated results
with observations made in actual plant conditions, as well as transients and accidents simulated on test facilities. In addition to the analyses submitted by the plant supplier, STUK has commissioned comparative analyses using independent calculation methods, and these have provided additional proof of the sufficiency of the plant supplier’s calculation methods and the analyses conducted using them.

Analysed events

The analysed events have been classified by their estimated frequency of occurrence into transients, class 1 and 2 accidents, and severe accidents. In Chapter 15 of the Preliminary Safety Analysis Report they have been further divided into six different event types:
- reduced heat transfer to the secondary circuit
- increased heat transfer to the secondary circuit
- reduction in primary circuit flow
- reactivity and power disturbances
- increase in amount of primary coolant
- loss of primary coolant.

The events have been analysed in the different operational states of the plant: normal power operation, plant start-up and shutdown, hot and cold standby states, and outages during which the reactor head can be open or closed.

Long-term coolability of the fuel has also been assessed in connection with all events. In the case of primary circuit leaks, this requires that coolant recirculation from the containment building should function reliably, although loose material is released into the containment building from the heat insulation, which will be damaged in connection with the leaks (see Chapter 3.4.2), and that the plant unit can subsequently reach a state in which the fuel can be removed from the reactor.

The results of transients and accidents are assessed in Chapters 5.3 to 5.5, which deal with the assurance of the integrity of the physical barriers (fuel, primary circuit, containment building). The results of radiation dose calculations are assessed in Chapters 4.4 to 4.5.

The results of the strength analyses of the mechanical components are dealt with in Chapter 5.4.

Computational analyses have also been used to assess the adequacy of the building design against dimensioning events. For buildings, dimensioning events include internal pressure and temperature loads, earthquakes and aircraft crashes. Their effects are considered using construction engineering strength analyses in the first place; aircraft crashes, for example, include analyses dealing with impact forces, dynamic behaviour of structures, and combustion phenomena. In order to assess the analyses
21.1.2005

prepared by the plant supplier, STUK has had its own comparative analyses prepared on these topics, using independent methods. The results are discussed in section 5.8.

Threat analyses of area hazards to be considered in safety design have been prepared for selected items - in particular, combustion analyses for the assessment of the adequacy fire effects and planned countermeasures. The results are discussed in section 5.8.

Preliminary failure analyses have been made of the basic equipment used in electrical and automation systems. Automation system design is discussed in more detail in section 5.10.

3.4.2 DEMONSTRATION OF THE PLANT SAFETY THROUGH EXPERIMENTS

Where reliable computational methods are not available, the implementation of the safety objectives of the Olkiluoto 3 Nuclear Power Plant has been demonstrated through experiments. Plant design has been based on decades-long experimental work performed by both the plant supplier's own institutions and international research institutions. In recent years experimental research has focused on the features of the Olkiluoto 3 Nuclear Power Plant Unit that deviate from the currently operating French and German plants. Special studies have been made of features that have been planned for severe accident management and are totally missing in the currently operating plants. Some studies are still partly ongoing or in the design stages.

The plant supplier is designing the filter structures that take part in the recirculation of emergency cooling experimentally in such a way that even the worst estimated impurity load will not block them in the estimated accident time frame. The filter structures will be equipped with a pressure differential gauge and a cleaning flushing system that will function through the minimum flow lines of the emergency cooling system. These are being used to ensure the long-term operation of the emergency cooling system. The design of the filter structure functions is almost totally experimental because the theoretical knowledge related to the design phenomena is not adequate.

The plant supplier will perform thermal hydraulic testing of the internal and bottom parts of the reactor pressure vessel in order to ensure the functioning of the control rod drive mechanisms, upper internal parts, lower internal parts and the reflector in relation to vibrations and flow distribution. Additionally, tests related to primary circuit thermodynamics, steam generator mechanical behaviour and vibrations will be performed.

Severe accident research has for years been conducted as large-scale international co-operation in both programmes co-ordinated by OECD and the 4th and 5th framework programmes of the EU. The strategy for severe accident management at the Olkiluoto 3 Nuclear Power Plant Unit is described in section 5.5.
Studies have been made of the interaction of the molten core material with the protective material used as thermal insulation in the reactor shaft. In order to ensure the cooling strategy of the molten core selected for the Olkiluoto 3 Nuclear Power Plant Unit, large-scale tests have been performed on the melt spreading to the spreading area. The plant supplier has performed thermal-hydraulic testing on the functioning of the melt cooling system, and the tests have been verified with independent tests commissioned by STUK. Based on the test results, the cooling system is operational, though supplementary tests are still needed to definitely establish the effect of certain phenomena (flow oscillation) and factors (impurities in the cooling water).

Hydrogen production in accidents, mixing and burning are physical phenomena that are not specific to a certain plant solution. They have been studied with international experiments, such as in the 4th and 5th Framework Programmes of the EU. Computer programs used in hydrogen analyses have been qualified through testing. The supplier of recombinators and international research institutions have tested the functioning of the passive autocatalytic recombinators designed for hydrogen management in the Olkiluoto3 Nuclear Power Plant in their assumed operating conditions using comprehensive series of tests.

On the basis of test results that describe key phenomena connected with a severe reactor accident, the plant supplier has been able to design the plant in such a way that a steam explosion threat to the integrity of the containment building can be practically eliminated. The threat to the integrity of the containment building caused by a discharge of molten material in connection with a high-pressure failure of the pressure vessel has been eliminated by making the depressurisation function of the primary circuit very reliable.

Dynamic structure analyses related to aircraft crashes belong to an area that contains very little experimental and computational basic knowledge, especially in published literature. For this reason, experimental crash research has also been started in Finland. STUK will use the results of such research to assess the results obtained by calculations in a power plant application. Both calculations and experimental research will continue during construction until detailed designs for the structures can be estimated.

### 3.4.3 Probabilistic Safety Analyses (PSA)

**General**

The plant supplier has prepared a design phase probabilistic safety analysis (design phase PSA) for the Olkiluoto 3 Nuclear Power Plant Unit. The PSA will be complemented during the construction of the plant unit when detailed design is available.
21.1.2005

Regulatory guide YVL 2.8, which specifies the following probabilistic design objectives, applies to the PSA.
- The mean value of the probability of core damage is less than 1.0E-5/year; this will be estimated in level 1 PSA.
- The mean value of the probability of a release that exceeds the limit (section 4.6) referred to in section 12 of the Decision of the Council of State (395/1991) is less than 5.0E-7/year; this will be estimated in the level 2 PSA.

Accident sequences that result in the damage of the reactor core and their probabilities have been determined in level 1 PSA. Events treated as accident initiating events include events originating in the plant's internal faults, failures and errors, loss of off-site power supply, fires, floods, abnormal weather conditions, seismic phenomena, and other factors caused by the environment, as well as external risks caused by human activities.

The level 2 PSA has assessed the physical progression of a severe reactor accident and the timing of barrier damage in accidents which threaten the structural integrity of the containment building or its functional tightness, or in which a release from the primary circuit occurs through systems located outside the containment building (by-pass of the containment building). The quantity, probability and timing of radioactive materials leaking from the containment building have been determined in level 2 PSA. The assessment deals with leaks from the containment building, and damages of containment and controlled releases from it, as well as by-passes of the containment building.

In connection with the PSA review, STUK has made its own verification calculations because of inaccuracies found in the PSA model. The calculations have been used to ensure that the plant can be built to meet the above design objectives with sufficient confidence.

Internal initiating events:

The events treated as internal initiating events include loss of coolant accidents (LOCA), transients and loss of off-site electrical power supply. Internal initiating events are the cause of a relatively large part of the plant's total risk, because risks caused by fires, floods and external events have been kept very low with the help of physical separation between the plant's structures and systems, as well as with layout solutions.

Since the safety systems of the plant unit are multi-redundant (mainly 4 subsystems), the significance of common cause failures is emphasised in event sequences leading to core damage. The utilisation of diversity within safety systems (e.g., emergency feed water system) that are the most important from the viewpoint of safety and the utilisation of functional diversity (e.g., primary circuit feed and bleed that provides
21.1.2005

diverse safety function to the secondary side heat removal) reduce the risk of core
damage and the significance of common cause failures.

Because the design is still incomplete, no comprehensive dependence analysis of the
significance of possible system dependencies and common cause failures has been
presented for all systems (especially automation systems). In the review of the design
phase PSA and PSAR, and the design principles presented, new factors that would
essentially increase the risk estimate have not been identified.

The design phase analysis of the internal initiating events of the Olkiluoto 3 Nuclear
Power Plant Unit appears to be sufficiently comprehensive for assessing that the plant
unit can be built to meet the quantitative objectives set in the regulatory guide YVL 2.8
with sufficient confidence.

Fires and floods

The conceptual design of the plant against fires and floods is described in Chapter 5.8.
Their risk is assessed in the design phase and construction phase fire and flood risk
analyses. The aim has been to demonstrate that the contribution of fires and floods to
the total core damage frequency is small and that there are no design defects left in the
plant that would dominate the risk. While performing the design phase PSA, not all
design details were known, which means that expert judgement and conservative
assumptions were used.

At present, Olkiluoto 3 design phase fire and flood risk analyses do not cover all
potential fire and flood events. According to the design phase analysis, both the plant's
fire and flood risks contribute approximately 2 to 3% to the core damage frequency.
The estimate can be considered acceptable at this stage.

No detailed fire and flood risk analysis can be made until the construction stage of the
plant unit when the design is finalised. For the time being, the fire and flood risk
analyses ignore the plant's operation at low power and shutdowns states. However, the
principles outlined in the PSAR, building layout drawings, and topical reports provide
an adequate basis for the implementation of the plant unit in such a way that the
requirements related to fire protection can be met.

The spreading of floods to more than one redundant subsystem can adequately be
prevented with good lay-out.

Outages

In the low power and shutdown PSA an analysis has been made of the internal risks
during the annual maintenance outage of the plant. At the design phase, however, not
all the factors that have an effect on the risk are yet known, such as the maintenance
strategy for the outage. For example, actions related to the preventive maintenance of the equipment during the outage can be analysed in detail in construction phase PSA.

One of the outage situations analysed is the loss of cooling of the spent-fuel storage pool located outside the containment building during the annual maintenance outage when all of the fuel from reactor has been transferred into the pool.

The low power and shutdown risk analysis should also cover risks caused by possible drop of heavy loads. So far, calculations have been made of the frequency of the reactor pressure vessel head drop when the pressure vessel is opened and closed during the annual maintenance outage. The analyses must be complemented at the construction phase so that they also cover other drops of heavy objects onto the top of the stored fuel or the open reactor.

So far, the low power and shutdown PSA lacks an analysis of initiating events caused by fires and floods. Consideration of plant layout, the use of technical barriers and separation principle in the design process provides the basis to assess that fire and flood risks during low power and shutdown states are small, at maximum of the same order of magnitude as during power operation.

External events

The design phase PSA has been used to ensure the adequacy of the plant design basis and adequacy of the design requirements related to external events (weather phenomena, earthquakes, etc.). The PSA of the Olkiluoto 3 Nuclear Power Plant Unit includes a screening analysis of external phenomena covering weather phenomena (wind, temperature, lightning, rain) and seawater-related phenomena, such as variations in seawater level, temperature of seawater, and blockage-causing phenomena (algae, mussels, frazil ice, oil spills). The analysis of external events also covers risks connected with industrial activities, transport and other normal human activities in the vicinity of the plant site, but not activities malevolently aimed at damaging the plant. The provision against malevolent damage to the plant is discussed in Chapter 8, Physical Protection Arrangements.

Following the qualitative analysis, the phenomena chosen for the quantitative risk analysis of external events are frazil ice, organic material in seawater (algae) and the combined phenomenon of storm and snowfall. Since the detailed design of the plant is still incomplete, the quantitative analyses represent order of magnitude estimates. However, they can be used to provide the assessment that the impact of the above-mentioned external events on the core damage frequency is small when the detailed design, construction and drawing up of procedures is implemented in accordance with the principles stated.

No risk analysis of seismic events has yet been performed for the Olkiluoto 3 Nuclear Power Plant Unit because the design has not yet proceeded to a sufficiently detailed
level for the assessment of the earthquake resistance of the structures, systems and components. However, TVO has presented an assessment which claims that it is possible to demonstrate that the plant unit meets probabilistic design objectives with a sufficient safety margin for earthquake risks, provided the plant unit is implemented according to the principles of earthquake design stated in the Preliminary Safety Analysis Report. A description of provisions against earthquakes is provided in section 5.8.

Analyses of releases

The amount and probability of releases of severe accidents have been assessed in the level 2 PSA. According to the analysis of the Olkiluoto 3 Nuclear Power Plant, when the containment functions according to the severe accident management plans, the release of cesium-137 amounts to approximately one thousandth of the 100 TBq cesium-137 limit for major releases specified in section 12 of the Council of State Decision (395/1991). Releases will be below this limit if the containment building functions as designed and in situations in which the containment has a small leakage and the containment spray functions properly (the spray water efficiently absorbs radioactive aerosols from the containment atmosphere).

Otherwise, a cesium-137 release would exceed the limit set for major releases, in which case it must be shown that the combined frequency of such events will not exceed the above-mentioned frequency of 5E-7/year. Such accidents include the following event sequences:
- the containment building does not close tightly enough
- the leak takes place from the primary circuit directly into the environment through a leaking pipeline or a steam generator (containment by-pass).
- the containment building breaks down as a result of a hydrogen burn, steam explosion or energetic breach of the primary circuit
- the molten core material can not be controlled as designed, which will cause a melt-through the basemat of the containment building
- the pressure in the containment building slowly exceeds the fracture pressure due to steam and/or uncondensed gases, which will likely result in a small leak.

Results of PSA analyses

According to the design phase PSA of the Olkiluoto 3 Nuclear Power Plant Unit, the mean value for core damage frequency value is approximately 1.8E-06/year (power operation and outages) and is divided among initiating event groups as follows:
- Transients 45% (loss of feed water and component cooling system failures being the most important)
- Loss of Coolant Accidents (LOCA) 24% (small LOCA being the most important)
- Loss of off-site power supply 5%
- Fires 2%
According to the plant supplier's preliminary calculations, the frequency of exceeding the release limit for a severe accident is 1.0E-7/year. STUK has reviewed the assessment and agrees with its conclusions.

3.4.4 SUMMARY

To summarise, STUK states that for the purpose of demonstrating compliance with safety regulations the construction permit-stage design for the Olkiluoto 3 Nuclear Power Plant Unit have been analysed adequately using both accident analysis and probabilistic safety analysis methods. STUK considers the research and development activities related to the operational events and progression of accidents to be adequate. A few tests and computational analyses required for the justification of certain individual solutions still have to be undertaken. As the project proceeds and the plans are made more specific, the completion of the analyses shall be continued in a corresponding manner as a part of the licensing process of the technical solutions for the plant unit. The acceptability of the results is discussed in section 5.


4.1 Section 7: Limitation of radiation exposure

Radiation exposure arising from the operation of a nuclear power plant shall be kept as low as reasonably achievable. A nuclear power plant and its operation shall also be designed so that the limits presented in this decision are not exceeded.

Consequently, exposure to radiation must be controlled in accordance with the As Low As Reasonably Achievable (ALARA) principle. The design and operation of the plant unit from the point of view radiation exposure is discussed in section 4.2 and the exposure limits in sections 4.3 to 4.6.

The International Commission on Radiation Protection (ICRP) is currently revising its radiation protection policies. According to the ICRP, the reforms will not, however, require any changes to the existing national radiation protection regulations.
4.2 Section 8: Radiation safety of nuclear power plant workers

A nuclear power plant's design and operation shall be implemented so that radiation exposure to workers can be limited as separately enacted.

The regulations concerning the radiation exposure of staff members are the Radiation Act 592/1991, Radiation Decree 1512/1991, and the ST and YVL Guides issued by STUK. Under Section 2 of the Radiation Act, to be considered acceptable, the use of radiation and practices involving exposure to radiation shall meet the following criteria:

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

In the design of the Olkiluoto 3 Nuclear Power Plant Unit the radiation exposure of the workers is limited by the following measures:
- fission product leakage from the nuclear fuel is kept at a low level during operation;
- materials selections are optimized with regard to materials contributing to radiation doses (such as stellite coatings containing cobalt). However, cobalt is used at critical places, such as on the contact surfaces between reactor internals, because no material with similar mechanical properties that would be more advantageous in terms of radiation doses is available. The use of completely new materials may also involve other technical risks;
- structural radiation shields are provided to reduce doses, particularly during maintenance;
- radiation protection has been taken into account in maintenance operations as follows:
  o components have been positioned to facilitate testing, maintenance, inspection, repair and replacement;
  o the number of welded joints in pipe lines have been minimized to reduce the number of items to be inspected;
  o maintenance-free components are used in areas with high radiation levels;
  o sampling, measuring and monitoring equipment are placed in areas with a low radiation level;
  o components emitting high radiation fields are handled remotely;
  o thermal insulation is in cassette form to enable quick installation and removal;
  o space is provided for preparatory work in low-radiation areas.

The plant supplier estimates that the collective radiation dose received by the workers at the Olkiluoto 3 Nuclear Power Plant Unit would be in the region of 250 to 500 man-mSv/year, depending on the duration of the refuelling cycle. The estimate is greater than the actual doses received at the best German pressurised water reactors but, even at its highest, no greater than the doses received at the best French PWRs. This difference
is largely explained by the different material selections in Germany and France. In STUK's view, the collective radiation exposure of the workers has been estimated properly and the result satisfies the Finnish requirements. At this point the levels are still estimates. The actual cumulative dose will be determined once the plant unit is in operation based on the personal dose monitoring of the workers in accordance with the radiation safety requirements.

The design of the Olkiluoto 3 Nuclear Power Plant Unit offers a sufficient level of safety as far as the radiation exposure of the personnel is concerned.

4.3 Section 9: Limit for normal operation

The limit for the dose commitment of the individual of the population, arising from normal operation of a nuclear power plant in any period of one year, is 0.1 mSv. Based on this limit, release limits for radioactive materials during the normal operation of a nuclear power plant are to be defined.

Radioactive releases from a nuclear power plant during normal operation are, to a great extent, determined by leakage from the nuclear reactor fuel rods (fuel leaks), reactor coolant and its impurities (fission and corrosion products), coolant leaks, decontamination of radioactive systems, maintenance operations and waste management (including purification and retention of exhaust gases and liquids).

Due consideration has been given to the minimization of fuel leaks in the design of the Olkiluoto 3 Nuclear Power Plant Unit. Over the past few years fuel leaks at the German and French reference plants have been very limited. The materials for the reactor cooling circuit have been selected and the water chemistry designed with a view to minimizing the creation of radioactive corrosion products.

Systems have been designed for the purification of liquids and gases containing radioactive materials to limit the release of such materials into the environment and to reduce related radiation exposure. At the Olkiluoto 3 Nuclear Power Plant Unit the reactor coolant purification system, the processing system for gaseous wastes, the storage and processing system for liquid wastes and the processing system for radioactive concentrates are be based on technology used at the German reference plants, with minor improvements based on operating experience. The purpose of these systems is to limit the releases of radioactive materials into the environment and to reduce the related radiation exposure. These systems are designed with due regard to the Best Available Techniques (BAT). Similarly, adequate exhaust air filters have been designed for installation in the ventilation systems of the plant unit.

The limit for the dose commitment resulting from the normal operation of the nuclear power plant applies to the entire site. To ensure compliance, the limits for radioactive releases are defined for each individual unit on the site to ensure that the total dose commitment due to the releases will not exceed the pre-determined level.
Under conservative assumptions, the dose commitment resulting from the operation of the Olkiluoto Nuclear Power Plant Units 1 and 2 is estimated at 0.044 mSv/year. During the past few years the theoretical dose commitment received by an individual member of the population most exposed to radiation due to the measured radioactive releases has been considerably lower, less than 0.0002 mSv/year. There are no plans to adjust the release limits of the existing plant units when the Olkiluoto 3 Nuclear Power Plant Unit is placed in operation. The unit-specific release limits to be applied to the Olkiluoto 3 Nuclear Power Plant Unit will be established in connection with the operating licence. Based on the foregoing, the release limits can be easily determined in such a way that the total dose commitment caused by the releases of the individual units will not exceed the limit specified in the applicable Decision of the Council of State.

Under conservative assumptions, the theoretical dose commitment of an individual member of the population most exposed to radiation due to the operation of the Olkiluoto 3 Nuclear Power Plant Unit is estimated at 0.014 mSv. According to the operating experience gained at the German and French reference plants, it may be assumed, with a wide confidence margin, that the actual releases will fall short of the levels presented in the PSAR. Once the Olkiluoto 3 Nuclear Power Plant Unit becomes operational, the annual dose commitment, together with the Olkiluoto 1 and 2 units, is estimated to remain far below 0.058 mSv (0.014 mSv from the new unit + 0.044 mSv from the two existing units) - i.e., lower than the specified 0.1 mSv level. Considering the limitation of the dose commitment to be caused to an individual member of the population by the Olkiluoto plant units, the Olkiluoto 3 Nuclear Power Plant Unit is therefore designed to provide an adequate level of safety.

4.4. Section 10: Limit for an anticipated operational transient

The limit for the dose of the individual of the population, arising as the result of an anticipated operational transient, from external radiation in the period of one year and the simultaneous radioactive materials intake, is 0.1 mSv.

The probability of fuel damage during anticipated transients is very low.

The dose commitment caused by anticipated transients has been calculated for the worst-case exposure situations. The methods of calculation are discussed in section 3.4. The situations analysed were the break of one heat transfer pipe in the steam generator and the loss of condenser vacuum. Both incidents lead to a release of the reactor coolant into the environment. Of these two events, the more severe is the loss of condenser vacuum, which has been analyzed using the aggravating assumptions applied to transients (see section 3.4.). According to the analyses, the Olkiluoto 3 Nuclear Power Plant Unit would cause a maximum dose commitment of 0.02 mSv to the most exposed member of the population.
With a considerable degree of certainty, the computed dose commitment will remain below the limit, so that, in this respect, the Olkiluoto 3 Nuclear Power Plant Unit has been designed to provide an adequate level of safety.

4.5 Section 11: Limit for a postulated accident

The limit for the dose of the individual of the population, arising as the result of a postulated accident, from external radiation in the period of one year and the simultaneous radioactive materials intake, is 5 mSv.

The dose commitment due to a postulated accident has been calculated for a number of situations causing the largest radiation doses. The largest theoretical dose received by the most exposed individual member of the population would be caused by a fuel handling accident in the fuel building of the Olkiluoto 3 Nuclear Power Plant Unit. This case has been analyzed using the aggravating assumptions applied to postulated accidents (see section 3.4.) According to the analysis, a fuel handling accident at the Olkiluoto 3 Nuclear Power Plant Unit would cause a maximum dose commitment of 0.7 mSv to the most exposed member of the population.

In a pressurised water reactor, primary-to-secondary circuit leaks are the most challenging in terms of safety because such a leak may, at once, bypass two physical barriers, namely the primary circuit boundary and the containment building. A primary-to-secondary circuit leak may occur as a result of damage to the steam generator heat transfer piping. At the Olkiluoto 3 Nuclear Power Plant Unit a special focus in the management of primary-to-secondary circuit leaks is on the minimization of releases. In the early phases of the accident before the primary circuit pressure falls low enough, there is a short blow-down of steam via the relief valve of the damaged steam generator, unless the turbine condenser is available. As a result, a release into the atmosphere cannot be completely avoided, as required in the Preliminary Safety Assessment. The selected strategy helps minimize the release in all postulated accidents, ensuring that it remains clearly below the dose commitment criterion (5 mSv) for such accidents. In the Olkiluoto 3 Power Plant Unit concept, the medium head safety injection (MHSI) cooling pump is a functional equivalent of the high-pressure emergency core cooling system used at existing plants, but the maximum pressure at which it can deliver water is lower than the opening pressure of the secondary circuit safety valves. This helps prevent the occurrence of a long-term environmental release.

As well as for postulated accidents, supplementary analyses have been made for Design Extension Conditions (DEC). Such situations are assumed to be less probable than postulated accidents, which is why the related analyses may make use of the best-estimate assumption as to the progress of the accident at the plant. However, the calculations concerning the dispersion of radioactive materials and dose estimates are carried out in the same way as for postulated accidents, and the limit is the same 5 mSv dose commitment as applied to postulated accidents.
The analyses of DEC cases include accidental falling of a heavy load on the reactor, as well as several different cases of damage to the steam generator heat transfer tubing combined with more failures than included in the assumptions used in a postulated accident analysis. Under highly conservative assumptions, the highest radiation dose is caused by the accidental falling of the RPV head on the reactor pressure vessel during lifting. The calculated dose commitment remains below the limit of 5 mSv.

The limit applied to postulated accidents is also used for evaluating aircraft crashes, except that best-estimate assumptions may be used in calculating the dose commitment (see section 3.4). The precautions for an aircraft crash are discussed in more detail in section 5.8 (and 5.6). The dose commitment due to an aircraft crash is estimated at a maximum of 2.5 mSv and assumed, with a high degree of confidence, to remain below the limit. Otherwise, an aircraft crash is not treated as a postulated accident but as being in a class by itself.

In summary, STUK states that from the point of view of the dose commitment caused to the population by a postulated accident, the Olkiluoto 3 Nuclear Power Plant Unit is designed to provide an adequate level of safety.

4.6 Section 12: Limit for a severe accident

The limit for the release of radioactive materials arising from a severe accident is a release that causes neither acute harmful health effects to the population in the vicinity of the nuclear power plant nor any long-term restrictions on the use of extensive areas of land and water. For satisfying the requirement applied to long-term effects, the limit for an atmospheric release of cesium-137 is 100 TBq. The combined fall-out consisting of nuclides other than cesium-isotopes shall not cause, in the long term, starting three months from the accident, a hazard greater than would arise from a cesium release corresponding to the above-mentioned limit. The possibility that, as the result of a severe accident, the above-mentioned requirement is not met, shall be extremely small.

The dose commitment caused by a severe reactor accident (reactor core meltdown) has been calculated for the worst possible situation using conservative estimates for the release of radioactive materials into the containment building atmosphere and its subsequent behaviour inside the building. In this case, the containment building is assumed to perform as designed. According to the analyses made under these assumptions, the Olkiluoto 3 Nuclear Power Plant Unit would, in a severe reactor accident, cause a maximum cesium-137 release of 1.5 TBq, while the other nuclides would not cause a greater long-term hazard. The precautions for a severe reactor accident are addressed in greater detail in section 5.5.

According to the Guide YVL 2.8, the expectation value for the frequency of a cesium-137 release exceeding 100 TBq should be below 5E-7/year in a probabilistic analysis. According to the latest PSA level 2 calculations, the expectation value for this
frequency is about 1E-7/year. The same calculations suggest that the total fall-out due to other nuclides will not cause a greater hazard than a 100 TBq cesium-137 release.

With a considerable degree of confidence, the estimated dose commitment will remain below the limit, so that, in this respect, the Olkiluoto 3 Nuclear Power Plant Unit has been designed to provide an adequate level of safety.

5 DESIGN CRITERIA FOR NUCLEAR SAFETY (DECISION OF THE COUNCIL OF STATE 395/1991)

5.1 Section 13: Levels of protection

In the 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 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).

In order to prevent transients and accidents, the Olkiluoto 3 Nuclear Power Plant Unit will, as a rule, make use of design, construction and operational concepts that are employed at the newest French and German pressurised water reactors (reference plants N4 and Konvoi respectively) or that can be developed from the existing concepts with a few changes. In particular, the design of the reactor primary circuit makes use of the defence-in-depth approach, in which the integrity of the primary circuit is ascertained in a more versatile manner than at the plants mentioned above using diversified solutions. This issue is addressed in greater detail in section 5.4.

To prevent transients, all the equipment affecting the reliable operation of the plant is to be manufactured and inspected by applying systematic quality assurance.

To detect transients and accident situations, the Olkiluoto 3 Nuclear Power Plant Unit will be equipped with automatic operation, limitation and protection systems that are capable of detecting deviations from normal conditions (more or less) independently and initiating the control, limitation and protection measures required for limiting the transient or accident (automation systems are discussed in more detail in section 5.10). The plant will include safety systems that provide the required safety functions and
protection functions as described in greater detail in section 5.6. The most important safety functions, such as reactor shutdown, reactor core cooling and removal of residual heat, are guaranteed by diverse systems in order to achieve the required level of safety. The defence-in-depth approach is also to be applied to the electrical and automation systems, so that if the main system fails, its central functions can be assumed by an independent system or arrangements. This issue is addressed in greater detail in sections 5.6 and 5.10.

The Olkiluoto 3 Nuclear Power Plant Unit has been designed with barriers to limit release of radioactive substances, and systems that ensure integrity and leak tightness of the barriers (sections 5.2 through 5.5) and operation of the safety functions (section 5.6) even in post-accident situations. The melt cooling concept designed for controlling a severe accident at the Olkiluoto 3 Nuclear Power Plant Unit is not in use at any existing power plant. Among other things, the proposed concept requires a lot of free floor space and cannot therefore be installed in an operational plant. (The original design for the existing plants made no provisions for severe reactor accidents). To date, certain phenomena of the proposed cooling concept have been studied in fairly extensive testing programs in Central Europe. As described in section 3.4, independent research on some phenomena is also being carried out in Finland specifically for the Olkiluoto 3 Nuclear Power Plant Unit. STUK has also commissioned independent calculations to evaluate the phenomena of melt control and its integral performance.

Apart from the technical safeguards, accident control is supported by precautionary measures: the effects of an accident may extend to the other plant units and functions on the site and beyond. Provisions have been made for protecting the in-house staff and the local population around the site.

To mitigate the off-site consequences of accidents, preparations have been made in the form of precautionary measures in the same way as for Plant Units 1 and 2. The precautionary measures are described in section 9 of this Safety Assessment.

In summary, STUK states that the levels of protection to prevent and control transients and accidents, and mitigate their consequences, designed for the Olkiluoto 3 Nuclear Power Plant Unit are adequate.

5.2 Section 14: Technical barriers for preventing the dispersion of radioactive materials

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.

The first barrier to the dispersal of radioactive materials is provided by the ceramic structure of the fuel. The fuel to be used at the Olkiluoto 3 Nuclear Power Plant Unit will consist of fuel pellets made from uranium oxide enriched in the U-235 isotope to a
maximum level of 5%. TVO has declared that it will exclusively adhere to the uranium oxide fuel in its core loading design.

The fuel pellets are placed inside a protective cladding to create fuel rods. The cladding will be made of a zirconium-based alloy known as M5 because tests and operating experience have shown that this material offers superior performance in normal operating conditions and in case of accidents compared with previously used cladding materials. The fuel rods are assembled in bundles in a square array with 17x17 rod positions. Each bundle is 4.2 metres long.

In the reactor core, the fuel bundles fill a core area shaped like a straight cylinder. The core is surrounded by a "heavy reflector" consisting of a stack of iron plates equal in height to the core, designed to minimize neutron leakage from the reactor core. The heavy reflector is advantageous in that it equalizes the power distribution and reduces the (embrittling) neutron flux the reactor pressure vessel is exposed to.

The steps to ensure the integrity of the fuel are discussed in section 5.3

The reactor cooling circuit of the Olkiluoto 3 Nuclear Power Plant Unit is a standard primary circuit of a pressurised water reactor, where the pressure boundary consists of the reactor pressure vessel; four steam generators; four reactor coolant pumps; and the primary circuit piping from the pressure vessel to each steam generator, from the steam generators to the pumps, and from the pumps back to the pressure vessel, with the pressurizer connecting line and other pipes connected directly to the primary circuit. Inside the steam generator, the pressure boundary consists of the steam generator heat transfer pipes (tubes) and the "tube plate".

The integrity of the steam generator tubes is central to the integrity of the pressure boundary because of their large area and dual role: normally, the tubes serve as an interface not only of the primary circuit but also of the containment building because in pressurised water reactors the steam generated on the secondary side of the steam generators is carried outside the containment building as directly as possible via large-diameter pipes. The proposed tube material is Alloy 690TT, which is assumed to offer the most favourable properties for this purpose. Existing Western plants have exhibited a lot of defects in steam generator tubes and complete generators have been replaced as a routine measure, so that the steam generator manufacturers have had both the need and opportunity to develop and test new improved tube materials. Favourable experiences of the use of Alloy 690TT have been accumulated in France over a period of more than 10 years.

The primary circuit is designed by applying the Break Preclusion methodology, and pipe whip restraints are provided to limit the range of movement of the pipes and thus the maximum possible leakage area of pipe breaks. This will reduce the mechanical loads acting on the reactor internals and steam generator tubes in accidents.
The risk of brittle failure at the Olkiluoto 3 Nuclear Power Plant Unit is reduced by the choice of reactor pressure vessel material, by increasing the distance between the reactor core and the walls of the reactor pressure vessel, and by inserting the heavy reflector between the core and the reactor pressure vessel. As far as the risk of brittle failure is concerned, the capacity of the medium head safety injection system is advantageous.

The steps to ensure the integrity of the primary circuit are discussed in section 5.4.

The containment building of the Olkiluoto 3 Nuclear Power Plant Unit is a double containment made of reinforced concrete. The inner, gas-tight and pressure-bearing containment will be made of pre-stressed reinforced concrete with the inside liner of 6 mm thick steel. The wall thickness is 1.3 m in the cylindrical section and 1 m in the dome. In the Preliminary Safety Analysis STUK required steel liner because previous experiences suggest that the tightness of unlined RC buildings is poor. The design pressure of the inner containment is 0.53 MPa(abs), and the leakage at the design pressure does not exceed 0.5% of the gas inventory in 24 hours.

The outer containment, made of reinforced concrete, is designed to provide protection against external threats, such as the impact of a large passenger airliner, without jeopardizing the integrity of the inner containment or the operation of the safety functions. Normally, the annulus between the inner and outer containment is maintained at a sub pressure and the air sucked from this space is filtered before being released back into the atmosphere.

During normal operation, access to the containment building is provided via the airlock. A reserve airlock is also provided. The tightness of the containment building is maintained by keeping one of the two successive doors of the air lock always closed. The equipment hatch is opened for annual outages when necessary.

The access openings, wall penetrations and isolation valves of the containment building will be designed to ensure that the tightness of the containment building is guaranteed and their operation and performance can be tested regularly. The tightness of the containment building is to be verified with regular testing.

The steps to ensure the integrity of the containment building are discussed in section 5.5

A sufficient number of technical barriers have been provided at the Olkiluoto 3 Nuclear Power Plant Unit to prevent the dispersal of radioactive materials.
5.3 Section 15: Ensuring fuel integrity

The probability of significant degradation of fuel cooling or of fuel damage 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 limited and fuel coolability may not be endangered.

The possibility of a criticality accident shall be extremely low.

The following comments were made on the core design of the EPR plant in the Preliminary Safety Assessment: Fuel and core design will be based on similar practices currently applied to large existing pressurised water reactors. Reactivity control during the refuelling interval is achieved with boric acid dissolved in the primary coolant in concentrations equivalent to that used at existing plants. The discharge burnup based on Central European needs exceeds the Finnish safety criteria by a wide margin. However, core loading design can be carried out in a way that satisfies Finnish requirements.

The following comments were made in the Preliminary Safety Assessment on the reactivity control of the EPR:
- reactivity control (power control) is effected by means of control rods and boric acid dissolved in the coolant, so that any reactivity disruptions are essentially identical to those encountered at existing pressurised water power plants; the boron concentration has been maintained at the same level as at existing plants. The reactor can be shut down not only passively by allowing the control rods to fall into the reactor core but also actively by using the 2x50% borating system.

The integrity of the nuclear reactor fuel can only be endangered if one or more of the following conditions met:
1. the power change rate of the reactor is too fast;
2. fuel cooling is insufficient;
3. impurities have found their way into the fuel bundles;
4. control of the reactor water chemistry fails.

The reactor fuel and its loading in the core will be designed specifically for each individual refuelling interval. Transient and accident analyses will also be redone to the required extent with due regard to any changes in the performance characteristics of the reactor. Every loading plan will be reviewed by STUK. At this point, evaluations have been made to determine that adequate cooling of the fuel can be ensured with a proper margin of safety for each refuelling interval, and that the loads acting on the fuel as a result of power changes remain below the acceptance limits.

Normal operation
As in all other pressurised water reactors, reactor power at the Olkiluoto 3 Nuclear Power Plant Unit is controlled by means of control rods or a borating system. Short-term control is achieved using control rods, while long-term fuel burnup is compensated by means of the borating system by pumping either boron-free or borated coolant into the reactor. As far as fuel integrity is concerned, the greatest risk is posed by the speed of control rod movement and the need to adjust the rods. Adjustments made using boron are relatively slow and usually affect the entire reactor core, so that they do not cause any problems to the integrity of the fuel.

The preliminary maximum power change rate specified for the Olkiluoto 3 Nuclear Power Plant Unit is clearly lower than the fuel damage limit determined in fuel tests. To minimize the need to manoeuvre the control rods and ensure the integrity of the fuel, control of reactor power at levels exceeding 60% is accomplished by maintaining the primary circuit average temperature constant. This is achieved with the turbo generator power regulator that adjusts the steam flow to the turbine: when the power demand decreases, the secondary circuit pressure increases, and when the power demand increases, the secondary circuit pressure decreases. This causes the primary circuit cold leg temperature to change and the reactor power either decreases or increases due to the negative reactivity coefficient of the reactor coolant temperature. The reactor power controller makes minor adjustments by driving the control rods in order to maintain reactor power within a pre-determined variation range and to keep the primary circuit average temperature constant.

The mode of operation and structure of the control rods are designed to minimize their impact on local power changes. There are a total of 89 control rod bundles divided into 9 control groups (a total of 36 rods) and one scram group (the remaining 53 rods). The control groups are subdivided into four operating sequences that are to be changed during operation at monthly intervals in order to minimize the control rod history effects. The control rods consist of two sections, with the upper section made of boron carbide (B₄C) and the lower section of a silver-indium-cadmium alloy. The effect of the lower section on reactor power is far weaker per unit of length than that of the top section. This design moderates local power changes in the reactor compared with rods made completely of boron carbide, but, at the same time, the total reactivity value of the rods is reduced. When the reactor operates at levels exceeding 60%, only the lower ends of the control rods are inside the reactor.

Typically for a large reactor core, the Olkiluoto 3 Nuclear Power Plant Unit is susceptible to xenon oscillation. Xenon oscillation refers to slow changes in power distribution caused by the feedback between the xenon generated in the reactor and the reactor power, which is due to the high neutron absorption ability of xenon. In the absence of corrective action, xenon levels in the core are prone to start fluctuating locally over a 24-hour time constant. The three-dimensional power distribution in the reactor is monitored by 72 local power sensors. If oscillation occurs, it is suppressed by maintaining the axial power distribution (in the vertical direction of the core) within pre-determined limits by means of the control rods. Xenon-induced radial oscillation
can be eliminated by correct core design. These measures make it possible to maintain
the linear heat rate of the fuel and the power change rates within acceptable limits.

Long-term reactivity control (compensation for surplus reactivity) is achieved with a
boric acid solution fed into the primary circuit as the $^{10}\text{B}$-isotopes of the solution absorb
neutrons. The boric acid concentration is at its highest at the beginning of the operating
period to decline to zero by the end of the interval. A slightly alkaline water chemistry
($\text{pH}_{300\degree C} 7.2..7.4$), which is less aggressive considering the corrosion of the primary
circuit components, is maintained by introducing the right amount of lithium hydroxide
(LiOH) into the primary circuit. However, lithium hydroxide is highly corrosive to the
fuel cladding material. To eliminate this, the boric acid is enriched in the $^{10}\text{B}$ isotope to
about 30% (natural boron contains 20% $^{10}\text{B}$ isotope). As a result, the required reactivity
effect is achieved with a lower boric acid concentration than if natural boric acid were
used, while the pH level favourable for the primary circuit is attained at a lower lithium
hydroxide level. No operating experience from the use of lithium hydroxide as an
alkalizing agent in the primary circuit of a pressurised water reactor is available in
Finland; Loviisa uses potassium hydroxide for this purpose. However, lithium
hydroxide is commonly used in Western pressurised water plants. Nor is there any
experience of the use of $^{10}\text{B}$-enriched boric acid available in Finland; enriched boric
acid is being used at some plants in Central Europe.

At high linear heat generation rate levels of the fuel, power distribution anomalies may
occur in large pressurised water reactors when (sub-cooled) boiling on the surface of
the fuel produces a boron rich crud deposit. This can be prevented by keeping the
primary circuit water free of corrosion products, for example by providing an efficient
primary coolant purification system and maintaining the water chemistry slightly
alkaline as described above. Of great importance to the reduction of corrosion products
is the optimum control of the water chemistry in reactor shutdowns, when changes in
the process may cause corrosion products to be dislodged from the primary circuit
surfaces and released into the coolant.

Boron and lithium hydroxide concentrations are adjusted with the chemical and volume
control system. To monitor borating and dilution, the additional water feed into the
primary circuit is equipped with a four redundant boron concentration monitoring
system based on the measurement of the neutron absorption of the water to be
introduced to the primary circuit. Any accidental or excessive dilution is automatically
stopped by the monitoring system.

Anticipated transients

What is essential in the design of the fuel and reactor core is that a sufficient margin in
respect of a heat transfer crisis is maintained in all foreseeable transients.

A scram initiated by control rods - i.e., the dropping of the rods into the reactor core by
the force of gravity - shuts down the reactor immediately in all operational states with a
21.1.2005

sufficient shutdown margin. In situations where reactor power must be quickly reduced but a complete shutdown is not required, a partial scram can be achieved by allowing some of the control rods to fall into the reactor core. An automatic reactor scram ensures that the maximum permissible linear heat generation rate limit of the reactor is not exceeded and that the minimum acceptable margin against a heat transfer crisis is maintained in normal operation and anticipated transients.

As far as the heat transfer crisis is concerned, the worst anticipated transient is the loss of off-site power, which would stop all the reactor coolant pumps simultaneously and slow down the primary circuit flow very quickly. However, the margin against the lowest value permitted by the design criteria would still be great in such a transient, just as in other anticipated transients. The anticipated transients do not limit the maximum permissible linear heat generation rate of the fuel. The main limitations for core design are imposed by the accident class 2 inadvertent break of the primary circuit, which puts a limit on the maximum permissible linear heat generation rate.

The required safety analyses will be carried out in connection with the fuel loading plans to be prepared specifically for each individual operating cycle ensuring that fuel loading will satisfy all applicable acceptance criteria.

Postulated accidents

Class 1 and 2 postulated accidents are evaluated in terms of the power regulation and fuel cooling that pose the main challenges to the maintenance of fuel integrity. The acceptance criteria for Class 1 accidents is that at maximum 1% of the fuel rods inside the reactor may experience a heat transfer crisis. The maximum temperature of the fuel cladding may not exceed 650°C. In Class 2 accidents the temperature of the fuel cladding may not exceed 1200°C, nor may the cladding be embrittled (due to oxidization) to such an extent that it does not withstand normal fuel handling after the accident. An additional acceptance criterion is that the percentage of fuel bundles damaged in the accident does not exceed 10% of all the fuel rods inside the reactor. For the Olkiluoto 3 Nuclear Power Plant Unit, the last-mentioned criterion is the most limiting, so that the maximum temperature of the fuel cladding will remain essentially lower than 1200 °C in all analyzed situations.

To ensure fuel cooling in case of primary circuit leakage, the plant features a safety injection system consisting of four parallel, but separate, sub-systems. Each sub-system alone is capable of providing emergency cooling in postulated accidents. Each sub-system incorporates a medium head and low head section used for pumping borated water from a coolant tank inside the containment building to the primary circuit. The coolant tank (In-containment Refuelling Water Storage Tank, IRWST) is located at the bottom of the containment building, so that any water leaking from the primary circuit into the containment building is collected in the tank. Outside the containment building, the pipes from this tank to the medium and low head injection pumps are double-cased (two pipes one inside the other) up to the isolation valves. This design prevents the tank
from being emptied if the inner pipe starts leaking. Additionally, the low-pressure system includes four passive pressurized tanks for additional emergency cooling water. Moreover, the low head system incorporates a heat exchanger, through which the residual heat generated in the reactor is removed to the ultimate heat sink. The low head system is normally used for residual heat removal from the plant during an outage.

If a leak occurs in the primary circuit, pressure starts falling. When the pressure decreases below the maximum pressure delivered by the medium head injection pumps, they start pumping water to each cold leg through the nozzle between the reactor coolant pump and the reactor pressure vessel. If the capacity of the medium head injection pumps is not enough to compensate for the leak, the pressure in the primary circuit continues to fall. When the pressure drops below the pressure in the emergency cooling additional water tanks (hydro accumulators), they start feeding water into the circuit via the above-mentioned nozzles. If the pressure continues to fall to the maximum pressure delivered by the low head injection pumps, they start pumping water into the circuit via the same nozzles. If the situation persists, the feed from the low head injection pumps can be switched from the cold leg to the hot leg to make it possible to feed water into the reactor from above the core. The purpose of this arrangement is to reduce the amount of steam released to the containment building through the leak and to prevent the boric acid from crystallizing on the core. In case of a primary circuit leak, residual heat is removed via the heat exchangers in the low head emergency cooling system to the intermediate circuit and finally to the ultimate heat sink - i.e., the sea. Two of the four sub-systems are enough for residual heat removal.

Following a primary circuit leak, long-term cooling of the reactor (months or years) requires recirculation of the leaking coolant to the reactor. The coolant is recirculated by the emergency cooling system pumps. At the Olkiluoto 3 Nuclear Power Plant Unit, the coolant leaking into the containment building flows back into the IRWST tank that is used to feed the safety injection pumps in the first place. In this respect the plant unit is simpler in design than its reference plant, where the emergency cooling water tank is located outside the containment building.

The jet forces associated with primary circuit leaks damage the thermal insulation used in the containment building to reduce heat losses from the process systems (e.g. primary and secondary circuits). Other loose material may also be dislodged as a result of a leak. The materials carried by the water may damage the safety injection pumps or interfere with reactor cooling. To minimize these drawbacks, the water entering the intake of the safety injection pumps is filtered with filters mounted in the IRWST tank. The Olkiluoto 3 Nuclear Power Plant Unit makes use of a multi-stage filtering system, where the solids carried by the water can be permanently trapped at several locations along the flow path. The last-stage filter is self-cleaning in geometry (the filtered material is released from the surface when suction is turned off) and fitted with a pressure differential gauge and an alarm connection to the control room. If necessary, the filtering surface can be flushed with the water flow delivered by the safety injection system.
In the Olkiluoto 3 power plant concept, the medium head safety injection (MHSI) pump is a functional equivalent of the high-pressure emergency cooling system used at older plants, but the maximum pressure at which it can deliver water is lower than the opening pressure of the secondary circuit safety valves. This reduces the risk of long-term emission in a primary-to-secondary leak. For the same reason, the steam generator relief and safety valves have been qualified to operate with all conceivable combinations of physical media, such as steam, water/steam and water, so that in the postulated accident "Steam generator heat transfer tube break" these valves are not assumed to be stuck in the open position. (Additionally, a special isolation valve is provided in the blow-down valve line to abort accidental blow-down).

The accident analyses carried out for the Olkiluoto 3 Nuclear Power Plant Unit examine several primary circuit leaks of various sizes. The smallest of these leaks (less than 20 cm\(^2\)) belong to Class 1 postulated accidents and leaks greater than that to Class 2 postulated accidents. The largest leak analyzed was the complete double ended guillotine break of the largest pipe in the primary circuit. This scenario has been used as a design basis for determining the emergency core cooling system capacities. According to the analyses performed by the plant supplier, the criteria for the coolability and integrity of the fuel in Class 2 postulated accidents are satisfied. STUK commissioned independent comparative analyses of this scenario showing that the plant supplier's conclusions hold true.

Traditionally, the ejection of a control rod has been regarded as the worst Class 2 reactivity accident. At the Olkiluoto 3 Nuclear Power Plant Unit, the reactivity values of individual control rods are at their highest at partial power levels when the plant unit is being started up, but, even so, they are limited to such a low level that the enthalpy increase in the fuel rods remains clearly below the acceptance limit.

In a pressurised water reactor excess reactivity is controlled by means of boric acid, whose concentration is at its highest at the beginning of the operating cycle. If significant amounts of boron-free water find their way into the reactor core in such a situation, it may result in a power transient, which at its worst can lead to fuel damage. Boron-free water can enter the reactor primary circuit from external sources, or boron may become separated from the water as a result of a minor leakage in the primary circuit as the water is vapourized in the reactor and condenses into water in the steam generator (boron is separated during evaporation and only boron-free water is carried to the steam generators).

The boron-free water separated as a result of a minor leak is collected in the pipe bends in the cold legs and may find its way into the reactor when natural circulation starts. The analyses carried out by the plant supplier indicate that boron-free water is mixed with borated water to a sufficient degree before it reaches the reactor core to prevent recriticality. The independent analyses commissioned by STUK support this position.

A boron-free water plug may develop in the primary circuit if boron-free water is mistakenly fed into the circuit when the reactor coolant pumps are at a standstill. The
provisions made for this eventuality at the Olkiluoto 3 Nuclear Power Plant Unit are primarily based on the automatic protection system. Other supplementary measures to eliminate the possibility of a boron-free water plug include structural solutions, control systems and additional administrative instructions. The plant supplier has analyzed this scenario thoroughly in the Preliminary Safety Analysis Report. The analyses show that even in a worst-case situation the amount of boron-free water accessing the reactor is so low, and it is mixed with the borated water in the primary circuit to such an extent, that the reactor cannot become re-critical as a result of this type of transient. The independent analyses commissioned by STUK arrive at the same conclusion.

Transients where the reactor scram is assumed to fail (ATWS) have also been analyzed as Class 2 accidents. The two worst-case incidents in this category are the loss of off-site power and the loss of normal feed water supply. The primary circuit maximum pressure and the maximum temperature of the fuel cladding have been calculated for both events. Acceptable results were obtained in both analyses. In an ATWS situation, the reactor can be shut down using the boron system, which is independent of the control rod system. The boron system can be used to feed highly concentrated borated water (7,000 ppm of 30% \( B_{10} \)) to the primary circuit via two independent pipelines using three boron pumps. Both lines have their own pumps, whereas the third pump can be connected to either line if necessary. One pump is enough to perform the required safety function. Additionally, the reactor can be shut down using the normal make-up system, which is independent of the boron system and consists of two separate subsystems with a shared feed water line. The system can be used to pump highly concentrated boron solution into the primary circuit. According to the analyses submitted by the plant supplier, the reactor can be shut down in ATWS situations either by using the boron system and/or the normal make-up system without exceeding the values representing the acceptance criteria. The independent analyses commissioned by STUK corroborate this conclusion.

The worst Class 2 accident that does not involve a primary circuit leak is an inadvertent reduction in the primary circuit flow due to the seizure of the reactor coolant pump rotor or shaft breakage. The analyses carried out by the plant supplier show that part of the fuel would then be affected by a heat transfer crisis. However, this is acceptable because the number of fuel rods affected by the crisis is low and clearly below the 10% limit specified in the applicable acceptance criteria, and because the fuel cladding temperature does not exceed the level permitted by the applicable criteria.

Primary circuit water can leak to the secondary circuit in connection with damage to one or several steam generator heat transfer tubes. This situation is difficult to control and poses a number of safety challenges simultaneously. Water leaking from the primary circuit to the secondary side may find its way into the atmosphere, meaning that the accident results in a radioactive release due to the activity contained in the primary coolant. If the leak into the atmosphere were sustained for a long period, the borated emergency cooling water used for replacing the lost coolant could run out. The loss of cooling would endanger fuel integrity. On the other hand, reducing the primary circuit pressure below that of the secondary circuit would turn the direction of the leak
flow from the secondary side back to the primary circuit, meaning that the originally boron-free water in the secondary side could create a diluted water plug in the primary circuit. Due consideration has been given to the control of primary-to-secondary leaks in the design of the Olkiluoto 3 Nuclear Power Plant Unit (section 4.5) and the sizing of the emergency core cooling and secondary side pressure regulation systems. Additionally, a strategy has been designed to minimize releases into the environment. According to the analyses, the Olkiluoto 3 Nuclear Power Plant Unit will perform acceptably in case of primary-to-secondary leaks.

Nuclear criticality safety

Fresh and spent fuel rods are stored in submerged racks in the fuel storage building, providing a total of 954 storage locations in two separate pools filled with boron-free water; 420 of these locations are available for storage during normal operation. Nuclear criticality safety is ensured by encasing each bundle with absorber plates made of boron steel (with minimum boron content of 1.75%). In this design the multiplication factor of fresh, 5% enriched fuel that contains no burnable poisons remains below the acceptance limit of 0.95, even after the computational uncertainties have been taken into account. This is the worst-case scenario as far as criticality is concerned. As the concept performs acceptably, nuclear criticality safety is also ensured for irradiated fuel bundles containing burnable poisons.

For the storage of fresh fuel bundles, the fuel storage building also includes two dry storage racks with a total capacity of 110 bundles inclusive of any control rods. The criticality safety of the dry storage racks is ensured in the same way as that of the submerged racks.

Summary

Analyses carried out by the plant supplier are available for the evaluation of the events required for ensuring the integrity of the fuel. Additionally, STUK has carried out and hired independent parties to perform comparative analyses of the most important cases. Based on these analyses, STUK states that the performance characteristics and systems of the Olkiluoto 3 Nuclear Power Plant Unit designed to guarantee the integrity of the fuel are adequate.

5.4 Section 16: Ensuring the integrity of the primary circuit

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 also be low.
The strength design of the primary circuit of the Olkiluoto 3 Nuclear Power Plant Unit and its most important mechanical components is described in Chapter 5 of the PSAR and the related Topical Reports. Because these components take a long time to manufacture, STUK addressed strength design when reviewing the pre-inspection documentation related to manufacture. Special attention in the pre-inspection was paid to adequate dimensioning: the basic dimensions in respect of pressure and other mechanical loads were reviewed, and preliminary stress, fatigue and brittle fracture analyses of the most critical places were carried out.

The plant supplier has designed the plant unit using the French RCC-M standard applicable to the design of nuclear facilities. The design criteria presented in the said standard are based on the ASME Boiler and Pressure Vessel Code, Section III, NB, Class 1 Components, Rules for Construction of Nuclear Power Plant Components (American Society of Mechanical Engineers), to which reference is also made in the Finnish YVL Guides.

The loads acting on the primary circuit in the various operational states and accident situations, and the other effects of the operating environment have been duly considered in the design of the Olkiluoto 3 Nuclear Power Plant Unit so as to ensure that adequate safety margins are maintained throughout the contemplated 60-year service life of the facility. The reactor pressure vessel is designed and manufactured in such a way as its rupture can be regarded as highly improbable.

The design of the basic version of the EPR is based on the Break Preclusion (BP) approach, which includes the application of the Leak Before Break (LBB) principle. The Preliminary Assessment comments on the application of the LBB approach by saying that its application to Finnish nuclear power plants will be addressed in the Guide YVL 3.5 due for publication. STUK applies this principle as follows: if the requirements of the Guide are satisfied, the pipe whip restraints may be omitted but no changes may be made to the dimensioning of the emergency core cooling system.

Design basis pipe breaks

Provisions for primary circuit pipe breaks have been made in the design of the Olkiluoto 3 Nuclear Power Plant Unit by applying a three-staged defence-in-depth approach. The first stage consists of the Break Preclusion approach, meaning that the integrity of the primary circuit is ensured by extensive strength analyses exceeding the requirements applied to standard Safety Class 1 pressure equipment, as well as by stringent quality requirements and a sufficiently extensive in-service inspection program. Additionally, the inspections are backed up by parallel diversified leak monitoring systems, so that the LBB condition is fulfilled even in the case of a defect leading to a leak, and so that the damaged pipe section offers an adequate margin of safety against inadvertent pipe breaks in respect of all design basis loads.
An important role in the application of the BP rule is played by prefabricated piping sections forged from austenitic stainless steel, which reduces the number of welded joints. Even so, technically complex welds between different metals are required at the locations subjected to the greatest loads - i.e., the nozzles of the main components. In order to avoid intercrystalline corrosion, these welds are to be made using a predominantly nickel-based filler material and narrow-gap welding. Preliminary calculations suggest that the LBB condition can be satisfied with this structural design, provided the leak monitoring systems are sufficiently sensitive. The leak detection systems designed for the Olkiluoto 3 Nuclear Power Plant Unit are capable of detecting a leak of 0.01 to 0.02 kg/s, which offers an adequate level of sensitivity.

The second stage consists of the limitation of breaks. This is achieved with pipe whip restraints installed close to the outer surface of the primary circuit pipe to restrain the whip of the broken components in case of a pipe break, thereby preventing the components and jets emitted by them from hitting the containment building walls and important equipment near the break location. At the same time, the pipe whip restraints reduce the impact of reaction forces and flow transients transmitted internally to various parts of the primary circuit. These forces and transients serve as design bases in dimensioning the primary circuit main component supports, reactor pressure vessel internals, heat transfer tubes and other steam generator internals, and the flywheel masses of the reactor coolant pumps. The pipe whip restraints are positioned with due regard to the dynamic behaviour of the primary circuit, assuming that any welded joint between main coolant lines and the reactor pressure vessel, steam generator or reactor coolant pump may fail.

The third stage consists of the risk reduction arising out of an unlimited double ended guillotine break of the primary circuit piping (unobstructed leak across the entire cross-sectional area of the broken pipe). Despite the pipe whip restraints, unlimited pipe breaks still serve as the basis for the thermal-hydraulic design of the reactor, as well as for determining the capacity of the emergency core cooling system, the environmental qualification of the components used to control accidents, the resistance of the containment building against global pressure and temperature loads, and the resistance of the rooms surrounding the primary circuit against the pressure differences generated in the process. The internals of the primary circuit main components, particularly the reactor core basket, control rod guide tubes, steam generator heat transfer tubes and the rotating parts of the reactor coolant pumps, have been designed to absorb dynamic loads in case of a limited leak, but their strength will also be analyzed in case of an unlimited primary circuit pipe break as design extension conditions. These non-dimensioning analyses will be carried out using the best-estimate methodology, assumptions and criteria. The purpose of these analyses is to demonstrate that the permanent deformations of the reactor internals are so limited that the coolability of the fuel is not compromised, the steam generator heat transfer tubes will not lose their integrity, and that the flywheel masses of the reactor coolant pumps will not cause any damage as a result of over-speed.
21.1.2005

The primary circuits of existing Finnish plants have been constructed to current design standards, ensuring that adequate margins of safety are provided against all the safety implications of an unlimited break of the primary circuit pipe, including the loads acting on the internals of the main components, and that the impacts on adjacent equipment resulting from a pipe break are prevented using pipe whip restraints. This is also the primary design basis under YVL 3.5. However, there has been a gradual shift in the Western world towards a policy where a pipe break limited by pipe whip restraints is used as the design basis for the main component internals and supports, or, in some cases, just the Break Preclusion approach, in which case these loads are not analyzed, nor are any pipe whip restraints provided. In the Konvoi and N4 plants on which the EPR facility is modelled, an unlimited pipe break was only used as a design basis for the emergency core cooling system, parts of the containment building and the environmental conditions of the equipment inside containment. All other effects are determined according to varying pipe break size assumptions smaller by one order of magnitude.

The design basis for a primary circuit pipe break used for the Olkiluoto 3 Nuclear Power Plant Unit differs from the YVL 3.5 requirements but it still provides at least an equivalent level of safety. The Break Preclusion approach and the pipe whip restraints limiting the leak in real-life conditions offer adequate compensation for the alternative solution: that the effects of an unlimited break of the primary circuit pipe on the reactor pressure vessel and steam generator internals are analyzed as isolated events using the best-estimate approach. The analyses show that the coolability of the core and the integrity of the containment building are not endangered in such a situation.

Provisions for secondary circuit pipe breaks

At the Olkiluoto 3 Nuclear Power Plant Unit, the principles of Break Preclusion are also applied to the secondary circuit main steam and feed water pipes inside the containment building, as well as to the main steam pipes outside the containment building up to the fixed point after the isolation valves. Accordingly, the plan is not to provide these pipes with pipe whip restraints, or at least to reduce their number. For this, the stresses acting on the pipes must not be too high, and provisions must be made for the risks associated with a complete double ended guillotine break. The containment building penetrations are designed to remain leak tight in case of an internal and external pipe break, and the reaction forces caused by such breaks and related flow transients are to be taken into account when determining the design loads for steam generator supports and internals. Similarly, the effects on the primary circuit and, in particular, the potential for a break of the steam generator heat transfer tubes will be analyzed.

At the Konvoi plants serving as a model for the EPR facility, the Break Preclusion approach has been applied to the main steam and feed water pipes as proposed here.
21.1.2005

The main steam and feed water pipes fall into the category of the high-energy piping referred to in the Guide YVL 3.5. Accordingly, provisions must be made for all the safety effects resulting from the break of such pipes. Under the same Guide, the pipe whip restraints for the primary circuit piping can be omitted if the Break Preclusion approach is applied. These guidelines were primarily based on the high quality requirements derived from the design standards for Safety Class 1 piping and a high standard of leak monitoring in the containment building. These principles also apply to the secondary circuit piping of the Olkiluoto 3 Nuclear Power Plant Unit because they are manufactured to Quality Class 1 requirements. Stress analyses will be carried out in accordance with the YVL 3.5 requirements, and a preliminary analysis of the fulfillment of the LBB condition has already been presented in the PSAR. The limited application of the Break Preclusion principle to the equivalent piping of other plant types is due to the damage mechanisms encountered: erosion and corrosion, pressure shocks and temperature stratification. A number of technical solutions to these problems have been proposed in the design documentation of the Olkiluoto 3 Nuclear Power Plant Unit, such as a sufficiently high chromium content, hydrazine water chemistry and an ascending feed water piping design towards the steam generator. There is good potential for resolving the pending issues in the structural design, and the required level of safety can be achieved.

The provisions made for secondary circuit pipe breaks at the Olkiluoto 3 Nuclear Power Plant Unit differ from the YVL 3.5 requirements but provide an equivalent level of safety because, following the proposed technical improvements, the possibilities for applying the Break Preclusion approach are identical to those for the primary circuit.

Primary circuit over-pressure protection

Over-pressurization protection for the primary circuit is accomplished with three safety valves connected to the pressurizer. In the design of the safety valves and related piping, due consideration was given to the effects of uncondensed gases and the blow-down of the steam/water mixture and water. The opening pressure of the safety valves is staggered, and each valve is equipped with two spring-loaded pilot valves. The same safety valves are used for the over-pressure protection of the primary circuit at low operating temperatures, for which the valve opening pressure is reduced and the valves are controlled by electrically operated pilot valves. The primary circuit safety valve system satisfies the single failure criterion in all design basis situations.

Analyses have been carried out to demonstrate that the actuation of the spray system prevents the primary circuit safety valves from opening in accidents that serve as the design basis for over-pressure protection. Power supply to the pressurizer spray system is backed up by a redundant power supply. Consequently, the pressurizer spray system can be regarded as a diverse over-pressure protection system.
Pressure reduction in the primary circuit using the operator-controlled feed-and-bleed function takes place via a separate 2x100% pressure reduction line that is used for reducing primary circuit pressure in a severe reactor accident.

**Brittle fracture of the reactor pressure vessel**

In nuclear reactors the reactor pressure vessel is exposed to fast neutron fluence that increases the possibility of brittle fracture as the vessel ages. A pressure vessel made of ferrite steel always carries a risk of brittle fracture if its temperature falls below the brittle-ductile transition temperature of the steel grade used. This reduces the plastic deformability of the steel and makes it brittle. If the steel is subjected to a strong stress when the temperature is below the transition temperature, and if there is a large enough crack in the area subjected to the stress, it starts growing quickly and the structure fails. The transition temperature of a new reactor pressure vessel is always less than 0°C, but the neutron radiation that the vessel is exposed to increases it. This increase in transition temperature is known as radiation embrittlement.

Elimination of the brittle fracture has been considered in the design of the Olkiluoto 3 Nuclear Power Plant Unit and steps have been taken to minimize its probability. Measures to inhibit radiation embrittlement include optimized composition of the reactor pressure vessel shell (low Cu and P content), a large gap between the core outer perimeter and the pressure vessel inner surface ("water gap"), and provision of a heavy reflector around the core area that returns part of the fast neutrons back to the core area and so reduces the exposure of the pressure vessel. Additionally, the safety injection system feeds water to the primary circuit when its pressure is clearly lower than in normal operation, which reduces the stresses acting on the walls, especially when cold safety injection water cools down the pressure vessel causing thermal stress in the pressure vessel walls.

**Secondary circuit water chemistry**

The secondary circuit water chemistry affects, among other things, the integrity and service life of the steam generator heat transfer tubes. For them, the most favourable water chemistry would be alkaline (high pH coefficient). At the Olkiluoto 3 Nuclear Power Plant Unit the pH coefficient of the secondary circuit is maintained (pH$_{25°C} > 9.8$) by means of hydrazine introduced into the circuit. Hydrazine is a chemical widely used in the secondary circuits of nuclear power plants and conventional boiler plants. The problem with hydrazine is that it is carcinogenic. While the industrial use of this chemical is still permitted, more stringent regulations are being introduced to ensure chemical safety.

**Summary of the assurance of the integrity of the primary circuit**
To summarize, STUK states that the necessary preconditions exist for ensuring the integrity of the primary circuit at the Olkiluoto 3 Nuclear Power Plant Unit and that the technical issues that are still pending can be clarified in the structural design documents for the pressure equipment involved.

5.5 Section 17: Ensuring the containment building integrity

The containment building shall be designed so that it will reliably withstand pressure and temperature loads, jet forces and the impacts of missiles arising from anticipated operational transients and postulated accidents.

Furthermore, the containment building 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 respects in designing the containment building concept.

The following section will primarily discuss the design of the primary (inner) containment building. The design bases for the outer, or secondary, containment building are determined by external events that are addressed in more detail in section 5.8.

The following comments were made in the Preliminary Safety Assessment on the containment building of the EPR:
- the primary containment building is a large "dry" containment building made of pre-stressed reinforced concrete and encircled by a secondary containment building of reinforced concrete. The manufacture proposes that no steel lining be used on the inside of the primary containment building but experiences accumulated in France suggest that the tightness of non-lined reinforced concrete buildings is poor.

As described in more detail in section 5.2, the primary containment building of the Olkiluoto 3 Nuclear Power Plant Unit will be provided with a steel liner.

The containment building will not be subjected to any special loads during normal operation, or operational transients for that matter. The primary containment building is designed to withstand pressures and temperatures caused by postulated accidents, with due regard to the pressure and temperature effect resulting from severe accidents. Similarly, due consideration has been given to any local loads, such as jet forces caused by the failure of pressure-bearing systems and the impact of missiles. Considering local
loads, the massive containment building of pre-stressed reinforced concrete designed for the Olkiluoto 3 Nuclear Power Plant Unit is highly advantageous because it is capable of absorbing major local loads without losing much of its tightness, let alone integrity. The tightness of the containment building is discussed in section 5.2.

The design basis for penetrations and access openings are the same as for the inner containment.

**Management of severe reactor accidents**

The Preliminary Safety Assessment discusses severe reactor accident - i.e., situations where a large part of the reactor fuel is damaged - as follows: Successful control of a serious reactor accident calls for a strategy that gives due consideration to the specific features of the plant and the phenomena threatening the containment building. Such a strategy must define sound methods for preventing or controlling the energetic phenomena related to the development of the accident (e.g. hydrogen burn, high-pressure melt eruption, energetic molten core-coolant interaction). Additionally, the strategy must ensure the coolability of the molten core and the removal of residual heat from the containment building in such a way that the containment building remains intact during the accident and for a long time thereafter, and the systems designed for controlling serious reactor accidents must perform their functions even if any single piece of equipment in the system fails ($N+1$ failure criterion). The systems to be designed for controlling serious reactor accidents must be independent of other safety systems; and a serious reactor accident must be controllable in all operational states of the nuclear power plant, not only during power operation but also in shutdowns.

As far as severe reactor accidents at the EPR are concerned, the Preliminary Safety Assessment states as follows: The provisions for serious accidents would be based on the cooling of the molten core in a special core catcher area in the lower part of the containment building next to the reactor cavity. The procedure is fairly complicated and even though the individual stages of cooling the molten core by spreading it out are relatively well understood, it is still unclear whether the timing of the core movements can be controlled with the accuracy required by this procedure. The reduction of primary circuit pressure is necessary in order to control a serious accident but the basic concept provides only one blow-down valve for this purpose. The version offered to Finland includes two pressure-reduction valves. Cooling in the core catcher area would be achieved with a 2x50% active system, so that the single failure criterion applied to systems designed to control a serious accident is not satisfied in this respect. Hydrogen control would be provided passively by catalytic recombinators very much in the same way as in the existing equivalent pressurised water facilities where the containment building would be actively cooled by a separate cooling system.

A strategy for controlling a severe reactor accident has been drawn up for the Olkiluoto 3 Nuclear Power Plant Unit. The central functions defined in the strategy are:
- depressurisation of the primary circuit before the pressure vessel fails;
transport of the molten core material to a special core catcher compartment inside
the containment building, followed by solidification and long-term cooling;
- removal of hydrogen by means of passive autocatalytic recombinators;
- removal of residual heat from the containment building by means of a separate
cooling system.

Most of the radioactive materials contained in the reactor will remain trapped in the
molten core. The final state foreseen in the strategy is that the molten core is solidified
and remains coolable indefinitely. Quick solidification of the molten core improves the
retention of radioactive materials, and also reduces the risk of steam explosions. The
appropriateness of the strategy has been evaluated by means of analyses and
independent experiments, as described in section 3.4.

The reduction of primary circuit pressure prevents a high-pressure melt ejection into the
containment building. For this purpose, two independent high-capacity pressure-
reduction lines are provided in the primary circuit pressurizer. Pressure reduction is
initiated by opening the motor-controlled valves blocking the lines. The system satisfies
the required N+1 failure criterion.

Ultimate cooling of the molten core material occurs in a separate core catcher section of
the containment building designed for this purpose. The molten core discharged from
the pressure vessel is first collected in the retention area at the bottom of the reactor
cavity. Underneath the retention area there is a gate that, when broken, allows the
molten core material to pass via a short transfer tunnel to the core catcher area. The
passage of the molten core material to the core catcher area and the commencement of
cooling take place without any active control measures.

The molten core material is held in the retention area in the reactor cavity to ensure that
the maximum amount of molten material can be collected before it is spread out. For
this purpose, the floor and walls of the retention space will be lined with a 50 cm-thick
layer of special sacrificial concrete. Similarly, the gate giving access to the transfer
tunnel will be covered with a 50 cm concrete layer. To protect the load-bearing
cement of the reactor shaft, thermally insulating brickwork will be provided between
the load bearing cement and the sacrificial concrete.

The functional requirement for the gate giving access to the transfer tunnel is that a
sufficiently large opening is created when the gate is broken. An opening with an area
of 0.1 m$^2$ is enough to distribute the molten material evenly over the core catcher area
in a few tens of seconds. The gate material has not yet been selected. The operation of
the gate needs to be demonstrated in the final design, but there is no technical reason
why such a design could not be successful.

The area of the core catcher is 170 m$^2$. Its floor will consist of 20 cm-thick iron
elements on which a concrete layer of about 10 cm will be poured to protect the floor
from the high temperatures in the core catching situation. Under the floor there will be
cooling canals connected to the In-Containment Refuelling Water Storage Tank
(IRWST) via two independent pipe lines. The valves blocking the lines will open when the melt discharge cuts the cables that keep them closed. The IRWST tank is above the level of the core catcher area, so water will flow into the cooling canals by gravity. Flooding is passive and satisfies the N+1 failure criterion. The capacity of the IRWST tank is so large that a fair amount of water will remain there even after flooding. The plant supplier has carried out thermal-hydraulic tests indicating that the cooling works as designed at the anticipated thermal loads. The results have been verified by tests carried out in Finland in which the boric acid dissolved in the cooling water and solid impurities were also taken into account.

The cooling canals are filled in 5 to 10 minutes, after which the coolant starts to flow over the sidewalls of the core catcher on top of the molten material, cooling it from above as well. The amount of coolant flowing from the IRWST tank by gravity is enough to fill the spreading room up to the ceiling, after which the flooding is terminated as the water levels in the IRWST tank and collection spare are in equilibrium. The steam generated in the course of the cooling passes into the containment building, condensing on the structural surfaces and flowing back into the IRWST tank.

At a later stage in the course of the accident the water used for removing residual heat from the containment building can be pumped to the cooling canals to raise the water level along the transfer path of the molten material up to the top of the reactor core. This ensures that any core material left on the transfer path is also cooled.

A design basis for the containment building of the Olkiluoto 3 Nuclear Power Plant Unit is that residual heat removal from the building will not have to be initiated until 12 hours after the onset of the accident event. Removal of residual heat is provided by the containment spray system consisting of two redundant trains. The system draws coolant from the IRWST tank and delivers it to a heat exchanger outside the containment building. Heat is transferred to the sea via a specific cooling circuit. The cooled-down coolant is pumped back to the containment building and sprayed into the containment air space from the nozzles mounted in the ceiling. Spraying condenses the steam collected in the containment building and thereby reduces the pressure inside it. The system is designed to ensure that one of the two trains is enough to maintain the pressure under the containment building design pressure, meaning that it satisfies the N+1 failure criterion. Once the pressure inside the containment building has decreased, coolant can be redirected to the cooling canals as described above.

If the containment building remains tight, radioactive fission products cannot escape from the building, even in the case of a severe accident. Most of the radioactive fission products are carried by the molten core to the core catcher area and are trapped in the solidifying core material. Releases into the containment building atmosphere include radioactive noble gases Kr and Xe, as well as volatile I, Cs and Sr isotopes. The latter will be in aerosol form. Most of these substances will be removed from the atmosphere by deposition and the spray water, and be finally trapped in the water pools. A small percentage of the fission products remaining in the containment atmosphere will leak to
the annulus between the inner and outer containment, and may be released into the atmosphere. A negative pressure is maintained in the annulus and the air vented from the annulus is filtered before being released into the outdoor atmosphere. The analyses made by the plant supplier estimate that the maximum release via this emission path would be 1.5 TBq Cs-137. STUK contracted VTT to carry out verification analyses that estimated the release at 2.5 TBq. In both cases the release clearly falls short of the 100 TBq limit specified in the Decision of the Council of State 395/1991.

The containment building of the Olkiluoto 3 Nuclear Power Plant Unit differs from the original EPR design in that the building is divided into two separate parts by air-conditioning systems. The gas spaces of the two parts must be combined during an accident to ensure that the concentrations of hydrogen released into the containment building can be diluted using all the gas space available. The sections are separated by rupture disks and flaps similar to fire dampers. The rupture disks are broken when the pressure difference between the containment sections increases high enough. The flaps are designed to open when the pressure inside the containment building exceeds the pre-determined level of 1.5 bar (abs). The flaps also open automatically on loss of electrical power.

During a severe accident the core melting process releases a maximum of about 2,000 kg of hydrogen. The removal of hydrogen from the containment building is carried out by passive autocatalytic recombinators, where the hydrogen reacts with oxygen and forms water. A total of 47 recombinators with a combined capacity of 350 kg/h will be installed in the containment building. The recombinators are capable of removing all the hydrogen generated in a severe accident in 5 to 7 hours.

In most severe accidents hydrogen is generated so slowly that the recombinators are capable of keeping the hydrogen level throughout the containment building below the ignition limit. The Guide YVL 2.2 specifies that hydrogen control must be designed with taking into account situations where emergency core cooling may be restored after core damage. In such a case, hydrogen may be generated so quickly that a combustible gas mixture may accumulate in some part of the containment building. The consequences of local hydrogen burns have been evaluated using adverse initial assumptions. Even then, the containment building was found to retain its integrity despite any hydrogen burns.

A filtered venting system in accordance with the Guide YVL 1.0 will be installed in the containment building of the Olkiluoto 3 Nuclear Power Plant Unit. At a later stage in the course of the accident, the system can be used to remove any uncondensed gases released in a severe reactor accident. The venting will reduce the pressure inside the containment building to close to atmospheric pressure.

The safety functions designed to control severe accidents require electrical power to open the primary system depressurisation valves, power the monitoring and control instrumentation, ensure the closure of the outer isolation valves of the containment building, and remove residual heat from the containment building. At a later stage,
power may be needed to open the isolation valves in the filtered venting system of the containment building. A more detailed description of the redundant power systems of the Olkiluoto 3 Nuclear Power Plant Unit is provided in section 5.6. To ensure power supply in severe accidents, the plant unit includes two SBO diesel generators in addition to the supplies presented in section 5.6. Moreover, there are two parallel battery banks reserved to severe accidents, each with enough capacity for 12 hours. The battery power is sufficient for opening the depressurisation valves, maintaining the monitoring instrumentation and ensuring the closure of the outer isolation valves of the containment building. To remove residual heat from the containment building at a later stage of the accident, at least one of the SBO diesels is required if no other power source – off-site power or unit-to-unit connections, emergency power diesel generators or the gas turbine – is still not available.

After the issuance of STUK's Preliminary Safety Assessment Report, the systems required for implementing the strategy for controlling a severe reactor accident have been modified to conform to the Finnish regulations (N+1 failure criterion, independence from other systems, passive cooling of the core catcher area).

In the design of the Olkiluoto 3 Nuclear Power Plant Unit, due consideration has been given to the habitability and accessibility of necessary spaces in a severe accident in accordance with the Guide YVL 7.18. Such spaces include the control room and emergency rooms, sampling sites, laboratory, and manual control points for the filtered venting system of the containment building for example.

Provisions have also been made for a severe reactor accident during an outage. In a shutdown, the cooling circuit pressure and decay heat power are lower than in accidents occurring at full power. However, the containment building air locks may be open at the time of the onset of the accident. Therefore, proper isolation of containment is essential in shutdown accidents.

Considering the time available for isolation, the most limiting conditions are imposed by postulated accidents taking place when the pressure vessel head is being opened. At that point, the coolant level in the pressure vessel is at the level of the cooling circuits, the pressurized emergency water tanks are isolated and the steam generators are not available for the removal of residual heat. The equipment hatch of the containment building is kept closed. If the decay heat removal system used during outages is lost, the coolant starts boiling in about 30 minutes and the core starts heating up in about 2 hours after the accident. This time is enough for isolating the containment building if the equipment hatch is already closed.

Normally, closing the equipment hatch and making it airtight takes about two hours. If no power (electricity) is available to operate the hatch hoisting equipment, airtight closure takes 4.5 hours. During an outage, the hatch is not opened until the reactor, transfer and storage pools are filled. After filling, the amount of coolant submerging the fuel is so great that in a case of loss of the decay heat removal capability the coolant will not reach the boiling temperature until about six hours later.
Fuel is transported between the containment building and the fuel storage building via a special transport tube. Thus the transport tube locks are part of the containment building isolation system. According to the plant supplier's preliminary plans, the inner lock would be manually operated. In STUK's view, manual operation is not fast enough.

STUK requires that the designs are upgraded in respect of the mode of operation, airtight closure, and the barriers and air locks of the equipment hatch and fuel transport tube.

**Summary of the assurance of the integrity of the containment building**

The integrity of the containment building of the Olkiluoto 3 Nuclear Power Plant Unit is adequately assured. The design of the strategy for controlling severe accidents and related systems presented in the Preliminary Safety Analysis Report for the plant unit is sufficient for the issuance of the construction licence. A number of details will be finalized during construction.

### 5.6 Section 18: Ensuring safety functions

*In ensuring safety functions, full use shall be made, from the beginning, of the inherent safety features attainable by design. In particular, the combined effect of the physical feedbacks of a nuclear reactor shall be such that it inhibits the increase in reactor power.*

*If use cannot be made of the inherent safety features in ensuring the operation of a safety function, priority shall be given to systems and components that do not require any off-site power supply or that, on loss of power supply, change over to a state that is advantageous from the safety point of view.*

*Systems performing the most important safety functions shall be able to carry out their tasks even if any individual component in any system were to fail and any component affecting the safety function were to be out of service 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.*

*Mutually redundant safety systems, as well as parallel parts of safety systems, shall be separated from each other, so that their failure due to an external common mode failure is unlikely.*
In ensuring the critical safety functions, systems based on diverse principles of operation shall be used where possible.

Inherent safety features

The initial core of the Olkiluoto 3 reactor is designed so as to ensure that the combined effect of the physical feedback inhibits the increase in reactor power in all operational states (negative reactivity feedback to prevent power excursions). The functional properties of the reactor may change in connection with refuelling (loading), so the presence of this safety feature must be monitored throughout the reactor's service life. TVO has declared its intention to adhere to the uranium dioxide fuel in the loading schemes, so no major detrimental changes in the basic performance characteristics of the reactor are expected.

The water volumes available for cooling the Olkiluoto 3 Nuclear Power Plant Unit also represent inherent safety: the greater the amount of water available, the more slowly many of the potential transients develop and the easier it is to initiate mitigating counter-measures. In particular, the volume of water normally present on the secondary side of the steam generator is, relative to the designed power of the reactor, slightly greater than in Western pressurised water reactors in general, although somewhat smaller than at the Loviisa pressurised water reactor (the inherent safety features of the reactor type in use in Loviisa are, in many respects, essentially superior to those of other pressurised water reactors).

A primary containment building made of reinforced concrete is inherently highly resistant to local mechanical loads (such as missiles, pipe whips and similar) and short-term thermal loads (e.g. hydrogen burns).

Passive systems and changeover to safe state of active components upon loss of power

In the EPR concept providing the basis for the Olkiluoto 3 Nuclear Power Plant Unit, the safety systems are deliberately designed to be powered and controlled by external sources (active systems). Consequently, the requirement presented in the Decision of the Council of State that the equipment should operate without any external power source is not satisfied. The choice is justified by the fact that there is more operating experience of systems powered by external power sources than of other systems, and that their principle of operation is always straightforward as long as power is available. Similarly, more experimental research has been carried out on the performance of active systems in rare transients and accident situations than on passive systems that utilise small quantities of natural energy. However, there is very little experience of the performance of active systems in real-life situations because of the rare nature of accidents. Moreover, the experimental research in this field since the early 1990s has focused more on passive systems.
However, the Olkiluoto 3 Nuclear Power Plant Unit incorporates a number of safety functions that are naturally powered, even at existing plants: the reactor scram is implemented by allowing the control rods to be dropped into the reactor core by gravity, and systems participating in emergency core cooling include gas-pressurized injection water tanks (hydroaccumulators). Of the new design features, those related to the control of severe reactor accidents (see section 5.5) include the gravity driven manipulation of the molten core material and flooding of the core catcher area. Additionally, the automatic opening of the doors used for hydrogen control and the catalytic recombination of hydrogen also take place without any external power source.

With active systems, due consideration is given to the requirement that they must always fail on the safe side. Programmable automation systems include self-diagnostics and are capable of maintaining safety functions even if individual components fail. Alarms are generated immediately when any defects are detected, and the technical specifications for the plant determine the steps that should be taken next. In automation systems, failing on the safe side is complicated by the fact that the safest system status (or the most advantageous function in terms of safety) following a defect cannot always be defined unambiguously; the safest state/function also depends on the state of the rest of the facility and may be affected by a change in the overall plant status.

Failure and maintenance considerations

To satisfy the applicable failure criteria, the design of the Olkiluoto 3 Nuclear Power Plant Unit is based on the principle that all systems used in normal operation are two redundant - i.e., no single defect can paralyze the system (2x100% single-failure tolerant, or N+1, systems). There are always at least two separate functions for controlling transients, both of which are at least two redundant (N+1 + D+1), and there are four redundant systems for controlling postulated accidents (typically with a 4x50% capacity, which gives a failure tolerance of the N+2 type; this makes it possible to service and/or repair the systems one sub-system at a time when the plant unit is in operation). In contrast, the systems designed for controlling severe accidents are double redundant (N+1). Parallel sub-systems performing the same function are physically separated. Separation is also consistently applied to the auxiliary systems required by the safety systems. Sub-systems performing different tasks are located in the common rooms Sub-systems 1 and 2 of the two redundant systems are located in the same area as sub-systems 1 and 4 of the four redundant systems.

The Preliminary Safety Assessment states that the central safety functions of the EPR have been implemented in a manner commonly used at existing plants:
- ...the reactor can be shut down with the active 2x50% borating system;
- emergency core cooling and residual heat removal systems are designed to be 4x50% active with regard to both the primary and secondary circuits. Electricity supply is similarly redundant. The design basis for the emergency core cooling system is the rupture of the largest pipe connected to the primary circuit (i.e., not
21.1.2005

the primary circuit pipe); for a primary circuit pipe rupture, the emergency core cooling capacity is 4x34%. The design of the emergency core cooling system is based on the Leak Before Break (LBB) approach.

A more detailed description of the boron system of the Olkiluoto 3 Nuclear Power Plant Unit is provided in section 5.3. The capacities of the Olkiluoto 3 emergency core cooling and residual heat removal systems conform to the original designs, but subsequent analyses have shown that two sub-systems are enough to provide adequate emergency core cooling and residual heat removal capacity even in case of a complete double ended guillotine break of the largest pipe. The Leak Before Break principle is discussed in section 5.4.

Off-site and on-site electrical power supply

The Olkiluoto 3 Nuclear Power Plant Unit will be connected to Finland's national grid via 400 kV and 110 kV transmission cables. Structurally and functionally, these systems are designed to be as independent from each other as possible. However, the voltage levels of the power transmission network are interconnected on the grid side, so a major disruption resulting in the loss of the 400 kV supply will probably lead to the loss of the 110 kV network as well.

In accordance with the division applied to safety systems, the backed-up electrical power supply systems inside the reactor plant are divided into four redundancies (functionally and structurally isolated sub-systems). Each redundancy is provided with an emergency diesel generator. Each of the diesel generators is designed to provide enough capacity to supply the power required by all the consumers important to safety included in a single redundancy. The diesel generators switch on automatically if the connection to the off-site grid is lost and supply from the plant unit's in-house generator is for some reason unavailable. Within each of the four redundancies supplies to consumers requiring uninterruptible power supply, such as automation systems, are backed up by UPS assemblies with a 2-hour battery capacity.

The distribution system allows partial cross-connection of parallel redundancies between sub-system pairs 1 & 2 and 3 & 4 respectively. This cross-connection capability improves the serviceability and reliability of individual sub-systems, for example during maintenance and repairs.

Provisions have been made for the simultaneous loss of off-site power, the in-house power supply and the emergency diesel generators by furnishing the plant unit with two SBO (Station Black-Out) diesel generators that have lower output and represent a different type than the actual emergency diesel generators. The SBO diesels are capable of sustaining the critical safety functions that help maintain the plant unit in a safe state.

As all the diesel generators are air-cooled, their operation is independent of the ultimate heat sink (the sea). They are located in two physically separate buildings with other
massive plant buildings in between. Both diesel buildings house two diesel generators, each in their separate rooms, and one SBO generator, as well as fuel tanks for 72-hour operation (SBOs for 24 hours).

When the Olkiluoto 3 Nuclear Power Plant Unit is built, Fingrid Oyj will construct an on-site reserve power plant with an output of approx. 120 MW that is powered by gas turbines. TVO and Fingrid have agreed that in case of a major disruption in the power transmission network TVO will use this gas-turbine plant for supplying power to all the Olkiluoto plant units. The gas-turbine plant is not suitable for use in grid restoration carried out by Fingrid after a major disruption.

A description of the power supply systems designed for controlling severe accidents is provided in section 5.5. The power supply to control severe accidents is segregated from other power supply systems to the greatest possible extent, but without compromising the reliability of the systems. The acute stage functions (<12 hours) can be maintained by means of battery banks independent of other power supplies. SBO diesels are also used for controlling accidents in the station black-out situations discussed earlier. Formally, the situation after 12 hours represents a departure from the YVL requirements under which the power sources for controlling postulated accidents and severe accidents should be separate and independent of one another. However, the required level of safety is achieved as there are more optional power sources available than was foreseen at the time the YVL Guides were prepared.

The plant supplier has not yet specifically identified the equipment to be selected for inclusion in the electrical systems. If, as the design work progresses, components incorporating programmable technology are selected, the plant supplier is prepared to use diverse components or qualify the components for common mode failures in accordance with the applicable safety class. Diversification would be implemented according to the 2+2 principle - i.e., two sub-systems would share identical equipment.

Separation of safety systems and redundancies

In accordance with the basic concept, the Olkiluoto 3 Nuclear Power Plant Unit applies the principle of separation, where parallel safety systems are separated by placing them in different buildings (or building sections). The most important safety systems are housed in four safeguard buildings located in the immediate vicinity of the reactor building. The access paths between the buildings are designed so as to ensure that incidents jeopardizing the safety functions, such as fires or floods, cannot spread from one structure to another.

The emergency diesel generators are located in two physically separate buildings, as described above. No direct connections exist between the power supply sub-systems, excluding a few minor exceptions (temporary cross-connections between sub-system pairs 1 & 2 and 3 & 4). Similarly, the four seawater circuits designed for the removal of residual heat are located in pairs in two pumping stations. Additionally, both pumping
stations have one separate pump and connection to the immediate cooling circuit designed for controlling DEC situations and severe accidents. All the four seawater circuits have their own tunnels, but the actual tunnels run side by side in pairs. Access paths are provided between the tunnels for personnel and fire safety reasons, but they are normally kept closed.

When parallel safety systems are placed close to each in pairs, such pairs are located physically as far from each other as possible and, in the case of the most critical pairs, there are always other massive buildings in between. This arrangement reduces the risk that any influence from outside the plant unit (weather phenomena, aircraft crash, etc.) would prevent both pairs from performing the tasks.

Use of diverse systems

In the design of the Olkiluoto 3 Nuclear Power Plant Unit the diversity principle has been applied to the safety functions required for controlling anticipated transients and the most frequent Class 1 postulated accidents. The diversity approach has been applied to the following safety functions:
- reactor shutdown;
- primary pressure control;
- reactor core cooling and residual heat removal;
- containment building isolation.

The same principle is also applied to the following auxiliary functions required for sustaining the aforementioned functions:
- power supply;
- automation and instrumentation;
- cooling and air-conditioning;
- control and monitoring of equipment from the control room.

The diversity approach has been used to process systems performing safety functions fairly extensively, as shown in the following table:

<table>
<thead>
<tr>
<th>Function/Main system</th>
<th>Diverse redundant system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reactor shutdown: reactor control rods</td>
<td>emergency boration</td>
</tr>
<tr>
<td>Emergency cooling to control minor leaks: Medium Head Safety Injection (MHSI)</td>
<td>quick pressure reduction in primary and secondary circuits + emergency cooling accumulators + low head safety injection (LHSI)</td>
</tr>
<tr>
<td>Emergency cooling to control major leaks: Low Head Safety Injection System</td>
<td>emergency cooling accumulators + MHSI + quick cooling via secondary circuit</td>
</tr>
</tbody>
</table>
## Removal of Residual Heat in Hot Shutdown

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam Generator Emergency Cooling Feed Water</td>
<td>Feed and Bleed: MHSI and pressurizer blow-down lines</td>
</tr>
</tbody>
</table>

## Residual Heat Removal during Normal Shutdown and Cooldown

- **Residual Heat Removal (RHR)**
- Intermediate Cooling Circuit and Sea-Water Circuit

## Ultimate Heat Sink: Seawater Circuit

Closed reactor circuit: cooling by evaporating water in the secondary circuit. Open reactor circuit: LHSI + evaporation inside containment building, filtered venting from containment 24 hours later or spray system heat transfer chain.

## Cooling of Fuel Pools: Standard Pool Cooling System

Evaporation inside containment building + additional water.

## Isolation Principles of Containment Building

- Diverse operating principles of isolation valves, e.g., motor valve and check valve on same line, or
- Similar operating principle but different type, or
- Identical isolation valves from different manufacturers.

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Diversity is provided in the automation systems by setting up the systems implementing the various levels of defence in depth on different hardware platforms. The process automation system (PAS) and the safety automation system (SAS) complementing the protection system will be built using the Teleperm XP product family, whereas the reactor control, surveillance, limitation and protection systems (RCSL and PS) will be based on the Teleperm XS platform (technology designed for nuclear safety).
21.1.2005

applications). A description of these systems is provided in section 5.10. The platform for the automation system designed for controlling severe accidents has not yet been selected but as far as the safety criteria are concerned, it can be either of the platforms mentioned above. The hardwired back-up automation (HWBU) system will be built on a platform (Safety Class 3) that uses no programmable technology. To some extent, the systems make use of the same measurement signals because it is advisable to optimize the number of physical measurement connections to the process. The automation systems are sufficiently diversified.

Electrical power to the plant unit is available from six diverse sources: off-site 400 kV and 110 kV grid, unit-to-unit supply connections via the Olkiluoto 400 kV substation, supply from the in-house main generator, emergency diesel generators, SBO diesel generators, and the gas-turbine plant to be built on the site. Additionally, auxiliary supplies to the electrical and automation systems are backed up by battery banks. The optional power sources are not fully mutually redundant - in particular, the output of the SBO diesels is low compared with the other sources but is nevertheless sufficient for sustaining the most important safety functions and responding to severe reactor accidents.

Electrical components incorporating programmable technology will be diversified in locations important to safety on the 2+2 basis unless the component can be qualified in accordance with the requirements imposed by programmable technology.

In summary of the measures described above to guarantee the performance of the safety functions, it is stated that the safety functions of the Olkiluoto 3 Nuclear Power Plant Unit are adequately ensured.

5.7 Section 19: Avoiding human errors

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 is well able to withstand errors and deviations from planned operational actions.

The general principle of safety design (a sufficient degree of redundancy, diversity and independence) and the defence-in-depth approach protect the plant unit against human errors as well. The operational and protective automation systems prevent the onset and development of transients and limit their scope. The human role is to ensure the performance of these systems and control the plant unit as a whole. Plant design is governed by the principle of autonomy, under which the plant unit must carry on for 30 minutes after the initiating event with no operator interference from the control room and for 60 minutes with no human control action elsewhere on the site.

The operating personnel receive information about the status of the plant via instrumentation and the control room user interface for automation systems. The
The control room plays a central role in the operation of the plant. Therefore, the vendor has appointed a working group specializing in the evaluation of human factors to oversee the control room design. This team is responsible for creating the procedures required for assuring and verifying that the operating personnel have access to the necessary information and the ability to control the plant in all situations. Features essential to the performance of the tasks assigned to the control room will be assured from the human point of view in a four-stage design and validation procedure specified for the control room and its user interface.

The main tasks necessary for the operation and safety of the plant provide the basis for defining the functional requirements that are then used for determining which tasks are assigned to automation systems and which to operators. The role of automation relative to the tasks to be assigned to users will be defined on the basis of task analyses. The tasks that the operators are responsible for have been evaluated in terms of urgency, complexity and the accuracy required. The tasks have been evaluated with due regard to the limitations and potential of human performance. The ability of the control room staff to control the plant is of primary importance to safety and serves as a human back-up against problems caused by technology.

An operating manual will be prepared for the operation of the plant and validated, where possible, by simulation and trial operation and in the commissioning phase. The experiences gained from the EPR reference plants will be utilized in the preparation of the operating manual. The manual also provides for human redundancy in that, in emergencies, the critical plant functions important to safety are also monitored by an individual not on regular control room duty in accordance with his or her specific instructions. This is one way of preventing human error and taking the related corrective action.

The importance of considering the human factor has been emphasized for each design organization. User-friendliness in the operation, maintenance and servicing of the systems and equipment is part of an advanced design philosophy.

To summarize the above measures, it is stated that adequate attention has been paid to the avoidance, detection and correction of human error in the design of the Olkiluoto 3 Nuclear Power Plant Unit and its operations.

5.8 Section 20: Protection against external events and fires

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, all conceivable combined effects of accident conditions induced by internal causes and simultaneous natural phenomena shall be taken into account where possible.
Structures, systems and components important to safety shall be designed and located, as well as protected by means of structural fire barriers and adequate fire fighting systems so that the likelihood of fires and explosions remains low and their effect on plant safety insignificant.

The point of departure for the design and dimensioning of the Olkiluoto 3 Nuclear Power Plant Unit has been to ensure that the adequate performance of the systems and equipment required for controlling the plant is not jeopardized by external events. Special steps have been taken to guarantee that the reactor can be shut down and kept in a safe state even after the worst-case external events and in extreme external conditions.

Protection against most external events, including internal incidents, is based on a careful physical separation of parallel sub-systems. The sub-systems are independent in such a way that no single failure or external cause can damage more than one, or in extreme cases (major aircraft crash) two sub-systems at a time. A sufficient level of performance is maintained even following the loss of two sub-systems because there are a total of four sub-systems (see section 5.6). Special protective systems will be provided in view of certain external events, such as strokes of lightning and frazil ice.

Weather and other natural phenomena

The following weather conditions and external circumstances have, among others, been considered in the design of the Olkiluoto 3 Nuclear Power Plant Unit: low and high outdoor temperature, air humidity, strong wind and any missiles generated or carried by the wind, low and high seawater temperature, low and high seawater level, rain or snow, lightning, blocking of the seawater intake by ice, frazil ice, objects, seaweed or waterborne organisms (algae, mussels, fish) or oil spills, and the blocking of the air intakes, for example by a snow storm. Various combinations of the foregoing phenomena have also been analyzed.

Due consideration has been given to the loads and capacity requirements related to extreme weather conditions in the design of all the systems important to safety. For one thing, steps have been taken to prevent complete clogging of the seawater systems by means of heating and cleaning systems, and by providing an optional water intake route. Additionally, provisions have been made for situations where the supply of seawater is cut off for about 72 hours. To prevent the clogging of the air intakes of the emergency diesel generators, the intakes will be protected by structural designs and electric heating, and on the other hand, the power supply is ensured by several mutually independent power sources. Disruptions due to lightning are prevented by means of an array of lightning protection system.

To evaluate the occurrence of potentially extreme weather phenomena and other environmental conditions, and the adequacy of the level of on-site preparedness for such phenomena, statistical methods have also been employed in addition to conventional design methodology (see section 3.4). The plans for responding to
extreme weather and other environmental conditions are sufficiently extensive and acceptable for the issuance of the construction licence.

Earthquakes

The plant systems, structures and components have been classified in terms of earthquake resistance. The safety classification is discussed in greater detail in section 5.9. The plant sections performing safety functions are capable of operating correctly after the design-basis earthquake. The peak ground acceleration (PGA) of the design-basis earthquake used in Finland is 0.1 g, which is a relatively low figure but acceptable considering the low seismicity of the country.

A design-basis earthquake is estimated to occur at most once per 100,000 years. This evaluation is based on observations in Finland and the neighbouring areas, and the basic geological data available on the region. Based on the general knowledge of the consequences of earthquakes, it is estimated that the appearance of damage detrimental to nuclear safety would require an earthquake essentially far more intense and rare than the design-basis earthquake.

The general principles applied to the earthquake design of the Olkiluoto 3 Nuclear Power Plant Unit are acceptable. TVO will submit more detailed analyses of the earthquake resistance of the structures and equipment for approval in connection with the detailed design.

Threats associated with human action; illegal activities, aircraft crash

Risks associated with industrial activities, transportation and other normal human activities have been considered. There are no industrial facilities, warehouses or transport routes in the immediate vicinity of the Olkiluoto plant site where accidents might jeopardise the safety of the plant due to explosions or releases of toxic, corrosive or combustible chemicals. As far as oil spills associated with accidents at sea are concerned, it should be noted that there are no sea routes in the vicinity of the plant trafficked by vessels carrying large volumes of oil. In case of an oil spill, there would be enough time for shutting down the plant and taking appropriate protective actions, for example by deploying oil containment booms. If seawater could not be used for cooling the plant unit, removal of residual heat from the Olkiluoto 3 Nuclear Power Plant Unit can be accomplished and maintained via the secondary circuit into the atmosphere for several days (and by providing an additional feed water supply for an indefinite period of time).

The plant is also designed to withstand illegal activities. In particular, safeguards have been put in place against external threats, such as an aircraft crash, electromagnetic interference, chemical and biological toxins. The security arrangements of the plant (prevention of illegal activities and limitation of their consequences) are discussed in
more detail in section 8 in accordance with the applicable Decision of the Council of State 369/1991.

The Supplement to the Preliminary Safety Assessment concerning an aircraft crash states that the consequences of crash shall be evaluated both for large passenger aircrafts and military aircraft. The target shall be technical solutions, which do not need any modifications, even in the future, although aviation technology or air traffic frequencies would change during the expected operational lifetime of at least 60 years.

Additionally, a new nuclear power plant shall be designed against a possible aircraft crash or other external attack so that
- the event does not cause damage which would lead to an immediate release of significant amounts of radioactive substances to the environment;
- in spite of the direct consequences of the event (penetration of structures by impacting parts, vibration, explosion, etc.), the most important safety functions can be started with adequate certainty;
- in spite of later consequences of the event (e.g. fire at the plant site), the most important safety functions can be maintained with adequate certainty for such a long time that the consequences of the crash can be repaired without release of significant amounts of radioactive substances to the environment.

and Release of “significant amount” of radioactivity in this context means a release that is evaluated to lead at maximum to the dosage commitment according to section 11 of the Council of State Decision 395/1991 (so-called limit value for a postulated accident). When evaluating the population dosage, realistic assumptions can be used (so-called best-estimate assumptions) and the public protection actions, which are easily performed, can be taken into account.

At the Olkiluoto 3 Nuclear Power Plant Unit, provisions have been made against an aircraft crash by physically segregating the systems, equipment and structures important to safety on the site and, where possible, by placing the buildings critical to safety in such a way that there are other massive structures in between (geographical segregation). Additionally, buildings indispensable to safety, such as the outer reactor containment building, the fuel building, and two of the four safeguard buildings, are protected by thick walls made of reinforced concrete. The external walls are supported on the same base slab as the actual buildings but a space is provided between the external walls and the actual building walls. The external wall and inner (actual building) wall are not in contact with each other. As a result, the external wall can absorb major mechanical loads by deflection without directly affecting the components or structures embedded in the inner wall. However, various indirect effects (cracking of the inside of external wall, vibration impulses, etc.) will be created and be considered.

The walls are designed to ensure that the plant survives the direct impact of a large passenger airliner. However, damage to the external walls cannot be avoided upon such impact. In some cases, especially if the point of impact is close to the secondary circuit blow-down and safety valve stations, it is likely that the related systems will be
damaged. However, analyses (section 3.4) have been carried out showing that the damage due to the impact will be local. The integrity of the fuel and primary circuit will be maintained and safety functions can be started and sustained at a sufficiently high level of efficiency, even if one of the non-reinforced safeguard buildings were to be damaged.

The analyses cover the mechanical impacts of the crash. Analyses commissioned by STUK also address on-site fires.

The aircraft crash is used as a design basis for both the strength of the external walls and the width of the void between the external and inner walls of the protected buildings. Structural design is based on analyses carried out by Framatome ANP, specifying estimated rated loads for a small aircraft, a military aircraft and a large passenger airliner. To evaluate the strength of the buildings, STUK commissioned both VTT and the Gesellschaft für Anlagen und Reaktorsicherheit (GRS) to carry out comparative calculations. The STUK analyses examine loads of varying magnitudes up to the Airbus A380 "superjumbo" currently being built. The analyses are still partially incomplete because the preliminary structural design of the buildings was not finished until mid-2004. The results obtained so far suggest that at least no major modifications to the building dimensions are required. The final building design will be reviewed in connection with the pre-inspection.

The impact will also excite vibrations in the buildings that may jeopardize the integrity of the process systems or damage electrical and automation equipment. Vibration calculations have been made as part of the mechanical analyses and their effects will be taken into account either by providing additional structural and equipment supports (process systems) or by qualifying the components (vibration qualification of electrical and automation systems). These analyses are highly complex and will be revised during construction.

A fire would break out on impact as the aircraft fuel would ignite and burn either in the outdoor areas and, possibly, partly inside the damaged buildings. As a rule, a fire caused by an aircraft crash cannot pose a direct risk to the operation of the safety functions, particularly inside the protected buildings. However, the effects of such a fire must be taken into account in the detailed design of some other buildings or structures.

The impact of a large passenger airliner, and a military aircraft, has been taken into account in the design of the plant unit to the extent required for the construction licence. However, numerous design details need to be finalized, the on-going analyses need to be completed, and the results of the analyses must be verified experimentally.

Fires

The possibility of fires and associated accident risks has been duly taken into account in the functional design of the Olkiluoto 3 Nuclear Power Plant Unit and the layout plans.
The safeguard buildings are separate fire compartments. Safety systems are not installed inside the turbine building, which is separate from the safeguard buildings. Similarly, other plant sections primarily used for the normal operation of the plant, such as the switchgear building (house load, no diesel back-up), auxiliary building, radioactive waste storage, etc., are placed in separate buildings, so that fires breaking out in these buildings will not prevent the performance of the critical safety functions. Also, the annulus between the primary and secondary containment building is divided into four fire areas with parallel sub-systems located in their own separate sectors.

Large fire loads are placed in separate fire compartments. The detailed implementation of fire compartmentalization and protection (structural fire resistance, fire loads, extinguishing systems, etc.) will be primarily inspected in connection with the construction supervision. Cabling will be laid using a fire-retardant cable sheathing, which will be taken into account when the exact coverage of the extinguishing systems is evaluated.

Fire risks will also be assessed in connection with the probabilistic safety analysis. The current view is that the risks posed by fires are low compared with other risks. The information provided is sufficient for the processing of the construction licence application for the purpose of evaluating whether the spread of fires can be reliably prevented by the fire-fighting systems.

The proposed plant concept satisfies the YVL 4.3 design criteria for fire prevention at a nuclear power plant.

Summary

In summary, STUK states that sufficient consideration has been given to external risks and risk of fires in the design of the Olkiluoto 3 Nuclear Power Plant Unit. With regard to aircraft crashes, however, a number of design details need to be finalized, the ongoing analyses need to be completed, and the results of the analyses must be verified experimentally.

5.9 Section 21: Safety classification

The functions important to the safety of the systems, structures and components of a nuclear power plant shall be defined, and the systems, structures and components classified according to their safety significance.

The systems, structures and components important to safety shall be designed, manufactured, installed and operated so that their quality level, and the inspections and tests required to verify their quality level, are adequate considering any item's safety significance.
The safety and quality classification for the main components in the individual safety classes have been defined for all the fields of technology involved. The safety classification follows the accepted practice in Finland: systems, structures and components are assigned to Safety Classes 1 to 4 (descending order) and to Class EYT (not safety related). Importance to safety is evaluated in terms of the significance of the system, structure or component for nuclear and radiation safety. Along the lines of the classification based on importance to safety, there is a seismic classification system designed to address the safety concerns related to earthquakes, as described in section 5.8.

Of the barriers, the fuel cladding and the pressure-bearing interface of the primary circuit are assigned to the highest safety class. Systems, structures and components performing essential safety functions are assigned to Safety Class 2. Safety Class 3 includes auxiliary safety functions and other items important to nuclear safety that are not assigned to either of the higher classes. Safety Class 4 includes systems whose failure could cause an initiating event detrimental to nuclear safety, jeopardize the safety of the plant environment, or complicate the safe operation of the nuclear power plant or the control of transients and accidents (such as fire extinguishing systems, turbine plant protection, computer systems designed for controlling accidents).

The safety class determines the level of quality to be applied to the design and implementation of the item involved, and the applicable level of supervision. However, different requirements and procedures are applied to individual fields of technology. The requirements are set out in the YVL Guides applicable to the various fields of technology where reference is frequently made to established international standards and norms (or Finnish standards with regard to construction).

The attainment of the quality requirements will be monitored throughout construction because they relate to the real-life production of the systems, structures and components. They are designed to ensure that the required standard of reliability is achieved by means of a sound production process. Supervision covers every stage in the production of structures and components; in the highest safety class, the manufacture of the materials used for making the components and structures is also supervised. The primary responsibility for supervision rests with TVO, while independent control by STUK verifies TVO's activities and ensures the appropriateness of the supervision in other respects as well.

The safety classification of systems, structures and components has also been evaluated with reference to the PSA in order to ensure that the quality management criteria applicable to each piece of component under the classification system are correctly defined with due regard to the risk-related importance of such component. The results of the PSA evaluation have been taken into account in the preparation of the classification document.
In summary, STUK states that the safety classifications of the Olkiluoto 3 Nuclear Power Plant Unit are appropriate.

5.10 Section 22: Monitoring and control of a nuclear power plant

A nuclear power plant's control rooms shall contain equipment that provides information about the plant's operational state and any deviations from the normal operational state, as well as systems that monitor the state of the plant's safety systems during operation and their functioning during operational transients and accidents.

A nuclear power plant shall incorporate automatic systems that maintain the plant in a safe state during transients and accidents long enough to give the operators enough time to consider and implement the correct actions.

An emergency control post independent of the control room and local control systems must be provided at a nuclear power plant to permit the shutdown and cooling of the nuclear reactor and the removal of residual heat from the nuclear reactor and spent fuel storage.

Monitoring, control and protection of the Olkiluoto 3 Nuclear Power Plant Unit will be implemented using programmable automation technology. The Preliminary Safety Assessment states that the protection system structure also includes a sufficient amount of diversity. In order to reduce the need for the actuation of the protection systems during transients, a special limitation function, more reliable in operation than the process automation system, has to be provided between the operating automation and the actual protection system and STUK applies European standards to the assessment of the programmable automation important to safety.

The reference to European standards in the Preliminary Safety Assessment relates mainly to the preferred order of precedence of automation standards, with STUK primarily applying the European IEC standards and secondarily the US IEEE standards. A position paper has been prepared in cooperation with the regulators within the EU entitled “Common position of European regulators for the licensing of safety critical software for nuclear reactors” (EUR 19265), which STUK also applies. As far as programmable automation technology is concerned, the level of requirements applied by STUK conforms to international nuclear automation standards.

The automation functions of the reactor plant of the Olkiluoto 3 Nuclear Power Plant Unit are assigned to several groups, or "lines of defence", based on importance for safety: the Process Automation System (PAS), Reactor Control, Surveillance and Limitation (RCSL) system, Protection System (PS) and the Safety Automation System (SAS) complementing and backing up the protection system, and the analogue Hard-Wired Back-Up (HWBU) system.
The limitation functions are designed to reduce the need for triggering the protection system by addressing initial transients as early as possible. When a transient appears, the reactor control, surveillance and limitation system is the first to detect it and initiate functions that are similar in nature to the safety functions triggered by the actual protection system but less intense.

The purpose of the PS system is to detect a transient or accident and trigger the required safety functions in order to place the plant in a safe state - i.e., in a state where the safety functions can be sustained for an extended period of time until the threat to the integrity of the barriers is removed. The supplementary safety automation system SAS is used for cooling down the plant unit from a controlled state to a cold shutdown. The SAS system also provides redundancy for some protection system functions, for example in view of DEC conditions.

The logics triggering the functions of individual "lines of defence" will be implemented on several different automation system platforms. However, there are fewer hardware platforms than there are separate lines of defence, which results in a certain inter-dependence between the lines. The limitation and protection functions important to safety (RCSL and PS) will be implemented on Framatome ANP's Teleperm XS platform, whereas the process automation and safety automation systems (PAS and SAS) will be implemented on Siemens Power Generation's Teleperm XP platform. Automation at the turbine plant will be entirely based on the Teleperm XP platform. In the following, this safety assessment will focus on the reactor plant automation systems.

The Teleperm XS and Teleperm XP platforms differ from each other to the extent that they can be used to provide mutual diversity at the Olkiluoto 3 Nuclear Power Plant Unit as designed (additionally, a hard-wired back-up system is to be provided). The development of the Teleperm XS system platform began in the early 1990s. Designed for demanding safety applications, the design bases of Teleperm XS refer to the IEC, IEEE and KTA nuclear safety standards. The Teleperm XS system platform was launched in 1999. Teleperm XP is designed for use as a universal industrial automation system. With regard to system-level design bases, the supplier refers to industrial quality management standards and the IAEA guidelines for the design of I&C systems for nuclear power plants (2002). The system has been used for conventional tasks at nuclear power plants since 1996. In 2004 the IEC released the standard 62138 relating to the design of Safety Class 3 systems; to fulfil the requirements of this standard, further development of Teleperm XP is probably required.

The life cycle of universal industrial automation platforms is shorter than that of the automation systems based on hard-wired technologies used at existing plants. Because of the continuous updating of the standards, the standards used for the different design bases may differ from one another. The compatibility of the hardware and software to be installed at the plant will be checked when the suitability of the equipment for the intended purpose is evaluated. The increasingly shorter life cycle of system versions produced using programmable technology will pose additional challenges to the
maintenance organisation of the nuclear power plant and due consideration must be
given to this when the systems are designed.

The most critical and urgently required protection measures (reactor scram, including
related ancillary actions) are also backed up by an analogue (hard-wired) protection
system that is completely independent of all other logic. Its technology platform has not
yet been selected, but suitable technology conforming to the required standard of
quality (Safety Class 3) is available in abundance.

Additionally, all safety functions can be initiated manually from the control via a hard-
wired system. The manually triggered safety functions include reactor scramming with
control rods and by borating, removal of residual heat from an intact primary circuit
(emergency injection, or in its absence, feed-and-bleed of the primary circuit using the
emergency core cooling pumps and pressure-reduction lines), emergency core cooling
and removal of residual heat from a non-intact primary circuit, isolation of the
containment building, and supply of back-up power to the emergency cooling systems.

Actions to control severe accidents are independent of other control systems. Operator-
initiated measures include pressure reduction in the primary circuit, spraying of the
containment building, introduction of cooling water to the core catcher cooling
channels, and filtered containment venting. When power is lost, the SBO diesel
generators are started manually. The operator can secure the automated functions by
closing the isolation valves of the containment building and opening the flaps used for
hydrogen management. So far, it is not yet known which platform, Teleperm XS or
Teleperm XP, will be used for this purpose; technically, both systems are feasible.

Measurements important for controlling transients and accidents will be made using
only analogue transmitters. Similarly, the actuators important to safety will be
implemented without programmable logic (or qualified to the applicable programmable
logic standards). However, automation systems representing different levels partly
make use of the same process measurements, which increases the inter-dependence
between the systems. To identify anticipated transients and Class 1 ("minor") accidents,
two independent process variables within a single protection system are used, so that
the safety function is triggered whenever either of the two exceeds the pre-determined
limit. For the detection of less frequent incidents, the PS protection system may only
use one variable, which is backed up by an independent measurement of another
variable to be made by the SAS system. Both systems will initiate the necessary safety
functions. Reliance on two variables reduces the dependency on a single chain of
measurements and common mode failures of one type of measuring devices. Common
mode failures may be caused by maintenance errors (calibration errors) or irregularities
in the process interface (soiled sensors, clogging of impulse tubes, etc.). For this reason
alone, it is important to measure and rely on several variables when initiating safety
measures.

A general requirement concerning both the automation systems important to safety and
the process automation systems is that they are highly fault tolerant in respect of single
and common mode failures, both in terms of structure and architecture. To ensure single failure fault tolerance, the limitation and protection systems are four-channelled, reflecting the basic process design approach in that the systems most important to safety are divided into four mutually independent sub-systems.

Provisions for common mode failures must be made, above all, in software and measurements. With software, the dominant error function is precisely a common mode failure because the software, as such, cannot be "broken". A common mode failure arises as a result of the combined effect of the susceptibility to errors of the programmable device and the simultaneous impulse received from the operating environment. In the protection system (PS), internal diversity is used to provide protection against common mode failures. This means that system functions are, within each sub-system, assigned to mutually diverse processing chains, so that the different chains process the measurements on different variables. The processing chains may also incorporate diverse logic. This makes it possible to minimize both susceptibility to errors (because the applications in the individual chains process different data and are thus, at least to some extent, structurally different) and the effect of the impulse (because the individual chains receive different impulses, and processing seldom proceeds at the same pace). The protection system is designed to include internal diversity to the extent called for by the general diversification principles of the plant unit, so that the point of focus is on the most probable initiating event (anticipated transients and the most common Class 1 accidents). With regard to safety functions required to respond to less common situations, a sufficient degree of diversity is achieved through the lines of defence (different main systems) using independent measurements.

Safety-related data transmission within the automation systems takes place via hard-wired connections outside the entities consisting of process-based equipment. In contrast, bus data transmission is limited to internal transmission within individual logic devices and process-based systems and between the same, and to maintenance connections. According to the proposed concept, bus connections will be used between redundant sub-systems primarily for voting. Bus connections are also needed between diverse sub-systems for certain signal transmission, permissives, and comparison for control purposes. Measurement and controls less important to safety and/or designed for normal operation can also be implemented using programmable field devices. According to the proposed concept, field buses will not be used for safety-classified functions. The limited resistance to radiation of programmable field devices limits their use, particularly inside the containment building or in safety systems.

The control room of the Olkiluoto 3 Nuclear Power Plant Unit is designed as a hybrid control room where the plant is mainly controlled by means of computer-based user interfaces. However, the most important process variables, including the measurements required for controlling accidents, are also displayed by means of hard-wired measurements, and the essential safety functions can be initiated manually via hard-wired connections. The operating manual and instructions for dealing with disruptions are in hardcopy format.
The Olkiluoto 3 Nuclear Power Plant Unit includes a separate emergency control room, from which the plant unit can be shut down in a controlled manner. Plant operation is controlled from the emergency control room using the user interface for normal operation. Essential process measurements are displayed in the emergency control room via hard-wired connections. The emergency control room is located in a fire compartment separate from the main control room but fairly quickly accessible from the main control room.

At the time the issuance of the construction licence is being considered, the automation design of the plant unit will not be sufficiently advanced so that the structure of all the systems important to safety will be known to the extent required under the Guide YVL 5.5. However, the plans for the protection system architecture and signalling have been completed, as have the plans for signal processing "before" the limitation system and for the automation system that serves as a partial back-up for the protection system. The four-channelled automation system is highly tolerant against random failures, and, based on the information available on the overall architecture and how signals are distributed between the systems, it is possible to evaluate the system's common mode fault tolerance in respect of sensor defects. A sufficient level of common mode fault tolerance with regard to sensors is achieved by means of diversity provided either within individual systems or between systems representing different levels.

A preliminary fault and effect analysis of the basic protection system designs has been carried out, indicating that the failure of a single device within a system will not prevent triggering and will lead to inadvertent triggering only rarely (normally due to a component at the end of the signal processing chain).

Based on this information, and the design criteria presented in the PSAR, it is stated that the automation design can be carried out in a technically acceptable manner. The final acceptability of the basic concepts will be inspected before the system licensing process during construction.

In the field of I&C technology (particularly with regard to computerized technology), the high standard of quality of the system is largely demonstrated through careful planning of the work process, planned verification and validation (V&V) performed between work phases, and through documentation of the work phases, verifications and validations. To date, only a preliminary evaluation of the I&C system design processes applied by Framatome ANP and Siemens has been made. So far, the following elements required under international standards in accordance with importance to safety have been provisionally identified for systems in each safety class: the work processes including appropriately segregated work phases, intermediate V&Vs at different levels, and independent inspections. STUK understands that TVO's experts will also participate in the V&V processes and that in the highest safety classes the processes will also include STUK’s hold points. Supervision by STUK is designed to verify the functionality of the V&V process and is thus not part of the actual process. The
evaluation of work processes continues as an integral part of the regulatory control of the construction.

Regular type approvals are also required of automation equipment in the highest safety classes as part of the qualification process. Type approvals of the components in the proposed basic product families have not yet been exhaustively assessed for the Olkiluoto 3 Nuclear Power Plant Unit, but, on the basis of the assessments carried out in various contexts in accordance with similar criteria, sufficient type approvals either already exist or can be obtained. Even completely new components (priority module PM10 as an alternative to priority module AV42) have been proposed for the Olkiluoto 3 Nuclear Power Plant Unit, meaning that they have to be duly qualified during the project. The supplier is deemed to be competent to carry out the qualifications acceptably. More detailed planning of the qualification process and related supervision will be carried out before the detailed design is initiated.

In summary, STUK states that sufficient consideration has been given to monitoring and control in the design of the Olkiluoto 3 Nuclear Power Plant Unit. The acceptability of the detailed concepts and procedures will be evaluated as part of the system licensing process to be carried out during construction as the plans are finalized.


6.1 Section 23: Technical Specifications and plant procedures

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.

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.

The technical and administrative requirements for the operation of the Olkiluoto 3 Nuclear Power Plant Unit - the so-called technical specifications (TTKE) - and the entire set of instructions for the plant unit are to be drafted well in advance during plant construction so that the operating personnel can be trained to operate the plant unit.

The preliminary technical specifications have been presented in Chapter 16 of the PSAR and the plans for drafting the instructions required during operation have been
presented in Chapter 17\(^1\) of the PSAR. The drafting of the instructions is at an initial stage and the issue has not yet been processed in detail by STUK. TVO has been informed of the general inspection observations so that TVO can take them into account when drafting the final technical specifications. It has been particularly expressed that TVO shall deliver the technical specifications in Finnish for STUK’s approval when applying for an operating licence.

The technical specifications will be set so that the limits and acceptance criteria utilised in the design and safety analysis of the power plant unit shall also apply during operation. The technical specifications list periodic tests of equipment and systems, and maximum times for repairing any failed safety-related equipment, as well as the required actions in case the repair work cannot be completed within the time limit. In addition, the technical specifications define the situations where actions such as plant unit shutdown must be taken immediately.

Adequate plans concerning the regulations and a set of instructions for operating the Olkiluoto 3 Nuclear Power Plant Unit have been presented for the construction permit.

6.2 Section 24: Operation and maintenance

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.

The aspects affecting the operation of the nuclear power plant and the operability of the equipment have been considered in the design of the Olkiluoto 3 Nuclear Power Plant Unit, following the French model in particular. During construction the plant unit operators will be informed of the progress of the construction, but actually operation of the plant unit commences only when the testing and commissioning phase starts.

Preparations for implementing the periodic tests of the systems and equipment, as well as maintenance during operation, will be included in the design of the plant unit. The applied failure criteria \((N+1 + D+1\) and \(N+2\)) provide the possibility to temporarily switch off parts of the safety systems for implementing periodic tests and/or short-time maintenance operations without substantially endangering the reliability of the entire systems’ function.

\(^1\) Translator’s note: shall be chapter 13
With regard to operation and maintenance, keeping the workers’ radiation doses as low as is practically possible has also been taken into account in the design of the power plant unit, as described in section 4.2.

Periodic inspections using non-destructive inspection methods will be implemented for components belonging to safety classes 1 and 2, as well as other nuclear safety related components and structures. Operations that fulfil the inspection method requirements in actual inspection conditions will be guaranteed through qualifications. Such qualification will consist of practical tests that shall be implemented using test pieces representing the inspection object, and/or technical justification used for justifying the inspection system performance. The licence holder must have an expert and independent qualification body for the administration, implementation, supervision and evaluation of the qualifications, as well as for granting qualification certificates. The licensee has presented the Finnish SFS-Certification to be nominated as the qualification body. Since the resources of the above-mentioned Finnish qualification body will probably be insufficient, it will utilise both Finnish and foreign independent expert organisations for technical support.

The Olkiluoto 3 Nuclear Power Plant Unit has been designed for a 60-year service life. The starting point for the ageing management is that the construction materials and manufacturing techniques for the components are of the state-of-the-art level of technology. The ageing mechanisms and their minimisation have been investigated during design. The components subject to ageing mechanisms are to be considered in the inspection and maintenance activities carried out during operation.

The remaining service life of components can be estimated on the basis of in-service load monitoring, component design and manufacturing data, and the inspection results obtained from the service life management programme. The maintenance of sufficient safety margins is to be verified in all normal and transient conditions.

The service life management programme will be continuously developed by utilising the knowledge obtained from research and operating experiences. The ageing management plans regarding the electrical, automation and instrumentation components, and the buildings (concrete structures) will have to be supplemented during the construction.

As a conclusion, STUK states that the aspects affecting operation and maintenance for the construction permit have been taken sufficiently into account in the design of the Olkiluoto 3 Nuclear Power Plant Unit.
6.3 Section 25: Personnel

Nuclear power plant personnel shall be well suited for its duties, competent and well trained. Initial, complementary and refresher training programmes shall be established for the personnel.

For ensuring safety in all situations, competent personnel shall be available in a sufficient number.

TVO has established practices to employ and train the required personnel. However, the Olkiluoto 3 Nuclear Power Plant Unit is a pressurised water reactor, and is thus totally different to the present TVO boiling water reactors. Due to the basic differences between pressurised water reactors and boiling water reactors, the operating personnel at the present plant units cannot directly start to operate the Olkiluoto 3 Nuclear Power Plant Unit. The construction period offers TVO the possibility to master the technology and operations required for pressurised water reactors. TVO’s organisation and its requirements for development have also been discussed in sections 3.2, 3.3 and 12.4.

TVO has organised the work related to the construction of the Olkiluoto 3 Nuclear Power Plant Unit in the project department, which utilises the expertise of the other organisational units. According to TVO’s estimates, the construction project will employ – besides the vendor workforce – a maximum of nearly three hundred of TVO’s personnel. This additional requirement will be covered through recruitments and extensive utilisation of external experts. This number also includes the anticipatorily employed operation and maintenance personnel that will be trained during construction and will take part in the systems commissioning and the start-up testing of the plant unit. To meet the demand for additional personnel TVO recruited plenty of new personnel last year, and recruitment will continue during the construction. Moreover, TVO has contracted experienced consultants to ensure that external expertise will be available during construction and operation.

The construction-time organisation of the plant unit, personal responsibilities and tasks have been described in the regulations approved by STUK, and in more detail in the organisation handbook delivered to STUK for information. Moreover, STUK has approved the construction-time responsible director and his deputies, and, separately, the persons who take care of the emergency planning, physical protection and supervision of the nuclear material. The actual operations organisation will only be nominated at a later stage. However, the recruitment of personnel requiring longer special training (the operators) has already started. Information and experience acquired during the project will be later utilised by the operation and maintenance departments of the plant unit, as many of the people participating in the construction project will be employed by the plant unit’s operations organisation and the other supporting TVO organisation units.
A training simulator for training the control room personnel will be constructed in conjunction with the new nuclear power plant. TVO’s objective is to have the simulator in operation at least a year before the start-up testing of the plant unit begins in order to have enough time to train the personnel.

As a conclusion, STUK states that the arrangements for acquiring the required personnel and the setting up of the organisation for safe operation of the Olkiluoto 3 Nuclear Power Plant Unit are adequate.

6.4 Section 26: Monitoring releases of radioactive materials

*Releases of radioactive materials from a nuclear power plant and their concentrations in the environment shall be effectively monitored.*

At the Olkiluoto 3 Nuclear Power Plant Unit, radioactive releases into the environment consist of gaseous and particulate releases into the atmosphere and liquid releases into the sea. During normal operation releases into the atmosphere take place through the plant unit’s stack and into the sea through the pipeline connected to the seawater channel. In transients and accidents releases into the atmosphere could also occur through other routes, for example via the over-pressurization protection systems of the steam generators.

Radioactive releases from the plant unit into the atmosphere are monitored by continuously measuring the radioactivity of the air in the stack and in the exhaust air channels of the rooms. In addition to continuous measurements, samples are collected and taken regularly and analysed in the laboratory. If required, releases through the over-pressurization protection systems of the steam generators and the turbine hall building roof exhaust fans can be evaluated on the basis of continuous radiation monitoring, sampling and flow data acquired from steam and water in the secondary circuit. In an accident situation radioactive releases into the atmosphere can also be evaluated on the basis of continuous radiation monitoring acquired at the Olkiluoto power plant site and the vicinity.

Radioactive waste water from the Olkiluoto 3 Nuclear Power Plant Unit is cleaned and collected in tanks. Representative samples will be taken from the contents of the tanks. If the radionuclide content of the water is below the prescribed limits, the contents of the tank can be released into the sea. The radiation level in the pipeline used as the release route is monitored during the release, and if the prescribed limit were exceeded, the release would stop automatically with isolation valves.

The objective of radiation monitoring in the vicinity is partly to ensure that the population’s radiation exposure caused by the nuclear power plant shall be kept as low as reasonably achievable and that the limits presented in the regulations are not exceeded. Moreover, monitoring facilitates observation of potential short-term and
long-term changes in the normal radiation situation of the environment. Monitoring also helps to verify the measuring results acquired from radioactive releases and the calculation methods utilised for evaluating the dispersion of the releases from the nuclear power plant.

The environmental monitoring and sample collecting programme required by STUK is already being implemented at the Olkiluoto plant site in order to verify the release measurements that are carried out at the Olkiluoto 1 and 2 plant units. The programme contains external radiation measurements and determination of radioactive substances in air, and in samples representing the various parts of food chains of man, as well as determinations of the internal radioactivity in man. The maximum frequency of sample taking is once a week. The Olkiluoto 3 Nuclear Power Plant Unit will become part of the Olkiluoto power plant environmental monitoring and sample collecting programme.

In addition, there is automatic radiation measurement stations at the plant site and in the vicinity intended for use in emergency situations (addressed in more detail in Chapter 9). They will alarm if the radiation level differs from normal background radiation. The environment radiation measurement stations beyond the Olkiluoto plant unit site will remain unchanged, but three stations will be added at the plant site.

The measurements designed for defining the releases of radioactive materials from the Olkiluoto 3 Nuclear Power Plant Unit and the Olkiluoto power plant environmental monitoring programme adequately cover the radionuclides, release rates and release routes significant for radiation exposure to the population.

As a conclusion, STUK states that adequate and efficient arrangements have been designed for monitoring the releases and the concentrations of radioactive substances in the environment of the Olkiluoto 3 Nuclear Power Plant Unit.

6.5 Section 27: Operating experience and safety research

*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.*

In addition to the other design goals, the new plant unit design has taken operating experience gained from the other plants into account, as well as the results of safety research. The background information is based on experience of the development history of both German and French pressurised water reactors through several reactor generations. Utilisation of the research data becomes apparent in, for example, the management strategy of a severe reactor accident, which exploits nearly all research
work performed in the field of a severe reactor accident (sections 3.4 and 5.5). The effect of newer operation experience is shown in the attention devoted to the design of the emergency core cooling systems filters (section 3.4).

On the basis of the inspections and testing performed during construction, both TVO and STUK have considered the requirements and possibilities of improving safety. In case new research data or operational experience is estimated to be significant for safety and requires modifications to the structures or operation of nuclear power plants, STUK will ascertain that TVO performs the corrective actions required by the issue before the plant unit implementation. Utilisation of operation experiences and further safety enhancements have been taken into account in the construction-time quality management system. The principles of procedures relating to the utilisation of operation experiences correspond to the procedures of operating plant units.

The design criteria of the new plant unit will be reassessed in connection with the operating licence procedure regarding the best knowledge at the time.

Operating experience of nuclear power plants, as well as the results of safety research, have been sufficiently accounted for in the design of the Olkiluoto 3 Nuclear Power Plant Unit.


7.1 Section 28: Nuclear power plants in operation

For the part of such a nuclear power plant for which an operating licence was issued before the entry into force of this decision (an operating nuclear power plant) the limit for the dose referred to in Section 11 is 100 mSv, unless the application of the provisions contained in Section 11, as such, is justified, considering the provisions of Section 27, second paragraph.

The provisions of Sections 12, 17 and 18 of this decision are applied to an operating nuclear power plant to the extent justified based on the provisions of Section 27, second paragraph, and taking into account the technical solutions of the nuclear power plant in question.

The Olkiluoto 3 project has not yet been granted the operating licence, and thus the limit for the dose referred to in section 11 (5 mSv) is valid for it.
7.2 Section 29: Detailed regulations

Detailed regulations relating to the safety of a nuclear power plant are issued by the Finnish Centre for Radiation and Nuclear Safety.

STUK has issued, and will continue to issue, detailed regulations and opinions in its decisions and YVL Guides.

8 PHYSICAL PROTECTION (DECISION OF THE COUNCIL OF STATE 396/1991)

The regulations for physical protection are defined in the Nuclear Energy Act, Nuclear Energy Decree, and the Council of State Decision 396/1991. Detailed application instructions for the requirements and STUK’s control procedures are described in the classified YVL Guides 6.11, “Physical protection at nuclear power plants” and YVL 6.21, “Physical protection of nuclear fuel transports”. Moreover, some YVL Guides, for example YVL 1.0, YVL 2.0, YVL 5.5 and YVL 5.6, contain requirements where the need to consider unlawful actions against the nuclear power plant shall be taken into account.

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

Responsibility and control

According to the law, the licensee is unambiguously responsible for the safety of the nuclear power plant. However, the licensees’ means and authorisations are not adequate as such in, for example, a situation caused by terrorism. Even then it must also be able to dimension the applicable counter-measures, both as regards the extent and timing of the verified threat. In addition to the licensee, the police and other authorities providing executive assistance to the licensee also have legal obligations to secure safety in the
event of various unlawful cases. Therefore, the significance of cooperation between the safety authorities and the various parties should be emphasised in cases related to threat situations and provisions against them in nuclear power plants. There have not been any actions aiming to damage nuclear power plants in Finland.

In cases related to the use of nuclear energy, STUK also works as the regulatory authority for physical protection. To provide safety precautions against unlawful action, STUK has summoned a separate expert team whose task is to regularly follow and assess threat scenarios and any changes in them, to develop operational preparedness and the flow of information, and to widen its members’ expertise. In addition to STUK and experts from the power companies, the team includes representatives from the main Finnish police and safety authorities. The member organisations of the team have an extensive international cooperation network, through which information and opinions concerning international developments are forwarded to the team.

**Special requirements for the new nuclear power plant**

In connection with an aircraft crash, the Preliminary Safety Assessment also discussed the provision of precautions against threats caused by other unlawful actions:

...provision against aircraft collisions also protects the plant unit from other external threats and the possibility of malicious damage, but not against actual military operations. Provision against State-level military operations does not belong to the technical design basis of nuclear power plants. Here (VNp 396/1991 4§) unauthorised access also means – except for intrusion and infiltrating the site of a nuclear power plant – endangering the safety of the plant from outside the plant. Thus the general plant design, besides the use of explosives and weapons, should also take account of the use of High Power Microwave (HPM) radiation targeted towards the nuclear power plant and, especially, the possibility of using chemical and/or biological weapons which would endanger control room operation.

The effect of aircraft crashes and other external threats on the design of the plant unit has been discussed in section 5.8 with regard to layout, structure and functional design.

The protection of the plant unit against electromagnetic interference is based on a comprehensive solution where all crucial buildings related to plant safety and the cable channels connecting them attenuate electromagnetic interference to a sufficient extent. Generally, this objective is not reached by way of the utilised lightning protection, concrete reinforcements or sheet metal façade elements, and not necessarily even by utilising a combination of all the above-mentioned means. Thus the buildings will be furnished with custom-built copper gauze elements used to form the so-called Faraday cage. If necessary, the protection of electrical and electronic devices can be supplemented where required.
Plan for physical protection

TVO has drafted a preliminary security arrangements plan for the Olkiluoto 3 Nuclear Power Plant Unit describing the physical protection of the new plant unit. The Nuclear Energy Decree requires the drafting of a security plan and seeking approval for it from the Radiation and Nuclear Safety Authority. The security plan describes the way in which the physical protection consists of several structural barriers or restrainers, technical surveillance systems and administrative procedures completing each other. In connection with the acceptance procedure, the Radiation and Nuclear Safety Authority has asked the Ministry of the Interior for a statement on the issue. In addition to TVO’s plans, various other authorities have their own operation plans for threat situations at nuclear power plants.

The Radiation and Nuclear Safety Authority sent a request for comments concerning TVO’s security plan and security instructions to the Ministry of the Interior on August 31, 2004. The statement given by the Police Department of the Ministry of the Interior was sent to the Radiation and Nuclear Safety Authority on November 1, 2004. The Radiation and Nuclear Safety Authority sent the statement in question to TVO on November 5, 2004, for information and for actions. The statement given by the Ministry of the Interior contains some remarks concerning the planned physical protection and TVO’s security instructions. TVO has revised its security instructions in these respects and has also updated them, with the exception of some unfinished issues.

The reports sent by TVO present how the design bases and special requirements concerning physical protection have been taken into account. Thus no issues regarding physical protection have arisen indicating that the Olkiluoto 3 plant unit could not be implemented in accordance with the requirements.

Exercises and training related to physical protection are arranged regularly, both within the licensees organisation and in cooperation with various authorities. Certain development needs have become evident in the coordination between the licence-holder and the authorities at Olkiluoto. Thus the carrying out of alarms and operational cooperation should be developed by way of exercises related to more versatile communication tests and activation of operation than at present.

Summary

The Olkiluoto 3 Nuclear Power Plant Unit and its physical protection have been adequately designed to withstand external threats and unlawful actions.
The preliminary emergency preparedness plan belongs to the documents that shall be submitted to STUK in conjunction with the construction licence application, as provided in Section 35, paragraph 5 of the Nuclear Energy Decree. According to the Decision of the Council of State 397/1991, the emergency preparedness plan is prepared for the entire nuclear power plant, i.e. all the various plant units located at the site are considered in the same plan. Therefore, the Olkiluoto 3 Nuclear Power Plant Unit emergency preparedness plan to be applied during plant operation will be the same as the emergency preparedness plan for the existing units in an extended form.

During construction, the Olkiluoto 3 Nuclear Power Plant Unit as such will not cause any emergency response arrangements until radiation sources and/or nuclear fuel are brought to the plant - i.e., at the earliest, some time before operation is started. However, the construction site will cause updating requirements in the Olkiluoto 1 and Olkiluoto 2 plant units’ emergency planning; 500 - 600 people work at the operating plants each day, while during the construction phase a maximum of 2,500 people may work at the construction site. A separate access control has been planned for the construction site as well as an alarm system and evacuation spot for emergency situations. These correspond to the arrangements utilised at operational units for evacuating the personnel in a danger situation. According to present information, TVO is not planning to expand the accommodation facilities located at the plant site (accommodation for approximately 450 people).

The person who is responsible for emergency preparedness and physical protection at the Olkiluoto 3 Nuclear Power Plant Unit has been approved by STUK. The Olkiluoto power plant emergency response organisation has been complemented by taking account of the construction site of the new plant unit.

Training at the construction site contains instructions for the personnel’s activities in cases of accidents, and the construction site has also been taken into account in the emergency response organisation training and exercises of the Olkiluoto power plant.

The Olkiluoto 3 Nuclear Power Plant Unit design takes account of the emergency operation requirements by reserving room space near the control room for the emergency control centre. The support group belonging to the emergency response organisation will be located in the same office building shelter as the support group for the Olkiluoto 1 and 2 plant units. The type of the new plant unit differs from the present Olkiluoto plant units and presenting its process data using the present equipment utilised by the emergency response organisations requires the development of tools both at Olkiluoto and STUK. The environment radiation measurements beyond the Olkiluoto plant unit site will remain unchanged, but three stations measuring external radiation will be added at the plant site.
Data transfer between the new plant unit and TVO’s alert areas is included in the emergency planning, as well as data transfer from the plant location to STUK. Data transfer will be implemented according to the same principles as data transfer between the present plant units and emergency response organisations. STUK has presupposed that the renewal requirement concerning the present data transfer procedure will be evaluated at the same time. The objective is to secure a uniform procedure between the different plant units. Like the present plant units, the data transfer connection will also be constructed from the new plant unit’s training simulator to TVO’s and STUK’s emergency control centre.

The first emergency response exercise at the new plant unit in cooperation with the emergency response and rescue authorities will be organised before the granting of the operating licence.

TVO is obliged to regularly inform the local population in order to make provisions for emergency response situations. TVO, in cooperation with the rescue authorities, will update the information bulletin containing information on activities in cases of accidents distributed to the local population in accordance with Section 4 of the regulation 774/2001 issued by the Ministry of the Interior, and provides the population with iodine tablets up to 5 km distance from the plant, replenishing them according to the ageing of the tablets.

In accordance with Section 37, paragraph 3, of the Nuclear Energy Decree, STUK has asked the Department of Emergency Services of the Ministry of the Interior to submit a statement on the preliminary emergency preparedness plan. In its statement the Department of Emergency Services of the Ministry of the Interior has paid attention to the fact that, according to the present Rescue Act (468/2003), the on-site emergency manager of the power plant cannot act with authorisation power at the plant site. As a result of the rescue operation renovation, changes have also taken place in the terminology concerning it, and partly out-of-date terms have been used in the preliminary emergency preparedness plan. TVO has updated the emergency manager’s authorisations in the Olkiluoto power plant emergency preparedness plan and the terminology to be in accordance with the present Rescue Act.

With regard to emergency response arrangements, the design of the Olkiluoto 3 Nuclear Power Plant Unit, as well as the other actions and plans for actions related to it, and its construction are adequate at the plant site.

10 NUCLEAR WASTE MANAGEMENT

According to Section 19, paragraph 5, of the Nuclear Energy Act, one prerequisite for granting a construction permit for a nuclear facility is that the methods available to the applicant for arranging nuclear waste management, including the final disposal of nuclear waste and the decommissioning of the facility, are sufficient and appropriate.
The following is an assessment of the presented reports on nuclear waste management arrangements, which are mainly included in Appendix 12 of the construction licence application and Chapters 11 and 20 of the Preliminary Safety Analysis Report.

10.1 Final disposal of nuclear waste (Decision of the Council of State 398/1991)

The requirements specified in the Decision of the Council of State 398/1991 concern the final disposal of low and intermediate-level wastes from nuclear power plants, also known as reactor wastes. Detailed safety requirements are included in the Guide YVL 8.1. The holder of the construction licence and, subsequently, the holder of the operating licence, is responsible for the final disposal of reactor waste.

As of 1992, the reactor waste from the Olkiluoto 1 and 2 plant units has been disposed of in the disposal facility (VLJ cave) that is built in the bedrock in the vicinity of the plant site. The reactor waste from the Olkiluoto 3 Nuclear Power Plant Unit is also planned to be disposed of in the VLJ cave, with the exception of activated metal waste. The waste would be first disposed of in the current facilities and later in their extensions. Based on the current operating licence of the VLJ cave, only the waste from the Olkiluoto 1 and 2 plant units can be disposed of there, so the disposal of the waste from the Olkiluoto 3 Nuclear Power Plant Unit requires a revision to the operating licence for the VLJ cave.

The maintenance waste (trash, metal scrap etc.) of Olkiluoto 3 unit is similar to that of the Olkiluoto 1 and 2 plant units in terms of material characteristics and packaging method, which means their disposal would also be similar.

For drums containing dried ion exchange resins, concentrates and filter cartridges, a disposal package has been designed, which uses current 12-drum disposal boxes or a separately manufactured “half of the current 16-drum disposal box”. The first would contain six drums placed horizontally and the second four drums, after which the empty space in the box would be filled with concrete.

On the basis of preliminary judgement, the proposed disposal package is no poorer in terms of safety than the current disposal package for the bituminised waste from the Olkiluoto 1 and 2 plant units. To ensure that the requirements of the Guide YVL 8.1 are complied with, the waste product’s characteristics and possible interactions in disposal environment should be analysed more closely; significantly harmful effects, if any, could probably be reduced by changing the handling process or packaging method of the waste, if required.

The used ion exchange resins, which represent the most important waste type in terms of activity concentration but which are not accumulated in large amounts, could also be solidified in the bitumen solidification plant facilities of the Olkiluoto 1 and 2 plant units, if required.
STUK considers the plans for reactor waste disposal sufficient for the construction licence. However, the disposal of reactor waste generated at the Olkiluoto 3 Nuclear Power Plant Unit shall also be considered in the safety analysis of the VLJ cave, which will be updated in 2007.

10.2 Final disposal of spent nuclear fuel (Decision of the Council of State 478/1999)

After issuing a Decision of Principle concerning the new nuclear power plant unit on 17 January 2002, the Council of State also issued a Decision in Principle stating that the construction of the disposal facility for spent nuclear fuel, designed by Posiva Oy and to be built at Olkiluoto in Eurajoki, in an extended form for the processing and disposal of the spent nuclear fuel originating from the operations of the nuclear power plant unit, referred to in the Application for a Decision in Principle submitted to the Council of State by Teollisuuden Voima Oy on 15 November 2000, is in line with the overall good of society. On 24 May 2002, the Parliament decided that this decision shall remain in force (Parliament brief 9/2002 vp - M 5/2001 vp).

The requirements specified in the Decision of the Council of State 478/1999 concern the final disposal of spent nuclear fuel originating from the operations of the nuclear power plant. Detailed safety requirements are included in the Guides YVL 8.4 and YVL 8.5.

The spent fuel produced by the Olkiluoto 3 Nuclear Power Plant Unit is, with regard to its essential technical and safety features, similar to the fuel types for which the current disposal plans for spent nuclear fuel and the respective treatment methods have been developed by Posiva Oy. The specifications for the spent fuel bundles of the Olkiluoto 3 Nuclear Power Plant Unit are the following:
- a square lattice of 17x17 rods, width 21.4cm, length 480cm, total weight 800kg
- the amount of uranium is 533kgU, the maximum initial enrichment is 4.4%, and the maximum bundle burnup is 50MWD/kgU (the highest value for bundle burnup accepted in Finland to date is 45MWD/kgU).

The dimensions of a fuel bundle at the Olkiluoto 3 Nuclear Power Plant Unit are, therefore, substantially larger than those of the bundles at the current plant NPP units. Some fuel bundles include control rod groups or reactor instrumentation. The annual accumulation of spent fuel is estimated as being 40 tonnes of uranium (tU), amounting to 75 bundles. The current power plants generate approximately 70tU of spent fuel per year.

The spent fuel of the Olkiluoto 3 Nuclear Power Plant Unit is intended to be taken care of as follows: initially, the spent fuel is to be stored in the water pool storage at the fuel building for a few years and thereafter in the extension of the spent fuel storage at the plant site. The spent fuel is planned to be disposed of in the Olkiluoto bedrock after a cooling period of 30 to 40 years. This management concept is well founded in respect of both the statutory requirements and current technical possibilities.
The fuel building constructed together with the Olkiluoto 3 Nuclear Power Plant Unit withstands the external threats that are to be considered in the design (weather phenomena, aircraft crash, etc.). Given that the interim storage capacity for spent fuel generated by the Olkiluoto 1 and 2 units must in any case be extended towards the mid-2010s, the extension for the Olkiluoto 3 Nuclear Power Plant Unit can be made at the same time.

According to current legislation, final disposal in the domestic bedrock is, in practice, the only possible option for taking care of the spent fuel of the Olkiluoto 3 Nuclear Power Plant Unit, which has also been used as the starting point in the construction licence application. The Decision in Principle mentioned above covers also the final disposal in the Olkiluoto bedrock of the spent fuel generated by the Olkiluoto 3 Nuclear Power Plant Unit, equalling the amount of 2,500 tU. Because the final disposal with regard to the Olkiluoto 3 Nuclear Plant Unit would commence around 2040 at the earliest, other waste management options will for a long time remain technically possible.

Taking the spent fuel of the Olkiluoto 3 Nuclear Power Plant Unit into consideration will result in substantial changes in the current disposal plan of Posiva Oy, both in technical terms and in terms of schedule. A new type of waste canister must be designed for the fuel bundles of the Olkiluoto 3 Nuclear Power Plant Unit, and the disposal plans must also be adjusted to cover the handling of the larger bundles. The capacity of the final disposal repository will be increased by 60%, and the disposal schedule will span over the turn of the century.

The description of nuclear waste management presented in Appendix 12 of the construction licence application is quite generic in nature. The adjustment of Posiva’s disposal plan to suit the needs of the Olkiluoto 3 Nuclear Power Plant Unit should commence so that more detailed plans can be presented in the three-year program report for nuclear management – TKS-2006 – to be published in 2006.

As a conclusion, STUK states that TVO has sufficient plans and arrangements in place, with regard to the construction licence of the Olkiluoto 3 Nuclear Power Plant Unit, to implement the final disposal of spent nuclear fuel in Finland.

10.3 Decommissioning of plant units

On the basis of Section 20 of the Preliminary Safety Analysis Report, decommissioning has been accounted for in the design of the Olkiluoto 3 Nuclear Power Plant Unit. Many of the solutions obtained in order to decrease in-service radiation doses (for example the selection of materials, structural radiation protection, treatment of surfaces, and room arrangements) also improve the safety of decommissioning. The decommissioning plans for the existing nuclear power plant units at Olkiluoto are quite detailed. They also contain disposal plans for the decommissioning waste, including the
respective safety assessments. STUK last assessed these plans in 2004, in connection with which STUK gave a statement thereof to the Ministry of Trade and Industry. According to STUK's understanding, the decommissioning of the Olkiluoto 3 Nuclear Power Plant Unit and the disposal of the decommissioning waste can, in principle, be executed in a similar manner.

According to STUK's understanding, the decommissioning of the Olkiluoto 3 Nuclear Power Plant Unit has been sufficiently considered for the construction licence.

11 NUCLEAR FUEL MANAGEMENT AND HANDLING OF NUCLEAR MATERIALS

In addition to being a plant supplier, Framatome ANP is also a significant fuel supplier, and the analyses presented in the Preliminary Safety Analysis Report have therefore been made assuming that the reactor will be loaded with fuel supplied by Framatome ANP (the first loadings are included in the delivery contract). The maximum fuel bundle discharge burnup of 50MWd/kgU proposed by Framatome ANP exceeds the highest value of 45MWd/kgU currently accepted in Finland. However, the loading of the reactor core can be designed such that the acceptance limits specified on the basis of the analyses will not be exceeded.

When commencing the operation of the new plant unit, TVO is likely to organise a competition between fuel suppliers. The fuel types from the same supplier are also changing continuously, so provisions must be made for a case where the reactor, after a few operational periods, contains several types of fuel from several suppliers. This presents special requirements for maintaining Finnish expertise at TVO's and STUK's disposal, independent of plant suppliers, in order to be able to correctly dimension the safety margins for the ‘mixed cores’ so that unnecessary risks will not be taken. The required expertise and the measures needed for ensuring its availability are further discussed in section 12.4 below.

The nuclear safeguards are based on the Non-Proliferation Treaty (NPT) and the subsequent Safeguards Agreement signed by the IAEA, the EU Commission and the non-nuclear weapon states of the EU, in addition to the national Nuclear Energy Act and Decree. The EU Commission also has its own safeguards system that is based on the European Atomic Energy Community (Euratom) Treaty. In addition, the Commission has issued the regulation No. 3227/76 concerning the implementation of the safeguards. This regulation has subsequently been renewed by the proposal COM(2002)99 that is expected to enter into force in March 2005.

TVO has submitted to STUK a plan for arranging the safeguards that is necessary to prevent the proliferation of nuclear weapons in conjunction with the construction licence application, as provided in Section 35, paragraph 5, of the Nuclear Energy Decree. With regard to nuclear materials (uranium and plutonium) and other nuclear

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2 Translator’s note: Shall be European Atomic Energy Community
21.1.2005

items, the safeguards at the Olkiluoto 3 Nuclear Power Plant Unit are in accordance with the practices used in the existing units. TVO has announced that it will, on its own initiative, apply for all required import and possession licences during the construction phase, including those concerning nuclear items other than nuclear materials proper.

The Additional Protocol for the Safeguards Agreement based on the Non-Proliferation Treaty entered into force in the EU on 30 April 2004. The declarations required in the Additional Protocol in respect of the present plants at Olkiluoto and the new plant project have been submitted to the IAEA and, to the relevant extent, to the EU Commission within the time limits specified in the Protocol. The description of the plant site prepared in accordance with the Additional protocol, by which the IAEA must be granted access for the purpose of carrying out complementary accesses, also covers the new plant project.

TVO has been actively in contact with STUK in nuclear substance matters. In the light of the experience so far, it can be concluded that TVO takes the requirements concerning nuclear safeguards seriously and attempts to act in a manner that ensures the fulfilment of the international obligations of Finland and TVO.

STUK's opinion is that the safeguards to prevent the proliferation of nuclear weapons can be arranged effectively and comprehensively in Finland during the construction and operation of the new plant.

12 OTHER REQUIREMENTS

In addition to the safety requirements recorded in the Decisions of the Council of State, a few other safety-related issues or requirements imposed by the Nuclear Energy Act are also discussed below. These concern the environmental impact of the new plant unit at Olkiluoto (Section 19, paragraph 2, of the Nuclear Energy Act), the arrangements for the implementation of control carried out by STUK during the construction phase (Section 19, paragraph 7, of the Nuclear Energy Act) and the applicant's expertise and, in part, financial prerequisites (Section 19, paragraphs 8 and 9, of the Nuclear Energy; this also relates to the safety culture and quality management discussed above in sections 3.2 and 3.3).

The new plant unit does not cause radiation or nuclear safety hazards during the construction phase. As a rule, nuclear safety and radiation-related safety issues only actualise when fresh fuel is brought into the plant for the first time. However, some of the measuring devices containing radiation sources, the installation of which might become necessary well before the reactor is ready for loading, may constitute an exception to this rule. Fresh fuel will be brought into the plant towards the end of the construction phase, before the start-up testing of the plant unit. However, the nuclear start-up testing may only be commenced after the operating licence has been granted for the plant.
Provisions for emergencies occurring at the Olkiluoto 1 and 2 nuclear power plant units will be made for the construction site of the new plant unit as detailed in section 9 below.

12.1 Siting in Olkiluoto in terms of environmental impact

Chapter 4 of this safety assessment discusses the siting of the Olkiluoto 3 Nuclear Power Plant Unit in Olkiluoto with regard to radiation releases, Chapter 8 with regard to physical protection arrangements and Chapter 9 with regard to emergency preparedness arrangements. The siting has other environmental impacts as well; these have been presented in the Environmental Impact Assessment that was completed in 2000 (EIA, concluded by a statement from the liaison authority, dated 17 February 2000, No. 10/815/98, Ministry of Trade and Industry).

TVO applied for an environmental permit to supplement the Olkiluoto power plant by a new nuclear power plant unit in January 2003, and subsequently supplemented the application in September 2004. STUK will submit a statement about TVO's application to the Western Finland Environmental Permit Authority in the first quarter of 2005.

The thermal load arising from the discharge of cooling water will be one of the most significant environmental impacts of the normal operation of the plant unit. Taken together, the nuclear power plant units Olkiluoto 1 and 2 consume cooling water at an approximate rate of 60 $\text{m}^3/\text{s}$, and the temperature of the cooling water increases in the plants by approximately 10 °C. The cooling water need of the new unit is approximately 53 $\text{m}^3/\text{s}$, with a temperature increase of 12 °C. The thermal load on seawater arising from the new plant thus slightly exceeds the total thermal load arising from the existing units. The cooling water of the new plant unit is pumped from Olkiluodonvesi, from the west side of the cooling water intake channels of the existing plant units. The discharge will be carried out using the discharge channel of the existing units, which will be extended for the purpose. According to EIA, the warmed-up cooling water will approximately double the size of the water area being warmed up. The shape of the affected area will remain roughly the same. In the winter the size of the area with weakened ice and molten water is estimated to grow more than double. The shape of the area affected by the warmed-up water is determined by the weather (wind conditions in particular), both in the summer and in the winter, rather than the location of the discharge site. According to EIA, the selected discharge site is among the most beneficial in terms of the environment.

The new nuclear power plant will be connected to the national power transmission grid via new 400 kV and 110 kV transmission lines. In connection with the construction of the new plant unit, the present 400 kV substation at Olkiluoto and the line routes connected to it will be extended to accommodate two 400 kV transmission lines per

Translator’s note: the 10°C stated in the original is a typographical error; the correct value would have been 13°C.
each plant unit. The new transmission lines will enhance the reliability of the 400 kV power transmission grid. In this conjunction, Fingrid Oyj will strengthen the national grid by constructing new transmission links from Olkiluoto to Huittinen and Ulvila to Kangasala. These arrangements will enhance the national grid's ability to withstand disturbances, such as those arising when units are disconnected from the grid. The environmental impact of the new transmission lines outgoing from Olkiluoto has been discussed in a separate EIA report concerning the actual transmission line construction work, which has been prepared by Fingrid.

The environmental impact arising from the siting of the Olkiluoto 3 Nuclear Power Plant Unit in Olkiluoto have been sufficiently accounted for with regard to the matters falling within the scope of STUK's area of expertise.

As a summary to the aforementioned conclusions, as well as those presented in Chapters 4, 8 and 9, STUK considers the Olkiluoto plant site an appropriate location for the Olkiluoto 3 Nuclear Power Plant Unit with regard to the matters STUK is commissioned to review.

### 12.2 STUK's opportunities for supervision

According to Section 19, paragraph 7, of the Nuclear Energy Act, TVO is obliged to arrange entry for STUK to inspect and control the manufacture of nuclear fuel and the constructions and/or equipment intended as parts of the nuclear facility, as well as their quality control to the extent defined in the Finnish regulations, in all locations where any work relating to the safety of the Olkiluoto 3 Nuclear Power Plant Unit is being carried out. TVO's and STUK's opportunities for supervision have been recorded in the plant contract concerning the Olkiluoto 3 Nuclear Power Plant Unit, from which they will be forwarded to the partial delivery and sub-contracting agreements.

A description of the supervision opportunities in accordance with Section 35 of the Nuclear Energy Decree has been submitted to STUK. The emphasis therein is on the submission of components, structures and system important to safety documents for assessment by the regulatory body. The review of documents and the acceptance of designs are indeed a precondition for manufacturing the components, structures and systems in accordance with the design approved by the applicable authorities. The manufacture cannot therefore be initiated until the applicable authority and TVO have approved the documents pertaining to the activity in question. This requirement has not always been met in the Olkiluoto 3 project, and the lack of clarity relating to the preconditions for initiating manufacture have been dealt with in cooperation with STUK, TVO and the plant supplier. Together with the plant supplier, TVO has created a procedure for ensuring the identification and approval of matters that require the approval of the authorities prior to initiating manufacture.

In light of the experience so far, STUK's on-site access to supervise the manufacture of equipment at its own discretion has involved no problems.
In addition to the document review and the supervision of manufacture, it is also essential to arrange entry for the authorities to inspect the design concerning the Olkiluoto 3 Nuclear Power Plant Unit, as well as the testing and research indicating the functionality of safety-significant components, structures and systems. With regard to design activities, STUK's opportunities have been sufficiently described in the Preliminary Safety Analysis Report. With regard to tests and research, the information is to be delivered to STUK in the documents relating to the respective component, structure or system.

For the purposes of supervising the construction, installation and commissioning work that is subsequently carried out at the plant site, STUK is to be provided with sufficient surveillance facilities with adequate accessories. The designing of these facilities has already been commenced.

STUK has approved the aforementioned description of surveillance opportunities. Ensuring the surveillance opportunities during the construction phase requires that all parties involved have a shared understanding of the approvals that are required before the manufacture can be started. In addition, a sufficient amount of time must be reserved for the authorities to process the matters in question. Information about the manufacturing schedule of safety-important components, structures and systems must be submitted to STUK early enough to allow STUK to ensure that the supervisory measures required in the YVL Guides can be carried out.

12.3 Applicant's prerequisites for implementing the project

Implementing the nuclear power plant construction project requires that the applicant has the necessary expertise available (Section 19, paragraph 8, of the Nuclear Energy Act) and sufficient financial prerequisites (Section 19, paragraph 9, of the Nuclear Energy Act). In this section STUK provides an assessment of the expertise TVO has at its disposal. With regard to TVO's financial prerequisites, STUK assesses the experience gained from the operations in the deregulated electricity market in respect of the safety of nuclear power plants. Other financial prerequisites of the project are assessed by other authorities (Ministry of Trade and Industry).

Expertise

The most important expert body servicing TVO in the plant project is the plant vendor. As was the case with the previous plant units Olkiluoto 1 and 2, the Olkiluoto 3 Nuclear Power Plant Unit has also been ordered on a turnkey basis. The plant vendor has the whole globe as its market area; a construction project for a new plant unit has been initiated in France. The vendor markets its products continuously and on a global scale. On the basis of the inspections and observations made in connection with the processing of the construction licence application it can be stated that the consortium
formed by Framatome ANP and Siemens AG holds sufficient expertise in the field of nuclear technology. However, the consortium's responsibility for the plant ends after the operating licence process, when the plant unit is ready for final commissioning. TVO is also responsible for the licensing of the plant unit during the construction phase; according to the delivery contract, the consortium is responsible for the licensability of the plant unit.

TVO needs to have sufficient internal expertise in all technical and other areas relating to the safety of the plant unit in order to be able to successfully bear the responsibility for the total plant safety attributable to the holder of the operating licence. This section discusses the internal expertise of TVO. Section 12.4 also discusses the maintenance of domestic expertise, as most of the company's experts will be hired from Finland in the future as well.

In the Preliminary Safety Assessment it is ascertained that *TVO bought the Olkiluoto plants from the supplier on a turnkey basis, who, in problematic situations, was ready to offer its clients help even beyond the clients' requests. The experience related to plant modifications and the modernization project proves that this kind of integrated service is no longer available on the market. A significant reason for the service-mindedness of the then-current plant vendor, Asea Atom, was that, for this vendor, Finland was the most important foreign market at the time the Olkiluoto units were purchased, and Olkiluoto, in turn, was the first, and ultimately the only, nuclear power plant assembly the vendor ever sold abroad.*

The Preliminary Safety Assessment emphasised that *if the new plant will be constructed, already at the construction phase TVO has to familiarize itself with the construction and design basis of the plant thoroughly in a considerably more profound way than during the construction of its existing units. TVO's own familiarity is the prerequisite of successful plant operations and maintenance, which respectively require development of TVO's organization and lines of action.*

On the use of external expert organisations and consultants to support internal organisation and operations, the Preliminary Safety Assessment states that *Using the outside consultants is an appropriate alternative when due to large amount of work, particular specialties or other corresponding reasons it is not feasible to have adequate expertise or personnel inside the company. This procedure also requires of TVO deep and profound expertise in all fields of technology having effect on the plant safety in order to be able to utilize the outside expertise to carry out right tasks at the right moment. The one who needs outside special services has to attend to maintaining the needed services to a sufficient extent throughout the lifetime of the plant.*

When setting up the implementation project for the plant unit, TVO expanded its organisation and recruited experts from several fields, especially regarding project implementation. With regard to high-level nuclear and safety engineering technology expertise, TVO's technical organisation is still thin and quite heavily loaded due to the tight project schedule. An energy company cannot, of course, be structured like an
engineering organisation in other areas of technology related to the power plant, but in
the case of demanding technology TVO should nevertheless ensure that it has sufficient
internal expertise for purchasing appropriate services – that is, for correctly defining the
tasks to be purchased and evaluating the results (this is often referred to with the
notions of 'customer competence' and 'intelligent customer').

Provided the Olkiluoto 1 and 2 Nuclear Power Plant Units are boiling water reactors,
the pressure water reactor of the Olkiluoto 3 Nuclear Power Plant Unit represents a type
of technology that is entirely new to TVO. There is, however, expertise relating to
pressure water reactor technology available in Finland, thanks to the Lovisa power
plant. Special effort is required from TVO to facilitate the development of special
expertise in the course of the project and to maintain it during the operation phase,
which is planned to be very long.

TVO should, therefore, ensure that its organisation, strengthened during the
construction phase, remains competent enough during the transition to the operation
phase, particularly in the fields of nuclear safety and mechanical and automation
technology.

About the applicant's financial preconditions

The financial preconditions of the Olkiluoto nuclear power plant project are primarily
assessed by authorities other than STUK (Ministry of Trade and Industry). The licensee
has financial obligations to, e.g., make provisions for the costs of nuclear waste
management (for the related technical aspects, see section 10.2 above) and to cover the
nuclear liability (see section 12.5 below). The financial position and business
environment of the licensee also has effect on the safety of the plants, and STUK is
therefore keeping track of the trends in investments made to improve the safety of
plants currently in operation.

As the Finnish electricity market was deregulated nearly 10 years ago, there is
relatively long practical experience of the operations of nuclear power companies in the
deregulated market in Finland. Since the deregulation of the electricity market, there
have been no indications of TVO restricting its investments or otherwise attempting to
cut down its costs by means of personnel reductions. On the other hand, TVO does not
conduct its operations on a market-driven basis in the conventional sense of the term
because the owners purchase its all of its production. However, the owners have always
required that TVO's electricity production be competitive in the market. TVO has
adhered to a policy whereby the financial performance of operations is ensured by
maintaining a high availability factor of the plant, meaning that even minor
disturbances are to be avoided, which, in turn, requires that the plant units be kept in
good condition. This requires investments that, for their part, contribute to the
improvement of safety; proactive prevention of disturbances is always the primary goal
in safety planning as well.
12.4 Maintaining domestic expertise

Sufficient domestic expertise in those technology areas that are crucial with regard to nuclear safety is one of the basic preconditions of safe operation for the entire service life of the plant. The maintenance of the competence infrastructure is essential for ensuring the operational capabilities of all organisations operating in the industry. In addition to the licensees, the Radiation and Nuclear Safety Authority and relevant research institutions also need sufficient internal expertise in order to be capable of successfully carrying out their respective tasks.

Foreign expertise cannot be utilised without sufficient domestic expertise, and there are no guarantees that precisely the kind of expertise we need is maintained in other countries. At this moment, one of the two originating countries of the Olkiluoto 3 Nuclear Power Plant Unit, France, is strongly committed to nuclear technology, whereas German nuclear power plants have traditionally relied on the support from the German plant suppliers. Similar confidence was placed in the continuous availability of support from Sweden, the originating country of the plant units Olkiluoto 1 and 2, and from the Swedish plant supplier when the units were being constructed, but the situation has changed since then. It is, therefore, not enough that the expertise in the industry is considered sufficient at the construction phase; provisions need to be made for the long service life of the plant as well.

The funding of safety research for maintaining and renewing the expertise has been secured in Finland up to the necessary minimum level when considering the needs arising from the present scope of nuclear energy usage by means of two new separate funds formed in 2004 into the State Nuclear Waste Management Fund. These monies are collected from the users of nuclear energy. Maintaining a high level of expertise also requires high-level undergraduate training in the nuclear sector as well as research organisations that value high-level special expertise. Both of these must to be maintained in Finland to ensure the preconditions for the use of nuclear power in Finland regardless of the energy and education policies opted for in other countries.

In recent years the general trend in the world of research and education has been to favour quantity over quality. This trend is the exact opposite of what the nuclear industry needs. The number of completed degrees is being used as the criterion for allocating teaching resources in the universities. This is disastrous for small disciplines with small numbers of students, such as nuclear engineering. The training needs of the nuclear energy industry to cover the generation change already underway, as well as the natural attrition of personnel, have been estimated to amount to 15 to 20 university graduates per year, and this number is further divided between several Finnish technology universities. After initiating the new plant project, the need for additional personnel has increased and is estimated to amount to 30 to 35 university graduates per year. According to the prevailing financing models, continuing with such small-scale undergraduate teaching at the universities would not be viable at all, not to mention post-graduate programmes and basic research.
In order to ensure the availability of high-quality expertise, undergraduate training alone is not enough; it is essential to also have post-graduate training and related basic research. During the past few years Finnish research organisations have not invested in maintaining excellence in nuclear technology research. At the same time, high-level expertise has transferred from the nuclear industry to other industries. As part of the emergent generation change in the nuclear industry, current employees are also retiring from work altogether.

The use of nuclear energy can only be kept in line with the overall good of society if the society, for its part, commits to maintaining an education and research infrastructure, as well as other social structures attending to safety (various authorities, emergency planning arrangements, etc.), that constitutes a precondition for the safe use of nuclear energy.

Measures need to be taken to secure a high quality of teaching and research, and the continuance of higher education, under- and post-graduate training and the related basic research, and research organisations, in particular, need to set their ambitions on a sufficiently high level, in order to ensure that the type of excellence and special expertise crucial in terms of nuclear safety can be maintained.

12.5 About factors presented in the Preliminary Safety Assessment and its supplement

The Preliminary Safety Assessment dated 7 February 2001, and its attachment dated 8 January 2002, discuss the factors to be considered when designing a new plant unit on the basis of the requirements specified in the respective Decision of the Council of State and the YVL Guides. The technical solutions of the EPR plant alternative, presented in the Decision of Principle phase, have in some respects been changed to comply with the Finnish requirements. All technical issues of this type, including those that are not directly evident in the requirements specified in the respective Decision of the Council of State, have already been discussed above. The technical factors to be considered as per the Preliminary Safety Assessment have been given sufficient consideration with regard to the construction licence.

With regard to the nuclear liability matters, the Preliminary Safety Assessment states that The nuclear liability is prescribed in the Nuclear Liability Act. The Nuclear Liability Act takes into account the international treaties concerning Finland, which mainly set the minimum limits to the liabilities for nuclear damage. Raised liabilities can be enacted nationally, as is also done in some countries. In this connection STUK wants to state that the present liabilities for damage in effect in Finland are not sufficient to cover the costs of all imaginable severe reactor accidents. Negotiations to develop the international treaties in question are under way. It is presumable that in the near future the minimum amounts of liabilities for damage will significantly increase. The case is problematic because no upper limit in marks can reasonably be determined for the liabilities for damage.
The international negotiations for the renewal of the Paris and Brussels Conventions concerning nuclear liability have been concluded, and in the conventions signed in 2004. It has been decided to more than triple the funds available for compensating nuclear damages compared with the present situation. The conventions are likely to be ratified in the member countries over the next few years. The possible needs for amending Finland's present nuclear liability legislation were assessed by a committee specifically appointed for the task, and the legislation is currently being changed on the basis of the committee's report. Amendments to the international conventions are likely to be incorporated in the Finish legislation as well. In addition, the committee's report proposes, as a significant new factor, that an unlimited liability be imposed on the licensee of the nuclear facility in cases where the damages exceed the funds allocated for compensations as specified in the conventions.

12.6 International Nuclear Safety Convention and International Nuclear Waste Convention

The International Nuclear Safety Convention, SopS 74/1996 (INFCIRC/449), a collection of top-level nuclear safety principles legally binding the States that have joined the convention, was signed in 1994. Finland joined the convention right from the beginning, and it has been effective as of 1996.

Likewise, the International Nuclear Waste Convention, SopS 36/2001 (INFCIRC/546), a collection of top-level nuclear waste management principles legally binding the States that have joined the convention, was signed in 1997. Finland joined the convention right from the beginning, and it has been effective as of 2001.

The matters regulated by the International Nuclear Safety Convention and the International Nuclear Waste Convention are covered by the Finnish legislation, Decisions of the Council of State and regulations, on which this safety assessment is based. The implementation of the conventions is reviewed at the meetings organised by the IAEA every three years, for the purpose of which each member country must submit a report on its actions. The next international review meeting in which the implementation of the International Nuclear Safety Convention will be assessed will be held in April 2005. The Finnish report was submitted to the parties for review in September 2004, and the plan for constructing the Olkiluoto 3 Nuclear Power Plant Unit has been considered in the report.
13 SUMMARY

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

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

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

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

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

The use of nuclear energy requires a licence (Section 19 of the Nuclear Energy Act).

Because the Olkiluoto 3 Nuclear Power Plant Unit is a nuclear facility of considerable general significance as defined in Section 11 of the Nuclear Energy Act, a Decision in Principle of the Council of State is required for granting a construction licence (Section 18 of the Nuclear Energy Act). The Council of State issued a Decision in Principle on the construction of the plant unit on 17 January 2002, and Parliament decided on 24 May 2002 that it shall remain in force. According to Section 19 of the Nuclear Energy Act, the granting of a construction licence requires, in addition to a Decision in Principle remaining in force, that the 10 preconditions below be fulfilled. In this assessment STUK has assessed the fulfilment of the requirements marked in bold; the section of this assessment in which the matter is discussed is provided within parentheses. Matters not falling within the mandate of STUK will be assessed by other authorities.

According to Section 19 of the Nuclear Energy Act, a licence to construct a nuclear facility can be granted:

1. if plans concerning the nuclear facility, its central operational systems and components entail sufficient safety and protection of workers, and the population's safety has otherwise been taken into account appropriately when planning operations (sections 2 to 7 and 9);

2. if the location of the nuclear facility is appropriate with respect to the safety of the planned operations and environmental protection has been taken into account appropriately when planning operations (sections 4, 8, 9 and 12.1);

3. if physical protection has been taken into account appropriately when planning operations (sections 5.8 and 8);

4. if a site has been reserved for constructing a nuclear facility in a town plan or building plan in accordance with the Building Act (370/58), and the applicant has possession of the site required for the operation of the facility;
21.1.2005

5. if the methods available to the applicant for arranging nuclear waste management, including the final disposal of nuclear waste and the decommissioning of the facility, are sufficient and appropriate (section 10);
6. if the applicant's plans for arranging nuclear fuel management are sufficient and appropriate (section 11);
7. if the applicant's arrangements for the implementation of control by the Radiation and Nuclear Safety Authority (STUK) as referred to in paragraph 3 of section 63(1) [of the Nuclear Energy Act], in Finland and abroad, and for the implementation of control, as referred to in paragraph 4 of section 63(1) [of the Nuclear Energy Act], are sufficient (section 12.2);
8. if the applicant has the necessary expertise available (sections 12.3 and 12.4);
9. if the applicant has sufficient financial prerequisites to implement the project and carry on operations; further
10. if the applicant is otherwise considered to have the prerequisites to engage in operations safely and in accordance with Finland's international contractual obligations (sections 11, 12.5 and 12.6); and the planned nuclear facility otherwise fulfils the principles laid down in sections 5-7.

With regard to points 1 to 3, the plans and arrangements presented by TVO are sufficient and appropriate in respect of safety for granting the construction licence, with the following reservations and restrictions:

- Instead of the upper limit for maximum fuel bundle discharge burnup of 50MWd/kgU presented in the Preliminary Safety Analysis Report (PSAR), the maximum limit of 45MWd/kgU shall be used, unless it can be proven through tests that the targeted value fulfils all of the safety requirements; and

- The detailed design of the systems and structures of the new plant unit shall be continued and further specified during the construction phase. STUK has required that TVO submit detailed, system-specific pre-inspection documents to STUK for approval.

With regard to points 5 to 8, the plans, methods and arrangements presented by TVO are sufficient and appropriate in respect of the safety of the Olkiluoto 3 Nuclear Power Plant Unit for granting the construction licence, with the following reservations and restrictions:

- The safety analysis of the disposal facility for reactor waste, the VLJ cave, is intended to be revised in 2007. The disposal of reactor waste generated at the Olkiluoto 3 Nuclear Power Plant Unit shall also be considered in the revised analysis because the present safety analysis only covers the reactor waste generated at the Olkiluoto 1 and 2 nuclear power plant units;

- The account of nuclear waste management presented in Appendix 12 of the construction licence application is quite generic in nature. The adjustment to Posiva Oy's disposal plan to suit the needs of the Olkiluoto 3 Nuclear Power Plant Unit...
should be commenced so that more detailed plans can be presented in the three-year assessment of nuclear management – TKS-2006 – to be published in 2006;

- To guarantee STUK's opportunities for regulatory control, a sufficient amount of time shall be reserved for the authorities to process the required matters during the construction phase. Information on the manufacturing schedule of safety-important components, structures and systems shall be submitted to STUK early enough to allow STUK to ensure that the supervisory measures required in the YVL Guides will be implemented;

- TVO is to ensure that its expertise remains sufficient during the future operation of the plant unit. Due to the special features of the new plant unit and the technology used therein, TVO should therefore ensure that its organisation, strengthened during the construction phase, remains competent enough during the transition to the operation phase, particularly in the fields of nuclear safety and mechanical and automation technology; and

- The use of nuclear energy can only be kept in line with the overall good of society if the society, for its part, commits to maintaining an education and research infrastructure, as well as other social structures attending to safety (various authorities, emergency planning arrangements, etc.), that constitutes a precondition for the safe use of nuclear energy. In particular, measures need to be taken to maintain domestic expertise, to secure the continuance of higher education (under- and post-graduate training) and the related basic research in the field of nuclear industry, and to further excellence in research.

With regard to point 9, STUK states that the Finnish electricity market has already been open to competition for 10 years with no adverse effects in respect of the investments relating to the safety of TVO's plant having been observed.

With regard to point 10, the international contracts concerning nuclear material control and nuclear liability matters, as well as the International Nuclear Safety Convention and International Nuclear Waste Convention, fall within STUK's area of responsibility. The requirements of the international contracts are fulfilled through Finnish legislation and prevailing practices. No such factors on the basis of which the planned nuclear facility could be deemed not to comply with the principles laid down in Sections 5 to 7 of the Nuclear Energy Act have arisen in the course of STUK’s supervisory activities.

As a conclusion to all of the above, the overall assessment of STUK is that the Olkiluoto 3 Nuclear Power Plant Unit can be considered as being safe for construction in accordance with Sections 5 to 7 of the Nuclear Energy Act.