Dose reduction at Leibstadt

BY SIMON RIPPON

The Leibstadt plant, in Switzerland, boasts performance indicators generally better than world averages, including a new low in 1998 for annual collective dose.

SWITZERLAND'S FIFTH AND largest nuclear power plant, at Leibstadt, broke several of its records in 1998: its highest net output, at 750 GWh; a new low in the annual collective dose which was a fraction more than 1 person-Sv (100 person-rem); a new low for radwaste volume (which includes both low-level and medium-level waste), nearly down to 4000 kg; and the plant's shortest annual outage, at 24 days. The energy availability factor was over 80 percent, as it has been for the past 10 years, and there were no reactor scrams to add to just one in the past seven years. The power station, which is equipped with a General Electric boiling water reactor, is the newest plant in Switzerland. When it began commercial operation in December 1984, it had a net output of 942 MWe. Since the mid-1980s, the plant has been uprated in stages to an output of 1080 MWe, which was authorized at the end of last year and will likely be achieved on a regular basis next spring. The plant is now supplying about one-fifth of Switzerland's electricity.

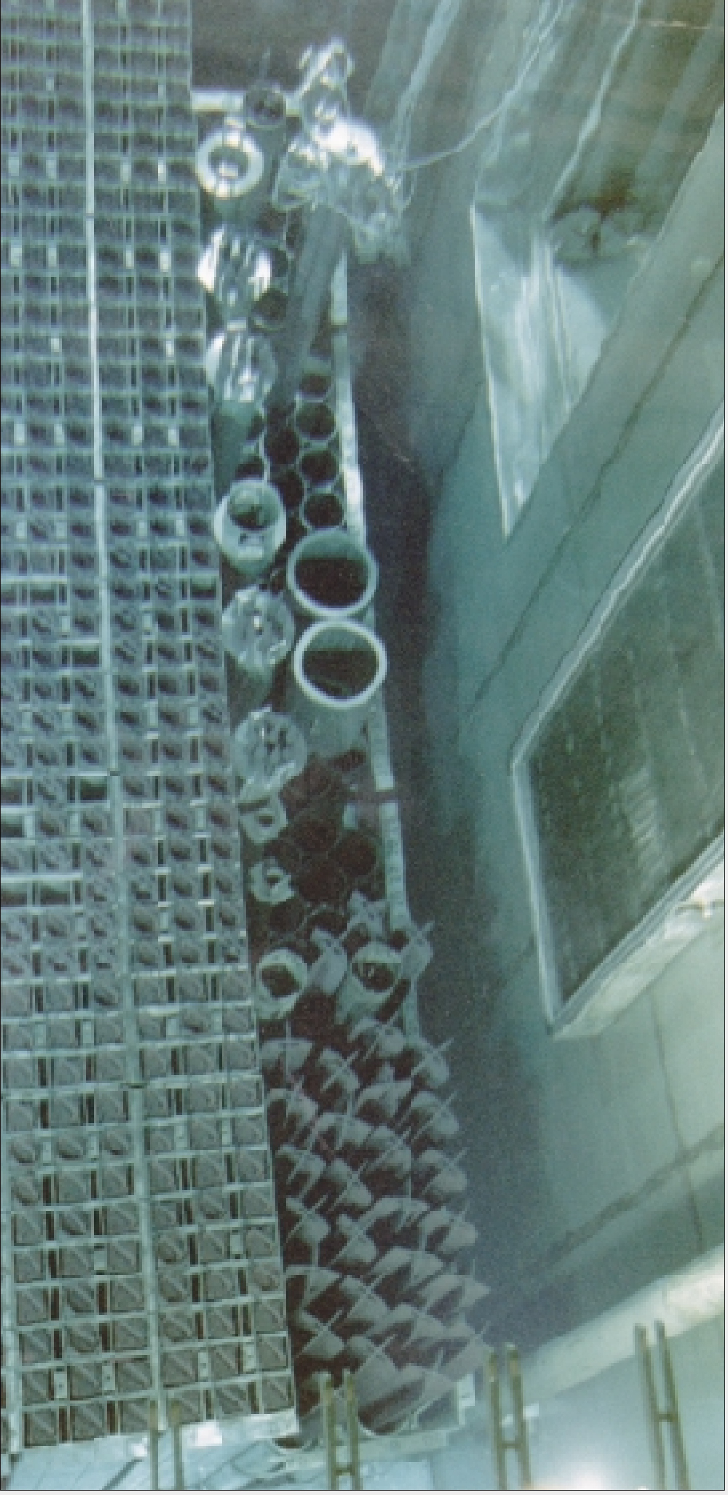
Deputy plant manager and head of radiation protection at Leibstadt is Willy Blaser. He said that the performance indicators for the plant are generally better than world averages, and, in particular, the collective doses are down to a level comparable with those of more modern designs of BWRs with in-vessel recirculation pumps. When *Nuclear News* visited the plant in late April, Blaser was preparing to host the General Electric BWR Users Group the following week. The main subject of the meeting, appropriately, was to be ALARA (as low as reasonably achievable) practices.

At Leibstadt, Blaser said, the biggest problem from the health physics point of view has been the two primary coolant recirculation loops outside the reactor pressure vessel. These recirculation loops, which drive jet pumps inside the vessel, are a feature of the relatively early BWR design that was adopted for Leibstadt when the project was in the early planning stages in the late 1960s. The pipework associated with the recirculation loops in the drywell is described by Blaser as "like a Christmas tree." In the early years, the Stellite used in valve seals and in control rod components in the high flux region above the core led to obvious problems of cobalt-60 contamination of the main coolant circuits.

In the first five years of operation—from 1985 to 1990—the dose rates measured near the recirculation piping increased rather sharply, from about 0.5 mSv/h to 3.8 mSv/h, due mainly to the buildup of Co-60 contamination. The resulting collective doses for maintenance activities increased to 3.3 person-Sv/yr, which was getting rather too close for comfort to the rather demanding limit of 4 person-Sv/yr for all operations, stipulated by the Swiss regulatory authorities (this includes a maximum guidance level of 3.8 person-Sv/yr for maintenance work).

"At the beginning of the 1990s, we started dosing (the primary coolant systems] with zinc," said Blaser, adding that "the cobalt decreased very nicely." To start with, natural zinc with a Zn-64 content of 46.6 percent was used for the dosing, but this leads to neutron activation to Zn-65, producing high-energy gamma-ray emission that is nearly as bad as that from Co-60. Later, therefore, dosing with zinc depleted to 4 percent Zn-64—and eventually to less than 1 percent—was used. This was effective in driving down the Zn-65 levels, except for a small peak when some old fuel that had seen natural zinc was reloaded into the reactor for one cycle.

Leibstadt nuclear power station in Switzerland, across the Rhine river from two small German towns. Although the plant is located at the confluence of the Rhine and Aare rivers, it was still required to have a large cooling tower (*Nuclear News* photos by Simon Rippon).



Immaculately clean water in Leibstadt's fuel storage pond allows easy visibility of stored fuel control rods.

Of course, a great deal has also been done to remove the sources of cobalt. Blaser said, "Every time we have to replace something, we take a special look to see if it sees the primary water, if it sees the vapor phase, the condensate, or the feedwater, and for these we put something in to reduce the cobalt content." Now, he said, there is no new cobalt inside the pressure vessel. In particular, the control rods have been replaced with a special alloy that is cobalt-free.

Shorter outages mean less dose

Outages for fueling, maintenance, and modifications and backfits account for most of the occupational radiation dose accumulated during the year. This is seen in the diagram of the radiation dose for the life of the plant. Leibstadt experience has also indicated that the dose accumulated during outages is closely related to the length of the outage. So shorter outages are good for dose reduction, as well as for better station performance.

All five of the Swiss nuclear power plants arrange their outages in the summer months, when plentiful electricity is usually available from the country's many hydro-power plants. Blaser noted that one nuclear plant did try going to 18-month cycles with outages in the spring and fall, but rather quickly decided that it was better to return to the one annual outage. The plants coordinate their outages, with the two largest units at Leibstadt and Gösgen more or less fixed in August and June-July, respectively, while the smaller units at Beznau and Mühleberg arrange their outages before and after.

Blaser said that currently at Leibstadt, there are no difficulties with the availability of qualified contractor personnel during the busy summer months. Typically, 700 to 800 contractor employees supplement the permanent station staff of about 400 during annual outages.

In advance of the outage, contractors have to submit special Swiss permits to the plant for individual workers to certify their qualification to enter controlled areas. The permits record individual dose records and a required yearly medical check, as well as other information such as accreditation to use respiratory equipment. On arrival, radiation workers receive a short training—or retraining—in radiation protection procedures at Leibstadt. They also undergo whole body monitoring at the beginning and end of their work at the site.

Advance planning—as all nuclear operators know—is the first priority for good outages. Radiation protection staff are closely involved with the planning. With the benefit of an increasing fund of knowledge from previous years, they are able to develop expected dose burdens for different tasks and to suggest ways that tasks may be combined to optimize dose reduction. Blaser said that this planning work will include a sort of cost-benefit analysis of the most appropriate measures to adopt for dose reduction. For example, if a number of tasks are planned around one section of the plant, it may be justified to decontaminate that section in advance. But decontamination is very expensive and tends to create additional waste, so where only one task is involved, it may be more cost-effective to install localized temporary shielding.

Preparatory training is another effective way of reducing the time taken to carry out tasks and thus to reduce doses. The Leibstadt power station was built during the era of large construction models. These models have been retained and kept up to date with all plant modifications and backfits in a special building at the site. Together with other special mock-ups, they provide an excellent facility for planning of and training for maintenance operations and modifications. Blaser said that surrogate tools are not yet being used, mainly because of the cost—both in money and dose—of retrospectively producing accurate computer-generated models of the plant. "You have to go and take a lot of pictures [inside the plant] and you spend a lot of dose doing just these things," he said. Plant staff, however, are keeping an eye on the rapid developments in this area, and they now take pictures with digital cameras whenever they are carrying out maintenance tasks in different sections of the plant.

The most important thing, however, Blaser said, is know-how from the construction of the plant. If you know how a pump, valve, or section of piping was installed in the first place, then you are better able to prepare when you have to carry out work on it.

When all the job planning and dose optimization have been completed, a chart is compiled showing the monthly goals for collective dose and a graph of the accumulation over the year. This is updated regularly with figures of the actual doses incurred. Copies of these charts—together with tables showing the dose burden expected and incurred each day for the most important current tasks—are displayed at the entrance to the plant and again at the entrance to the controlled area. The accompanying diagram shows that it is possible to see that Leibstadt got off to a good start in the first three months of 1999, with actual doses almost half the expected levels. According to Blaser, however, this is partly attributable to a temporary halt to shipments of spent fuel from the plant. The chart also highlights the dominant contribution of the annual outage in August to overall dose burden. This year the outage includes additional tests and inspections—including a three-day containment leak test—which are required by Swiss nuclear regulators at roughly five-year intervals of operation. Despite this, the plant is aiming for a new record low dose for the year of below 1 person-Sv (100 person-rem).

Monitoring and control

The Leibstadt plant is well-equipped with health physics monitoring and control equipment. Procedures require people entering the controlled area to present a job ticket with a bar code to an electronic reader along with

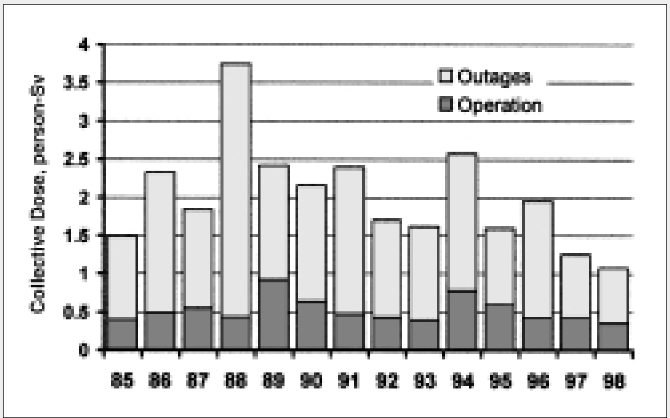


Fig. 1. Collective dose record at Leibstadt nuclear power plant

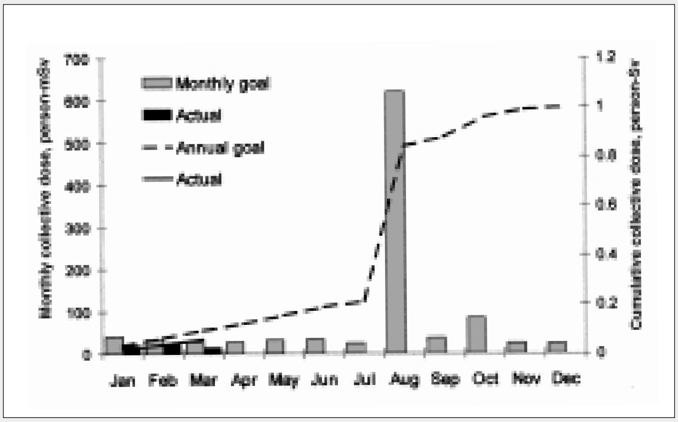


Fig. 2. Expected and actual collective doses for 1999

their personal identification and film badge packets. Electronic personal dosimeters are collected from plug-in racks at the entrance to the controlled area and deposited there on departure for automatic reading into the main health physics computer system. Normal hand, foot, and body monitoring equipment is located at the exit gates to the controlled areas. At the plant's final exit gate, a scintillation monitor located behind the screen up to which security passes are held provides a final radiation check.

Switzerland was one of the first countries to adopt legislation to enforce new individual dose limits based on the latest recommendations of the International Commission for Radiological Protection. The reduction in the individual dose limit from 50 mSv/yr to 20 mSv/yr has caused no difficulties for Leibstadt because, Blaser said, "we have no individuals above 20 mSv/yr."

Leaky fuel problems

The main operational problem encountered by the Leibstadt plant has been a rather high incidence of fuel leaks. Only one annual cycle has so far been free from fuel leaks, although Blaser was hopeful that the current cycle was going to be a clean one. On one occasion in 1994, an unplanned shutdown was necessary to deal with leaking fuel, and this is reflected in the collective dose for that year being above the general trend. The main cause of the fuel leaks is fretting corrosion. One problem, Blaser says, is that the sophisticated 10×10 fuel assemblies now in use have such small gaps between the fuel pins that they act almost like filters, trapping small particulate matter from the cooling water.

Despite the fuel leak problems, Leibstadt has been able to set operating limits for iodine-131 in the coolant water at 3.7×10^7 Bq/m^3, compared with the General Electric technical specification of 5.5×10^8 Bq/m^3. Tramp uranium—the small amounts of uranium that can get into the water and be deposited on the outside of the fuel if defects are large enough to allow wetting of the fuel pellets—is limited to 50 g, compared with the GE tech spec of 150. The generally tighter limits are imposed to help ensure that there is no possibility of exceeding boundary fence limits for radioactive releases in a densely populated country where the size of the nuclear power plant sites is somewhat restricted and areas of population are relatively close to the fences. In the case of Leibstadt, there are also two small German towns just on the opposite side of the River Rhine.

"During operation with leaking fuel, you have to have a tight plant," Blaser said. "We take a very hard look at keeping the plant tight—to have no leaking valves or tubes or whatever." The off-gas removal plant has 60 te of active charcoal in its filter, and, Blaser added, "We have really, really low release rates. We use up only a few percent of the regulatory body's boundary fence annual release limits."

Waste management

Handling operations for spent fuel and medium-level operational wastes constitute a significant contribution to radiation doses at a nuclear power station. It is no surprise that the pattern of early rise and subsequent steady reduction in medium-level operational waste volumes at Leibstadt closely match the trends in collective radiation doses over the years of plant operation.

In the first three years of operation, the volume of medium level operational wastes—mainly ion exchange resins and filters—rose to more than 18 000 kg, of which 16 000 kg was attributable to the condensate polishing plant. "We had real bad behavior," Blaser

Listening to valves at Vogtle

Inspections of 10-in. check valves are now done acoustically rather than visually at the two-unit Vogtle nuclear power plant. The valves, located in pipes that are part of the safety injection system inside reactor containment, have flappers that must open properly to allow water to flow to the reactor in the event of a loss-of-coolant accident.

The new inspection method, known as non-intrusive testing, has cut exposures to a fraction of what they used to be, according to Clark Bourne, senior nuclear specialist in health physics. For four valves acoustically inspected during Vogtle-1's most recent outage ending last March, a dose total of about 0.5 person-rem was received by workers, compared with the 8–10 person-rem for four valves that was usually received by workers when manual inspections were done, Bourne said.

Using the new method, workers prepare a valve for inspection by removing insulation covering the pipe area being worked. The exposed exterior of the valve is then spotted with acoustic sensors that have wires running out to a remotely located PC. Data are collected by the PC from signals sent by the sensors, and a technician interprets the data to determine whether a valve's flapper is opening properly. Only then, if a flapper is determined as not operating properly, would a valve be physically opened for repair. Following any repair work, the valve is again acoustically tested to make sure it is opening properly. The sensors are then removed and the insulation is reinstalled on the pipe.

Under the old method, workers had to physically disassemble each valve to perform a visual inspection to determine whether a flapper was opening properly.

"We take that acoustic data as a successful test of the valves and no longer have to manually disassemble and inspect them," Bourne said. Besides reducing exposure to workers, "it saves on time and manpower, too, compared to the hours and the number of workers it once took to visually inspect these things."

The acoustic method was first tested on the valves at Vogtle in 1996. "The first time we did it, there were some problems with our confidence in the data that was collected," Bourne said. "But since that time, we've expanded it to where we've done all of the 10-in. check valve testing, so we don't have to go into any of the valves manually."

Vogtle, located in Waynesboro, Ga., is operated by Southern Nuclear Operating Company. The two units at the site are Westinghouse pressurized water reactors and are each rated 1225-MWe (net). NN commented, because the design of the condensate polishing plant was right at the upper limit of the operational requirements. After a lot of work on the system, the upward trend in waste volume was turned around after 1986, and has since been steadily reduced to around 4000 kg.

The Leibstadt power station has its own facility to treat and store medium- and low-level wastes. This includes a plant for cementation of waste in drums. It is also possible to send combustible wastes to the nearby Würenlingen research center of the Paul Scherrer Institute, where Zwilag—a company owned by the Swiss nuclear utilities—operates a radioactive waste incinerator. Residues are returned to the power station for incorporation with other waste material in cement in storage drums. Storage capacity for the medium- and low-level waste at Leibstadt has been greatly increased, from the initial seven years of waste production to 30–35 years.

Stringent seismic regulations prohibit the holding of spent fuel in the fueling pool within the Leibstadt reactor containment during plant operation. Therefore, it has to be transferred through a chute to a large ground-level fuel storage building outside the containment. Leibstadt has some small reprocessing contracts with Cogema in France and British Nuclear Fuels plc for some tens of tonnes of spent fuel. But pending policy decisions on long-term strategy, most of the spent fuel is destined for a period of interim storage. The utility company Zwilag is close to completing a new interim cask storage facility adjacent to the Würenlingen center—about 13 km from Leibstadt—and it should be possible to start the shipment of spent fuel to that site at the end of this year or in early 2000. This will be none too soon for the Leibstadt plant, where the ponds of the fuel storage building are nearly full.

Radiation fields mapped for different floors of the turbine building are displayed in an elevator.

With the Würenlingen center nearby, and also Switzerland's first two PWR units at Beznau within sight of the steam plume from the Leibstadt cooling tower, the region at the confluence of the Aare and Rhine rivers is subject to some of the most intense environmental monitoring to be found anywhere. The remote monitoring stations operated by the three nuclear sites are linked into a wider national system covering the whole of Switzerland, and are also hooked into the radiation monitoring network of Germany on the other side of the Rhine. NN