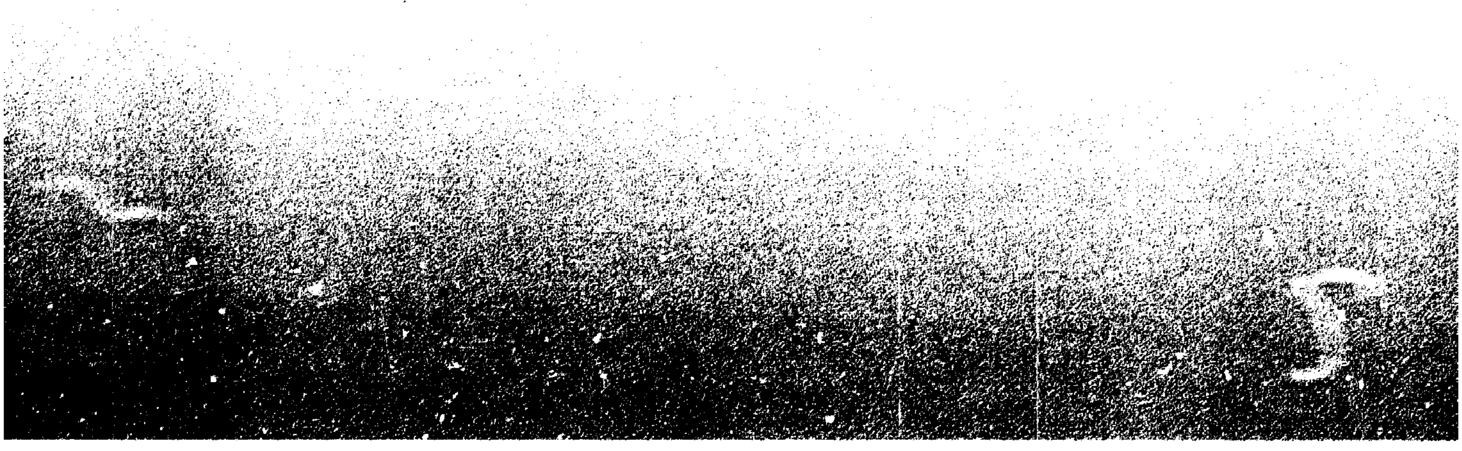
STUK-B-YTO 88

Operation of Finnish nuclear power plants

Quarterly report
1st quarter, 1991

Kirsti Tossavainen (Ed.)

AUGUST 1991



SÄTEILYTURVAKESKUS
Strålsäkerhetscentralen
Finnish Centre for Radiation and
Nuclear Safety

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Quarterly report
1st quarter

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Index terms PWR type reactors, BWR type reactors, NPP operating experience

ABSTRACT

In the Quarterly Reports on the operation of the Finnish nuclear power plants such events and observations are described relating to nuclear and radiation safety which the Finnish Centre for Radiation and Nuclear Safety considers safety significant. Also other events of general interest are reported. The report also includes a summary of the radiation safety of the plants' workers and the environment, as well as tabulated data on the production and load factors of the plants.

The Finnish nuclear power plant units Loviisa 1 and 2 as well as TVO I and II were in commercial operation during the whole first quarter of 1991. The load factor average was 99.7 %.

Failures have been detected in the uppermost spacing lattices of nuclear fuel bundles removed from the Loviisa nuclear reactors. Further investigations into the significance of the failures have been initiated.

In this quarter, renewed cooling systems for the instrumentation area were introduced at Loviisa 1. The modifications made in the systems serve to ensure reliable cooling of the area even during the hottest summer months when the possibility exists that the temperature of the automation equipment could rise too high causing malfunctions which could endanger plant safety.

Occupational radiation doses and external releases of radioactivity were below prescribed limits in this quarter. Only small amounts of radioactive substances originating in nuclear power plants were detected in samples taken in the vicinity of nuclear power plants.

CONTENTS

1 INTRODUCTION

As prescribed by the Nuclear Energy Act (990/87), regulatory control of the use of nuclear energy rests with the Finnish Centre for Radiation and Nuclear Safety. The functions of the Finnish Centre for Radiation and Nuclear Safety also include regulatory control of physical protection, emergency preparedness and nuclear material safeguards. The scope of regulatory control related to nuclear power plants is specified in Appendix 1. General information relating to the Finnish nuclear power plants is presented in Appendix 2.

The Finnish Centre for Radiation and Nuclear Safety publishes a quarterly report on the operation of Finnish nuclear power plants. The report on the fourth quarter also contains a summary of the information reported during the year in question. The report is based on the information reported to the Finnish Centre for Radiation and Nuclear Safety by the power companies and the observations made by the Finnish Centre for Radiation and Nuclear Safety during regulatory control. The events and observations described in the report are classified according to the International Nuclear Event Scale which is currently undergoing a trial period.

Apart from event descriptions, the report contains a summary of the radiation safety of nuclear power plant workers and the environment and tabulated data on the production and load factors of nuclear power plants.

2 OPERATION OF NUCLEAR POWER PLANTS IN JANUARY-MARCH 1991

The Finnish nuclear power plants were in commercial operation for the whole first quarter of 1991.

2.1 Production data

Nuclear electricity accounted for 31.8 % of the total amount of electricity generated in Finland during this quarter. The load factor average of the plant units was 99.7 %. Production and availability figures are presented in more detail in Tables I and II.

Power diagrams describing electricity generation at the plant units and summaries of power reductions are presented in Figures 1 – 4.

Table I. Electricity production and availability of the units.

	Electricity production (gross, TWh)		Availability factor (%)		Load factor (%)	
	First quarter 1991	Whole year 1990	First quarter 1991	Whole year 1990	First quarter 1991	Whole year 1990
Loviisa 1	0.99	3.46	100.0	86.8	98.4	84.9
Loviisa 2	1.01	3.44	100.0	86.6	100.3	84.5
TVO I	1.59	6.08	100.0	95.4	100.5	94.4
TVO II	1.58	5.97	100.0	94.3	99.5	92.7

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

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

Table II. Nuclear energy in the Finnish production of electricity.

	First quarter 1991	Whole year 1990	1989
Production of nuclear electricity (net, TWh)[a]	5.0	18.1	18.0
Total production of electricity in Finland (net, TWh)[a]	15.7	51.7	50.8
Share of nuclear electricity of total production	31.8	35.0	35.4
Load factor averages of the Finnish plant units (%)	99.7	89.1	89.9

[a] Source: Statistics compiled by the Finnish Association of Electricity Supply Undertakings.

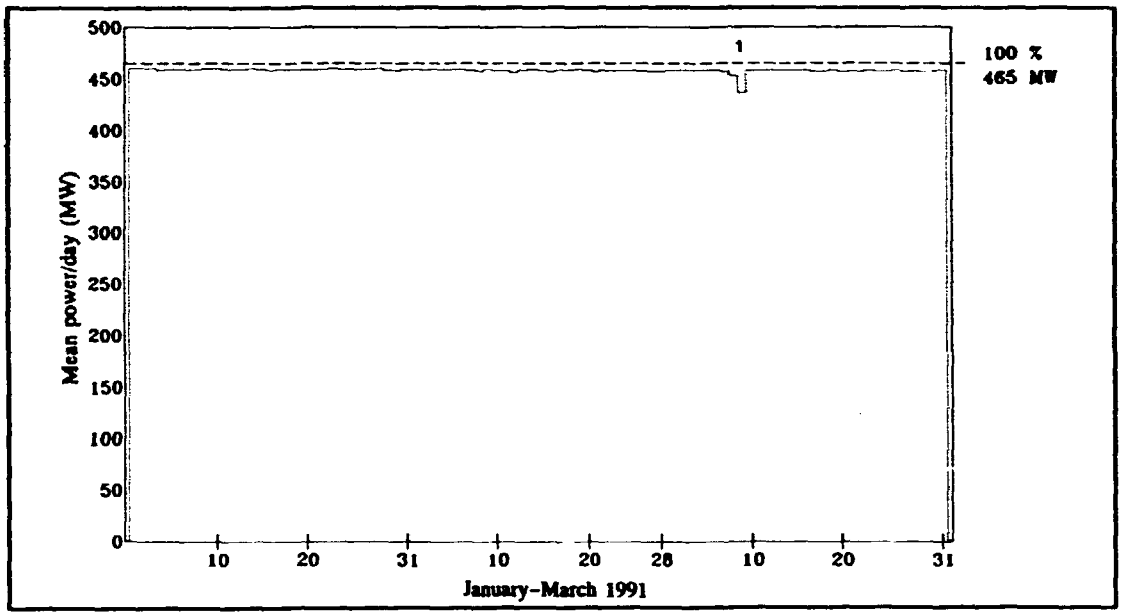

Fig 1. Average daily gross power of Loviisa 1 in January–March 1991

1 Primary circulation pump trip due to a voltage control relay failure, reactor power level to 75 %

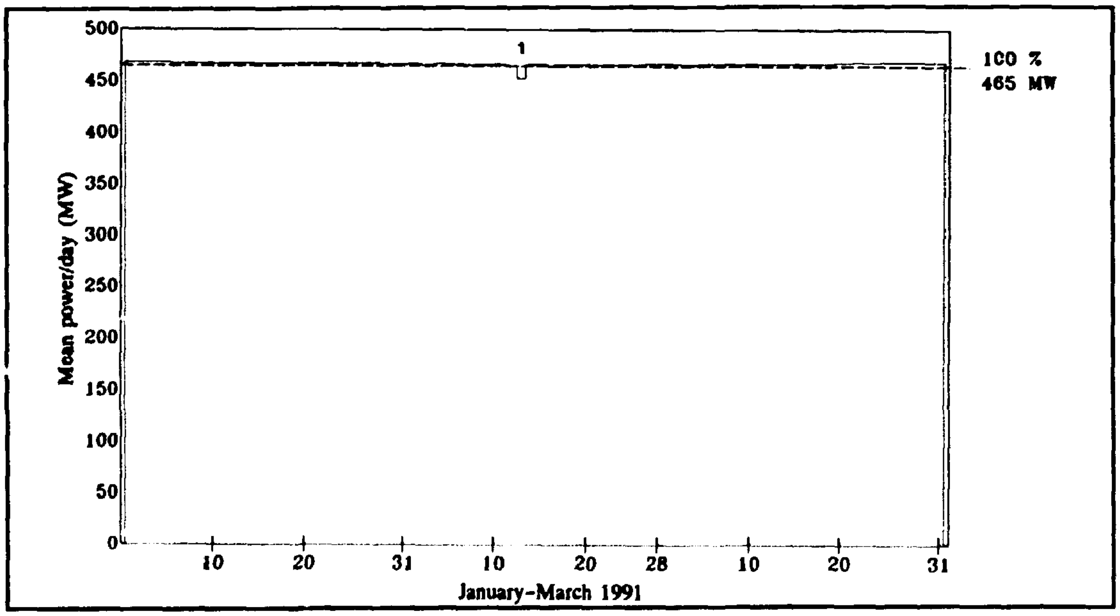

Fig 2. Average daily gross power of Loviisa 2 in January–March 1991.

1 Primary circulation pump trip due to an auxiliary relay short-circuit, reactor power level to 75 %

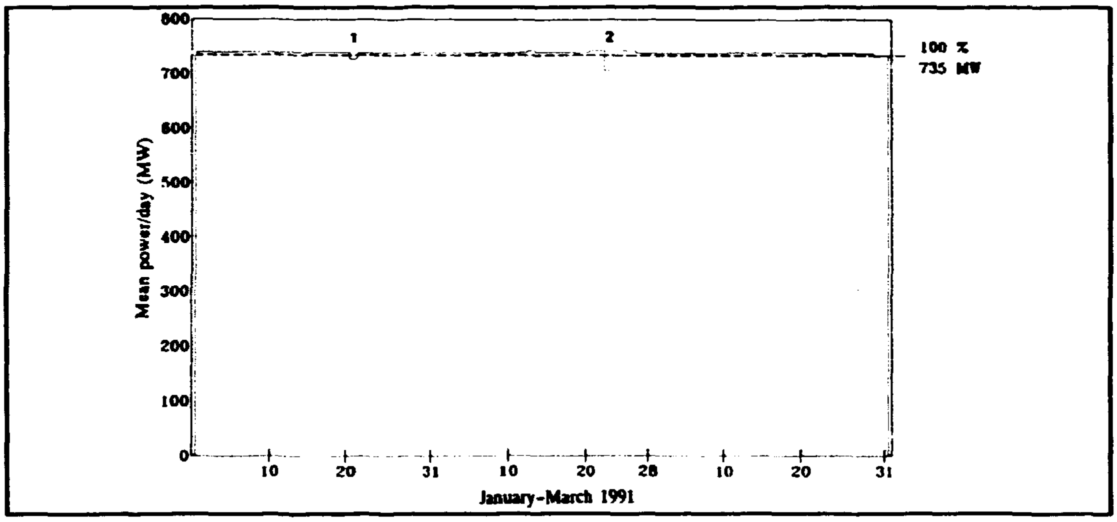

Fig 3. Average daily gross power of TVO I in January–March 1991.

1 The operator erroneously depressed the trip push button of the primary circulation pumps, reactor power level to 55 %. A periodic test was also conducted while operating at reduced power.

2 Periodic test, reactor operating at 65 % power

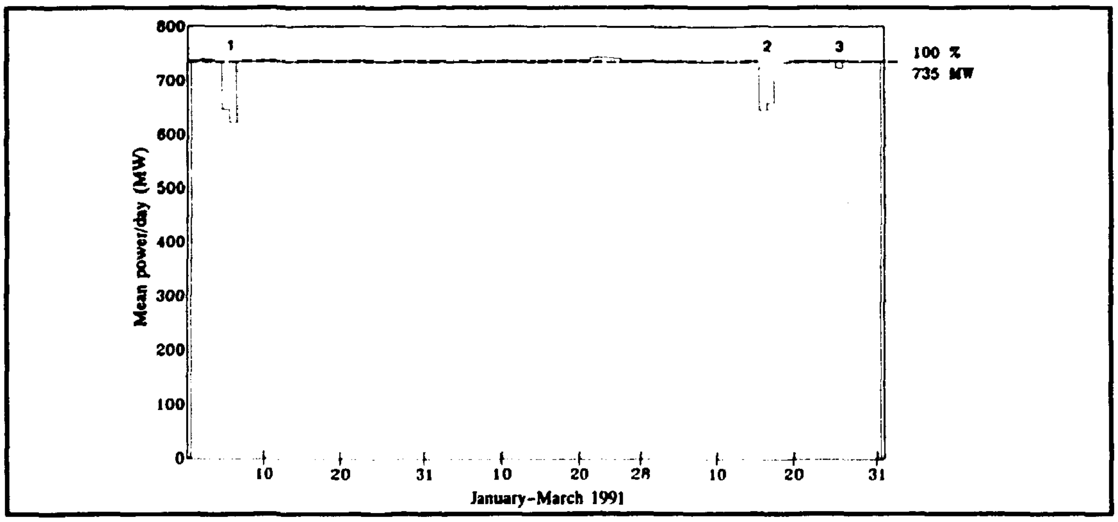

Fig 4. Average daily gross power of TVO II in January–March 1991.

1 Periodic tests and localisation of a fuel cladding leak (see Report STUK-B-YTO 85), reactor operating at 50 % power

2 Periodic tests and localisation of a fuel cladding leak (see Report STUK-B-YTO 85), reactor operating at 50 % power

3 Identification of the cause of a leak in a flow tube between HP turbine and reheater, reactor operating at 60 % power

3 EVENTS AND OBSERVATIONS AT EACH PLANT UNIT

Loviisa 1

Failures have been detected in the uppermost spacing lattices of nuclear fuel bundles removed from the Loviisa nuclear reactors. Further investigations into the significance of the failures have been initiated.

3.1 Fuel bundle spacing lattice failures

There are 126 fuel rods in the fuel bundles of the Loviisa nuclear power plant the diameter of which is 9.1 mm and length 250 cm. The rods are held in place by ten spacing lattices through which the rods pass. The bundle is encased in metal, a so called fuel channel. The uppermost spacing lattice is attached to the fuel channel. The nuclear fuel proper which is in the form of ceramic UO_2 pellets 10 mm long is placed inside tubes. The spacing lattices which keep the fuel rods in place are designed to allow for a lengthwise increase in rod length as elevated temperatures, neutron irradiation and mechanical interactions between the UO_2 pellets and the tubes serve to increase rod length.

Since 1989, leaking bundles removed from the reactors of the Loviisa plant units have been subject to measurements and visual inspections in the fuel storage pond. Deformation and relocation of the uppermost spacing lattices has been detected in 14 fuel bundles of the 15 bundles which were inspected by 14.6.1991, ten of which were removed from the reactor owing to leaking. The failures may have been due to the jamming of the fuel rods in the holes of the uppermost spacing lattices which prevented free rod movement and resulted in the deformation of the spacing lattices when the rods got longer.

The failure of individual spacing lattices has no safety connotations. As similar faults were detected in several spacing lattices, further investigations are necessary.

Loviisa 2

At Loviisa 2 no reportable events occurred during the first quarter of 1991.

TVO I

At TVO I no reportable events occurred during the first quarter of 1991.

TVO II

At TVO II no reportable events occurred during the first quarter of 1991.

4 RADIATION SAFETY

Individual occupational radiation doses during the first quarter of 1991 were below the dose limit. External releases of radioactivity were considerably below the release limits. Only small amounts of radioactive substances originating in nuclear power plants were detected in samples taken in the vicinity of nuclear power plants.

4.1 Limitation of radiation exposure

Radiation exposure arising from the operation of nuclear power plants shall be kept as low as practicable. To accomplish this objective the sum doses i.e. the collective radiation doses of individuals working in a nuclear power plant and the general public in the vicinity of nuclear power plants shall be monitored. The health effects arising from radiation doses received is compared with measures to limit radiation exposure of workers and the general public. Furthermore, limitation of individual radiation doses below confirmed dose limits shall be implemented.

Radiation protection of nuclear power plant workers and the general public is based on Finnish legislation, the Decision of the Council of State on the General Regulations for the Safety of Nuclear Power Plants and the guides issued by the Finnish Centre for Radiation and Nuclear Safety.

4.2 Occupational radiation exposure

Radiation safety of nuclear power plant workers is dependent on one hand on the plant layout and condition and, on the other, on the radiation protection measures applied during work.

Individual occupational radiation doses in the report period remain below the dose limit for three months, 25 mSv. The highest individual radiation dose during the report period was 2.5 mSv and it was received at the Loviisa nuclear power plant.

The limits for individual occupational radiation doses have been so set that the health risk to workers from radiation is small and comparable to occupational risks in professions considered safe.

The distribution of individual occupational doses in the report period and during 1990 is given in Table III which specifies the number of individuals in each dose range and at each plant site. The Table also shows a distribution which is the total number of workers in each dose range. The distributions comprise the doses of persons who have been recorded as nuclear power plant workers in the central dose file of the Finnish Centre for Radiation and Nuclear Safety.

In the report period, the collective radiation dose at the Loviisa plant was 0.02 manSv and at the TVO plant 0.03 manSv. The dose limit given in the guides of the Finnish Centre for Radiation and Nuclear Safety is 5 manSv/GW_e per installed electrical power in a year which means a collective radiation dose of 4.45 manSv/year for the Loviisa plant and 7.1 manSv/year for the TVO plant.

Table III. Occupational dose distribution in the first quarter of 1991 compared with the overall dose distribution in 1990.

Dose range (mSv)	Number of persons in the dose range					
	First quarter 1991			Whole year 1990		
	Loviisa	TVO	Total*	Loviisa	TVO	Total*
< 0.5	33	67	100	201	366	556
0.5 - 1	7	17	24	86	238	301
1 - 2	4	5	9	102	210	312
2 - 3	2	-	2	40	104	147
3 - 4	-	-	-	46	69	102
4 - 5	-	-	-	27	34	61
5 - 6	-	-	-	39	19	52
6 - 7	-	-	-	33	10	50
7 - 8	-	-	-	22	9	44
8 - 9	-	-	-	10	5	22
9 - 10	-	-	-	20	6	33
10 - 11	-	-	-	15	-	16
11 - 12	-	-	-	12	2	15
12 - 13	-	-	-	12	3	13
13 - 14	-	-	-	5	1	10
14 - 15	-	-	-	8	-	12
15 - 16	-	-	-	7	-	8
16 - 17	-	-	-	10	-	8
17 - 18	-	-	-	5	-	5
18 - 19	-	-	-	5	-	7
19 - 20	-	-	-	8	-	8
20 - 21	-	-	-	3	-	3
20 - 25	-	-	-	1	-	1
> 25	-	-	-	-	-	-

* These columns also include the data of those Finnish workers who have received doses at the Swedish nuclear power plants. The same person may have worked at both Finnish plant sites as well as in Sweden.

4.3 External radioactive releases and radiation exposure of the general public

The radiation exposure of the general public in the vicinity of a nuclear power plant arises from releases of radioactive substances into air and water during operation. Releases are restricted by technical and administrative means. Furthermore, the operational condition of the plant and its releases are continuously monitored and compared with pre-determined limitations.

External radioactive releases in the report period were considerably below prescribed release limits (Table IV).

The release limits have been so determined that for the individuals with the highest exposure, the annual whole-body radiation dose will not exceed 0.1 mSv. This is about a fiftieth part of the dose annually received from natural background radiation, radon in dwellings included. The release limits have been established for such nuclides and release channels as have significance from the viewpoint of the possibility of exceeding the individual dose limit.

The radiation doses of individuals living in the vicinity of nuclear power plants calculated on the basis of release reports are low and at most less than about a thousandth part of their annual radiation exposure.

The release from nuclear power plants of the long-lived carbon-14 nuclide causes a global collective dose approximately as high as the dose limit for a period of 500 years (5 manSv/GW_e per installed electrical power) given in a guide issued by the Finnish Centre for Radiation and Nuclear Safety. This collective radiation dose limit is based on the definite limitation of annual dose arising from the widespread use of nuclear power below 0.1 mSv even for individuals living in the future. When defining the collective dose limit it was assumed that an average of 10 kW of electric power per person will be generated by nuclear power in the whole world truncated at 500 years. The current use of nuclear energy in Finland is about a twentieth part of the mentioned value.

4.4 Radiological monitoring of the environment

Radiation safety in the vicinity of nuclear power plants is monitored by means of regular sampling and analysis programmes to follow the dispersion into the environment of radioactive discharges and to ensure that doses to the general public remain below set limits.

Annually, about 500 samples are examined taken in the vicinity of both the Loviisa and Olkiluoto nuclear power plants. Samples of i.a. air, rain water, sea water as well as foodstuffs such as milk, meat, grain, vegetables and fish are collected and analysed. By their help the amounts of radioactive substances possibly finding their way to man can be evaluated. Also terrestial and marine indicator organisms are analysed which effectively enrich radioactive substances. By their help even very low levels of radioactive substances can be detected and their dispersion monitored. Nuclides most important for human exposure are determined from the samples.

During this quarter, only samples of air, fall-out, domestic water and sea water as well as milk and fry were analysed in accordance with monitoring programmes. Caesium-137 originating in the Chernobyl accident still was the dominant artificial radionuclide in all samples. In a sea water sample taken near the water outlet of the Loviisa nuclear power plant, 11 Bq/l of tritium was detected which exceeds the present mean amount of tritium in sea water originating in (atmospheric) nuclear testing. An extremely low volume (0.22 Bq/m^2) of cobalt-60 originating in the Olkiluoto nuclear power plant was detected in one sample of fall-out and 7.1 Bq/m^3 was detected in a sample of sea water taken near the plant's water outlet. All the measured concentrations were low and require no action.

Table IV. External releases of radioactivity at each plant site, first quarter 1991.

Releases into the air (Bq)[a]

Plant site	Noble gases (Krypton-87 equivalents)	Iodines (Iodine-131 equivalents)	Aerosols	Tritium	Carbon 14
Loviisa					
Report period	[bc]	$6.6 \cdot 10^{4}$	$1.0 \cdot 10^{7}$	$2.1 \cdot 10^{11}$	[d]
1990	[bc]	$1.7 \cdot 10^{7}$	$2.0 \cdot 10^{8}$	$7.4 \cdot 10^{11}$	[d]
Olkiluoto					
Report period	$2.0 \cdot 10^{12}$	$4,4 \cdot 10^{7}$	$1.6 \cdot 10^{8}$	$4.1 \cdot 10^{10}$	[d]
1990	$1.2 \cdot 10^{12}$	$5.6 \cdot 10^{7}$	$2.2 \cdot 10^{8}$	$1.0 \cdot 10^{11}$	[d]
Annual release limits					
Loviisa	$2.2 \cdot 10^{16}$[e]	$2.2 \cdot 10^{11}$[e]			
Olkiluoto	$1.8 \cdot 10^{16}$	$1.1 \cdot 10^{11}$			

Releases into water (Bq)[a]

Plant site	Tritium	Other nuclides
Loviisa		
Report period	$1.9 \cdot 10^{12}$	[b]
1990	$1.2 \cdot 10^{13}$	$1.8 \cdot 10^{7}$
Olkiluoto		
Report period	$4.4 \cdot 10^{11}$	$2.3 \cdot 10^{9}$
1990	$1.3 \cdot 10^{12}$	$3.1 \cdot 10^{10}$
Annual release limits		
Loviisa	$1.5 \cdot 10^{14}$	$8.9 \cdot 10^{11}$[e]
Olkiluoto	$1.8 \cdot 10^{13}$	$3.0 \cdot 10^{11}$

[a] The unit of radioactivity is Becquerel (Bq); 1 Bq = one nuclear transformation per second.
[b] Below the detection limit.
[c] The calculatory release of argon-41 from Loviisa 1 and 2 expressed as krypton-87 equivalents was $4.3 \cdot 10^{11}$ Bq during the report period. In 1990, the release was $1.5 \cdot 10^{12}$ Bq.
[d] The carbon-14 release estimate based on experimental data was $8.9 \cdot 10^{10}$ Bq in Loviisa and $1.7 \cdot 10^{11}$ Bq in Olkiluoto during the report period. The 1990 estimates were $3.1 \cdot 10^{11}$ Bq and $6.4 \cdot 10^{11}$ Bq, respectively.
[e] The numerical value shows the release limit for the plant site on the presumption that there will be no releases of other release types. The release limit is so set that the sum of the various types of release limit shares is equal to or smaller than 1.

5 OTHER MATTERS RELATING TO THE USE OF NUCLEAR ENERGY

At Loviisa 1 modifications have been made in the ventilation of the instrumentation area containing systems important to safety. The modifications significantly reduced the risk of an accident leading to core melt in case the ventilation system failed.

5.1 Modifications in the cooling of the instrumentation area at Loviisa 1

According to the Probabilistic Safety Assessment for Loviisa 1 accomplished in 1989, 73 % of the risk of core melt is attributable to loss of the ventilation system of the instrumentation area of the control room. The analysis contained simplified pessimistic assumptions,however. Failure of the ventilation-related cooling function was assessed, with high probability, to lead to a large evolution of heat in the area affected. This was further assumed to lead to an uncontrolled condition which resulted in severe core damage. The instrumentation area concerned contains i.a. the automation equipment of the plant and reactor protection systems and their 24 V direct current units. An own air cooling unit using a chilling agent provides additional cooling for the reactor protection system.

Originally, there was one radiator in the cooling unit (UV20) of the instrumentation area of Loviisa 1 which cooled down the area and provided for overall ventilation. When the temperature outdoors was too high, it was possible to cool the water circulating in the radiator by means of the chilled water system (UV25). This system, too, contained one chiller only. A back-up line controlled by room thermostats which blows in fresh air had later been added to the cooling unit (UV20). A cooling unit malfunction would have become a real problem during the hottest summer months only during which the back-up line could not have replaced regular ventilation.

The operation of the ventilation systems was so changed that the chilled water system (UV25) cools the control room instrumentation area and the cooling unit (UV20) provides for overall ventilation and functions as a back-up cooling system. A schematic of the operating principle of the ventilation systems is given in Fig. 5.

The intake and exhaust air cooling units of the ventilation system were modified to function at two rates of speed: the lower rate manages overall ventilation and the higher cooling, if necessary. Air cooling units controlled by room thermostats were installed in the area. The electronic cubicles of the external neutron flux measurement system were fitted with own cooling units for use during normal operation. Previously, cooling air from the area had been channelled via ducts to below the cubicles.

In the chilled water system (UV25), an air cooled chiller was added to function abreast with a sea water cooled chiller. In summer one device is used for cooling the area and the other for maintaining the temperature of intake air for overall ventilation constant. In winter the chillers operate alternately for periods of four weeks.

In connection with the modifications, also the standard ventilation units (UV23) of the control room which maintain control room temperature and humidity within a certain range were connected to the chilled water system(UV25) network.

After the modifications, the risk, still pessimistically calculated, of an accident sequence starting with loss of the cooling system and leading to core melt was reduced to about 5 % of the total risk.

The modifications were carried out during operation. Work which required the making inoperable of the existing cooling system was conducted during the cool season by exemptions granted by the Finnish Centre for Radiation and Nuclear Safety (temperature outside below +15°C). In some cases, e.g. during the replacement of the control room standard ventilation units, additional cooling was required. It was provided by a movable cooling unit and by lowering the intake air temperature of the ventilation system. Modifications were accomplished in March 1991.

At Loviisa 2 there is no need for modifications of a corresponding magnitude since the ventilation of the instrumentation area was better arranged originally than at Loviisa 1. The area is fitted with i.a. thermostat-controlled air cooling units.

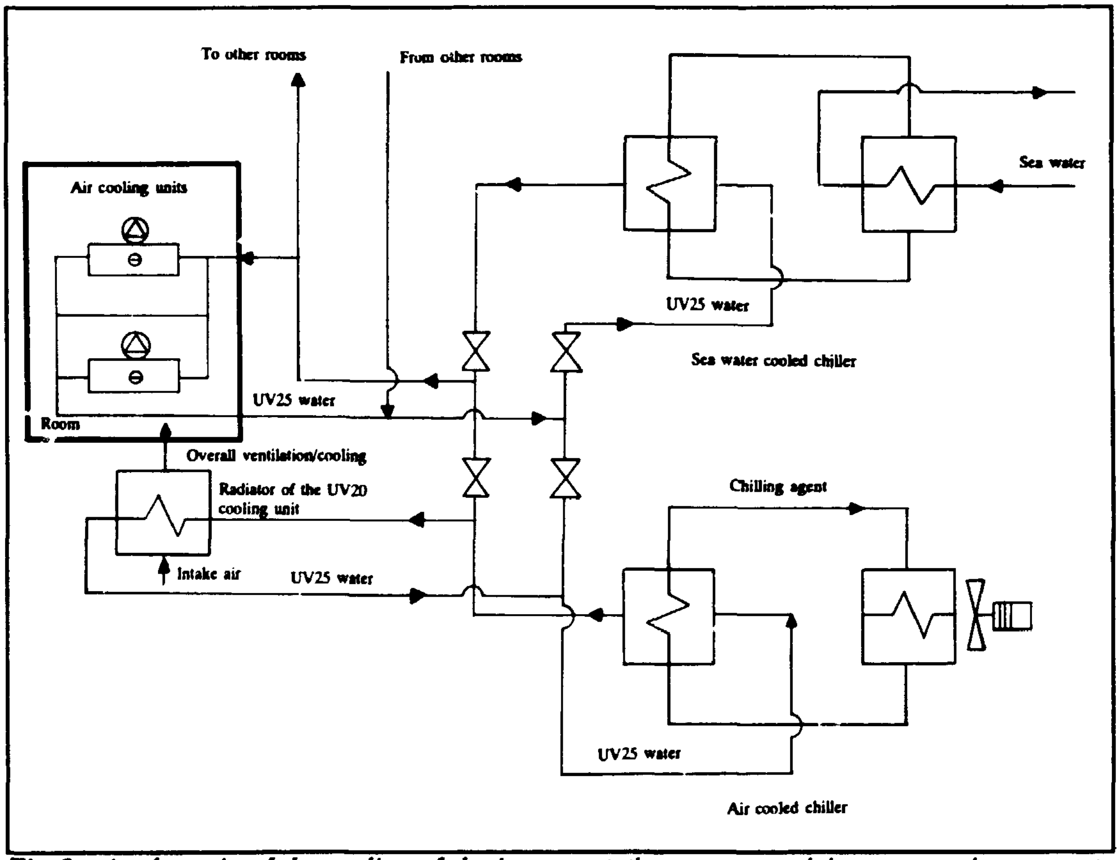

Fig 5. A schematic of the cooling of the instrumentation area containing systems important to safety at Loviisa 1.

APPENDIX 1

REGULATORY CONTROL OF NUCLEAR FACILITIES

The regulatory control performed by the Finnish Centre for Radiation and Nuclear Safety encompasses the following areas (the granting of the licenses mentioned in parentheses is recommended when the control activities have been completed and no reason for withholding the license has arisen):

Construction Phase

- Preliminary plans of the nuclear facility
- Location and environmental effects of the plant
- Arrangements for nuclear fuel and nuclear waste management
  (Decision in principle)

- Preliminary safety analysis report on the planned structure and operation of the plant as well as the preliminary safety analyses
- Safety classification of components and structures
- Quality assurance plan
- Plans concerning nuclear fuel and nuclear waste management
- Physical protection and emergency preparedness
  (Construction permit)

- 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
- Composition and competence of the operating organisation
- Technical specifications
- Nuclear fuel management and safeguards
- Methods of nuclear waste management
- Physical protection and emergency preparedness
- (Operating licence)

Operating Phase

- Start-up testing at various power levels
- Maintenance, inspections and testing of components and structures
- Operation of systems and the whole plant
- Operation and competence of the operating organisation
- Exceptional events
- Repairs and modifications
- Refuelling
- Nuclear fuel management and safeguards
- Nuclear waste management
- Radiation protection and safety of the environment
- Physical protection and emergency preparedness
- Observance of quality assurance programme

APPENDIX 2

PLANT DATA

Plant unit	Start-up	Commercial operation	Rated power (gross/net,MW)	Type, supplier
Loviisa 1	8.2.1977	9.5.1977	465/445	Pressurized water reactor (PWR), Atomenergoexport
Loviisa 2	4.11.1980	5.1.1981	465/445	Pressurized water reactor (PWR), Atomenergoexport
TVO I	2.9.1978	10.10.1979	735/710	Boiling water reactor (BWR),Asea Atom
TVO II	18.2.1980	1.7.1982	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.

Experts

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