

STUK-B-YTO 40

OPERATION OF FINNISH NUCLEAR
POWER PLANTS

Quarterly Report
Fourth Quarter, 1986
and Annual Summary

Compiled by Pekka Lehtinen

July 1987



Säteilyturvakeskus

Strålsäkerhetscentralen

Finnish Centre for Radiation and Nuclear Safety

PL-P.O.BOX 268, SF-00101 Helsinki 10, Finland

STUK-B-YTO 40 A

OPERATION OF FINNISH NUCLEAR
POWER PLANTS

Quarterly Report
Fourth Quarter, 1986
and Annual Summary

Compiled by Pekka Lehtinen

July 1987

FINNISH CENTRE FOR RADIATION AND NUCLEAR SAFETY
Department of Nuclear Safety

Helsinki 1987

Government Printing Centre

ISBN 951-47-0829-6
ISSN 0781-2884

July 1987

Compiled by Pekka Lehtinen

OPERATION OF FINNISH NUCLEAR POWER PLANTS
Quarterly Report, Fourth Quarter 1986 and Annual Summary

ABSTRACT

These general reviews of the operation of the Finnish nuclear power plants concentrate on such events and discoveries related to reactor and radiation safety that the regulatory body, the Finnish Centre for Radiation and Nuclear Safety, regards as noteworthy. The report also includes a summary of the radiation safety of the personnel and the environment, as well as tabulated data on the production and load factors of the plants.

No event in the report period, or in the whole year of 1986, essentially degraded plant safety nor posed a radiation hazard to the personnel or the environment. For remedying certain defects found in the administrative procedures concerning plant operation and maintenance, the Loviisa power plant was shut down for several days in September.

INDEX TERMS Reactor operation, PWR type reactors, BWR type reactors

UDC 621.039.56

ISBN 951-47-0829-6

ISSN 0781-2884

21 pages

DISTRIBUTED BY: Finnish Centre for Radiation and Nuclear Safety
Department of Nuclear Safety

CONTENTS	page
REGULATION OF NUCLEAR FACILITIES	4
PLANT DATA	5
1 OPERATION OF THE NUCLEAR POWER PLANTS	6
2 INCIDENTS AND DISCOVERIES	7
Loviisa 1	
Loviisa 2	
TVO I	
TVO II	
3 OTHER MATTERS	9
4 RADIATION SAFETY	9
Personnel	
Environment	
5 ANNUAL SUMMARY	11
TABLES	
FIGURES	

REGULATION OF NUCLEAR FACILITIES

The regulatory actions and inspections performed by the Finnish Centre for Radiation and Nuclear Safety concern the following areas (it is recommended that the licenses given in parentheses be granted when the inspections have been completed and no reason for withholding the license has been found):

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 and the safety analyses
- Safety classification of components and structures
- Quality assurance plan
- Plans concerning nuclear fuel and nuclear waste management
- Physical protection
(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 organization
- Technical specifications
- Nuclear fuel management and safeguards
- Methods of nuclear waste management
- Physical protection and preparedness
(Operating license)

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 organization
- Exceptional events
- Repairs and modifications
- Refuelling
- Nuclear fuel management and safeguards

- Nuclear waste management
- Radiation protection and environmental safety
- Physical protection and preparedness
- Observance of the quality assurance program

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 units in Loviisa and Teollisuuden Voima Oy the TVO I and II units in Olkiluoto, Eurajoki.

OPERATION OF THE NUCLEAR POWER PLANTS IN OCTOBER - DECEMBER 1986

All units, i.e Loviisa 1 and 2 and TVO I and II were in commercial operation. No event during the report period degraded plant safety in any essential way nor posed a radiation hazard to the personnel or the environment.

The Loviisa 1 and 2 units operated well.

At Loviisa 1, power had to be reduced for repairing a leak in the pipe from one turbine to the reheater. It caused a production loss equal to about 24 hours' production. An inadvertent insertion of one reactor control rod caused also a minor reduction of power for a short period of time.

At Loviisa 2, power had to be reduced for repairing one turbine bearing. It caused a production loss equal to about 24 hours' production. In addition, plugging of leaking tubes in the turbine condenser caused a minor reduction of power for a short period of time. At the end of the year, the unit was placed in cold shutdown for approx. four days for repairing check valves leaking through in the feed water system.

The TVO I and II units operated well.

There were no appreciable power reductions at TVO I.

At TVO II, a failure in the converter of a main recirculation pump, a low demand of electricity and packing of a leaking manhole on the reheater caused brief reductions of power.

The amount of electricity produced by the Finnish nuclear power plants to the national grid in the report period totalled 5.03 TWh. According to the statistics compiled by the Finnish Association of Electricity Supply Undertakings, the net production of electricity in Finland was at the same time 13.0 TWh. Nuclear power accounted for 38.5 % of the net production. The average load factor of the four units was 98.4 %. The production and availability figures are presented in more detail in Tables I and II. A general picture of the operation of the units can be obtained from the power diagrams (Figures 1-4). The most important events, discoveries and actions taken at the plant units are discussed in Chapters 2 and 3.

The radiation doses received by the personnel, as well as the releases of radioactive substances into the environment were considerably below the established limits. Radiation safety is discussed in Chapter 4.

2 INCIDENTS AND DISCOVERIES

Safety-related incidents at Loviisa 1

Nothing reportable

Other incidents at Loviisa 1

Nothing reportable

Safety-related incidents at Loviisa 2

Inadvertently closed valve in the feed line of chemicals

The purpose of the feed system of chemicals is to, among other things, supply the emergency cooling systems with potassium hydroxide and hydrazine in order to bind fission products possibly released by an accident. For feeding the chemicals, the system comprises one tank and two pumps, shared by Loviisa 1 and 2, and separate pipelines to each of the two units.

As a result of a leakage through the shut-off valve in the feed line, chemicals were absorbed in the emergency core cooling system while testing the pumps of the low-pressure core cooling system. To keep the emergency core cooling system clean, the feed line was washed occasionally with boron water, until the leaking shut-off valve was repaired in the outage that began on September 28.

Such washing was performed on September 9, whereafter the process was restored in normal condition and the relevant acknowledgments were entered in the operation order and shift supervisor's record. During a renewed washing on September 13, another valve in the feed line was found to be locked in closed position. The valve had been closed since the previous washing.

In the event of an accident, the automated supply of radioactive iodine binding chemicals to the emergency cooling systems would not have been possible. Otherwise, the emergency core cooling systems were operable.

Other incidents at Loviisa 2**Outage for repairing check valves in the main feed water lines**

While performing tightness tests after the annual maintenance in the summer of 1986, some of the check valves in the main feed water lines were found to be leaking through in reverse flow. The proper function of the check valves prevents the loss of emergency feed water via the normal feed water lines, in case a leakage would occur in the feed water line. The loss of emergency feed water can also be prevented by closing two shut-off valves and one control valve in each of the feed water lines. In order to ensure the operability of this function, an extra operator was posted in the control room and training was given in the subject. The Finnish Centre for Radiation and Nuclear Safety accepted the power company's proposal for repairing the check valves in the next cold shutdown, however on September 31, 1986 at the latest.

The plant unit was placed in hot shutdown on September 28 for testing. While performing tightness tests, four of the six check valves in the main feed water lines were still found to be leaking, whereafter the plant unit was placed in cold shutdown. The check valves were disassembled and repaired. In addition, in order to ensure the supply of emergency feed water, the automatic control of the shut-off valves in the main feed water lines was modified so that the valves close, if emergency feed water is needed when the surface level in the steam generator is below 1600 mm.

In the tests during the start-up after the repairs, all six check valves were found to close tightly. The plant unit was out of production for 83 hours.

Safety-related incidents at TVO I

Nothing reportable.

Other incidents at TVO I

Nothing reportable.

Safety-related incidents at TVO II

Nothing reportable.

Other incidents at TVO II

Nothing reportable.

3 OTHER MATTERS

Nothing reportable.

4 RADIATION SAFETY

Individual doses of the personnel

The individual doses of the nuclear power plant personnel in the the report period remained clearly below the quarterly dose limit of 25 mSv. The highest individual dose was 4.9 mSv; it was received at the Olkiluoto units.

The individual radiation doses of the personnel in 1986 were clearly below the annual dose limit of 50 mSv. The highest dose was 21.1 mSv and it was received at the Loviisa units.

The dose limits of the persons who are exposed to radiation in their work are included in the legislation on radiation protection and they are based on the recommendations of the International Commission on Radiological Protection (ICRP). The limits are set so that the health risk due to radiation is comparable to other work-related risks in occupations regarded as safe.

The distributions of the individual doses of the nuclear power plant personnel in the report period and from the beginning of the year till the end of the report period (Tables III and IV) specify the number of persons in each dose range and at each plant site. In addition, 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 entered in the central dose database of the Finnish Centre for Radiation Protection and Nuclear Safety as nuclear power plant workers.

Collective radiation exposure of the personnel

In the report period, the collective radiation dose of the nuclear power plant personnel at the Loviisa 1 and 2 units totalled 0.052 manSv and at the Olkiluoto units 0.059 manSv.

The cumulative collective dose of the personnel in 1986 was 2.645 manSv at the Loviisa units and 1.373 manSv at the Olkiluoto units.

The dose limit recommended in the guides of the Finnish Centre for Radiation and Nuclear Safety is 0.005 manSv/MW(e) in one year, which would be in total 4.4 manSv/year for the Loviisa units and 7.1 manSv/year for the Olkiluoto units.

Releases and radiation doses in the environment

The releases of radioactive substances into the environment in the report period were considerably below the guide release limits (Table V).

In accordance with the Resolution of the Ministry of Trade and Industry, the release limits are determined so that for the persons with the highest exposure the annual whole-body radiation dose is no more than 0.1 manSv. This is less than one thirtieth of the dose received from natural background radiation, including radon, and 1/50 of the dose limit given in the legislation.

Thus, the radiation doses calculated on the basis of the release reports are very small.

Radiation safety of the environment

The total amount of samples taken in the surroundings of both plant sites in accordance with the measurement program of environmental samples was in this quarter 200. Substances originating from nuclear power plants, ^3H , ^{54}Mn , ^{60}Co , ^{65}Zn and ^{110}Ag , were detected only in the samples of sea water and sedimenting matter, in about five per cent of the total amount of the samples. The concentrations measured in the samples do not give rise to any actions.

The fallout caused by the nuclear accident in Chernobyl had still a certain impact on the monitoring of the nuclear power plant surroundings, especially as regards ^{134}Cs and ^{137}Cs . There were plenty of these nuclides in the fallout and they remain a long time both in the soil and sea water. The amounts of ^{134}Cs and ^{137}Cs released by the nuclear power plants were so small compared to the existing amounts in the environment that the increase by them was hidden by the background variations. Part of the ^{54}Mn and ^{110}Ag , typical of nuclear power plant releases, still originated from the fallout caused by the accident in Chernobyl. Of the ^3H that was detected in sea water samples, part came from power plants, part from an older fallout.

In addition to the above-mentioned radioactive substances originating from nuclear power plants and the accident in Chernobyl, the environmental samples contained, in general, also nature's own

radioactive substances (natural decay series and ^7Be and ^{40}K).

As regards the nuclide composition, the results obtained from the measurement of environmental samples containing radioactive substances originating from power plants are consistent with the release reports of the power companies from this and the previous quarters. In doing this comparison, one must take into account the behaviour of nuclides in nature and their detection limits in measurements.

5 ANNUAL SUMMARY 1986

All units, i.e. Loviisa 1 and 2 and TVO I and II were in commercial operation and their production of electricity was near to the theoretical maximum. No event in 1986 essentially degraded plant safety nor posed a radiation hazard to the personnel or the environment. At Loviisa nuclear power plant, shortcomings were found in the administrative procedures concerning plant operation and maintenance, and deviations from regulations were detected. For remedying the defects, the plant was shut down for several days in September.

The Finnish Centre for Radiation and Nuclear Safety has considered the following events, discoveries and actions noteworthy at each plant unit (the issue has been dealt with in the Quarterly Report indicated in parentheses):

Loviisa 1

Leak through an isolation valve in the coolant purification system (1st quarter)

Shortcomings in the fire protection of cables (1st quarter)

Violations of the Technical Specifications (1st quarter)

Inadvertently closed manually operated valves in the boron feed system (3rd quarter)

Inadvertent shut-off of the control room ventilation (3rd quarter)

Inspection of the main circulation pump due to abnormal operating noise (3rd quarter)

Sea water leakage into the lower parts of the turbine hall (3rd quarter)

Loviisa 2

Violation of the Technical Specifications
(1st quarter)

Risk of damage in a safety system pump
(2nd quarter)

Cross-connected extension stems in two
valves (3rd quarter)

Leak in the primary system during start-
up (3rd quarter)

Leaks in check valves in the main feed
water lines and outage (3rd and 4th quar-
ter)

Inadvertently closed valve in the feed
line of chemicals (4th quarter)

TVO I

Faulty settings in the emergency ventila-
tion of the main control rooms (1st quar-
ter, TVO I and II)

Stress corrosion cracks (2nd quarter)

Leaking fuel (2nd quarter)

Faults in the pilot valves of the relief
system (2nd quarter, TVO I and II)

Leak in a non-return valve in the contain-
ment pressure suppression system (3rd
quarter)

Overflow of low-active water in the radio-
active waste building (3rd quarter)

TVO II

Leaking fuel (2nd quarter)

The amount of electricity produced by the nuclear power plants to the national grid in 1986 totalled 18.0 TWh. According to the statistics compiled by the Finnish Association of Electricity Supply Undertakings, the total production of electricity in Finland was at the same time 46.9 TWh. Nuclear power accounted for 38.4 % of the production. The average load factor of the four units was 88.8 %. The production and availability figures are presented in more detail in Tables I and II. A general picture of the operation of the units can be obtained from the power diagrams (Figure 5). The development of load factors, reactor

trips and collective radiation doses since the start-up of the units is depicted in Figure 6.

The radiation doses received by the personnel, as well as the releases of radioactive substances into the environment were considerably below the established limits (Tables IV and V).

Table I Electricity production and availability of the units

	<u>Electricity production</u> (gross, TWh)		Since start-up	<u>Availability</u> factor %		<u>Load factor</u> %	
	Fourth quarter	1986		Fourth quarter	Fourth quarter	1986	1985
Loviisa 1	1.02	3.71	31.7	100	99.6	91.0	93.0
Loviisa 2	0.97	3.34	20.9	96	94.9	81.9	91.7
TVO I	1.62	5.68	40.0	100	99.7	88.1	87.4
TVO II	1.61	6.06	31.4	100	99.4	94.2	87.4

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

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

Symbols (if needed)

- c modifications
- f refuelling
- m maintenance and inspections
- r repairs
- z power restriction

Table II Nuclear energy in the Finnish production of electricity

	Fourth quarter	1986	1985	1984
Production of nuclear electricity (net, TWh)	5.03	18.0	18.0	17.8
Total production of electricity in Finland (net, TWh)	13.0	46.9	47.3	43.3
Percentage of nuclear electricity of total production	38.5	38.4	38.0	41.1
Load factor averages of the Finnish plant units %	98.4	88.8	89.9	89.3

Table III Dose distribution of the personnel in the report period

Dose range (mSv)	Number of persons in the dose range		
		Loviisa	Olkiluoto
< 0.5	698	883	1572
0.5 - 1	31	23	54
1 - 2	11	12	23
2 - 3	1	2	3
3 - 4	1	-	1
4 - 5	-	1	1
-	-	-	-
- 25	-	-	-

* This column also includes the data on 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.

Table IV Dose distribution of the personnel in 1986

Dose range (mSv)		Number of persons in the dose range		
		Loviisa	Olkiluoto	Total *
<	0.5	197	380	567
0.5	- 1	104	209	312
1	- 2	110	174	274
2	- 3	59	79	136
3	- 4	37	58	97
4	- 5	36	24	56
5	- 6	36	20	55
6	- 7	24	16	41
7	- 8	28	7	34
8	- 9	14	2	17
9	- 10	18	3	29
10	- 11	19	3	30
11	- 12	13	3	17
12	- 13	15	1	18
13	- 14	8	-	9
14	- 15	6	-	7
15	- 16	5	-	6
16	- 17	3	-	4
17	- 18	1	-	1
18	- 19	5	-	4
19	- 20	4	-	7
20	- 21	2	-	2
21	- 22	1	-	1
22	- 23	-	-	-
-	-	-	-	-
-	50	-	-	-

* These columns also include the data on 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.

Table V Releases of radioactive substances into the environment at each plant site

Plant site	<u>Gaseous effluents</u>		<u>Liquid effluents</u>	
	Noble gases (⁸⁷ Kr-equiv., TBq)	Iodines (¹³¹ I-equiv., MBq)	Tritium (TBq)	Other nuclides (GBq)
<u>Loviisa</u>				
Report period	*	*	2.9	17
in 1986	*	*	13	17
<u>Olkiluoto</u>				
Report period	*	*	0.41	2.2
in 1986	0.65	78	1.6	35
<u>Annual release limits</u>				
Loviisa	22,000 ^b	220,000 ^b	150	890 ^b
Olkiluoto	17,000	120,000	19	300

* Below detection limit. The calculatory release of ⁴¹Ar from the Loviisa 1 and 2 units expressed as ⁸⁷Kr-equivalents was 0.43 TBq in the report period and 1.5 TBq in the whole year 1986.

^b The figure shows the release limit of the plant site on the presumption that there will be no releases of other release types. The guide release limit is set in such a way that the sum of the release limit shares of the various types is equal to or smaller than 1.

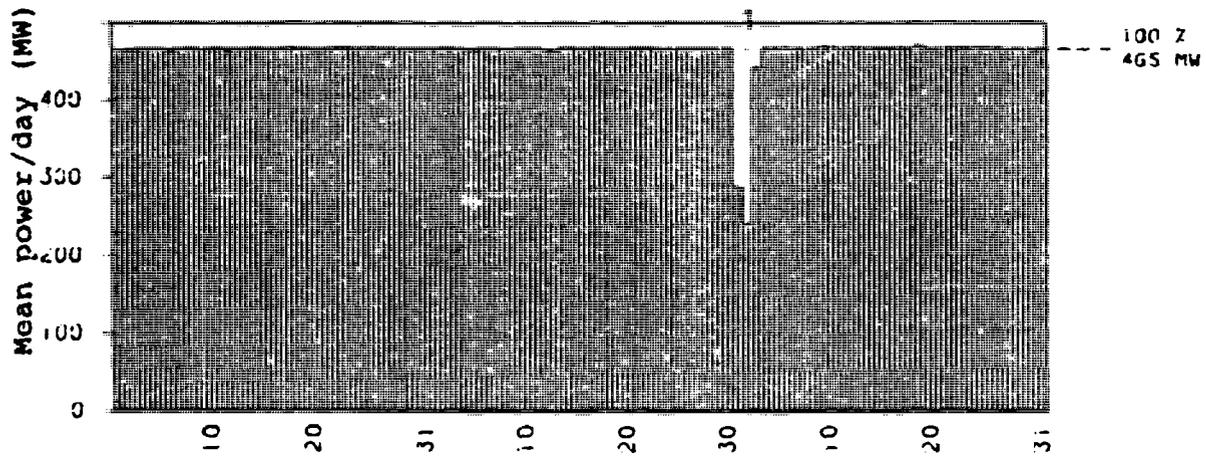


Figure 1 Daily gross power of Loviisa 1 plant unit in October - December 1986

1 Leakage in the line to the reheater

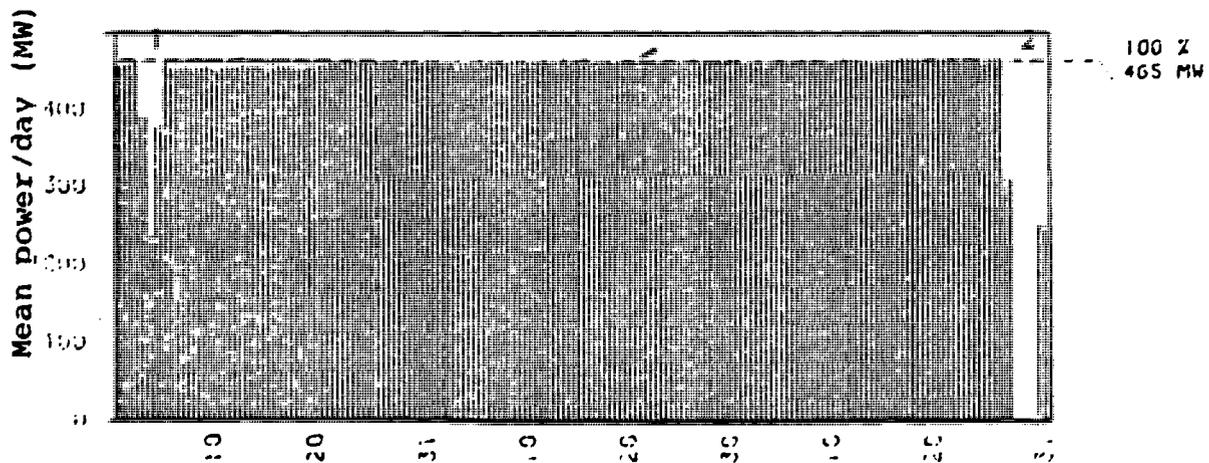


Figure 2 Daily gross power of Loviisa 2 plant unit in October - December 1986

1 Repair of one generator bearing

2 Repair of check valves in the feed water lines

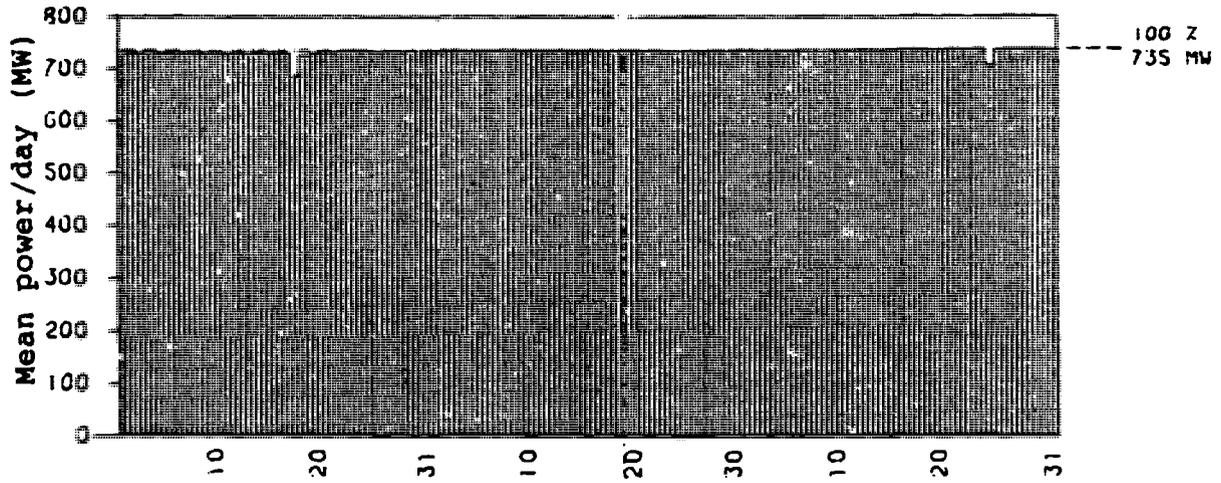


Figure 3 Daily gross power of TVO I plant unit in October - December 1986

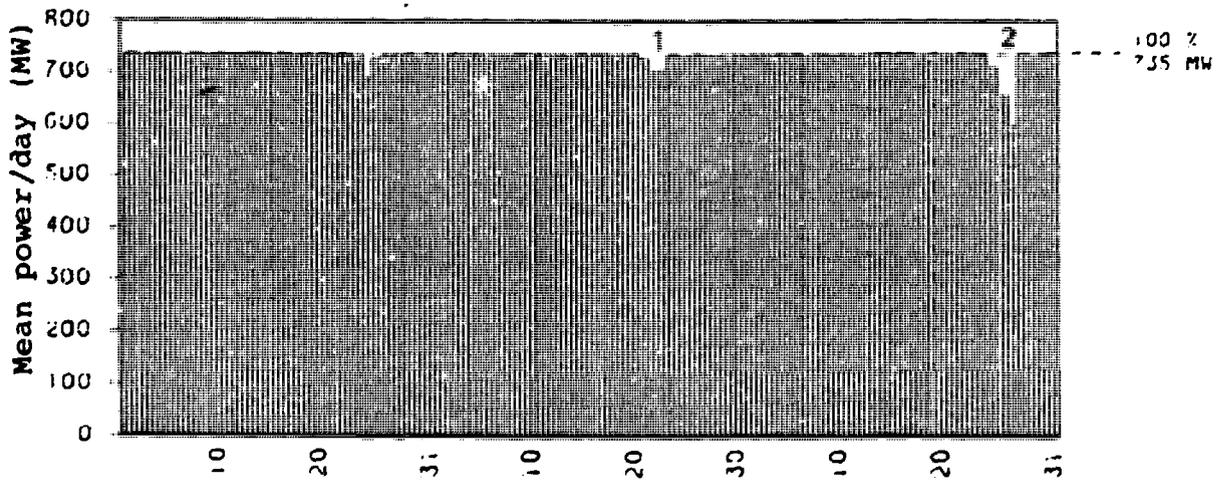


Figure 4 Daily gross power of TVO II plant unit in October - December 1986

- 1 Low demand of electricity
- 2 Packing of a manhole on the reheater



Loviisa 1



Loviisa 2



TVO I



TVO II

Figure 5 Operating diagrams for 1986

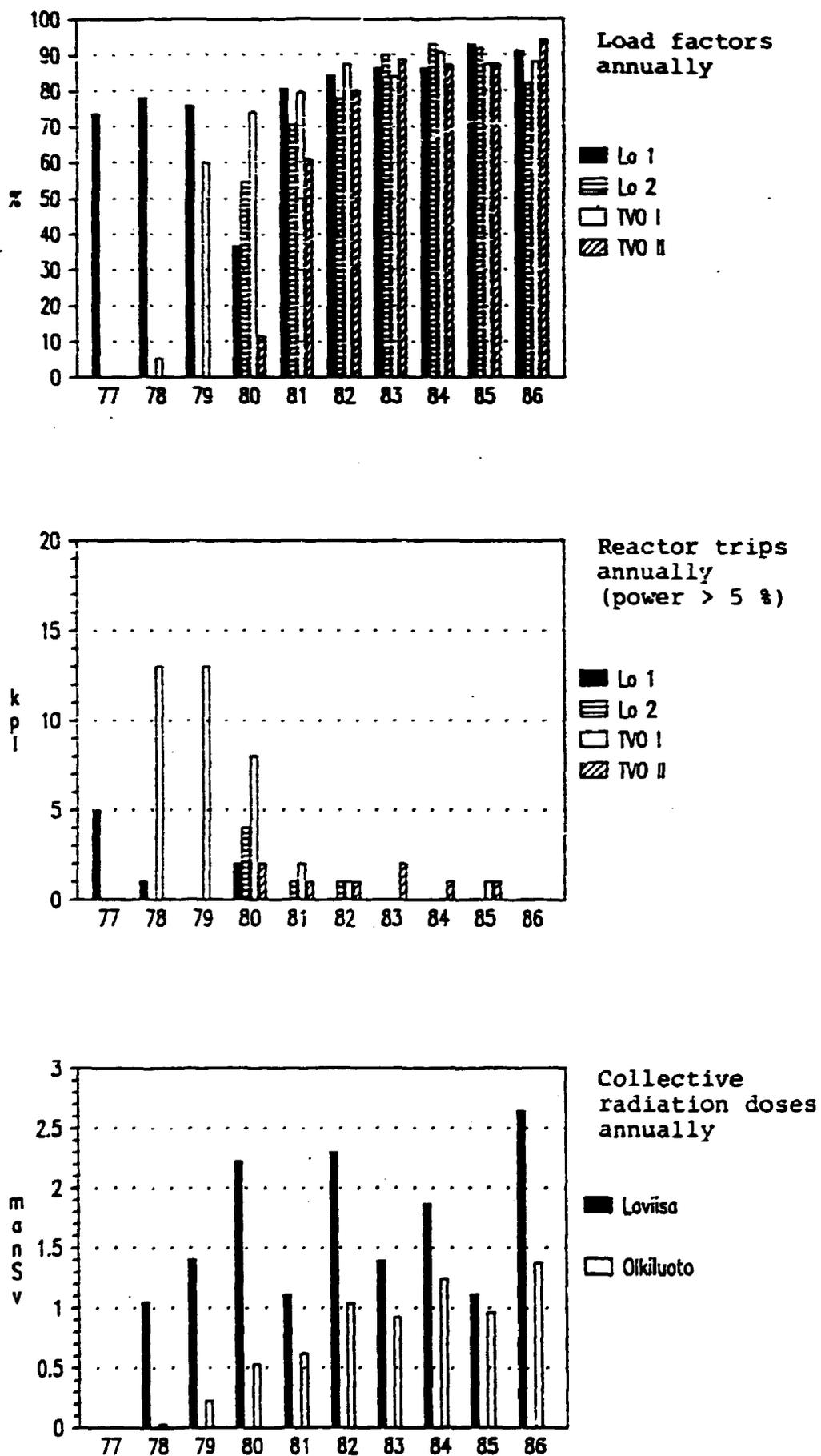


Figure 6 Tabulated data on the Finnish nuclear power plants 1977 - 1986