Doing it right: The Loviisa way

BY SIMON RIPPON

Impressive performance at Loviisa in Finland stems from good management decisions, involvement of plant personnel, efficient outages, and reliance on the expertise of many companies.

LOVIISA NUCLEAR POWER station in Finland has one of the best, if not *the* best, operating performance records in the world. The cumulative capacity factor for Unit 1 since the start of commercial operation in 1977 is 84 percent, and for the last 19 years, the annual figure has five times been above 90 percent and has never been below 80 percent. For Unit 2, the cumulative load factor since startup in 1980 is 87 percent, with eight of the last 16 years above 90 percent and only one year below 80 percent (at 79.2 percent).

Other performance indicators are equally impressive, including the collective radiation doses, which have been at or below 1 person-sievert per year per unit for most of the operating lives of each of the two reactors, and the duration of refueling outages, which have been progressively reduced to a record 15.5 days at Loviisa-1 in 1997.

When the plant's general manager Arvo Vuorenmaa—who from 1984 to the end of last year was maintenance manager at the plant—was asked, "What have you been doing right?" he cited three main factors that have contributed to Loviisa's excellent performance:

■ "A good management decision was made very early on that we should learn to do things ourselves. That meant that even during the construction and commissioning, our engineers were very heavily involved in the process. And this formed a very good basis for subsequent operations."

■ "Early on we learned how important it is to have really short and efficient outages. In the early '80s, shortly after commissioning, we started to plan how could outages be done in a short time and with high quality."

■ "We involved many companies so as to have competition. Already during construction many Western companies were involved, so we could utilize the knowledge of these companies and we have been able to improve the plant progressively."

In many respects, Loviisa is a unique nuclear power station. It is equipped with two VVER-440 pressurized water reactors supplied by the former Soviet Union, and each unit has two turbo-generator units also of Russian/Ukrainian supply. But the Finns insisted on Western-style reactor containment rather than the confinement and bubbler condenser system provided for contemporary VVER-440s in eastern Europe.

In addition, they sought Western suppliers for the instrumentation and control systems and contracted a substantial proportion of component design and manufacture to very competent Finnish engineering companies. A large-diameter containment was required to accommodate the six-loop VVER-440 plant, with its horizontal steam generators. This led to the adoption of an ice condenser system to provide pressure suppression rather than a full pressure containment.

From a maintenance point of view, these unique features of the Loviisa plant have presented quite a challenge, both to the plant operators and Finnish regulators, and it was for this reason that they decided from the outset that they must learn to do things themselves. This

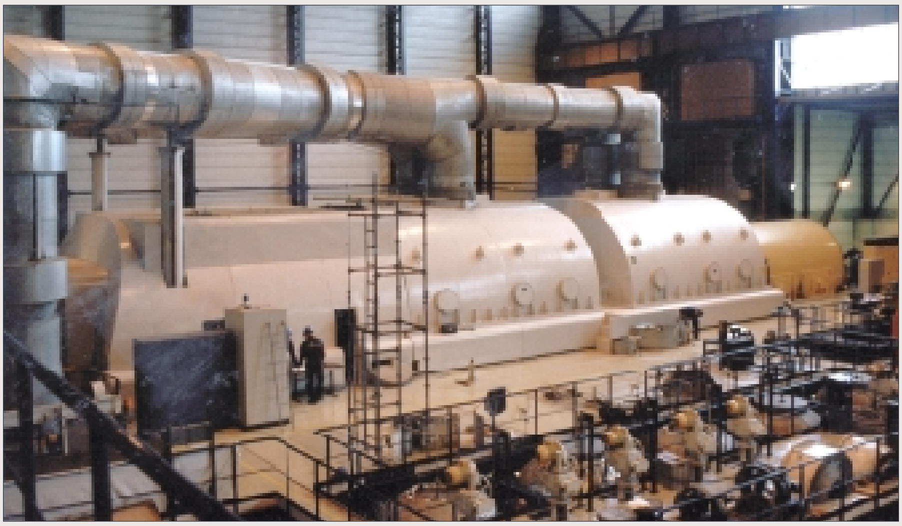
The two-unit Loviisa nuclear power station in Finland (*Nuclear News* photo by Simon Rippon)

Turbine maintenance under way at Loviisa-1 (Loviisa photo)

included the original development of maintenance schedules, which, Vuorenmaa says, involved a very great effort during the plant construction. The international diversity of original equipment supplied has also led to a wide international spread of maintenance contractors from Russia, western Europe, and the United States.

Design features of the Loviisa plant pose good and bad news for maintenance operations. Six primary loops and two turbo-generators per unit is the main bad news. "Too many valves!" declared Jorma Aurela, the Loviisa communications manager, who has also been involved as a safety engineer with licensing issues on the plant. On the other hand, Vuorenmaa pointed out that the Soviet components are very sturdy. "I would say this combination of Soviet mechanical components, which have high margins, and Western instrumentation is a very reliable combination." This is particularly the case with the turbines and the steam generators—it has only been necessary to plug two steam generator tubes in 25 years, and these, Vuorenmaa said, were due to original manufacturing defects.

Bad news from the Western equipment side includes one of the most tedious maintenance tasks that has to be carried out every year on the ice condensers. This involves hacking off the ice that builds up on the walls of the condenser chambers and placing it back in the ice baskets.



One of four turbines at Loviisa that are being progressively uprated from 508 MWe each to 516 MWe, between 1998 and 2002 (*Nuclear News* photo by Simon Rippon)

Another unique situation has arisen with some of the Finnish-supplied components, notably the primary circulation pumps. These are controlled-leakage pumps instead of the canned motor pumps adopted on other VVER-440 plants, and were developed and fabricated by one of Finland's highly qualified engineering companies. But after the Loviisa order for 14 pumps (six for each reactor and two spares), there were no more customers for these pumps, and the company no longer provides maintenance support. And so, this is one of the regular maintenance tasks that has to be carried out in well-equipped electrical and mechanical workshops at Loviisa.

Maintenance goals

"The main goal here," Vuorenmaa says, "is to make sure that the plant remains in safe and reliable operation for the period of the license." In effect, plant life management is an integral part of the maintenance program. There are two things that have to be taken care of to reach these goals. First, there is the confidence of the public—which, of course, involves the safety of the plant. "And," Vuorenmaa says, "it is not just a case of convincing the public, we have to convince ourselves and make sure that the plant is safe."

The other thing that has to be taken care of is the economics. "And here we have to convince the owners [Fortum] of the situation," said Vuorenmaa. There is already a very competitive free market for electricity in the Nordic countries, he added, and it is necessary to maintain the competitive position of nuclear electricity.

The top of one of the ice condensers at Loviisa-1, where the maintenance task of chipping ice off the walls had already commenced before the annual refueling outage (*Nuclear News* photo by Simon Rippon)

To meet these goals, Vuorenmaa said, "we make plans for the next year and the coming 10 years, and we must take care of both these sides [safety and economics]."

Vuorenmaa believes that "the main tool today from the safety point of view is PSA [probabilistic safety analysis]." Loviisa maintains a living PSA to show the effectiveness of different maintenance and improvement measures in reducing the hypothetical core melt frequency. From 1990 to 1998, there was an impressive thirtyfold reduction from just below 6×10^{-4} per year to about 2×10^{-5}. The PSA analysis shows clearly the contributions of improvements to some 23 different safety systems in achieving the overall reduction in core melt frequency. The very low core melt frequency is also an indication of some of the good safety features of the Soviet-designed reactors—notably the large primary water inventory and generous safety margins.

Vuorenmaa thinks that the organization of maintenance at Loviisa "is to some extent very different to many other countries. The main idea here is that the same people who are responsible for the operation are also responsible for the maintenance. This sounds like a simple thing, but I think it is important. We are still using a lot of outside contractors—there are about 800 additional people working during an outage, and the maintenance staff at the plant numbers about 200. It is not possible to do all the work ourselves, but we try to do it in such a way that all the decisions, even the small ones, are made by our own people."

Basically, there is one specialist from the Loviisa staff who is responsible for each system of the plant during both operation and maintenance. For every maintenance task for the system, that person acts as a coordinating foreman to whom the managers and foremen of outside contractors report.

"So it is developed from the inside at every level," Vuorenmaa says, ". . . every day, small decisions are made—should we repair this, should we redesign that, what should we do with this—and there are always our own people involved in that decision situation. . . . If all the decisions are made by our people then they are responsible for the consequences."

Vuorenmaa himself assumed responsibility for developing this philosophy when he became maintenance manager at Loviisa in the early 1980s. "We have the three goals from the operational point of view: The first goal is minimum disturbances during operation—that's the main goal; the next one is minimal duration of the reload and these two, I think, can conflict a little. To take care of these conflicts, I decided that if a decision has to be made that some work needs to be done, at least it will be accepted by those responsible for operation. And the third goal, which I think is becoming stronger, is that we should have the outages during the summer."

In the competitive Nordic market, the prices of electricity in the summer are very much less than in winter. So all decisions, even those concerning the duration of the outage, should be made with a view to avoiding any interruptions in operation during the winter. For the last 10 years, the outages for the two units have been in August and September. There is now some pressure from Fortum to change to July and August, although this may be unpopular since July is the main holiday time in Finland. The outages also have to be coordinated with Finland's other nuclear power reactors at Olkiluoto.

Because of the large and steadily increasing demand for electricity in the winter months, there is no incentive at all to change to 18-month fueling cycles, and two-year cycles are not possible with present fuel enrichment levels. Rather, the Loviisa plant is adopting short outages limited to the 15 or 16 days needed for refueling, and slightly longer outages of 20 to 21 days every other year. Every fourth year the longer outage has to be extended to 30 to 40 days to meet regulatory requirements for increased inspections, including full inspection of the pressure vessels and reactor internals.

When *Nuclear News* visited at the end of August, the Loviisa plant was in the middle of two short outages. Loviisa-1 was preparing for a final tightness test of the primary circuits at the end of an 18-day outage, and Loviisa-2 was coasting down in preparation for a 16-day outage in September.

The interface between the station staff and contractors was witnessed at a short briefing meeting in the outage management center located between the two reactor containment buildings. The open plan office space is divided into two areas, one for the Loviisa managers and the other for contractors. They have separate entrance doors and are segregated by a low, but relatively informal, barrier. The briefing was closely followed by very atten-

Fortum Group

The Loviisa nuclear power station is today owned and operated by Fortum Group, a large energy utility formed two years ago by a merger of Finland's state-owned electricity utility Imatran Voima Oy (IVO) and the oil and gas company Neste. About a quarter of Fortum shares are now in private ownership. Fortum also has a 25.7 percent shareholding in Teollisuuden Voima Oy (TVO), the mainly private utility that operates Finland's other nuclear power plant at Olkiluoto, as well as shares in the Forsmark and Oskarshamn nuclear power plants in Sweden. In all, Fortum has interests in 10 nuclear power units.

Currently the Loviisa power plant is within Fortum Power & Heat Oy, one of the five business units of the Fortum Group. Another business unit is Fortum Engineering Oy, incorporating the former IVO Engineering company, which has established an international reputation for its technical support services, particularly in the nuclear field.

At the beginning of next year, Fortum Group plans to introduce a new organizational structure, with 32 independent performance units reporting through managers directly to the corporate management of Fortum. Loviisa will be in the Power Production performance unit, along with other Finnish hydro power plants and conventional power stations with condensing turbines (i.e., those that produce electricity only and excluding plants that produce both heat and power). The manager of Power Production will be Jussi Helske, who was Arvo Vuorenmaa's predecessor as plant manager of Loviisa.

The scheduling manager (far left) briefs an attentive meeting of maintenance foremen in the outage management center, located between the two Loviisa reactor containment buildings. Known as "Mr. Schedule," he tells them that the important tightness test at the end of the Loviisa-1 outage will, "as always," be taking place around midnight. (*Nuclear News* photo by Simon Rippon)

tive foremen on both sides of the barrier, who were told by the scheduling manager that due to a slight holdup, the tightness test would, "as always," take place at around midnight.

Maintenance and management

"You have to be very efficient during outages and the quality of the work has to be of a very high level," Vuorenmaa said. "So you have to choose the work to be done and to avoid any unnecessary work. The main tool for that is condition-based maintenance. We have condition monitoring systems on the plant and we measure what is necessary in the work program of the next outage. For example, with the main circulation pumps, a few weeks before the outage we decide which pumps will be overhauled during the outage. It depends on the results of measurements."

But there is also a need to take care of the improvement and the continuous modernization of the plant. This is essentially a plant life management program that aims to ensure that the plant will operate safely and reliably to the end of the next 10-year licensing period and beyond.

It is obviously desirable to try to plan this work so that it does not unduly disturb the production of the plant. "So we try to make a long-term program," Vuorenmaa said. "Normally we start to plan details of the work to be carried out two years ahead of outages. But we have a modification and improvement program for the next 10 years. And this is planned so as to disturb the short and long outages as little as possible." All the outage planning is carried out by Loviisa staff, although they may have technical support from Fortum Engineering or other specialist contractors for the planning of big projects.

The reactor pressure vessels of VVER-440 plants are well known to be an area of concern for life management because of the vulnerability to neutron radiation embrittlement of the rather small-diameter vessel and its circumferential weld at the midcore level. From the outset, the Loviisa reactors adopted a fuel loading regime to minimize the fast neutron flux at the corners of the core nearest to the pressure vessel, and plentiful steel samples were placed around the core to monitor the rate of embrittlement. Nevertheless, the operators were taken a little by surprise by the early rate of embrittlement of the Loviisa-1 vessel. After careful planning, the vessel was annealed in 1996.

"That annealing was a great success," Vuorenmaa says. But of course there is a continuing program of monitoring samples, and this was the reason for a slight increase in the latest outage at Loviisa-1 from 16 to 18 days. Some samples were taken out of the vessel, annealed in a special furnace and placed back in the vessel for further irradiation as part of a complicated program to study the effectiveness of annealing and the rate of reembrittlement.

Jari Snellman, the new maintenance manager at Loviisa who is specially concerned with the plant life management programs, believes that to go beyond the present 10-year license, it may be desirable to anneal the Unit 1 pressure vessel once more and to anneal the Unit 2 vessel once. It so happens that Loviisa has a spare pressure vessel, which was acquired, along with spare steam generator units, from an abandoned Polish nuclear power project. Although a tentative study of the feasibility of vessel replacement has been carried out, nobody is yet taking the idea very seriously. The spare pressure vessel lid, however, may prove useful as a replacement since there have been some early indications of cracking in control rod penetrations similar to the problems encountered on French PWRs. So far this is not a problem at Loviisa, but Snellman said that they were keeping a careful check on the situation.

There is a particular need for very good cooperation between the maintenance and operation activities. Great emphasis, therefore, is placed on the designation of people from the operating staff who are responsible for different sections of the plant and who, during outages, become the foremen in charge on any maintenance tasks that have to be undertaken in their area of responsibility. These same people are then responsible for collecting all the information from the craft workers involved in the maintenance tasks and for compiling reports on the completion of the work, noting in particular any new information that has come to light.

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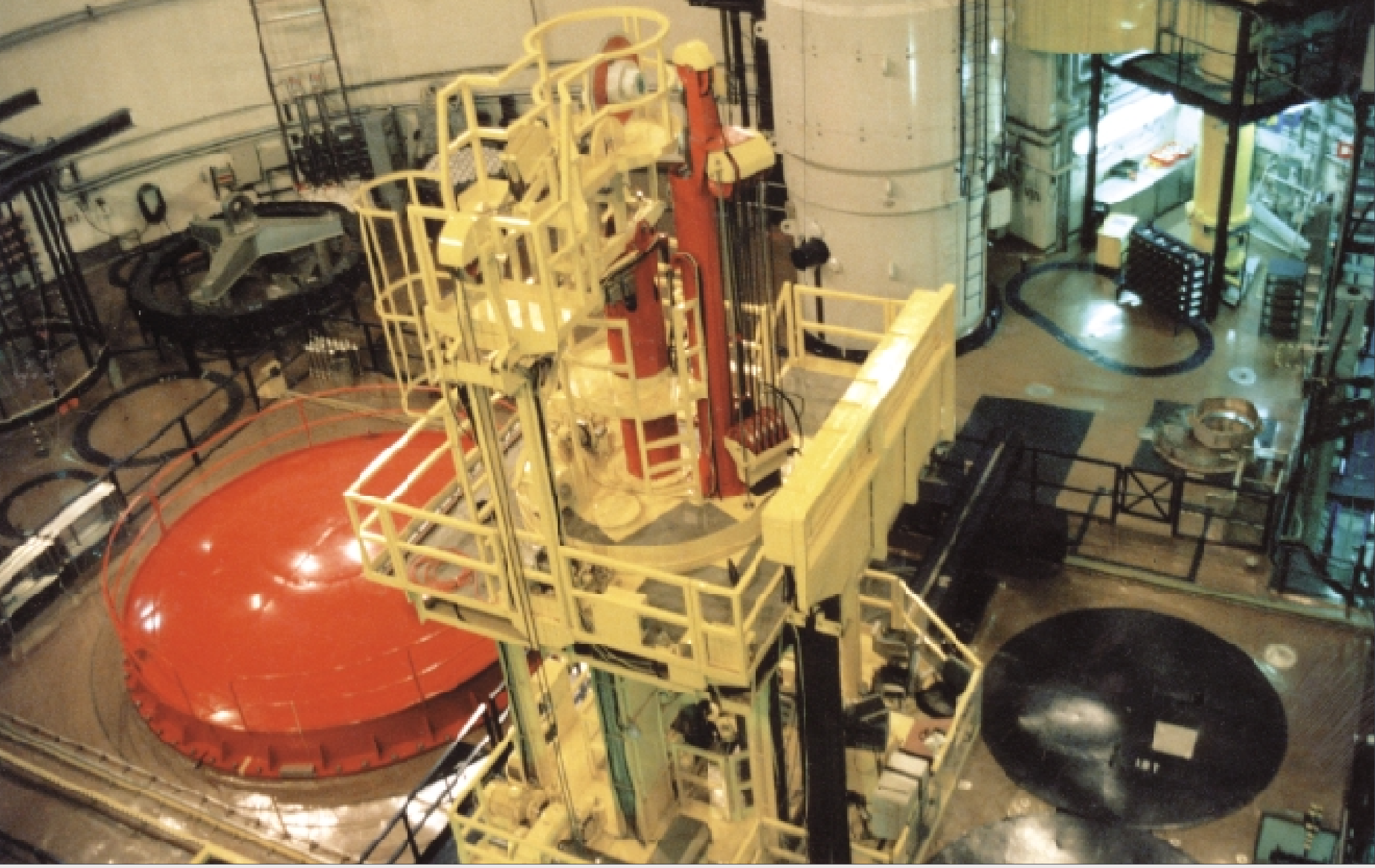
The Loviisa-1 control room, preparing for a final tightness test before restart after the annual refueling outage. Personnel in the control room are strictly limited to those with a task to perform. (*Nuclear News* photo by Simon Rippon)



A view inside the reactor containment building: Loviisa-2 readied for its annual refueling outage. The new fuel is in place in the pool (right) and the refueling machine is prepared (center), while the red missile cover remains in place over the enclosure of the reactor, which—at the time of this photo—was in coast-down mode. (*Nuclear News* photo by Simon Rippon)

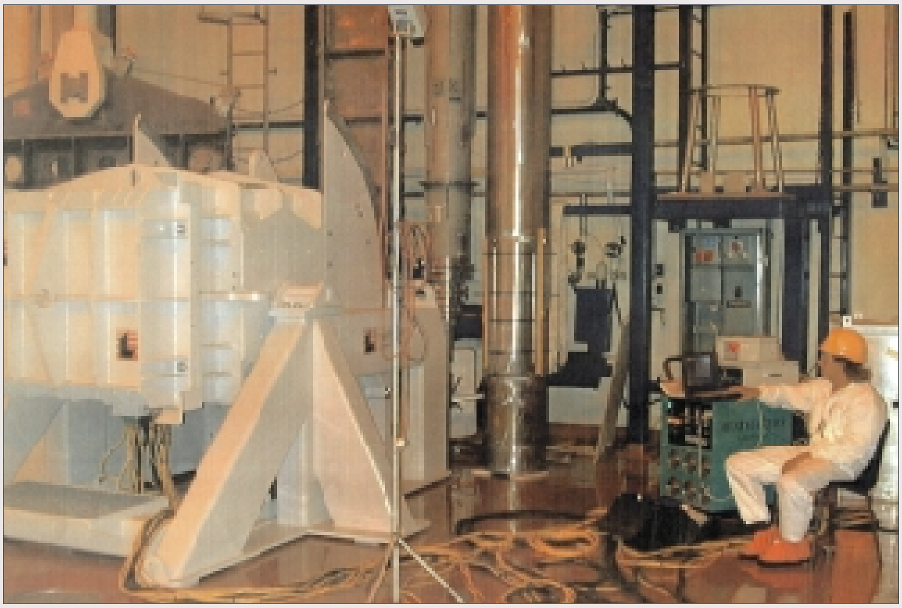
Loviisa has its own computer system for preparing all the work orders for maintenance tasks and for recording the complete maintenance histories of all components and systems. During the just completed outage on Loviisa-1, for example, this involved the preparation of work orders for some 2100 tasks that had been planned in advance, and an additional 500 tasks that cropped up during the outage.

Reporting back to the computer on the completion of tasks is inevitably in a rather codified form, but the engineers responsible for the different sections of the plant also prepare more wordy reports on standardized forms that are saved as documents on a computer disk system. This relatively simple system allows any Loviisa technical staff to access the records using desktop computers and to examine the current status and condition of different sections of the plant.

In these reports, Snellman said, “First there is general information about the system—What are the devices that are followed in this subsystem? What are the aging mechanisms? Then there is some estimation of the state of the components or devices. And finally there is something about what actions have been planned, what kind of analysis has been done, and what are the long-term plans. There will also be a note of what has come up recently and particular things that need to be investigated or developed.”

“Then,” Snellman continues, “once a year, we have a meeting of all these people who are responsible for the different systems and the reports, and we develop an overall picture of where we are now and what we have to do next or particular areas where we have to do much more than now.”

Relevant feedback information is also welcomed from other nuclear power plants operating around the world. Loviisa is a member of the Moscow Centre of the World Association of Nuclear Operators (WANO), while the other Finnish plant at Olkiluoto is a member of the Paris Centre. A particularly



A furnace used for annealing specimens of pressure vessel steel before they are placed back in the reactor for further irradiation (Loviisa photo)

During the recent refueling outage at Loviisa-1, personnel modify the support structures for cabling of temperature measurement systems on the primary loops. (Loviisa photo)

close relationship has been established with the Paks nuclear power plant in Hungary, which, among operators of Soviet-designed reactors in eastern Europe, is generally regarded to be the best. Vuorenmaa says, "I would think that our engineers phone their contacts at Paks every week, and every week they contact us. We arrange every year in Paks or Loviisa a maintenance seminar. We spend one week telling each other what problems we have found and what modifications we have done."

Aging management

Important lessons about aging effects were learned from two incidents that occurred at Loviisa in 1990 and 1993. Erosion-corrosion effects on pipework in regions of flow disturbance caused guillotine ruptures in 325-mm-diameter feedwater pipes. Although the leakage of the nonradioactive secondary cooling water did not represent any hazard and was quickly isolated by operating staff, the second incident was rated level 2 on the International Nuclear Event Scale (INES) because of its generic similarity to the previous incident. Now the regular inspection of the tortuous pipework systems at Loviisa is an important part of plant maintenance.

Aging of a rather different kind is also becoming a concern at Loviisa. While the plant has benefited greatly from the intimate knowledge of it that engineers who have been around for a long time have acquired, and the turnover of personnel has been very low, the reality is that as much as 70 percent of the technical staff will be approaching retirement age in the next 10 years. An important goal, therefore, if Loviisa is to get a further extension of its license, will be to train a new generation of engineers.

Aurela says that things are already starting to happen throughout the whole organization, and new, young engineers are being appointed to work alongside the experienced managers. While economic pressures are leading to some reductions in administrative staff numbers, there has been a slow increase in technical staff, attributable mainly to the recruitment of a new generation of young engineers.

Modernization

For much of the past decade, Loviisa has been undertaking a program of modernization, which also is carefully coordinated with the maintenance outages. A major achievement of this program was the granting last year of the new 10-year operating licenses, with a 9 percent increase in the thermal power rating to 1005 MW for each reactor. This is allowing gross electrical output to be progressively increased from the previous level of 508 MWe to 516 or 517 MWe per unit when modernization work on the turbines is completed in 2002. For the past year, both units have been operating at 510 MWe.

Aurela said, "We chose the 10-year period [for the license extensions] because it [approximately] matches the original 30-year design life of the plants." (Unit 1 began commercial operation in May 1977, and Unit 2 in January 1981.) But during the next 10 years, the life management programs will be seeking to establish a safety case for license extension to 45 years.

The modernization program has included a lot of work to further enhance the safety of the reactors, and this program of work will continue thru 2002, with an emphasis on a number of additional measures to deal with severe accidents. This will include the provision of an emergency control room.

Other upcoming work at Loviisa will be the doubling of the capacity of spent fuel storage ponds to provide for interim storage of all arisings from as many as 45 years of operation of both reactors. The need for this extra interim storage has occurred since the Finnish parliamentary decision in 1994 to halt, by the end of 1996, shipments of spent fuel back to Russia.

Also planned for 2001 operation is a concrete solidification plant for liquid radioactive waste currently held in storage tanks. Loviisa has recently completed the first phase of construction of a final repository for low- and medium-level waste. The repository has been excavated in granite at a depth of 110 to 130 metres below the site. Emplacement of LLW has already commenced, and MLW will follow with the completion of the solidification plant. A later phase will extend the repository to accommodate decommissioning wastes.

As for the final disposal of spent fuel, a preference for the development of a site near the Olkiluoto power station was recently announced on behalf of Teollisuuden Voima Oy (TVO) and Fortum by their joint company for high-level waste disposal, Posiva. NN

The personnel access shaft to the low- and medium-level radioactive waste repository, located at a depth of 110 to 130 metres in granite below the Loviisa site (*Nuclear News* photo by Simon Rippon)