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Operation of Finnish nuclear power plants

Quarterly report 2nd quarter 1996

Tuulikki Sillanpää (ed.)

NOVEMBER 1996

SÄTEILYTURVAKESKUS
Strålsäkerhetscentralen
Finnish Centre for Radiation and Nuclear Safety

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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 second quarter of 1996, the Finnish nuclear power plant units were in power operation except for the annual maintenance outages of TVO plant units and the Midsummer shutdown at TVO II which was due to low electricity demand, a turbine generator inspection and repairs. The load factor average of all plant units was 88.9%.

Events in the second quarter of 1996 were classified 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.

2 OPERATION OF NUCLEAR POWER PLANTS IN APRIL–JUNE 1996

Finnish nuclear power plant units were in power operation in the second quarter of 1996 except for the annual maintenance outages of TVO plant units and the shutdown of TVO II at Midsummer due to low electricity demand, a turbine generator inspection and repairs.

2.1 Production data

Nuclear's share of total electricity production was 28.7%. The load factor average the plant units was 88.9%.

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.

2.2 Reactor scram at TVO II

A reactor scram occurred at TVO II on 26 February 1996 which was due to an external grid disturbance. The event is described in chapter 3.3. After the scram, the plant unit was brought back on-line the next day.

Table I. *Plant electricity production and availability.*

	Electricity production (gross, TWh)		Availability factor (%)		Load factor (%)	
	Second quarter 1996	From beginning of 1996	Second quarter 1996	From beginning of 1996	Second quarter 1996	From beginning of 1996
Loviisa 1	1.02	2.04	100.0	100.0	100.0	100.2
Loviisa 2	1.02	2.04	100.0	100.0	100.4	100.7
TVO I	1.18	2.79	75.8	87.9	73.5	87.0
TVO II	1.31	2.91	83.9	91.7	81.8	90.8

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

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

Table II. Nuclear energy in Finnish electricity production.

	Second quarter 1996	From beginning of 1996	1995	1994
Nuclear electricity production (net, TWh)*	4.3	9.4	18.1	18.3
Total electricity production in Finland (net, TWh)*	15.0	33.6	60.6	62.1
Nuclear's share of total electricity production (%)	28.7	28.0	29.9	29.5
Load factor averages of Finnish plant units (%)	88.9	94.7	88.8	90.0

* Source: Statistics compiled by the Association of Finnish Electric Utilities.

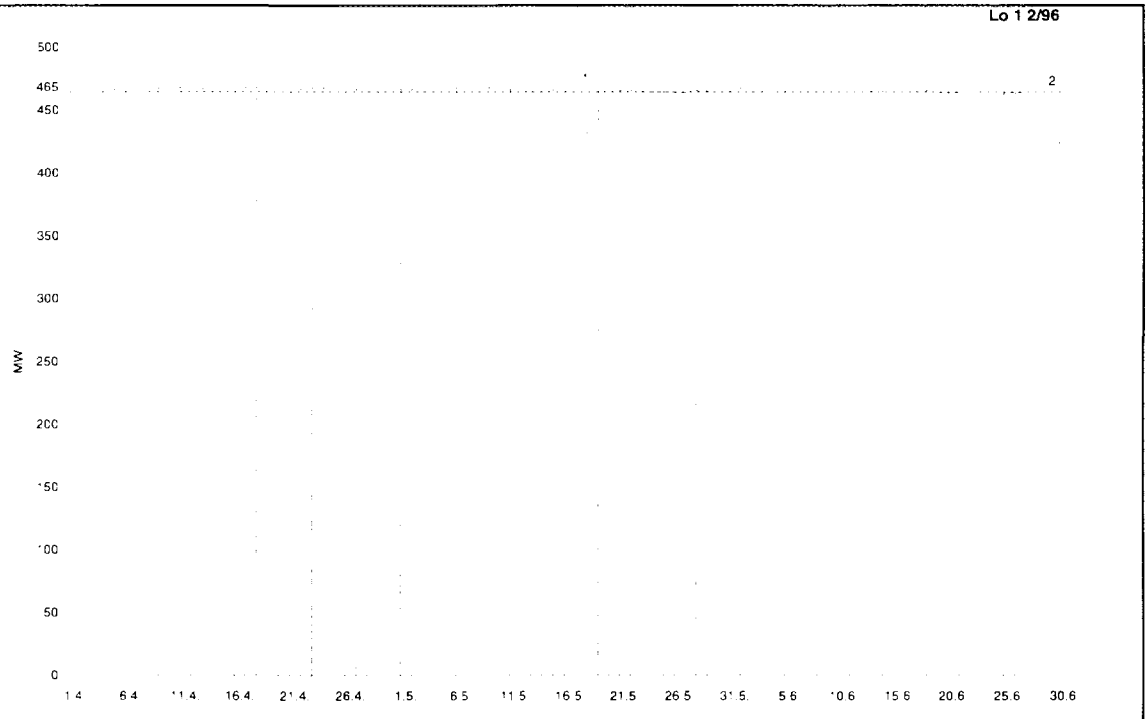
2.2 Annual maintenance outage at TVO I

The 17th refuelling and maintenance outage of TVO I was held from 19 May to 8 June 1996. The plant unit was off the national grid for 20 days.

Apart from Teollisuuden Voima Oy's own staff, the maximum number of contract workers participating in the outage was 1060. The collective radiation dose incurred in outage work was 1.0 manSv (0.21 manSv in 1995). The increase was due to extensive modifications. The higest individual dose was 11.1 mSv.

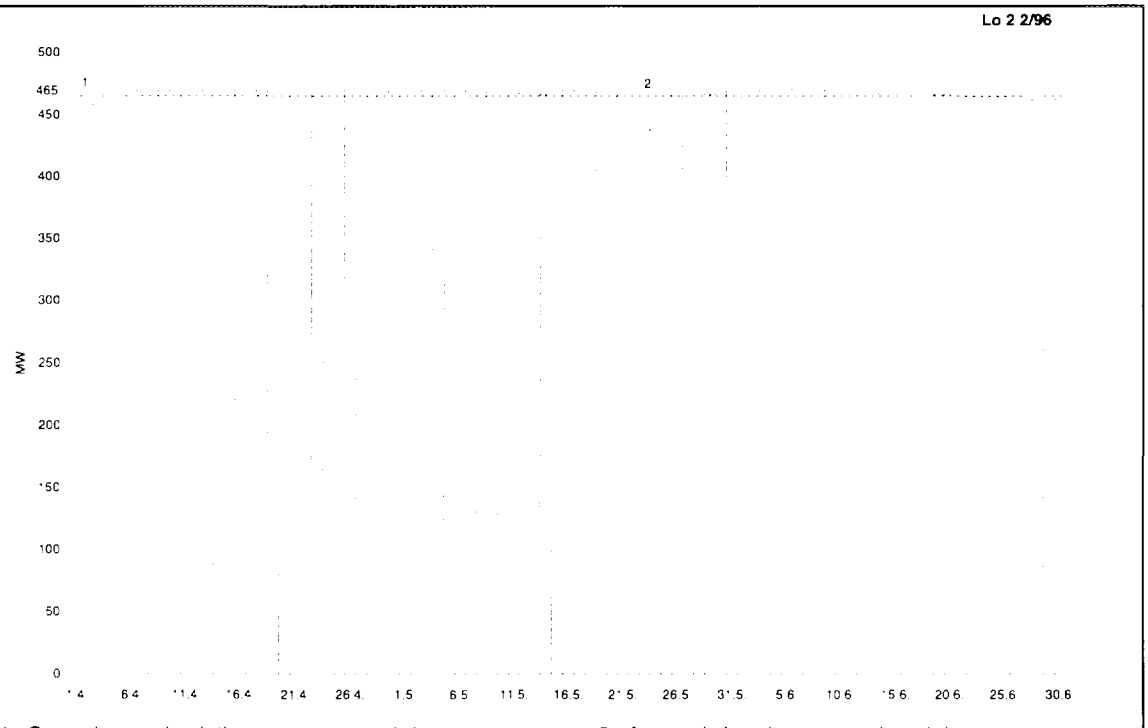
Modifications made during the outage to improve safety are described in chapter 5.

In fuel inspections during the outage, on 28 May 1996, the refuelling machine's telescope fell freely about 30 cm. The event occurred when it was intended to transfer a fuel assembly from a rack submerged in fuel pool water to an inspection point in the same pool. When the telescope dropped, a gripper at its lower end hit the upper end of a fuel assembly which was in the rack The event occurred when an old program in the test program file of the refuelling machine's new automation system started while a malfunction relating to the telescope's rotation was being examined using an other test program.



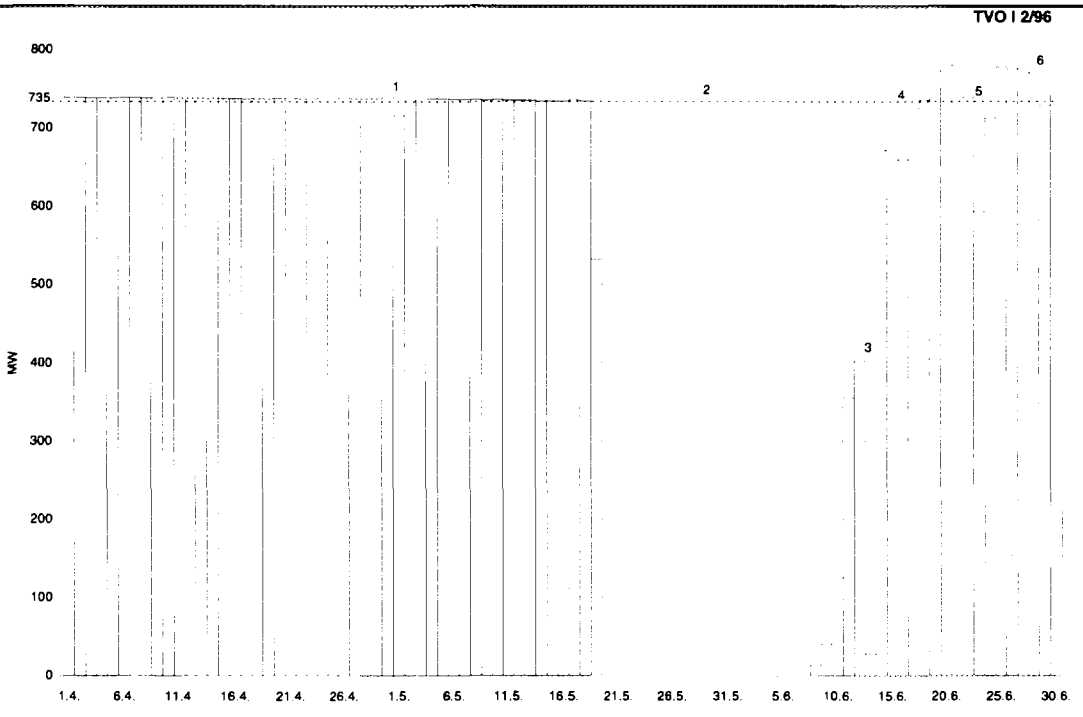
1. Power reduction due to degradation of the steam generator water chemistry, lowest reactor power was 74%.
2. Annual testing of the steam line safety valves, lowest reactor power was 74%.

Fig 1. *Daily average gross power of Loviisa 1 in April–June 1996.*



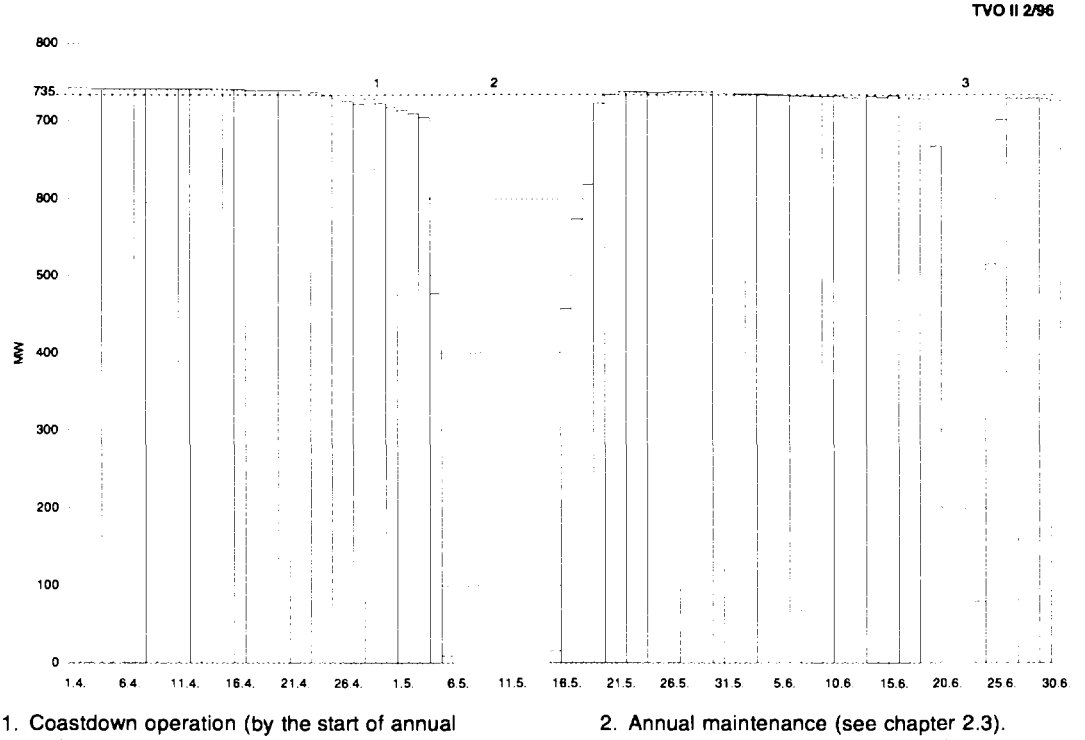
1. One primary circulation pump stopped due to a level measurement malfunction, lowest reactor power was 82%.
2. A pump's bearing was replaced, lowest reactor power was 80%.

Fig 2. *Daily average gross power of Loviisa 2 in April–June 1996.*



1. Periodic tests requiring power reduction, lowest reactor power was 70%.
2. Annual maintenance (see chapter 2.2).
3. Reactor scram in consequence of a turbine by-pass valve malfunction.
4. Testing and trial operation relating to the power upgrade, i.a. a turbine trip test (see chapter 3.2).
5. Low electricity demand, lowest reactor power was 80%.
6. Load reduction test, whereafter long-term test operation at 105% uprated power was started (see chapter 3.2).

Fig 3. Daily average gross power of TVO I in April–June 1996.



1. Coastdown operation (by the start of annual maintenance, the reactor power had reduced to 96%).
2. Annual maintenance (see chapter 2.3).
3. Hot shutdown due to low electricity demand and turbine generator rotor repairs (see chapter 2.4).

Fig 4. Daily average gross power of TVO II in April–June 1996.

When the program started, the brake of the telescope's driving motor opened.

No visible signs of damage were observed in the fuel assembly and the refueling machine's gripper. The fuel assembly was not loaded to the reactor but is kept in the fuel pool for closer inspections later. As an immediate measure to prevent corresponding malfunctions, an administrative order was drawn up prohibiting failure localisation, repairs and modifications of the refuelling machine during operational functions. The refuelling machine was also modified so as to more quickly stop the telescope during a transient.

After the annual maintenance, the plant unit was brought back on-line on 8 July 1996.

2.3 Annual maintenance outage at TVO II

TVO II's 15th refuelling and maintenance outage was from 5 to 15 May 1996. The plant unit was off the national grid for 11 days.

Apart from Teollisuuden Voima Oy's own staff, the maximum number of contract workers participating in the outage was 792. The collective radiation dose incurred in outage work was 0.43 manSv (0.63 in 1995). The highest individual dose was 14.0 mSv.

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

After the annual maintenance, the plant unit was brought back on-line on 15 May 1996.

When the plant unit reached 90% power level during power raising on 18 May 1996 the generator switch opened and the plant came off the grid. A turbine trip and a partial reactor scram resulted. The transient was caused by an increase in the temperature of the generator cooling water due to erroneous pressure control of the cooling system. The generator protection system safeguards the generator in events of this kind by taking it off the grid.

Erroneous pressure control for its part was due to excessive closing of the cooling water system control valve due to which the system pressure abruptly dropped. The control valve and the pressure gauge indicating system pressure are in different rooms. To prevent recurrence, the utility plans to fit a pressure gauge in the vicinity of the control valve to observe pressure change during pressure control.

The plant unit was resynchronised with the national grid in 30 minutes from the transient.

2.4 TVO II's shutdown at Midsummer

TVO II was placed in hot shutdown state on 19 June 1996 due to low electricity demand. During the shutdown it was also clarified what had caused the changes observed earlier in the vibration levels of the turbine generator i.a. by inspecting the ventilation blades of the generator rotor. On the basis of the inspection, all ventilation blades on the the exciter side were replaced. Some other minor repairs were also made during the shutdown. The plant unit was brought back on-line on 23 June 1996.

3 EVENTS AND OBSERVATIONS

Loviisa 1

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

Loviisa 2

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

TVO I

In the second quarter of 1996, TVO I lost the external grid connection twice during the annual maintenance outage. During these events, the plant unit's systems functioned as designed by means of the back-up diesels. The events are level 0 on the INES scale. After the accomplishment of the annual maintenance outage, the reactor's test operation and tests at the uprated 105% power level were started at TVO I.

3.1 External grid losses during the annual maintenance outage

During annual maintenance, the TVO plant units are supplied the electrical power they require by either the 400 kV or the 110 kV external grid. If both grid connections are lost the back-up diesels start and automatically provide the safety systems with the electrical power they require.

During TVO I's annual maintenance outage on 21 May 1996, the 110 kV grid connection was being serviced and the plant unit was being supplied the necessary electrical power by the 400 kV external grid via the plant switch. An unplanned opening of the plant switch then occurred, however. The opening of the switch brought about a power failure at the plant unit due to which the back-up diesels were started by a control device. The supply of electrical power from the 400 kV grid could be continued in about half an hour from the event when the plant switch was closed. An identical transient occurred in about half an hour and lasted about 15 minutes.

The events were of minor safety significance, since the plant unit's back-up diesels and systems operated according to design in connection with the power failures.

On both occasions the plant switch opened because errors were made in connection with simultaneous tests relating to the upgrading of turbine automation.

As a corrective measure, additional attention will be paid to the dates of tests relating to the control circuits of the switches and to the explicitness of the instructions for the performance of the tests.

3.2 Trial operation of TVO I at 105% reactor power

In connection with the power uprating of the TVO plant units, trial operation at 105% reactor power was started at TVO I after the 1966 annual maintenance outage. It is intended to continue the trial operation of TVO I at this reactor power until the 1997 annual maintenance outage. According to a decision by the Ministry of Trade and Industry, trial operation at a reactor power exceeding rated power can be conducted by virtue of the current operating licence, provided that an approval from the Finnish Centre for Radiation and Nuclear Safety is obtained.

Based on TVO's clarifications and the Centre's own safety assessment, the Finnish Centre for Radiation and Nuclear Safety has noted that trial operation of TVO I at 105% power is safe, provided that the planned plant modifications are implemented in the 1996 annual maintenance outage. In its statement, the Advisory Committee on Nuclear Safety was in agreement with the Centre's opinion about the acceptability of the long-term trial operation of TVO I plant unit at 105% reactor power.

The most important modifications implemented in the 1996 annual maintenance outage as regards the TVO I power uprating were the

increasing of the reactor overpressure protection capacity, the renewal of the turbine control system and the increasing of the shutdown reactor residual heat removal. In addition to these, the plant unit main generator was replaced and extensive turbine modifications were carried out. The electric drive of one primary circulation pump was altered to slow down the pump's stopping in the event of loss of electrical power. Other pumps will be correspondingly modified later provided that no problems are observed in the operation of the modified pump during the one-year trial operation period.

Prior to the commencement of the long-term trial operation at 105% reactor power, tests were carried out at TVO I in connection with the plant's start-up to ensure the performance and acceptability of systems modified during the outage in both normal operation and during certain transients. The most important transient test was a load reduction test during which the plant's connection to the national grid was cut off while operating at 105% reactor power. In the load reduction test, TVO I successfully switched on to house-load operation during which the plant unit is supplied the necessary electrical power by its own main generator. After the test, the plant unit was resynchronised with the national grid.

The Finnish Centre for Radiation and Nuclear Safety oversaw the trial operation i.a. by checking the trial operation programmes and the plant modifications made, by witnessing tests at the plant site and by reviewing the test reports. Based on this control, the Centre gave its approval for the commencement of long-term trial operation at 105% power.

TVO II

No reportable events occurred at TVO II in the second quarter of 1996.

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 was 14.3 mSv and it was received at TVO 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 was started at the beginning of 1992. Radiation doses at Loviisa and TVO 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 TVO 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 TVO units in this 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 2.22 manSv/year and of 3.56 manSv/year for the Loviisa and TVO units respectively.

4.2 Radioactive releases into the environment

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.

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 and their transfer to food chains is monitored and it is thus ensured that the releases remain below authorised limits. In this quarter, a total of 180 samples was analysed according to the programmes.

In one sample of air from the vicinity of TVO nuclear power plant manganese-54 and cobalt-60 originating from the power plant were measured. In three samples of deposition cobalt-60 was measured. One sample of sea water contained manganese-54 and cobalt-60. All samples of seaweed contained manganese-54 and cobalt-60 and some of them also chromium-51, cobalt-58, cobalt-57 and iodine-131. Samples of bivalve and sedimenting matter contained manganese-54, cobalt-58 and cobalt-60.

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

Dose range (mSv)	Number of persons by dose range					
	Second quarter 1996			From beginning of 1996		
	Loviisa	TVO	Total*	Loviisa	TVO	Total*
< 0.5	64	525	599	81	430	616
0. 5–1	14	263	282	26	272	304
1–2	6	206	221	12	219	241
2–3	–	86	91	5	87	96
3–4	–	47	68	5	49	74
4–5	–	29	36	1	37	46
5–6	–	11	15	–	10	14
6–7	–	13	21	–	13	21
7–8	–	5	8	–	6	9
8–9	–	4	9	–	5	10
9–10	–	4	5	–	5	6
10–11	–	5	8	–	5	8
11–12	–	7	7	–	9	9
12–13	–	–	4	–	–	4
13–14	–	–	3	–	–	3
14–15	–	1	1	–	1	1
15–16	–	–	–	–	–	–
16–17	–	–	1	–	–	1
> 17	–	–	–	–	–	–

* 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 dose to a Finnish nuclear power plant worker this quarter, 16.2 mSv, was received at a nuclear power plant in Sweden.

Two samples of deposition collected around Loviisa nuclear power plant contained cobalt-60 and one of them also silver-110m. The tritium concentrations of three samples of sea water were clearly higher than in sea water in general. Three bladder wrack samples contained cobalt-60, two manganese-54 and silver-110, and one cobalt-58. The same radioactive substances were also measured in the samples of sedimenting matter and, with the exception of cobalt-58, also in the sample of crustacean. All the measured concentrations were low.

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

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

Gaseous effluents (Bq) a)

Plant site	Noble gases (Krypton-87 equivalents)	Iodines (Iodine-131 equivalents)	Aerosols	Tritium	Carbon-14
Loviisa					
Report period	$5.9 \cdot 10^{9}$ b)	c)	$2.3 \cdot 10^{5}$	$5.5 \cdot 10^{10}$	$4.0 \cdot 10^{10}$
Early 1996	$1.5 \cdot 10^{10}$ b)	$1.4 \cdot 10^{4}$	$2.9 \cdot 10^{6}$	$1.1 \cdot 10^{11}$	$6.9 \cdot 10^{10}$
Olkiluoto (TVO)					
Report period	$2.5 \cdot 10^{12}$	$2.0 \cdot 10^{7}$	$1.1 \cdot 10^{7}$	$4.5 \cdot 10^{10}$	d)
Early 1996	$8.5 \cdot 10^{12}$	$2.3 \cdot 10^{7}$	$1.2 \cdot 10^{7}$	$1.0 \cdot 10^{11}$	d)
Annual release limits					
Loviisa	$2.2 \cdot 10^{16}$	$2.2 \cdot 10^{11}$			
Olkiluoto	$1.8 \cdot 10^{16}$	$1.1 \cdot 10^{11}$			

Liquid effluents (Bq) a)

Plant site	Tritium	Other nuclides
Loviisa		
Report period	$3.5 \cdot 10^{12}$	$7.6 \cdot 10^{5}$
Early 1996	$5.4 \cdot 10^{12}$	$4.5 \cdot 10^{7}$
Olkiluoto (TVO)		
Report period	$1.1 \cdot 10^{12}$	$8.1 \cdot 10^{9}$
Early 1996	$1.7 \cdot 10^{12}$	$1.1 \cdot 10^{10}$
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) In addition, the calculated release of argon-41 from Loviisa 1 and 2 in krypton-87 equivalents was $4.3 \cdot 10^{11}$ Bq in the report period and $8.6 \cdot 10^{12}$ Bq from beginning of 1996.
c) Below th detection limit.
d) The carbon-14 release-estimate based on experimental data was $1.3 \cdot 10^{11}$ Bq in Olkiluoto in the report period and $3.0 \cdot 10^{11}$ Bq from beginning of 1996.
e) The figure 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 1996 were the annual maintenance outages of the TVO plant units during which a considerable number of plant modifications relating to the plant's modernisation were implemented at TVO I. No safety-significant plant modifications were made at Loviisa 1 and 2 in this annual quarter.

At the turn of the year, the back-up diesels of TVO plant units were fitted with dampers opening on pressure difference and having actuator motors, suction air then being drawn from the room atmosphere (STUK-B-YTO 149 and 150). Manually operated dampers which were installed earlier were equipped with automation and eletricity during annual maintenance.

At TVO I, the protection and control automation systems of the turbine plant, which originally were partly hydraulic, were replaced with technology based on digital and analog electronics. The modification improved i.a. the reactor's pressure control and reduced the turbine plant's susceptibility to transients. At the same time, also field instrumentation was improved i.a. by installing a number of pressure, level and temperature detectors. Post-modifiction tests ensured a marked improvement in the correctness and reliability of pressure control.

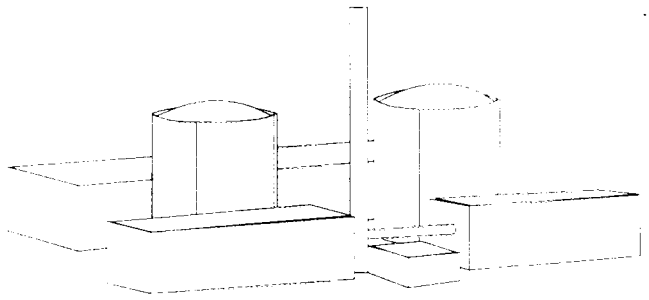
The electric drives of TVO I's one primary circulation pump were replaced and the stopping time of the pump was extended.

At TVO I, protection of the reactor against overpressurisation was improved by adding two safety valves. The new valves increase the system's reliability and the overall safety of the plant. The additional capacity also facilitates the reactor power uprating.

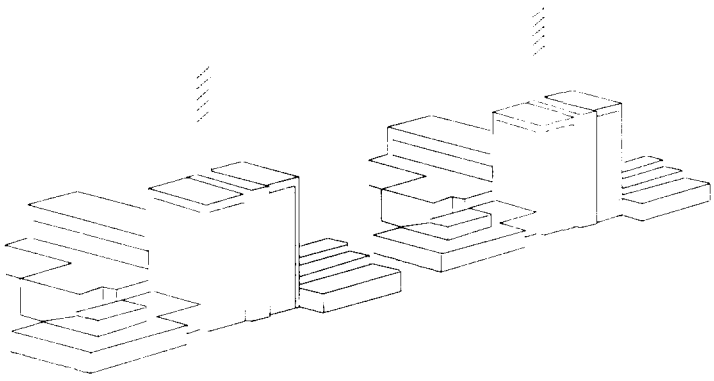
The residual heat removal capacity of TVO I's reactor was increased by adding plates to the heat exchangers.

Fire protection at TVO I was improved by complementing the automatic fire extinguishing systems in the turbine cellar.

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



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
TVO I	2 Sept. 1978	10 Oct. 1979	735/710	Boiling water reactor (BWR), Asea Atom
TVO II	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 TVO I and II plant units in Olkiluoto, Eurajoki.

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