STUK

STUK-B-YTO 167 December 1997

OPERATION OF FINNISH NUCLEAR POWER PLANTS

Quarterly report, 2nd quarter 1997

Kirsti Tossavainen (ed.)

29- 10

STUK • SÄTEILYTURVAKESKUS • STRÅLSÄKERHETSCENTRALEN
RADIATION AND NUCLEAR SAFETY AUTHORITY

STUK

STUK-B-YTO 167 December 1997

OPERATION OF FINNISH NUCLEAR POWER PLANTS

Quarterly report, 2nd quarter 1997

Kirsti Tossavainen (ed.)

STUK • SÄTEILYTURVAKESKUS • STRÅLSÄKERHETSCENTRALEN
RADIATION AND NUCLEAR SAFETY AUTHORITY

ISBN 951-712-239-X
ISSN 0781-2884

Oy Edita Ab, Helsinki 1997

TOSSAVAINEN, Kirsti (ed.). Operation of Finnish nuclear power plants. Quarterly report, 2nd quarter 1997. STUK-B-YTO 167. Helsinki 1997. 22 pp. + Appendices 2 pp.

ISBN 951-712-239-X
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 which STUK – Radiation and Nuclear Safety Authority 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 second quarter of 1997, except for the annual maintenance outages of Olkiluoto plant units and the Midsummer outage at Olkiluoto 2 due to reduced demand for electricity. There were also brief interruptions in power operation at the Olkiluoto plant units due to three reactor scrams. All plant units are undergoing long-term test operation at upgraded reactor power level which has been approved by STUK. The load factor average of all plant units was 88.7%.

One event in the second quarter of 1997 was classified level 1 on the INES. The event in question was a scram at Olkiluoto 1 which was caused by erroneous opening of switches. Other events in this quarter were 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 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 APRIL–JUNE 1997

Finnish nuclear power plant units were in power operation in the second quarter of 1997 except for the annual maintenance outage of the Olkiluoto nuclear power plant units and the Midsummer outage at Olkiluoto 2. In addition, three reactor scrams occurred at the Olkiluoto plant units due to which power operation was discontinued for a short while. All the plant units are currently undergoing 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 30.6% and the load factor average of the plant units was 88.7 %. Long-term test operation at upgraded 103% reactor power continued at Loviisa 1. Test operation at upgraded 105% power level was started at Loviisa 2 on 10 June 1997. Olkiluoto 1 test operation at upgraded 108% power level was started on 18 June 1997 and Olkiluoto 2 test operation at upgraded 105% power level on 28 May 1997.

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 factor.*

	Electricity production (gross, TWh)		Availability factor (%)		Load factor (%)	
	Second quarter 1997	From 1.1.1997	Second quarter 1997	From 1.1.1997	Second quarter 1997	From 1.1.1997
Loviisa 1	1.03	2.08	100.0	100.0	98.5	100.4
Loviisa 2	1.05	2.04	100.0	97.1	100.2	98.3
Olkiluoto 1	1.35	3.05	79.3	89.6	78.8	89.5
Olkiluoto 2	1.24	2.83	77.0	88.4	77.1	88.7

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

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

Table II. Nuclear energy in Finnish electricity production.

	Second quarter 1997	From 1.1.1997	1996
Nuclear electricity production (net, TWh)*	4.5	9.6	18.7
Total electricity production in Finland (net, TWh)*	14.7	33.8	66.4
Nuclear's share of total electricity production (%)	30.6	28.4	28.2
Load factor averages of Finnish plant units (%)	88.7	94.2	90.8

* Source: Statistics compiled by the Finnish Electricity Assiciation

2.2 Olkiluoto 1 annual maintenance outage

The 18th refuelling and maintenance outage of Olkiluoto 1 was from 27 May to 14 July 1997. The plant unit was off the national grid for 18 days.

In addition to Teollisuuden Voima Oy's own staff, the maximum number of contract workers simultaneously participating in the annual maintenance outage was 1072. The collective radiation dose incurred in work done during the outage was 0.59 manSv (1 manSv in 1996). The highest individual dose was 6.2 mSv.

During the outage, the reactor scram system inadvertently actuated when a reactor protection system functional test was being performed on 28 May 1997. The test instructions were inaccurate and wrong action was taken which resulted in scram system actuation. An actual scram did not occur because all control rods were in the reactor core.

During plant unit start-up after the annual maintenance outage on 13 June 1997 a reactor scram occurred with the reactor at about 6% power. The plant unit had not yet resumed power generation. Its safety systems functioned according to design. The scram was attributed to a position indicator failure of a reactor feedwater system control valve. The reactor water level consequently rose high enough to actuate the scram system. The fault was repaired and power ascension was continued.

Safety improvements during the outage are described in Chapter 5.

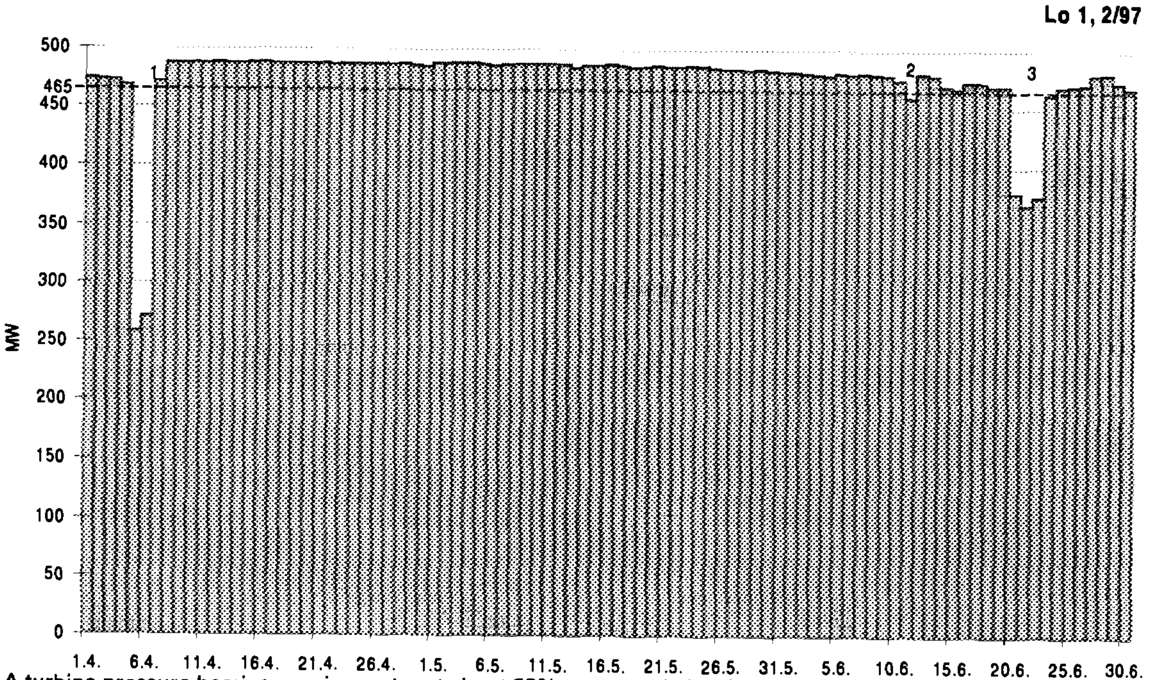
After annual maintenance, the plant unit was brought back on line on 14 June 1997.

2.3 Olkiluoto 2 annual maintenance outage

The 16th refuelling and maintenance outage of Olkiluoto 2 was from 4 to 22 May 1997. The plant unit was off the national grid for 18 days.

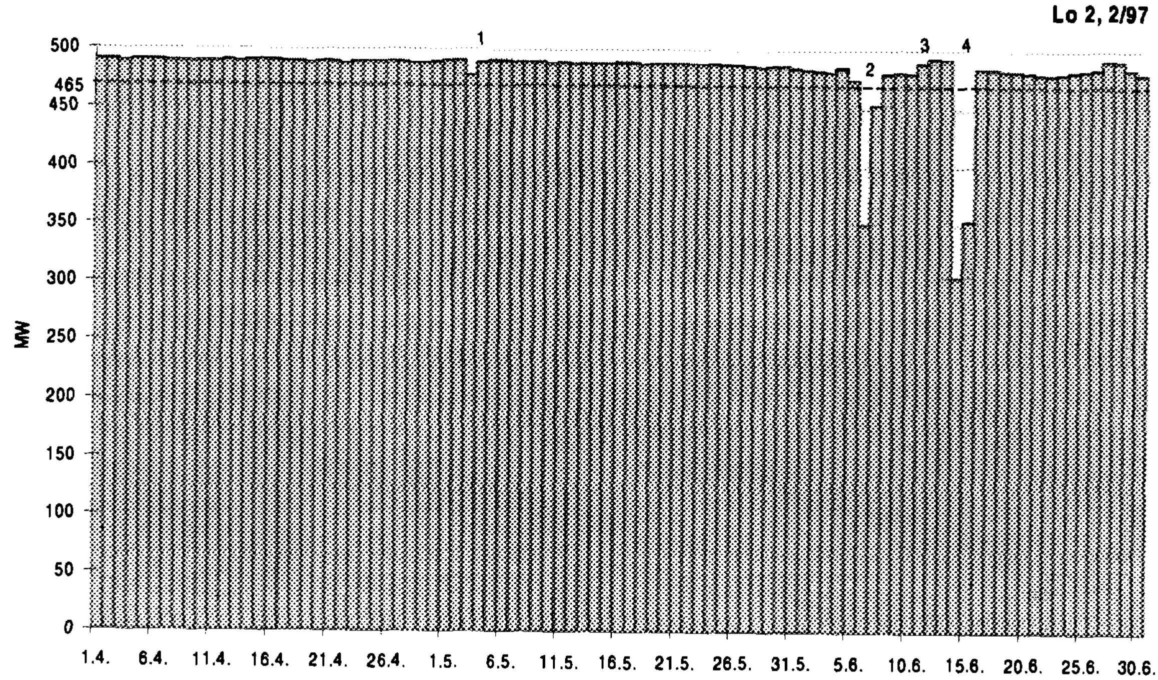
In addition to Teollisuuden Voima Oy's own staff, the maximum number of contract workers simultaneously participating in the annual maintenance outage was 1140. The collective dose incurred in work done during the outage was 0.89 manSv (0.43 manSv in 1996). The highest individual dose was 10.2 mSv.

In connection with the plant unit's shutdown on 4 May 1997, a reactor scram occurred at about 11% reactor power level. At the time of the event, the plant unit was already off the grid. The scram was caused by a stopped reactor feedwater flow and a consequent decrease in the reactor water



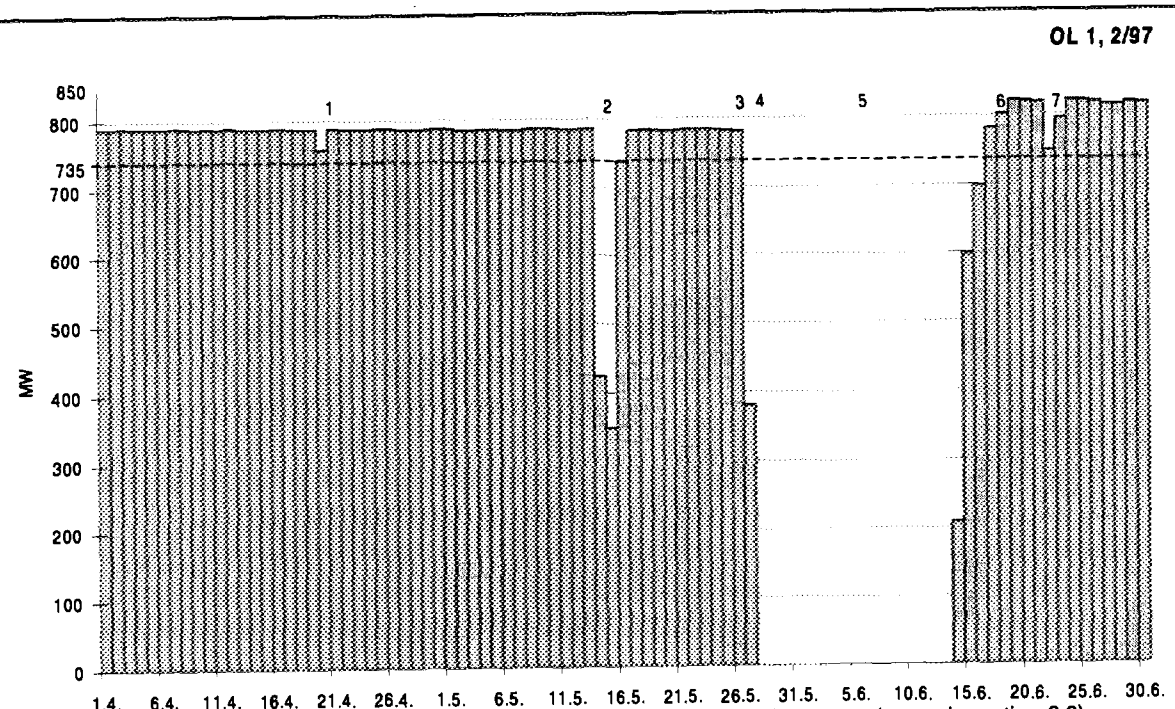
1. A turbine pressure bearing repair, reactor at about 53% power.
2. A main circulation pump trip in consequence of a balancing magnet adjustment failure, reactor power decreased to 75%.
3. Low demand for electricity in Midsummer.

Fig 1. Daily average gross power of Loviisa 1 in April–June 1997.



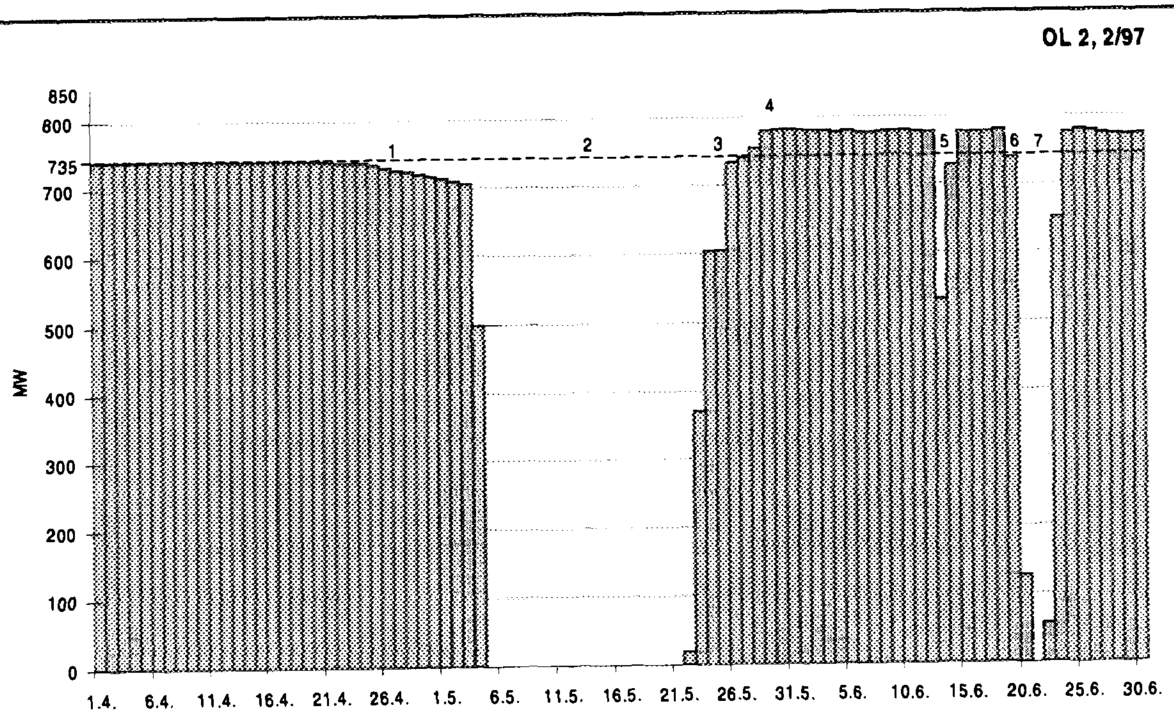
1. Feedwater control valve repair, reactor at 82% power.
2. Main transformer failure repair, reactor at about 53% power.
3. Long-term test operation at 105% upgraded power started (see sub-section 2.6).
4. Main transformer insulator replaced, reactor at about 53% power.

Fig 2. Daily average gross power of Loviisa 2 in April–June 1997.



1. Periodic tests requiring power reduction, lowest reactor power was about 70%.
2. Reactor scram (see sub-sections 2.5 and 3.1)
3. Coast-down operation (reactor power decreased to 104.4% by start of annual maintenance).
4. Reactor scram (see sub-sections 2.5 and 3.2).
5. Annual maintenance (see sub-section 2.2).
6. Long-term test operation at 108% upgraded power level started (see sub-section 2.7).
7. Repair of a leaking venting plug of turbine plant feedwater system heat exchanger, and low electricity demand in Midsummer, reactor at 73% power.

Fig 3. Daily average gross power of Olkiluoto 1 in April–June 1997.



1. Coast-down operation (reactor power decreased to 96.3% by start of annual maintenance).
2. Annual maintenance (sub-section 2.3).
3. Tests relating to the power upgrade (i.a.load reduction test and turbine trip)
4. Long-term test operation at 105% power started (see sub-section 2.7).
5. Reactor scram (see sub-section 2.5 and 3.4).
6. Load reduction test relating to the reactor power upgrade.
7. Hot shutdown due to low electricity demand in Midsummer (see sub-section 2.4).

Fig 4. Daily average gross power of Olkiluoto 2 in April–June 1997.

level. The plant unit's safety systems functioned as designed. A feedwater pump control disturbance caused the stopping of the flow of feedwater. The liquid coupling of the pump's control motor which caused the disturbance was replaced in the annual maintenance outage.

Safety modifications made during the outage are described in Chapter 5.

The plant unit was brought back on line after the annual maintenance on 22 May 1997.

2.4 Olkiluoto 2 Midsummer outage

Olkiluoto 2 was placed in hot shutdown on 20 June 1997 due to low electricity demand. In the outage, a generator cooling water tube and a main steam system relief line control valve were repaired and some other minor repairs were also made. A minor modification relating to the turbine automation was also made in the outage. The plant unit was brought back on line on 22 June 1997.

2.5 Olkiluoto 1 and 2 reactor scrams

In the second quarter of 1997, two reactor scrams occurred at Olkiluoto 1 and one in Olkiluoto 2 while the plant units were generating electricity. The first scram in Olkiluoto 1 was on 14 May 1997 and the plant unit resumed electricity generation on 15 May 1997. The second scram was on 27 May 1997. The plant unit was in the process of being shut down for annual maintenance and was not restarted before the outage. The reactor was operating at 105% power when both scrams occurred. These events are described in sub-sections 3.1 and 3.2.

The reactor scram at Olkiluoto 2 was on 13 June 1997 and the plant unit was brought back on line the same day. The unit was operating at 105% power at the time of the event. The event is described in sub-section 3.4.

2.6 Test operation of Loviisa plant units at upgraded reactor power levels

Long-term test operation at upgraded 103% reactor power level started at both Loviisa plant units early January. At the beginning of June, the reactor power level of Loviisa 2 was upgraded from rated to 105% power.

Both Loviisa plant units are undergoing a project to operate the units at upgraded 109% reactor power level. The power upgrading does not require significant modifications to the plant systems. The project also includes a renewal of the operating licences of the plant units which are in force until the end of 1998.

An essential part of the project is test operation of the plant units at 109% reactor power level and at levels below that. According to a decision of the Ministry of Trade and Industry, test operation at a reactor power level exceeding rated power is allowable by virtue of the existing operating licence provided that STUK's approval is obtained. STUK decided in May that reactor power at both Loviisa nuclear power plant units can be gradually upgraded to 109%. STUK will make a separate, overall safety assessment of Loviisa 1 and 2 in connection with the review of Imatran Voima Oy's operating licence application.

Imatran Voima Oy plans to continue test operation of the Loviisa plant units: after the 1997 maintenance outages, the reactor power of Loviisa 1 will be first upgraded to 105% and later to 107%. Plans are to operate the Loviisa 2 reactor at 107% power as of the autumn of 1997. Before the turn of the year 1997-1998, plans are for a one-week test operation period at 109% reactor power for both units.

2.7 Test operation of Olkiluoto plant units at upgraded reactor power levels

The Olkiluoto 1 reactor power level was upgraded to 108% after the 1997 maintenance outage and tests were conducted to check modifications to the plant systems implemented in the outage. The reactor power of Olkiluoto 1 was upgraded to 105% after the 1996 annual maintenance outage. The reactor power of Olkiluoto 2 was upgraded to 105% after the 1997 maintenance outage.

Long-term reactor test operation at power levels which exceed rated power defined in the existing operating licence is an essential part of the modernisation projects presently under way at the Olkiluoto plant units. Test operation serves to demonstrate the operation of the modified systems and the capability of the reactors for long-term operation at the upgraded power levels. According to a decision of the Ministry of Trade and Industry, the test operations can be carried out within the framework of the current operating licence if STUK approves this. According to a decision made by STUK in May, the reactor power level of Olkiluoto 1 can be upgraded to 109% and that of Olkiluoto 2 to 107% after the 1997 annual maintenance outages after the modifications to the systems of the plant units have been made.

Teollisuuden Voima Oy plans to operate Olkiluoto 1 at 108% reactor power level for about a year. The increase of reactor power to the allowable 109% level is not possible until the turbine plant capacity has been changed to cope with the corresponding increased steam flow. Olkiluoto 2 plans to continue long-term test operation at 105% reactor power until the autumn of 1997 and, after that, to upgrade it to 107%.

3 EVENTS AND OBSERVATIONS

Loviisa 1 and 2

No reportable events occurred at the Loviisa plant units in the second quarter of 1997.

Olkiluoto 1

In the second quarter of 1997, two reactor scrams occurred at Olkiluoto 1. One resulted from the erroneous opening of switches and was classified INES level 1. The other was INES level 0.

3.1 Olkiluoto 1 reactor scram and reactor water clean-up system valve leak

A reactor scram occurred at Olkiluoto 1 on 14 May 1997. The plant unit was at 105% power at the time of the event. As a result, slightly radioactive water leaked onto the floor of the instrument room through the sealing of a reactor water clean-up system valve.

The event was initiated by tests conducted in the switchyard using an incorrect electrical diagram. Due to the faulty diagram, the trip circuit of the fault protection of the plant unit's 400 kV plant switch was not disconnected for the duration of the tests, which led to the switch's unplanned opening. In a situation such as this, plant automation switches the plant unit's power supply to take place from the 110 kV offsite grid via two start-up transformers and, at the same time, reduces the reactor power. At the time of the event, one start-up transformer was being serviced. Diesel generators started as designed and replaced the start-up transformer which was being serviced. As regards the switching of power supply to the 110 kV grid, a malfunction occurred in the control oil system which controls the turbine control valves. The malfunction resulted in a turbine trip and a reactor scram at about 30% reactor power. The plant unit's safety systems functioned according to design during the reactor scram.

The event stopped non-diesel-backed equipment which would have been supplied power via the 110 kV start-up transformer which was being serviced. Thus i.a. two operating turbine plant feedwater pumps tripped because pumps providing cooling their oil coolers stopped. Correspondingly, pumps of a system cooling the reactor water clean-up system cooler also tripped. After an increase in the temperature of water circulating in the clean-up system, the flow of water switched, as designed, to the filter bypass line to prevent damage to the filters.

One valve seal was damaged during restoration of the reactor water clean-up system to normal operation. A pressure peak in the pipeline was suspected to have caused the leak. About one cubic metre of slightly radioactive water escaped to a room through the damaged seal. In connection with the valve's repair, a mechanic sustained burns from hot water. The event had no bearing on the radiation safety of the environment or personnel.

The plant unit was brought back on-line on 15 May 1997 after the damaged seal had been replaced and the the equipment whose power supply was lost had been checked.

Teollisuuden Voima Oy has looked into measures to prevent recurrence of similar events. The event revealed functional defects in the plant unit's systems. Teollisuuden Voima Oy will pay special attention in the future i.a. to the timing of switchyard tests to avoid the loss of offsite grid connections, to the functioning of the turbine control oil system, and to the separation of power supply to operating systems. Measures are also being examined to prevent damage to valve seals of the broken type.

3.2 Olkiluoto 1 reactor scram due to erroneous opening of switches

A reactor scram occurred at Olkiluoto 1 on 27 May 1997 which was caused by an operational error.

At the time of the event, the plant unit was in power operation at 105% power level and preparations were made to shut it down for annual maintenance. Safety measures prior to shutdown include i.a. disconnection of the TIP (Traversing Incore Probe) drive mechanisms from the 400 V battery-backed switchgears supplying power to them. A mistake was made during the disconnection, however. Instead of the switches of three drive mechanisms, the main switches of three distribution cubicles were opened. When the distribution cubicles de-energised process transients and a reactor scram resulted. The restoration of voltage to the distribution cubicles took about an hour. After this event, Teollisuuden Voima Oy decided to start the annual maintenance outage which otherwise would have been started three hours later.

The power failures caused alarm printer and process computer malfunctions which impaired the work of the control room personnel. The functioning of all safety systems during the power failure was not recorded on computer completely. Thus, it has not been possible to check afterwards the functioning of the systems. The safety systems start to operate independently of the process computer. The process computer displays became operational immediately on restoration of power supply.

The event was due to human error made by the operators. Teollisuuden Voima Oy will arrange refresher training to the operating personnel about the disconnection of electrical systems to prevent recurrence of similar events. Also the relevance and adequacy of existing procedures pertaining to the disconnection measures will be assessed.

Olkiluoto 2

In the second quarter of 1997, Olkiluoto 2 events included control rod manoeuvring in violation of the Technical Specifications, a reactor scram, and an overflow of radioactive water from a tank in the waste building. All the events were level 0 on the INES scale.

3.3 Control rod manoeuvring in violation of the Technical Specifications at Olkiluoto 2

Towards the end of the annual maintenance outage at Olkiluoto 2 on 19 May 1997, tests of the reactor protection system were conducted which included slight manoeuvring of the control rods. One detector of the SRM (Source Range Monitoring) system, which measures the neutron flux, was inoperable. According to the Technical Specifications, all four SRM detectors must be operable during control rod manoeuvring in an outage situation such as the one in question.

The SRM system monitors reactor core power within the lowest power range and it consists of four detectors each of which is placed in it own quadrant of the core. The system relays reactor power data to the reactor operator in the control room and initates the reactor protective functions if two out of four detectors indicate the measuring value to exceed set limits. For the reactor protection functions to actuate reliably when required, all four detectors must be operable in situations where control rods are manoeuvred.

This situation came about because there was no certainty about the detector fault and insufficient attention was attached to the requirements of the Technical Specifications. In order to prevent recurrence, Teollisuuden Voima Oy will, in training to be given to the personnel, place special empahsis on the importance of neutron flux monitoring and on work co-ordination. Furthermore, testing instructions will be supplemented with restrictions of the Technical Specifications.

3.4 Olkiluoto 2 reactor scram in connection with steam line activity measurement tests

A reactor scram occurred at Olkiluoto 2 on 13 June 1997 during the periodic testing of the reactor-to-turbine steam line radiation monitoring system. The testing caused a spurious scram signal and a reactor shutdown at 105% power.

The reactors of Olkiluoto nuclear power plants are equipped with fixed radiation monitoring systems which continuously measure radiation levels i.a. in reactor steam, the off-gas system, gaseous and liquid effluents, and certain rooms. The steam line has been complemented with the reactor scram function which shuts down the reactor if the set radiation limits have been exceeded. The monitoring system has four parallel measuring channels. The scram function actuates if the measuring signal of two channels exceeds the set limit. The measuring system's operation is tested regularly both electrically and using radiation sources. Tests can also be conducted during reactor operation, one measuring channel at a time.

During the periodic testing of the radiation monitoring systems of the steam line, a scram signal caused by one measuring channel was not reset to normal state prior to the testing of the next channel. A situation was created in which the measurement data indicated elevated radiation levels from two radiation measurement channels simultaneously and the reactor scrammed.

The control room immediately identified the cause of the scram. The malfunction was looked into and the plant unit was brought back on line the same day. Teollisuuden Voima Oy will review the testing instructions to avoid corresponding events.

In connection with the scram, the reactor water level decreased more than is usual in corresponding events. The unexpectedly great drop in the water level was due to the reactor being operated at an upgraded power level and to the modifications made to the reactor pressure vessel internals in connection with the plant's modernisation project. In consequence of a decrease in water level of the occurred size, the reactor process systems operate in a way which causes unnecessary loads on the pipe assemblies of certain systems. Teollisuuden Voima Oy has launched measures to improve the behaviour of the Olkiluoto plant units during transients which lead to a decreased reactor water level.

3.5 Radioactive water overflow from a tank in Olkiluoto 2 waste building

On 23 June 1997, about 3 m^3 of radioactive water ended up onto the floor of the liquid waste water treatment room in Olkiluoto 2. The event occurred during the treatment of radioactive waste water at a time when a separator which removes solids had been stopped and left on wet circulation mode after use. Flushing circulation which is stopped manually was on and the system's two tanks filled up at the rate of 2 m^3/h. When the tanks filled up, water started to flow onto the floor through an overflow pipe.

The water flowing onto the floor was returned to one of the tanks after the tank had been partially emptied. The activity of the water which ended up onto the floor was 8 Bq/ml, which falls below the 11 Bq/ml pumping limit for waste waters. Radiation doses incurred in the cleaning of the room were very low.

The ca. 20 m^2 room has no pipe penetrations and is equipped with a sump for radioactive waters. On the basis of its general radiation level, the room has been classified to a radiation class (orange area) above basic level. It is kept closed during normal operation and may only be accessed by persons with special training in radiation protection.

A corresponding event at Olkiluoto 2 on 17 January 1997 (STUK-B-YTO 163) and a separator equipment trial run had already shown it was necessary to direct the equipment flushing water to a bigger tank to prevent overflow. The modification was made at both plant units early 1997. Because of a separator equipment malfunction during the flushing operation, the water was directed to a smaller tank.

After the overfilling of the tanks in January, a decision was made to modify the separator wet circulation control logic so that both the separator and the flushing water injection will stop within an hour. The modifications were made at both plant units after Midsummer.

The event did not cause radioactive releases into the environment or any significant radiation exposure of the plant personnel.

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 second annual quarter of 1997 was 12.4 mSv and it was received at Olkiluoto 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 monitoring of the annual average has started at 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 Olkiluoto plant units were in this annual quarter.

The individual dose distribution of nuclear power plant 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.

Collective occupational dose at the Loviisa plant units was 0.03 manSv and 1.49 manSv at the Olkiluoto units in the second annual quarter. 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; 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

Radiation safety in the vicinity of Finnish nuclear power plants is ensured by regular sampling and analysis programmes. The environmental distribution of radioactive releases from power plants and their transfer to food chains is monitored and it is ensured that the releases remain below authorised limits. In this quarter, a total of 170 samples was analysed according to the programmes.

Cobalt-60 originating from the power plant was measured in one sample of deposition collected in the vicinity of Loviisa nuclear power plant. Three samples of bladder wrack contained cobalt-60, two samples contained manganese-54 and silver-110m and one sample contained cobalt-58. The same radioactive substances, with the exception of silver-110m, were also measured in samples of sedimenting matter. The sample of crustacean contained only cobalt-60 and silver-110m. Tritium concentrations above normal were measured in three samples of sea water.

Cobalt-60 originating from the power plant

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

Dose range (mSv)	Number of persons by dose range					
	Second quarter 1997			From 1.1.1997		
	Loviisa	Olkiluoto	Total*	Loviisa	Olkiluoto	Total*
< 0,5	61	498	570	65	505	577
0.5–1	9	216	233	22	224	254
1–2	3	198	231	18	195	241
2–3	1	93	105	11	103	119
3–4	–	54	68	6	58	81
4–5	1	33	45	1	31	45
5–6	–	23	35	1	24	37
6–7	–	14	32	–	15	32
7–8	–	7	16	–	9	18
8–9	–	3	9	–	3	9
9–10	–	3	8	–	3	9
10–11	–	2	11	–	2	11
11–12	–	3	7	–	3	7
12–13	–	1	2	–	–	1
13–14	–	–	–	–	1	1
14–15	–	–	–	–	–	–
> 15	–	–	–	–	–	–

* 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.

was measured in one sample of air, two samples of sea water and all samples of bladder wrack taken in the vicinity of Olkiluoto nuclear power plant. Some samples of bladder wrack also contained manganese-54 and two contained cobalt-58. Manganese-54 was measured in three and cobalt-60 in six samples of sedimenting matter. Tritium concentrations exceeding normal level were detected in one sample of deposited material and in one sample of sea water.

All the measured concentrations were low and require no measures.

Strontium-90, caesium-134 and -137 originating from the Chernobyl accident are still measurable in environmental samples. Natural radioactive substances (i.a. beryllium-7, potassium-40, uranium and thorium decay series) are also detected in the samples and their concentrations are usually higher than the concentrations of nuclides originating from the power plants or fallout.

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

Gaseous effluents (Bq) a)

Plant site	Noble gases (Krypton-87 equivalents)	Iodines (Iodine-131 equivalents)	Aerosols	Tritium	Carbon-4
Loviisa					
Report period	$1.5 \cdot 10^{12}$	b)	$1.8 \cdot 10^{6}$	$8.8 \cdot 10^{10}$	$6.8 \cdot 10^{10}$
Early 1997	$2.8 \cdot 10^{12}$	$7.2 \cdot 10^{4}$	$2.2 \cdot 10^{8}$	$1.6 \cdot 10^{11}$	$1.1 \cdot 10^{11}$
Olkiluoto					
Report period	$6.5 \cdot 10^{10}$	$1.7 \cdot 10^{7}$	$2.7 \cdot 10^{7}$	$4.5 \cdot 10^{10}$	c)
Early 1997	$2.1 \cdot 10^{11}$	$1.7 \cdot 10^{7}$	$3.0 \cdot 10^{7}$	$9.0 \cdot 10^{10}$	c)
Annual release limits					
Loviisa	$2.2 \cdot 10^{16}$ d)	$2.2 \cdot 10^{11}$ d)			
Olkiluoto	$1.8 \cdot 10^{16}$	$1.1 \cdot 10^{11}$			

Päästöt veteen (Bq) a)

Plant site	Tritium	Other nuclides
Loviisa		
Report period	$8.2 \cdot 10^{12}$	$1.7 \cdot 10^{6}$
Early 1997	$1.2 \cdot 10^{13}$	$3.1 \cdot 10^{6}$
Olkiluoto		
Report period	$5.0 \cdot 10^{11}$	$4.8 \cdot 10^{9}$
Early 1997	$8.7 \cdot 10^{11}$	$7.4 \cdot 10^{9}$
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 $1.4 \cdot 10^{11}$ Bq in Olkiluoto in the report period and $3,1 \cdot 10^{11}$ 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

In the second quarter of 1997, several plant system modifications were implemented at both Olkiluoto plant units. The modifications are mostly related to the ongoing modernisation projects at the plant units. No significant modifications were made at the Loviisa plant units in this quarter.

5.1 Loviisa nuclear power plant

The Loviisa nuclear power plant units were in power operation for the whole quarter and no significant safety modifications were implemented.

5.2 Olkiluoto nuclear power plant

Several systems modifications were made at Olkiluoto nuclear power plant. They are part of an ongoing modernisation project which has the aim of reviewing the safety features of the plant units, and of decreasing their environmental impact and the radiation doses received by the personnel. Teollisuuden Voima Oy also aims to improve the output capacity of the plant units by reducing operational transients, improving plant efficiency and upgrading the reactor power. The most important modifications made to the plant unit systems in the second quarter of 1997 are given below.

Reactor overpressure protection

The quick and reliable operation of a boiling water reactor's safety valves providing overpressure protection is of essential importance to prevent an excessive increase in reactor pressure and power and to ensure a reactor scram in the event of a transient involving blocked transfer of steam from reactor to turbine condenser. The upgrading of the reactor power requires an increased capacity for overpressure protection.

Two safety valves of a new type were added to the reactor overpressure protection system of Olkiluoto 2 in the 1997 annual maintenance outage. The system previously had two safety valves, eight pressure relief valves equivalent to the safety valves, and two quick-opening valves. The new safety valves were set to open at the same pressure as the two safety valves of the old type. In order to increase the system's reliability, the operating principle of the new safety valves was different from that of the old ones. The blowing capacity of the new safety valves is somewhat larger than that of the old valves. The new valves are also capable of operating in situations where the substance blown is water, not steam. This helps ensure overpressure protection during reactor shutdown states.

Corresponding new safety valves have been installed in Olkiluoto 1 in the 1996 annual maintenance outage.

Containment condensation pool heat transfer

A reactor power upgrading increases the production of decay heat after shutdown in proportion to the power upgrading. In connection with normal reactor shutdown, decay heat is removed from the reactor through systems specifcally designed for the purpose.

During an accident, decay heat from the reactor would be removed to the containment condensation pool. From the condensation pool it would then be transferred to the sea through the heat exchangers of the containment spray system. The temperature in the containment and the condensation pool must not, in case of accidents, exceed the containment design limits. Heat transfer from the condensation pool has been improved by increasing the surface area of the containment spray system heat exchangers so that the design limit values would not be exceeded after the reactor power upgrading either. The modifications were implemented in Olkiluoto 1 in the 1996 annual maintenance outage and in Olkiluoto 2 in the 1997 annual maintenance outage. It has been demonstrated by measurements of the heat transfer chains and by containment analyses that condensation pool temperature and pressure are kept below the limit values after the modifications even if the plant units were operating at the upgraded reactor power level in the event of an accident.

Turbine control and protection system

The turbine control and protection systems of both Olkiluoto plant units have been renewed. Renewal of the old system made with hydraulic technology from the 70s was prompted by plants to improve system serviceability and reliability. The new system is made with programmable technology. The Olkiluoto 1 modifications were made in the 1996 annual maintenance outage and those at Olkiluoto 2 in the 1997 annual maintenance outage. In the 1997 Olkiluoto 1 outage, modifications to improve the system's reliability were made.

In connection with the system's renewal, the protection and control channels have been changed to comprise three channels instead of the previous two. The turbine controller governs i.a. the turbine plant main steam line control valves during different operational conditions and the control system monitors the turbine plant and actuates the reactor scram function where necessary. The modification improves the system's reliability. Because there are three channels, the failure of one controller does not disturb the operation of the control valves during plant unit operation. The operation of the turbine controller was tested after the annual maintenance outage during load reduction and turbine trip situations which are the most critical operational transients from the viewpoint of controller operation. The controller operated faultlessly in the tests.

The improved reliability of the turbine control and protection system has for its part facilitated the reactor power upgrading. The possibility of a turbine pressure controller failure, which previously restricted reactor operation, has been reduced in connection with the system renewal.

Main circulation pump electric drives

Teollisuuden Voima Oy has planned renewal of the electric drives of all six primary circulation pumps of both Olkiluoto plant units. The renewal anticipates the ageing of the frequency converters of the primary circulation pump motors. Spare parts for the old frequency converters are also becoming harder to get. Modifications are also planned to the electric drives to extend the run-down time of the pumps during a power failure. The run-down time extension slows down changes in the reactor cooling water flow induced by pump trips and increases the safety margin to fuel failure.

The new electric drive system corresponds to the old system electrotechnically. The flywheel motor added to the system is an exception. The energy stored up in the motor facilitates controlled shutdown of a primary circulation pump during a power failure. The system's frequency converter part employs modern frequency converter technology and the control units are based on programmable technology.

In the 1996 annual maintenance outage, Olkiluoto 1 was fitted with its first new frequency converter equipment for testing purposes. The equipment's control unit was replaced with a more efficent unit in the 1997 outage. Olkiluoto 2's first new frequency converter equipment was installed in the 1997 annual maintenance outage. Presently, both plant units have in use for testing purposes one new primary circulation pump electric drive. The review of the validation plans and reports required for the final approval of the systems has not been completed yet. This applies to the programming logic in particular. This is why the schedule for the implementation of the complete renewal of all electric drives of the primary circulation pumps can only be decided upon later.

Neutron flux measuring system

The fact that the system's maintenance has become more difficult with the ageing of the technology used has prompted the renewal of the neutron flux measuring system. The new system consists of two sub-systems: one measures neutron flux during reactor start-up and the other during reactor operation. The system's new programmable technology facilitates even more detailed core monitoring. The new system is also more user-friendly than the old one.

In the 1997 Olkiluoto 2 annual maintenance outage, two SRM and IRM range channels were installed redundantly with the old system for testing purposes. Teollisuuden Voima Oy aims to take into service the entire neutron flux measuring system at Olkiluoto 2 in the 1998 annual maintenance outage.

In the Olkiluoto 1 annual maintenance outage of 1996, two SIRM sub-systems, i.e. channels using new programmable technology, had been installed redundantly with the old SRM and IRM range neutron flux measuring systems to test the new technology. The new neutron flux measuring system was taken into operation in its entirety after the 1997 annual maintenance outage. The Olkiluoto 1 neutron flux measuring system has been approved for operation until the 1998 annual maintenance outage. The qualification of the system's programmable part continues.

Intensified partial scram

The reactor control rods of the Olkiluoto plant units consist of 14 scram groups. In a partial scram, one scram group is hydraulically inserted into the reactor core to reduce reactor power. The control rods can also be inserted into the core by means of electric motors. A partial scram will be performed in such reactor feed water system and turbine plant disturbances which cause the feed water to become substantially colder than usual. In these situations reactor power is also reduced by decreasing the rotation speed of the main circulation pumps which reduces reactor power to ca. 30–40%. Gradually cooling feedwater tends to raise the reactor power, however. A partial scram compensates for this power increase and an actual scram will thus not be necessary.

Earlier, the first partial scram was immediately initiated in the above situation. Should cold feedwater increase the reactor power beyond 55%, a second partial scram would be initiated by means of the hydraulic scram system. Despite the fact that some control rods would be in the core, the reactor power could then become relatively high again. Reactor stability could be in jeopardy in a situation such as this. The situation would be further aggravated by the reactor power upgrading.

In the annual maintenance outage, the partial scram function of both Olkiluoto plant units was modified. The first partial scram occurs the same way as before, but the second partial scram is simultaneously actuated by the insertion of one scram unit into the reactor by electric motors. Rods inserted by electric motors compensate for the effect of the power increase caused by the gradual cooling of feedwater. Power will thus be a steady ca. 30–40% and the power increase problem, which occurred earlier, is eliminated.

Steam separators

The steam separators of both Olkiluoto plant units were replaced in the 1997 annual maintenance outage. The separators are located in the the upper part of the reactor pressure vessel and their function is to separate steam from the steam-water mixture coming from the reactor. The most important reason for the modification is that the humidity content of the steam produced by the old steam separators is too high. Excessively humid steam causes increased erosion and elevated radiation levels at the turbine plant. This effect is further aggravated by the reactor power upgrading. The new steam separators resolve the problem because they produce steam the humidity content of which is extremenly low.

The pressure loss with the new steam separators is also smaller than with the steam separators presently in use. This has a favourable effect on plant behaviour in anticipated operational transients. Reactor stability is also significantly improved in consequence of the reduction in pressure loss.

Electrical systems

Due to the upgrading of the reactor power of the plant units it has been necessary to make modifications to the electrical systems. The main transformer and a generator breaker were replaced in the Olkiluoto 1 annual maintenance outage. The rated power of the new main transformer is 1000 MVA, whereas that of the old transformer was 800 MVA. The new main transformer corresponds to the old transformer by design and engineered features. The new type of generator breaker meets the requirements of the reactor power upgrading and is capable of breaking full-power short-circuit current if necessary. Also the relay protection of the main transformer and generator was replaced which improves the protection of the electrical systems against various short-circuit situations.

The short-circuit and nominal current strength of the generator bus was raised from 25 kA to 32 kA in the Olkiluoto 1 annual maintenance outage. This was done by replacing the couplings, cooling unit and current transformers of the bus. The increased short-circuit and nominal current strength of the bus also required the strengthening of the bus supports.

Corresponding modifications are planned to be implemented in the Olkiluoto 2 annual maintenance outage of 1998.

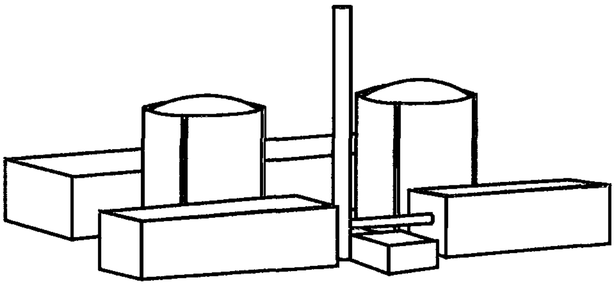
Liquid waste treatment

Olkiluoto nuclear power plant has plans to reduce the releases of radioactive liquid effluents. The waste treatment systems of the plant units will be fitted with new equipment for separating very fine solids from waste waters. A fuel pool water recovery system will also be added to the pool water system to enable water clean-up and recirculation. The system includes a 1500 m^3 storage pool for reactor and condensation pool waters which are removed for the duration of annual maintenance outages. The stored water is slightly radioactive and is cleaned up both when pumped to the pool and when injected back to the reactor.

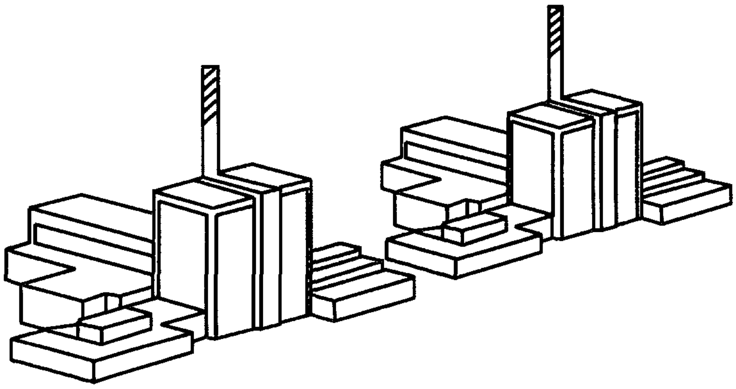
The new waste water clean-up equipment has been taken into service at both plant units. The Olkiluoto 1 storage tank for reactor and fuel pool pool water was completed in the spring and was used in the annual maintenance outage. The corresponding Olkiluoto 2 system is due for completion by next summer.

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

APPENDIX 2 PLANT DATA



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.

CONTRIBUTORS

STUK / Nuclear Reactor Regulation:
Tapani Eurasto
Marja-Leena Järvinen
Jarmo Konsi
Pekka Lehtinen
Hannu Ollikkala
Mervi Olkkonen (translation)
Jorma Rantakivi
Veli Riihiluoma
Vesa Ruuska
Tuulikki Sillanpää
Seija Suksi
Keijo Valtonen
Olli Vilkamo

STUK / Research and Environmental Surveillance:
Tarja K. Ikäheimonen
Seppo Klemola

STUK-B-YTO 167 Operation of Finnish nuclear power plants 2/97

STUK

ISBN 951-712-239-X
ISSN 0781-2884

Oy Edita Ab, Helsinki 1997