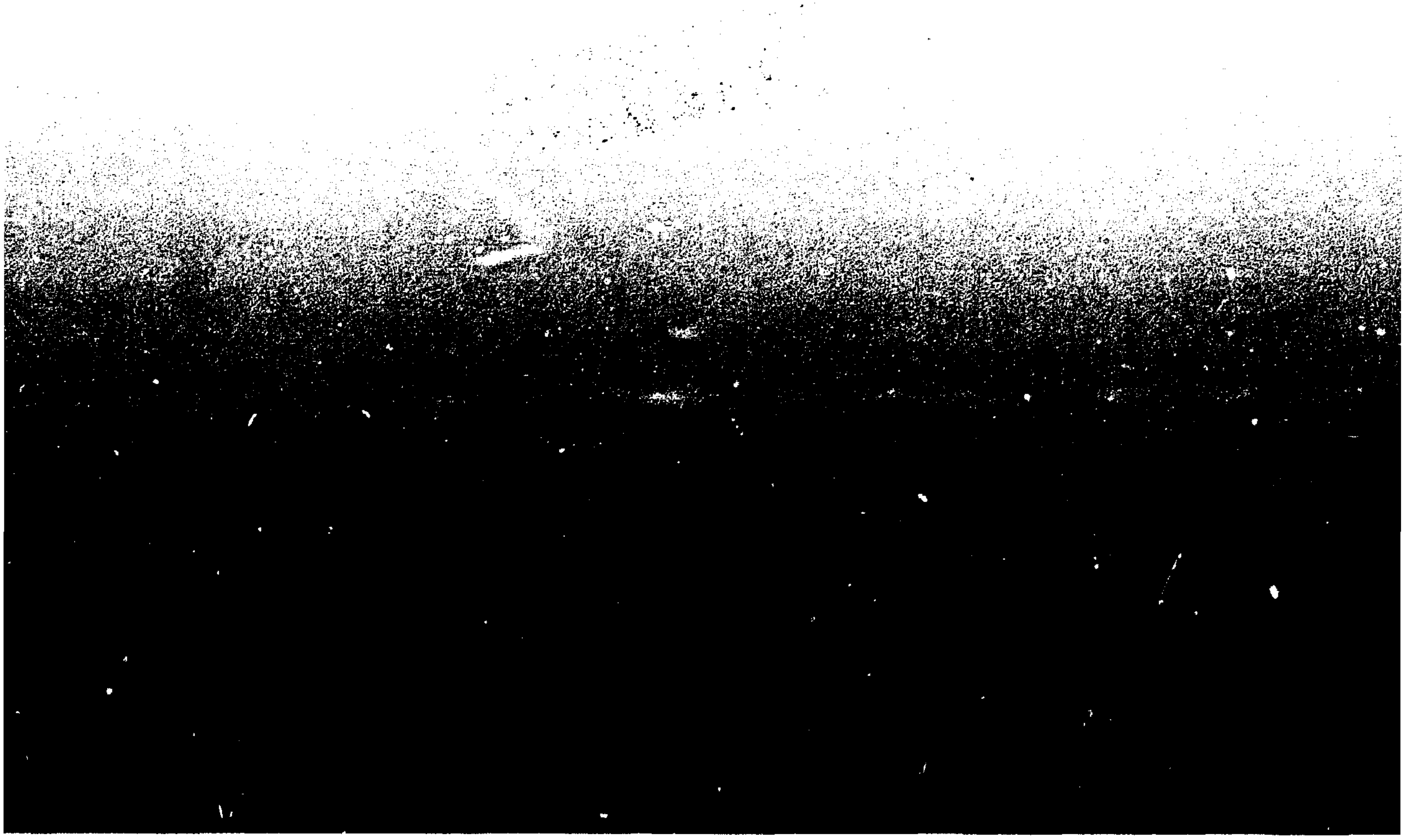
STUK-B-YTO 78

Operation of Finnish nuclear power plants

Quarterly report 3rd Quarter, 1990

Kirsti Tossavainen (Ed.)

FEBRUARY 1991



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Quarterly report
3rd 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 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 third 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. The annual maintenance outages of the Loviisa plant units were held during the report period.

All events during this quarter are classified as Level Zero (Below Scale) on the International Nuclear Event Scale. Occupational radiation doses and external releases of radioactivity were below authorised limits. 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 safe 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 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 contains also 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.

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.

2 OPERATION OF NUCLEAR POWER PLANTS IN JULY–SEPTEMBER 1990

Finnish nuclear power plants were in commercial operation for the most part of the 3rd quarter of 1990. The Loviisa plant units were disconnected from the national grid for a total of 73 days due to annual maintenance outages. In addition, a three-day cold shutdown was held at TVO II.

2.1 Production data

Nuclear electricity accounted for 38.7 % of the total amount of electricity generated in Finland during this quarter. The load factor average of the plant units was 75.7 %. 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 (%)**	
	Third quarter 1990	**As of beginning 1990**	**Third quarter 1990**	**As of beginning 1990**	**Third quarter 1990**	**As of beginning 1990**
Loviisa 1	0.57	2.46	61.0	82.8	55.5	80.8
Loviisa 2	0.54	2.42	58.5	82.0	52.6	79.5
TVO I	1.61	4.45	100.0	93.8	98.9	92.4
TVO II	1.56	4.35	97.8	92.4	95.9	90.3

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

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

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

	Third quarter 1990	As of beginning 1990	1989	1988
Production of nuclear electricity (net, TWh)[a]	4.1	13.1	18.0	18.4
Total production of electricity in Finland (net, TWh)[a]	10.6	37.3	50.8	53.5
Share of nuclear electricity of total production	38.7	35.1	35.4	34.4
Load factor averages of the Finnish plant units (%)	75.7	85.8	89.9	91.2

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

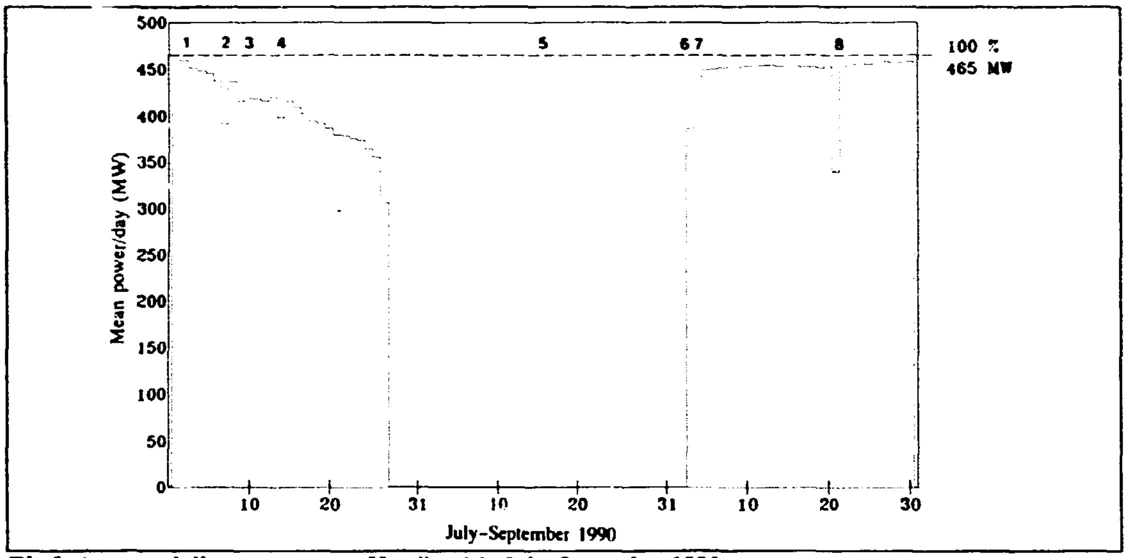

Fig 1. Average daily gross power of Loviisa 1 in July–September 1990

1 Nuclear fuel had burnt to such an extent that reactor power started to decrease gradually (so called stretch-out)
2 Testing of safety valves of the fresh steam lines, reactor operating at 65 % power
3 Stand-by feedwater pump trip, reactor to 89 % power
4 Turbine tripped by high level of collecting tank for water separated from the superheater, reactor to 40 % power
5 Annual maintenance (see Chapter 2.2)
6 Generator was disconnected from the grid to repair an endoscope nozzle
7 Turbine tripped by high level of collecting tank for water separated from the superheater
8 Generator was disconnected from the grid to repair superheater leaks

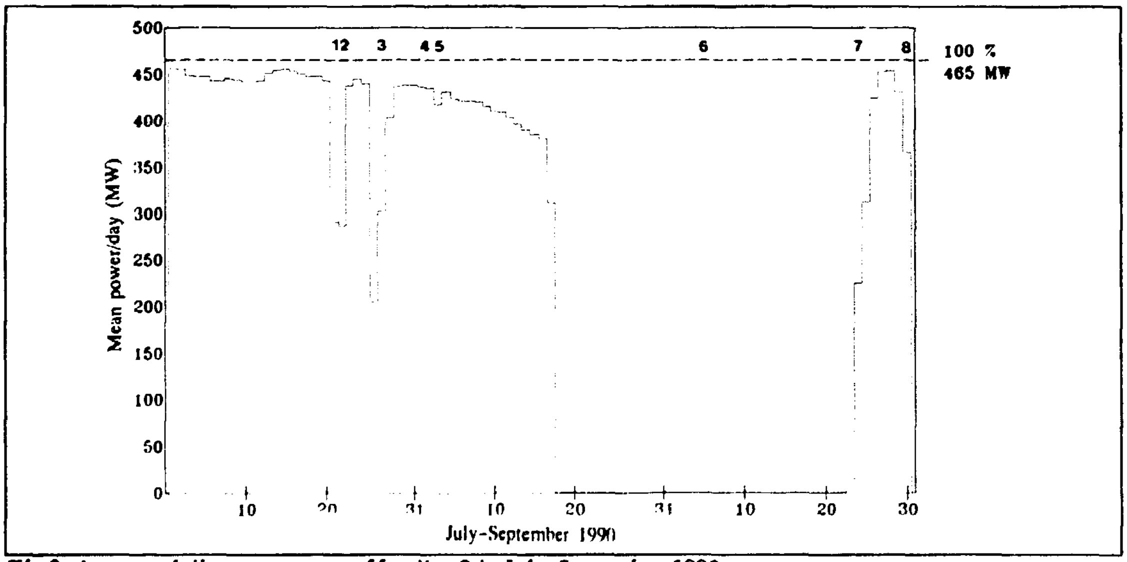

Fig 2. Average daily gross power of Loviisa 2 in July–September 1990.

1 Testing of safety valves of fresh steam lines, reactor operating at 67 %
2 Repair of a superheater leak, reactor operating at 77 % power
3 Hot shutdown for repairing a check valve of the emergency core cooling system (see Chapter 3.4)
4 Nuclear fuel had burnt to such an extent that reactor power started to decrease gradually (so called stretch-out)
5 Generator disconnected from the grid owing to a magnetizing disturbance, reactor to 71 % power
6 Annual maintenance (see Chapter 2.3)
7 Generator was disconnected from the grid for repairing leaking flanges of superheater
8 One HP turbine was repaired, the other turbine's bearings were tested for vibrations and a leaking superheater flange was repaired, reactor operating at 50 % power

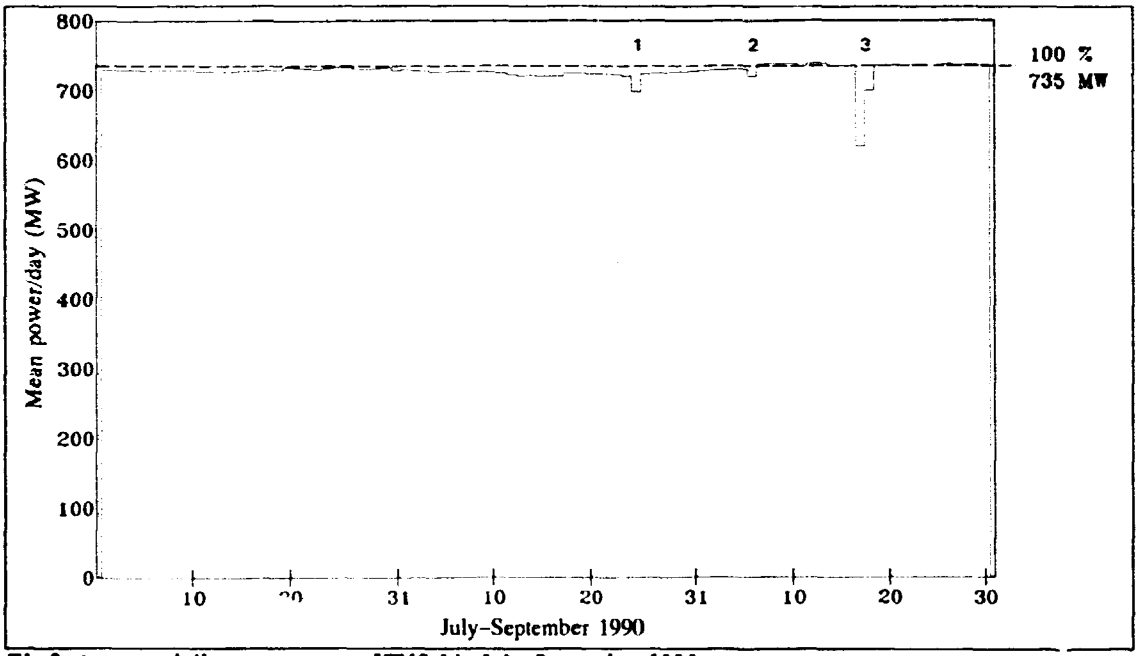

Fig 3. Average daily gross power of TVO I in July–September 1990.

1 Periodic tests, reactor operating at 70 % power
2 Test of reactor protection system and flattening of drainage pipe of the seal and leakage steam system, reactor operating at 60 %
3 Repair of a sealing weld of a HP pre-heater access hatch in the feedwater system of the turbine plant, reactor operating at 60 %

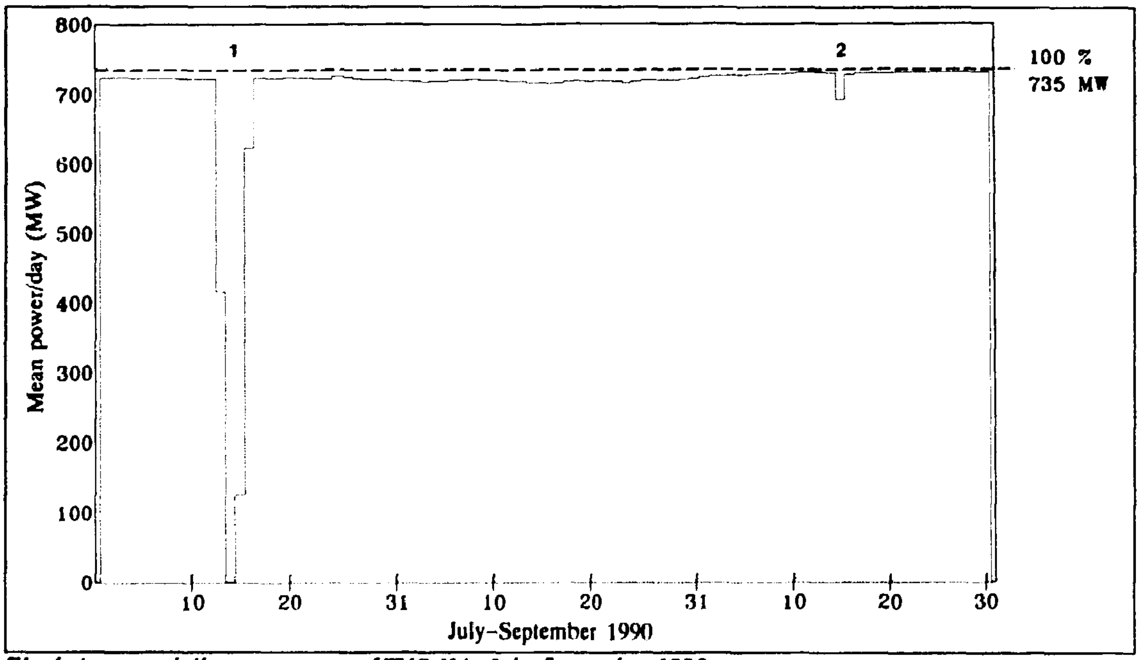

Fig 4. Average daily gross power of TVO II in July–September 1990.

1 Cold shutdown for repairing an inner isolation valve of the auxiliary feedwater system (see Chapter 2.4)
2 Periodic tests, reactor operating at 60 % power

2.2 Annual maintenance outage of Loviisa 1

The thirteenth refuelling and annual maintenance outage of Loviisa 1 was arranged on 28.7.-2.9. The plant unit was off the national grid for 36 days. The outage was about two weeks longer than planned.

In 1989, erosion corrosion induced wear was detected in the feedwater distribution collectors of all the six steam generators of the unit (see the report STUK-B-YTO 67). One distribution collector had perforations in it and was repaired temporarily at that time. In this outage, the feedwater distribution collectors of the two next most worn steam generators were repaired. The remaining distribution collectors are scheduled for repair in the annual maintenance outages of the next two years. The erosion corrosion defects of the steam generators proved more difficult to repair than anticipated and extended, for their part, the duration of the outage.

Owing to the feedwater pipe rupture which occurred at the plant unit on 28.5.1990, it was not yet necessary to replace the flanges of the orifice plates of the feedwater pumps repaired temporarily then (see the report STUK-B-YTO 76). But the steam generator specific flanges of orifice plates used for power measurement, located in the feedwater lines together with their associated piping were replaced with corresponding components which have a better erosion corrosion resistance. Also, fire extinguishing systems which had been repaired temporarily were repaired permanently.

During the outage, moisture separators were installed in the turbine's steam extract lines and in the other turbine's main steam line downstream of the HP turbine. Along with the reduction of steam humidity, the efficiency of the turbine plant is enhanced and the potential for corrosion defects is reduced.

When the primary circuit was heated during plant unit start up, leaks were noted in several penetrations for the RPV head neutron flux measuring instruments. The primary circuit had to be cooled to repair the leaks. During the repairs, the construction of the penetrations was modified to increase the tightening force exerted on the seal. In a new RPV leak tightness test, leakage was still observed in some penetrations which tightened up, however, after temperature differences reached a balance. Re-inspections were carried out after plant unit start-up. The outage was extended from what was planned by about one week owing to the repairs of the leaking penetrations and the associated leak tightness tests and the replacement of one main circulation pump motor which failed during start-up.

The collective radiation dose arising from work performed during the outage was 0.98 manSv which is 40 % higher than last year. 40 % of the collective radiation dose was caused by the repairing of the feedwater distribution collectors of the steam generators. The highest individual radiation dose was 20.3 mSv. The authorized quarterly dose is 25 mSv.

2.3 Annual maintenance outage of Loviisa 2

The tenth refuelling and annual maintenance outage of Loviisa 2 was arranged on 18.8.-20.9. The plant unit was off the national grid for 37 days. The 1990 outage was a so called extended annual maintenance outage which is arranged every fourth year. In the extended outage all fuel assemblies are removed from the RPV and the internals and inner surfaces of the RPV are inspected by a TV camera.

In the outage, the other turbine's whole condenser had been replaced with a titanium structure which has a better corrosion resistance. When also a half of the other turbine's condenser was fitted with new austenitic steel tubes to replace the old ones, condenser modifications of the plant unit's both turbines were accomplished.

Last year, erosion corrosion had been detected also in the feedwater distribution collectors of the steam generators of Loviisa 2 (see the report STUK-B-YTO 67). Three feedwater distribution collectors were inspected last year and the remaining three now. Two most worn out collectors were repaired during this outage. The remaining collectors will be repaired in the next annual maintenance outages, two each year.

Also at Loviisa 2, the steam generator specific flanges of orifice plates used for power measurement with their associated pipings were replaced with components which have an improved erosion corrosion resistance.

The collective radiation dose arising from work performed during the outage was 1.72 manSv which is 20 % lower than in the previous extended annual maintenance outage (in 1986). 15 % of the collective radiation dose was caused by the repairs of the feedwater distribution collectors of the steam generators. The highest personal radiation dose was 18.0 mSv. The limit authorised for a quarter of a year is 25 mSv.

2.4 Cold shutdown at TVO II

TVO II was placed in cold shutdown on 13.7. for repairing the inner isolation valve of the auxiliary feedwater system. Valve closing could not be ascertained by tests. The part in question of the auxiliary feedwater system supplies water for the core spray system which, for its part, is one means of cooling nuclear fuel in the event of a possible accident involving loss of reactor water. By the tight closing of the isolation valve it is ensured that, in the possible event of an auxiliary feedwater line rupture, no water is lost from the RPV.

The position indicating mechanism of the isolation valve had prevented the valve's complete closing. Upon the detection of the failure, the same pipeline's outer isolation valve was closed. The valve was repaired and tested prior to plant unit start-up.

Also other servicing assignments were carried out during the outage as part of regular maintenance. The plant unit was brought back on the national grid on 15.7.

3 EVENTS AND OBSERVATIONS AT EACH PLANT UNIT

Loviisa 1

During the annual maintenance outage of Loviisa 1 during the third quarter of 1990, a LP emergency core cooling system pump started inadvertently due to a failure of the plant protection system. During the outage, also natural circulation of the primary circuit was lost as not enough gas was removed from the primary circuit. Furthermore, failures of valves which were unsuited for their function brought about leaks in two parallel lines of the service water system. The events are classified as Level Zero (Below Scale) on the International Nuclear Event Scale.

3.1 Inadvertent start of LP emergency core cooling pump during annual maintenance outage due to a failure of the plant protection system

At the Loviisa plants, in the early stages of a possible LOCA, the reactor is cooled by borated water pumped from the emergency make-up tank (900 m^3). Water is pumped direct to the RPV by i.a. four LP emergency core cooling system (TH) pumps. The plant protection system (YZ) which is an automatic protection system activates certain safety functions in the event of disturbances. The plant protection system comprises two parallel systems i.e. redundancies both of which comprise two subsystems i.e. channels.

During the annual maintenance outage, the automatic actuation of the LP emergency core cooling system is prevented by a keyswitch. During the annual maintenance outage, on 8.8., that part of the plant protection system failed the function of which is to prevent the automatic actuation of the LP emergency core cooling system. The fault presented itself in one channel of one redundancy only. In consequence of the fault the plant protection system sent spurious protecting signals. A spurious signal(YZ26) actuated one LP emergency core cooling pump and opened a valve (TH20S01) on the pressure side of the line in question. Simultaneously, another spurious protecting signal (YZ27) opened a containment isolation valve (TH20S03) located in the same line. In consequence of these events an emergency core cooling pump began to inject water into the reactor. The RPV head was not in its place and after the pressure vessel had filled up, water began flooding into the containment sumps. Water ended up in the sump of the steam generator space the drainage pump of which auto-started on the sump's filling. The water could not be pumped, however, since two other spurious protecting signals (YZ33 and YZ34) traced to the same fault had closed the isolation valve (TZ10S01) of the sump's drainage line. Therefore, the water which flooded the RPV ended up, to some extent, on the floor of the steam generator space.

The isolation valve (TZ10S01) of the sump's drainage line opened after the resetting of plant protection signals (YZ33 and YZ34) at the control panel located in the control room. Attempts to stop the pumping of water into the RPV succeeded when the containment building isolation valve (TH20S03) was closed manually from the control room. By the aforementioned actions also two other spurious protection signals (YZ26 and YZ27) were reset after which the pump stopped, the valve (TH20S01) on the pressure side closed and the containment building isolation valve (TH20S03) assumed the closed state permanently.

About 12 m^3 of water was pumped from the emergency make-up tanks some of which remained in the reactor. The event did not have any bearing of the radiation dose rate of the steam generator space since the leaked water was clearly a less significant radiation source than the primary circuit pipes. The floor of the steam generator space was appropriately decontaminated.

Imatran Voima Oy has looked into the causes of the failure of the plant protection system. The actions by which the automatic actuation of the emergency core cooling system can be prevented during an outage will be more closely specified in the maintenance instructions.

3.2 Loss of natural circulation during annual maintenance outage

Residual heat generated by the Loviisa reactors during outages is transferred to the secondary side of the steam generators by the introduction of natural circulation in the primary circuit. The hydrostatic pressure difference resulting from the density difference due to the warm water in the primary circuit hot leg which comes from the reactor and the colder water in the cold leg which has cooled in the steam generators serves as the driving force for natural circulation. A schematic representation of the primary circuit is given in Fig. 5. The Loviisa plant units have been so designed that during an outage, natural circulation in one of the six primary coolant loops is sufficient to remove heat from the reactor. To ensure safety, however, also an other loop shall be in stand-by to function by natural circulation.

During the annual maintenance of Loviisa 1 on 24.8. the reactor water level was lowered for repairing a mechanical position indicator of a control rod drive. For this purpose the reactor water level had to be lowered from level +20.5 m to level +16.5 m which is about three meters above the upper edge of the hot leg main circulation pipes. Primary circuit mean temperature was 79°C. The RPV head was on its place but the primary circuit was devoid of pressure. Residual heat removal took place by the introduction of natural circulation in two loops. Increased reactor

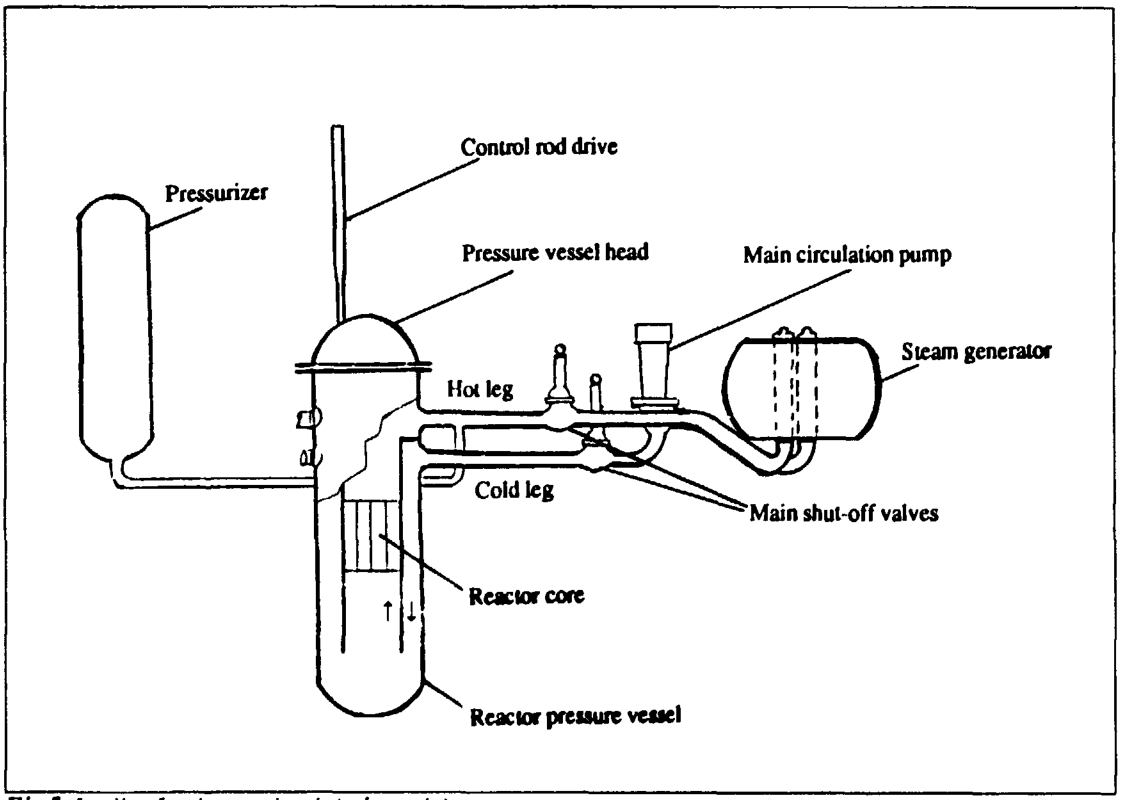

Fig 5. Loviisa 1 primary circuit (schematic).

water temperature was an indication of disturbed natural circulation. The reactor water level was re-raised for restoring natural circulation. Each coolant loop at a time was isolated from the reactor by isolation valves and gas was removed by venting from the water circulating in the loops. Natural circulation was thus restored.

A considerable volume of gases escapes from reactor water during the depressurization of the reactor. These gases are removed by the recirculation of primary water and by venting the primary circuit. In this case, removal of gas was incomplete. The minute decrease in pressure resulting from the lowering of reactor water level had resulted in the ca 1.3-fold expansion of released gases in the upper bends of the coolant loop. The formation of gas bubbles prevented natural circulation.

In future, the primary circuit will be vented more efficiently in connection with the lowering of the reactor water level to avoid recurrence of the event.

3.3 Simultaneous leak from both lines of the service water system during annual maintenance outage

At the Loviisa plants a special sewerage line is divided into two redundant lines before it connects to the two parallel discharge lines of the service water system. In each special sewerage line (diameter 70 mm) there are plastic valves by which special sewerage is isolated from the discharge lines of the service water system. The intersection of the special sewerage and the service water system is located in the piping channel between the plant and the laboratory building. The service water system cools the heat exchangers of several systems important to safety. On 24.8. a leak was observed in the flange of a plastic valve of one special sewerage line. The plant unit was in the middle of an annual maintenance outage at the time. When the leaking flange was tightened it broke breaking, at the same time, the plastic valve of the other line as well as the special sewerage line which connects to the lines of the service water system. The water circulating in the service water line escaped through the broken line to the pipe channel and further to a lower level in the laboratory building from where it was channelled to the sea through the sumps. The leak was repaired temporarily by blocking the special sewerage line's other branch by a blind flange and by replacing the line's other plastic valve and parts of the piping. The valve of the blocked line and parts of piping were also replaced later. For the carrying out of repairs, the two sub-systems of the service water system had to be removed from operation alternately. The special sewerage line was not in operation during the event.

The event was traced to a valve not suited for its function. Also piping supports proved inadequate.

The event indicated locations at the facility where parallel lines can be lost, at least in part, as the result of a single failure which is against NPP safety principles. In this case the operation of the service water system was not endangered since the leak was on the discharge side of the system. The leak caused an abnormal flooding of the facility internals, however, which, in this case, had no bearing on safety.

In consequence of the event Imatran Voima Oy identified such locations in the service water systems of both plant units in which a corresponding failure of a plastic valve would result in the loss of two redundant lines. On the basis of the indentification, two valves and the hose nozzles of two valves were removed from the service water system of Loviisa 1. By the identification it was also ensured that no plastic valves were left at the plant unit which could cause the loss of any system important to safety. Work to assess the durability of plastic parts continues in Imatran Voima Oy.

Loviisa 2

During the third quarter of 1990 a leak traceable to the ageing of a check valve seal occurred in the emergency core cooling system of Loviisa 2. The event is classified as Level Zero (Below Scale) on the International Nuclear Event Scale.

3.4 Leak of a check valve in the emergency core cooling system

In the components of the reactor core cooling system and the associated other systems, pressure retaining detachable parts have usually been fitted with two successive seals in between of which any leakage through the inner seal may be collected. Leaks are collected into a drains collection system common to several components.

On an inspection round on 25.7. the seal of the cover of a check valve of the HP emergency core cooling line to the RPV was noted to leak into the drains collection and monitoring line. Furthermore, the sump of the special sewerage system gave an alarm indication. The plant unit was placed into hot shutdown to identify the cause of the leak and to repair it. This was necessary since the valve in question is located in the steam generator space, in the reactor containment building,in an area unaccessible during operation. Closer examination indicated a loose pipe joint of a drain valve stem seal of the primary coolant loop in an other location in the drains collection system through which water escaped on the floor and ended up in the sump of the special sewerage system. The leak onto the floor was finally stopped by closing the relevant isolation valves of the drains collection system. It was also ensured on spot that the outer seal of the check valve of the emergency cooling system did not leak. The check valve seal was replaced in the annual maintenance outage which commenced four weeks later.

The event was traced to the ageing of a check valve seal or an erroneous fitting during an earlier annual maintenance outage as well as a pipe joint which was left untightened during the servicing of the stem seal of the drain valve.

The water which leaked through the seals of the check valve flowed at almost hydrostatic pressure along a small-diameter pipe and escaped onto the floor through a loose pipe joint of the stem seal of the drain valve located lower. A 4mm-diameter throttle in the piping before the drain valve restricted the volume of outcoming primary water so that it was insignificant.

As a precaution against leaks through the outer seal of the check valve, there is a sealing cover which can be fitted outside the valve. The Finnish Centre for Radiation and Nuclear Safety required the power company to assess the volume of the leak which would result from the possible giving in of the outer seal and the sufficiency of the capacity of the drains collection line in case of a leak thorough the inner seal.

TVO I

During the third quarter of 1990, a mixture of ion-exchange resin and water which contained radioactive substances escaped onto the floor of the waste building at TVO I when a shut-off valve was opened erroneously. At TVO I, also power oscillations occurred in connection with a power reduction. These events are classified as Level Zero (Below Scale) on the International Nuclear Event Scale.

3.5 Mixture of ion-exchange resin and water containing radioactive substances ended up on waste building floor

A valve in a miniflow line of the ion-exchange pump of the liquid waste system failed at TVO II in November 1989. The system is used to transfer ion-exchange resin from the collecting tank to the solid waste system. The system is activated when the collecting tank fills up. The failed valve could not be replaced immediately since its manufacturing had been discontinued. The procurement of a corresponding valve from other manufacturers was started. The procurement was not urgent since there was a parallel line for the same purpose in the system. Later in December of 1989 the pump of the parallel line failed. To make the system operable, a corresponding valve at TVO I was removed and used as replacement.

Removal of the valve from the TVO I line required the keeping closed of an other valve of the same line. The valve was closed and a work permit note relating to the assignment was attached to it in which the valve was required to be kept closed. A blockage was observed in the pipeline of the system in question on 11.7. For de-blocking, a work permit was required in which the closing of i.a. the above mentioned valve, which was closed already, was required. The process was restored after de-blocking. I.a. the valve which was ordered to be kept closed was opened. The valve was opened since only the work permit note relating to de-blocking was attached to the valve. The work permit note which was attached to the valve in November 1989 had disappeared. As a regular operating procedure, a mixture of ion-exchange resin and water was pumped on 18.7. from the waste system tank to the solid waste system. When pumping was completed, flushing of the pipeline was commenced. In connection with the flushing, it was noted that part of the pumped mixture had escaped into various spaces in the waste building. Some 200 litres of water mixed with resin had ended up on the floor.

In designing the spaces in question, precautions had been taken against water leaks and the event thus had no far-reaching implications. No significant air contamination and, thus, no radioactive releases offsite occurred. Protective equipment was worn when decontaminating the room and no dose uptake occurred to workers. The external radiation uptake to personnel from clean-up and inspection was extremely low, 1.2 millimanSv. For comparison's sake, an advance plan shall be submitted to the Finnish Centre for Radiation and Nuclear Safety concerning e.g. maintenance assignments during which a 100 millimanSv's dose uptake may be expected.

By the improved maintenance procedures Teollisuuden Voima Oy ensures that recurrence of corresponding events is avoided. Also the facilities for the monitoring of the waste building will be complemented to facilitate an improvement in the reliable monitoring of the status of the waste handling systems.

3.6 Power oscillations in connection with a power reduction

In a BWR, of which type the TVO plants are, cooling water boils when passing through the reactor core. The steam generated during boiling strongly affects reactor power so that an increase in steam decreases power and a decrease in steam increases power. Power changes for their part alter the rate of steam generation after the small time lapse caused by the slow rate of heat conduction. This so called power-steam concentration-feedback is negative since growing power increases the volume of steam which, for its part, decreases power. Owing to the time lapse in heat transfer power oscillations may occur if coolant flow is too slow in relation to power level. Fuel cladding failures may result from violent power changes. All BWRs are inherently prone to power oscillations. Oscillations are prevented by defining the slowest allowable rate of coolant flow at every power level which is maintained by recirculation pumps.

At TVO I, repairs were scheduled for 17.9. and, for this purpose, power was decreased by reducing reactor coolant flow. In this connection, power oscillations occurred at the 63–65 % power level while the reactor coolant flow was about 3360 kg/s. The oscillations were damped by switching from power control to speed control and by inserting the control rods in compliance with the instructions for such events.

Based on experiences from this and an earlier (in 1987) power oscillation event, Teollisuuden Voima Oy is considering reparative measures by which oscillations could be avoided in future. Reparative measures are scheduled for implementation in next summer's annual maintenance outages.

3.4 TVO II

There were no reportable events at TVO II during the third quarter of 1990.

4 RADIATION SAFETY

Individual occupational radiation doses during the third quarter of 1990 were below the dose limit. Also the collective occupational radiation dose at both plant sites as of the beginning of the year was clearly below the limit recommendation given in the guides of the Finnish Centre for Radiation and Nuclear Safety. 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 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 21.9 mSv and it was received at the Loviisa plant. The highest individual radiation dose as of the beginning of 1990 until the end of the report period was 24.9. The corresponding annual limit is 50 mSv.

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 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 2.70 manSv and at the TVO plant 0.05 manSv.

The collective occupational radiation exposure as of the beginning of 1990 until the end of the report period was 2.78 manSv at the Loviisa plant and 1.53 manSv at the Olkiluoto plant.

The collective radiation dose mainly accumulates during the annual maintenances of the plant units. The annual maintenances of the Loviisa plant units took place during this report period. The dose limit recommended 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 is in total 4.45 manSv/year for the Loviisa units and 7.1 manSv/year for the TVO units.

Table III. Occupational dose distribution during the report period and from beginning of 1990 until end of the report period.

Dose range (mSv)	Number of persons in the dose range					
	Third quarter 1990			As of beginning 1990		
	Loviisa	TVO	Total[a]	Loviisa	TVO	Total[a]
<0,5	175	86	295	198	360	551
0,5 – 1	82	14	106	83	232	290
1 – 2	102	10	127	99	209	310
2 – 3	38	1	45	42	99	146
3 – 4	42	–	48	43	69	98
4 – 5	28	–	32	30	32	62
5 – 6	40	1	43	39	18	52
6 – 7	32	–	32	31	9	46
7 – 8	24	–	24	22	9	45
8 – 9	11	–	12	11	4	20
9 – 10	15	–	15	19	6	33
10 – 11	16	–	16	18	1	20
11 – 12	11	–	11	10	2	13
12 – 13	12	–	12	13	2	13
13 – 14	2	–	2	2	1	7
14 – 15	9	–	9	9	–	13
15 – 16	7	–	7	7	–	8
16 – 17	11	–	11	9	-	7
17 – 18	4	–	4	6	–	6
18 – 19	5	–	5	5	–	7
19 – 20	8	–	8	8	–	8
20 – 25	2	–	2	3	–	3
>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.

4.4 Releases and radiation doses in the environment

External releases of radioactivity in the report period were considerably below the authorised 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 for the population prescribed 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.

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 about a thousandth part of their annual radiation exposure.

Release of carbon 14 causes a global collective dose which is approximately as high as the reference dose limit (5 manSv/GW$_e$ per installed electrical power) in the guide of the Finnish Centre for Radiation and

Nuclear Safety. 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 was 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 current consumption of nuclear energy in Finland is about 1/20 of the mentioned value.

***Table IV.** External releases of radioactivity at each plant site, third quarter 1990.*

Releases into the air (Bq)[a]

Plant site	Noble gases (Krypton 87 equivalents)	Iodines (Iodine 131 equivalents)	Aerosols	Tritium	Carbon 14
Loviisa					
Report period	b c	$1.3 \cdot 10^{7}$	$1.8 \cdot 10^{8}$	$2.0 \cdot 10^{11}$	d
Early 1990	b c	$1.7 \cdot 10^{7}$	$2.0 \cdot 10^{8}$	$5.4 \cdot 10^{11}$	d
Olkiluoto					
Report period	b	b	$3.7 \cdot 10^{6}$	$2.7 \cdot 10^{10}$	d
Early 1990	$8.7 \cdot 10^{11}$	$2.9 \cdot 10^{7}$	$8.6 \cdot 10^{7}$	$7.3 \cdot 10^{10}$	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	$1.1 \cdot 10^{12}$	$1.4 \cdot 10^{9}$
Early 1990	$1.0 \cdot 10^{13}$	$1.4 \cdot 10^{9}$
Olkiluoto		
Report period	$2.1 \cdot 10^{11}$	$8.3 \cdot 10^{9}$
Early 1990	$9.6 \cdot 10^{11}$	$2.7 \cdot 10^{10}$
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 $2.4 \cdot 10^{11}$ Bq during the report period and $1.1 \cdot 10^{12}$ Bq as of beginning 1990.
d The carbon 14 release estimate based on experimental data was 4.8×10^{10} Bq in Loviisa and $1.7 \cdot 10^{11}$ Bq in Olkiluoto during the report period. As of beginning 1990 the estimates were $2.2 \cdot 10^{11}$ Bq and $4.7 \cdot 10^{11}$ 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 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 to follow the dispersion into the environment of radioactive discharges and to ensure that they remain below set limits.

Samples are collected i.a. from air, rain water, sea water as well as foodstuffs such as milk, meat, grain, vegetables and fish. By their help the amounts of radioactive substances possibly finding their way to man can be evaluated. Furthermore, terrestial and marine indicator organisms are analysed which effectively enrich radioactive substances from their environment. By their help even very low levels of radioactive discharge can be detected and their dispersion monitored.

During this quarter about 180 samples were examined. Of the radioactive substances released into the air by the Loviisa power plant, silver 110m was detected in six samples of air and in three samples of rain water. Furthermore, cobalt 58 was found in one and cobalt 60 in two rain water samples. In samples of the marine environment, cobalt 60 and silver 110 originating in liquid discharges was detected in equally many samples: both were detected in three samples of bladder wrack and three samples of sedimenting matter as well as in one sample of mussel and one sample of green algae. Manganese 54 and cobalt 58 were detected in two samples of bladder wrack as well as cobalt 58 in one sample of sedimenting matter.

No radioactive substances originating in a nuclear power plant were detected in the samples of soil taken in the vicinity of the Olkiluoto plant. Radioactive substances were detected in all indicator samples of the marine environment (algae, mussels and sedimenting matter) as well as in one sample of roach. The most common radionuclides were manganese 54 and cobalt 60 which occurred in all the above mentioned samples. Furthermore, zinc 65 was detected in a sample of roach and in four samples of bladder wrack and cobalt 58 in a sample of the common mussel and in all samples of bladder wrack and green algae. The major part of the silver 110m detected in the *Macoma baltica* (a mussel) originates in a nuclear power plant but other observations of silver 110m may still be accountable for the Chernobyl fallout as is the case with all observations containing cesium 134 and 137.

Part of the tritium detected in sea water samples taken near the Loviisa and Olkiluoto plants originates in discharges from the local nuclear power plant and part in fallout from nuclear tests. In environmental samples, the concentrations of radioactive substances originating in nuclear power plants correlate with power company release reports for this quarter and the preceding quarters taking into account the different behaviour of nuclides in nature and their detection limits in measurements. All the detected concentrations were low and require no action.

5 OTHER MATTERS RELATING TO THE USE OF NUCLEAR ENERGY

Nothing reportable.

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.

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