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Operation of Finnish nuclear power plants

Quarterly report, 4th quarter 1996

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ABSTRACT

Quarterly Reports on the operation of Finnish nuclear power plants describe events and observations relating to nuclear and radiation safety which the Finnish Centre for Radiation and Nuclear Safety (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.

In the fourth quarter of 1996, the Finnish nuclear power plant units were in power operation except for the annual maintenance outage of Loviisa 2 and a shutdown at Olkiluoto 1 to repair a condensate system stop valve. The load factor average of all plant units was 96.5%.

Events in the fourth quarter of 1996 were level 0 on the International Nuclear Event Scale.

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 Finnish Centre for Radiation and Nuclear Safety (STUK). The Centre's functions also include control of physical protection, 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 the Centre 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 OCTOBER–DECEMBER 1996

Finnish nuclear power plant units were in power operation in the fourth quarter of 1996 except for the annual maintenance outage of Loviisa 2 and a shutdown at Olkiluoto 1 to repair a condensate line stop valve.

2.1 Production data

Nuclear's share of total electricity production in Finland was 27.2% and the load factor average of the plant units was 96.5 %. Trial operation of Olkiluoto 1 was continued at 105% reactor power.

Detailed production and availability figures are given in Tables I ja 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 (%)	
	Fourth quarter 1996	From beginning of 1996	Fourth quarter 1996	From beginning of 1996	Fourth quarter 1996	From beginning of 1996
Loviisa 1	1.04	3.37	100.0	82.9	100.9	82.5
Loviisa 2	0.88	3.81	85.3	93.7	85.5	93.2
Olkiluoto 1	1.71	6.16	99.0	93.5	99.0	92.4
Olkiluoto 2	1.63	6.14	100.0	95.8	100.5	95.1

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

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

Table II. Nuclear energy in Finnish electricity production.

	Fourth quarter 1996	From beginning of 1996	1995	1994
Nuclear electricity production (net, TWh)*	5.0	18.7	18.1	18.3
Total electricity production in Finland (net, TWh)*	18.4	66.4	60.6	62.1
Nuclear's share of total electricity production (%)	27.2	28.2	29.9	29.5
Load factor averages of Finnish plant units (%)	96.5	90.8	88.8	90.0

* Source: Statistics compiled by the Finnish Electricity Association.

2.2 Annual maintenance outage of Loviisa 2

The 16th refuelling and maintenance outage of Loviisa 2 was from 21 September to 14 October 1996. The plant unit was off the national grid for 23 days.

Apart from Imatran Voima Oy's own staff, the maximum number of contract workers participating in the outage was about 850. The collective radiation dose incurred in outage work was 0.71 manSv (0.34 manSv in 1995). The highest individual dose was 17.0 mSv.

Modifications made during the outage to improve safety are described in chapter 5.

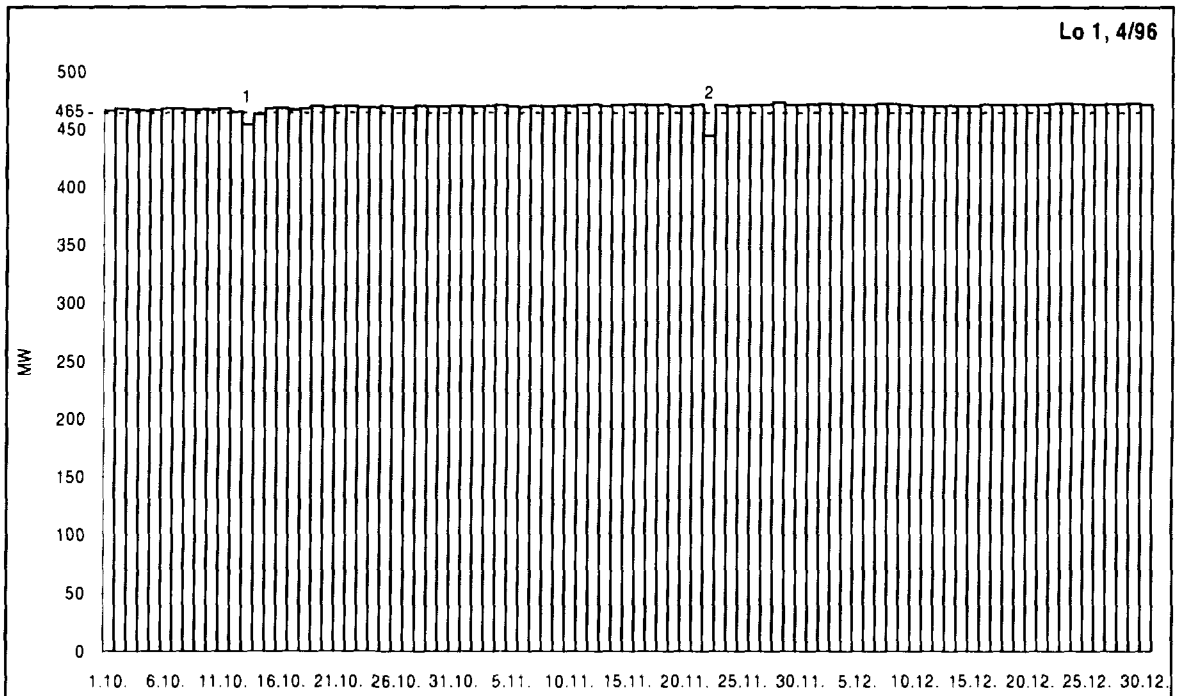
After the annual maintenance outage, the plant unit resumed electricity generation on 14 October 1996.

2.3 Repair outage at Olkiluoto 1 to repair a condensate system closing valve

Olkiluoto 1 was placed in hot shutdown on 25 December 1996 to repair a condensate system LP pre-heater line closing valve. The pre-heater line warms up condensate coming from the condenser, and the line in question can be bypassed with a closing valve.

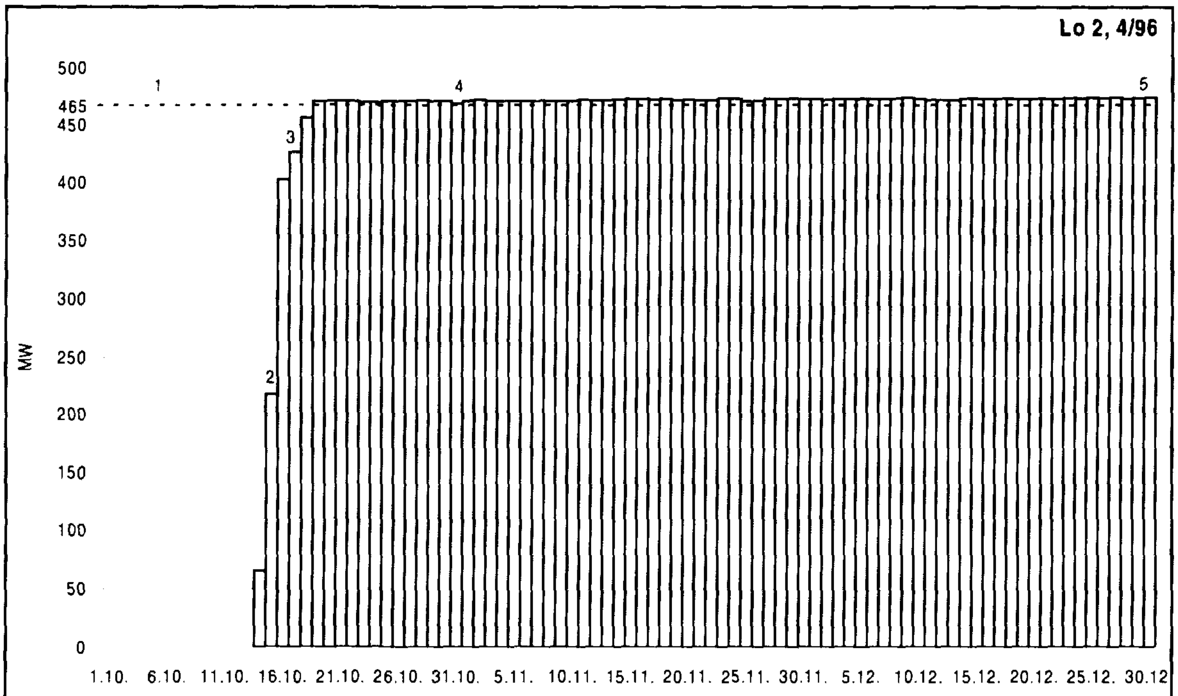
The stem of the closing valve broke off on 15 December 1996 during a bypass test periodically conducted on the pre-heater line. After the breaking of the valve stem, the pre-heater line was bypassed and the plant unit was operated until Christmas Day. The plant was operated at reduced capacity and plant safety was not affected. The failed valve was repaired during the hot shutdown and other maintenance and repair work was also done. The plant unit resumed electricity generation the next day.

The failed valve's actuator and its motor were examined and tested in a test bench. In the test, defects were detected in the actuator motor's micro switch which stops the motor. The breaking of the stem was due to a malfunction of the micro switch. Moisture had penetrated the switch case of the micro switch via a cracked view glass. Teollisuuden Voima Oy has plans to inspect corresponding items in the forthcoming annual maintenance outage.



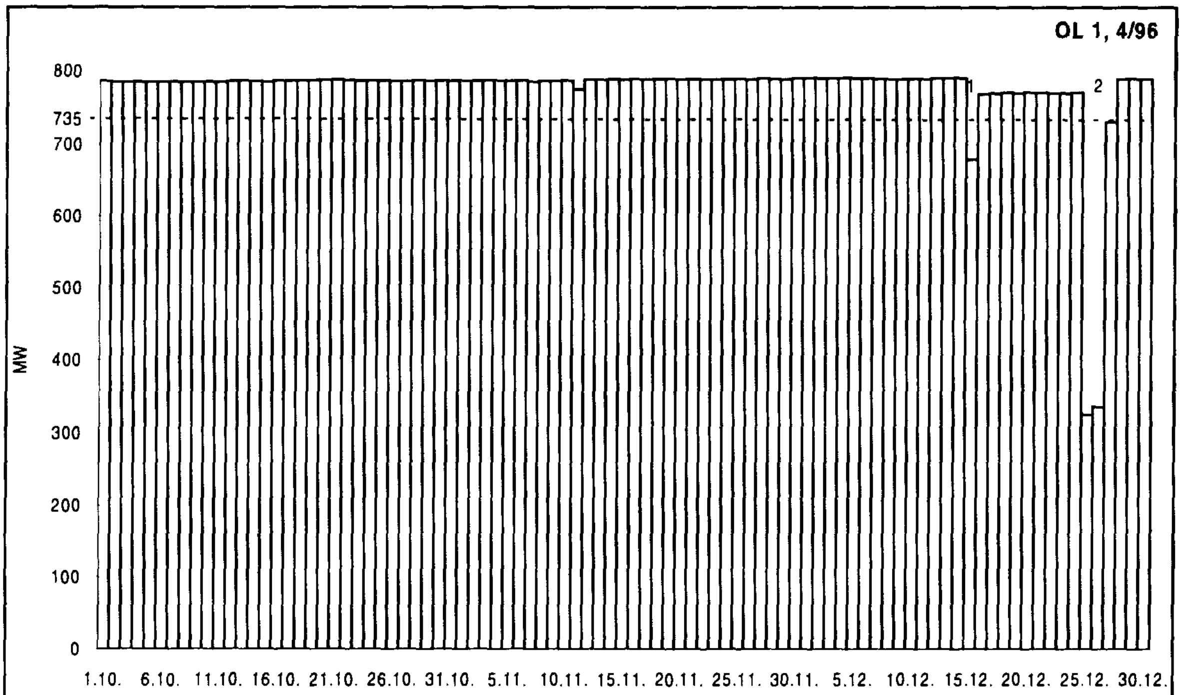
1. Turbine power decreased due to a controller malfunction, reactor power reduction to 58% power level
2. Primary circulation pump stopped when a balancing magnet failed, reactor power reduction to 76% power level.

Fig 1. *Daily average gross power of Loviisa 1 in October–December 1996.*



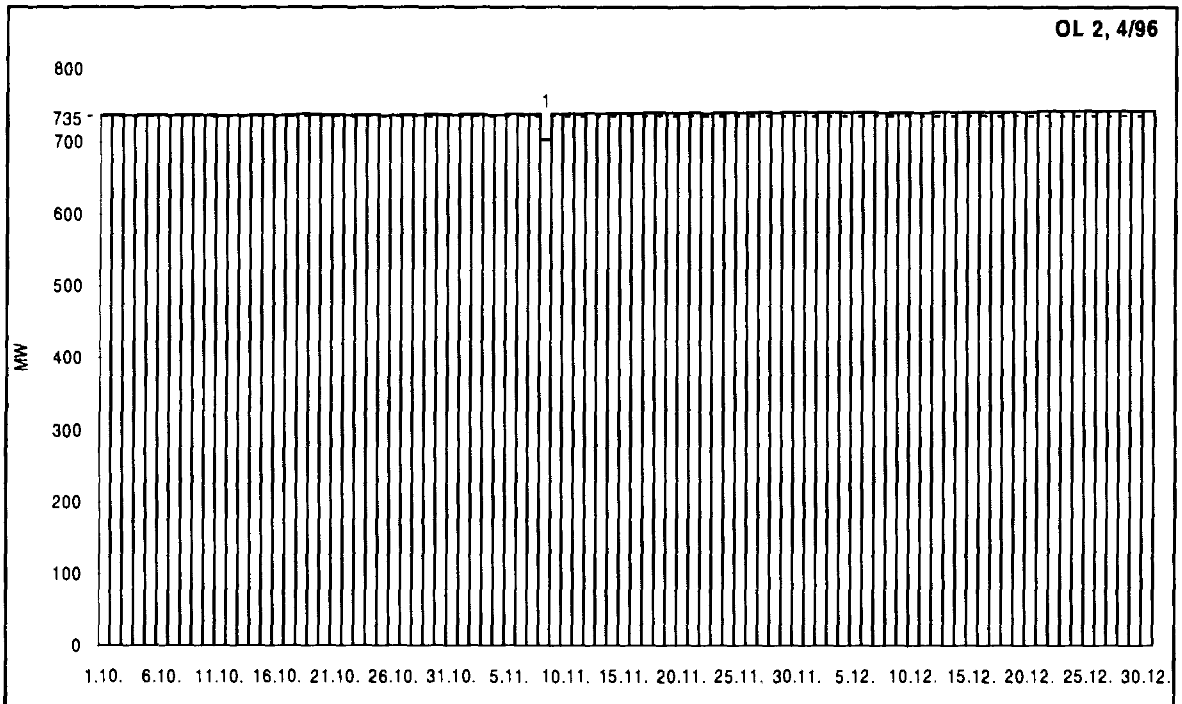
1. Annual maintenance (see chapter 2.2)
2. Turbine trip due to a flange leak in the steam line, reactor power reduction to 24% power level.
3. A steam line valve remained in start-up step during testing, reactor power reduction to 83% power level.
4. Control rod dropped due to a low frequency converter failure.
5. Control rod dropped due to a low frequency converter failure, reactor power reduction to 92% power level.

Fig 2. *Daily average gross power of Loviisa 2 in October–December 1996.*



1. Periodic tests requiring power reductions, the reactor was operating at 70% power.
2. Repair outage to repair a condenser line valve (see chapter 2.3).

Fig 3. Daily average gross power of Olkiluoto 1 in October–December 1996.



1. Periodic tests requiring power reductions, the reactor was operating at 70% power.

Fig 4. Daily average gross power of Olkiluoto 2 in October–December 1996.

3 EVENTS AND OBSERVATIONS

Loviisa 1

No reportable events occurred at Loviisa 1 in the fourth quarter of 1996

Loviisa 2

No reportable events occurred at Loviisa 2 in the fourth quarter of 1996

Olkiluoto 1

No reportable events occurred at Olkiluoto 1 in the fourth quarter of 1996.

Olkiluoto 2

No reportable events occurred at Olkiluoto 2 in the fourth quarter of 1996.

Final repository for operating waste from Olkiluoto

A deviation was made from the periodic testing date of the radiation monitors in the final repository for operating waste from Olkiluoto and a discrepancy was observed between the readings of the radiation monitors and the computer display. The event is level 0 on the INES scale.

3.1 A deviation was made from the periodic testing time of radiation monitors in the final repository for operating waste from Olkiluoto

There are two fixed radiation monitors measuring the dose rate in the final repository for operating waste from Olkiluoto. One is on the upper level of the intermediate-level waste silo and the other on the upper level of the low-level waste silo.

The monitors in question are subject to periodic testing every six months to ensure their operation. The test which was due towards the end of 1996 was conducted on 12 November 1996, about one month late. According to Teollisuuden Voima Oy, the test was late because of the introduction of a new ADP system to control management of work. In connection with the taking into service of the system it was forgotten to activate the periodic tests. Teollisuuden Voima Oy sent the Finnish Centre for Radiation and Nuclear Safety a report about the matter.

In the above periodic test it was also observed that there was a discrepancy between the readings of the radiation monitors in question and the computer display. In the same connection it was noted that the periodic test in question was not performed to sufficient extent in 1996. The Finnish Centre for Radiation and Nuclear Safety requested a further clarification from Teollisuuden Voima Oy as to when the mutual equivalence of the meters' displays was last tested.

The safety significance of fixed radiation monitors is not high since portable dosimeters are used to monitor the radiation doses of workers and visitors in the final repository for operating waste.

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 Limitation of exposure

Exposures arising from operation of nuclear power plants shall be kept as low as reasonably achievable (the ALARA principle). This requires that the sum doses, i.e. the collective doses of those working at a nuclear power plant and of the surrounding population, are monitored and that action is taken to limit occupational exposure and radioactive discharges. Furthermore, individual doses may not exceed authorised limits.

4.2 Occupational exposure

The highest individual dose at a Finnish nuclear power plant in the last annual quarter was 17.5 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. The monitoring of the annual average was 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 outage of Loviisa 2 was during 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 0.57 manSv in this quarter and 2.64 manSv during 1996, and 0.05 manSv and 1.68 manSv respectively at the Olkiluto 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; this means a total annual collective dose of 1.11 manSv/year and of 1.78 manSv/year for one Loviisa and one Olkiluoto unit respectively. For Loviisa 1's part this dose limit was slightly exceeded (1.20 manSv) due to the long annual maintenance outage. During the outage, apart from the annealing of the reactor pressure vessel, extensive modernisation, maintenance and inspections were accomplished.

4.3 Radioactive releases and population exposure

Population exposure around a nuclear power plant is caused by releases of gaseous and liquid radioactive effluents during operation. These releases are limited by technical means. The plant's operational condition and the releases are also continuously monitored and compared against pre-determined limits.

In Table IV, the releases of radioactive effluents 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.

The release limits have been so determined that the annual dose to the most exposed individuals does not exceed 0.1 mSv, i.e. about 1/40 of the

Table III. Occupational dose distribution in the fourth quarter of 1996 and from beginning of 1996.

Dose range (mSv)	Number of persons by dose range					
	Fourth quarter 1996			From beginning of 1996		
	Loviisa	Olkiluoto	Total*	Loviisa	Olkiluoto	Total*
< 0,5	205	90	302	223	540	699
0,5–1	82	18	108	111	268	350
1–2	82	8	91	118	219	322
2–3	36	1	36	63	97	147
3–4	15	–	15	55	50	110
4–5	8	–	8	34	42	75
5–6	8	–	8	38	10	54
6–7	3	–	3	27	12	50
7–8	5	–	5	31	9	58
8–9	1	–	1	15	4	35
9–10	2	–	2	18	5	36
10–11	–	–	–	12	4	30
11–12	1	–	1	10	9	23
12–13	–	–	–	7	–	11
13–14	–	–	–	7	–	12
14–15	–	–	–	7	3	17
15–16	–	–	–	3	–	5
16–17	1	–	1	3	–	7
17–18	1	–	1	3	–	7
18–19	–	–	–	4	–	6
19–20	–	–	–	5	–	6
20–21	–	–	–	2	–	3
21–30	–	–	–	1	–	5
> 30	–	–	–	–	–	–

* 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.

dose annually received in Finland from natural background radiation, radon in dwellings included. The release limits have been determined for nuclides and release pathways which have bearing on individual dose.

Calculated on the basis of release reports, doses to individuals of the surrounding population are low and, at most, less than about a thousandth part of the annual exposure of these individuals.

4.4 Environmental monitoring

For external radiation measurement, dosimeters have been placed in about 20 locations in the vicinity of nuclear power plants at a distance of 1–10 kilometres from the plants and 25 continuous-operation radiation dose rate measuring stations at about 5 kilometres' distance from the plants. The measurement data from these stations are transferred to both the power plants' control rooms and the national radiation monitoring network The monitoring is complemented by spectrometric measurements.

Radiation safety in the vicinity of Finnish nuclear power plants is also ensured by regular sampling and analysis programmes. The environmental distribution of radioactive releases is monitored and it is thus ensured that the releases remain below authorised limits.

Table IV. Radioactive releases by plant site, fourth quarter 1996.

Gaseous effluents (Bq) a)

Plant site	Noble gases (Krypton-87 equivalents)	Iodines (Iodine-131 equivalents)	Aerosols	Tritium	Carbon-14
Loviisa					
Report period	b) c)	$2.8 \cdot 10^5$	$7.2 \cdot 10^7$	$6.0 \cdot 10^{10}$	$1.9 \cdot 10^{10}$
In 1996	$2.3 \cdot 10^{10}$ c)	$9.4 \cdot 10^5$	$2.2 \cdot 10^8$	$2.2 \cdot 10^{11}$	$9.9 \cdot 10^{10}$
Olkiluoto					
Report period	$1.0 \cdot 10^{12}$	$2.0 \cdot 10^6$	b)	$6.1 \cdot 10^{10}$	d)
In 1996	$9.7 \cdot 10^{12}$	$2.6 \cdot 10^7$	$1.4 \cdot 10^7$	$2.1 \cdot 10^{11}$	d)
Annual release limits					
Loviisa	$2.2 \cdot 10^{16}$ e)	$2.2 \cdot 10^{11}$ e)			
Olkiluoto	$1.8 \cdot 10^{16}$	$1.1 \cdot 10^{11}$			

Liquid effluents (Bq) a)

Plant site	Tritium	Other nuclides
Loviisa		
Report period	$1.9 \cdot 10^{12}$	$1.7 \cdot 10^6$
In 1996	$9.4 \cdot 10^{12}$	$5.6 \cdot 10^7$
Olkiluoto		
Report period	$4.2 \cdot 10^{11}$	$2.1 \cdot 10^9$
In 1996	$2.4 \cdot 10^{12}$	$1.6 \cdot 10^{10}$
Annual release limits		
Loviisa	$1.5 \cdot 10^{14}$	$8.9 \cdot 10^{11}$ e)
Olkiluoto	$1.8 \cdot 10^{13}$	$3.0 \cdot 10^{10}$

a) The unit of radioactivity is Becquerel (Bq); 1 Bq = one nuclear transformation per second.
b) Below the detection limit.
c) In addition, the calculatory release of argon-41 from Loviisa 1 and 2 in krypton-87 equivalents was $4.0 \cdot 10^{11}$ Bq in the report period and $1.5 \cdot 10^{12}$ Bq from beginning of 1996.
d) The carbon-14 release-estimate based on experimental data was $1.7 \cdot 10^{11}$ Bq in Olkiluoto in the report period and $6.5 \cdot 10^{11}$ Bq from beginning of 1996.
e) 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.

Samples are collected and analysed among other things from air, fallout (dry deposition and rainwater) and seawater, as well as from foodstuffs such as milk, meat, grain, vegetables and fish, for assessment of the quantities of radioactive substances potentially accumulating in man. Also some terrestrial and marine indicator organisms are analysed which efficiently accumulate radioactive substances from their environment. By means of these organisms, even minor discharges can be detected and their distribution monitored.

In this quarter, a total of 127 samples were analysed according to the programmes. Also 26 external dose measurements were made.

Radioactive substances originating from Loviisa nuclear power plant were measurable in three samples of air, three samples of fallout and three samples of sinking matter. In addition, the tritium concentration of two samples of sea water was somewhat above normal. The samples of air contained manganese-54, cobalt-58, cobalt-60 and antimony-124. The following radionuclides originating from the plant were present in the sample of fallout collected in October: chromium-51, manganese-54, iron-59, cobalt-57, cobalt-58, cobalt-60, niobium-95, silver-110m and antimony-124. The fallout samples of November and December only contained manganese, cobalt and silver. Apart from these, also antimony-124 was present in the samples of sinking matter. Manganese-54 and cobalt-60 originating from Olkiluoto nuclear power plant were present in all four samples of sinking matter. There was also cobalt-60 in three samples of fallout. All the measured concentrations were low.

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

5 SAFETY IMPROVEMENTS AT NUCLEAR POWER PLANTS

In the fourth quarter of 1996 was the annual maintenance outage of Loviisa 2 during which several safety-significant plant modifications were made. The Olkiluoto plant units were in power operation most of the time and the number of plant modifications was thus modest.

Modifications to improve safety at both Loviisa plant units during the 1996 annual maintenance outages have been described in more detail in the previous quarterly report (STUK-B-YTO 154) in connection with the plant modifications made at Loviisa 1. The modifications included the installation of a new, shared auxiliary emergency make-up water tank and piping, measures to reduce the risk of clogged up band screens at sea water intake, renewal of the primary circuit overpressure protection and pressure reduction system and improvement of the accuracy and reliability of pressuriser level measurements.

At Loviisa plant units, the original steam generator feed-water distributors are made of carbon steel and they are located inside the steam generator's heat transfer tube bundle. There has been erosion-corrosion damage in the feed-water distributors which is extremely hard to repair due to the location of the distributors. Therefore, the feed-water distributors of the steam generators will be replaced with an entirely new type of stainless steel distributor in a space above the steam generator tube bundle. There has been extensive experimental research into the taking into service of the new type of distributor. The durability of the steam generator heat transfer tubes has been tested, subjecting bare heat transfer tubing to cold water. Also the possibility of water hammers in the distributor and loads caused by them have been clarified. A new type of distributor was installed in one of the six Loviisa 2 steam generators. The distributor in another Loviisa 2 steam generator which was installed in 1994 and modified in the 1995 annual maintenance outage, was approved for operation until the 1997 annual maintenance outage.

A water recirculation system was introduced at the Olkiluoto plant units for directing warm cooling water (about 10 °C) from the discharge side of the sea water tunnel to the inlet tunnel. Under certain unfavourable weather conditions frazil ice can clog up the structures of the cooling water intake. Two submersible pumps have been installed on the cooling water discharge side of Olkiluoto 2 from which water is directed via plastic pipes to the inlet side of the cooling tunnels. Water is fed from two smaller pipes to coarse bar screens at the mouth of the seawater inlet tunnel. The water recirculation system prevents the formation of frazil ice and the subsequent clogging of cooling water intake structures thus ensuring the supply of cooling water to the plant units.

6 OTHER MATTERS RELATING TO THE USE OF NUCLEAR ENERGY

In the last quarter of 1996, the last batch of spent nuclear fuel from Loviisa nuclear power plant was transported to Russia.

6.1 Transportation of spent nuclear fuel from Loviisa nuclear power plant to Russia

Spent nuclear fuel from Loviisa nuclear power plant was transported to Russia during 2–4 December 1996. The fuel from Loviisa 1 and 2 totalled about 28 tonnes which corresponds to the amount of spent fuel arising at the plant units every year. Before the transport the fuel had been cooling down for five years. This was the 15th shipment; the previous shipment was in autumn 1995.

The spent fuel was first transported from the power plant to Loviisa railway station and further by rail to Russia. The transport packages are designed to withstand potential accidents. The design bases include, among other things, a drop test onto a hard surface from nine metres, a fire test and an immersion test.

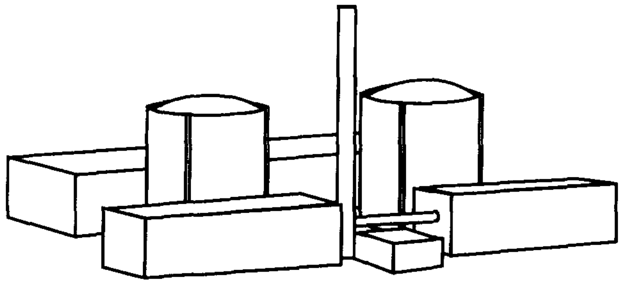
The transport packages were inspected at Loviisa nuclear power plant before spent fuel was placed in them. The fuel was transported in eight water-filled packages, 30 nuclear fuel bundles in every package.

The transport was in compliance with a transport and physical protection plan approved by STUK. There were special arrangements to ensure safety, i.a. transport package minimum temperature to ensure ductility of steel, low transport speed, one-way rail traffic and increased preparedness in provision against accidents. The shipment went according to the plans.

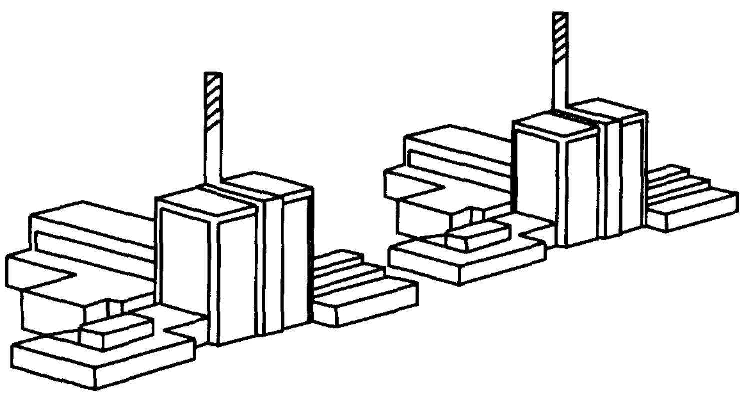
According to amendments to the Nuclear Energy Act which took effect on 30 December 1996, spent nuclear fuel must be treated, stored and disposed of in Finland. Therefore, this was the last transportation of spent fuel to Russia.

Council of State Decisions	**Regulatory control and inspections by the Finnish Centre for Radiation and Nuclear Safety**
Decision in Principle	**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
Construction Permit	**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
Operating Licence	**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
	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 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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