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OPERATION OF FINNISH NUCLEAR POWER PLANTS

Quarterly report, 1st quarter 1998

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ABSTRACT

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

The Finnish NPP units were in power operation for the whole first quarter of 1998. All the units were in long-term test operation at uprated power level authorised by STUK. The load factor average of the plant units was 100.8%.

An oil leak at Olkiluoto NPP Unit 2 caused an ignition that was promptly extinguished. A subsequent appraisal of the event disclosed deficiencies in the functioning of the plant unit's operating organisation and the event was classified INES level 1. Other events in this quarter had no bearing on nuclear or radiation safety.

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

STUK publishes quarterly a report on the operation of Finnish NPPs. 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 the environment is summarised. Plant safety improvements are also reported.

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

2 OPERATION OF NPPS IN JANUARY–MARCH 1998

The Finnish NPPs were in power operation for the whole first quarter of 1998.

2.1 Production data

Nuclear's share of total electricity production in Finland in this quarter was 28.3% and the load factor average of the plant units was 100.8%. Detailed production and availability figures are given in Tables I and II.

Long-term test operation at uprated reactor power levels approved by STUK continued at all plant units. The reactors of the Loviisa units operated at 107% and those of Olkiluoto at 108.6% power.

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 (%) [a]	
	First quarter 1998	1997	First quarter 1998	1997	First quarter 1998	1997
Loviisa 1	1.08	3.98	100.0	94.9	100.4	93.6
Loviisa 2	1.10	3.99	100.0	94.4	101.8	93.6
Olkiluoto 1	1.79	6.61	100.0	94.2	101.1	93.9
Olkiluoto 2	1.73	6.31	100.0	94.2	99.8	93.6

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

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

a) The load factor average takes the plant unit power upratings into account in such a way that the value of rated electrical power that corresponds to maximum allowable reactor power in each point of time is used as rated electrical power (gross).

Table II. Nuclear energy in Finnish electricity production.

	First quarter 1998	1997	1996
Nuclear electricity production (net, TWh) a)	5.5	20.0	18.7
Total electricity production in Finland (net, TWh) a)	19.3	65.9	66.4
Nuclear's share of total electricity production (%)	28.3	30.4	28.2
Load factor averages of Finnish plant units (%)	100.8 b)	93.7 b)	90.8

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

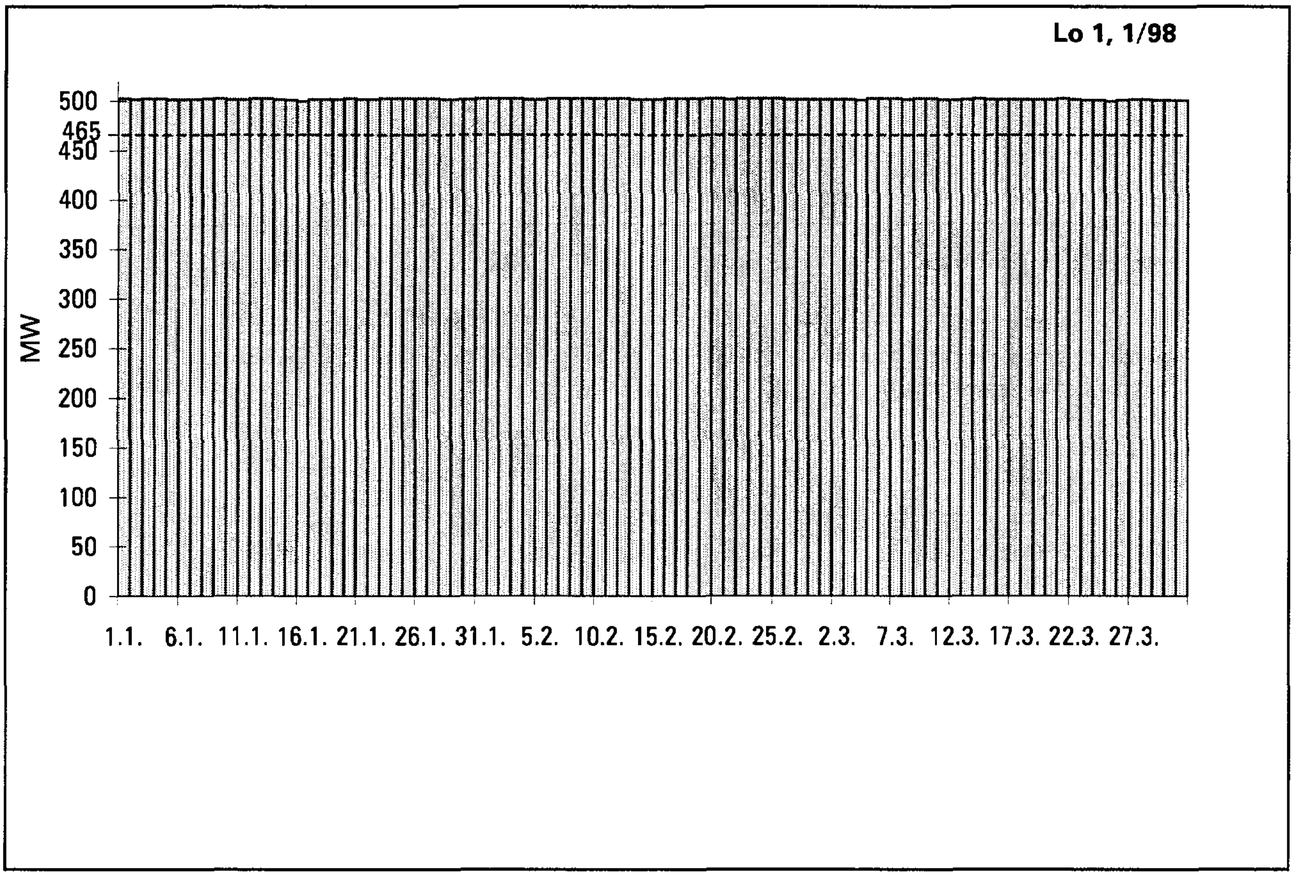


Fig 1. Daily average gross power of Loviisa 1 in January–March 1998.

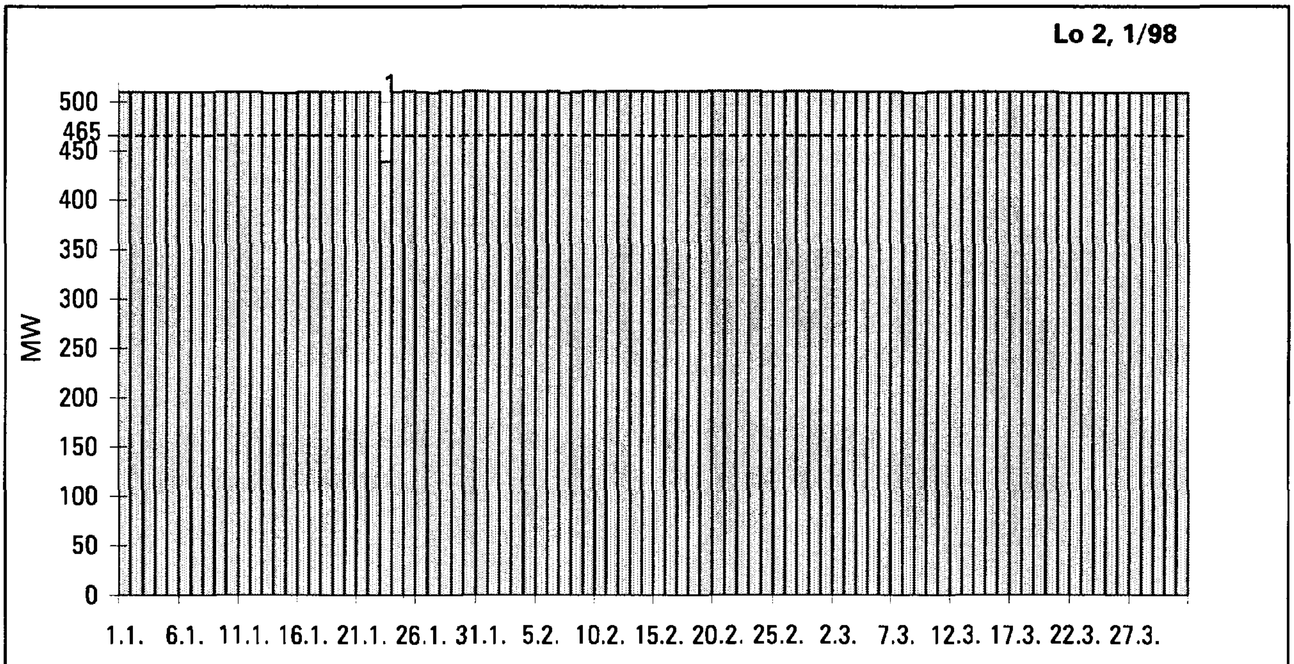
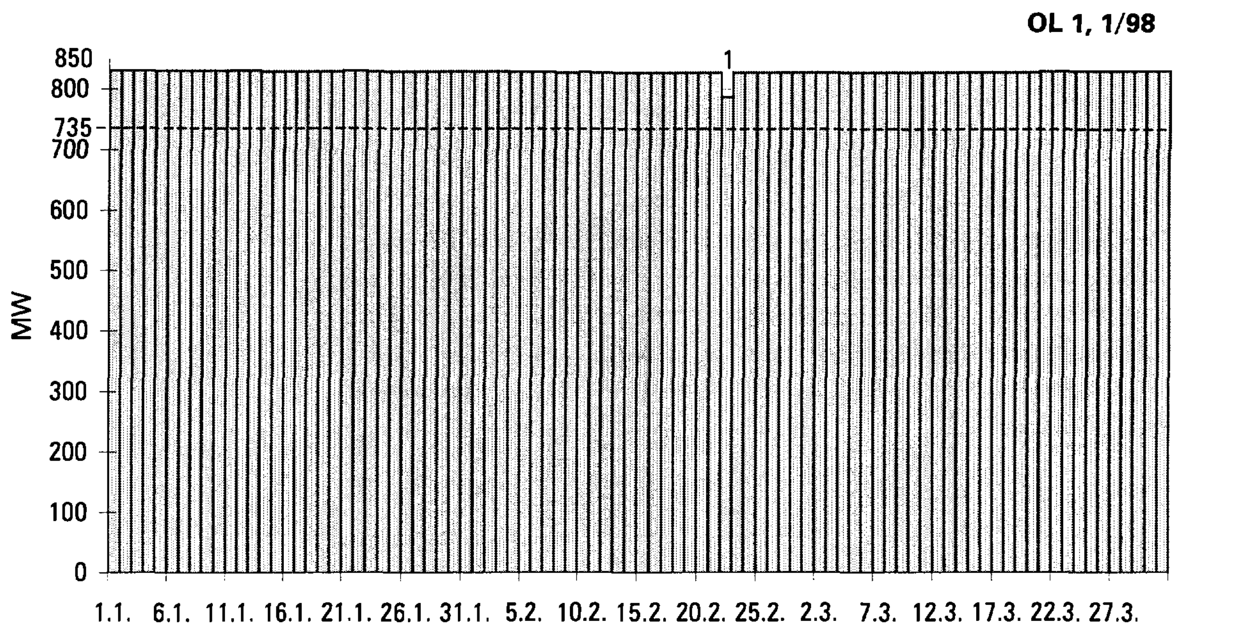
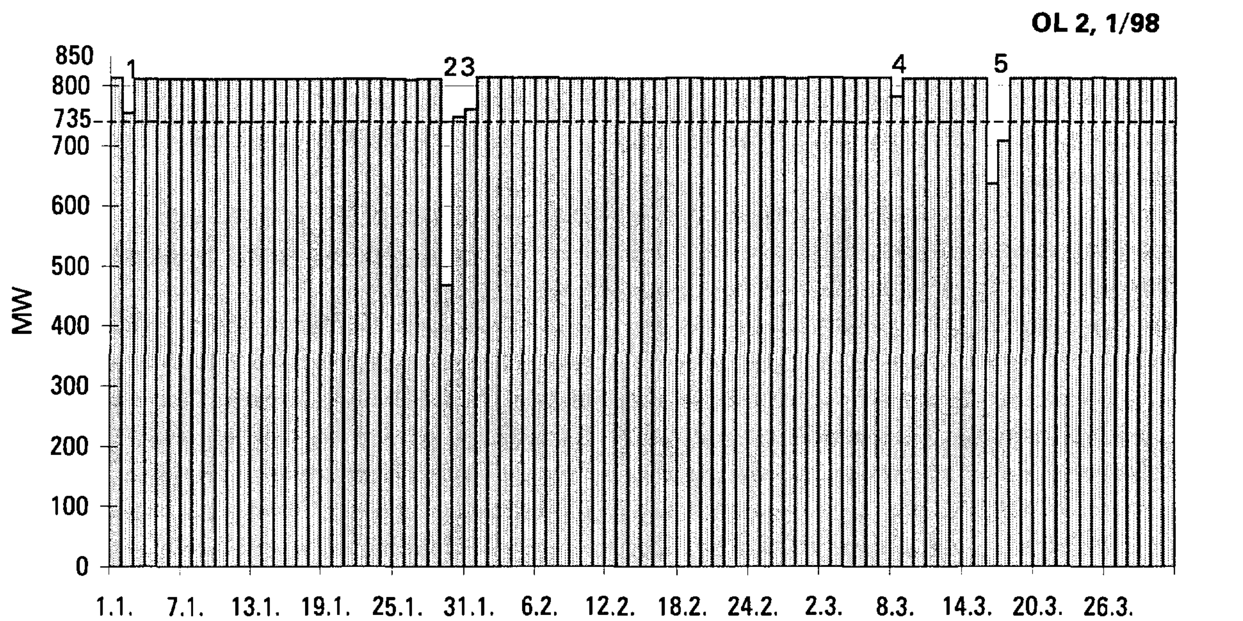


Fig 2. Daily average gross power of Loviisa 2 in January–March 1998.



1. Periodic tests requiring power reduction. Lowest reactor power was ca. 65%.

Fig 3. Daily average gross power of Olkiluoto 1 in January–March 1998.



1. Periodic tests requiring power reduction. Lowest reactor power was about 65%.
2. Oil leak and a consequent ignition at the turbine plant (see subsection 3.5). Reactor power was reduced to ca. 25%.
3. Feed water pump motor was replaced. Reactor power was kept at ca. 92% during the replacement.
4. A reactor stability measurement and periodic tests requiring power reduction. Lowest reactor power was ca. 65%.
5. Localisation of a turbine plant steam leak for the duration of which reactor power was reduced to ca. 70%. The leak was localised to a bleed steam system valve sealing, which was replaced. Reactor power was reduced to ca. 53% for the duration of the replacement.

Fig 4. Daily average gross power of Olkiluoto 2 in January–March 1998.

3 EVENTS AND OBSERVATIONS

Loviisa 1

In the first quarter of 1998, a float position indicator malfunction was observed in a pressurised emergency water tank as well as an error in the method of installation of an emergency feed water pump in the secondary circuit. Primary circuit pressuriser safety valve values were incorrectly interpreted during testing at both Loviisa plant units. These events were classified INES level 0.

3.1 Float position indicator of a pressurised emergency water tank malfunctioned

The sinking of a float of a pressurised emergency water tank at Loviisa 2, which was observed in the autumn of 1997 (see STUK-B-YTO 169, 1998), lead to inspections at Loviisa 1, too. On 7 January 1998, the position indicators of three emergency water tanks were checked since their operation could not be guaranteed after maintenance measures taken in the 1997 annual maintenance outage. The operation of the fourth position indicator had already been demonstrated in an annual maintenance outage.

A float prevents the access of nitrogen gas to the reactor in accidents. When the water level in a tank decreases the float sinks along with it and closes the discharge pipe. For inspection purposes, the level of the tanks, one at a time, was decreased to ascertain the correct functioning of the float's position indicator. One tank's position indicator failed to operate at Loviisa 1. The position indicator, which failed in the upper position (normal position), was in one of two "hot tanks". The water in two of four emergency cooling system tanks is kept at ca. 100°C to reduce the effects of heat stress on the reactor pressure vessel.

Substitutive procedures were introduced at Loviisa plant to ascertain the funtioning of the float. The failed position indication function was replaced by regular float manoeuvring tests. In addition, the hot emergency water tanks of both plant units were subjected to a water level reduction test. The tank with defective position indication mechanisms was subjected to weekly tests. Furthermore, enough water was removed from this tank to reliably ascertain the operation of the float by position indicator manoeuvring. The operation of the position indicator was confirmed by X-ray examination. This testing method was replaced in February with a simpler procedure for weekly ascertaining the float's correct position by ultrasonic testing through the tank wall and without reducing the water level. This substitutive procedure will be in use at both Loviisa plant units until the 1998 annual maintenance outages.

3.2 Incorrectly installed emergency feed water pump

At Loviisa 1 on 17 March 1998, a faulty flanged joint between the pressure side and piping of one of two pumps in the secondary circuit emergency feed water system was observed. The fault was revealed when a leak was observed in the flanged joint when preparing for the pump's testing. The same joint had leaked on 19 January 1998 during the pump's periodic testing. A worker was exposed to a steam jet but not injured. The leak was repaired by a sealing replacement.

Emergency feed water pumps automatically start to inject water to the plant unit's steam generators for example in case the primary feed water pumps trip.

Investigation revealed that the fastening flanges of the pump and piping complied with different standards. The screw fastening holes of the flanges were on different-sized perimeters (difference between the diameters was 10.5 mm) which is why the loading on fixing screws was off-centre. Eccentrical loading will cause a "plastic hinge" in screws that are pre-tightened, i.e. the entire cross-sectional area of the screw is in the same state and even the slightest increase in loading will permanently elongate the screws. With increased loading, for example during pump start-up, the screws become more elongated and make the joint loose.

Due to a pump failure at Loviisa 1, the pump in question had been transferred from Loviisa 2 to Loviisa 1 in the 1997 annual maintenance outage (STUK-B-YTO 169). In connection with the transfer, the effect of flanges that do not comply with the same standard was overlooked. The repaired Loviisa 1 pump was installed at Loviisa 2.

Because there had been two leaks, the emergency feed water system's reliability could not be entirely trusted anymore. The pump's incorrect installation had minor bearing on the plant unit's safety, however.

The fixing screws were temporarily replaced with headless screws that are thin in the middle. In addition, a 10-mm thick, loose base plate was mounted beneath the nuts. With these modifications the screws became axially loaded, which prevents the flanges from becoming loose. Shields were also mounted around the joint for reasons of occupational safety. The flanges will be replaced in the 1998 annual maintenance outage to ensure that they all comply with the same standard. Screws thin in the middle were originally used in the installation of the repaired Loviisa 1 pump that was transferred to Loviisa 2, and this problem did not occur there.

3.3 Incorrect interpretation of pressuriser safety valve values during testing at Loviisa 1 and 2

It was discovered at both Loviisa plant units on 20 March 1998 that the opening pressures of the safety valves of the primary circuit pressuriser had been set too high. The mistakes in the setting of the opening pressure had been made in the 1997 annual maintenance outage and revealed during periodic inspections of valve testing equipment.

The pressuriser adjusts primary circuit pressure and maintains it sufficiently high and stable during reactor operation. It has two safety valves guided by three pilot valves. Of the pilot valves of both main valves two are in service and one on standby. One main valve is set to open at the highest primary circuit operating pressure, i.e. 13.6 MPa. The other valve's opening pressure is 14.3 MPa.

To set the opening pressure of the pressuriser pilot valves, a test set was taken into service at Loviisa plant in spring 1997 for testing and adjusting the pilot valves in a pressure and temperature equivalent to the process circumstances. This test set was used for adjusting the pilot valves of the pressuriser safety valves of both plant units in the annual maintenance outage of autumn 1997. As a deviation from plant normal procedures, the pressure measurements indicated overpressure, not absolute pressure. Therefore, the opening pressures of the pilot valves of the pressuriser safety valves were set 0.1 MPa too high.

This error was due to some misunderstandings in the purchase of pressure transmitters for the test set. As established in regular procedures, Imatran Voima Oy ordered the test set calibrated for absolute pressure. The delivered test set was calibrated for overpressure, however, which was not noticed when the set was taken into use at Loviisa plant.

The meaning of incorrect pressure settings to reactor and primary circuit pressure control was examined. Set pressure was so little exceeded that it has no bearing on primary circuit overpressure protection or plant behaviour in transient situations.

The incorrect pressure settings will be changed in the 1998 annual maintenance outages. When components are ordered in the future, special attention will be paid to the definition of values. Specifications will be made more explicit to avoid incorrect interpretations by manufacturer and receiving personnel. In addition, training in the matter will be arranged to relevant personnel at Loviisa plant.

Loviisa 2

No reportable events occurred at Loviisa 2 in the first quarter of 1998.

Olkiluoto 1

No reportable events occurred at Olkiluoto 1 in the first quarter of 1998.

Olkiluoto 2

Exceptional nuclear fuel cladding corrosion at the plant unit was examined. On the basis of preliminary results it was classified INES level 0. An oil leak caused an ignition, which was promptly extinguished. The event's subsequent appraisal revealed shortcomings in the functioning of the plant unit's operating organisation and it was thus classified INES level 1.

3.1 NPP fuel cladding corrosion

The examination of nuclear fuel cladding corrosion at Olkiluoto 2 was started after abnormal oxide layer buildup was observed on nuclear fuel rods in visual examinations in the 1997 annual maintenance outage. Corresponding corrosion had occurred in nuclear fuel rods of the same type at the Swiss Leibstadt NPP.

The Olkiluoto 2 reactor has 500 fuel assemblies, each containing about 100 fuel rods. The fuel rods are thin pipes filled with uranium-dioxide pellets and gas-tightly closed at both ends. The fuel rod walls form a cladding that prevents the release of fission products, which build up during reactor operation, from the fuel to the reactor coolant. The amount of gaseous radioactive substances is monitored by continous-operation process measurements and the amount of radioactive substances dissolved in water by regular laboratory measurements. The measurements have shown that no fuel leaks have occurred in consequence of the increase in cladding corrosion in the time period in question.

Teollisuuden Voima Oy drew up a corrosion study programme. The first phase was implemented during the 1997–1998 operating cycle with fuel assemblies stored in the refuelling pool and the second phase during the annual refuelling outage with assemblies from the reactor. Possible further measures will be decided on the basis of the results.

The slight increase in the oxide layer buildup has no bearing on plant safety during normal operation.

3.2 An oil leak caused an ignition

An oil leak was observed in the turbine control oil system of Olkiluoto 2 during the night of 28 January 1998. In consequence of the leak, steam piping insulation ignited. Firemen in oil control duties onsite promptly extinguished the ignition.

The plant unit was in power operation when, during a night shift inspection round, it was detected that the oil level of the turbine main oil tank had began to decrease. The oil leak was localised into a valve in the turbine control oil system. After leak localisation, the plant unit's power was decreased to 75% and the leak stopped when the leaking pressure indicator valve was closed. Because there was a fire hazard the plant fire brigade was called to control the oil.

After the leak had ended, check-up rounds were made at the turbine plant during which oil smoke and an ignition were observed below the leak point on the surface of a pipe connecting to the main steam system. The firemen promptly extinguished the ignition. The plant unit power was decreased to 25% and, for the sake of safety, also the Eurajoki and Rauma (neighbouring municipalities) fire brigades were called onsite. The ignition did not cause any personal injuries or significant material damage.

In BWRs of the Olkiluoto type steam is directed to the turbine plant. It contains short-lived activation products of oxygen and nitrogen. The radiation level of the turbine plant is so high during plant operation that work there is avoided during full power operation. When power was reduced, the radiation level in the turbine hall fell enough to make possible fire guarding, cleaning of surfaces from oil and later examination. After cleaning and check-up, power ascension to full power was started at 11.10 hours on 29 January 1998. Fire-watching in the turbine hall was discontinued in the morning of 30 January 1998.

The ignition was caused by oil and insulation mass on a hot pipe surface. The oil leak for its part was attributed to a failed valve in the high pressure turbine control oil system. Inspections ascertained that the valve's bellows sealing had broken.

The oil leak was about 900 l, which makes a significant fire load. The event did not endanger plant safety because the ignition was promptly detected and extinguished. The collective dose incurred by those later participating in cleaning and checkup was about 30 mmanSv, i.e. less than 2% of the 1997 collective dose for both Olkiluoto plant units. The event had no bearing on environmental radiation safety.

Later examination of the event revealed some matters requiring improvement. For example, there were delays in the detection and stopping of the oil leak and the fire detection system of the turbine plant was not sensitive enough to detect the amount of oil smoke or mist; also, the flow of information within the organisation of Teollisuuden Voima Oy was not adequate. After the incident, the utility has increased monitoring of the plant by increased control measures by the shift personnel. In addition, smoke detectors were tested and found operational. The sufficiency of the fire detection and alarm system that covers the area in question will be assessed by the next annual maintenance outage. Teollisuuden Voima Oy's directions for internally providing an alarm have also been revised. A computer-assisted contact and alarm system is being taken into use.

4 RADIATION SAFETY

Individual doses to NPP personnel did not exceed the dose limits. Environmental releases were also well below the release limits. In samples collected around NPPs, radioactive substances originating from the plants were measurable in such quantities only as have no bearing on the radiation exposure of the population.

4.1 Limitation of exposure

The highest individual dose received at a Finnish NPP in the first annual quarter was 4.9 mSv and it was received at Loviisa NPP. The Radiation Decree stipulates that the effective dose caused by radiation work to a worker shall not exceed 50 mSv in any single year. The dose may not exceed 20 mSv per year as an average over any period of five years. The radiation doses received at Loviisa and Olkiluoto NPPs have been below authorised limits.

Occupational dose is mainly incurred in work performed during annual maintenance outages. Neither NPP underwent annual maintenance in this quarter.

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

Collective occupational dose for the Loviisa plant units was 0.04 manSv in the first quarter of 1998 and 0.09 manSv for the Olkiluoto units. According to a STUK Guide, the collective dose limit for one plant unit is 2.5 manSv per one gigawatt of net electrical power averaged over two successive years. When the effect of the power upratings of the plant units is assessed calculationally the limit value is 1.14 manSv for Loviisa 1 and 2, 1.88 manSv for Olkiluoto 1, and 1.81 manSv for Olkiluoto 2.

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 before authorised limits.

4.3 Environmental monitoring

Radiation safety in the vicinity of Finnish NPPs is ensured by regular sampling and analysis programmes. The environmental distribution of radioactive releases and their transfer to food chains is monitored to ensure that the releases remain below authorised limits.

In the first annual quarter, a total of 103 environmental samples were analysed according to programmes. The tritium content of one sample of sea water collected in the environment of Loviisa NPP exceeded normal level. Cobalt-60 originating from Olkiluoto NPP was measured in one sample of air. The detected concentrations were low and require no action.

Radioactive isotopes of strontium and caesium (strontium-90, caesium-134 and -137), plutonium (plutonium-238 and -239,-240) and tritium originating from the Chernobyl accident and the fallout from nuclear weapons tests are still measurable in environmental samples. Natural radioactive substances (i.a. beryllium-7, potassium-40 and uranium and thorium with their decay products) are also detected. Their concentrations are usually higher than the concentrations of nuclides originating from the power plants or fallout.

Table III. Occupational dose distribution in the first quarter of 1998 and in 1997.

Dose range (mSv)	Number of persons by dose range					
	First quarter 1998			1997		
	Loviisa	Olkiluoto	Total*	Loviisa	Olkiluoto	Total*
< 0,5	54	147	202	171	519	636
0,5–1	4	26	30	70	228	291
1–2	11	19	30	77	214	294
2–3	1	–	1	45	107	145
3–4	–	3	3	21	58	84
4–5	2	–	2	23	40	67
5–6	–	–	–	15	25	63
6–7	–	–	–	13	14	39
7–8	–	–	–	13	10	38
8–9	–	–	–	7	5	22
9–10	–	–	–	4	3	18
10–11	–	–	–	7	3	18
11–12	–	–	–	3	3	15
12–13	–	–	–	5	–	14
13–14	–	–	–	3	–	6
14–15	–	–	–	2	1	5
15–16	–	–	–	–	–	3
16–17	–	–	–	1	–	2
17–18	–	–	–	1	–	5
18–19	–	–	–	–	–	4
19–20	–	–	–	1	–	5
20–25	–	–	–	–	–	6
> 25	–	–	–	–	–	–

* The data in these columns also include Finnish workers who have received doses at Swedish nuclear power plants. The same person may have worked at both Finnish nuclear power plants and in Sweden. The highest individual radiation dose in 1997, 23.3 mSv, was received at a nuclear power plant in Sweden.

Table IV. Radioactive releases by plant site, first quarter 1998.

Gaseous effluents (Bq) a)

Plant site	Noble gases (Krypton-87 equivalents)	Iodines (Iodine-131 equivalents)	Aerosols	Tritium	Carbon-4
Loviisa					
Report period	$1,3 \cdot 10^{12}$	$6,9 \cdot 10^{4}$	$9,9 \cdot 10^{5}$	$5,3 \cdot 10^{10}$	$9,4 \cdot 10^{10}$
In 1997	$5.0 \cdot 10^{12}$	$7.2 \cdot 10^{4}$	$2.5 \cdot 10^{8}$	$2.5 \cdot 10^{11}$	$2.3 \cdot 10^{11}$
Olkiluoto					
Report period	b)	b)	$2,7 \cdot 10^{5}$	$1,1 \cdot 10^{11}$	c)
In 1997	$2.1 \cdot 10^{11}$	$1.7 \cdot 10^{7}$	$4.4 \cdot 10^{7}$	$3.0 \cdot 10^{11}$	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	$4,3 \cdot 10^{12}$	$1,2 \cdot 10^{7}$
In 1997	$1.2 \cdot 10^{13}$	$1.2 \cdot 10^{7}$
Olkiluoto		
Report period	$2,6 \cdot 10^{11}$	$5,5 \cdot 10^{8}$
In 1997	$1.3 \cdot 10^{12}$	$9.5 \cdot 10^{9}$
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 transformation 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 $6.7 \cdot 10^{11}$ Bq in 1997.
d) The numerical value shows the release limit for the Loviisa plant site by nuclide group assuming that other releases would not occur. The total release limit is calculated so that the sum of the various types of release limit shares does not exceed 1.

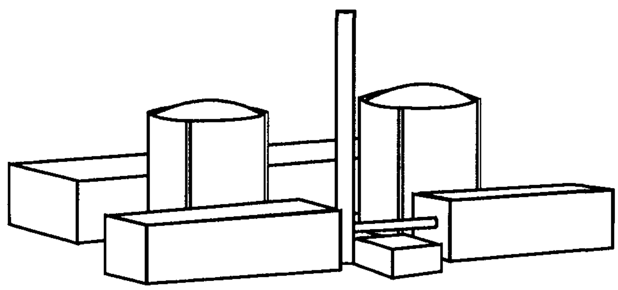
5 SAFETY IMPROVEMENTS AT NPPS

No modifications important to safety were made at the NPP units.

REGULATORY CONTROL OF NUCLEAR POWER PLANTS **APPENDIX 1**

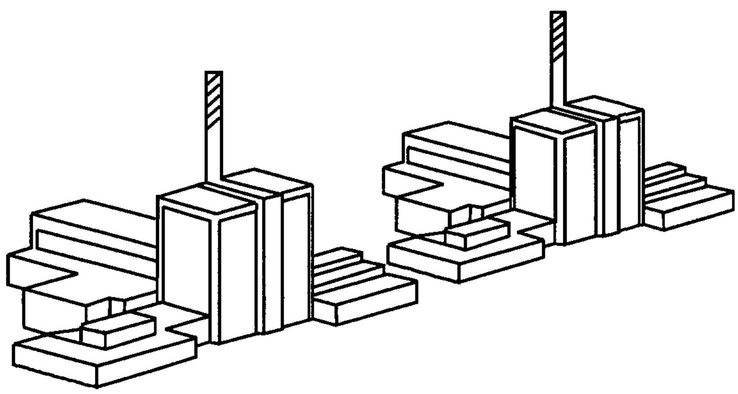
Council of State decisions	**Regulatory control and inspections by STUK**
	Preparation of a nuclear power plant project • Preliminary plans for the plant and safety principles • Location and environmental impact of the plant • Arrangements for nucler fuel and nuclear waste management
Decision in Principle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

[1)] 510/488 since 1 May 1998



Plant unit	Start-up	Commercial operation	Rated power (gross/net, MW)	Type, supplier
Olkiluoto 1	2 Sept. 1978	10 Oct. 1979	735/710[2)]	Boiling water reactor (BWR), Asea Atom
Olkiluoto 2	18 Feb. 1980	1 July 1982	735/710[2)]	Boiling water reactor (BWR), Asea Atom

[2)] 870/840 since 20 Aug. 1998

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.

STUK'S EXPERTS

Nuclear Reactor Regulation:
Juhani Hyvärinen
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