STUK-B-YTO 132

Operation of Finnish nuclear power plants

Quarterly report
4th quarter, 1994
and annual summary

Kirsti Tossavainen (Ed.)

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ABSTRACT

Quarterly Reports on the operation of Finnish nuclear power plants describe nuclear and radiation safety related events and observations which the Finnish Centre for Radiation and Nuclear Safety (STUK) considers safety significant. Safety improvements at the plants and general matters relaung to the use of nuclear energy are also reported. A summary of the radiation safety of plant personnel and of the environment, and tabulated data on the plants' production and load factors are also given.

The plant units were in power operation the whole last quarter, with the exception of a reactor scram at Loviisa 1. The load factor average of all Finnish plant units was 100.2%. The annual average was 90.0%.

All events in the fourth annual quarter were assigned level 0 (no safety significance) on the international INES scale. Four events in 1994 were classified level 1 (an anomaly).

The Finnish Centre for Radiation and Nuclear Safety in December approved Imatran Voima Oy's application to extend the operation of the reactor pressure vessel of Loviisa 2 until the annual maintenance outage of 2010. During this quarter, a batch of spent fuel from Loviisa power plant was transported to Russia.

Occupational doses and radioactive releases off-site were below authorised limits. Only such quantities of plant-based radioactive materials were measurable in samples collected around the plants as have no bearing on the radiation exposure of the population.

This report includes a summary of all the items described in the Quarterly Reports of 1994.

CONTENTS

1 INTRODUCTION

According to the Nuclear Energy Act (990/87), regulatory control of the use of nuclear energy rests with STUK. The Centre's functions also include regulatory 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 the plants in Appendix 2.

The Finnish Centre for Radiation and Nuclear Safety publishes quarterly a report on the operation of Finnish nuclear power plants. The report describes plant events and observations during each quarter, gives tabulated data on the plants' production and availability factors and summarises the radiation safety of plant personnel and the environment. Safety improvements at the plants and general matters relating to the use of nuclear energy are also reported. The fourth Quarterly Report contains a summary of information reported earlier in the year.

The Report is based on information submitted to the Centre by the utilities and on the Centre's observations 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 1994

The Finnish nuclear power plants were in power operation in the fourth quarter of 1994, with the exception of a reactor scram at Loviisa 1.

2.1 Production data

Nuclear's share of total electricity production in Finland was 29,8 %. The load factor average of the plant units was 100,2 %.

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 unit electricity production and availability.*

	Electricity production (gross, TWh)		Availability factor (%)		Load factor (%)	
	Fourth quarter 1994	As of beginning of 1994	Fourth quarter 1994	As of beginning of 1994	Fourth quarter 1994	As of beginning of 1994
Loviisa 1	1.01	3.68	99.7	91.9	98.3	90.3
Loviisa 2	1.04	3.30	100.0	81.6	101.0	80.9
TVO I	1.63	6.21	100.0	96.9	100.7	96.4
TVO II	1.63	5.95	100.0	92.8	100.7	92.4

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

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

Table II. *Nuclear energy in Finnish electricity production.*

	Fourth quarter 1994	1994	1993	1992
Nuclear electricity production (net, TWh)[a]	5.1	18.3	18.8	18.2
Total electricity production in Finland (net, TWh)[a]	17.1	62.1	58.1	54.7
Nuclear's share of total electricity production (%)	29.8	29.5	32.3	33.3
Load factor averages of Finnish plant units (%)	100.2	90.0	92.8	89.2

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

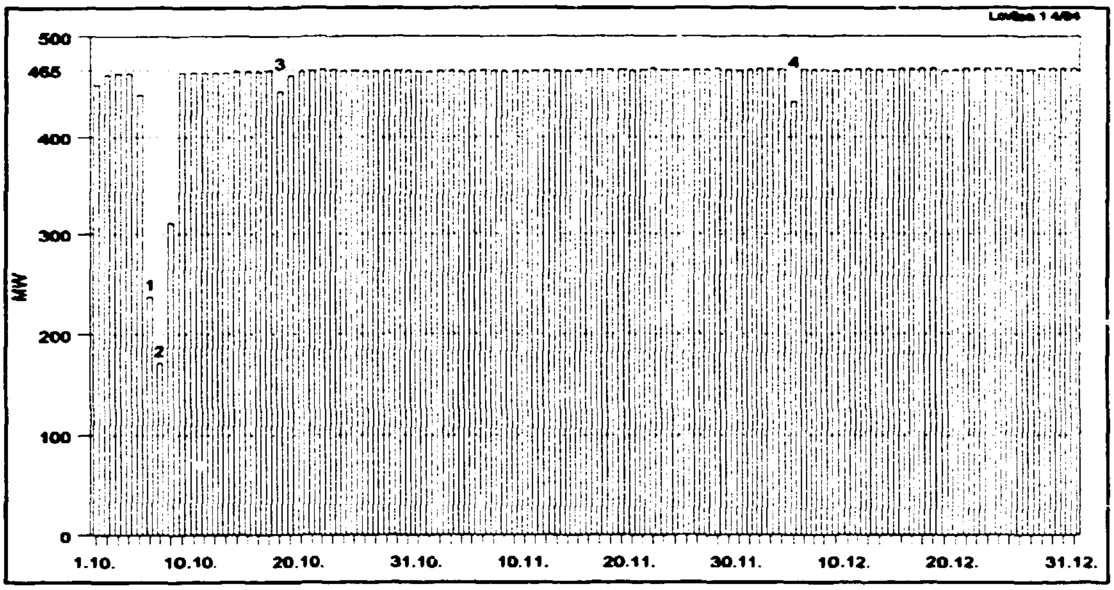

Fig 1. Daily average gross power of Loviisa 1 in October - December 1994.

1 Bearings of one of two generators were repaired, the reactor at 51% power.
2 Reactor scram (see ch. 2.2).
3 The output of one of two turbines decreased due to a turbine wall temperature measuring device malfunction. One main circulation pump was stopped to repair a signal line leak, the reactor was at 69% power.
4 The output of one of two generators was reduced to replace a main condensate pump motor, the reactor at 41% power.

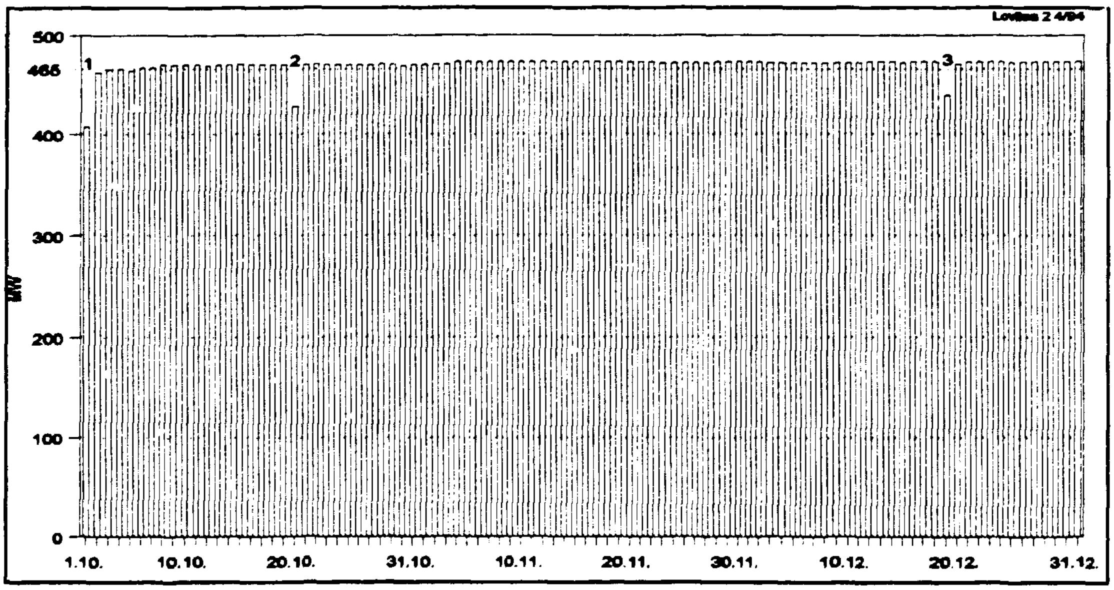

Fig 2. Daily average gross power of Loviisa 2 in October - December 1994.

1 Start-up from annual maintenance outage (STUK-B-YTO 128, 1994).
2 One of two turbines tripped in consequence of an auxiliary condensate automatic controller malfunction, the reactor to 61% power.
3 One of two turbines tripped while the automatic voltage control of its generator was being switched off, the reactor to 54% power.

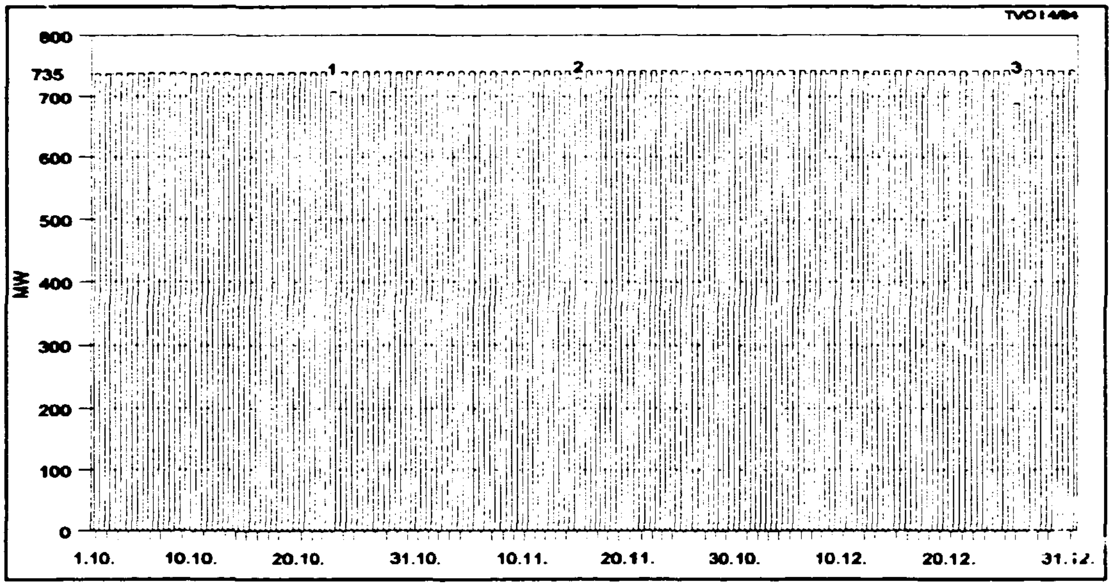

Fig 3. Daily average gross power of TVO I in October - December 1994.

1 Periodic tests and reactor stability measurements, the reactor minimum power was 62%.

2 One main circulation pump tripped, the reactor minimum power was 72%.

3 Periodic tests and reactor stability measurements, the reactor minimum power was 60%.

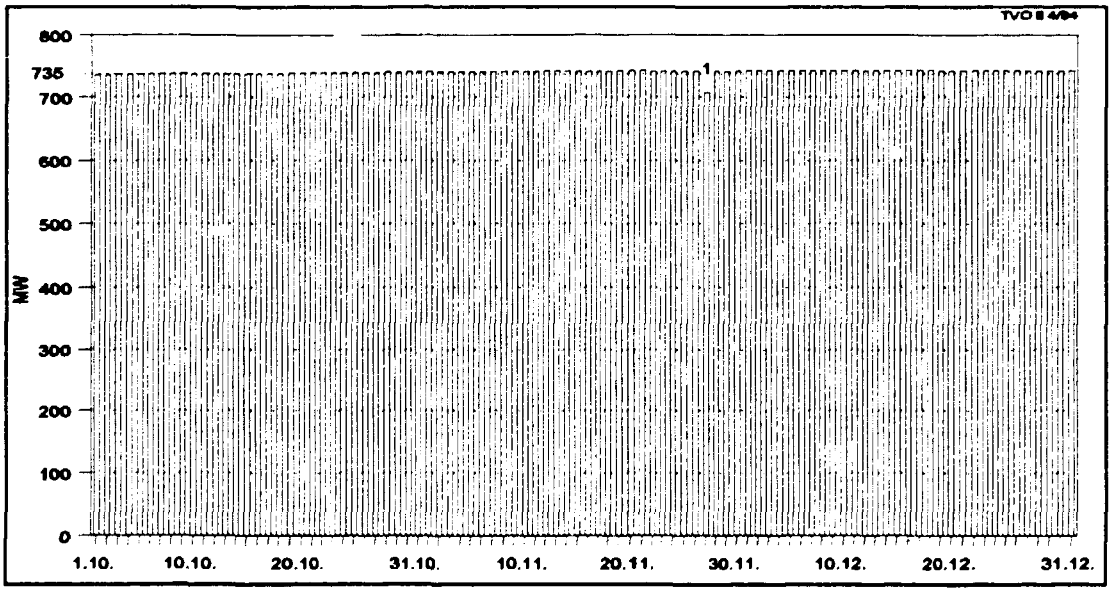

Fig 4. Daily average gross power of TVO II in October - December 1994.

1 Periodic tests, the reactor at 70% power.

2.2 Reactor scram at Loviisa 1

A reactor scram occurred at Loviisa 1 on 7 October, 1994. The bearings of one of two generators had been repaired and the reactor was at about 51% power. At the same time, other repairs had been carried out in the same section of the turbine plant due to which i.a. high-pressure pre-heaters had been removed from service. These pre-heaters heat up the feedwater which is fed into the steam generators. An error was made when returning the pre-heaters into service after repair. A pressure decrease in the collector pipeline downstream of the feedwater pumps followed, stopping the operating pumps. When the operator noticed this, he shut down the reactor by pushing the scram button. An automatic reactor scram would have occurred somewhat later.

The plant unit's other generator was synchronised with the national grid the same day and the generator under repair on 8 October, 1994.

3 EVENTS AND OBSERVATIONS

Loviisa 1

In the last quarter of 1994, a steam generator level controller malfunction occurred. The event was classified level 0 on the international INES scale.

3.1 Spurious functioning of steam generator level controller

A transient occurred at Loviisa 1 on 24 November, 1994 during which one steam generator's level decreased because of a level controller failure. The failure closed a control valve in a line feeding water to the steam generator, ending supply of water to the steam generator.

Both Loviisa plant units have six steam generators which utilize primary circuit heat in converting secondary circuit feedwater to steam. This steam is then directed to turbines. The steam generators also remove decay heat generated after reactor shutdown. Supply of feedwater to the steam generators is important for maintaining heat transfer from the primary to the secondary circuit. If feedwater is depleted, steam generator water level decreases, exposing heat transfer pipes. This reduces tne heat transfer capability of the steam generator. To avoid such a situation, one of two emergency make-up pumps starts immediately if the water level decreases, and supplies make-up water to the steam generator. The start-signal is provided by the pump's own automatic system. If the water level further decreases, the plant protection system sends a start signal to the other make-up water pump. The system also sends a new signal to the pump which already received a signal to start, in case the pump was not started by its own automatic system.

The fact that the signal which starts both make-up water pumps took effect only after about one-and-a-half minutes later than required by the water level was due to a level transmitter failure. One of the two pumps had already been started by its own automatic system. However, the plant unit being at 100% power, the pump's capacity was insufficient to stop the water level from decreasing further. The decrease in water level stopped when an operator manually opened the feedwater-line control valve which had received the spurious closing signal.

The electronics units of the steam generator level controller and of its level transmitter were found to be defective and were replaced.

When the matter was clarified, it was found out that when the water level in one steam generator decreases, the signal starting both make-up water pumps becomes dependent on one level measurement only. The reliability of this protective function has been considered sufficient, since all the other steam generators are available for decay heat removal. Due to this event, however, its reliability is now being reassessed.

Loviisa 2

There were no reportable events at Loviisa 2 in the last quarter of 1994.

TVO I

In the last quarter of 1994, a leak in a nuclear fuel cladding was detected at TVO I. The event measured level 0 on the INES scale.

3.2 Nuclear fuel cladding leak

A slight activity increase in turbine steam exhaust gases was observed at TVO I in June 1994 which was due to a minor fuel leak (STUK-B-YTO 125, 1994). The leak was localised to a supercell (an entity comprising four fuel assemblies) in the reactor core edge zone. Only fission gases were released through this minor failure in the fuel rod cladding. Towards the end of the summer, the fission gas leak rate decreased to a level almost equal to normal background.

On 6 December 1994, laboratory measurements indicated that the combined fission-gas leak rate had increased from the background value of 5 MBq/s to 94 MBq/s, from which it soon decreased to ca. 40 MBq/s. The primary coolant was not in contact with the uranium-dioxide, however, since the activity concentrations of iodine-131 and of actinide in the primary coolant did not increase.

On 20 December 1994, the fuel leak was tentatively localised to a supercell other than the one in a low power assembly in summer 1994. The new leak is located more in the centre of the core, in a high power assembly. The leak is monitored during the operating cycle, and the actual leak will be identified and the leaking assembly removed from service in the next annual maintenance outage.

TVO II

A radioactive mixture of ion-exchange resin and water escaped into two rooms at TVO II. The event measures level 0 on the INES scale.

3.3 Radioactive mixture of resin and water escaped into two rooms

At TVO II, radioactive ion-exchange resin from the cooling and purification system of the fuel and reactor pools escaped to two rooms on 21 December, 1994. The event occurred when spent ion-exchange resin was flushed from the system's filter by circulating water through the filter. After the first flushing, the foreman went to the filter room to check that everything was as required. He then noticed that water with ion-exchange resin in it had escaped into the filter room and to the room next to it.

The rooms have sumps connected to a controlled drainage system for collecting leaks which contain radioactive substances. The volume of the resin-water mixture was so large (ca. 70 m^3), however, that one sump's capacity proved insufficient to prevent the mixture from escaping to the adjacent room over a low threshold.

In the filter room, a dose rate of 195 mSv/h was measured on the surface of the resin-water mixture and of 20-40 mSv/h at about one metre's height. The occupational collective dose to those cleaning the room was 0.020 manSv. No releases of gaseous radioactive effluents occurred during the event.

According to the dose rate classification, both rooms are in the "red zone" (external dose rate in excess of 1 mSv/h). The rooms are therefore kept locked and only a limited number of staff with special training in radiation protection may access them via one door only. There are also detailed instructions covering work in this zone.

During clarification of the event, it was detected that the drainage valve of a venting tank required during resin replacement was not closed after a repair on 16 August, 1994. The radioactive resin-water mixture found its way into the room via the open valve.

4 RADIATION SAFETY

Individual doses to nuclear power plant personnel were below the dose limit. Also environmental releases were well below the release limits. Only such quantities of plant-based radioactive materials were measurable in samples collected around the nuclear power plants 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. Individual doses may not exceed authorised limits.

4.2 Occupational exposure

The radiation safety of nuclear power plant personnel depends, on one hand, on plant structure and condition and on the other hand on the implementation of radiation protection during work assignments. Occupational dose is mainly incurred in annual maintenance outage work.

The highest individual dose at Finnish nuclear power plants in this quarter was 3.3 mSv and it was received at Olkiluoto nuclear power plant. The Radiation Decree stipulates that the annual effective dose incurred in radiation work may not exceed 50 mSv. The dose may not exceed the 20 mSv annual dose averaged over a period of five years. This monitoring of the annual average was started at the beginning of 1992. Radiation doses have remained below authorised limits both at Loviisa and Olkiluoto nuclear power plants.

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. The information given in the Table is taken from STUK's central dose register.

The collective occupational dose at Loviisa plant units was 0.05 manSv and at TVO 0.06 manSv 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 Olkiluoto units respectively.

4.3 Radioactive releases and population exposure

Population exposure around a nuclear power plant is due to releases of gaseous and liquid radioactive effluents. These releases are limited by technical means. The plant's operational state 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 the report period, the releases 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 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.

Table III. Occupational dose distribution in the last quarter of 1994 and in the whole year.

Dose range (mSv)	Number of persons by dose range					
	Fourth quarter 1994			Whole 1994		
	Loviisa	TVO	Total[a]	Loviisa	TVO	Total[a]
< 0,5	71	77	152	210	522	674
0,5 - 1	15	21	42	143	237	356
1 - 2	13	10	23	158	178	296
2 - 3	5	6	12	115	105	201
3 - 4	2	1	4	68	73	134
4 - 5	-	-	1	68	58	116
5 - 6	-	-	2	53	29	79
6 - 7	-	-	-	22	24	53
7 - 8	-	-	-	12	14	39
8 - 9	-	-	-	13	8	29
9 - 10	-	-	-	9	11	30
10 - 11	-	-	-	7	11	21
11 - 12	-	-	-	10	3	19
12 - 13	-	-	-	4	8	12
13 - 14	-	-	-	5	8	17
14 - 15	-	-	-	2	3	7
15 - 16	-	-	-	2	3	8
16 - 17	-	-	-	1	-	3
17 - 18	-	-	-	-	1	5
18 - 19	-	-	-	-	-	2
19 - 20	-	-	-	-	1	1
20 - 21	-	-	-	-	1	3
21 - 25	-	-	-	1	-	2
> 25	-	-	-	-	-	-

a These 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 in 1994, 21.7 mSv, was received in Sweden.

Table IV. Radioactive releases at each plant site, fourth quarter 1994.

	Gaseous effluents (Bq)[a]				
Plant site	**Noble gases (Krypton-87 equivalents)**	**Iodines (Iodine-131 equivalents)**	**Aerosols**	**Tritium**	**Carbon 14**
Loviisa					
Report period	$1.6 \cdot 10^{10}$ b)	c)	$5.2 \cdot 10^{6}$	$4.9 \cdot 10^{10}$	$2.7 \cdot 10^{10}$
In 1994	$1.0 \cdot 10^{11}$ b)	$1,7 \cdot 10^{5}$	$2.3 \cdot 10^{8}$	$2.1 \cdot 10^{11}$	$1.8 \cdot 10^{11}$
Olkiluoto					
Report period	$2.9 \cdot 10^{10}$	c)	$4.3 \cdot 10^{6}$	$8.8 \cdot 10^{10}$	d)
In 1994	$3.5 \cdot 10^{12}$	$1.1 \cdot 10^{9}$	$1.3 \cdot 10^{8}$	$2.4 \cdot 10^{11}$	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	$2.6 \cdot 10^{12}$	$1.7 \cdot 10^{6}$
In 1994	$1.1 \cdot 10^{13}$	$4.1 \cdot 10^{8}$
Olkiluoto		
Report period	$2.9 \cdot 10^{11}$	$1.1 \cdot 10^{9}$
In 1994	$2.7 \cdot 10^{12}$	$9.3 \cdot 10^{10}$
Annual release limits		
Loviisa	$1.5 \cdot 10^{14}$	$8.9 \cdot 10^{11}$ e)
Olkiluoto	$1.8 \cdot 10^{13}$	$3.0 \cdot 10^{11}$

a The unit of radioactivity is Becquerel (Bq); 1 Bq = one nuclear transformation per second.
b The calculatory 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 $1.5 \cdot 10^{12}$ Bq from beginning of 1994.
c Below the detection limit.
d The carbon-14 release-estimate based on experimental data was $1.7 \cdot 10^{11}$ Bq in Olkiluoto in the report period and $4.7 \cdot 10^{11}$ Bq from beginning of 1994.
e The numerical value shows the release limit for the Loviisa plant site, assuming that the sum of the various types of release limit shares shall be smaller than or equal to 1.

4.4 Environmental monitoring

Radiation safety in the vicinity of Finnish nuclear power plants is monitored by regular sampling and analysis programmes. This monitoring is intended to follow the environmental dispersion of radioactive releases and to ensure that the releases remain below authorised limits.

To assess the quantities of radioactive substances potentially accumulating in man, samples are taken and analysed of i.a. air, deposited material, rainwater and sea water, as well as of foodstuffs such as milk, meat, grain, vegetables and fish. Also terrestrial and marine indicator organisms are analysed which effectively enrich radioactive substances from their environment. By means of these organisms, even minor discharges can be detected and their dispersion monitored. External radiation is measured at about ten stations, located 1 - 10 kilometres from the power plant. This monitoring is complemented by spectrometric measurements.

In this quarter, a total of 177 samples were analysed in accordance with the monitoring programmes.

Radioactive substances originating in Loviisa nuclear power plant were detected in two samples of deposited material and in three samples of sinking matter. All these samples contained cobalt-60 and two of them also contained silver-110m. Manganese-54 and cobalt-60 from TVO nuclear power plant were present in all four samples of sedimenting matter. All the detected concentrations were low.

Radioactive isotopes of strontium and caesium (strontium-90, caesium-134 and -137) and of plutonium (plutonium-238 and 239,240) originating in the Chernobyl accident and in the fallout from the atmospheric testing of nuclear weapons are still measurable in environmental samples. Natural radioactive substances (such as beryllium-7 and potassium-40) are also detected. Their concentrations are usually higher than those of substances detected in samples from power plant releases or fallout.

5 SAFETY IMPROVEMENTS AT NUCLEAR POWER PLANTS

In the fourth quarter of 1994, few safety improvements were implemented at the nuclear power plants, since modifications are usually made during annual maintenance outages and there were none in this annual quarter.

At Loviisa 2, the discharge channels of heat exchangers in the emergency cooling pump rooms were enlarged. The volume of cooling water had been increased earlier, and the enlargement of the channels was implemented to prevent flooding and to ensure that the discharge channels can handle the increased volume of water. Also the fire-fighting water system reconstruction started earlier at the plant units was continued, with a number of modifications made to valves and piping.

At both TVO units, an alarm signal indicating low outdoor air temperature (below -25°C) was added to the process computer and to the alarm printer. On receipt of the alarm signal, circulation of back-up diesel fuel between tanks located in the auxiliary systems building and in the plant yard is started to avoid solidification of the fuel. Before the modification was made, fuel circulation was started on the basis of thermometer readings.

No significant safety improvements were made at Loviisa 1 in this quarter.

6 OTHER MATTERS RELATING TO THE USE OF NUCLEAR ENERGY

During the last quarter of 1994, the Finnish Centre for Radiation and Nuclear Safety made a decision to extend operation of the reactor pressure vessel of Loviisa 2. A batch of spent nuclear fuel from Loviisa nuclear power plant was transported to Russia in this quarter and regulations relating to the use of nuclear energy were revised.

6.1 Operation of Loviisa 2 reactor pressure vessel extended

The 1992 decision made by the Finnish Centre for Radiation and Nuclear Safety to extend operation of the reactor pressure vessel of Loviisa 2 was in force until the end of 1994. In December 1994, the Centre made a new decision allowing the vessel's operation until the annual maintenance outage of 2010. A corresponding decision about Loviisa 1 is in force until the annual maintenance outage of 1996.

The Centre has restricted operation of the reactor pressure vessels of Loviisa nuclear power plant units to closely monitor neutron irradiation-induced changes in vessel material and to ensure that up-to-date research data is obtained and utilised. The situation at Loviisa 2 is clearly better than at Loviisa 1; extended operation of the Loviisa 2 reactor pressure vessel is therefore possible for a longer period before measures to improve the ductility of its material are required.

Neutron irradiation causes transformations in the steel's micro structure which increase the steel's "ductile transition temperature". Below this temperature, the steel's plastic transformation ability deteriorates and it becomes brittle. If, at such a temperature, a structure is subjected to heavy stress, and if a sufficiently large crack exists at the point subject to stress, rapid crack-propagation will result and the structure breaks. Changes in the transition temperature are speeded up by the steel's impurities which are particularly abundant in welded seams.

Prior to commissioning, the ductile transition temperature of the reactor pressure vessel steel at both Loviisa plant units was clearly below -30°C but that of welded seams in the core region was +25°C at Loviisa 1 and +5°C at Loviisa 2. The ductile transition temperature of a critical welded seam in the Loviisa 1 reactor pressure vessel has been calculated at 135°C for 1996 and that of Loviisa 2 at 100°C for the year 2010.

The operating temperature of the reactor pressure vessel (300°C) significantly exceeds the ductile transition temperature of steel. The danger of a pressure vessel rupture grows e.g. in an accident during which cold water must be injected into the vessel and, in addition to pressure-induced stress, high thermal stress builds up in the vessel wall. Quick external cooling of the pressure vessel may also take place. This can occur in accidents during which the reactor pit would fill up with water from a coolant leak and from melting ice from the containment building ice-condenser. Structural and operational modifications have been implemented at both Loviisa plant units to decease the risk of brittle fracturing.

In its decision, the Finnish Centre for Radiation and Nuclear Safety required an external inspection of the reactor core region of the pressure vessel by improved ultrasound technique, not later than in the annual maintenance outage of 1966. In addition to this, Imatran Voima Oy was required to monitor items related to the reactor pressure vessel and to complement safety analyses, where necessary.

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

Spent nuclear fuel from Loviisa 1 and 2 was transported to Russia during 31 October - 2 November 1994. The fuel had been cooling down for five years and amounted to about 26 tonnes. A total of about 25 tonnes of spent fuel arises at both plant units every year. Fuel was now shipped for the 13th time; the previous shipment was in spring 1994.

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

The transport containers were inspected at Loviisa nuclear power plant before spent fuel was placed in them. The fuel was transported in seven water-filled containers and in one gas-filled container. 30 fuel bundles were placed in each water-filled container. In the gas-filled container, in tight shipping flasks, were six bundles which had leaked during operation.

The transport was arranged in accordance with a transport and security plan approved by STUK. There were special arrangements to ensure safety: i.a. transport container minimum temperature to ensure ductility of steel, low transport speed, one-way rail traffic and increased preparedness in provision against accidents. The shipment was uneventful.

6.3 Regulations

The Nuclear Energy Act was amended to correspond to the European Union's directives. The principles of action which apply to nuclear waste management were revised at the same time.

According to the new Act, licence to use nuclear energy may be granted to an EU citizen, corporation, foundation or authority. The amendment also takes into account i.a. the EU common market, Euratom's supervisory rights and the directive dealing with transportation of radioactive materials. The Ministry of Trade and Industry was designated the competent authority referred to in the Euratom Treaty.

The new Act prescribes, with minor exceptions, that nuclear waste generated in Finland is handled, stored and finally disposed of in Finland. Furthermore, nuclear waste generated outside Finland may not, according to the Act, be handled, stored or finally disposed of in Finland.

Also radiation legislation was amended to correspond to EU directives.

In this quarter, the Finnish Centre for Radiation and Nuclear Safety issued Guide YVL 1.11, Utilisation of nuclear power plant operating experiences. This Guide presents the bases and requirements for utilisation of nuclear power plant operating experiences. Requirements are set for items such as monitoring, assessment and screening of operating events, root cause analysis, and utilisation of fault statistics. Operating events other than those at Finnish nuclear power plants are to be monitored and analysed, too. The Centre's regulatory activities are also outlined in the Guide.

STUK published an English-language translation of the Guide YVL 6.7, Quality assurance of nuclear fuel.

7 ANNUAL SUMMARY 1994

All four nuclear power plant units operated reliably the whole year and no event at the power plants compromised safety. Doses to personnel and to the surrounding population were below set limits.

The combined duration of the annual maintenance outages of Loviisa plant units was 84 days. At the beginning of the Loviisa 2 outage, a 10-day primary circuit decontamination was carried out. The combined duration of the TVO annual maintenances was 35 days. Breaks in power generation were also caused by the replacement of a pressurizer auxiliary spray line valve at both Loviisa units, reactor scrams at Loviisa 1 and TVO I and the shutdown of TVO II for Midsummer due to low electricity demand. The load factor average of the plant units was 90.0%.

Nuclear's share of all electricity production in Finland was 29.5%. Power diagrams describing the electricity output of Finnish plant units are given in Figs 5 - 8.

Events at the plant units in 1994 did not exceed level 1 on the INES scale. Pressurizer auxiliary spray line valve cracking at both Loviisa plant units, which was detected at Loviisa 2 owing to leakage, was classified level 1. Level 1 events at the TVO plant units were as follows: reactor scram circuit neutron flux protection limits remained at too low a level, shut-down service-water system reliability was impaired and there was carbon dioxide deficiency in the fire extinguisher system. Level 1 denotes an anomaly beyond the authorised operating regime, or a plant operational state which may be due to a component failure, human error or procedural inadequacies.

Events and observations reported in STUK's Quarterly Reports were as follows:

Loviisa 1

- Reactor protection-system temperature transmitter was installed at wrong plant unit (1st quarter)
- Errors in work order procedure (1st quarter)
- Primary circuit hydrogen concentration decreased (2nd quarter)
- Loss of containment outer intermediate ring underpressure (2nd quarter)
- 20kV switch plant sustained damage in consequence of a fire (2nd quarter)
- Erroneous activation of primary circuit boron injection (3rd quarter)
- Steam generator level-control malfunction (4th quarter)

Loviisa 2

- Pressurizer auxiliary spray line valve cracks (2nd quarter)
- Primary circuit pressure increased during annual maintenance outage (3rd quarter)
- Containment spray system was partially inoperable during annual maintenance outage (3rd quarter)

TVO I

- Nuclear fuel cladding leak (1st quarter)
- Capacity shortage observed in off-gas filter system
- Reactor scram circuit neutron flux protection limits remained at too low a level (2nd quarter)
- Nuclear fuel cladding leaks (2nd quarter)
- Shut-down service water system reliability was impaired (2nd quarter)
- Shift supervisor's maximum working hours were exceeded (3rd quarter)
- Carbon dioxide deficiency in the fire extinguisher system (3rd quarter)
- Nuclear fuel cladding leak (4th quarter)

TVO II

- Errors in control rod manoeuvres (1st quarter)
- Nuclear fuel cladding failures (2nd quarter)
- Radioactive mixture of resin and water escaped into two rooms (4th quarter)

The highest individual radiation dose at Finnish nuclear power plants was 21.6 mSv and it was received at Loviisa nuclear power plant. The Radiation Act stipulates that the annual effective dose incurred in radiation work may not exceed 50 mSv. When averaged over a period of five years, the annual dose may not exceed 20 mSv. This monitoring started at the beginning of 1992. The highest individual dose to a Finnish worker during 1992-1994 was 73.6 mSv and it was received at nuclear power plants in Sweden.

Total collective occupational dose was 2.33 manSv at the Loviisa plant units and 2.40 manSv at the TVO units. According to a Guide issued by STUK, the collective dose limit for one plant unit, as a mean of two successive years, is 2.5 manSv per one gigawatt of net electrical power. This means an annual collective dose of 2.22 manSv and 3.56 manSv for Loviisa and TVO plants respectively.

At the end of 1994, the collective radiation dose accumulated at Loviisa 2 as of the beginning of 1993 was 2.70 manSv. This exceeds the plant-specific mean threshold value for two successive years determined in a STUK Guide. In cases like this, the utility reports to STUK the causes for the excessive doses and the measures necessary to improve radiation safety. At Loviisa 2, a large number of work assignments which are demanding as regards radiation protection had been focused in the 1994 annual maintenance outage. Conditions for the carrying out of these assignments were favourable as regards radiation protection, however, since the plant unit's primary circuit was decontaminated early in the same outage (STUK-B-YTO 128, 1994).

Some 700 samples collected in the vicinity of nuclear power plants were analysed. As in the previous years, the nuclear power plants had only a minor impact on the radiation levels around them. Isotopes of radioactive strontium and caesium (strontium-90, caesium-134 and -137) and of plutonium (plutonium-238 and -239,240) originating in the Chernobyl accident and in fallout from the atmospheric testing of nuclear weapons are still measurable in environmental samples.

In 1994, several safety improvements were made at the plant units, the most important of which were as follows:

Loviisa nuclear power plant

- At Loviisa 1, pumping of water from the make-up water tank to primary circuit water storage tanks by pumps external to the plant unit was made possible (1st quarter).
- Fire-fighting water system reconstruction was continued (2nd and 4th quarter).
- Containment outer intermediate ring was fitted with hatches to balance pressure fluctuations during accidents (2nd and 3rd quarter).
- Loviisa 2 primary circuit was decontaminated (3rd quarter).
- Stationary nitrogen containers were installed to blow open the filter units of containment building sumps during accidents (3rd quarter).
- Safety functions providing against steam generator failures were improved by making possible isolation of the steam generator due to high water level (3rd quarter).
- The possibility of the reactor cooling water boron concentration being diluted was reduced to prevent reactivity disturbances (3rd quarter).
- At Loviisa 2, diesel-backed main busbars were equipped with protection against arcing (3rd quarter).
- Cooling of back-up diesel room heat exchangers at Loviisa 2 was improved (4th quarter).

TVO nuclear power plant

- Piping connecting back-up diesel heat exchangers was replaced at TVO II with piping which better resists corrosion (1st quarter).
- Steam line mineral wool insulation was replaced with mirror insulation due to the danger of emergency cooling water circulation being clogged up by insulation dislodging during a potential pipe failure (2nd quarter).
- Filters were installed on the upstream side of the pressure reduction valves of the containment building spray system (to reduce the pressure of nitrogen by which strainers are cleaned) to improve reliability of the valves (2nd quarter).
- Fuel leak monitoring was improved by connecting activity measuring points to the process computer (2nd quarter).
- The core grid supporting nuclear fuel assemblies was replaced at TVO II (2nd quarter).
- Fire protection at TVO II was improved by installing sprinkler protection for the main and the plant transformers (2nd quarter).
- An alarm signal giving an indication of low outdoor air temperature was added to the process computer and to the alarm printer to ensure supply of fuel to back-up diesels (4th quarter).

Other matters relating to the use of nuclear energy were as follows: STUK reviewed TVO's plans for the disposal of spent nuclear fuel (1st quarter), spent nuclear fuel from Loviisa nuclear power plant was transported to Russia (2nd and 4th quarter) and STUK approved extended operation of the Loviisa 2 reactor pressure vessel until the 2010 annual maintenance outage (4th quarter).

The Nuclear Energy Act was amended to correspond to EU directives and because the principles of action in nuclear waste management have changed (4th quarter). During the year 1994, STUK published two YVL Guides and English-language translations of three Guides which had come into force on an earlier date.

Talks about an agreement between Finland and Russia on information exchange concerning nuclear facilities and early notification of a nuclear accident were concluded (2nd quarter). Finland signed the International Convention on Nuclear Safety and STUK assessed how Finnish regulations fulfill the Convention's obligations (3rd quarter).

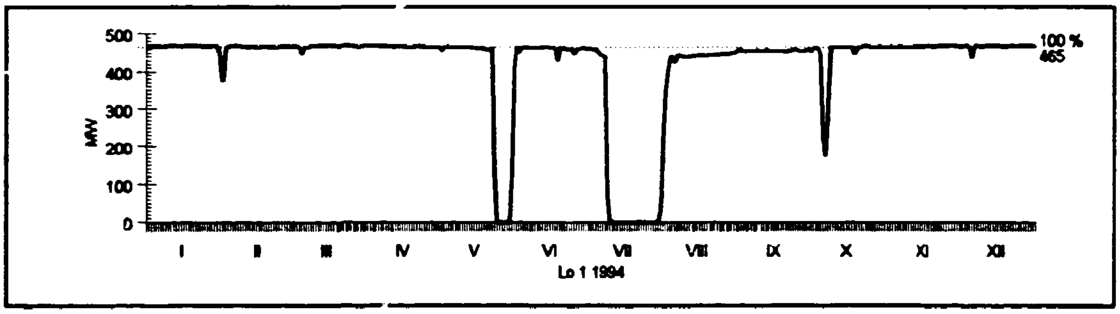

Fig. 5. Mean power of Loviisa 1 in 1994.

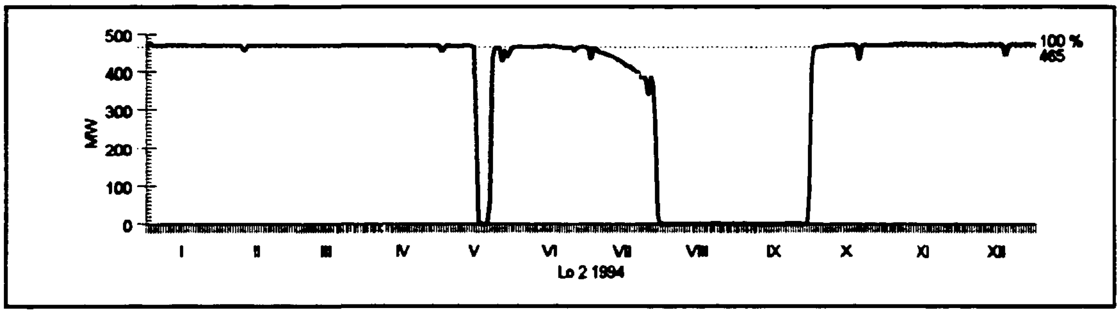

Fig. 6. Mean power of Loviisa 2 in 1994.

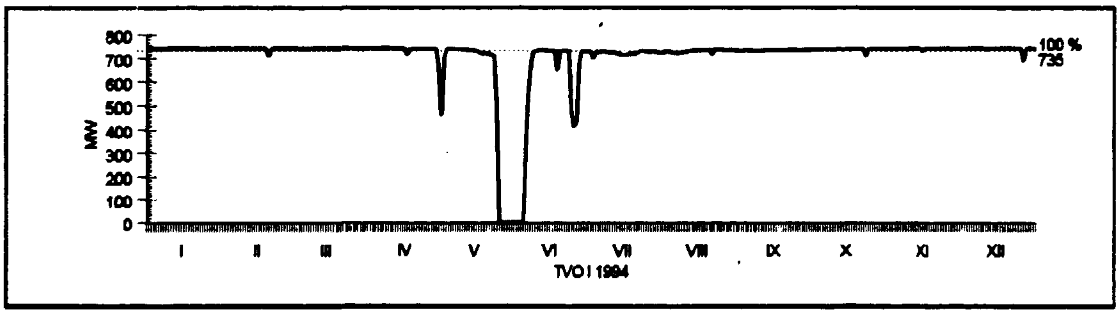

Fig. 7. Mean power of TVO I in 1994.

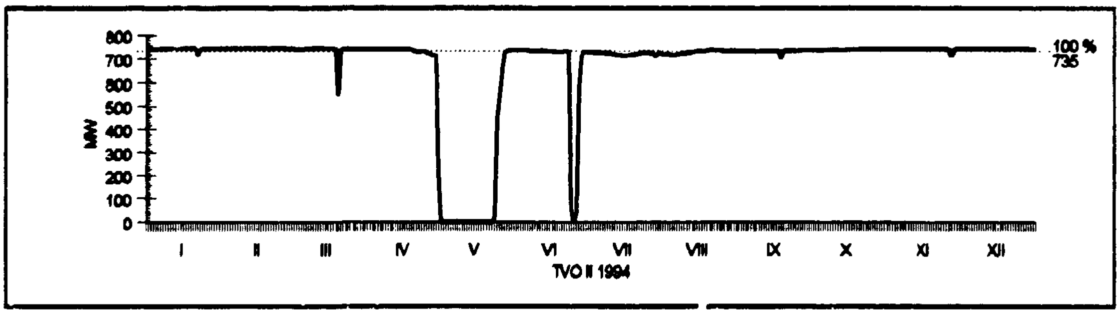

Fig. 8. Mean power of TVO II in 1994.

APPENDIX 1

REGULATORY CONTROL OF NUCLEAR FACILITIES

Council of State Decisions	**Regulatory control and inspections by the Finnish Centre for Radiation and Nuclear Safety**
	Preparation of a nuclear power plant project
Decision in Principle	• Preliminary plans for the plant and safety principles • Location and environmental impact of the plant • Arrangements for nucler fuel and nuclear waste management
	Plant design
Construction Permit	• 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 of plant
Operating Licence	• 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 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
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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