FI9800065

STUK

STUK-B-YTO 169 April 1998

OPERATION OF FINNISH NUCLEAR POWER PLANTS

Quarterly report, 3rd quarter 1997

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STUK • SÄTEILYTURVAKESKUS • STRÅLSÄKERHETSCENTRALEN
RADIATION AND NUCLEAR SAFETY AUTHORITY

ISBN 951-712-253-5
ISSN 0781-2884

Oy Edita Ab, Helsinki 1997

TOSSAVAINEN, Kirsti. Operation of Finnish nuclear power plants. Quarterly report, 3rd quarter 1997. STUK-B-YTO 169. Helsinki 1998. 21 pp. + Appendices 2 pp.

ISBN 951-712-253-5
ISSN 0781-2884

Keywords: PWR, BWR, NPP operating experience

ABSTRACT

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

The Finnish nuclear power plant units were in power operation in the third quarter of 1997, except for the annual maintenance outages of Loviisa plant units which lasted well over a month in all. There was also a brief interruption in electricity generation at Olkiluoto 1 for repairs and at Olkiluoto 2 due to a disturbance at the turbine plant. All plant units were in long-term test operation at upgraded reactor power level approved by STUK. The load factor average of all plant units was 87.5%.

One event in the third quarter was classified level 1 on the International Nuclear Event Scale (INES). It was noted at Loviisa 2 that one of four pressurised water tanks in the plant unit's emergency cooling system had been inoperable for a year. Other events in this quarter were INES level 0.

Occupational doses and radioactive releases off-site were 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 (990/87), 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 of emergency preparedness, and nuclear material safeguards. The scope of nuclear power plant regulatory control and inspections is given in Appendix 1 and general information about Finnish plants in Appendix 2.

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

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

2 OPERATION OF NUCLEAR POWER PLANTS IN JULY–SEPTEMBER 1997

Finnish nuclear power plant units were in power operation in the third quarter of 1997 except for the annual maintenance outages of the Loviisa nuclear power plant units. In addition, production was briefly discontinued at Olkiluoto 1 for repairs and at Olkiluoto 2 due to a turbine plant disturbance. All plant units were in long-term test operation at upgraded reactor power level.

2.1 Production data

Nuclear's share of total electricity production in Finland in this quarter was 35.5% and the load factor average of the plant units was 87.5 %. Long-term test operation at upgraded reactor power levels continued at all plant units. In this quarter, the Loviisa 1 reactor power level was upgraded from 103% to 105% on 25 September 1997 and that of Olkiluoto 2 from 105% to 107% on 15 September 1997. The test operation of Loviisa 2 at upgraded 105% power level and of Olkiluoto 1 at upgraded 108% power level continued.

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 (%)	
	Third quarter 1997	From 1.1.1997	Third quarter 1997	From 1.1.1997	Third quarter 1997	From 1.1.1997
Loviisa 1	0.79	2.87	79.7	93.1	74.7	91.6
Loviisa 2	0.84	2.88	83.1	92.5	78.9 [a)]	91.9 [a)]
Olkiluoto 1	1.78	4.83	99.6	93.0	98.2	92.6
Olkiluoto 2	1.70	4.53	99.9	92.3	98.1	92.0

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

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

a) Loviisa 1 test operation at 105% reactor power started on 10 June 1997. When the load factors for the third quarter of 1997 were calculated, a gross electric output nominal value was used that corresponds to the plant unit's 103% reactor power. The figures are thus slightly larger than in actual fact.

Table II. Nuclear energy in Finnish electricity production.

	Third quarter 1997	From 1.1.1997	1996
Nuclear electricity production (net, TWh)*	4.9	14.5	18.7
Total electricity production in Finland (net, TWh)*	13.8	47.7	66.4
Nuclear's share of total electricity production (%)	35.5	30.4	28.2
Load factor averages of Finnish plant units (%)	87.5 b)	92.0 b)	90.8

a) Source: Statistics compiled by the Finnish Electricity Assiciation
b) Loviisa 2 test operation at 105% started on 10 June 1997. When the load factors for the third quarter of 1997 were calculated, a gross electric output nominal value was used that corresponds to the plant unit's 103% reactor power. The figures are thus slightly larger than in actual fact.

The gross electric power nominal value 820 MW, which corresponds to the upgraded 109% reactor power, was introduced at Olkiluoto 1 on 1 July 1997. Correspondingly, Olkiluoto 2 introduced on 1 July 1997 the gross electric power nominal value 785 MW, which corresponds to the upgraded 105% reactor power.

No changes were made to the electric power nominal values of the Loviisa plant units in this quarter. On the basis of the reactor power upgrades carried out the next annual quarter, Loviisa 1 on 1 November 1997 and Loviisa 2 on 1 December 1997 introduced the gross electric power nominal value of 500 MW that corresponds to the upgraded 107% reactor power. The Loviisa 2 load factors given in Table I were calculated using a gross electric power nominal value that corresponds to 103% reactor power, for which reason the figures are slightly higher than the actual values.

2.2 Loviisa 1 annual maintenance outage

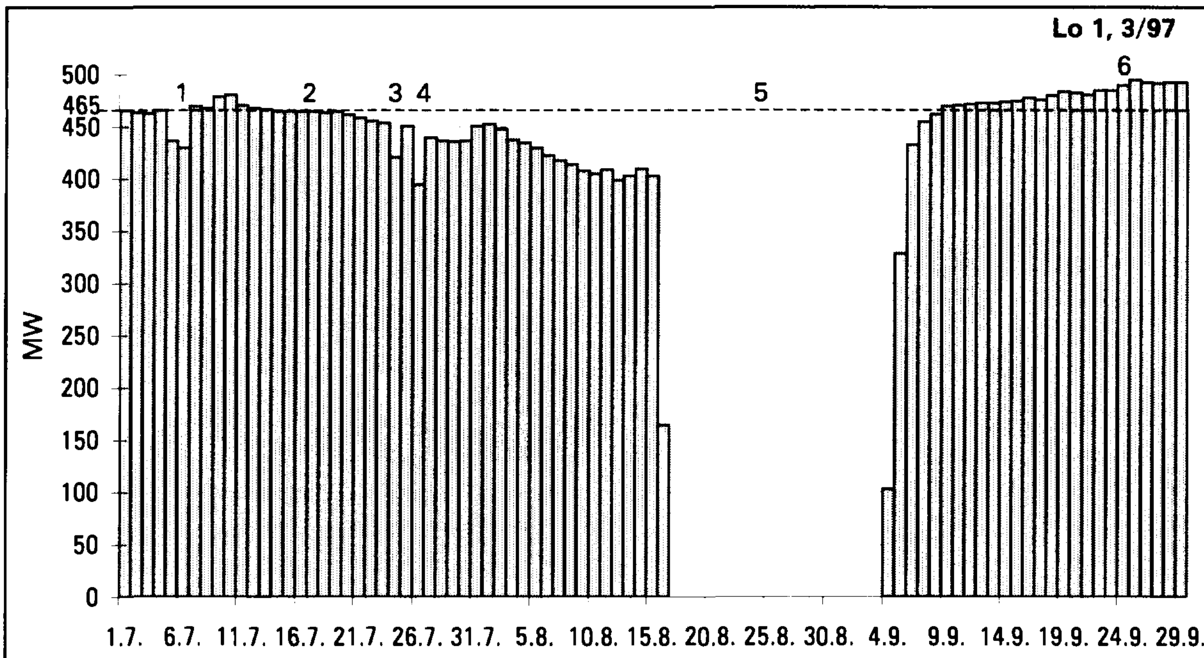
The 20th refuelling and maintenance outage of Loviisa 1 was from 16 August to 4 September 1997. The outage was four days longer than planned because an emergency feed water pump sustained damage during testing.

In addition to Imatran Voima Oy's own staff, the total number of contract workers participating in the annual maintenance outages of both units was 778. The collective radiation dose incurred in work done at Loviisa 1 during the outage was 0.54 manSv (1.79 manSv in 1996). The highest individual dose was 12.6 mSv.

Events that occurred during the annual maintenance outage as well as observations made during inspections are described below. The safety improvements made to the plant unit's systems during the annual maintenance outage are described in Chapter 5.

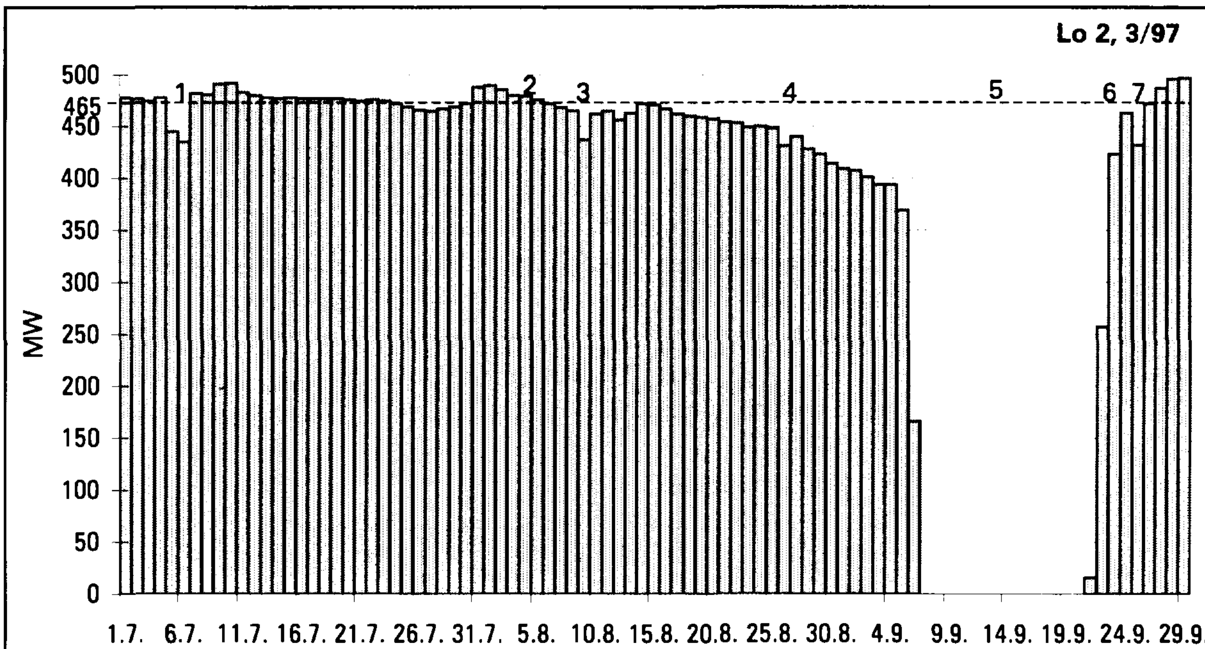
Emergency feed water pump sustained damage in connection with testing

One of two emergency feed water pumps of the Loviisa 1 secondary circuit was damaged towards the end of the annual maintenance outage when operated during a back-up diesel testing on 29 August 1997. The pump stopped ca.16 minutes from starting due to the tripping of a protection function from low pressure on the pump's pressure side. In trouble-shooting, several attempts were made to start the pump, but its protection



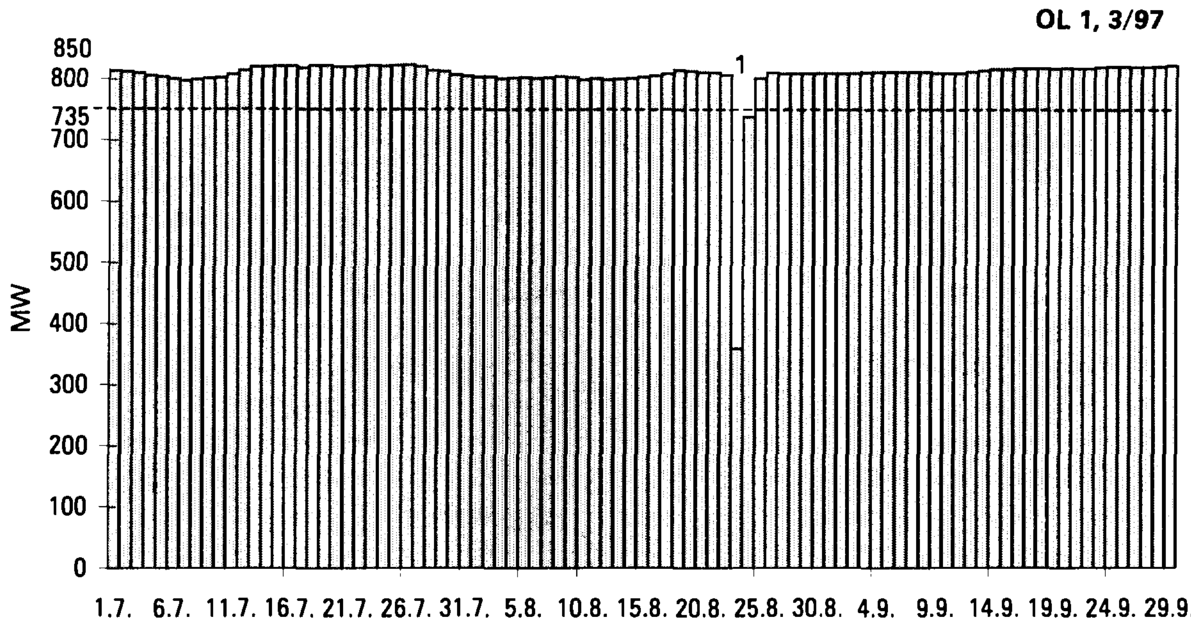
1. Low demand for electricity.
2. Stretchout operation.
3. One turbine tripped in consequence of a thunderstorm-induced disturbance in a wire of the 400 kV national grid, reactor power adjusted by automation to about 50%.
4. Live steam line safety valve tests, the reactor operated at about 80% power during the tests.
5. Annual maintenance (see sub-section 2.2).
6. Long-term test operation at 105% started.

Fig 1. Daily average gross power of Loviisa 1 in July–September 1997.



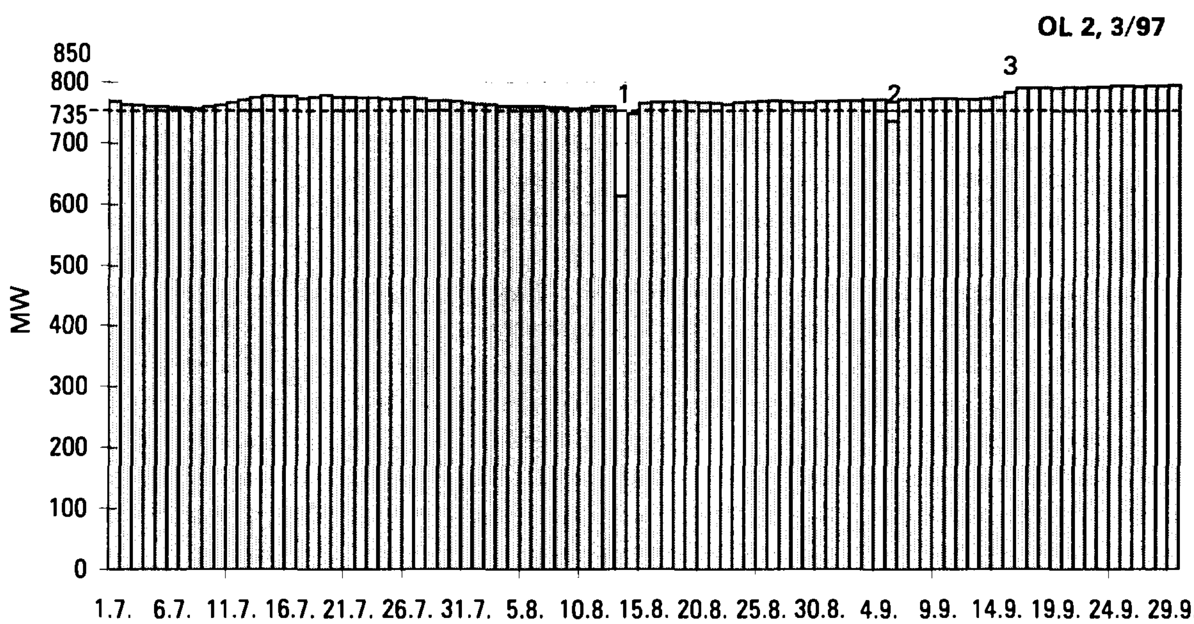
1. Low demand for electricity.
2. Stretchout operation.
3. Live steam line safety valve tests, the reactor operated at about 80% power during the tests.
4. One primary circulation pump oil pump replaced, the reactor at 82% power.
5. Annual maintenance (see sub-section 2.3).
6. One turbine tripped after the water level of the water collection tank of the turbine plant auxiliary condensate system exceeded limit value. The event did not affect reactor power because the plant unit's other turbine and generator were in operation and the reactor was operating at 45% power at the time of the event.
7. A leak in the bleed steam line of one turbine was repaired, the reactor was operating at about 50% power.

Fig 2. Daily average gross power of Loviisa 2 in July–September 1997.



1. Hot shutdown to repair steam line and feed water system leaks (see sub-section 2.4).

Fig 3. *Daily average gross power of Olkiluoto 1 in July–September 1997.*



1. Turbine shutdown due to a turbine automation failure, automation reduced reactor power to about 25% (see sub-section 2.5).
2. Periodic tests, lowest reactor power was 65%.
3. Long-term test operation at 107% power started.

Fig 4. *Daily average gross power of Olkiluoto 2 in July–September 1997.*

prevented starting. The pump was dismantled and its internals were found to be heavily stuck. The pump sustained damage because the closing valve of its minimum flow circuit was erroneously in the closed position. The minimum flow circuit is needed when the pump is started and in tests such as this. The pump failed because, due to the closed valve, there was no flow path available for the water to be pumped.

The valve had remained in the closed position in connection with an earlier job during the outage and its incorrect position was not detected in the inspection conducted to ensure valve normal state. To prevent recurrence, a preliminary analysis has been performed at Loviisa power plant on the basis of which the operating personnel have been given further training in procedures relating to the checking and restoration of valve normal state.

The damaged pump was sent to the manufacturer for repair. The plant unit's both emergency feed water pumps must be operational when plant mode changes from outage state to power operation and, thus, the start-up of Loviisa 1 could not be continued. Imatran Voima Oy therefore decided to detach and move a corresponding Loviisa 2 back-up pump to Loviisa 1. Unlike at Loviisa 1, the emergency feed water system of Loviisa 2 has been fitted with separate back-up pumps that are capable of replacing the pump proper, one at a time and for one week, when certain conditions are met. The pump that was repaired by the manufacturer was installed at Loviisa 2. The temporary replacement of the Loviisa 2 emergency feed water pump with a back-up pump and the detachment, installation and taking into service of the emergency feed water pump proper at Loviisa 1 required STUK's approval.

An administrative error occurred in the taking into service of the pump that had been moved from Loviisa 2 to Loviisa 1. The operability of the feed water pump was a precondition for power ascension 2 % beyond power level. There must be a marking of the verification of the pump's operability in STUK's inspection protocol. Power ascension was started a few hours before the inspection protocol was acknowledged as completed. In a leak test relating to the pump's structural inspection, a leak was detected in the sealing of the pump's shaft. The sealing was replaced and a new leak test was conducted in connection with the pump's test run. The test run was started at 23.20 hours on 3 September 1997. An inspector from STUK and a quality control inspector from Imatran Voima Oy checked the pump's leaktightness. The pump was ascertained leaktight, which information was entered also in STUK's inspection protocol. The acknowledgement of the protocol as completed presupposes that also the results of the test run are presented to STUK's inspectors. After the leak tests, the inspectors of STUK and Imatran Voima Oy left and Imatran Voima Oy continued the pump's test run according to the test programme until about 2.00 a.m. The pump's operation was continued for further testing. Reactor power ascension 2 % beyond the power level was started at about 5.30 a.m. and the results of the trial run were presented to STUK's inspector at about 8.00 a.m. The inspection protocol was acknowledged as completed on the basis of the results of the trial run.

Cracks in supporting structures of main circulating pump diffusers

In inspections conducted during the Loviisa 1 annual maintenance outage, cracks were observed in the supporting structures of the internal diffusers of one main circulating pump of the primary circuit. The pump was operational in spite of the cracks. Both Loviisa plant units have six main circulating pumps for circulating reactor coolant water.

Cracked supporting structures have been reported at the Loviisa plant units even before this. Cracks in a supporting structure caused a main circulating pump malfunction and a repair shutdown at Loviisa 2 in 1995 (STUK-B-YTO 149, 1996). Also Loviisa 1 was stopped because of abnormal vibrations detected earlier in one main circulating pump. The damaged parts were replaced or repaired in the outages. The supporting structure in which cracks were now detected was original and had been repaired in the 1995 outage. The cracking has been attributed to material fatigue.

In the Loviisa 1 annual maintenance outage, two original supporting structures still in use were replaced with new ones. All the supporting structures of the diffusers of Loviisa 1 main circulating pumps are now new, with the exception of one. At Loviisa 2, all these supporting structures have been replaced. The fatigue resistance of the new supporting structures is better than that of the originals. Also vibration monitoring has been improved to avoid loading situations that cause fatigue. The final cause of the damage and vibrations is being examined.

Coating of pistons of main safety valve pilot valves peeled off at Loviisa 1 and 2

In inspections performed in connection with valve maintenance it was detected at both Loviisa 1 and Loviisa 2 that the coating of load reducing pistons of several pilot valves controlling pressuriser main safety valves had peeled off in places. No damage was observed in other components having ion-implanted coatings. Owing to the damage, Imatran Voima Oy decided to replace all pistons at both units with pistons having induction-hardened surface finishing. The component manufacturer has good experiences of this treatment pertaining to valves delivered to German plants.

In the 1996 annual maintenance outage, new pressuriser main safety valves had been installed at the Loviisa nuclear power plant units. A new coating method (ion implantation) was used for certain abrasion resistance requiring slip surfaces of the main safety valves and their pilot valves. The new method provides a significantly harder surface and better glide properties than e.g. stellite. It also helps avoid an increased cobalt load that has a negative effect on the primary circuit radiation levels of the plant units.

The damage observed did not jeopardise the operation of the main safety valves, which operated according to design in tests. In connection with dismantling relating to pilot valve maintenance work the pistons were ascertained to move smoothly despite the damaged coatings.

After the annual maintenance, Imatran Voima Oy together with the manufacturer started investigations into what caused the damage and into the suitability of ion implantation as surface treatment for the components in question.

Operational time limit was exceeded during replacement of seawater circuit piping

An administrative error was made during the replacement of seawater circuit piping components during the annual maintenance outage. Due to the repair work, the seawater cooling of all heat exchangers of the turbine intermediate circuit had to be taken out of service, which is a deviation from the Technical Specifications that requires STUK's permission. According to the permit granted by STUK, seawater recirculation could be discontinued for one day during refuelling.

The replacement of piping components was started in the morning and was completed in the evening of 22 August 1997. A temporary permit for trial operation was granted for the piping and seawater coolant recirculation was taken into service in good time before the operational time limits were exceeded. The piping should also have been inspected for leaktightness and after that the inspection should have been entered in the work order as completed. The leak test was only performed on 26 August 1997 at what time also the work order was signed as completed.

The event was due to a human error. The work order had been filed in a folder containing work orders covering work for which leak tests at operating pressure are required later, process conditions permitting. Due to the event, Loviisa power plant will review the procedure pertaining to the matter.

2.3 Loviisa 2 annual maintenance outage

The 17th refuelling and maintenance outage of Loviisa 2 was from 6 to 21 September 1997.

In addition to Imatran Voima Oy's own staff, the total number of contract workers participating in the annual maintenance outages of Loviisa 1 and 2 was 778. The collective radiation dose incurred in work done during the outage at Loviisa 2 was 0.45 manSv (0.71 manSv in 1996). The highest individual dose was 10.2 mSv.

No safety-related events other than those mentioned in sub-section 2.2 were observed in the annual maintenance outage. Safety improvements made to the plant unit's systems during the annual maintenance outage are described in Chapter 5.

2.4 Olkiluoto 1 hot shutdown to repair steam line and feed water system leaks

Olkiluoto 1 was placed in hot shutdown on 23 August, 1997 to repair a water leak within the containment. The leak was in a sealing of a flange belonging to the main steam system and in a pipe belonging to the feed water system. Repair work could not be done during plant unit operation because the nitrogen inside the containment during plant unit operation must be removed before work can be done within the containment. After the repairs were accomplished, the plant unit was started and brought back on-line the same day.

There were four successive turbine trips during the start-up phase when the turbine operating speed was being increased. Due to the short duration of the outage, the temperature of the turbine's metal parts had remained high, which lead to an increase in the operating speed that exceeded set value, and further to the actuation of the turbine protection function. To prevent recurrence, Teollisuuden Voima Oy has increased at Olkiluoto 1 the set value of the protection function in question. A corresponding change at Olkiluoto 2 is due in connection with the next outage.

2.5 Olkiluoto 2 came off the national grid due to a disturbance in turbine automation

Olkiluoto 2 came off the national grid on 13 August 1997 due to a disturbance at the turbine plant. The plant unit was operating at full 105% power at the time of the event. The disturbance was initiated when the turbine control system was switched from manual to automatic operation after previous alarm signals in the system had been examined. The turbine shutdown was actuated due to an incorrect coupling made during a turbine control and monitoring system modification during the annual maintenance outage. There was a design error in the connection diagram that had been detected and fixed earlier at Olkiluoto 1. Owing to an error in the administrative routines pertaining to modifications, the connection diagram of Olkiluoto 2 was not changed. Also, a partial reactor scram occurred during the turbine shutdown and the reactor power decreased to about 25%.

The connection error was repaired and the plant unit's ascension back to full power was started. The plant unit was brought back on-line the same day.

3 EVENTS AND OBSERVATIONS

Loviisa 1

In the third quarter of 1997, the planned reactor power level of Loviisa 1 was slightly exceeded when power was being raised to the next power level according to the power upgrading programme. It was also noted at Loviisa 1 that the containment supply air fans did not start after reactor protection system periodic test. Both events were classified INES level 0.

3.1 Unexpected exceeding of power level due to erroneous flow measurement during Loviisa 1 power ascension

The planned power level of Loviisa 1 was slightly exceeded on 24 September 1997 due to the inadequate measuring range of equipment that measures feed water flow for calculation of power level. The plant unit went beyond its planned power level during ascension to a new power level in connection with test operation.

Power ascension from 103% reactor power to 105% power was started in the morning of 24 September 1997. During the power ascension, behaviour of the reactor and plant unit parameters was monitored according to the test programme. The following morning it was noticed that the ultrasound measurements of two primary feed water lines used in the calculation of reactor thermal power displayed the mass flow rate maximum values 394 and 396 kg/s. One of two total feed water flow volume measurements employing steam generator specific flange measurements functioned correctly. The feed water mass flow rate is basic data essential for the calculation of the thermal power of the Loviisa reactors. The feed water mass flow rates yielded by the two measuring methods differ from each other slightly, and when the reactor thermal power is calculated, the measurements are weighted so that the weight of ultrasound measurements is two thirds and that of flange measurements one third part.

On the basis of the maximum values obtained by the ultrasound measurements it was concluded that the reactor thermal power values calculated on the basis of feed water flow rates were too low. The set point of electrical power of the plant units was immediately decreased to reduce the reactor power level. Also the obtained electrical power output supported the notion that the 105% reactor power level had already been exceeded.

The measuring range of ultrasound measurements ended at about 395 kg/s, which caused the measurement error. The measuring ranges were immediately changed to meet the requirements of the reactor power upgrading. During the repairs, the reactor thermal power was calculated using the feed water mass flow rate values yielded by steam generator specific flange measurements. In the afternoon of 25 September, the calculation of reactor thermal power had resumed regular accuracy.

On the basis of calculations made afterwards, the reactor thermal power was assessed to have exceeded the planned reactor power of 105% by 0.8% at the highest. However, plant unit safety was not in jeopardy and the plant unit's Technical Specifications were not violated. STUK has approved the gradual upgrading of the reactor power of the Loviisa plant units up to 109%. After this event, the functioning of ultrasound measurements was checked at Loviisa 2 when operation at 105% power level was started in June 1997 and the error that occurred at Loviisa 1 was not observed.

3.2 Fans failed to operate after Loviisa 1 plant protection system periodic test

A plant protection system periodic test was conducted at Loviisa 1 on 23 September 1997 after which both supply air fans of the containment vacuum and purification system failed to start. The plant unit was operating at full power at the time of the event.

The containment isolation valves must close in the containment protection system periodic test conducted every four weeks, in which case also the fans of the containment vacuum and purification system stop. After the test, an exhaust air fan was started and after that there was an attempt to start the supply air fans, which both failed to start.

If both supply air fans fail during power operation the Technical Specifications require the plant unit to be placed in shutdown state without delay. In compliance with the requirements of the Tech Specs, preparations for shutdown were started during which attempts to start the other supply air fan proved successful. The fans were out of operation simultaneously for about 1.5 hours. If one supply air fan is inoperable, three days are allowed for repairs during plant unit operation.

The fans were rendered inoperable by earlier repair work on the other fan relating to the operation of the limit switch of the fan's gate valve. The repair was carried out according to an incorrect connection diagram and, therefore, both fans failed to start.

During the event, containment underpressure was maintained by means of exhaust air fans and the system was thus capable of performing its safety function.

Loviisa 2

In the third quarter of 1997, it was found out at Loviisa 2 that the float in the pressurised emergency water tank of the plant unit's emergency cooling system, which had sunk to the bottom, would have prevented the tanks operation in an accident. The event is classified INES level 1.

3.3 Pressurised emergency water tank inoperable due to a sunken float

The Loviisa 2 plant unit was being shut down for annual maintenance when it was noted on 7 September 1997 that the float in one pressurised emergency water tank of the plant unit's emergency cooling system had erroneously closed the tank's discharge pipe. No alarm signal was transmitted of the movement of the float and, thus, the exact closing time of the discharge pipe is not known. The tank's previous discharge test, which would have disclosed this failure to operate, was conducted in the 1996 annual maintenance outage. The tank had performed faultlessly in the test. In a potential accident situation, the float closing the discharge pipe would have prevented injection of water from the tank to the reactor, and this would have been impossible to repair during an accident.

Emergency cooling systems remove heat from the reactor in loss of coolant etc accident situations. The emergency cooling systems of the Loviisa plant units include i.a. four pressurised emergency water tanks containing a total of ca. 160 m^3 of borated water. 5.5 MPa pressure is maintained in the tanks by means of nitrogen. Nitrogen pressure blows water from the tank to the reactor pressure vessel if, in consequence of an accident, primary circuit pressure goes below the tank internal pressure. Two tanks supply water to the lower part of the reactor pressure vessel and two above the reactor core. The supply of water is sufficient if at least one tank feeding the upper and one feeding the lower part are capable of operation.

The float serves to prevent access to the reactor of nitrogen gas inside the tank after the tank's drawdown. Nitrogen inside the reactor would disturb fuel cooling and if the nitrogen were released via the reactor to the containment it would cause extra pressure increase inside the containment. The float is hollow and normally floats on the tank water surface. When water decreases the float sinks along with the water level and closes the discharge pipe after tank drawdown. The float is equipped with a steering arm and an associated control mechanism that transmits an alarm signal to the process computer of any deviating float positions. Access of nitrogen to the reactor can also be prevented by means of tank-to-reactor feedline isolation valves that the plant unit operator can close after tank drawdown.

The faulty float was removed and its position indicating mechanism was dismantled. The float's surface had several pit corrosion marks through which water from the tank had leaked inside the ball, causing it to sink. Among other things a twisted steering arm had caused sticking of the position indicating mechanism. Position monitoring was thus unable to follow the position of the float.

The faulty float was replaced, the steering arm of the position indicating mechanism was straightened and the position of the detection instrument's inductance coil was adjusted for improved sensitivity of operation.

After the event, Imatran Voima Oy examined the operation of three other pressurised emergency water tanks at the Loviisa 2 plant unit. Their alarm signals for deviating float positions functioned faultlessly and it was noted on the basis of the tank water level changes that water would have been discharged from the tanks according to design.

Imatran Voima Oy has also assessed the adequacy of measures routinely taken at Loviisa 1 during annual maintenance to disclose faults of this type. On the basis of the assessment, complementary testing has been planned to ensure faultless operation of the tanks and functioning of the float position indicating mechanisms also at Loviisa 1.

Imatran Voima Oy has also planned changes to procedures to ensure the faultless operation of float control and position indicating mechanisms in connection with the servicing and testing of the tanks.

Olkiluoto 1

In the third quarter of 1997 it was observed that the cables of measuring transducers monitoring the reactor core neutron flux had been incorrectly coupled for about two weeks at Olkiluoto 1. The event is classified INES level 0.

3.4 Incorrect coupling of neutron flux measuring transducers at Olkiluoto1

It was detected at Olkiluoto 1 on 3 July 1997 that four measuring transducers of a system monitoring the reactor core neutron flux were incorrectly coupled. The coupling error was detected on the basis of conflicting neutron flux signals. The mistake had been made in connection with the replacement of the system's cubicles for electronics during annual maintenance outage.

The neutron flux monitoring system that measures the power distribution of the reactor core during plant operation has 28 fixed probes at regular intervals in between the fuel assemblies in the reactor core. Each probe has four neutron flux measuring transducers vertically placed at regular intervals. The local power level in the core is determined by means of signals transmitted by the transducers. The signals actuate the reactor protection functions if the measured values exceed set limits. In the event in question, the signals of the two lowest transducers of two probes had been cross-connected.

In connection with the replacement of the electronics cubicles, the connectors of the cables of the measuring transducers were replaced and the symbols of the cables were temporarily detached. Two coupling errors were caused by mixed-up cable symbols. According to the working instructions, the connectors were to be changed one by one to avoid mistakes. It is also possible that the cable symbols were incorrect from the start.

The event is of minor safety-significance. The reactor core power is monitored not only by fixed measuring sensors but also by motor-operated movable detecting instruments and by a computer program based on neutronphysical calculation. According to these, power restrictions were not exceeded during the time that the measuring transducers were cross-coupled. The coupling error would not have essentially affected the protection signals that are actuated by neutron flux.

After the event, the correct coupling of all neutron flux measuring transducers of the plant unit's reactor was ensured by a cable scanner. Teollisuuden Voima Oy will improve work planning and control to avoid recurrence.

Olkiluoto 2

No reportable events occurred at Olkiluoto 2 in the third quarter of 1997.

4 RADIATION SAFETY

Individual doses to nuclear power plant personnel were below the annual dose limit. Also environmental releases were well below the release limits. In samples collected around the Finnish nuclear power plants, 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 nuclear power plant in the third annual quarter of 1997 was 14.1 mSv and it was received at Loviisa nuclear power plant. 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 five years. This annual average has been monitored since the beginning of 1992. Radiation doses at Loviisa and Olkiluoto nuclear power plants have been below authorised limits.

Occupational dose is mainly incurred in work performed during annual maintenance outages. The annual maintenance outages of the Loviisa plant units were in this annual quarter.

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

Collective occupational dose at the Loviisa plant units was 1.0 manSv and 0.06 manSv at the Olkiluoto units in the third annual quarter. As established by STUK in YVL Guides, the collective dose limit for one plant unit is 2.5 manSv per one gigawatt of net electrical power averaged over two successive years; this means a total annual collective dose of 1.11 manSv/year and of 1.78 manSv/year for the Loviisa and Olkiluoto units respectively.

4.2 Radioactive releases into the environment

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

Regular sampling and analysis programmes ensure radiation safety in the vicinity of Finnish nuclear power plants. The environmental distribution of radioactive releases from power plants and their transfer to food chains is monitored and it is ensured that releases remain below authorised limits. In this quarter, a total of 175 samples were analysed according to the programmes. In addition to these analyses, 26 external radiation measurements were performed.

Two samples of deposition collected in the vicinity of Loviisa nuclear power plant contained radioactive cobalt-60 isotope originating from the power plant. One sample also contained radioactive silver-110m. Two samples of bladder wrack contained radioactive manganese-54, cobalt-60 and silver-110m isotopes. Radioactive substances originating from the plant (manganese-54, cobalt-58 and cobalt-60) were also measured in some samples of sedimenting matter. Tritium concentrations exceeding normal level were measured in four samples of seawater.

Table III. Occupational dose distribution in the third quarter of 1997 and from 1.1.1997.

Dose range (mSv)	Number of persons by dose range					
	Third quarter 1997			From 1.1.1997		
	Loviisa	Olkiluoto	Total*	Loviisa	Olkiluoto	Total*
< 0,5	171	114	300	169	517	634
0,5–1	67	19	100	75	231	299
1–2	56	16	109	74	208	286
2–3	42	2	66	44	101	138
3–4	25	–	35	21	58	84
4–5	18	1	32	24	36	66
5–6	13	–	21	14	23	59
6–7	11	–	15	14	16	43
7–8	15	–	18	14	9	37
8–9	4	–	9	4	4	16
9–10	6	–	16	5	4	21
10–11	5	–	9	6	2	17
11–12	5	–	9	4	3	19
12–13	6	–	6	5	–	11
13–14	1	–	1	3	1	7
14–15	1	–	2	3	–	4
15–16	–	–	–	1	–	3
16–17	–	–	–	–	–	1
17–18	–	–	–	–	–	4
18–19	–	–	–	–	–	3
19–20	–	–	1	–	–	4
20–25	–	–	–	–	–	6
> 25	–	–	–	–	–	–

* This 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. The highest individual radiation dose in 1997, 23.3 mSv, was received at a nuclear power plant in Sweden.

Radioactive cobalt-60 originating from the Olkiluoto power plant was measured in one sample of deposition collected in the vicinity of the plant and in all seaweed samples. In addition, most seaweed samples contained radioactive manganese-54 isotope and also a more short-lived radioactive cobalt isotope (cobalt-58). Two samples of mussels contained radioactive cobalt-60. Radioactive manganese-54 was measured only in one sample of mussels. Two samples of sedimenting matter contained radioactive manganese-54 and four contained radioactive cobalt-60 isotope. A small amount of tritium was measured in one sample of deposited material.

All the measured concentrations were low and require no measures.

Radioactive strontium, caesium and plutonium isotopes originating from the Chernobyl accident or nuclear weapons tests are measurable in environmental samples. Natural radioactive substances (i.a. beryllium-7, potassium-40, uranium and thorium decay series) are also detected in the samples.

Table IV. Radioactive releases by plant site, third quarter 1997.

Gaseous effluents (Bq) a)					
Plant site	**Noble gases (Krypton-87 equivalents)**	**Iodines (Iodine-131 equivalents)**	**Aerosols**	**Tritium**	**Carbon-4**
Loviisa					
Report period	$9.4 \cdot 10^{11}$	b)	$2.5 \cdot 10^{7}$	$4.2 \cdot 10^{10}$	$4.1 \cdot 10^{10}$
Early 1997	$3.8 \cdot 10^{12}$	$7.2 \cdot 10^{4}$	$2.5 \cdot 10^{8}$	$2.0 \cdot 10^{11}$	$1.5 \cdot 10^{11}$
Olkiluoto					
Report period	b)	$4.6 \cdot 10^{5}$	$1.1 \cdot 10^{7}$	$1.2 \cdot 10^{11}$	c)
Early 1997	$2.1 \cdot 10^{11}$	$1.7 \cdot 10^{7}$	$4.1 \cdot 10^{7}$	$2.1 \cdot 10^{11}$	c)
Annual release limits					
Loviisa	$2.2 \cdot 10^{16}$ d)	$2.2 \cdot 10^{11}$ d)			
Olkiluoto	$1.8 \cdot 10^{16}$	$1.1 \cdot 10^{11}$			

Liquid effluents (Bq) a)		
Plant site	**Tritium**	**Other nuclides**
Loviisa		
Report period	$1.7 \cdot 10^{12}$	$5.4 \cdot 10^{6}$
Early 1997	$9.9 \cdot 10^{12}$	$7.2 \cdot 10^{6}$
Olkiluoto		
Report period	$1.9 \cdot 10^{11}$	$1.1 \cdot 10^{9}$
Early 1997	$1.1 \cdot 10^{12}$	$8.4 \cdot 10^{9}$
Annual release limits		
Loviisa	$1.5 \cdot 10^{14}$	$8.9 \cdot 10^{11}$ d)
Olkiluoto	$1.8 \cdot 10^{13}$	$3.0 \cdot 10^{11}$

a) The unit of radioactivity is Becquerel (Bq); 1 Bq = one nuclear transaction per second.
b) Below the detection limit.
c) The carbon-14 release-estimate based on experimental data was $1.8 \cdot 10^{11}$ Bq in Olkiluoto in the report period and $4.9 \cdot 10^{11}$ Bq in early 1997.
d) The numerical value shows the release limit for the Loviisa plant site, assuming that the sum of various types of release limit shares shall be smaller than or equal to 1.

5 SAFETY IMPROVEMENTS AT NUCLEAR POWER PLANTS

The annual maintenance outages of the Loviisa plant units were in the third quarter of 1997 and safety-related improvements were made to the systems of the plant units. The Olkiluoto plant units were in power operation for most of this quarter and no significant modifications were made.

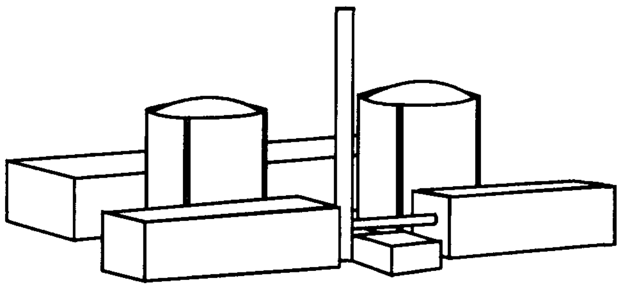
At the Loviisa plant units, the minimum flow circuits of emergency cooling pumps were replaced with new flow circuits equipped with heat exchangers. These circuits ensure sufficient minimum flow to protect pumps from overheating. The new flow circuit lines were installed from emergency cooling pump pressure side direct to suction side. At Loviisa 1, one of two emergency cooling lines was modified in this way in the 1996 annual maintenance outage. These modifications improve the reliability of reactor core emergency cooling. They helped eliminate a situation where some water would be recirculated to the emergency make-up water tank due to the valves of the minimum flow circuits having erroneously remained open during an accident. This would have lead to the pump's suction source alternating between the tank and the reactor containment sumps and to potential failure of the valves. A valve failure in connection with repeated changeover switching such as this could have caused loss of emergency cooling in a potential accident situation. The minimum flow circuits of the containment spray system pumps, which are used in accident situations, were removed because the recirculation function provided by the lines in question is not required in the starting of the pumps.

During the annual maintenance outages of the Loviisa plant units, the replacement of steam generator distributors was continued. New distributors were installed at Loviisa 1 to one and at Loviisa 2 to two of the six steam generators of the plant units. The new distributors are less prone to erosion corrosion and easier to service than the old ones.

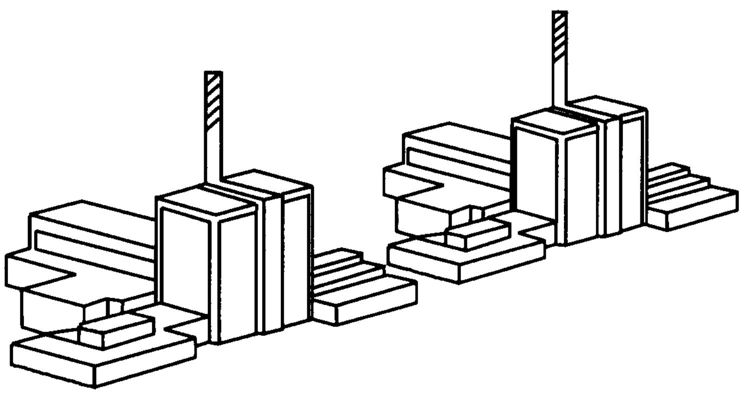
Council of State decisions	**Regulatory control and inspections by STUK**
	Preparation of a nuclear power plant project • Preliminary plans for the plant and safety principles • Location and environmental impact of the plant • Arrangements for nucler fuel and nuclear waste management
Decision in Principle	
	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	465/445	Pressurized water reactor (PWR), Atomenergoexport
Loviisa 2	4 Nov. 1980	5 Jan. 1981	465/445	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	735/710	Boiling water reactor (BWR), Asea Atom
Olkiluoto 2	18 Feb. 1980	1 July 1982	735/710	Boiling water reactor (BWR), Asea Atom

Imatran Voima 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.

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STUK-B-YTO 169 Operation of Finnish nuclear power plants 3/97

ISBN 951-712-253-5
ISSN 0781-2884

Oy Edita Ab, Helsinki 1998