The Leibstadt approach to improvement: Evolution rather than revolution

BY DICK KOVAN

A power uprate, efficiency improvements, shorter outages, and reduced unavailability have contributed to a nearly 30 percent increase in electricity generation from the mid-1980s to now.

THE LEIBSTADT PHILOSOPHY, said David Burns—manager of the Swiss nuclear power plant's mechanical department, as well as being one of two deputy plant managers—is to continue to build on what has already been achieved: Change should be evolutionary, rather than radical; major new initiatives are not always necessary. Plant performance has been good since the start of operation in 1984. "We have been awarded GE plaques every year to prove it," noted Burns. In 1985, the plant was already operating at 80 percent load factor. Improvements have continued. The plant was producing 7 million MWh per year in the mid-1980s and is now generating more than 9 million MWh, an increase of nearly 30 percent. Much has contributed to this: a power uprate, efficiency improvements, shorter outages, and reduced unavailability.

Burns began his career with Britain's nationalized utility, the Central Electricity Generating Board, working at both fossil and nuclear stations, and moved to the United States in 1975 to work for what was then the Washington Public Power Supply System at a time when the utility had a massive nuclear building program under way (only one nuclear unit, however, was completed). In 1981, Burns left to join Kernkraftwerk Leibstadt (KKL), in Switzerland, during the project's licensing stage, bringing useful experience in a range of materials engineering areas.

Management and maintenance

The plant management structure currently consists of five main departments: administration and procurement, operations, electrical maintenance and engineering, mechanical maintenance and engineering, and surveillance. Until a few years ago, there was also a projects department, which had evolved from a nuclear department that was part of the original structure. Burns had been manager of the projects department when there were a lot of projects going on. Some three years ago, the activities of the projects department were integrated into other departments, particularly mechanical.

The Swiss have traditionally taken on multifunctional roles, said Burns. At KKL, engineering and maintenance functions are integrated, with the same people doing both. The maintenance and engineering functions are carried out at the first departmental level, known as "ressorts," in which the system engineers, planners, and mechanics are located.

Maintenance is split along classical—mechanical and electrical—lines. The mechanical department has overall responsibility for most components and systems, calling on the electrical department for maintaining the electrical components within its systems. The electrical department has primary responsibility for I&C, cables, the turbo-generator, transformers and other heavy electrical machines.

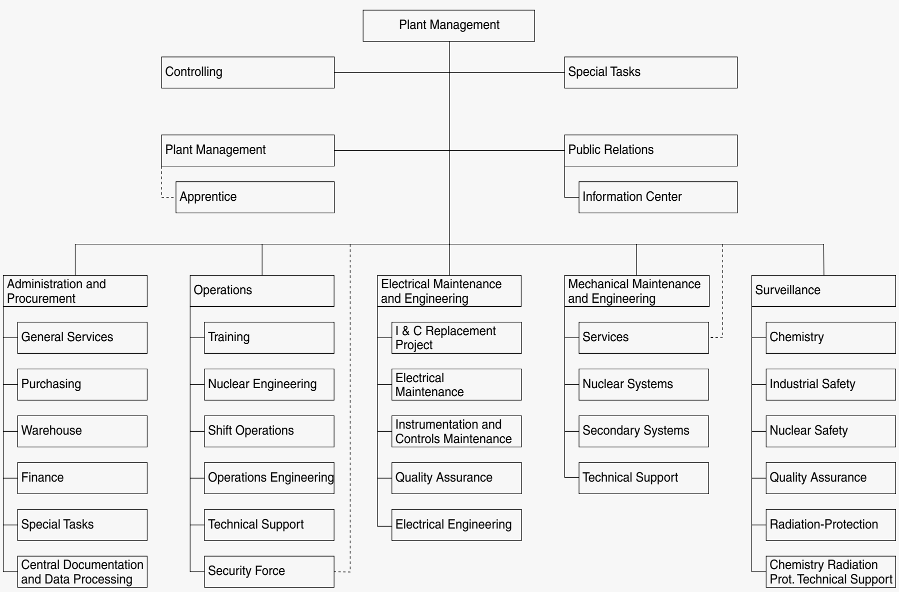
At Leibstadt, the system engineer is responsible for all activities related to his system: system design, system design basis, modifications, maintenance planning, diagnosis when problems occur, and initiating work orders, etc.

David Burns: Change should be evolutionary.

Burns explained that the responsibilities given to the engineering and maintenance staff carried over to decisions on investments, which, he believes, has been important in the success of the plant, particularly in its power uprate program. That program was not imposed on the organization. The department's engineers knew what was wanted, and were involved in defining what was to be done, as well as doing it. As a result, they bought into the program and made a real success of it.

The maintenance process

In the early phase of operation, the staff focused on familiarizing itself with the plant, sorting out teething problems, and making the modifications needed to optimize operation. At Leibstadt, said Burns, maintenance optimization is a continual process. The learning was most intense in the first five or 10 years, but it never stops. "As quickly as possible, we began to extend the maintenance intervals, making use of the experience gained, as well as by monitoring and assessing equipment performance," he said. Of course, maintenance is component- and function-specific. Not everything is amenable to extension, particularly safety-related systems, where a more



Organization chart of the Leibstadt nuclear power plant (Source: KKL) conservative approach is needed. For example, the maintenance philosophy for the plant's control rod drives has not changed.

Next came a phase of significant modifications and investment. Besides power uprating and efficiency improvements, the plant put in a new training and information center with a full-scope simulator and a new radioactive workshop. A number of long outages were needed to complete this work.

The emphasis was then put on improving availability, reducing outage lengths, and other measures to reduce costs. Burns noted that experience has shown that costs have a linear relationship with the length of the outage: the shorter, the cheaper. "Experience elsewhere," said Burns, "suggests that this trend will continue down to much shorter outages."

Outage planning

All five Swiss nuclear plants follow traditional annual summer outage cycles. The plants coordinate outage restart dates to reduce the possibility that the safety authority (HSK), which has limited resources, is not ready to sign off on the work, as happened in 2000.

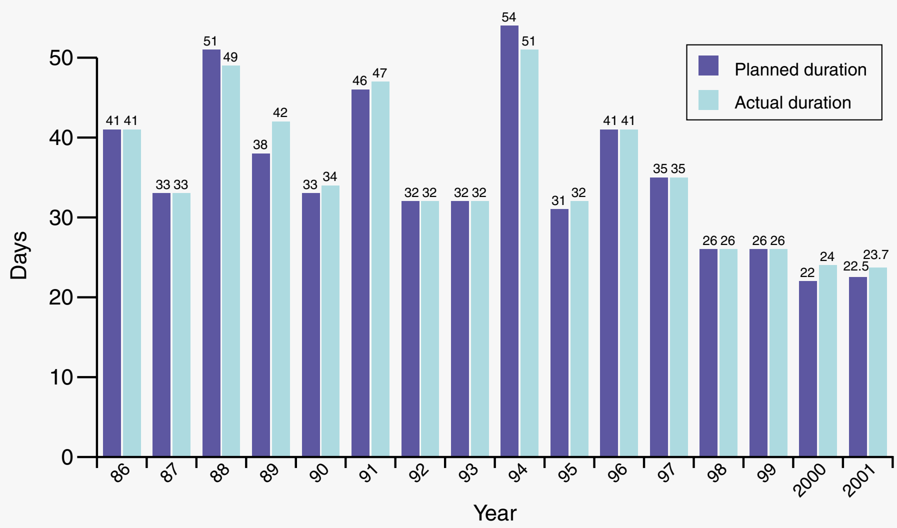
As part of its optimization processes, the plant is introducing a new refueling and maintenance cycle involving three different types of outages: "pit stop," "standard," and "extended." In the future, "standard" outages of about 22 days will alternate with short "pit stops," except when "extended" outages are planned for undertaking major modifications or special work. Although not yet fully defined, a pit stop should be around 16 days in length.

The first pit stop will be in 2002. A standard outage will occur 2003, similar to this year's, which was completed in 23.7 days. In 2004, the plant must close out its 2nd 10-year in-service inspection (ISI) program, including a vessel pressure test, which will require an outage of about 32 days. The ISI program follows the requirements laid out in ASME Section 11 that were adapted into the Swiss rules.

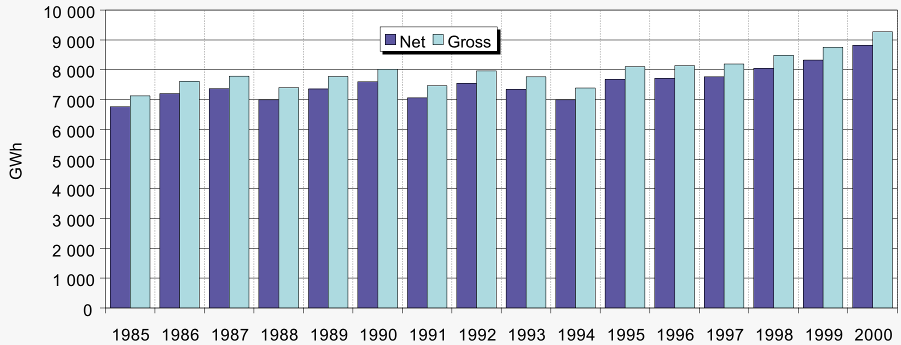
Although the license conditions do not require a yearly shutdown, some calibration and testing activities, as currently defined by technical specifications (tech specs), must be done on an annual basis. To extend these maintenance and testing intervals, the plant is now in the middle of a project, being run by the outage manager, examining possible changes to the tech specs.

"We are currently screening the whole tech spec test program to identify those items whose maintenance interval can be extended so we will be in a position to do 'pit stop' outages every other year. We must also provide the justification for this interval extension," said Burns. The majority of activities of concern involve calibration, instrumentation functional tests, system functional tests, and other tests, such as leak testing of containment penetrations. This effort has been going on since the end of 2000 with support from a U.S. contractor, General Physics Corp.

The work involves assessing the performance history of equipment calibration, setpoint drift, and the results of functional tests,



Outage durations at Leibstadt (Source: KKL)



Net and gross electricity production at Leibstadt (Source: KKL)

Year	Generator on grid, hours	Gross production, MWh	Net production, MWh	Availability, percent	Gross capacity factor, percent	Capability factor, percent
1985	7233.00	7 125 790	6 761 954	82.57	81.02	81.95
1986	7669.50	7 604 460	7 202 176	87.55	83.07	85.62
1987	7917.00	7 780 661	7 367 850	90.38	85.00	88.57
1988	7534.50	7 393 908	6 995 344	85.78	80.55	83.18
1989	7671.50	7 768 006	7 354 478	87.57	84.86	85.81
1990	7905.50	8 020 302	7 596 233	90.25	87.61	88.90
1991	7580.50	7 458 671	7 051 956	86.54	81.48	86.01
1992	7985.50	7 964 710	7 537 618	90.91	86.77	90.54
1993	7957.50	7 757 558	7 338 055	90.84	84.74	89.59
1994	7227.00	7 388 636	6 988 215	82.50	80.71	81.11
1995	7886.50	8 103 956	7 673 833	90.03	85.26	89.07
1996	7790.00	8 134 756	7 705 133	88.68	85.35	87.58
1997	7866.50	8 192 680	7 762 496	89.80	86.20	89.23
1998	8139.00	8 473 325	8 046 205	92.91	89.15	92.35
1999	8126.25	8 752 385	8 319 987	92.77	88.03	91.96
2000	8159.25	9 272 934	8 823 189	92.89	90.23	92.32

Leibstadt plant performance (Source: KKL)

to show that increasing the interval does not decrease the margin of safety. By the end of this year they should know which activities come into this category.

Burns does not see the change to its outage strategy as a radical step. Outage times have been shortening since the beginning: from 32–34 days down to 22–23 days, a 10-day improvement. He believes that the operational strategy and plant capabilities have evolved to the point where it can accommodate the "pit stop" strategy. He compared this to the United States, where progress over the last few years has been much more of a leap, from very long outages to very short outages. "We look more toward the Finnish nuclear operators, who have also continuously improved performance and reduced the time of outages."

Plant uprating

The few extended outages in the 1990s relate to power increase projects. KKL decided to undertake power uprating early in the life of the plant. "Already in 1986 we uprated by 4.2 percent (about 50 MWe) by taking credit for the margin in the safety calculations. We redid all the loss-of-coolant accident calculations using the tools available at the time, which showed that there was a large margin. We did not have to do any modifications, just some verification testing."

In 1994, the low-pressure turbines were replaced to provide an additional 40 MWe. The plant next began the analysis and licensing process to uprate the licensed thermal power of 3138 MW to 3600 MW, a 14.7 percent increase. Although licensed at 3600 MW, the HSK has not yet authorized operation at that level, but requires the increase to go in steps: The plant first increased power by 6 percent, then 9 percent, and has now reached the 12 percent level (3515 MWth). Electric capacity has now increased some 200 MWe since the start of commercial operation. The final step to 3600 MW is currently on hold.

"When we started, a 15 percent increase was considered an extremely large jump. Now, some U.S. operators are looking at extended power uprates of 20 percent," noted Burns.

According to Burns, Leibstadt had planned this uprate before Finland's Olkiluoto BWR plant, which achieved a similar increase much earlier. The Finns visited Leibstadt in 1994 to find out how KKL planned to do it. They were able to get on with the uprate quicker than Leibstadt because at the time, HSK had a number of licensing activities going on in parallel, and also some issues with fuel cladding corrosion added to the delay.

Mechanical department

There are four ressorts in the mechanical department. The primary ressorts focus on engineering and maintenance functions for the nuclear and secondary plant. The other two on support functions: engineering support functions (including projects and larger modifications) and general technical support functions.

The primary ressorts, with small exceptions, take care of the main activities of system engineering, maintenance and outage scheduling, preparing work orders, managing spare parts, performance of maintenance, etc. "We have assigned to these functions, as far as possible, all resources for the engineering and maintenance of the components and systems within their areas," explained Burns.

The support ressorts are responsible for functions that are plant-wide, including main-

Leibstadt KKL

Switzerland's Leibstadt nuclear station, owned by Kernkraftwerk Leibstadt AG (KKL), began commercial operation in December 1984. The plant, a 1145-MWe General Electric boiling water reactor, is located on the Rhine near the border with Germany.

KKL is owned by a group of 11 partners. Each partner has a right to the percentage of output equal to its relative shareholding and an obligation for meeting that percentage of costs. The lead partner is Watt AG, which was formed from the splitting up of Electrowatt several years ago (the technical part of Electrowatt was sold to Siemens). Today, Watt's main shareholder is NOK, which owns and operates the Beznau plant and has a separate shareholding in KKL. Other shareholders include Swiss and German utilities. Electricité de France also has an interest in KKL, through the Swiss company ATEL.

One of Watt's subsidiaries, EGL, acts as the "utility management," whose responsibilities include, among other duties, controlling the budgeting, providing legal services, and purchasing fuel and back-end fuel cycle services. Most other management functions are carried out on the site with less than 400 plant staff. The plant management reports to EGL on a regular basis.

tenance support functions, such as quality control and quality assurance, in-service inspection, and site supervision of welding, as well as maintenance not directly associated with the two primary functions, including general buildings, cranes, and transport equipment. The technical support functions include PRAs (level 1, 2, and shutdown), the design basis processes for maintaining and documenting the general plant design basis (e.g., designs for earthquake), analysis of piping systems, the structural integrity of components, fracture mechanics, etc.

While some of these functions could have been put in the two primary ressorts, the resources would have been difficult to split up and it was decided to put them together.

The split between maintenance and engineering is clearer in the electrical department, as shown in the organization chart. The electrical department works pretty much independently of the mechanical department even where they interface, such as the electrical motors of pumps, valves, and ventilators. Of course, it is important that the two departments communicate well. For I&C, much of the maintenance work is checking the chain of measurement and control functions, which can be done independently of the component itself. The installation and calibrations of sensors done by the electrical department, however, have to be coordinated with the mechanical staff. Generally, this works quite well.

During outages, when the schedules are quite tight, it is important to coordinate the activities so the resources are available to perform tasks when needed. There are coordination meetings each morning. But it is also important to keep in touch personally in the plant. "A lot is about how well people communicate with each other," said Burns.

The outage driver

While there is no outage department, there is an outage manager, Ludwig Nedelko, who runs two groups. One group plans and coordinates the maintenance activities during the outage and the other group does this for the activities during operation. It was these groups that were given the task of developing the new outage strategy. Besides sharing a manager, the groups, with a few exceptions, include the same people from each of the line organizations (electrical, mechanical, surveillance, and operations departments). The managers of the mechanical ressorts are in these groups.

The groups and the system engineers have worked together over the years to optimize the maintenance plans and, when possible, extend the intervals. The changes are reflected in the planning.

Continued

At Leibstadt, mechanics install a coupling on one of the main condensate pumps (*NN* photo by Dick Kovan)

Although the coordinating group has a vision of how long the outages will be over the next several years, their focus is on the next year's outage, whose planning commences before the present year's outage is completed. One of the first activities following the outage is to freeze the level 1 outage plan, which basically defines the critical path activities. The detailed maintenance plans for components and systems are defined by individual system engineers. This is fed back to the coordinating group, which evolves the detailed level 2 plan, an iterative process that goes on throughout the year. They make sure that the activities all fit together and meet the general strategic structure for that year's outage. As for 2003, although it is to be a "standard" outage, until the critical activities are known, it is not possible to develop the level 1 plan.

At the moment, the planning is relatively straightforward, as this is not a phase of large modifications. Of course, system problems that have to be resolved do arise. For example, there is an erosion-corrosion problem with a feedwater heater. While repairs have taken place, it has now been decided to replace the heater in the 2003 outage.

The plant is fortunate at the moment not to be under pressure to further reduce outage duration. "It is important," explained Burns, "that outages are long enough to complete the work with the required quality."

Generally, outages run pretty smoothly, measured by criteria such as: Does it get back on line as planned? Are there problems when back on line? Do problems occur that can be associated with activities that did not go correctly during the outage?

Another measure is general feedback. Leibstadt undertakes a structured feedback process at the end of the outage, when "people are fresh from the outage and make their points with the energy needed," said Burns. Each group first gets together and generates a consensus of what was good and bad, and then makes a list of necessary improvements.

On-line maintenance

One of the plant's strategic aims is to do as much maintenance as possible during plant operation. Because Leibstadt satisfies an n-2 redundancy criteria for the main safety functions, including core cooling and containment cooling, one of the plant's five divisions, with its associated diesel power supply and safety trains, can be taken out of operation at any time. Plants with only n-1 redundancy cannot take a full safety train out of service, unless they have made some other arrangements or modifications. As a result, they are more limited in terms of the amount of maintenance they can do on-line. "We do not have n-2 for all functions. For example, we cannot do on-line maintenance on scram systems except during main outages," noted Burns.

The plant is divided into basically five divisions: three main divisions of the GE design (Divisions 11, 21, 31) consisting of low-pressure core spray, low-pressure coolant injection, and high-pressure core spray systems with their associated diesel generators, and two special emergency heat removal (SEHR) divisions that provide core cooling and containment cooling with this bunkered function, each with its associated diesel.

"We can take out a single low-pressure core spray or core injection system, or either SEHR division during operation," said Burns. There is less redundancy with the high-pressure core injection systems, which can be maintained only during main annual outages.

The ability to remove a complete division has allowed the establishment of three maintenance periods: the annual outage; divisional outages; and other times. This also enables the plant to remove large peaks of work.

The scope of work on a division depends on the maintenance cycle of the individual components and any plant modifications. "If we have a plant modification in a division, we may complete it over several years, assigning a segment of work to each divisional outage. An example was MOVs, which several years ago required a number of modifications—these involved the motors, the drives, the setpoints, and mechanical components. We had a program for modifying these which was carried out during divisional outages over several years."

The divisional outages are scheduled according to the traditional yearly cycle—two divisions are done in autumn and two are done in spring. This gives a structure to the year and provides a balance of work. KKL can integrate all maintenance requirements into this general structure. "This tends to give us a year that is balanced in terms of our own resources and the work that we have to do," said Burns.

This scheme has developed over the past 15 years, and differences from year to year are very small.

Staffing issues

Leibstadt staffing is very stable. Many people have worked at the plant for a long time and built up close relationships. At the moment, the plant does not face a retirement problem, but this will change. As Burns explained, "We have a lot of people in mainte-

A general view of the refueling floor with the reactor vessel head (left) and drywell head (Source: KKL)

Retubing a heat exchanger in the turbine island closed cooling water system at Leibstadt (Source: KKL)

nance who have been there for 20 years or more and know their components inside out. These people have a lot of independence and can manage themselves. Many came from Swiss companies, like Brown Boveri and Sulzer, and were involved in construction programs around the world. When they had enough traveling, they took jobs in the nuclear plants. But many will be retiring over the next decade," he continued, "and while the plant has been able to recruit a reasonable number of young people, it is getting more difficult to find people with similar experience."

Leibstadt has not had problems with an "overtime" culture. There used to be arguments over whether some overtime work was really necessary or if the work should have been started earlier. Now, workers are required to manage their worked hours over the year, in cooperation with their supervisors. Also, annual goals are agreed and used as part of the annual assessment program. There are certain times, such as during an outage, when a lot of extra work is required. During slower times, hours can be compensated, which allows a balance to be struck. "If people are required to work on weekends, or unexpected work comes up, that is defined as overtime and earns extra pay. Only a certain number of hours can be carried over to the next year," explained Burns.

As to the work culture, noted Burns, part of the manager's job is to figure out which are the key positions within the organization and which are the key people to put in them. "We must make sure that they have clear knowledge of what is expected and what their responsibilities are and that they have the right resources, the right information, and the right environment to do their work," he said. If fully prepared and supported, they can then get on with their jobs. This leads to a motivated staff, when combined with a competitive salary structure and other related benefits.

Performance indicators

The plant makes use of a set of indicators that includes the WANO indicators to monitor performance. The statistics of on-line maintenance jobs in 2000 show that there were few unplanned work orders after 11 months, indicating that the plant is in good condition. If the number of unplanned work orders were increasing over the year, it would show that conditions were deteriorating.

KKL is working at extending the number of indicators. "We are now trying to identify the next level of indicators that reflect the quality of maintenance and operation, to pick up problems sooner—for example, if the work done during the last outage is not good or if the maintenance interval is too long," explained Burns.

Besides these indicators, the plant has initiated plant aging and risk-informed maintenance programs, which should also point the way to improved performance. Two risk-informed maintenance pilot projects are under way, one for the ISI program on the main coolant loop piping and the other on the high-pressure core spray piping. NN