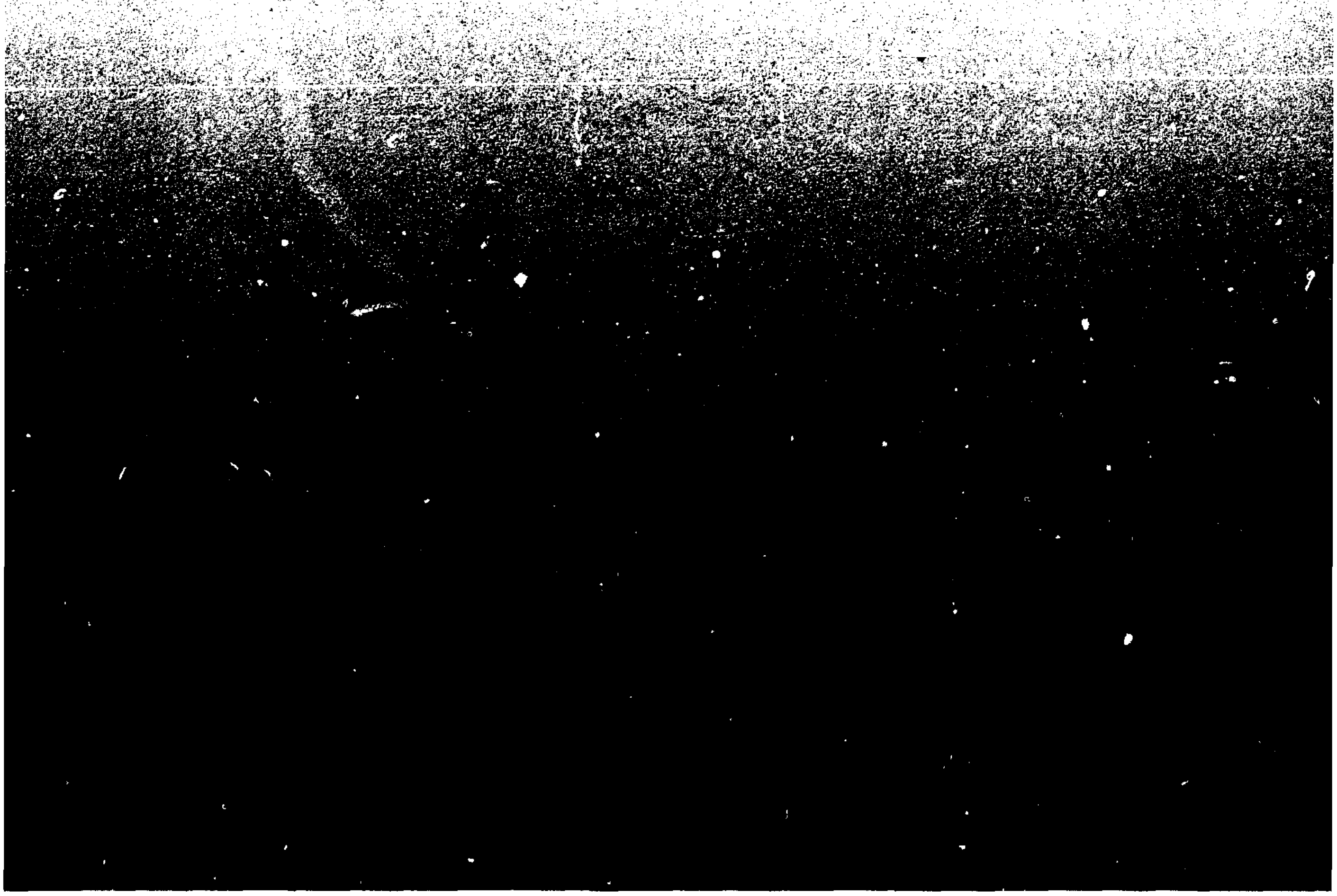
STUK-B-YTO 74

Operation of Finnish nuclear power plants

Quarterly report
1st quarter, 1990

Kirsti Tossavainen (Ed.)

AUGUST 1990



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Finnish Centre for Radiation and Nuclear Safety

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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 includes also 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.

During the first quarter of 1990 the Finnish nuclear power plant units Loviisa 1 and 2 and TVO I and II were in commercial operation for most of the time. Nuclear electricity accounted for 32.5 % of the total Finnish electricity production during this quarter. The load factor average of the nuclear power plant units was 99.0%.

An international nuclear event scale has been introduced for the classification of nuclear power plant events according to their nuclear and radiation safety significance. The scale first undergoes about a year long trial period in several countries. On the scale, events are divided into levels from 1 to 7 of which events at Level 7 are the most serious. Furthermore, Level 0 (Below Scale) is used for events with no safety significance. All events which occurred at the Finnish nuclear power plants this quarter are classified as Level 0.

Occupational radiation doses and external releases of radioactivity were considerably below authorised limits.

At the Loviisa plant, a back-up emergency feedwater system independent of the plant's other systems has been introduced which offers a new, alternative means of removing residual heat from the reactor. Owing to this system, the risk of a severe accident has been further reduced. At the TVO plants, systems have been introduced by which accident sequences which lead to containment failure could be eliminated and the consequences of a potential severe accident could be mitigated.

In this report, also the release of short-lived radioactive materials along the transfer route of an irradiated sample is described which occurred at the FiR 1 research reactor. The amounts of radioactive materials individuals received in their bodies in connection with this event were very low.

CONTENTS

1 INTRODUCTION

As prescribed by the Nuclear Energy Act (990/87), regulatory control of the safety 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 include also regulatory control of physical protection, emergency preparedness and nuclear material safequards. 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 quarterly a report on the operation of Finnish nuclear power plants. The report on the last 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 and inspections.

In addition to 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.

In this quarterly report also an event which occurred at the FiR 1 research reactor owned by the Technical Reserach Centre of Finland is accounted for.

In the classification of nuclear power plant events according to their degree of seriousness, the International Nuclear Event Scale has been introduced which was drawn up by the International Atomic Energy Agency and the OECD Nuclear Energy Agency. By means of this scale a generally known measure for the safety significance of nuclear power plant events is sought to be established. The scale will first undergo a trial period of about one year. In reporting for Finnish nuclear power plant events, this scale has been used as of the beginning of June 1990.

2 OPERATION OF NUCLEAR POWER PLANTS IN JANUARY–MARCH 1990

Finnish nuclear power plants were in commercial operation for the most part of the first quarter of 1990. Brief interruptions in production at Loviisa 2 and TVO I were caused by cold shutdowns.

Nuclear electricity accounted for 32.5 % of the total amount of electricity generated in Finland during this quarter. The load factor average of the plant units was 99.0 %. Production and availability figures are presented in more detail in Tables I and II.

No event degraded safety at any of the plant units during the report period. Occupational radiation doses and releases of radioactivity remained clearly below authorised limits during the report period.

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 1990	**Whole year 1989**	**First quarter 1990**	**Whole year 1989**	**First quarter 1990**	**Whole year 1989**
Loviisa 1	1.01	3.77	100.0	93.4	100.5	92.4
Loviisa 2	0.97	3.74	96.3	92.8	96.9	91.8
TVO I	1.56	5.25	98.6	83.1	98.5	81.5
TVO II	1.58	6.05	100.0	95.5	99.9	93.9

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

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

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

	First quarter 1990	Whole year 1989	1988
Production of nuclear electricity (net, TWh)[a]	4.9	18.0	18.4
Total production of electricity in Finland (net, TWh)[a]	15.1	50.8	53.5
Percentage of nuclear electricity of total production	32.5	35.4	34.4
Load factor averages of the Finnish plant units (%)	99.0	89.9	91.2

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

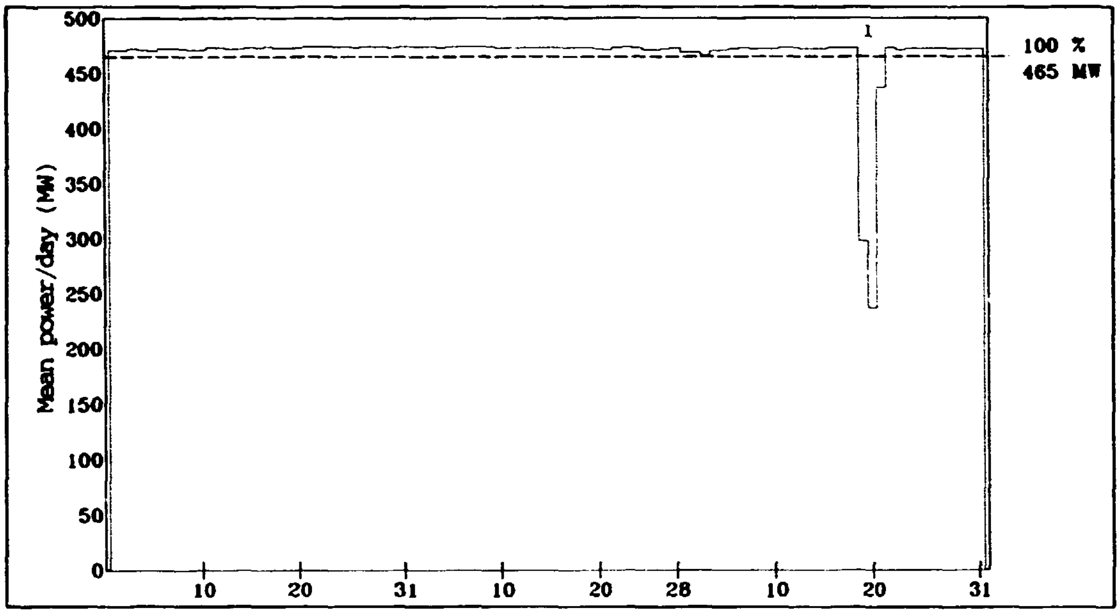

Fig 1. Average daily gross power of Loviisa 1 in January–March 1990.

1 Main transformer replacement, reactor operating at 50 % power

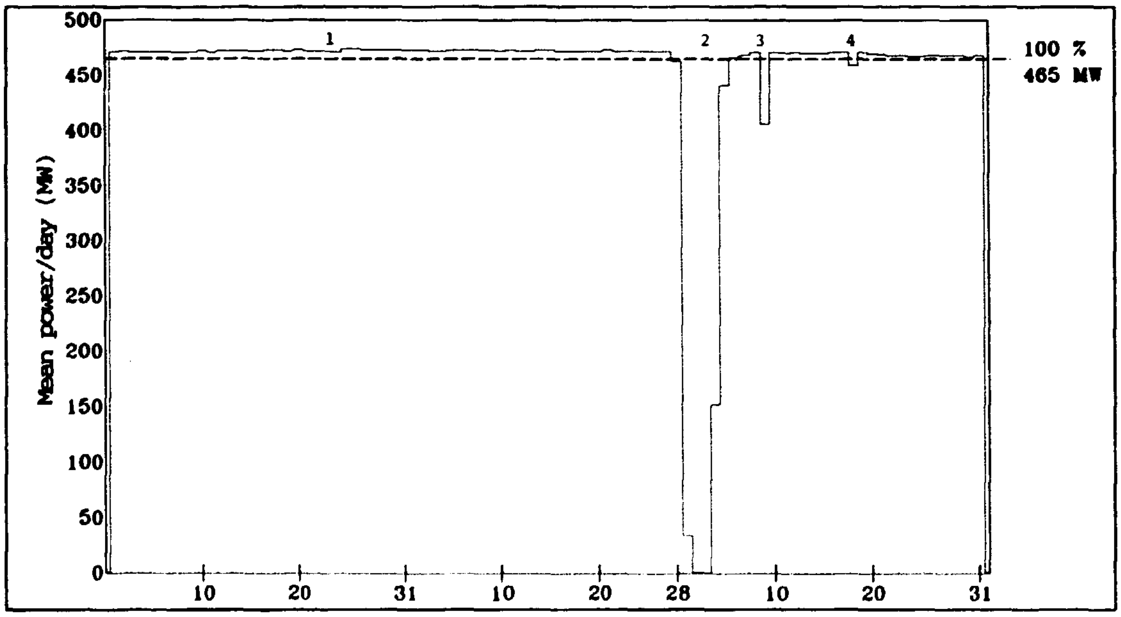

Fig 2. Average daily gross power of Loviisa 2 in in January–March 1990.

1 Isolation of a HP pre-heater owing to a control valve replacement, reactor operating at 99 % power
2 Cold shutdown for repairing leaking flange seals of two control rods
3 Actuation of service water and fire fighting water system spray during a pressure switch replacement and a consequent turbine trip, reactor to 51 % power
4 Repair of a condenser leak, reactor operating at 81 % power

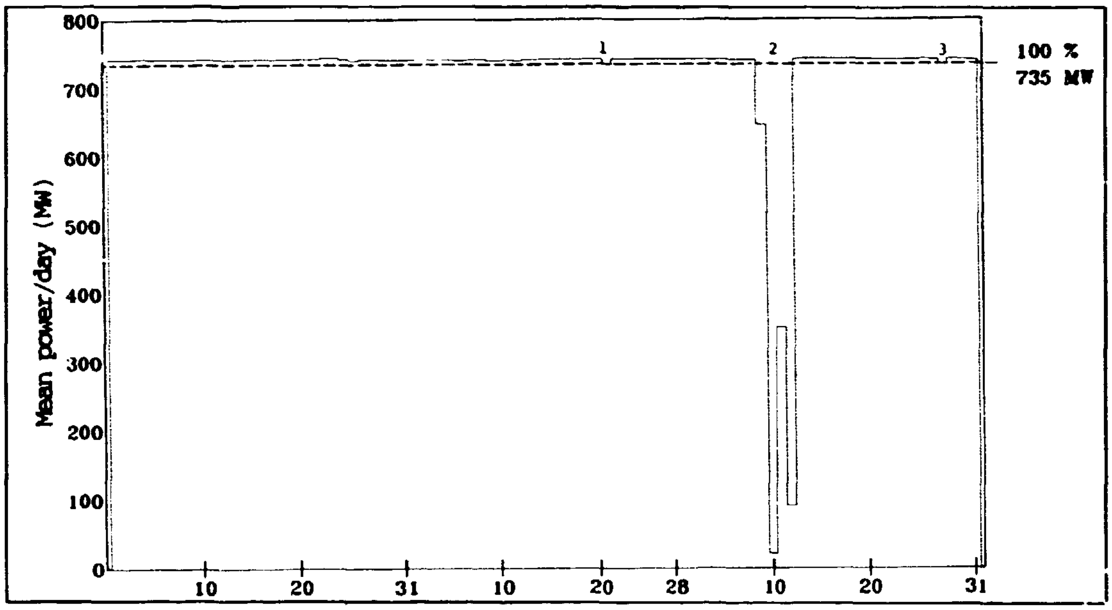

Fig 3. Average daily gross power of TVO I in January–March 1990.

1 Main circulating pump trip owing to an inverter failure, reactor operating at 75 % power
2 Periodic tests and a cold shutdown for repairing a feedwater line isolation valve
3 Main circulating pump trip owing to an inverter failure, reactor operating at 73 % power

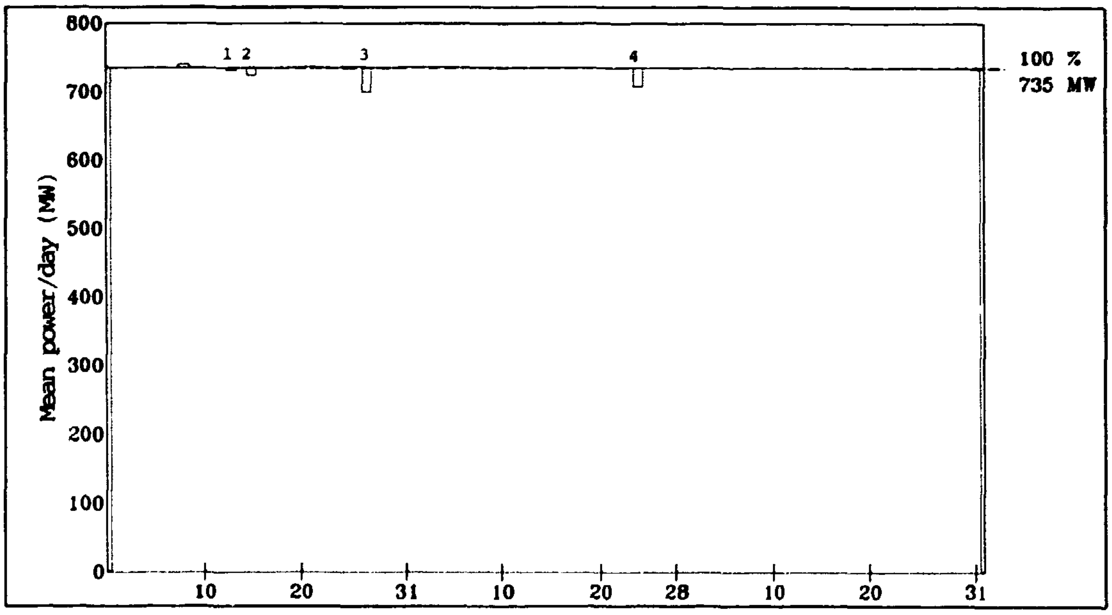

Fig 4. Average daily gross power of TVO II in January–March 1990.

1 Main circulating pump trip due to an inverter failure, reactor operating at 73 % power
2 Main circulating pump trip owing to an inverter failure, reactor operating at 73 % power
3 Repair of reheater drain pipe steam leak, reactor operating at 55 % power
4 Periodic tests, reactor operating at 70 % power

3 EVENTS AND OBSERVATIONS AT EACH PLANT UNIT

3.1 LOVIISA 1

No safety-related events occurred at Loviisa 1 during the first quarter of 1990.

3.2 LOVIISA 2

During the first quarter of 1990, a cold shutdown was held at Loviisa 2 for repairing two leaking flange seals of a control rod drive mechanism. During the shutdown, in addition to the above, the boric acid concentration of the primary circuit decreased below the set limit owing to an uneven blending of the boric acid solution added to primary circuit water. Both events are classified as Level 0 (Below Scale) on the International Nuclear Event Scale.

3.2.1 Repair of leaking flange seals

Loviisa 2 was placed in a so called cold shutdown state for the period 1.– 4.3. for maintenance and repairs. During cold shutdown, the water circulating in the reactor's coolant circuit is cooled below the water boiling point (to about 95 °C).

During the shutdown, two leaking flange seals were replaced in the tubes which penetrate the RPV head. The tubes are part of the reactor control rod drive mechanism. During the shutdown, also other service and repair assignments were accomplished which relate to regular maintenance.

3.2.2 Decrease in the boric acid concentration of primary circuit water during cold shutdown

At the Loviisa plants, boric acid has been added to the water which cools nuclear fuel by the means of which reactor power can be controlled. The possibility of controlling reactor power is based on boron's property of absorbing thermal neutrons effectively. Limits have been defined for the boron concentration of cooling water both for operational conditions and outages. During cold shutdown, the reactor can be maintained in a shutdown state with the help of boron. The reactor might start up uncontrollably if the boron concentration of cooling water decreased below a certain critical limit. During cold shutdown, the safety limit of the boric acid concentration of cooling water has been defined at 12 g/kg. The critical limit varies over the fuel cycle but is always significantly less than this. During an outage, the boric acid concentration is measured at the laboratory once during every shift. Also, continuous-motion boric acid concentration measurement equipment is in use. It has been calibrated for lower concentrations during operation, however, and is thus unreliable during an outage.

Loviisa 2 had been placed in a cold shutdown for repairs and maintenance on 1.3. A laboratory analysis of a primary circuit water sample gave 11.8 g/kg as the boric acid concentration which is below the limit prescribed in the Technical Specifications. The day before, a boric acid concentration of 12.1 g/kg was acidwas added to the primary circuit and the situation improved.

The decrease in boric acid concentration was due to an uneven blending into cooling water of the boric acid solution which was added during the process of going into cold shutdown. The boric acid concentration will stabilize in about two days after the adding of boric acid solution.

After the event, the Finnish Centre for Radiation and Nuclear Safety required Imatran Voima Co. Ltd to clarify the possibilities of obtaining reliable, continuous-motion boric acid concentration measurement equipment. Furthermore, the Finnish Centre for Radiation and Nuclear Safety required that in the future, the procedure of adding boric acid solution will be such that the boric acid concentration of the primary circuit will be raised to 12.5 g/kg for an outage. By this, recurrence of the event will be eliminated. Also, the results of laboratory analyses shall be made known to plant unit operators more promptly than before.

The event did not endanger plant unit safety as the plant unit was approaching the end of one year long fuel cycle and the boric acid concentration of cooling water which is required to maintain a shutdown state was about 6 g/kg at the time of the event.

3.3 TVO I

In the first quarter of 1990, one reportable event occurred at TVO I: the plant unit was shut down because of a fault in an isolation valve nearest to the reactor of the other feedwater line. The event is classified as Level 0 (Below Scale) on the International Nuclear Event Scale.

3.3.1 Shutdown due to a feedwater system valve failure

At the TVO plant units the water which cools nuclear fuel is fed to the reactor along two feedwater lines. There are two successive isolation valves in both lines which will close in the potential event of a feedwater pipe break. Closer to the reactor, inside the containment, is a check valve and further, outside the containment, an electromotor driven shut-off valve.

On 10.3. regular periodic tests of the feedwater line were conducted at TVO I. For the tests, plant unit power was decreased to about 55 %. In the operation test of the isolation valve nearest to the reactor of the other feedwater line, no closed-state signal was received. On the basis of this, it could be assumed that the valve did not close. According to the Technical Specifications, the operation of the plant unit could have been continued by closing the other valve on the line in question in which case the line would have been completely out of use. In this case the plant unit could not have been operated at full power. Since provisions had already been made for plant unit shutdown owing to a functional failure of an other valve, the decision was made to bring the plant unit to cold shutdown without delay and to check the state of the valve. The valve had actually jammed into an open position. A wrong sized hinge pin installed in the valve's position indicating shaft during servicing had prevented valve closure during testing. During the previous test the valve had closed. The pin was shortened and its head was rounded.

During the outage, also other pending repairs were conducted. The plant unit was synchronized with the national grid on 11.3. The plant unit was disconnected from the grid for 30 hours. The repaired valve was tested during start-up from the cold shutdown and it operated faultlessly.

3.4 TVO II

In the first quarter of 1990, no reportable events occurred at TVO II.

4 RADIATION SAFETY

Individual occupational radiation doses during the first quarter of 1990 were clearly below the dose limit. External releases of radioactivity were considerably below the release limits.

4.1 Criteria of occupational radiation protection

Occupational radiation protection is based on legislation and the recommendations of the International Commission on Radiological Protection (ICRP). Radiation doses are aimed to be kept as low as practicable.

In addition, dose limits for individual occupational radiation doses have been set by the authorities. The dose limits are set so that the health risk to workers from radiation is low and comparable to occupational risks in professions which are considered safe.

Total exposure arising from radiation is assessed by the sum of the individual occupational radiation doses, the collective radiation dose.

4.2 Individual occupational radiation doses

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 6.7 mSv and it was received at the TVO plant.

The distribution of individual occupational doses in the report period 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.

4.3 Collective occupational radiation exposure

In the report period, the collective occupational radiation dose at the Loviisa plant totalled 0.05 manSv and at the TVO plant 0.10 manSv.

The dose limit recommended in the guides of the Finnish Centre for Radiation and Nuclear Safety is 5 manSv/GWe per installed electrical power in one year which is in total 4.45 manSv/year for the Loviisa units and 7.1 manSv/year for the TVO units.

4.4 Releases and radiation doses in the environment

External releases of radioactivity in the report period were considerably below the authorised standard release limits (Table IV).

The release limits have been determined so that for the individuals with the highest exposure, the annual whole-body radiation dose will not exceed 0.1 manSv. This is about 1/50 of the dose received annually from natural background radiation, radon included, and 1/50 of the dose limit prescribed for the population by legislation. 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.

Table III. Occupational dose distribution in the report period and in 1989.

Dose range (mSv)	Number of persons in the dose range					
	First quarter 1990			Whole year 1989		
	Loviisa	TVO	Total[a]	Loviisa	TVO	Total[a]
<0,5	48	83	131	181	370	537
0,5 - 1	9	19	29	100	256	341
1 - 2	10	17	27	110	275	362
2 - 3	3	1	4	63	144	204
3 - 4	2	6	8	35	75	111
4 - 5	-	2	2	45	45	79
5 - 6	-	2	2	40	42	83
6 —7	-	1	1	31	30	58
7 - 8	-	-	-	14	27	47
8 - 9	-	-	-	11	20	35
9 - 10	-	-	-	4	9	19
10 - 11	-	-	-	7	8	16
11 - 12	-	-	-	3	8	14
12 - 13	-	-	-	3	5	12
13 - 14	-	-	-	6	3	10
14 - 15	-	-	-	2	-	2
15 - 16	-	-	-	2	2	7
16 - 17	-	-	-	1	1	3
17 - 18	-	-	-	-	1	1
18 - 19	-	-	-	2	2	4
19 - 20	-	-	-	2	-	2
20 - 21	-	-	-	1	2	4
21 - 25	-	-	-	-	1	2
> 25	-	-	-	-	-	-

[a] 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.

The radiation doses calculated on the basis of the release reports for those who live in the vicinity of nuclear power plants are low and are about a thousandth part of their annual radiation exposure.

A carbon 14-release will cause a global collective dose which is approximately as high as the reference dose limit (5 manSv/GWe per installed electrical power). This collective reference dose limit is based on the limitation of the annual dose arising from the widespread use of nuclear power below 0.1 mSv per individual living in the future. When defining the collective dose limit it has been presupposed 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 use of nuclear energy in Finland at present is about 1/20 of the mentioned value.

Table IV. External releases of radioactivity at each plant site, 1st Quarter 1990.

Plant site	Releases into the air (Bq)[a] Noble gases (Krypton 87 equivalents)	Iodines (Iodine 131 equivalents)	Aerosols	Tritium	Carbon 14
Loviisa					
Report period	[b] [c]	$7.8 \cdot 10^{5}$	$1.0 \cdot 10^{6}$	$2.0 \cdot 10^{11}$	[d]
In 1989	$2.2 \cdot 10^{10}$ [c]	$2.4 \cdot 10^{8}$	$1.7 \cdot 10^{9}$	$1.1 \cdot 10^{12}$	[d]
Olkiluoto					
Report period	[b]	[b]	$2.1 \cdot 10^{6}$	$1.8 \cdot 10^{10}$	[d]
In 1989	$1.9 \cdot 10^{12}$	$1.2 \cdot 10^{8}$	$1.8 \cdot 10^{8}$	$1.1 \cdot 10^{11}$	[d]
Annual release limits					
Loviisa	$2.2 \cdot 10^{16}$ [e]	$2.2 \cdot 10^{11}$ [e]			
Olkiluoto	$1.8 \cdot 10^{16}$	$1.1 \cdot 10^{11}$			

Plant site	Releases into water (Bq)[a] Tritium	Other nuclides
Loviisa		
Report period	$4.4 \cdot 10^{12}$	$1.2 \cdot 10^{7}$
In 1989	$1.5 \cdot 10^{13}$	$2.1 \cdot 10^{10}$
Olkiluoto		
Report period	$3.3 \cdot 10^{11}$	$3.7 \cdot 10^{9}$
In 1989	$1.3 \cdot 10^{12}$	$3.3 \cdot 10^{10}$
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] Below the detection limit.
[c] The calculatory release of argon 41 from Loviisa 1 and 2 expressed as krypton 87 equivalents was $4.4 \cdot 10^{11}$ Bq in the report period and $1.6 \cdot 10^{12}$ Bq in 1989.
[d] The carbon 14 release estimate based on experimental data was $8.5 \cdot 10^{10}$ Bq in Loviisa and $1.7 \cdot 10^{11}$ Bq in Olkiluoto in the report period. During 1989 the estimates were $3.2 \cdot 10^{11}$ Bq and $6.0 \cdot 10^{11}$ Bq, correspondingly.
[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 set so that the sum of the various types of release limit shares is equal to or smaller than 1.

4.5 Radioactivity of environmental samples

Radiation safety in the vicinity of nuclear power plants is monitored by means of regular sampling and analysis programmes. The objective of this monitoring is to follow the dispersion of external releases of radioactivity and their transfer to food chains and to ensure that discharges remain below set limits.

Silver 110m originating in a nuclear power plant was detected in two rain water samples taken near Loviisa.

Part of the tritium detected in a sea water sample taken in the immediate vicinity of the Loviisa plant originated in power plant releases and part in fallout. The detected concentrations were very low and comply well with power company release reports. In Olkiluoto, no radioactive materials originating in nuclear power plant emissions were detected. The other artificial nuclides detected originate in the fallout caused by the Chernobyl nuclear power plant accident. Apart from artificial radionuclides, environmental samples also usually contain natural radionuclides.

5 OTHER MATTERS RELATING TO THE USE OF NUCLEAR ENERGY

Other topical issues relating to the use of nuclear energy during the first quarter of 1990 were the introduction of a back-up emergency feedwater system at the Loviisa power plant and the introduction of systems by which provision is made against severe accidents at the TVO plant. The implemented measures aim at preventing severe accidents and at mitigating the consequences of potential accidents. During this quarter, a release of radioactive materials from an irradiated sample occurred along its transfer route at the FiR 1 research reactor. The amounts of radioactive materials received by individuals in their bodies were extremely low and the event had no significance for the safety of the surrounding population.

5.1 Introduction of the back-up emergency feedwater system at the Loviisa plant

In a nuclear reactor, heat, so called residual heat, is generated for a long time after shutdown. Its removal from the reactor is essential to prevent core damage. In a Loviisa type PWR plant the reactor core is continuously cooled by water circulating in the primary circuit. From primary circuit water, heat is trasferred to water fed to the steam generators' secondary side from where heat is transferred away via secondary circuit steam lines. Water is fed to the steam generators' secondary side by means of the feedwater system. For transients, there is the emergency feedwater system. Heat removal from the secondary circuit presupposes a reliable functioning of the isolation and safety valves of the steam lines.

A plan to better ensure residual heat removal has been under consideration at the Loviisa plant units for several years (see the report STUK-B-YTO 58). The project aims at ensuring residual heat removal particularly in connection with a potential major turbine hall fire in which case the systems which usually remove residual heat could be lost. Furthermore, the new systems give improved protection against a station blackout.

At the Loviisa power plant, residual heat removal was ensured even on an earlier occasion in 1980 to provide against the loss of feedwater systems. At that time the option was arranged of feeding water to steam generators by using the equipment of the primary circuit make-up water system. Also the construction of a new fire wall in the turbine hall in 1989 was a considerable improvement. It helps to protect the isolation and safety valves of the steam lines against the impact of fires.

As the last part of the plan to ensure the removal of residual heat, the back-up emergency feedwater system was now accomplished. This is a separate, independent feedwater system placed in its own building to ensure feedwater supply. This back-up emergency feedwater system is schematically presented in Fig. 5. The system has an own water supply, two diesel-driven pump units and own separate pipelines direct to the steam generators of both units. If necessary, water can be fed both to Loviisa 1 and Loviisa 2 by using either diesel pump. At both plant units, water is fed to four steam generators via the drainage nozzles in the bottom of

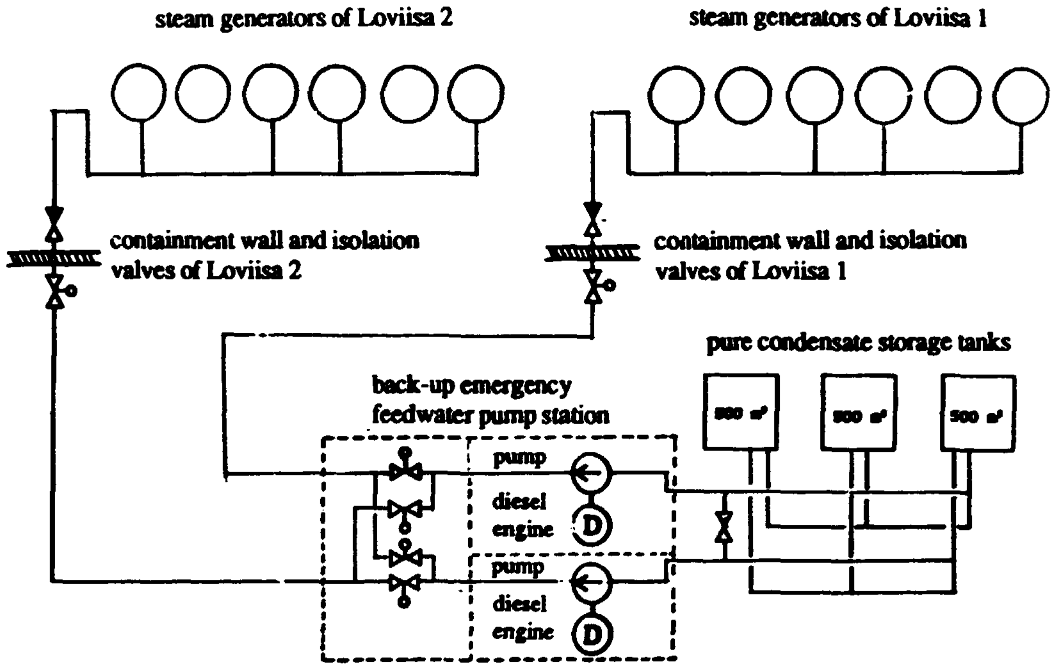

Fig 5. Diagram of the back-up emergency feedwater system of the Loviisa plant.

the steam generators. The required water is drawn from the already existing pure condensate storage tanks near which a separate back-up emergency feedwater pump station has been built.

The required connections to plant unit steam generators were made during earlier annual maintenance outages. What was left to be done was the installation and coupling of mechanical equipment, tanks, pipings and instrumentation. The commissioning phase included trial runs and tests. At the same time, operating procedures and modifications to the Technical Specifications and the emergency procedures were drawn up.

The new system has already been taken into account in the plants' PSAs. The improvements' diminishing effect on the probability of severe core damage is significant.

5.2 Introduction of systems installed to make provision against severe accidents at the TVO plant units

A severe accident denotes an accident during which major core damage occurs and during which reactor core may melt completely and penetrate through the RPV bottom to the containment building floor. The potential off-site impact of a severe accident is decisively dependent on how post-accident containment integrity and leak tightness can be ensured. If leak tightness cannot be maintained for an unlimited time it shall be taken care of that releases can be carried out in a controlled manner and with a warning period sufficiently long from the viewpoint of the surroundings.

At the TVO plant units, a plan has been accomplished which aims at both preventing the turning into a severe accident of design basis accidents used in the original design and to mitigating the off-site impact of potential severe accidents. Therefore, the plant units have been fitted with a containment overpressure protection system, a containment filtered pressure suppression system and a water filling system. Also, the containment lower space penetrations have been protected and new measurement equipment have been installed at the plant units. A schematic presentation of the systems is given in Fig 6.

With the containment overpressure protection system, a quick overpressurization of the containment and its failure is prevented if the containment's regular pressure suppression into the condensation pool designed for accidents would not function. The containment is designed to function so that in case of a break of a pipe containing reactor water or steam in the containment upper space, the so called drywell, the released steam would be relased via the blow-down pipes to the condensation pool where it would cool down to water. If this steam, for one reason or the other, could not be directed to the condensation pool it might overpressurize and fail the containment. Emergency cooling system piping which goes via the containment walls might fail and an accident could result which could have even severe off-site consequences. The new system installed consists of a large-size pipeline which is equipped with a bursting disc. The pipeline penetrates the reactor building wall. There are two successive isolation valves on the pipeline for resuming containment leak tightness after

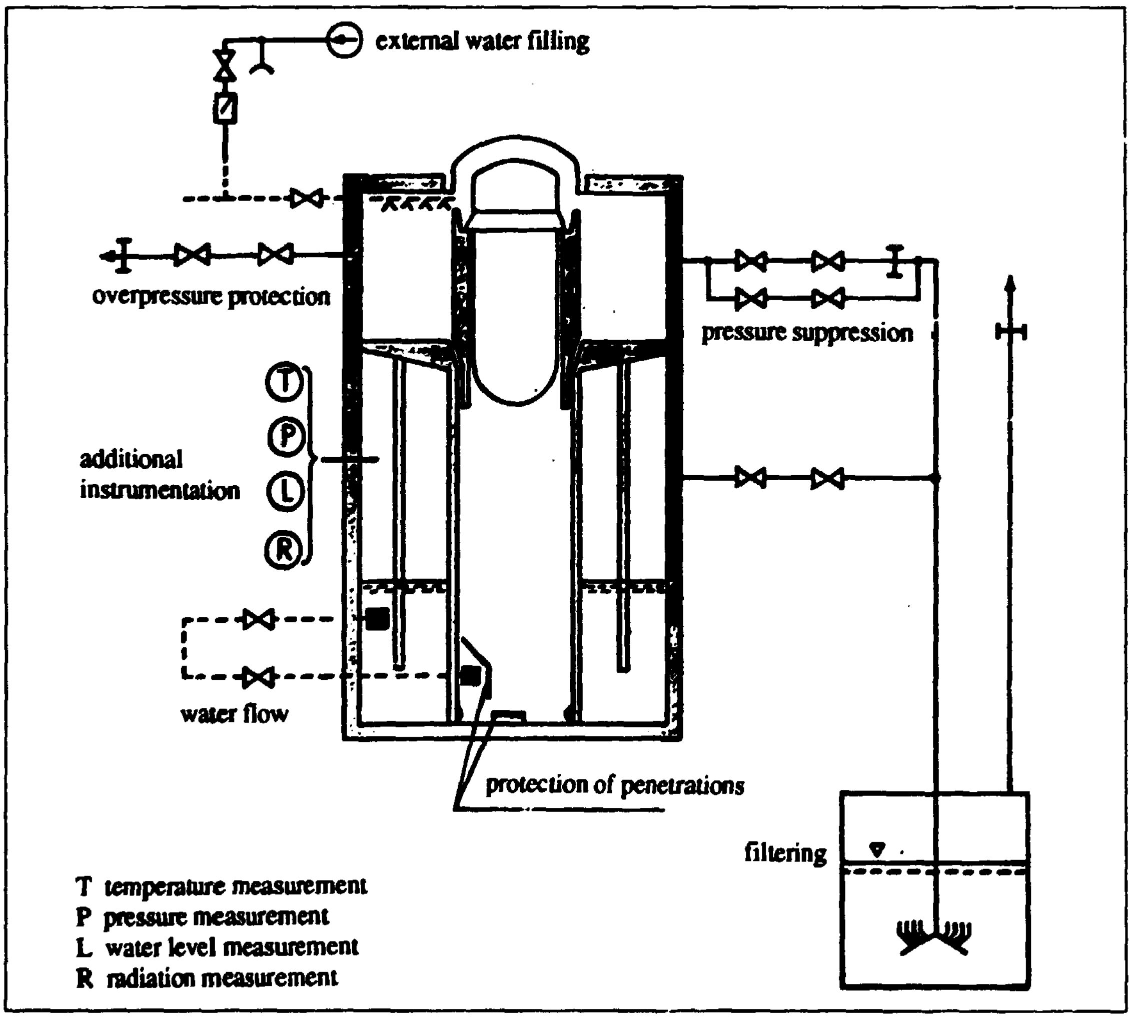

Fig 6. Diagram of the systems installed at the TVO plant to prevent serious accidents and to mitigate the consequences of potential accidents.

the failure of the bursting disc. There are no filtering equipment in the system since the reactor loop pipe rupture accident which is used as the basis of original plant unit design, would not directly cause such significant fuel failures as would result in nuclear fuel fission products being released into reactor water.

The containment pressure suppression system is intended for use during a post-accident situation during which external releases of radioactive steam and gas are essential to maintain containment integrity. This situation might arise if residual heat removal did not function. This would raise containment pressure so high in the long run that containment integrity would be endangered. The system consists of two parallel pipelines, a combined water pool and aerosol filter and an exhaust line which leads to the plant stack. A continuous-motion radiation measurement system has been installed in the exhaust line.

With the containment water filling system, the plant unit can be brought back under control after a severe accident. With this system, the containment can be filled with water up to the upper edge of the reactor core. During this filling, the water storage tanks of the fire water systems of the plant units or totally external water sources can be used. Water filling can be accomplished e.g. by using fire engine pumps and via the nozzles in the reactor building outer wall. Water pumped to the containment via the containment vessel spray system nozzles washes radioactive aerosols from the gas phase effectively, reducing release risks at the same time. Cold water reduces also containment pressure and gives thus more time for off-site preparations against a controlled release of radioactive containment gases.

During a severe accident, core melt may penetrate RPV bottom and drop on the floor of the containment's so called lower drywell. The core melt might damage electricity, piping etc penetrations and further melt the containment concrete floor. This is prevented by filling the drywell with water before the through-melt of the RPV bottom. Water is fed from the condensate pool via the already existing pipelines. Despite this filling option, penetrations in the drywell are specially protected against the direct drop of core melt and debris on the penetrations.

Accident management requires reliable information on the conditions which prevail inside the containment. For this purpose, new pressure, temperature and water level measurement equipment have been installed inside the containment which are designed to function in circumstances prevalent during severe accidents. The new measurement equipment receive electricity from their own, independent battery backed electricity supply system dimensioned for a 24-hour break in electricity supply.

The systems were introduced at the beginning of 1990. Apart from system and equipment installations and testing, making provisions against severe accidents has also required plant procedures development and personnel training.

During 1990, modifications of the containment radiation measurement system are due. After the accomplishment of these modifications, assessment of radioactive releases within the containment during an accident will be facilitated. Furthermore, Industrial Power Company Ltd will design a sampling system in the exhaust line of the containment filtered pressure suppression system.

5.3 Release of radioactivity at the FiR 1 research reactor

The Technical Research Centre of Finland operates a FiR 1 research reactor in its Reactor Laboratory in Otaniemi, Espoo. The reactor is of the Triga Mark II type. The reactor's thermal power is 250 kW which is about two ten thousandth parts of the thermal power of one Loviisa nuclear power plant unit. The reactor is used for training, research and generation of short-lived radioactive nuclides. The reactor is generally in power operation daily during regular working hours.

On Friday 9.3., at the FiR 1 reactor, 20 g of liquid, easily evaporating bromium compound, ethyl bromide, was irradiated in an irradiation and pressure resistant titanium capsule. About half an hour from end of irradiation, the irradiated sample was transferred covered to a car of the company which ordered the sample for transportation. As a consequence of the transfer, the reactor exit room radiation monitoring device sounded an alarm which continued even after the sample had been taken away.

In the reactor laboratory it could be clearly noted that the event was due to a low but unanticipated release of radioactive bromium compounds which were in a gaseous state (bromium 80, half-life 17 minutes and bromium 82, half-life 35 hours) from the irradiated sample along its transfer route. With the help of the accomplished measurements and actions, it could be ascertained that the released concentrations had no safety significance for the surrounding population.

On the same day, whole body measurements were conducted for four people at the laboratory of the Finnish Centre for Radiation and Nuclear Safety to find out the radioactive substances they had possibly received in their bodies. In this case, the amounts of radioactive materials people had received in their bodies were noted to be very low (less than one thounsandth part of the annual dose limit).

The FiR 1 reactor resumed operation on 27.3. Before start of operation, the reactor's activation tube into which bromium compounds could have become attached during irradiation was temporarily withdrawn from use for a special clean up.

After about a month's time from the event, the Reactor Laboratory inspected the irradiation capsule of the sample in question. It was noted to be leak tight. It is possible that a minor amount of bromium ended up outside gasket rings during fill-up and that the release of radioactivity originated in this share.

As a consequence of the event, the reactor laboratory will make changes in its sample irradiation practice. It will thus be ensured more efficiently than before that no unanticipated releases of radioactivity to working spaces will occur in connection with irradiations.

APPENDIX 1

REGULATORY CONTROL OF NUCLEAR FACILITIES

The regulatory control perforemd 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 Co. Ltd owns the Loviisa 1 and 2 plant units in Loviisa and Industrial Power Company Ltd the TVO I and II plant units in Olkiluoto, Eurajoki.

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