FINLAND

# Operations experience in Finland

*Performance factors are high, outage times low*

by Klaus Sjöblom and Ahti Toivola

The lack of domestic fossil fuel resources makes nuclear power an important means of electricity production for Finland. Nuclear's share of electricity in 1985 amounted to about 38% of the total consumption of 51.8 billion kilowatt-hours. The relatively high per capita consumption of electricity (10 800 kilowatt-hours per year) is mainly due to the extensive wood processing industry and the energy needed for house heating.

Regulatory review and assessment of nuclear power plants is conducted by the Finnish Centre for Radiation and Nuclear Safety. Regulatory requirements — a construction permit, a fuel license before the import of nuclear fuel into the country, and a plant operating license — are granted by the Ministry of Trade and Industry. In addition, the undergoing revision of nuclear legislation will include provisions for an agreement in principle before the start of a nuclear project from the House of Representatives and local acceptance.

So far the operation of Finnish nuclear power plants has been very satisfactory. Capacity factors have been high, radiation doses to personnel small, and releases to the environment negligible. This is due to a sound basic design, good operational practices, and competent personnel.

#### Loviisa nuclear power plant

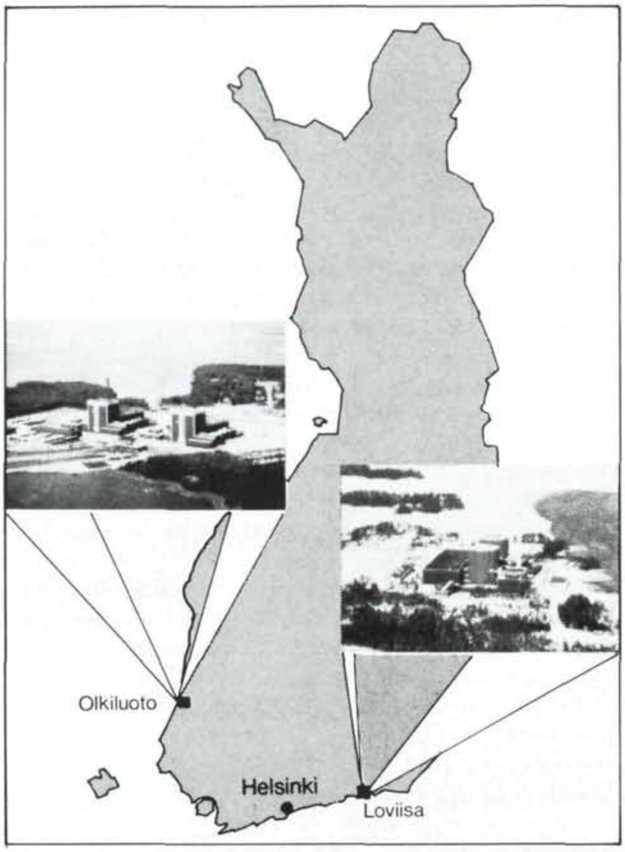
Loviisa nuclear power plant (two 440-megawatt units) is located about 100 kilometres east of Helsinki. The main supplier, Atomenergoexport of the Soviet Union, delivered the reactor and turbine systems. However, the domestic share of the total project costs was about 60%. Numerous companies from many countries contributed to this unique East-West project.

Since commissioning, capacity factors have shown an improving trend and are now approaching a theoretical maximum. Reactor trips have become quite rare, less than once a year during the past few years. So far, no disturbances have threatened reactor safety or caused noteworthy releases of radioactivity to the environment.

#### Design features

When negotiating technical solutions for Loviisa in 1967—70, it was established that Finnish safety requirements differed in several respects from the practice in the Soviet Union at that time. Extensive studies were done and the result was that Loviisa would be provided with a gas-tight containment according to the Western philosophy.*

Messrs Sjöblom and Toivola are at the Loviisa and Olkiluoto nuclear power plants, respectively.




The redundancy of the emergency cooling pumps, diesel generators, and some other active safety components is 4 x 100%, and of the passive components at least 2 x 100%. The level of automation is considerably higher than at the Soviet "mother" plants. Soviet designers have a rather conservative attitude regarding both process parameters and stresses. In many components this led to certain "oversizing" compared to performance requirements adopted by Western manufacturers. Consequently, the transients are slower and the equipment is less stressed.

#### Operational practices

The safety parameter limits, the periodical test requirements, and the allowable component repair times are defined in a technical specifications document, which is continually developed on the basis of accumulated experience. The governing principle is that the plant withstands any initiating event combined with any single failure; the component repair times are limited to three days or the plant will be shut down.

Repair and maintenance work is subject to strict quality requirements. Spare parts must meet the same standards as the original ones and all pertinent quality assurance (QA) procedures must be applied. A large number of in-service tests and

* The six horizontal steam generators made the diameter of the containment relatively large; it was also noted that some components would not withstand the accident conditions in a normal "dry" containment, and to re-design them would take too much time. Therefore, the ice condensor containment system was chosen. The design pressure of the containment is 1.7 bar, based on a double-ended break of the main primary pipe.

inspections are carried out according to approved programmes.

### Modifications

The main reasons for modifications important to safety have been operating experience; experience gained with the on-site training simulator; operating experience from other pressurized-water reactors (PWRs); the Three Mile Island (TMI) accident; new information on materials and components; changes in licensing requirements; and results of experiments carried out by the company.

The core region of the reactor pressure vessel embrittles during operation owing to the fast neutron flux. Extensive analyses and in-service inspections have been performed. To slow down the embrittlement rate, the outermost fuel elements have been replaced by dummies, without decreasing the total reactor thermal power level. The potential thermal shocks caused by emergency core cooling have been reduced by increasing the temperature of the cooling water.

In the aftermath of the TMI accident, several modifications were made. These included installation of instruments and equipment related to hydrogen concentration, radiation monitoring, and various other areas.

Several components also have been changed, and test procedures have been revised, for better attainment of reliability in normal use and during accident conditions. Numerous modifications also have improved fire protection.

### Radiation safety

Radiation doses have been relatively low, on the basis of international comparisons. The annual collective doses for personnel have been about 1 man-sievert for each nuclear unit. The annual collective doses to the population within 100 kilometres have been about 0.01 man-sievert. The reliability of power plant components (only one steam generator tube has been plugged) and the tightness of fuel claddings (only six leakages during 15 reactor years) have contributed to the excellent radiological history.

### Training simulator

In Loviisa there is an almost full-scale simulator that models plant behaviour in normal modes of operation and in various transients and even during small loss-of-coolant accidents (LOCAs).

The initial training of operators lasts six to eight weeks and the annual retraining is 10 days. The simulator is also used for validation of operational aids and instrumention improvements; formulation and verification of plant operating instructions; development of better simulation models; study of alarm reduction in plant transients; verification of plant modifications and defining success criteria for probabilistic risk assessment (PRA); and various kinds of research work.

### Safety analyses

The plant behaviour in various LOCA-sequences has been studied in numerous analyses. The reactor pressure vessel integrity in emergency cooling transients has been an object of extensive material, strength, and process studies. A PRA is being conducted that will identify the most significant risk contributors and will also give valuable information about plant behaviour during various postulated accidents.

### Olkiluoto nuclear power plant

The two-unit nuclear power station in Olkiluoto on the Western coast of Finland is owned by the Industrial Power Company Ltd (TVO). The plant units are 710-MWe boiling water reactors (BWRs) delivered by the Swedish Asea-Atom. The first unit, TVO-1, was first connected to the national grid in September 1978 and TVO-2 in February 1980.

The original rated power output of each unit was 660 MWe, but due to sufficient technical and safety margins it was found possible to increase the power output by 8%. Operation at the elevated rated power of 710 MWe has been licensed by the national safety authority since the beginning of 1985.

### Operations

During recent years, both units have been able to maintain a steady load factor well above 80%. Until 1981, both units suffered from technical problems in the generator set, which is reflected especially in the load factor of TVO-2. The generator has water cooling both to the stator and the rotor, which proved to be a technically demanding feature in a machine with a rotating speed of 3000 rpm. The rotor design was changed and new generator rotors were manufactured for both units. Since 1981 the new rotors have proved to be successful with no comparable operational problems.

### Outage experience

Both units are operated in 12-month fuel cycles and refuelling outages are placed in early summer due to the power demand pattern and the ample supplies of water to hydropower plants at that time. The importance of reducing the outage length in achieving good plant performance was soon realized. (See accompanying graph for outage time trends.) The minimum time that can be achieved is estimated to be 12 days, which allows the normal refuelling and regular recurrent

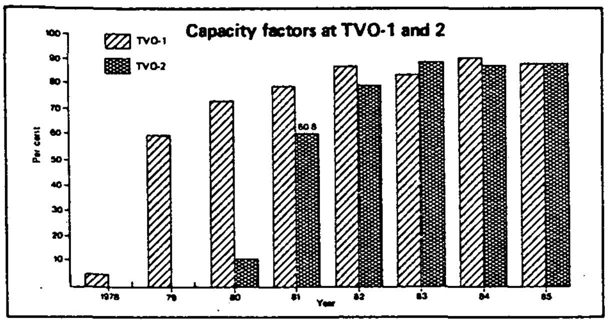
## Finland's radiation monitoring network

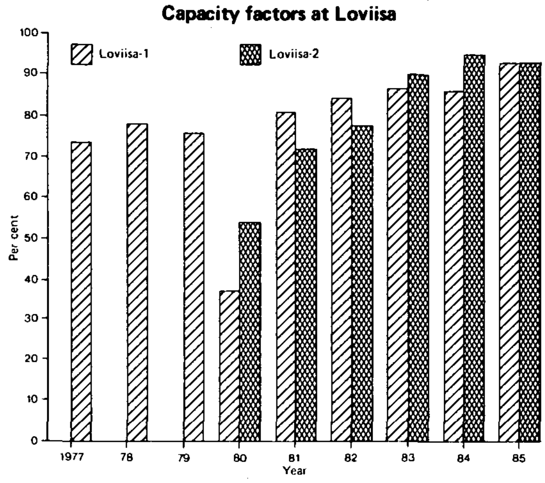
Finland's radiation monitoring network consists of about 270 radiation measurement stations kept by the Ministry of the Interior and the Finnish Defence Forces. Normally, the radiation measurement stations measure the radiation level every second day; the stations of the Ministry of the Interior and those of the Defence Forces on alternate days. The results are reported to the Finnish Centre for Radiation and Nuclear Safety through the Rescue Department of the Ministry of the Interior or through the NBC Defence Office of the General Headquarters.

The Finnish Meteorological Institute also has a network of 10 stations for the measurement of aerosols. By means of this network, it is possible to detect lower levels of radiation from artificial radionuclides than from the network described earlier, whose stations are equipped with Geiger counters.

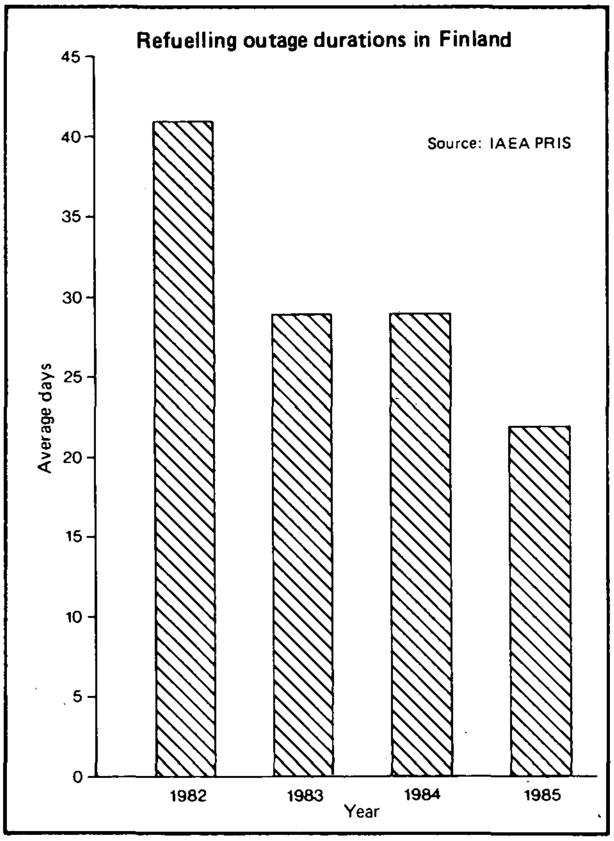
When necessary, the Finnish Centre for Radiation and Nuclear Safety (STUK) sends out measurement patrols, which can be provided with complete equipment for measuring dose rates, as well as portable gammaspectrometers. Both the Olkiluoto and Loviisa nuclear power plants also have fairly complete measurement equipment.

*— Information drawn from a report by the Finnish Centre for Radiation and Nuclear Safety.*




Note: In 1980, Loviisa-1 had a steam generator weld inspection.




inspections and maintenance activities to be carried out. The long-time strategy that has been adopted in outage planning tends to concentrate major repairs during a longer outage, performed every second year. This makes a very short outage possible every other year.

Length of outages in 1982 on TVO-2 and in 1983 on TVO-1 was partly due to extensive repair on reactor tank internals. The reactor core was completely unloaded and the core support grid removed from the tank. The reason was stress corrosion cracking in the fastening bolts of the core grid guide rails. The rails and bolts were replaced by new ones. As in other BWRs, stress corrosion cracking has been a major concern in TVO plants and annual comprehensive surveys are carried out. Due to the low carbon content of steels used for piping in Asea-Atom plants, stress corrosion has not caused major problems in pressure-bearing components. In reactor core internals and fuel bundle construction details, however, a number of changes in other materials less prone to stress corrosion cracking has been made.

### Safety principles and experience

All safety-related systems of TVO-1 and 2 are divided into four subdivisions, physically separated from each other. Normal performance of two out of four subsystems is sufficient to cope with all possible accidents. This 4 x 50% dimensioning of safety systems means that if one train of redundant systems is rendered inoperable, the safety function can still be accomplished, assuming a single failure. This fact has made it possible to establish a programme for preventive maintenance of safety-related systems during power operation. Total unavailability of three days per year is allowed for each subdivision for preventive maintenance. This programme has taken a considerable work load out of the refuelling outages and is one of the contributors to the short outage times.

Technical specifications of the plant require a special report to be written about violations and other occurrences having special importance to safety. During the last 5 operating years, an annual average of one or two special reports have been written on both units.

Cases reported in special reports can have a widely varying character, ranging from formal deviations from safety rules to problematic technical questions in safety systems. However, incidents that would have caused over-exposure of persons to radiation either inside the plant or in the environment have not occurred. One example of a case with considerable consequences was the finding of one broken exhaust valve rocker arm in one of the four emergency diesels on TVO-2. In the inspection which followed, indications of cracks were found in several rocker arms in the same diesel. After this finding, all diesel engines on both units were inspected. As several additional arms with cracks in the same position were found, it was deemed necessary by the manufacturer to redesign the rocker arms and, consequently, all were replaced.

### Radiological history

The annual collective doses to personnel have been low, as have levels of radioactivity, mainly because of a low fuel failure rate. Corrosion product activity also has remained low due to strict control of the cobalt content of steel used for components in contact with water. The contribution of strict rules of operational radiation protection also is noteworthy, as is the simple fact that no major repairs in the more radioactive systems of the plant have been necessary.

Low activities inside the plant are also reflected in the environment. Doses to the population group in the vicinity of the plant amount to a few tenths of one microsievert per year. For perspective, this means a few tenths of a per cent of the allowed limit, 100 microsievert per year.