STUK

STUK-B-YTO 196 December 1999

OPERATION OF FINNISH NUCLEAR POWER PLANTS

Quarterly report, 2nd quarter 1999

Kirsti Tossavainen (ed.)

STUK • SÄTEILYTURVAKESKUS • STRÅLSÄKERHETSCENTRALEN
RADIATION AND NUCLEAR SAFETY AUTHORITY

STUK

-B-YTO 196 December 1999

OPERATION OF FINNISH NUCLEAR POWER PLANTS

Quarterly report, 2nd quarter 1999

Kirsti Tossavainen (ed.)

STUK • SÄTEILYTURVAKESKUS • STRÅLSÄKERHETSCENTRALEN
RADIATION AND NUCLEAR SAFETY AUTHORITY

ISBN 951-712-354-X
ISSN 0781-2884

Oy Edita Ab, Helsinki 1999

TOSSAVAINEN, Kirsti. Operation of Finnish nuclear power plants. Quarterly report, 2nd quarter 1999. STUK-B-YTO 196. Helsinki 1999. 21 pp. + Appendices 2 pp.

ISBN 951-712-354-X
ISSN 0781-2884

Keywords: PWR, BWR, NPP operating experience

ABSTRACT

Quarterly reports on the operation of Finnish NPPs describe events and observations relating to nuclear and radiation safety that the Finnish Radiation and Nuclear Safety Authority (STUK) considers safety significant. Safety improvements at the plants are also described. The report includes a summary of the radiation safety of plant personnel and the environment and tabulated data on the plants' production and load factors.

All Finnish NPP units were in power operation for the whole second quarter of 1999, with the exception of the annual maintenance outages of the Olkiluoto plant units. The load factor average of the plant units in this quarter was 93.1%.

Two events in this quarter were classified Level 1 on the INES Scale. At Olkiluoto 1, a valve of the containment gas treatment system had been in an incorrect position for almost a month, owing to which the system would not have been available as planned in an accident. At Olkiluoto 2, main circulation pump work was done during the annual maintenance outage and a containment personnel air lock was briefly open in violation of the Technical Specifications. Water leaking out of the reactor in an accident could not have been directed to the emergency cooling system because it would have leaked out from the containment via the open personnel air lock.

Other events in this quarter had no bearing on the nuclear or radiation safety of the plant units.

The individual doses of NPP personnel and also radioactive releases off-site were well below authorised limits. Radioactive substances were measurable in samples collected around the plants in such quantities only as have no bearing on the radiation exposure of the population.

CONTENTS

1 INTRODUCTION

According to the Nuclear Energy Act (990/1987), regulatory control of the use of nuclear energy in Finland belongs to the Radiation and Nuclear Safety Authority (STUK). STUK's functions also include control of physical protection and emergency preparedness, and nuclear material safeguards. The scope of NPP regulatory control and inspections is given in Appendix 1 and general information about Finnish NPPs in Appendix 2.

STUK publishes quarterly a report on the operation of Finnish NPPs. In this report, plant events and observations are described, tabulated data on the plants' production and availability factors are given and the radiation safety of plant personnel and the environment is summarised. Plant safety improvements are also reported.

The report is based on information submitted to STUK by the utilities and on observations made by STUK. The events described in the report are classified on the International Nuclear Event Scale (INES).

2 OPERATION OF NPPS IN APRIL–JUNE 1999

The plant units were in power operation for the whole annual quarter, with the exception of the annual maintenance outages of the Olkiluoto plant units.

Nuclear's share of total electricity production in Finland was 36.3% in this quarter and the load factor average of the plant units was 93.1%. Detailed production and availability figures are given in Tables I and II.

Power diagrams describing electricity generation at each plant unit and the causes of power reductions are given in Figs 1–4.

Table I. *Plant electricity production and availability.*

	Electricity production (gross, TWh)		Availability factor (%)		Load factor (%)	
	Second quarter 1999	From beginning of 1999	Second quarter 1999	From beginning of 1999	Second quarter 1999	From beginning of 1999
Loviisa 1	1.10	2.20	100.0	100.0	98.4	99.1
Loviisa 2	1.11	2.22	100.0	100.0	99.6	100.2
Olkiluoto 1	1.66	3.56	90.7	95.3	87.2	94.3
Olkiluoto 2	1.64	3.55	89.0	94.5	86.6	93.8

$$\text{Availability factor} = \frac{\text{generator synchronized (h)}}{\text{calendar time (h)}} \cdot 100\%$$

$$\text{Load factor} = \frac{\text{gross electricity production}}{\text{rated power} \cdot \text{calendar time (h)}} \cdot 100\%$$

Table II. Nuclear energy in Finnish electricity production.

	Second quarter 1999	From beginning of 1999	1998
Nuclear electricity production (net, TWh) [a]	5.3	11.1	21.0
Total electricity production in Finland (net, TWh) [a]	14.6	33.9	67.2
Nuclear's share of total electricity production (%)	36.3	32.6	31.2
Load factor averages of Finnish plant units (%)	93.1	96.7	91.6 [b]

a) Source: Statistics compiled by the Finnish Electricity Association
b) The load factor average in 1998 takes the plant unit power upratings into account in such a way that the value of rated electrical power that corresponds to maximum allowable reactor power in each point of time is used as rated electrical power (gross).

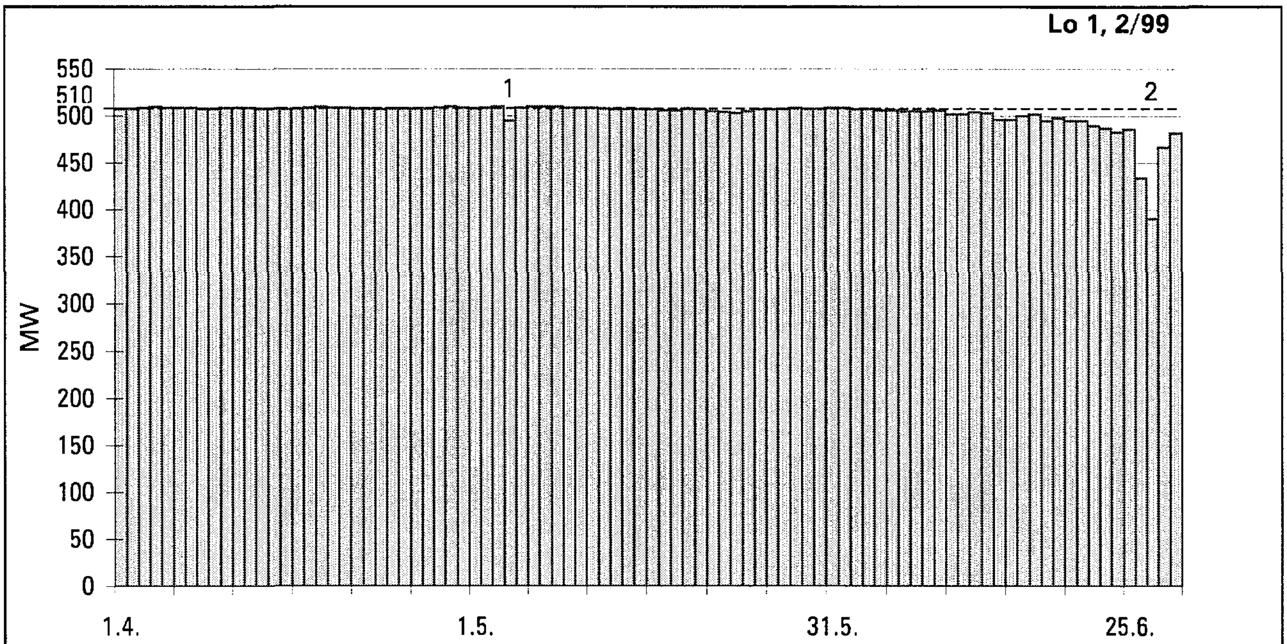
2.1 Annual maintenance outage of Olkiluoto 1

The 20th refuelling and maintenance outage of Olkiluoto 1 was from 16 to 25 May 1999. The plant unit was off the grid for about nine days.

In addition to Teollisuuden Voima Oy's own staff, the maximum number of external workers participating in the outage at a time was 644. The collective radiation dose arising from the outage work was 0.35 manSv (0.72 manSv in 1998). The highest individual dose was 9.0 mSv.

During the plant unit's shutdown phase on 16 May 1999, operation of the isolation valves of the reactor's main steam lines was tested. The valves are located inside the reactor containment and since they are part or the containment isolation function they must close tightly in case of various transient and accident situations. The valves close automatically if necessary. The test was meant to demonstrate that the valves operate reliably also at the uprated 2500 MW power. In post-testing valve tightness tests, one untight valve was found. Nothing out of the ordinary was found in its structure and the valve's untightness was attributed to particles, which had loosened into the piping during testing. According to STUK the reliable operation of the valves had not been demonstrated well enough. STUK therefore required that in the future the utility is to apply for STUK's approval for the starting up of both Olkiluoto 1 and 2 after outages that have been preceded by the closing of the valves in question. STUK's approval is usually not required for plant start-up after brief operational interruptions if the plant unit's systems have been operating as planned during the plant shutdown.

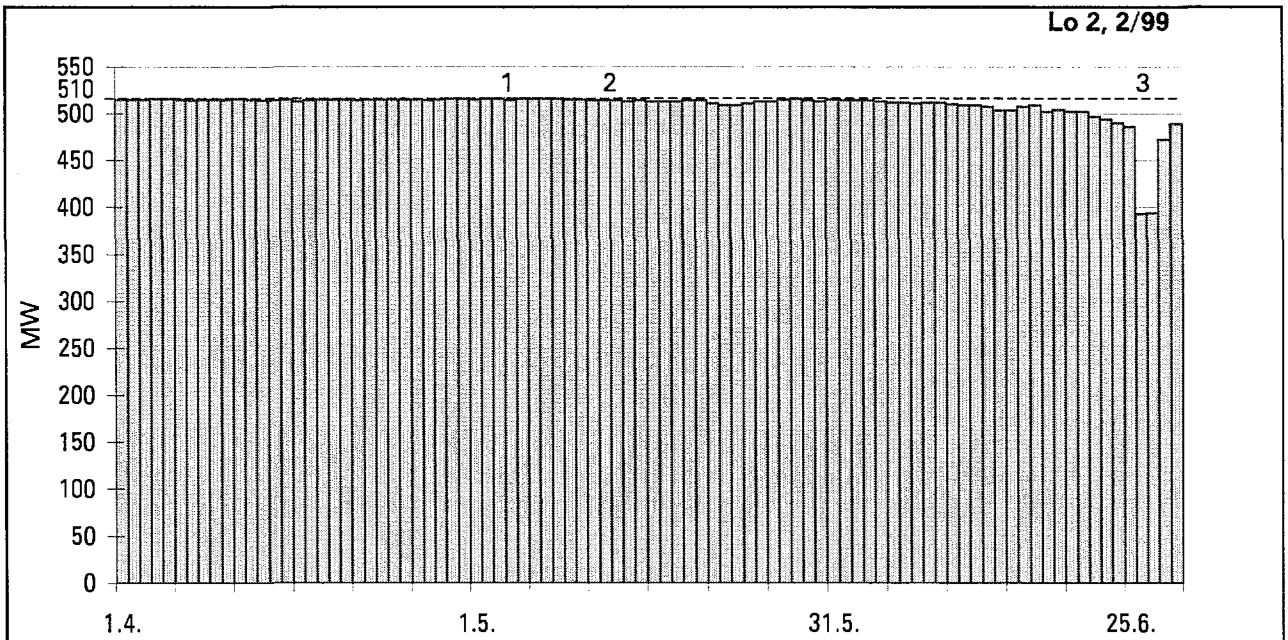
Cracked sections of the emergency cooling system piping located inside the reactor pressure vessel were repaired during the outage. The system comprises four redundant pipelines and, in the event of an accident, cooling water is directed to the reactor upper plenum by means of the piping sections located inside the reactor pressure vessel. During periodic inspections in the 1998 annual maintenance outage, cracks had been detected in these pipes, which were temporarily repaired (STUK-B-YTO 184, 1999). In the inspections now conducted, new cracks were observed in three of the system's pipelines. The largest one was a branching crack, assessed at ca. 24 cm in length. One of the cracks, temporarily repaired in 1998, had grown. The cracked piping sections were removed and replaced with new piping segments that had thermal protection. The uncracked pipe was equipped with a thermal shield. The thermal shield is made of material that has better thermal fatigue resistance than the piping and



1 Warranty tests of turbines.

2 Slight electricity demand during Midsummer; lowest reactor power was 84%.

Fig 1. Daily average gross power of Loviisa 1 in April–June 1999.

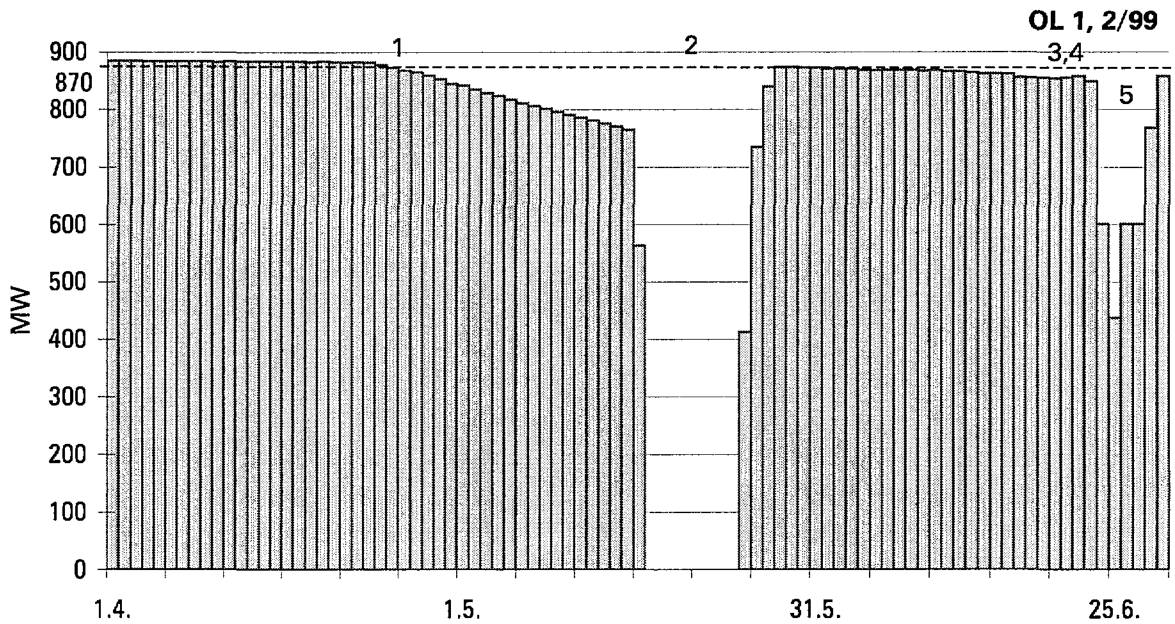


1 Warranty tests of turbines.

2 Rector control rod dropped to a low position owing to a low frequency converter failure.

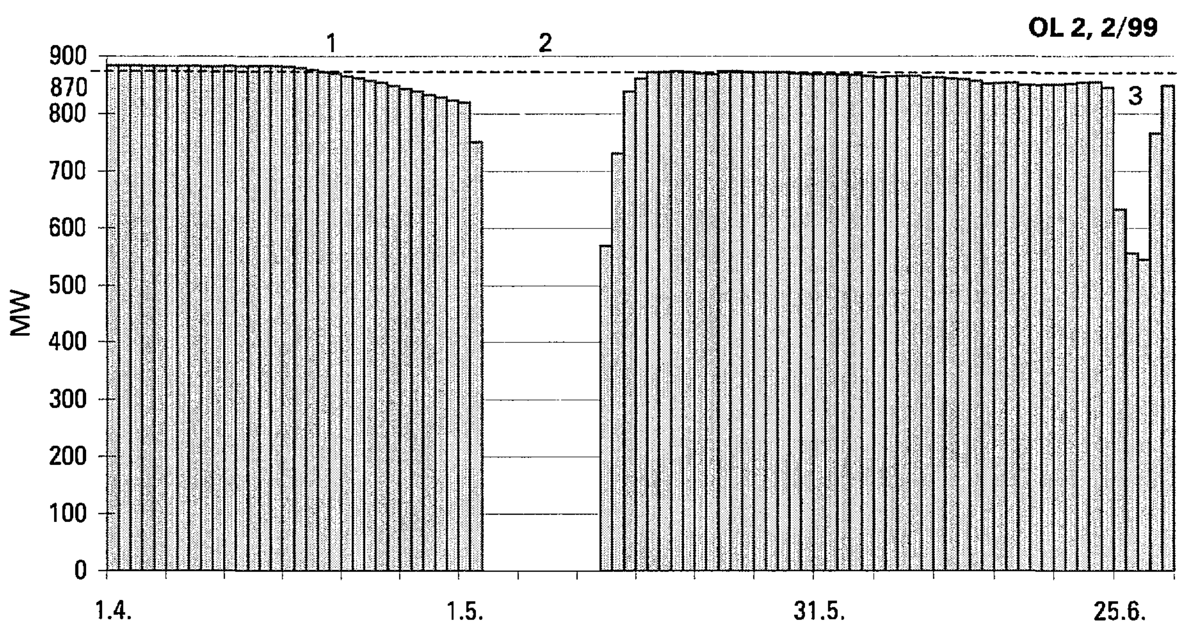
3 Slight electricity demand during Midsummer, lowest reactor power was 84%.

Fig 2. Daily average gross power of Loviisa 2 in April–June 1999.



1 Coastdown operation. By the start of the annual maintenance outage, power dropped to 87%.
2 Annual maintenance (see Chapter 2.1).
3 Malfunction of ejector line of turbine plant condenser; reactor power was lowered to 93%.
4 A failure signal from the turbine plant condenser vacuum suction pumps during periodic testing was erroneously interpreted as an ejector malfunction; reactor power was reduced to 93%.
5 Slight electricity demand during Midsummer; lowest reactor power was 44%.

Fig 3. *Daily average gross power of Olkiluoto 1 in April–June 1999.*



1 Coastdown operation. By the beginning of the annual maintenance outage, power dropped to 94%.
2 Annual maintenance (see Chapter 2.2).
3 Slight electricity demand during Midsummer; lowest reactor power was 38%.

Fig 4. *Daily average gross power of Olkiluoto 2 in April–June 1999.*

has no stress concentrations caused by discontinuities. In addition, the fourth uncracked pipeline was fitted with a thermal shield to prevent cracking. For the time being, owing to the risk of loose parts and thermal fatigue, the repaired piping sections are inspected every year.

Events and safety improvements during the outage are described in Chapters 3 and 5, respectively.

2.2 Annual maintenance outage of Olkiluoto 2

The 18th refuelling and maintenance outage of Olkiluoto 2 was from 2 to 12 May 1999. The plant unit was off the grid for ten days.

In addition to Teollisuuden Voima Oy's own staff, the maximum number of external workers participating in the outage at a time was 659. The collective radiation dose arising from the outage work was 0.38 manSv (1.1 manSv in 1998). The highest individual dose was 9.7 mSv.

In the final phase of the reactor shutdown on 3 May 1999, the reactor scram function actuated. All control rods were inserted into the core and the reactor was near atmospheric pressure. The plant unit was not generating electricity. The event was due to instantaneous high reactor water level values yielded by two level measurement channels simultaneously. The values can be instantaneously high for example owing to uncondensed gases that are released within the level measurement equipment during a reactor pressure reduction. The scram function always actuates if two channels send a measurement signal exceeding the set limit. An actual scram did not take place because the control rods were inside the reactor.

In connection with the replacement of the safety switches of relay cubicles on 4 May 1999, i.a. one pump of the core spray system and one pump of the auxiliary feed water system began to inject water into the reactor and the reactor pool. The pumps started when a mounter's hand accidentally contacted the switch of a nearby unit and changed its position. The switch was immediately turned to the right position but this did not stop the pumps. The level transmitters of the overflow channel of the reactor pool sent an alarm signal to the control room and the pumps were stopped. Water spilled over the upper edge of the channels but not over the edge of the reactor pool and to the reactor hall floor.

Cracked piping sections of the core spray system were repaired at Olkiluoto 2 as well. A branching crack, ca. 50 cm in length, was detected in inspections made during the outage. In the same piping section was a crack detected in 1998. In addition, three cracks were found in other pipes. The cracked piping sections were removed and replaced with new pipe segments having thermal shields. Pipes that had no cracks in them were provided with thermal protection only. For the time being, owing to the risk of loose parts and thermal fatigue, the repaired piping sections are inspected every year also at Olkiluoto 2.

Other events and improvements during the outage are described in Chapters 3 and 5, respectively.

3 EVENTS AND OBSERVATIONS

Loviisa 1

A leak in a valve of the residual heat removal system of the primary circuit occurred at Loviisa 1 owing to which the system was not fully operational. The event is INES Level 0.

3.1 Degradation of the operating capability of the primary circuit residual heat removal system of Loviisa 1

On 20 April 1999 a crack of ca.13 cm long was detected in a valve of the residual heat removal system of the Loviisa 1 primary circuit, which had been seeping water. The valve is in the turbine plant and the leaked water was not radioactive. Bringing the plant unit from hot to cold shutdown would have been more difficult because of the broken valve. The plant unit was operating at full power at the time of the event.

During shutdown the plant unit it is cooled down by means of the primary circuit residual heat removal system, which also transfers decay heat to the sea. The location of the cracked valve in the system is such that if it breaks the whole system becomes inoperable. In such a case the plant unit cannot be brought into cold shutdown by normal measures unless the leaking valve would have been separated from the pipeline by flanges. In some rare accident situations, the plant unit must be promptly brought into cold shutdown. At the time of this event, the plant unit could have been brought into hot shutdown as usual. However, bringing it into cold shutdown would have been difficult.

The valve's cracks have been attributed to casting defects that have, owing to testing and installation stresses during the valve's operation, grown into cracks that penetrate the entire valve body. The valve's structure and material characteristics considered, however, it is unlikely that the crack would have propagated quickly or that the entire valve body would have been torn.

The Loviisa plant did not have a suitable spare valve, which is why the valve had to be removed from the pipeline, repaired and returned to service.

In consequence of the event, the Loviisa plant is re-evaluating its spare parts maintenance and the testing principles of its primary circuit residual heat removal system. The condition of other corresponding valves will be checked as well.

Loviisa 2

The status of the containment spray system of Loviisa 2 was briefly in violation of the Technical Specifications. The event is INES Level 0.

3.2 Containment spray system status in violation of the Technical Specifications at Loviisa 2

On 7 April 1999 a work order was issued from the control room of Loviisa 2 for the repair a faulty pump of the containment spray system when the plant unit was operating at full power. At the same time a second work order was issued from the control room regarding the repair of a diesel generator of the stand-by electric supply system. The diesel generator in question supplies electricity to the other pump of the containment spray system in situations where the external grid has been lost. Owing to these two simultaneous repair jobs, the plant unit state was in violation of the Technical Specifications.

The containment spray system reduces containment pressure in accidents. The system comprises two parallel sub-systems, two pumps in each. According to the Technical Specifications, the plant unit must be stopped if a sub-system's both pumps are inoperable. If one pump is inoperable the plant unit need not be stopped. In this case the other pump was inoperable due to repairs and the same sub-system's other pump was not operable in the way meant in the Technical Specifications since it did not have stand-by electric supply.

The control room noticed the situation in connection with a trial run after the diesel generator's repair. For about 30 minutes the plant unit state was in violation of the Technical Specifications.

The situation was caused by human error due to a misunderstanding between the shift supervisor and a safety engineer during the safety inspections referred to in the two work orders. Similar situations have occurred at the Loviisa plant i.a. in 1993 (STUK-B-YTO 120, 1994) and in 1995 (STUK-B-YTO 149, 1996) when two simultaneous work orders had been issued inadvertently, resulting in a plant unit state that was in violation of the Technical Specifications. To avoid recurrence the utility assesses the functionality of and instructions for the procedures followed in safety inspections and also finds out the necessary corrective actions.

Olkiluoto 1

The operating capability of the containment gas treatment system of Olkiluoto 2 had decreased owing to an erroneous valve position. The event is INES Level 1. In addition, Olkiluoto 1 had problems relating to the functioning of a reactor containment isolation valve, and a minor fuel leak was observed at the plant unit. These events are INES Level 0.

3.3 Problems in operation of a reactor containment isolation valve at Olkiluoto 1

In a periodic test of the isolation valves of the feed water system of Olkiluoto 1 in October 1998, one valve was found not to operate as planned. In a manoeuvring test, the stem of a gate valve equipped with a motor-operated actuator did not close at first try. However, the valve operated normally after its movement was aided by the actuator's operating lever. After this it operated as normal in the periodical tests. The valve in question is one of the reactor containment's external isolation valves and it must close reliably in a situation where a feed water system pipe section inside the containment has broken.

On the basis of the observation that was made in October, the utility made a decision to check the valve and its actuator in the 1999 annual maintenance outage. The shaft of the valve's actuator was found to be bent. The actuator thus did not automatically switch from manual to motor-operation as designed. The valve stem had been manually driven against the back sealing of the valve enclosure in June 1998 because there had been a leak through the valve box. The utility forbade the driving of corresponding valves against their back sealing.

In the 1999 annual maintenance outage, the old actuator was replaced with a new actuator that had an altered, stronger stem structure. The utility also began to research the need to make changes to other corresponding actuators.

3.4 Nuclear fuel cladding leak at Olkiluoto 1

During the start-up of Olkiluoto 1 from annual maintenance outage on 25 May 1999, signs of a minor nuclear fuel cladding leak were detected. The observation was confirmed after the plant unit's power had been increased to 100%.

The Olkiluoto 1 reactor contains 500 fuel assemblies, ca. 90 fuel rods in each. The fuel rods are thin pipes filled with uraniumdioxide tablets. The fuel rod wall forms a gas-tight cladding preventing the entry of fission products, which are formed during reactor operation, from the fuel to the reactor cooling water. The amounts of gaseous and dissolved radioactive substances are continuously monitored by laboratory measurements. In addition, the activity of the reactor-to-turbine steam lines and the condenser off-gas lines are continuously monitored by on-line measurements, which are the quickest indication of a possible fuel leak.

The activity level of the turbine condenser off-gases measured in the delay line slightly exceeded the level measured before the annual maintenance outage. During the operating cycle preceding the annual maintenance outage, the reactor contained also leaking fuel (STUK-B-YTO 184, 1999). Two assemblies containing leaking fuel rods were removed from service in the outage. By the end of June 1999 as well as during the operating cycle preceding the annual maintenance outage, the iodine-131 content of the reactor cooling water had been less than parts per thousand of the limit specified in the plant unit's Technical Specifications, the exceeding of which requires reactor operation to be restricted. Until the end of June the leak had been so small that only gaseous fission products had escaped to the reactor water.

In a fuel leak localisation test on 25 June 1999, the leak was localised to an area comprising four fuel assemblies. The leak could have started during plant unit start-up from annual maintenance outage, or a leaking assembly could have been left in the reactor during the preceding operating cycle. The utility follows the leak's progression. The leaking assembly will be removed from service not later than in the 2000 annual maintenance outage.

3.5 Degraded operating capability of the containment gas treatment system of Olkiluoto 1

In a periodic test of the containment gas treatment system of Olkiluoto 1 on 18 June 1999 it was found out that an angle transmission connecting a butterfly valve and the valve's actuator of the system's other recirculation line had been incorrectly installed. The incorrect installation had been made in the annual maintenance outage that ended on 25 May 1999.

The containment gas treatment system is not in service during plant operation and its operation is tested once a month. The system comprises two identical circuits, each having a compressor and a recombiner for burning hydrogen to water. The system is started if the hydrogen or oxygen content of the containment atmosphere increases. Part of the gas flow through the recombiner is recirculated to the compressor's suction side to prevent the recombiner from overheating. Recirculation is important in accidents during which the system is required to operate for a long time. In an accident situation the operation of one circuit is sufficient.

A butterfly valve of the recirculation line was found to be erroneously open, and such a case the line's compressor did not sufficiently increase pressure in periodic tests. After the uncoupling of the valve actuator's angle transmission, the position of the valve flap was found to be 90 degrees misaligned toward the angle transmission. In consequence of this the valve's position indicator did not operate correctly and the valve did not move correctly during operation.

The valve actuator had been replaced in an annual maintenance outage in accordance with a preventive maintenance programme and the angle transmission had been serviced. During the angle transmission's reinstallation it was not noticed that, while being serviced, its position had changed from open to closed. The incorrect position went unnoticed even in the post-installation functional test.

The valve was open owing to the angle transmission's incorrect position, which reduces the line's capacity. Had the valve been opened, which has to be done in an accident, the valve would have closed, which would have lead to the recombiner temperature having become too high. In an accident the result would have been inoperability of the other circuit or at least a considerable reduction in its capacity.

The valve's position was corrected and the system was tested. In addition, the utility inspected the positions of equivalent-type valves. The valves' maintenance instructions are being revised and an inspection is added to the containment gas treatment system test to ascertain the correct functioning of the position transmitters of the butterfly valves of the recirculation line.

Olkiluoto 2

During the annual maintenance outage of Olkiluoto 2, a personnel air lock of the reactor containment was open in violation of the Technical Specifications. The event is INES Level 1. In a second Olkiluoto 2 event, two fuel assemblies were not quite fully inserted into the reactor core during annual maintenance refuelling. The preliminary INES classification of this event is Level 0. The event has been assigned a preliminary level because the analysisng of factors, which contributed to the event, has not been completed as yet.

3.6 Reactor containment personnel air lock open in violation of the Technical Specifications at Olkiluoto 2

The door of a reactor containment lower personnel air lock at Olkiluoto 2 was open for about an hour in violation of the Technical Specifications. The event occurred during the annual maintenance outage on 6 May 1999 in connection with the replacement of the motor of one main circulation pump.

The main circulation pumps of the Olkiluoto plant units are attached to the bottom of the reactor pressure vessel. The pumps are serviced one by one and, during part of the servicing time, the reactor cooling water is kept inside the pressure vessel by means of a plug or cap installed in a pump shaft hole in the bottom of the reactor pressure vessel. According to the plant unit's Technical Specifications, the door of the containment lower personnel air lock must be kept closed in such cases. By keeping the door closed it is ensured that, should the plug or cap fail, water leaking from the reactor through an open shaft hole would not escape from the containment via an open door but would be available for the reactor emergency core cooling system for recirculation into the reactor pressure vessel. Such a leak from the reactor pressure vessel could occur in consequence of a human error during the maintenance of pumps. The door of the containment lower personnel air lock is otherwise usually kept open during outages.

The door of the lower personnel air lock was left open during the replacement of the main circulation pump motor because a break occurred in the flow of information. The motor replacement was not originally planned for this outage. The job thus had not been included in the detailed schedule of jobs relating to the reactor pressure vessel, which gives also the closing times of the lower personnel air lock. When a motor is replaced also its impeller and shaft are replaced, which is why a plug was installed in place of the impeller shaft. A work order was drawn up for the replacement work, which included i.a. a requirement for the closure of the lower personnel air lock. Work was stopped for the night and, according to the shift supervisor, there was no need to open the lower personnel air lock. In the morning the men servicing the pump entered the containment via the upper personnel air lock to continue their work, trusting that the lower personnel air lock was closed. The morning shift supervisor had, however, authorised the opening of the lower personnel air lock for other work. The shift supervisor should have been told that maintenance work was continued so that he could have ordered the lower personnel air lock to be closed.

Various technical solutions and administrative procedures have been implemented even before this to minimise errors jeopardising primary circuit integrity during reactor pressure vessel maintenance work. Owing to the event the utility has reassessed the solutions and procedures currently in use. The maintenance documents of the main circulation pumps were complemented and the revised documents were in use already in the Olkiluoto 1 annual maintenance outage, which started after the Olkiluoto 2 annual maintenance had been completed. In addition, the utility will review the pump maintenance procedures and will also re-evaluate the management of other corresponding maintenance jobs relating to the reactor pressure vessel. Methods will also be looked into that would make it easier than presently for those participating in maintenance work to observe the position of the door of the lower personnel air lock.

3.7 Two fuel assemblies not properly inserted into the reactor of Olkiluoto 2

In an annual maintenance outage refuelling, two fuel assemblies had not been completely inserted into the reactor core. The slightly elevated position of the assemblies was detected on 13 May 1999 during plant start-up from the annual maintenance outage when the flow measurements of the neutron flux measuring system were calibrated. The flow value of one measurement point was found to deviate by 1.3 kg/s, i.e. ca. 10%, from the value given by the neutron flux measuring system. On the basis of this deviation it was concluded that the reactor contained a fuel assembly that had not been properly inserted into the core. A video tape taken during the checking of the elevation of the assemblies showed that two fuel assemblies were ca. 15 mm short of full insertion. The Olkiluoto 2 reactor contains 500 nuclear fuel assemblies, each ca. four metres long.

An elevated fuel assembly makes it possible that part of the coolant flow intended for the assembly could bypass it via the gap between the lower end of the assembly and the reactor's supporting structures; in such a case the coolant flow would not contribute to the cooling of the assembly. According to calculations the requirements of the plant unit's Technical Specifications for the sufficient cooling of the fuel assemblies are fulfilled. Thus, restrictions on the plant unit's operation were not necessary due to the elevated assemblies.

The position of the assemblies was observed during refuelling already when the position of assemblies loaded into the reactor was measured by the measuring equipment of the refuelling machine's telescope. On the basis of the measurements, 20 assemblies were ascertained not to have been properly inserted; they were later successfully inserted, with the exception of two assemblies. It was concluded that these two assemblies were properly inserted because, although several attempts were made, they could not be made to move downwards. In addition, the readings of the elevation measuring equipment of the refuelling machine's telescope were not trusted because there had been problems in the coiling of the cords related to the elevation measurement of the refuelling machine's telescope. It was noted afterwards, however, that the measurement values of the charging machine were correct. The elevated assemblies went undiscovered in the assembly elevation check-up that is part of the core final inspection. The video tape taken during the check-up was not viewed prior to the closing of the reactor pressure vessel lid. Had the tape been checked, the elevated assemblies would have been discovered and the situation corrected before plant start-up.

The event was due to both technical matters and human error. The technical ones i.e. the fuel rod sticking mechanisms are not known as yet. They will be looked into in inspections in the next annual maintenance outage. A corresponding event has occurred at Olkiluoto before. At Olkiluoto 1 it was detected in 1992 that one fuel assembly had not been fully inserted (STUK-B-YTO 101, 1992) in the 1991 annual maintenance outage refuelling. In consequence of the event, a post-refuelling assembly position check-up was introduced. The possible technical reasons for the sticking of the assemblies are under investigation. Among the most significant other reasons were human errors in refuelling and in the related inspections, which were due to a busy outage schedule.

After the event the utility increased monitoring of the coolant flow and of the stability characteristics of elevated fuel assemblies. In addition, the procedures that ensure the full insertion of fuel assemblies into the reactor were made more specific. The new procedures were employed in the 1999 annual maintenance of Olkiluoto 1 already, which started after the Olkiluoto 2 annual maintenance. The utility will also continue to look for a technical solution to ensure the correct positioning of fuel assemblies during refuelling. The effect of busy schedules on the careful carrying out of jobs will be looked into as well.

4 RADIATION SAFETY

Individual doses to NPP personnel were below the dose limits. Environmental releases were well below the release limits as well. In samples collected around the Finnish NPPs, radioactive substances originating from the plants were measurable in such quantities only as have no bearing on the radiation exposure of the population.

4.1 Occupational exposure

The highest individual dose received at a Finnish NPP in early 1999 was 15.4 mSv and it was received at Olkiluoto NPP. The Radiation Decree stipulates that the effective dose caused by radiation work to a worker shall not exceed 50 mSv in any single year. The dose may not exceed 20 mSv per year as an average over any period of five years. The radiation doses received at Loviisa and Olkiluoto NPPs have been below authorised limits.

Occupational dose is mainly incurred in work performed during annual maintenance outages. Both Olkiluoto plant units underwent annual maintenance in this quarter.

The individual dose distribution of NPP personnel is given in Table III, which specifies the number of exposed individuals by dose range and plant site. This information is from STUK's Central Dose Register.

The collective occupational dose in the second quarter of 1999 was 0.02 manSv for the Loviisa plant units and 0.77 manSv for the Olkiluoto units. According to a STUK guide, the collective dose limit for one plant unit is 2.5 manSv per one gigawatt of net electrical power averaged over two successive years. Thus the limit value for the Loviisa plant units is 2.44 manSv and for the Olkiluoto units 4.20 manSv.

4.2 Radioactive releases

In Table IV, the releases of radioactive substances measured at each plant site and the annual release limits are given. During this report period, releases into the environment were well below authorised limits.

4.3 Environmental monitoring

Radiation safety in the vicinity of Finnish NPPs is ensured by regular sampling and analysis programmes. The environmental distribution of radioactive releases and their transfer to food chains is monitored to ensure that the releases remain below authorised limits. In the second annual quarter, 172 environmental samples were analysed in accordance with the programmes.

A radioactive cobalt isotope (cobalt-60) originating from Loviisa NPP was measurable in three samples of fallout from the plant's environment. In the aquatic environment, cobalt was detected in a few samples of seaweed, a sample of crustacean and in a sample of sinking matter. In the seaweed samples, the other radioactive cobalt isotope (cobalt-58) as well as manganese and silver (manganese-54, silver-110m) were also measurable. Silver was detected in the sample of crustacean as well. In addition, the tritium concentration in three sea water samples was above normal level.

Table III. Occupational dose distribution.

Dose range (mSv)	Number of persons by dose range					
	Second quarter 1999			From beginning of 1999		
	Loviisa	Olkiluoto	Total*	Loviisa	Olkiluoto	Total*
< 0.5	48	344	397	61	340	410
0.5–1	9	159	177	12	159	178
1–2	2	112	121	7	130	142
2–3	–	35	48	6	41	58
3–4	–	16	26	–	20	29
4–5	–	11	17	–	13	23
5–6	–	7	12	–	7	11
6–7	–	3	5	–	5	8
7–8	–	–	1	–	–	1
8–9	–	1	4	–	1	4
9–10	–	3	5	–	3	5
10–11	–	3	3	–	3	3
11–12	–	4	5	–	4	5
12–13	–	1	1	–	1	1
13–14	–	2	2	–	2	2
14–15	–	1	1	–	1	1
15–16	–	1	1	–	1	1
16–17	–	–	–	–	–	–
17–18	–	–	–	–	–	–
18–19	–	–	–	–	–	–
19–20	–	–	–	–	–	–
20–25	–	–	–	–	–	–
> 25	–	–	–	–	–	–

* The data in these columns also include Finnish workers who have received doses at Swedish nuclear power plants. The same person may have worked at both Finnish nuclear power plants and in Sweden.

Radioactive cobalt originating from Olkiluoto NPP was detected in one sample of air and one sample of lichen collected in the environment of the NPP. The tritium concentration in one sample of sea water was 10 times the normal level. All samples of seaweed and bivalves contained cobalt and some of them also the other radioactive cobalt isotope and manganese. Only cobalt (cobalt-60) was measurable in sinking matter.

All the detected concentrations were low and require no action.

Radioactive isotopes of strontium and caesium (strontium-90, caesium-134 and -137) originating from the Chernobyl accident and the fallout from nuclear weapons tests are still measurable in the environmental samples. Natural radioactive substances (i.a. beryllium-7, potassium-40 and uranium and thorium with their decay products) are also detected. Their concentrations in the samples in question are usually higher than those of nuclides originating from power plants or fallout.

Table IV. Radioactive releases by plant site, second quarter 1999.

Gaseous effluents by nuclide group (Bq) a)					
Plant site	**Noble gases (Krypton-87 equivalents)**	**Iodines (Iodine-131 equivalents)**	**Aerosols**	**Tritium**	**Carbon-14**
Loviisa					
Report period	$1.6 \cdot 10^{12}$	$1.6 \cdot 10^{5}$	$6.2 \cdot 10^{5}$	$5.0 \cdot 10^{10}$	$8.4 \cdot 10^{10}$
Early 1999	$3.2 \cdot 10^{12}$	$8.1 \cdot 10^{5}$	$1.6 \cdot 10^{6}$	$1.1 \cdot 10^{11}$	$1.8 \cdot 10^{11}$
Olkiluoto					
Report period	$1.4 \cdot 10^{11}$	$1.1 \cdot 10^{7}$	$5.1 \cdot 10^{6}$	$1.1 \cdot 10^{11}$	b)
Early 1999	$1.4 \cdot 10^{11}$	$1.1 \cdot 10^{7}$	$5.1 \cdot 10^{6}$	$2.7 \cdot 10^{11}$	b)
Annual release limits					
Loviisa	$2.2 \cdot 10^{16}$ c)	$2.2 \cdot 10^{11}$ c)			
Olkiluoto	$1.8 \cdot 10^{16}$	$1.1 \cdot 10^{11}$			

Liquid effluents by nuclide group (Bq) a)		
Plant site	**Tritium**	**Other nuclides**
Loviisa		
Report period	$4.9 \cdot 10^{12}$	$9.1 \cdot 10^{6}$
Early 1999	$8.8 \cdot 10^{12}$	$2.8 \cdot 10^{7}$
Olkiluoto		
Report period	$3.1 \cdot 10^{11}$	$6.2 \cdot 10^{8}$
Early 1999	$5.9 \cdot 10^{11}$	$1.1 \cdot 10^{9}$
Annual release limits		
Loviisa	$1.5 \cdot 10^{14}$	$8.9 \cdot 10^{11}$ c)
Olkiluoto	$1.8 \cdot 10^{13}$	$3.0 \cdot 10^{11}$

a) The unit of radioactivity is Becquerel (Bq); 1 Bq = one nuclear transformation per second.
b) The carbon-14 release-estimate based on experimental data was $1,7 \cdot 10^{11}$ Bq in Olkiluoto in the report period and $3,7 \cdot 10^{11}$ Bq in early 1999.
c) The numerical value shows the release limit for the plant site by nuclide group, assuming that other releases would not occur. The total release limit is calculated so that the sum of the various types of release limit shares does not exceed 1.

5 SAFETY IMPROVEMENTS AT NPPS

In the annual maintenance outage of the the Olkiluoto plant units, some plant unit system modifications that had been made in connection with the power uprating were improved among other things. No significant modifications were made at the Loviisa plant units in this quarter.

The neutron flux monitoring system of Olkiluoto NPP was provided with added reliability

A hard-wired, filtered neutron flux monitoring function was added abreast with the digital, computer-based filtered neutron flux monitoring system at both Olkiluoto plant units. This section of the neutron flux monitoring system monitors neutron flux signal of which rapid, transient changes have been filtered out. The system part actuates the reactor scram function at a lower power level than the other section of the neutron flux monitoring system i.e. unfiltered neutron power monitoring.

The neutron flux monitoring systems of both Olkiluoto plant units have been renewed in 1996–1998 using programmable technology.

The renewed neutron flux monitoring system is based on programmable technology but, already with the original delivery, the trip signal made of unfiltered neutron power had been assured by parallel hard-wired electronics. Now also the filtered-power scram condition was assured by hard-wired electronics to improve the reliability of protection against slow changes in neutron power.

In connection with the modification, some other minor changes were made also to the neutron flux monitoring system. The series coupling of trips initiated by the system was separated so that the trips, which are initiated by a programmable system and those which are initiated by the watch-dog time relays that monitor programme execution are now sent independently to reactor protection and other systems. The modification improves trip identification and selectivity.

Renewal of electric drives of Olkiluoto NPP main circulation pumps

In the 1999 annual maintenance outage of Olkiluoto, new electric drives were installed for two main circulation pumps at both plant units. Improvements were also made to drives that had been introduced into service previously. All the six main circulation pumps of both plant units have now been provided with new electric drives. The modification work had been started in 1996.

The anticipated ageing of the original frequency converters of the motors of the main circulation pumps was the cause of the replacement. In addition, spare parts procurement was becoming more difficult. The electric drives had also been modified to extend the run-down time of the main circulation pumps during a power cut. The extension of the pumps' run-down time slows down pump-trip-induced changes in the reactor cooling water flow, making the safety margin against fuel failure larger than previously.

Where electrical engineering is concerned, the new electric drive system is equivalent to the old one. A motor added to the system is an exception; a main circulation pump can be controllably stopped during a power failure by means of flywheel energy stored up in the motor. Programmable technology has been used in the system's frequency converter units. Protection functions ensuring the controllable stopping of the pumps have been implemented by parallel control units based on non-programmable technology.

Assuring reactor pressure reduction in accidents at Olkiluoto NPP

At both Olkiluoto plant units a modification was improved that had been made during the 1998 annual maintenance outages to assure reactor pressure reduction in a severe accident. Pressure reduction during a severe accident is necessary to maintain containment integrity. Breaking of the reactor pressure vessel at high pressure owing to a reactor core melt would cause loads of such magnitude to be exerted on the containment that the loss of its tightness and integrity would be likely.

The Olkiluoto plant uses the primary circuit relief system, which has a total of 14 valves, for reactor pressure control in accident situations. Most of these valves can be kept open by electric pilot valves when the pressure difference between the reactor pressure vessel and the containment decreases to 1–4 bar. The valves close by force of gravity if the pressure difference decreases below that and their re-opening requires a pressure increase beyond the level of closing pressure. In addition, hot gases formed during an accident could prevent valve operation. Two quick-opening valves in the pressure control lines of the relief system have pneumatic pilot valves. In addition, the quick-opening valves have been fitted with tubing connecting to the valve for supply of nitrogen or water to keep the valves open at low pressure. After modifications made in the 1998 annual maintenance, the quick-opening valves can be kept open at a lower pressure than other valves. The modification was improved in the 1999 annual maintenance outages by placing outside the containment valves that open the nitrogen or water supply; in this way the valves are not exposed to the harsh ambient conditions of a severe accident.

Analyses made by the utility show that when the quick-opening valves are open this suffices to keep the reactor pressure vessel pressure at a level where containment integrity is not jeopardised, should the pressure vessel break.

Modifications at Olkiluoto NPP to provide against the Year 2000

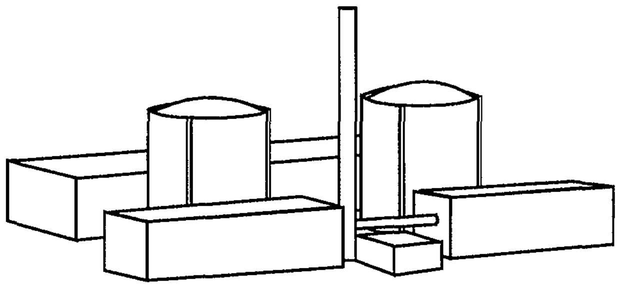
Modifications and testing of the process computer and its associated systems to eliminate problems relating to the Year 2000 were completed at both Olkiluoto plant units during the annual maintenance outage. Among other things, the assurance of correct date input in relation to the starting up of the process computer was improved and the operating systems of the workstations and testing computers of the neutron flux monitoring system and of the turbine pressure control system were updated. Post-modification functional testing was carried out.

APPENDIX 1 REGULATORY CONTROL OF NUCLEAR POWER PLANTS

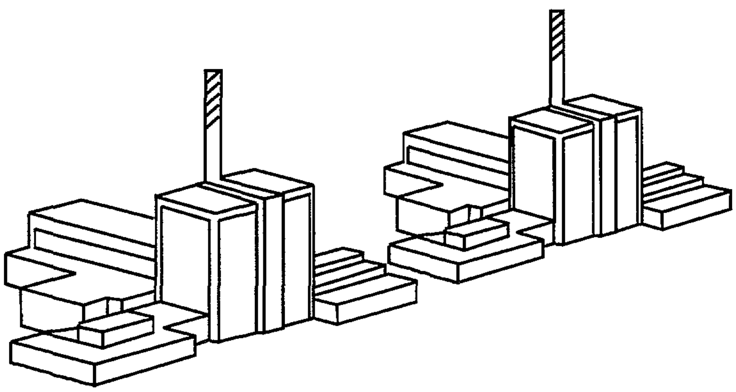
Council of State decisions	**Regulatory control and inspections by STUK**
	Preparation of a nuclear power plant project • Preliminary plans for the plant and safety principles • Location and environmental impact of the plant • Arrangements for nucler fuel and nuclear waste management
Decision in Principle	
	Plant design • Preliminary safety analysis report on the planned structure and operation of the plant plus the preliminary safety analysis • Safety classification of components and structures • Quality assurance plan • Plans for nuclear fuel and nuclear waste management • Physical protection and emergency preparedness
Construction Permit	
	Construction of plant • Construction plans, manufacturers, final construction and installation of components and structures • Performance tests of systems • Final safety analysis report on the structure and operation of the plant and the final safety analyses • Probabilistic safety analysis • Composotion and competence of the operating organisation • Technical Specifications • Nuclear fuel management and safeguards • Methods of nuclear waste management • Physical protection and emergency preparedness
Operating Licence	
	Plant operation • Start-up testing at various power levels • Maintenance, inspections and testing of components and structures • Operation of systems and the whole plant • The operating organisation and management • Training of personnel • Qualifications of individuals • Operational incidents • Repairs and modifications • Refuelling • Nuclear fuel management and safeguards • Nuclear waste management • Radiation protection and safety of the environment • Physical protection and emergency preparedness • Fire protection

PLANT DATA

APPENDIX 2



Plant unit	Start-up	Commercial operation	Rated power (gross/net, MW)	Type, supplier
Loviisa 1	8 Feb.1977	9 May 1977	510/488	Pressurized water reactor (PWR), Atomenergoexport
Loviisa 2	4 Nov. 1980	5 Jan. 1981	510/488	Pressurized water reactor (PWR), Atomenergoexport



Plant unit	Start-up	Commercial operation	Rated power (gross/net, MW)	Type, supplier
Olkiluoto 1	2 Sept. 1978	10 Oct. 1979	870/840	Boiling water reactor (BWR), Asea Atom
Olkiluoto 2	18 Feb. 1980	1 July 1982	870/840	Boiling water reactor (BWR), Asea Atom

Fortum Power and Heat Oy owns the Loviisa 1 and 2 plant units in Loviisa and Teollisuuden Voima Oy the Olkiluoto 1 and 2 plant units in Olkiluoto, Eurajoki.

STUK'S EXPERTS

Nuclear Reactor Regulation:
Kirsi Alm-Lytz
Tapani Eurasto
Timo Eurasto
Juhani Hyvärinen
Tapani Koljander
Jarmo Konsi
Jouko Mononen
Matti Ojala
Hannu Ollikkala
Mervi Olkkonen (translation)
Rainer Rantala
Seija Suksi
Heimo Takala
Petteri Tiippana
Keijo Valtonen

Research and Environmental Surveillance:
Tarja K. Ikäheimonen
Seppo Klemola

STUK-B-YTO 196 Operation of Finnish nuclear power plants 2/99

STUK

ISBN 951-712-354-X
ISSN 0781-2884

Oy Edita Ab, Helsinki 1999