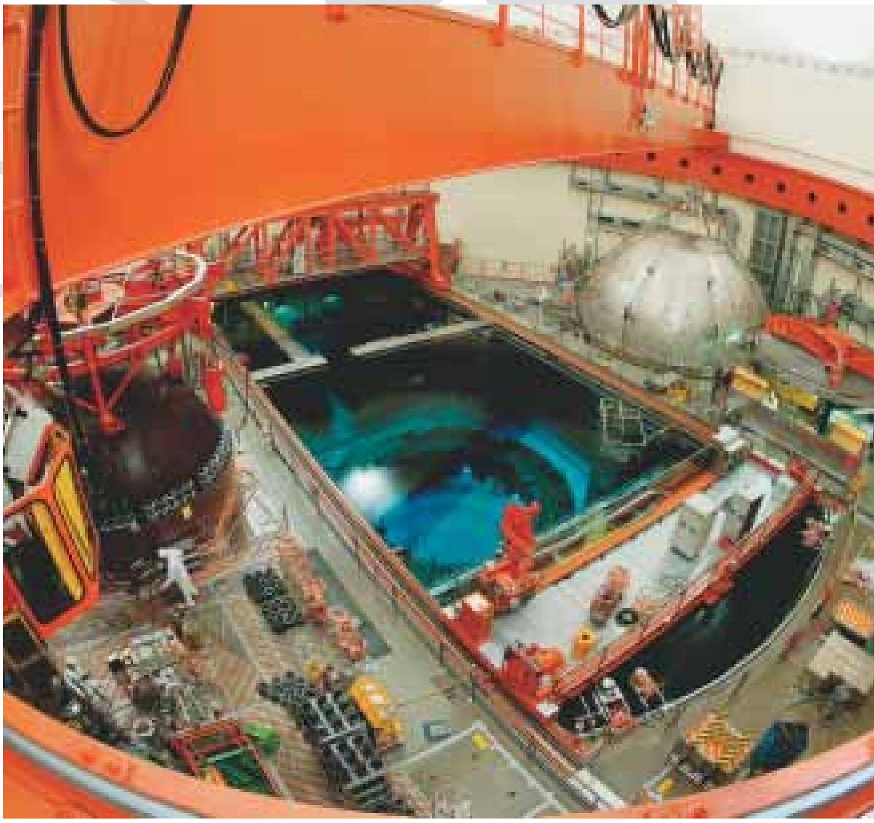
ANNUAL REPORT 2003

concerning nuclear safety and radiological protection in Swiss nuclear installations



Swiss Federal Nuclear Safety Inspectorate

Hauptabteilung für die Sicherheit der Kernanlagen

Division principale de la Sécurité des Installations Nucléaires

Divisione principale della Sicurezza degli Impianti Nucleari

ANNUAL REPORT 2003

Frontispiece
View of the opened pressure vessel of the Leibstadt nuclear power plant during inspection.

Photo: KKL

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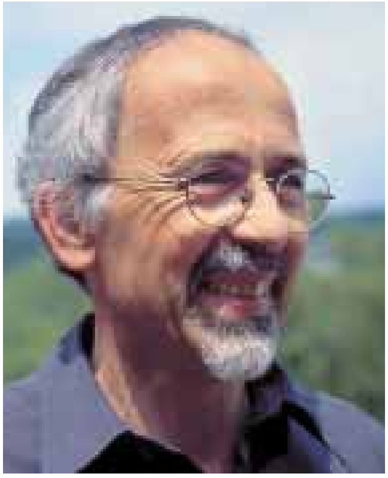
PREFACE



Supervision in a period of change

The clear decision of the Swiss people in the plebiscite of May 18th 2003 to reject a short- or medium-term exit from nuclear energy also paved the way for a new legislation on nuclear energy (KEG). The legislation, which will come into force at the beginning of 2005, provides Switzerland with a modern set of laws that set demanding standards for the safety of nuclear facilities.

Under the KEG, the safety of the nuclear facility is in the responsibility of the licensee. The Inspectorate, as the regulatory body is responsible for ensuring that a licensee exercises its responsibility in full. To discharge this responsibility it is required to conduct its own investigations and inspections and to review documents submitted so that it can arrive at an independent view on the safety of the nuclear power plant and thus assess its safety. In addition, the Inspectorate is required to provide regular information to the public on the condition and on the safety of the nuclear facilities.

There have also been developments in Europe with regard to the regulation of nuclear facilities. The European Commission has put forward directives designed to introduce primary safety requirements and a system of inspections to verify compliance. If the directives are approved, Switzerland – even if not a member of the EU – would be judged according to their contents.

The Western European Nuclear Regulators' Association (WENRA), set up in 1999 is seeking to harmonise safety standards for nuclear facilities throughout Europe. Membership of WENRA now includes countries about to join the EU such as the Czech Republic, Slovakia, Hungary, Lithuania, Slovenia as well as Bulgaria and Rumania. The safety standards cover not only the technical aspects of nuclear facilities, but also their organisation and their human resources. All members are required to demonstrate that they satisfy the criteria and standards set by WENRA. Experts from member countries carry out regular inspections in order to verify compliance with those standards and criteria. Switzerland will also be subject to these reviews and it will publish the results. We attach great importance to ensuring that the Swiss people are able to develop an understanding of the safety standards in our nuclear facilities – including the assessments of independent international experts.

The International Atomic Energy Association (IAEA) in Vienna publishes global safety standards for nuclear facilities. These standards are revised regularly to reflect developments in science and technology. The entire regulatory framework is currently undergoing comprehensive revision and expansion. The framework consists of Safety Fundamentals, Safety Requirements – subdivided into various technical and organisational areas – and operational Safety Guides. Switzerland and particularly the Inspectorate is an active contributor to the committees responsible for the drafting and revision of this framework. Each member state is required to incorporate the requirements and recommendations of the IAEA into its own binding regulatory framework.

Changes are also taking place within the nuclear facilities themselves, in particular the nuclear power plants. All Swiss nuclear power plants have introduced quality management systems that reflect current standards in the nuclear industry. Safety measures are an integral part of these systems. They ensure that the underlying conditions in these organisations allow a good safety culture to thrive.

A good safety culture is apparent from the nature and attitudes of the relevant individuals and organisations and is a culture where organisations and their personnel make safety an operational priority. The Inspectorate has stressed the importance of this issue in recent years and has published a guideline on organisational safety measures.

The Inspectorate must continuously adapt to changes in underlying conditions and standards, such as those arising from KEG and international agreements, recent developments in science and technology and the introduction of comprehensive quality management systems in nuclear power plants. This demands a flexible approach to supervision, so that a strategy that can respond quickly to changes in its environment and give safety the highest priority at all times. As part of its corporate plan for the first Management by Objectives period, the Inspectorate has produced the required framework in the form of a FLAG area (FLAG = Management by Objectives and Global Budgeting) and developed the strategy of Integrated Supervision. The core elements of this supervisory strategy are as follows:

- *Effectiveness:* The Inspectorate will implement decisions in a consistent manner, monitor their effectiveness and if necessary, take further action.
- *Balance:* The Inspectorate will take an integrated approach to the safety of a facility. In addition to deterministic and probabilistic aspects, this includes operating experience, maintenance and organisational procedures with priority always given to the important and essential issues. The Inspectorate will question, analyse and where necessary modify safety requirements and the nature and degree of monitoring.
- *Understandable:* The Inspectorate will operate a consistent, uniform supervisory concept and regulatory framework. It will base its decisions on uniform and transparent procedures. Measures that it requires to be implemented will be transparent and understandable.

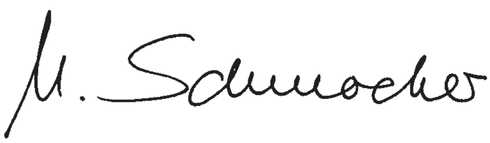
In future, the effects of our intervention will take centre stage at all levels, for the supervised, the licensing authority, parliament and the general public. To measure the effect on those affected, the Inspectorate will introduce specific indicators, which it will evaluate regularly and publish in reports.

With the introduction of Integrated Supervision, we are also seeking a new *supervisory culture*, the cornerstones of which are as follows:

- Responsibility for the safety of a nuclear facility rests with the operator of the facility and not with the supervisory body.
- The Inspectorate is responsible for ensuring that the operator actually exercises his responsibility.
- Action demanded by the Inspectorate shall improve the overall safety of a facility and not focus on individual safety issues.
- Through its supervisory activities, the Inspectorate shall encourage nuclear facilities to reflect on their own activities and to learn from them.

Integrated Supervision allows a comprehensive evaluation of the safety of a nuclear facility and creates a framework which ensures that current and future challenges are met. The Inspectorate will seek to support responsible organisations with the process of running nuclear facilities safely.

An important concern for us, both now and in the future, is to provide regular and comprehensive information on the safety of Swiss nuclear facilities that will allow recipients to understand the situation at all times. Should you require further documentation or wish to discuss an issue, we shall be pleased to hear from you. Visit our homepage at www.hsk.ch or call us.



U. Schmocker

SUMMARY

General comments on the work of the Inspectorate

Acting as a regulatory body for the Federation, the Inspectorate assesses and supervises Swiss nuclear facilities such as the individual nuclear power plants, the interim storage facilities at the individual plants, the Central Interim Storage Facility and the nuclear facilities of the Paul Scherrer Institute and two universities. The Inspectorate appraises their radiation protection and nuclear safety. With the aid of inspections, examinations and analyses together with reports by licensees, the Inspectorate obtains the necessary overview of nuclear safety. In addition, the Inspectorate monitors facilities to ensure compliance with regulations and that their operation accords to the rules. Its supervisory functions also include the transport of radioactive material and preparations for a geological repository for radioactive waste.

The Inspectorate issues guidelines as an aid to licensees. In co-operation with other federal agencies, it draws up additional rules and regulations on the use of nuclear energy, nuclear facilities, nuclear safety and radiation protection. The existing regulatory framework is reviewed regularly to ensure that it remains up to date and that it complies with other requirements. Guidelines are reviewed regularly and then updated or new guidelines issued.

In Switzerland, the Federal Council is the licensing authority for nuclear facilities. Its decisions are based primarily on reports compiled by the Inspectorate.

The Inspectorate maintains its own emergency organisation, which is an integral part of a national emergency organisation that would be activated in the event of a severe accident in a Swiss nuclear installation.

The Inspectorate provides regular information on issues relating to nuclear safety and radiation protection in Swiss nuclear facilities. It exercises this role both in times of normal operation and in the event of an incident in a Swiss nuclear facility. It seeks to provide the public with accurate, timely, transparent and understandable information. Much of this information is distributed via the media and at public events. A wide range of information is also available on its website (www.hsk.ch).

Content of the Annual Report

The main focus of the Inspectorate's activities during 2003 was again the supervision of operations and maintenance at the Beznau, Gösgen, Leibstadt and Mühleberg nuclear power plants. These activities are reported in Chapters 1–4 of this report. Chapter 5 deals with general issues relating to nuclear power plants, such as emergency preparedness and inspections.

Chapter 6 reports on the Central Interim Storage Facility "ZWILAG" at Würenlingen. ZWILAG has been storing radioactive waste from all Swiss nuclear power plants since 2001. Chapters 7 and 8 deal with the supervision of nuclear facilities at the Paul Scherrer Institute and the small research rectors at the universities of Basel and Lausanne. The transport of radioactive material from and to nuclear facilities is also subject to the supervision by the Inspectorate and is covered in Chapter 9. Chapter 10 deals with preparations associated to a geological repository for radioactive waste.

In Chapter 11, the Inspectorate discusses incidents with an impact on safety in nuclear power stations outside of Switzerland – both in terms of their relevance to safety and the lessons to be learned from them. The chapter also includes an analysis of their possible importance for the safety of Swiss nuclear facilities. Chapter 12 deals with nuclear safety research initiated, supported or monitored by the Inspectorate. Several of these projects involve international co-operation. Chapter 13 is devoted to selected international activities of the Inspectorate.

General impression of the nuclear facilities

The Inspectorate gives its overall impression of the nuclear power plants at Beznau, Mühleberg, Gösgen and Leibstadt at the end of Chapters

1–4 respectively. In general, it can confirm that the condition of all Swiss nuclear power plants in terms of their nuclear safety is good and that the required attention is paid to radiation protection. In 2003, there was general compliance with the regulations. During the year under review, the annual collective doses for personnel in all nuclear power plants were again low. This was helped by the careful planning of works in radiation fields and the use of shieldings. Release of radioactive material into the environment was significantly below the official limits. As a result, the radiation dose for the public as a whole was insignificant.

General impression of the Paul Scherrer Institute

The Inspectorate gives its overall impression of PSI East in Chapter 7. The Inspectorate is similarly responsible for the supervision of nuclear facilities on the East Site of the research institute Paul Scherrer (PSI), including the research reactor Proteus, the hot laboratory and the Federal Interim Storage Facility. Work on or in these nuclear facilities was carried out correctly and in compliance with radiation protection requirements. The annual collective dose at PSI was low. Releases of radioactive material into the environment was significantly below the official limits.

Central Interim Storage Facility, Würenlingen

The Central Interim Storage Facility of ZWILAG at Würenlingen consists of several interim storage halls, a conditioning plant and an incineration and melting plant. The storage halls have been in use since 2001. At the end of 2003, the cask storage hall contained twelve transport/storage casks containing spent fuel assemblies and vitrified residue packages plus six casks delivered during 2003 and containing decommissioning waste from the experimental nuclear power plant at Lucens. In terms of nuclear safety and radiation protection, the condition of this storage hall, the storage hall for medium-level waste and the associated reception building as well as the hot cell is good. Operation complied with regulations.

The Inspectorate granted operating approval to the conditioning plant in December 2003. However, apart from the high rack storage area, the plant is not yet in active operation. During the year, problems again arose with the inactive test phases of the incineration and melting plant and so active commissioning is further delayed.

Chapter 6 of the report deals with the Central Interim Storage Facility.

Transport of radioactive material

During the year under review, there were 15 transports of spent fuel assemblies from Swiss nuclear power plants plus one transport with vitrified high-level waste returned from France after reprocessing. In September 2003, six containers with decommissioning waste from the experimental nuclear power station at Lucens were transported to ZWILAG. All transports complied with the limits specified in the legislation on the transport of hazardous material and radiation protection requirements.

Details of these transports are contained in Chapter 9.

Preparations for a geological repository

During 2003, Nagra's exploratory boreholes at Wellenberg in the canton of Nidwalden were filled in under the supervision of the Inspectorate. Wellenberg had been proposed as a storage site for low-level and medium-level radioactive waste but in 2002 it had to be abandoned for political reasons.

Nagra continued work on its proof-of-disposal report until well into the summer 2003 with the report being submitted to the authorities in December 2002. The aim of the project is to demonstrate – using a site in the Opalinus Clay in the Zurich Weinland – that permanent and secure storage and final disposal of high-level and long-lived as well as medium-level waste is possible in Switzerland. The project is subject to comprehensive evaluation by the Inspectorate. In tandem with this work, an international group of experts is reviewing the safety analysis element of the proof of disposal.

Two information events were held on the subject of proof of disposal: One on June 6th 2003 in Marthalen for local authority representatives and the other on October 25th 2003 in Trüllikon for the public from a wide area around the Zurich Weinland on both sides of the border. In order to ensure the early involvement of Swiss and German authorities, the Swiss Federal Office of Energy (BFE), which is in charge of the procedure, has set up three committees: a political committee consisting of governmental representatives, a technical forum under the direction of the Inspectorate and a working group for information and communication.

Chapter 10 of the Annual Report deals in more detail with ongoing investigations of geological repositories for radioactive waste.

Regulatory safety research

The Inspectorate supports national and international research projects into materials, thermohydraulic issues, the interaction between man and machine, incidents and accidents and improvements to emergency and radiation projection. The associated findings serve to expand the scientific and technological expertise of the Inspectorate and so ensure a high level of safety in terms of supervision. Chapter 12 gives a brief summary of regulatory safety research projects. More detailed information is contained in the Inspectorate's report on regulatory safety research which is available on its website at www.hsk.ch.

International

The Inspectorate is an active member of international organisations where it seeks a harmonisation of the principles underlying supervision and which provide a forum for the regular exchange of information. In the course of these activities, it receives information on the regulatory framework of other countries and provides information on its own interests and expertise in Switzerland.

In 2003, the Inspectorate was involved in a range of committees and working groups within IAEA and OECD/NEA. As part of projects to assist East European countries, the Inspectorate supported the relevant governmental nuclear regulatory bodies with the completion of safety analyses and in doing so contributed indirectly to the safety of nuclear power plants of Russian design. In order to bring together the various technical co-operative projects with Central and Eastern European countries, CNS, the Center for Nuclear Safety was set up in Bratislava in 2002 with the support of DEZA (the Swiss agency for development and co-operation) and with the Inspectorate. As a regional center for the training of personnel from nuclear regulatory bodies, CENS organises workshops and trains personnel in the field of nuclear safety.

As part of bilateral agreements between Switzerland and Germany and between Switzerland and France, meetings were held with DSK, the German-Swiss commission for the safety of nuclear installations and with CFS, the Franco-Swiss commission for the safety of nuclear installations. Switzerland and Austria exchanged information on approval procedures and experience arising from the operation of nuclear facilities.

The first Review Meeting of the Joint Convention on the safety of spent fuel and radioactive waste ("Joint Convention") was held at IAEA in Vienna in November 2003. This meeting showed that the Swiss disposal programme for spent fuel and radioactive waste accords with the provisions of the Joint Convention and in some areas it is even regarded as exemplary.

The Inspectorate is also a member of WENRA (Western European Nuclear Regulators' Association). This organisation seeks to harmonise supervision and mandatory requirements in nuclear facilities. The requirements are based on the IAEA Safety Standards. WENRA intends to introduce measures designed to bring about a system of safety standards in Europe that is as uniform as possible. Chapter 13 provides more detail of the Inspectorate's international activities.

HSK

Organization Chart
January 2004

Swiss Federal Nuclear Safety Inspectorate (HSK)

Director: U. Schmocker, Dr. | 1. Deputy: H. Pfeiffer, Dr. | 2. Deputy: G. Schwarz, Dr.

Director's Secretary
Ms. A.R. Schneider

Special Tasks
P. Meyer

Division for Support, Coordination and Communication (ASKO)

Head: G. Schwarz, Dr., a.i.

Quality Management
Ms. E. Askitoglu, Dr.

Section for Human Resources and Logistics (REL)

Head:	G. Schwarz, Dr.
Finance:	Ms. M. Schwammberger
Human resources:	Ms. S. Segat
Computing and Logistics:	Head: P. Schmid

Section for Inspection Management (KAI)
Head: J. Huser

Section for Information, Safety Research and International Programs (ISI)
Head: S. Chakraborty
Information: Head: A. Treier

Division for Transport and Waste Management Safety (SITE)

Head: A. Zurkinden, Dr., a.i.

Section for Geological Disposal (GEL)
Head: J. Vigfusson, Dr., a.i.

Section for Transport and Waste Treatment (TAT)
Head: A. Zurkinden, Dr.

Division for Reactor Safety (RESI)

Head: W. van Doesburg, Dr.

Secretariat

Section for Electrical and Control Engineering (ELT)
Head: A. Turrian

Section for Mechanical and Civil Engineering (MBT)
Head: W. Pauli

Section for Prob. Safety Analysis and Accident Management (PSA)
Head: G. Schoen, Dr.

Section for Reactor, Fuel and Systems Engineering (RBS)
Head: A. Badur

Division for Radiation Protection and Emergency Preparedness (SANO)

Head: H. Pfeiffer, Dr.

Secretariat

Section for Radiation Measurement Techn. and Radioecology (MER)
Head: F. Cartier, Dr.

Section for Human and Organizational Factors (MOS)
Head: A. Frischknecht, Dr.

Section for Occupational Radiological Protection (RAS)
Head: J. Hammer, Dr.

Section for Accidents conseq. and Emergency Preparedness (SUN)
Head: M. Baggenstos

1. BEZNAU NUCLEAR POWER PLANT

1.1 Operational data and results

Beznau Nuclear Power Plant (KKB), which is owned by NOK, the Northeast Switzerland Power Company, consists of two largely identical dual-loop pressurised water reactor units (KKB 1 and KKB 2), which started operation in 1969 and 1971 respectively. Each unit has a net electrical output of 365 MW. Further details are to be found in Tables A1 and B3 of the Appendix. Figure B1 shows a functional diagram of a power plant with a pressurised water reactor. Units KKB 1 and KKB 2 achieved a load factor[1] of 95.9% and 91.4% respectively in 2003 and an availability[2] of 97.3% and 92.5% respectively. In both units, the maintenance shutdown was the main cause of downtime.

The figures for availability and load factor over the last ten years are shown in Figure A1.

Unit 1 was only shut down for a short time (approx. 10 days) similar to what had happened in 2001 with the period used mainly for refuelling.

In Unit 2, the maintenance shutdown lasted 25 days and was used for refuelling and for regular maintenance. During this period, various safety-related components and equipment was either improved or replaced.

Unit 1 experienced no unscheduled reactor scrams during the year under review. Unit 2 experienced three reactor scrams, two during functional tests and one during start-up after the maintenance shutdown at a power output of 12%. The emergency turbine trip triggered an automatic reduction in reactor power to 50%.

In 2003, the total quantity of heat output from the two units totalled 148 GWh_{th} and this was fed into REFUNA, the district-heating network for the region.

The maximum admissible coolant temperature at the condenser outlet and when discharged into the River Aare is 32 °C. If the initial temperature of the coolant is high, this can only be achieved by reducing power output. The hot weather and the resultant high temperature of the river water (maximum measured temperature: 25.6 °C) meant that power reductions of up to 15% were required in the afternoons on several days.

At 03.01 hours on 28 September 2003, one of the main power lines from Switzerland to Italy failed thus overloading all the other transmission lines between Italy and Switzerland, France, Austria and Slovenia, causing them also to fail. The power failure in Italy caused a grid fault in Switzerland and so ENL, the Swiss network regulator, ordered the Beznau nuclear power plant to reduce power to 65%. It was possible to return to full power the same day.

1.2 Plant safety

1.2.1 Particular events

The licensee reported the following notifiable events as required by Guideline R-15 of the Inspectorate ("Reporting on the operation of nuclear power plants").

In *Unit 1*, there was one Class B event as defined in Guideline R-15, which was given Level 0 on the International Nuclear Event Scale (INES) (see Appendix, Table B2):

– During commissioning of a new resin refill unit, the resin tank was connected to the gas system. On the same day, a reactor operator in the course of his regular patrol of an adjacent building noticed a significant drop in pressure in the gas system. On investigation, it was found that a small volume of residual gas had escaped through open valves into the drum preparation area and from there into the surrounding area. Based on a conservative calculation, the volume of gas released was only approximately 0.01% of the permitted maximum for short-time releases. As a result, there was no danger to the environment at any time. In response, design changes were made in order to prevent future uncontrolled releases of gas into the atmosphere.

In *Unit 2*, there were three Class B events as defined in Guideline R-15, given Level 0 on the International Nuclear Event Scale (INES):

– During collection of data on the availability of the pressure relief oil pumps required on a monthly basis, checks are made to ensure that the oil pressure required to open the main steam release valves is reached. In the test on

[1] Load factor (in %): energy produced as a proportion of rated power at 100% availability.

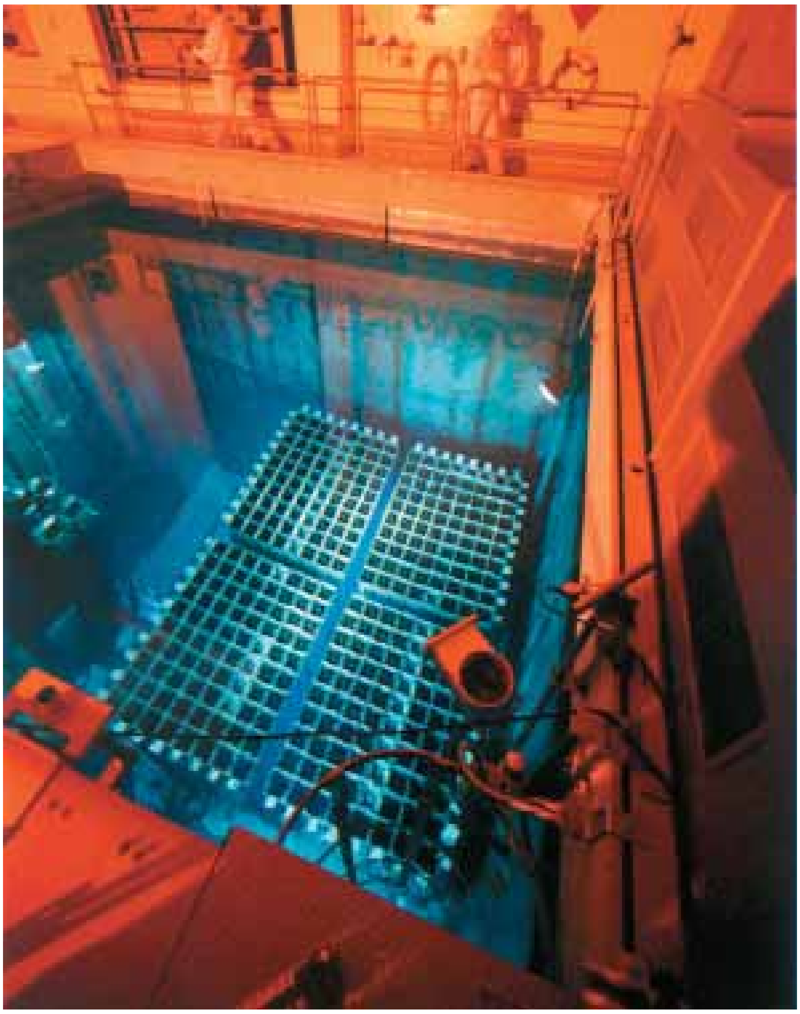
[2] Availability (in %): time for which the plant is operating or ready to operate.

29 January 2003, a malfunctioning oil pressure relief valve caused an unduly high increase in system pressure. This caused several steam relief valves to open and the system is so designed that this in turn triggers live steam isolation and a reactor scram. The plant was brought to cold stand-by status, and checks made to the relief valve oil system. Significant deposits of foreign matter were found on all of the relief valve servomotors. In addition, longitudinal grooves were found on one side of the oil pressure relief valve. The hydraulic components were cleaned, where necessary replaced and then the functionality check of the relief oil pumps was repeated, this time successfully. During the subsequent maintenance shutdown in summer 2003, the relief valve oil system was rinsed out to remove oil residues from the pipes, in particular from the backflow pipes.

– During the monthly test of the reactor trip function, trip breaker A was opened before the associated trip bypass was inserted resulting quite correctly in an immediate reactor scram. The incident involved experienced operators and the maloperation could have been avoided if operator awareness had been greater and if they had acted with greater control. In response, the test instructions were improved and the need for self-control emphasised.

– On completion of the maintenance shutdown and commissioning tests, the plant was restarted. When the first turbo generator set was put under load, the feedwater pump unexpectedly failed at a reactor power of 12% as the manual-operated valves in the line measuring the feed water flow had not been adjusted properly. It was impossible to switch to the spare feedwater pump either manually or automatically because the manostat monitoring the pump's suction pressure had failed, so cutting off the feed to the steam generators. In order to avoid a "steam generation level – low" state, i.e. a reactor safety criterion triggering an automatic reactor scram, the relevant turbo generator set was shutdown manually. However, the result was still a design-based reactor scram. After readjustment of the manual-operated valves on the feedwater flow meter and replacement of the faulty manostat, both feedwater pumps were tested successfully. As one of the measures taken in response to this incident, an additional check will be required after maintenance shutdowns and immediately before system start-up to ensure that the pressure and differential pressure monitors guarantee a safe and trouble-free operation of the plant.

View of the spent fuel pool.
Photo: KKB



The first event in Unit 2 was the result of technical deficiencies and in the case of the other two, organisational failures also played a crucial role. The events had little impact on nuclear safety. The Inspectorate verified the immediate action taken by KKB, the resultant investigations and the proposed additional measures and found them to be appropriate. In two cases, it asked for additional clarification.

Classified events over the last ten years are shown in Figure A2.

1.2.2 Work during refuelling shutdowns

Unit 1 was taken off line as scheduled on 10 June 2003 and, as had happened before, was only shut down for 10 days. This period was used primarily for refuelling purposes and the rest of the work focussed on system and component tests during the shutdown and start-up of the plant. Very few major maintenance jobs and plant modifications were carried out. Two worthy of mention were the age-related replacement of seismic instrumentation and the fitting of a new thrust bearing to the emergency feedwater pump.

Of the periodic inspections carried out, particular mention should be made to the visual examination of the head of the reactor pressure vessel and testing of seals on the containment isolation valves and air-locks. These inspections found no significant changes or defects that could have threatened the safe operation of components and systems.

The first turbo-set was synchronised with the grid on 20 June and the plant reached full load on 24 June 2003.

Unit 2 was shut down from 25 July 2003 to 19 August 2003 for regular routine work such as refuelling, electrical and mechanical inspections, non-destructive material testing, periodic functional checks of components and systems plus normal repairs and modifications. In addition to the normal maintenance work, numerous other changes were made to the system (see Chapter 1.2.3).

Details of the main periodic and non-destructive tests to containers and heat exchangers, pipes, pumps, valves and their supporting elements are given below. None produced significant findings:

– Extensive testing of the reactor pressure vessel (RPV) head: Eddy-current measurements were used for internal testing of all 36 penetrations of the RPV head at their weld joints to the head and seven penetrations at the mixed weld between pipe and flange. No findings requiring notification were found. An examination of nine head bolts similarly produced no findings requiring notification. A visual examination of the RPV-head, both at "cold shutdown" and at "pressure and temperature" with thermal insulation fitted revealed no evidence of leaks.
– For the first time, automatic ultrasonic testing was used on the mixed weld on the pressuriser surge-line nozzle and the circular welds on the surge lines. Nothing of note was found.
– Localised leak-tightness tests were conducted on the containment seals as per the Technical Specification. On the G4 ventilation penetrations, there was evidence of increased leakage rate and the valve at this penetration will be replaced during refuelling in 2004. The leakage rate did not exceed the maximum according to the Technical Specification.

Electrical equipment was tested and functional checks carried out in accordance with the periodic inspection programmes and the associated regulations, with good results. Worthy of particular note are diagnostic testing of motor drives, checks of safety settings, measurement and calibration of instrumentation and the integrated testing of reactor protection/control system, the special emergency reactor protection system and the I&C system for the emergency feedwater system.

Important preventive maintenance: the motor generator converter supplying the control rod drive mechanisms was overhauled, the control cabinets for both control rod drive mechanism converter sets were replaced as was the unit transformer on turbo-set 21, and the current transformers in the 6 kV auxiliary (internal) electricity supply system and the circuit breakers were checked. In addition, as part of the ageing monitoring programme, the entire cabling for the motor drive mechanisms on the sump recirculation pumps in the containment was replaced.

In terms of condition-related maintenance, worthy of note was the replacement of several cells in the emergency power supply batteries where acid and voltage levels had been found in discharge tests to be outside the tolerance range and the repair of a measurement channel for the hydrogen concentration in the containment.

No changes or defects were found likely to jeopardise the safe operation of components and systems.

1.2.3 Plant modifications

Since *Unit 1* was only shut down for a short period in 2003, few modifications were made:

– In both units, the existing seismic instrumentation, dating from 1977, was replaced with a new state-of-the-technology system. The new instrumentation installed during the maintenance shutdown consists of six sensors located at various places in the plant, local units and a central control cabinet located in the emergency building of Unit 2. Two of the six sensors were installed in Unit 1, two in Unit 2 and two on open ground. The installation work was carried out during the maintenance shutdowns in 2003. Acceptance tests were conducted in early September 2003 and new and old systems were then run in parallel for a set period. The Inspectorate examined the new more robust system and approved its commissioning.

- A thrust bearing with greater axial play was installed to replace the existing bearing on the emergency feedwater pump. By increasing the axial play, it was hoped to bring about a reduction in the bearing temperature, which was some 20 °C higher than the similar pump in Unit 2. However, it did not produce the desired effect and further measures will be discussed with the supplier and the pump manufacturer.

The following modifications were carried out in *Unit 2*:

- The hydrogen(H2) recombiners oxidise combustible gases (hydrogen and possibly carbon monoxide) released in a design-basis or severe accident and so convert them into steam and carbon dioxide respectively. The electrically heated active H2 recombiners installed at KKB in 1981 and 1982 respectively, are only designed for design basis accidents. However, they have now been replaced by seven significantly more powerful passive autocatalytic recombiners installed on three different levels of the containment. The catalytic reaction in the passive recombiners starts automatically even if H2 concentrations are only slight. Each recombiner contains 150 catalytic plates coated with platinum and palladium to produce the required catalytic reaction. The capacity of the recombiners is such that if a design basis accident or severe accident were to occur the volume of combustible gases released into the containment would remain at all times below the level that could be expected to trigger combustion processes that could endanger the containment.
- Modifications were made to the ventilation system to improve the removal of heat from the relay and equipment areas in Halon Zones 1–5. As a result, ambient temperatures will remain at about 22–25 °C even if external temperatures in mid summer are extremely high. This will significantly extend the service life of electrical equipment in those locations.
- The existing seismic instrumentation was replaced with a new system (see Unit 1).
- To improve fire protection in both the containment and the annulus around the containment, electrical penetrations were fitted with fire stops, the iodine filter systems were fitted with smoke detectors and the communication links for the fire service were installed and fire alarms and flame detectors in the containment have been replaced.
- A dual profiled rubber seal is fitted to the main and emergency air locks to seal off the inside of the reactor building from the outside of the lock cylinder. As replacement of the existing 30-year old seal would be difficult, a new seal was fitted in series with the existing one.
- The buckling strengths of various penetrations of the containment by process pipes were investigated. Small-diameter pipe penetrations were fitted with supports to strength them (similar to the work done on Unit 1 in 2002). This will prevent buckling of small process pipes in future when individual penetrations are tested for leaks.
- The upper seals on the thermocouple penetrations of the RPV head were replaced (similar to the work done on Unit 1 in 2002). The new, improved design will greatly reduce the time required to dismantle and reassemble the penetrations and will also significantly reduce the exposure of staff to radiation during this work.
- Work continued on the conversion of the 120 V direct current distribution system to a 4-train system involving the installation of two new sub-distribution boards with spatial separation. This improves not only distribution of the control-circuit monitoring but also the power supply to the reactor trip breaker.

1.2.4 Fuel assemblies and control rods

Neither unit experienced fuel assembly defects during the year under review.

During refuelling of Unit 1, a total of 16 new uranium oxide fuel assemblies were loaded into the core. This included eight fuel assemblies from reprocessed enriched uranium product (EUP). In the operating cycle 2003/04, the reactor core of Unit 1 contained a total of 32 uranium/plutonium mixed oxide (MOX) fuel assemblies, 24 of which were from the Belgian company Belgonucléaire and the remaining eight MOX fuel assemblies from the British company BNFL.

During the maintenance shutdown of Unit 2, a total of 24 fuel assemblies were replaced with new uranium oxide fuel assemblies, including four EUP fuel assemblies. During the operating cycle 2003/04, the reactor core in Unit 2 contained a total of 28 MOX fuel assemblies made by Belgonucléaire (12) and the French firm Cogema (16).

Investigations into the cause of damage to four defective MOX fuel assemblies supplied by BNFL (see Annual Reports 2000–2002) were concluded. The four fuel assemblies and, as a precautionary measure, the remaining eight (intact) fuel assemblies from the same consignment were removed from the core of Unit 1 in summer 2000. The investigations revealed that damage was due to temporary defects in the production process for fuel tablets. The Inspectorate verified the results of the investigation and approved the re-use of the eight intact MOX fuel assemblies as they were not affected by the production defects.

1.2.5 Inspectorate's Expertise on the application by NOK to remove the time limit on the operating licence for KKB 2

In 2003, the Inspectorate produced a report as part of its work to process the application[3] by NOK AG (Northeast Switzerland Power Company) to remove the time limit specified in the operating licence for the Beznau 2 nuclear power plant. The report is based on technical documentation submitted by NOK for the purposes of periodic safety monitoring and is an overall assessment of the plant's technical safety. This assessment is based primarily on an evaluation of plant-specific operating experience during the last ten years and the revised probabilistic safety analysis. It also reflects relevant operating experience and incidents at other power plants.

The Inspectorate concluded by stating that safety provision at the plant, both in terms of technical safety and organisational procedures, was considerable. During the last ten years, operation of the plant had been reliable and back fitting during this period had modernised and improved the plant further. An ageing monitoring programme had been introduced to ensure that age-related degradation mechanisms were systematically identified and monitored. Targeted measures had been introduced to guarantee safety and a comprehensive Quality Management System encouraged the use and development of safety-related processes on a permanent basis.

The measures called for in the report include a requirement on KKB to provide evidence documenting the high level of safety. If necessary, back fitting may be required.

The Inspectorate will present its findings in a report to be published in 2004.

View of the two units of the Beznau nuclear power plant.
Photo: KKB

1.3 Radiation protection

1.3.1 Protection of personnel

The following collective doses were measured at KKB in 2003 (figures for 2002 in brackets):

KKB 1		
Plant status	Collective dose Person-Sv	
Refuelling (2002: maintenance shutdown)	0.07	(0.37)
Power operation	0.06	(0.07)
Total annual collective dose	0.13	(0.44)

KKB 2		
Plant status	Collective dose Person-Sv	
Maintenance shutdown (2002: refuelling)	0.27	(0.09)
Power operation	0.06	(0.07)
Total annual collective dose	0.33	(0.16)

KKB 1 + 2		
Plant status	Collective dose Person-Sv	
Maintenance shutdown/ refuelling	0.34	(0.46)
Power operation	0.12	(0.13)
Total annual collective dose	0.46	(0.59)

[3] NOK Letter, Operating licence Nuclear Power Plant 2 (KKB 2), Application to remove restriction, 17th November 2000

Preparations before lifting off the head of a pressure vessel.
Photo: KKB

The implementation of an optimized shielding concept and the awareness of staff to radiation protection issues in the controlled zone meant that collective doses were low, even from the more major maintenance work during the shutdown period. The highest individual dose recorded by KKB was 9.5 mSv (11.7 mSv) and so was below the maximum of 20 mSv per year set by the Swiss Radiation Protection Order for persons occupationally exposed to radiation. Further details can be found in Tables A5–A10 and Figures A5–A8. During the period under review, there was no incidence of contamination of personnel in either Unit that could not be removed by usual means (hand washing, showering). Incorporation monitoring using the "Quick-Counter" revealed no evidence of incorporation. Continuous checks for contamination of air and surfaces revealed no unacceptable contamination in the generally accessible areas of either unit at Beznau.

In Unit 1, the installation of standard shielding to the RPV head again proved its worth. No specific work was carried out in the two lower floors of the safety building and so additional shielding was not required in those locations and the floors were sealed off. The ambient dose for the main cooling circuit components was similar to last year and continues to fall. The optimal water chemistry during plant shutdown (shutdown chemistry) again proved its worth. Using cleaning filters, it was possible to remove most of the isotope cobalt-58 (Co-58) from the primary water; this action was a response to the higher activity concentrations of previous years (see the Inspectorate's Annual Report 2002). The trend towards lower ambient doses in the primary circuit continues. There was no evidence of the spread or dispersal of contamination. The only contamination that occurred was slight air contamination when the sealing surfaces of the RPV head were cleaned with water jets. However, no special radiation protection measures were required. The ambient dose during the shutdown was low at 73 Person-mSv and so the collective dose at 92 Person-mSv was significantly below that scheduled for the shutdown period. The collective dose resulting from the replacement of undamaged fuel assemblies was low at 35 person-mSv.

In Unit 2, the collective dose during the shutdown was 267 Person-mSv, which was slightly below the collective dose of 286 Person-mSv scheduled for the shutdown. The ambient doses in the plant were similar to last year with the downward trend continuing. A total of 48 tonnes of lead was used for the shielding. It was also possible to dispense with some of the standard shielding measures in Unit 2 because no maintenance work was planned in one sector of the basement. Admission to the sealed area was subject to prior discussion with radiation protection staff.

The Inspectorate conducted numerous inspections (including one unannounced) and is satisfied that both KKB Units apply modern and effective radiation protection practices.

1.3.2 Releases into the environment and direct radiation

Table A4a shows the limit values for releases of radioactive substances from KKB, releases in the year 2003 and doses calculated in accordance with the Inspectorate's Guideline R-41 for individuals in the vicinity. Radioactive releases by way of the exhaust stack in the form of aerosols, iodine and noble gases were well below the limits specified in the operating licence and the same applied to wastewater releases excluding tritium. Tritium releases from KKB were approximately 16% (2002: 14%) of the annual limit and this is typical of pressurised water reactors. Table A4b shows the releases of noble gases and iodine via the exhaust stack and of tritium and other radioactive materials in waste water during the last five years. Releases of less than 0.1% of the specified limits are not shown.

The yearly dose for individual members of the public in the vicinity of KKB is calculated, assuming unfavourable circumstances, from the quantity of radioactive substances actually released by way of the stack and in wastewater. At approximately 0.0013 mSv for adults and 0.0022 mSv for infants, it is well below the source-related guidance value of 0.3 mSv per year contained in the revised Guideline R-11. The dose stems primarily from the release of carbon 14 (C-14). This nuclide occurs in the reactor when nitrogen, carbon and oxygen react with the neutrons. As in previous years, the C-14 releases from KKB used for calculating exposure rates are based on empirical evidence (see also Chapter 1.3.3). Articles 5 and 6 of the Swiss Radiation Protection Order state that activities resulting in an effective dose for the relevant persons of less than 0.01 mSv per year are deemed justified and optimised. That means that under radiation protection legislation no further action is required to reduce radioactive releases and the resulting dose for the population. However, in order to reflect the international PARCOM recommendation 91/4, which is designed to reduce radiation reaching the North Sea and its feeder rivers, KKB intensified its efforts during the year to reduce liquid releases into the River Aare. As a result, liquid radioactive releases excluding tritium were down some 50% on 2002 levels.

The dose-rate monitoring network (MADUK) operated by the Inspectorate in the vicinity of the plant produced no increased readings caused by operation of the plant (see Figure A10). The thermoluminescent dosimeters (TLD), which are used to measure dosage at several points along the perimeter fence, showed no significant increase over and above background radiation. Similarly, the backup control measurements performed quarterly by the Inspectorate at the perimeter fence detected no significant increases. Moreover, KKB did not exceed the emission limits for direct radiation outside the site as specified in Article 102.3 of the Swiss Radiation Protection Order, i.e. 1 mSv per year for residential, recreational and work premises and 5 mSv per year for other areas.

1.3.3 Radiation protection instrumentation

The Inspectorate used a system of random sampling to check instruments designed to measure activity and radiation levels in the plant, radiation releases into the environment and also personnel monitors and personnel dosimetry systems. Based on the records and documentation of the licensee and its own checks of the plant, the Inspectorate is satisfied that instrumentation is regularly tested by plant personnel as required and is in good working order.

As planned, an additional sampling point started trial operations at KKB I at the start of the year. It is designed to provide systematic measurements of tritium and radiocarbon (C-14) releases in the plume. The evidence from this sampling point will allow verification of the assumed releases of radiocarbon C-14 and tritium. During the commissioning and trial phase, it was established that further improvements would be required on the sampling equipment. As a result, the C-14 dose is based – as in previous years – on empirical evidence rather than actual measurements.

In addition, certain measuring systems are checked annually as part of comparative measurements involving other national laboratories and calibration services:

- The quarterly control measurements by the Inspectorate and the half-yearly comparative measurements by the Section for Radiation Monitoring in Freiburg (SUeR) of aerosols and iodine filters together with waste water sampling produced results very similar to those obtained by KKB.
- As usual, the dosimetry department at KKB took part in the comparative measurements for personnel dosimetry departments, which are organised annually by the Swiss Federal Office of Public Health (BAG) and the Inspectorate and which are required under the terms of the plant's operating approval. The KKB dosimetry department overestimated the dose at the reference point by some 14% and

so the result was outside the required measuring accuracy of ±10%. The Inspectorate did not ask for an immediate verification and recalibration of the existing personnel dosimetry system because the dosimetry system currently in use at KKB is due for replacement during the first half of 2004 and so new approval will be required in any case. In addition, the existing calibration of the system may well result in a slight overestimate of an individual's cumulative dose.

1.4 Personnel and organisation

1.4.1 Organisation and operational management

KKB created two new departments at the beginning of 2003. The Plant Security Division was split into two departments, Guards and Plant Security encompassing safety at work, fire protection including the fire brigade and the higher prioritised technical aspects of safety. The number of employees at the end of the year was 497 (2002: 481).

Each year, the Inspectorate meets with the director and senior managers of each nuclear power plant in Switzerland. These management meetings focus on the annual objectives of the plant, organisational changes, major projects and also financial issues, such as the impact of a changing electricity market on the operation of nuclear power plants. KKB indicated that it would like to continue producing electricity at both units. This will secure jobs at Beznau and allow it to hold its own in the electricity market of the future. According to KKB, this will demand a high level of plant safety, high quality workmanship, lower radiation, few industrial accidents, a high level of training and a good image.

The NOK Business Group "Nuclear Energy", of which KKB is a part, has created an integrated management system, which covers all aspects of the operation of the power plant: quality management, environmental management, safety at work and finance. In April 2003 following an audit by the company SQS lasting several days, NOK was awarded a certificate confirming compliance with the quality management aspects of ISO-9001:2000. Although the certificate guarantees compliance with ISO-9001:2000 requirements it does not necessarily guarantee compliance with nuclear safety provisions such as those in IAEA documents (Safety Series 50-C/SG-Q, Quality Assurance). For that reason, the Inspectorate will continue to monitor certain processes within the management system, both with regard to IAEA quality management parameters and the expectations formulated by the Inspectorate in Guideline HSK-R-17 (Organisation of nuclear power plants).

As part of its assessment of the periodic safety review carried out by KKB, the Inspectorate looked at the measures introduced by KKB to promote a suitable safety culture. The approach adopted by KKB is that it does not separate safety from other corporate objectives but maintains it as part of its integrated management system. The Inspectorate endorses this approach to safety, which also accords with the ideas of the IAEA (INSAG-13).

KKB has repeatedly submitted applications to the Inspectorate for Technical Specification purposes seeking approval for the short-term delays to work. This is work that can only be done when the plant is in a certain status. After careful investigation, the Inspectorate approved these applications but at the same time made it clear that this work must be planned sufficiently in advance in future so that it can be carried out when the plant is in the appropriate state.

1.4.2 Personnel and training

Operating staff subject to compulsory licensing receive basic and development training. This consists of an initial training in a specific plant operation, regular refresher courses to maintain skills and training associated with plant development and changes in the regulatory framework. The training of shift teams includes simulator training in the USA focussing on the control of operational transients and accidents, the organisation of co-operation between individual shift members, operating techniques and procedures relating to alarms and regulations. During the year under review, main points of training included aspects concerning steam generator tube rupture and other operating malfunctions. Shift leaders were given the opportunity to hone their management skills in a management seminar run jointly with other Swiss nuclear power plants. A special course was run shortly before the annual maintenance period so that staff could practise the refuelling shutdown scheduled for 2003 on the plant's own compact simulator.

The Inspectorate conducted thorough checks of procedures used by KKB to select new operating personnel and staff given additional training to equip them for more senior functions and monitored the periodic re-examination of licensed personnel. In addition, it examined the training programme and the advanced compact simulator course covering the operation of computer-aided emergency regulations.

As part of an IAEA project, the Inspectorate reviewed the policies introduced by KKB to retain knowledge skills and how they are transfered to new staff. KKB has a long-term plan for the early replacement of personnel due to retire and effective mechanisms for the transfer of knowledge and skills. In the last few years, KKB has successfully managed its first change of generations.

Two picket engineers and one shift leader passed their licence examinations during the year, under the supervision of the Inspectorate. Six members of the KKB staff passed the exams at the end of the Basic Nuclear Technology Course at the PSI Technician School, again under the supervision of the Inspectorate. The training and compulsory licensing of operating staff is based on the Inspectorate's Guideline R-27. The number of licensed personnel is shown in Table A2.

1.5 Overall judgement of the Inspectorate

The Beznau plant is in a good state with regard to nuclear safety, radiation protection and operational management.

During the year, there were four classified events, one of which was attributable to technical deficiencies and in the other three, organisational deficiencies also played a major role. The events had no detrimental effect on plant safety or on the protection of personnel and the public against radiation. The Inspectorate verified the immediate measures introduced by KKB, its investigations and the additional measures that it has proposed. It found them to be appropriate. In two cases, it asked for further clarification.

In 2001, Unit 1 was only shut down for some 10 days with the period being used primarily for refuelling

In Unit 2, the shutdown for refuelling and maintenance lasted about 25 days.

Both maintenance shutdowns were professionally planned and carried out. Various safety-related components and equipment were either improved or replaced. The results from both units of tests and functional checks of electrical equipment carried out in compliance with the in-service inspection programme and the associated regulations were extremely good. A total of seven passive autocatalytic hydrogen recombiners were fitted to mitigate the effects of severe accidents. These recombiners oxidise inflammable hydrogen resulting from a serious accident turning it into harmless steam. In addition, the system that removes heat from relay and equipment rooms in the halon zones was improved and additional fire protection measures introduced in the containment and the ring room. Mention should also be made of the age-related replacement of seismic instrumentation.

As part of its supervisory functions, the Inspectorate carried out some 75 inspections during the year. Particular attention was given to operational issues, radiation protection and maintenance and upgrade work in Unit 2. The licensee was advised of the Inspectorate's findings and carried out the required improvements. The Inspectorate identified no deficiencies in safety engineering that could have called into question the safe operation of the plant.

The basic and development training of operating personnel subject to compulsory licensing was thorough and well structured. The training focussed particularly on safety-related issues. KKB conducts a detailed assessment of reactor operators, shift leaders and picket engineers every two years using sophisticated simulator training so ensuring that the plant is op-

Transport of the pressure vessel head to its parking position.
Photo: KKB

erated solely by competent personnel with good team-working skills. From results gained by staff completing the Basic Nuclear Energy Course and the licensing exams it was clear to the Inspectorate that personnel subject to compulsory licensing had the required expertise.

As a result of its integrated management system, KKB has a good safety management system with the required priority being given to safety in all operating states.

The Inspectorate expressed some concern at decisions to delay work until the plant was in a different state, as the Technical Specification stipulates that such work may only be done when the plant is in a specific state. The Inspectorate approved each of the applications after careful vetting but at the same time made it clear that such work must be planned in good time in future so that it can be carried out when the plant is in the required state.

In terms of operational radiation protection, both routine work and work associated with the required in-service inspections of systems of relevance to nuclear safety were successful. Releases of radioactive substances into the environment were significantly below the statutory limits. As a result, the public's exposure to radiation compared with levels of exposure from naturally occurring radiation was insignificant.

2. MÜHLEBERG NUCLEAR POWER PLANT

2.1 Operational data and results

The Mühleberg Nuclear Power Plant (KKM) owned by the Bernische Kraftwerke BKW FMB Energie AG, started commercial operations in 1972. It has a boiling water reactor with a net electrical output of 355 MW. More details about the plant can be found in Tables A1 and B3 of the Appendix; Figure B2 shows a functional diagram of a boiling water reactor.

In 2003, the Mühleberg nuclear power plant achieved a load factor of 88.2% and an availability of 91.7%. Maintenance work, including refuelling, lasted 23 days and was the main reason for the lost availability.

Availability and load factors are shown in Figure A1.

Thermal energy of 1.9 GWh was supplied to heat the "Steinriesel" residential area.

In addition to scheduled periodic inspections, the reactor was shut down on two other occasions, an unscheduled shutdown following a leak in a feed water line and a scheduled shutdown to replace a mechanical seal on a recirculation pump and at the same time to locate and repair a leak resulting from a cracked nozzle on the return of the hydraulic control rod drive to the reactor pressure vessel. Neither event affected the safety of the plant.

When the plant was restarted after the maintenance shutdown, the reactor had to be shut down manually because of a loss of the heat sink. Similarly, this shutdown had no effect on the safety of the plant.

Plant power had to be reduced on several very hot days in summer 2003 in order to comply with the requirements of the cantonal cooling water licence; coolant temperature exiting the condenser and entering the River Aare must not exceed 33 °C.

Following the failure of the main power lines to Italy on 28 September 2003, and after consulting the load control centre, output was briefly reduced to 90% in order to maintain grid stability and security of supply.

2.2 Plant safety

2.2.1 Particular events

During the year, there were four events of Class B according to Guideline R-15, "Reporting on the operation of nuclear power plants", approximate to Level 0 on the International Nuclear Event Scale (INES) (see Appendix, Table B2).

In each case, it involved a fault that required a shutdown of the plant in order to remove it.

At the beginning of February during an inspection of the plant, steam was found to be leaking from the steam tunnel area in the turbine hall. A leak was located on the flow meter for the feed water line A. As it was not possible to isolate the location, the plant was shutdown in a hot standby state for repair purposes. The cause of the leak was found to be a crack in a superfluous pressure gauge connection on the orifice plate housing. To remedy the problem, the superfluous pressure gauge connection was screwed to the orifice plate housing using a dummy plug and then welded.

At the beginning of March, instrumentation monitoring the reactor water recirculation pump B indicated a slow deterioration in the efficiency of the mechanical seal. The temperature at the seal increased to a high level and so the plant was shutdown to replace the seal. The

Booster pumps of the auxiliary cooling system.
Photo: KKM

One of three feedwater pumps in the turbine building.
Photo: KKM

faulty seal was replaced and sent to the manufacturer for examination.

The occasion of the interim shutdown to replace the mechanical seal on the circulating pump was used to locate the source of water accumulation in the drywell sump identified in mid 2002. With the plant in a hot shutdown state, it was found that the water was leaking in the region of nozzle N9 (return of control rod water to the reactor pressure vessel). An investigation revealed fatigue cracks in the region of the connecting pipe of nozzle N9 caused by thermal cycles. A special welding process (overlay welding) was used to repair the cracks. To avoid thermal cycles in future, changes were made to the operation of the control rod return system. The Inspectorate has asked KKM to devise alternative ways to return the control rod water to the primary system.

During the annual maintenance period, both turbine groups were exchanged in preparation for the replacement of the pressurized controllers of the electro-hydraulic transformer for the position and speed controller. During work to adjust and optimise the new control parameters, the turbine's automatic mechanism briefly lost its speed signal and this automatically interrupted the vacuum in the turbine condenser. At the time this happened, the vacuum in the second turbine set had not yet been re-established and so the main heat sink was lost. As a result and in compliance with the "Loss of Heat Sink" operating instructions, it was necessary to introduce a manual shutdown of the reactor in order to avoid a large pressure transient.

The first three shutdowns were due to technical defects and the fourth a lack of co-ordination between the companies involved in the tests.

The classified events over the last ten years are shown in Figure A2.

2.2.2 Work during the refuelling shutdown

The plant was shutdown for maintenance on 10 August 2003 and the outage lasted 23 days. During this time, routine work was carried out, e.g. refuelling, electrical and mechanical inspections, non-destructive testing of materials, periodic testing of component and system functionality together with other repair and modification work. On completion of the maintenance, the plant was restarted on 1 September 2003. The following safety-related work is worthy of mention:

Testing of the reactor pressure vessel (RPV) and its internals: On the core shroud, the known crack zones on horizontal welds Nos. 4 and 11 underwent ultrasonic and eddy-current testing. It was found that – viewed as a whole and for the period since 1993 – the rate of crack growth is more or less equal to the long-term average. Overall, the existing cracks in the core shroud had no detrimental effect on safety during the 32nd operating cycle. Testing of selected longitudinal welds on the core shroud, a tie-rod and other core internals revealed no defects whatsoever.

In order to prevent the development of new cracks and reduce the rate of growth of existing ones, noble metals (Pt and Rh) in a complex chemical formula were added on a one-off basis shortly before the annual inspection in 2000. In addition, since November 2000 a small amount of hydrogen has been injected continuously into the reactor circuit. However, the resultant change in the water chemistry indicates that these measures have so far had no discernible effect on crack growth. As a result, the Inspectorate has demanded verification of the integrity of the core shroud modification and information on the further measures proposed in order to stem further growth of the stress crack corrosion of core internals.

Testing of pressurized components in the RPV: Ultrasonic tests, combined in some cases with other test procedures were conducted on two feed water nozzles, one core spray nozzle, one head spray nozzle, one main steam nozzle and six control rod penetrations. No notifiable results were identified in these areas.

Testing of piping: Material testing of piping system welds in the areas of Safety Classes 1 and 2 revealed nothing of an unacceptable nature.

Testing of electrical equipment: The annual testing of battery capacity in certain trains showed that the batteries were in excellent condition. The SUSAN instrumentation & control system and the reactor protection system also underwent testing and no problems were identified. Similarly, testing of transformer protection relays and the power rectifiers and inverters in the station's own power supply revealed nothing of an unacceptable nature.

Overall, the tests conducted this year confirmed the sound state of the mechanical and electrical systems.

Work during the shutdown was planned and executed to the customary high standards and in compliance with the regulations on radiological protection.

2.2.3 Plant modifications

Of the modifications and work in advance of future scheduled modifications carried out during the year, the following are worthy of mention:

Modifications to valves in the Shutdown and Torus Cooling System (STCS): To increase operating safety, the internal isolation valves in the STCS were fitted with housing pressure relief mechanisms.

Core spray lines A and B: In order to prevent a theoretical rupture at both ends of the spray lines causing damage to other components, in particular the drywell wall, the spray lines were fitted with pipe-whip restraints.

Shut-off valves in the Torus Cooling System (TCS): If only one train of the TCS is operating, it is essential that water does not reach the train that is not in operation. To prevent this happening, new non-return shut-off valves were fitted between the two trains to replace the existing shut-off valves.

Replacement of pressure regulator: In preparation for the replacement of the pressure regulator scheduled for 2004, both turbo sets were fitted with new converters to replace the existing electro-hydraulic converters on the speed control mechanism.

Back-fitting of alarms: A signal denoting "oil level high" in the diesel crankcase was added to the collective alarm "diesel mechanical fault" in the emergency diesel generator 90.

Cement Volume Reduction System (CVRS): The supplier of the current I&C system is no longer in existence and so it was necessary to find a new supplier. A new I&C system was fitted, thus guaranteeing future software support and hardware supply.

Condensate polishing system: a new user-programmable electronic control system was fitted to replace the existing conventional I&C system in turbine group A (relay system). At the same time, electronic transmitters were fitted to replace the pressure/differential pressure switches and the pneumatic transmitters.

2.2.4 Fuel assemblies and control rods

As a result of low activity concentrations in the reactor water and off gases from turbine condensers, it was concluded that no fuel cladding damage had occurred prior to the 2003 refuelling. For the 31st cycle (2003/04), 40 of the 240 fuel assemblies were replaced with new assemblies with their rods in a 10 × 10 configuration.

In order to test the operating behaviour of fuel assemblies in the event of a higher burn-up and the effect on fuel rods of adding noble metals to the reactor water, nine fuel assemblies with differing lengths of service were inspected during the maintenance shutdown with the aid of an underwater video camera. In addition, dimensional and oxide thickness measurements were conducted on four of these assemblies. All the fuel assemblies examined were found to be in good condition.

During the maintenance shutdown in 2003, new control rods were fitted to replace four that had been used up.

2.2.5 Periodic Safety Review – Pending List

In order to monitor the implementation of improvements specified by the Inspectorate following the Periodic Safety Review (PSR) in 2002, the Inspectorate has drawn up a Pending List. KKM completed the associated work on time and in full and has now dealt with 25% of the work specified in the Pending List, of which the most important were as follows:

- The number of radiation protection specialists has been increased in accordance with the Inspectorate's requirements.
- Zone plans for the controlled zones have been completed in accordance with Guideline R-07 and brought up to date.
- KKM submitted a long-term programme for the additional monitoring of thermal and neutron embrittlement in the RPV and it was approved by the Inspectorate. Work to imple-

ment this concept will start during the annual maintenance period in 2004 with the introduction of a fourth irradiation capsule.

– Modifications to the Technical Specification of the control rod drive system: This consisted of changes to the charging water pressure and gas pressure in the control rod scram accumulators and their alarm limits together with time limits on the operation of the plant following the failure of cooling water systems for the purposes of decay heat removal using the Torus Cooling System and the Shutdown and Torus Cooling System.
– As part of improvements to the radiation protection instruments, four new monitors were fitted to monitor radioactive aerosols in the ambient air.
– Phase 1 of work to replace the instrumentation for monitoring the exhaust plume to +90 m was completed.

Work on a further 35% of the Pending List was carried out as scheduled by the end of 2003. Details are with the Inspectorate for verification. The remaining work on the Pending List will be completed in accordance with the timetable specified by the Inspectorate.

2.3 Radiation protection

2.3.1 Protection of personnel

The collective doses measured at KKM in the calendar year 2003 (figures for 2002 in brackets) were as follows:

Plant status	Collective dose Person-Sv	
Maintenance shutdown	0.70	(0.52)
Power operation	0.37	(0.43)
Intermediate shutdown	0.06	(zero)
Total annual collective dose	1.13	(0.95)

The higher collective dose during the maintenance shutdown was the result of higher volumes of work in the drywell, including more in-service inspections. In addition, higher doses were recorded during the repairs that followed two of the reactor shutdowns (see Chapter 2.2.1) and this also had an impact on the total annual collective dose.

Despite the higher dose rate in the drywell, the collective dose of 0.76 Person-Sv estimated

Inspectorate employees inspecting the monitoring of discharged air in the stack.
Photo: KKM

for the 2003 maintenance period was only slightly exceeded showing that radiation protection measures were effective during this period.

The highest recorded individual dose was 13.1 mSv (11.2 mSv), which is still below the dose limit of 20 mSv per year set by the Radiation Protection Order for people occupationally exposed to radiation. Further details are contained in Tables A5–A10 and Figures A5–A8.

The incidence of personal contamination that could be remedied by the usual means, e.g. washing of hands and showering was slightly up on last year. However, there was no incidence of contamination that could not be remedied easily. Incorporation monitoring, using personnel screening monitors, indicated no evidence of incorporation.

There were no examples of unacceptable contamination in the plant. Evidence for this is provided by regular control measurements of air and surface probes.

The dose rate in the middle of the RPV closure head was up some 13% on last year and the average dose rate at recirculation loops up some 20% (3.86 mSv/h in 2003 compared with 3.19 mSv/h in 2002). The average dose rate in other parts of the plant (steam dryer, water separator) also increased slightly. The nuclide-specific measurements of contamination in the recirculation loops indicate that the build-up in activity and the associated dose rate is caused primarily by nuclide cobalt 60 (Co-60). Since 2000, Hydrogen Water Chemistry (HWC) with Noble Metal Chemical Addition (NMCA) has been used to reduce the incidence of stress corrosion cracking. This has resulted in the formation and deposition of activated corrosion products, in particular Co-60. From the initial decrease and the subsequent increase in Co-60 deposits, it is clear that the characteristics and structure of the surface layers of components are still not in balance and this impacts on the dose rates from these components.

The Inspectorate carried out numerous inspections and as a result can confirm that KKM has a modern and effective system of radiation protection.

2.3.2 Releases into the environment and direct radiation

Table A4a shows the prescribed limits for the release of radioactive substances from KKM, the releases over the year 2003 and the resultant doses for individuals in the vicinity calculated in accordance with the Guideline R-41. The radioactive releases via the exhaust-gas system in the form of aerosols, iodine and noble gases were well below the limits specified in the operating licence. This also applied to wastewater releases for tritium and other radioactive releases. Table A4b shows the release of noble gases and iodine via the exhaust-gas system and the releases of tritium and other radioactive materials via the wastewater system over the past five years. Details of releases of less than 0.1% of specified limits are not shown.

The annual dose for individual members of the public in the vicinity of KKM is based on a set of unfavourable assumptions and is calculated from actual releases of radioactive substances by way of the exhaust gas and waste water. Taking account of ground deposits of radioactive aerosols resulting from a release in 1986, this dose is approximately 0.0055 mSv for adults and 0.0053 mSv for infants and so is well below the source-related guideline dose of 0.3 mSv per year given in the Inspectorate's revised Guideline R-11. The dose rate based on releases in 2003 is 0.001 mSv for both adults and infants. The dose is primarily the result of releases of carbon 14 (C-14). This nuclide is formed in the reactor when nitrogen, carbon and oxygen react with neutrons. The calculation of C-14 releases from KKM during 2003 continues to be based on empirical figures (see also Chapter 2.3.3). Articles 5 and 6 of the Radiation Protection Order, state that activities resulting in an effective dose of less than 0.01 mSv per year for the people concerned are deemed in all cases justified and optimised. This means that, based on current legislation on radiation protection there is no need for further efforts to reduce radioactive releases and the resultant dose for the population. However, in order to take account of the international PARCOM Recommendation 91/4, the aim of which is to reduce radioactive discharges into the North Sea and its feeder streams, KKM intensified its efforts during the year to reduce liquid releases into the River Aare. This resulted in a reduction in liquid radioactive releases to about two-thirds compared with last year.

The dose rate monitoring network (MADUK) operated by the Inspectorate in the vicinity of KKM showed no elevated values caused by reactor operation (see Figure A10). In the vicinity of a boiling-water reactor, local dose rates are higher because there is direct and diffuse radiation from the turbine halls. Measurements recorded quarterly by the Inspectorate along the perimeter fence showed no significant change compared with last year. Evaluation by KKM of the thermoluminescent dosimeters (TLD) located at several points along the fence showed a maximum value in 2003 of 2.4 mSv, which included natural background radiation of approx. 0.75 mSv. Similarly, the annual emission limit of 1 mSv for direct radiation in residential, recreational and working locations outside sites and the annual emission limit of 5 mSv for other areas as specified in Article 102 Paragraph 3 of the Radiation Protection Order were not exceed during the year under review.

2.3.3 Radiation protection instrumentation

The Inspectorate uses a system of random sampling to check instruments for monitoring activity and radiation levels in the plant and radiation releases into the environment together with personnel monitors and personnel dosimetry systems. On the basis of the licensee's test records and documents and its own checks at the plant, the Inspectorate is satisfied that instruments are tested regularly by plant personnel as specified and are in good working order.

During the year and as planned, KKM installed a sampling system to measure the releases of tritium and radiocarbon in the exhaust plume. The system is designed to verify and monitor the C-14 and tritium releases that are assumed for the purpose of dose rate calculations. However, during the commissioning/trial phase, it was found that the test apparatus required further adjustment. As a result the dose rate for C-14 is based, as in previous years, on empirical values rather than actual test results.

In addition to controls by the Inspectorate, selected measuring systems are checked each year in the course of comparative measures involving various national laboratories and measuring stations:

- In general, the quarterly comparative measurements on aerosol and iodine filters and on stack-gas and wastewater samples showed a satisfactory correlation between the Inspectorate's readings and the plant's own readings. However in the case of a few random samples, the readings recorded by KKM for individual nuclides and those recorded by the Inspectorate differed by an amount outside the specified test tolerances. The Inspectorate has sought clarification and this is being actively pursued.
- As required under its operating approval, the KKM Dosimetry Department again participated in the annual comparison measurements for personnel dosimetry departments organised jointly by the Swiss Federal Office of Public Health and the Inspectorate and furnished proof of the required measuring accuracy at the reference point of ±10%.

2.4 Personnel and organisation

2.4.1 Organisation and operational management

There were no major organisational changes at KKM during the year. KKM had a workforce at the end of 2003 of 305 persons (2002: 295).

During the year, the KKM Management and the Inspectorate held their annual meetings to discuss issues ranging from the generic aspects of major projects to the strategy, objectives and development plans associated with investment in nuclear safety. KKM indicated that its objective is to generate electricity in a safe, reliable, non-polluting and commercial manner for as long as possible. It further indicated that it can only achieve this objective if it has good, well-educated personnel with the requisite skills. As a result, the plant gives high priority to staff training. As part of an IAEA project, the Inspectorate examined the strategies adopted by KKM to retain knowledge and transfer it to new staff. KKM has a long-term plan for the replacement of staff about to retire and this is reflected in the temporary increase in the number of employees – a measure designed to ensure sufficient overlap. KKM has introduced effective procedures to ensure that the knowledge and skills of existing staff is transferred to new staff. In the last few years, KKM has successfully managed its first generational change of staff.

The Quality Management System operated by KKM for approximately the last five years also helps to retain knowledge. The system has proved effective, is actively enforced and is the subject of regular improvements based on experience and user feedback.

The Inspectorate also noted that KKM is aware of the challenges facing the electricity market. Even though the commercial environment has become more difficult for a plant the size of Mühleberg, KKM expressly indicated that a nuclear power station can only be operated if safety is maintained, an opinion that the Inspectorate can only endorse.

2.4.2 Personnel and training

Operating staff subject to compulsory licensing receive basic and development training. This consists of initial training in a specific plant operation, regular refresher courses to maintain skills and training associated with plant development and changes in the regulatory framework. Simulator training is a central element of refresher courses. Using a plant-specific simulator located at Mühleberg, staff can practice on a regular basis the operational situations listed in General Operating Instructions and Accident and Emergency Regulations. Some of the training is used for updating the skills of reactor operators, shift leaders and piquet engineers and the associated assessments cover not only technical aspects but communication and team skills as well. During the late/night shift training, staff work through the theory of actual incidents at other plants that contain useful lessons of a general nature. In addition they discuss selected issues relating to the operation of their own plant.

The Inspectorate assessed thoroughly procedures used by KKM to select new operating staff, staff selected for training for more senior functions and the periodic refresher courses for licensed personnel. In addition, it inspected the training programme and simulator training for a shift team involved in an exercise to control a loss of coolant accident.

During the year under review, licences were granted to one picket engineer, one shift leader, two Grade A and two Grade B reactor operators, all with the Inspectorate in attendance. Three employees from KKM successfully completed their Basic Nuclear Technology Course at the Technical University (Fachhochschule) in Ulm and one employee completed the same course at the nuclear power plant school (Kraftwerkschule) in Essen, again all with the Inspectorate in attendance. Guideline R-27 regulates the training and testing of operating staff subject to licensing requirements. The number of licensed personnel is shown in Table A2. In addition, the Inspectorate approved an additional expert in radiation protection.

2.5 Overall judgement by the Inspectorate

In terms of nuclear safety, radiation protection and management, the Mühleberg plant is in good condition. In its 31st year of operation, the plant achieved a good load factor although considerable load reductions were required during the hot summer months in order to comply with the cantonal cooling water licence.

During the year, there were four notifiable events classified on the basis of Guideline R-15. In three cases, the cause was a technical fault that resulted in a reactor shutdown. In the fourth, the cause was lack of co-ordination during tests involving outside contractors when the plant was started up after the annual maintenance shutdown. This also resulted in a reactor scram. On the basis of Guideline R-15, these incidents had little impact on nuclear safety.

The maintenance shutdown lasted 23 days and was professionally planned and carried out. The maintenance work, the non-destructive testing of materials, periodic checks, inspections and functional testing of components and systems produced no significant findings. Tests on the core shroud and tie rods showed that the existing cracks did not reduce safety.

As part of its duties, the Inspectorate carried out some 60 inspections during the year, the majority of which took place during the annual maintenance shutdown. The inspections focussed on operations, radiation protection and in-service inspections. The licensee was advised of the results of inspections and identified improvements where indicated. The Inspectorate found no deficiencies in terms of technical safety that could have threatened the safe operation of the plant.

The Inspectorate is monitoring the implementation of safety-related improvements identified in the PSR. KKM is completing work resulting from Pending List thoroughly and on schedule.

The initial and development training of operating personnel subject to licensing requirements is given the requisite care and is well structured. Particular emphasis is given during training to the need for a safety-oriented culture. KKM conducts a comprehensive assessment of reactor operators, shift leaders and picket engineers at least every two years using sophisticated simulator techniques and so ensures that the plant is operated solely by skilled staff with the requisite team skills. The Inspectorate was present at the exams taken by staff doing the Basic Nuclear Technology Course and at the licensing exams and so can confirm that staff subject to compulsory licensing have the required specialist skills.

In terms of operational radiation protection, both routine work and the work associated with the in-service inspections specified in safety regulations were carried out successfully. The release of radioactive materials into the environment was significantly below official limits. The radiation dose for the general public, in comparison to naturally occurring radiation, was therefore insignificant.

3. GÖSGEN NUCLEAR POWER PLANT

3.1 Operational data and results

The Gösgen Nuclear Power Plant (KKG) is a 3-loop pressurised water reactor with a net electrical output of 970 MW. It started operation in 1979. Further technical details are summarised in Tables A1 and B3 of the Appendix; Figure B1 shows a functional diagram of a pressurised water reactor plant.

In 2003, KKG achieved a load factor of 94.5% and availability of 94.7%. The scheduled maintenance shutdown lasted 20 days and was the sole cause of the plant's unavailability. During the year, the plant delivered 164 GWh of process heat to the nearby cardboard factory. Despite extremely high temperatures in the summer of 2003, it was not necessary to reduce reactor output. Similarly, the power failure in Italy on 28 September 2003 caused no reduction in power output from the plant. On 25 December 2003, power output was reduced to about 50% for just over two hours because of a fault in the measuring transducer of the control rod position information system. The faulty transducer was replaced immediately. The plant displayed the expected behaviour and safety was in no way impaired.

Availability figures and load factors for the last ten years are shown in Figure A1.

This is the thirteenth year in succession without an unscheduled reactor scram, which even on the basis of global comparisons is an outstanding achievement.

Maintenance work at cooling tower internals. Photo: KKG

3.2 Plant safety

3.2.1 Particular events

During the year, KKG experienced two Class B events as defined in Guideline R-15, "Reporting on the operation of nuclear power plants", given, on the International Nuclear Event Scale (see Appendix, Table B2), a Level-0 rating.

During a check of the reactor protection system, a containment isolation valve for the cooling water system, belonging to primary containment, failed to shut fully. It was found that the valve was not moving freely and the fault was remedied immediately. The reactor protection system check was repeated and this time the valve worked properly. The closure function would have been guaranteed by the second valve fitted in series. An internal inspection of the valve during the maintenance shutdown in 2003 revealed nothing abnormal.

Examination of bolts of the reactor pressure vessel.
Photo: KKG

During preparations for the reactor protection check, a nuclear auxiliary cooling water pump failed to start. A fracture was found in the return tension spring on the mechanical closing lockout of the circuit breaker, which meant that the circuit breaker was unable to execute the closure command even though applied. In addition, the starting current was flowing for longer than normal and so a greater load was being put on coupling relays and closing solenoid. The circuit breaker and the coupling relays were replaced immediately and the reactor protection system check was then completed successfully. The non-availability of the nuclear auxiliary cooling water pump and the associated non-availability of one of the four emergency diesel generators lasted for less than one hour.

Both events were caused by technical faults, both of which were remedied immediately. KKG took immediate action, conducted further investigations and proposed additional measures, which the Inspectorate felt were appropriate and so required no further measures.

The notifiable events over the last ten years are shown in Figure A2.

3.2.2 Work during the refuelling shutdown

During the maintenance shutdown from 8–27 June 2003, KKG carried out routine work such as refuelling, electrical and mechanical inspections, non-destructive testing of materials and regular functional checks of components and systems together with other maintenance and modifications. Because of technical problems with measuring equipment, the scanning of individual rods on two fuel assemblies, which are not used in the reactor in the 2003/04 operating cycling, had to be postponed to a later date. Some of the work carried out is listed below:

- In 2002, a leak had been found in the inner sealing washer on the head seal of the reactor pressure vessel (RPV) and so in 2003 the seal grooves in the RPV head and the sealing surface of the RPV were thoroughly examined using laser profilometry and also visual inspection. Twelve small corrosion points were found in the inner seal groove and these were spot-welded. No anomaly was found in the external seal groove. The seal surface itself was spot welded at six points. The sealing washers used during the 2002/03 operating cycle were inspected and found to be in good condition and sealing lines were even.
- All screw bolts and flanged threads on the RPV underwent eddy-current testing. In addi-

tion, the flanged threads, floor nuts and shims were inspected visually. No significant changes had occurred since checks at the start of the 1980s when corrosion points had developed following the temporary use of an unsuitable lubricant.
– Numerous welds on the primary housing and the nozzles of steam generator designated "20" were examined using non-destructive methods. No significant anomalies were found.
– High- and low-pressure seals on the main coolant pump "20" were replaced. The axial bearing on the main coolant pump "30" was overhauled.
– A total of 35 pipes in two of the low-pressure pre-heaters were sealed off as a precautionary measure after eddy-current testing had revealed wall-thinning.
– Tests on 28 pipe supports and 100 hydraulic snubbers revealed no deficiencies. Tests were conducted on 143 mechanical snubbers, 43 of which failed to meet standards and were replaced. Three mechanical snubbers were replaced by hydraulic snubbers as part of work to upgrade the feedwater pipe supports.
– The first stage of a three-stage programme to modify the distribution of water in the cooling tower was completed. Some 70% of gutters and moisture drop separators made from asbestos cement were replaced by pipes and moisture drop separators made from polypropylene. This reduces the volume of material containing asbestos in the cooling tower and will improve cooling.
– Train 3 of the station's electrical services: The protection devices for the 10 kV and 6 kV loads were replaced by new digital protection devices. Initial experience with these new devices has been good. During the next few years, the protection devices on other trains will also be replaced.
– All direct current batteries in Train 4 of the station's electrical services were replaced.
– Various modifications were made as part of preparations for planned improvements in turbine and cooling tower efficiency designed to facilitate a higher electrical output. The generator cooling system will now operate at a hydrogen pressure of 6 bar instead of 5.1 bar, so improving the removal of heat. A new, more powerful generator breaker was installed in the 27 kV power transmission lines.
– A further 350 signals were added to the PRODIS process data information system. The system can now record some 7,000 signals, all accessible from any workstation.
– In connection with the containment evacuation alarm, a manual initiation was fitted to the fuel-charging machine. Were an incident to happen during handling of fuel assemblies, the containment could be evacuated without delay.

Overall, the inspections and tests performed produced good results and nothing was found that might affect the safe operation of the plant in the 2003/04 cycle.

Work during the shutdown was planned and executed to a high standard and completed in compliance with radiation protection requirements.

3.2.3 Plant modifications

The following modifications planned or executed during the year are worthy of particular mention:
– Similar to the work done on the first emergency feed pump in 2002, the second emergency feed pump was modified to increase its volumetric capacity. The second emergency feed pump can now also supply the steam generator when it is not under pressure, without imposing any limitations on the system.
– The edge height of one of the two wells used as an emergency water supply was increased by one metre. In addition, the well pump and the auxiliary cooling pump, both in use since the plant was commissioned, were replaced. A second, redundant auxiliary cooling pump was also fitted. Increasing the edge height of the well reduces the period when the well cannot be opened for inspection or maintenance purposes because the groundwater level is above the edge of the well. The fitting of a standby auxiliary cooling pump means that if the first auxiliary pump is unavailable for any reason, there is still one working pump, even if the first pump cannot be repaired immediately because of high groundwater levels. Similar modifications will be done to the second emergency well in 2004.
– In preparation for the proposed extension to the auxiliary plant building and the construction of a fuel element pool, an access road was built and site fencing erected within the existing perimeter fencing. Tensile tests were conducted on bearing piles in order to clarify the precise characteristics of the subsoil in this area.

Of the improvements recommended in the Periodic Safety Review (PSR), the following retrofits were completed or trial operations started:

- The new Process Visualisation System (PROVI) started trial operations during the year. An important function of PROVI is to concentrate the display of parameters of relevance to safety (Safety Parameter Display System, SPDS) under upset conditions, as required in the PSR.
- The Stanofon ring line in the so-called secure area was extended, so completing improvements to communications in the emergency control room in particular and the expansion of the emergency control room in general.
- As part of work to improve emergency instrumentation, a redundant differential pressure manometer was installed between the annular space of the reactor building and the atmosphere together with two redundant air thermometers in the same annular space. The final stage of this work, i.e. the installation of emergency-proof instrumentation, which will measure core-outlet temperature, will be done when the primary-side pressure relief system is retrofitted. Planning work on the primary-side pressure relief system continued during the year.
- On the three feedwater pipes, a total of eight pipe supports were overhauled, either by the fitting of new fixing points or by strengthening the existing ones in order to cope with any pipe fracture. The completion of this work enabled the plant to provide evidence – as demanded in the PSR – that dampened feedwater check valves were not required.

Work still outstanding from the PSR was progressed on schedule during the year. The Inspectorate was unable to approve the design plans for the construction work needed to improve earthquake protection in the emergency building because evidence that the proposed jointing materials (dowels) were suitable was not submitted in time.

3.2.4 Fuel assemblies and control rods

Concentrations of radionuclides in the reactor cooling water were low, indicating that there was no damage to fuel rod cladding during 2003. For the 25th operating cycle (2003/04), 44 out of the total of 177 fuel assemblies were replaced during the maintenance shutdown. This included 12 fuel assemblies with reprocessed uranium as fuel and 24 uranium/plutonium mixed oxide (MOX) fuel assemblies. In total, 52 reprocessed uranium and 64 MOX fuel assemblies were used in the core during the 25th operating cycle.

The plant continues to use and monitor experimental fuel with different cladding materials in order to study rod behaviour under conditions of advanced burn-up. In addition, it performed dimension and oxide thickness measurements on the structure of spent fuel assemblies. All fuel assemblies examined were found to be performing well.

During the maintenance shutdown, the cladding of all 48 control rods was checked for thinning in the wall surface and damage to cladding was measured using the eddy-current method. This resulted in the replacement of 20 control rods with used rods that had been tested and found to be still sound.

3.3 Radiation protection

3.3.1 Protection of personnel

In the calendar year 2003 (values for 2002 in brackets) the figures for collective doses at KKG were as follows:

Plant status	Collective dose Person-Sv	
Scheduled shutdown	0.45	(0.75)
Power operation	0.11	(0.18)
Total annual collective dose	0.56	(0.93)

In addition to the regular maintenance work, major work was done during the year to components in the primary circuit (see Chapter 3.2.2). Preparation for the testing of welds on the primary housing of steam generator 20 and the testing of RPV bolts each produced a collective dose in excess of 50 Person-mSv. The Inspectorate examined the dose estimates submitted in accordance with Guideline R-15 and considered that the basic principles of optimisation had been adhered to. Overall, the above work resulted in a collective dose of about 130 Person-mSv. Compared with collective doses in previous years, the figure for 2003 of 0.56 Person-Sv is extremely low.

The highest individual dose was 9.8 mSv, i.e. below the maximum of 20 mSv per year set by the Radiation Protection Order for persons occupationally exposed to radiation. Further details can be found in Tables A5–A10 and Figures A5–A8.

The dose rate measurement of selected components conducted at regular intervals during the maintenance shutdown showed no increase in radiation levels. During the maintenance period, components with higher radiation emissions are consistently fitted with temporary shields (some 10 t of lead was used) and KKG has calculated that this reduces the collective dose by some 80 Person-mSv. In addition, the fact that no fuel assemblies were faulty contributed to the good state of radiation protection at the plant.

During the year, there was no unacceptable contamination of air or surfaces. During the maintenance shutdown, only one person registered contamination in the chest area that could not be removed immediately. Until the contamination was removed, the individual concerned was not allowed to enter the controlled zone. There were no other cases of contamination to persons that could not be removed by the customary means. There were no instances of incorporation.

The Inspectorate conducted numerous inspections and as a result is satisfied that KKG operates a modern and effective system of radiation protection.

3.3.2 Releases to the environment and direct radiation

Listed in Table A4a are the limits for releases of radioactive substances from KKG, the releases in 2003 and the dose values for individuals in the vicinity calculated on the basis of the Inspectorate's Guideline R-41. Radioactive releases via the exhaust-gas system in the form of aerosols, iodine and noble gases were well below the limits specified in the operating licence. This was also true of radioactive releases in wastewater, except for tritium. Releases of tritium from KKG, typical for a pressurised water reactor, were similar to previous years at about 20% of the limit value for one year. Table A4b shows releases over the past five years of noble gases and iodine via the exhaust-gas system, and of tritium and other radioactive substances in waste water. Releases below 0.1% of the specified limits are not shown.

The annual dose for individual members of the public in the vicinity of KKG is based, assuming unfavourable circumstances, on the amount of radioactive substances actually released via the stack and in waste water. At approx. 0.0022 mSv for adults and 0.0037 mSv for infants, it is well below the source-related guide value of 0.3 mSv per year specified in the revised Guideline R-11. The dose is caused primarily by the release of carbon 14 (C-14). This nuclide is formed in the reactor when nitrogen, carbon and oxygen react with neutrons. Throughout the year, KKG measures releases of organic and inorganic (carbon dioxide [CO_2]) C-14 concentrations via the stack. These showed that about one-third of all C-14 releases from KKG are in the dose-relevant form of CO_2. Articles 5 and 6 of the Radiation Protection Order states that activities resulting in an effective dose of less than 0.01 mSv per year for the persons concerned are deemed justified and optimised. As a result, no further action is required to reduce radioactive releases and the resultant dose for the population. This statement remains valid even after account is taken of PARCOM Recommendation 91/4 because liquid releases from KKG are extremely low based on international comparisons.

Functional testing of snubbers.
Photo: KKG

The dose-rate monitoring network (MADUK) located around the plant and operated by the Inspectorate showed no increase in values as a result of reactor operation (see Figure A10). Measurements carried out quarterly by the Inspectorate at the plant perimeter detected no significant increase above the background radiation levels. This was also confirmed by measurements from the thermoluminescent dosimeters (TLD) set up by KKG at several points along the perimeter fence. The limits for direct radiation outside the site of 1 mSv per year for residential, recreational and work premises and 5 mSv per year for other areas, specified in Article 102 Paragraph 3 of the Radiation Protection Order were not exceeded during the year.

3.3.3 Radiation protection instrumentation

The Inspectorate uses a system of random sampling to check instruments for monitoring activity and radiation levels in the plant and radiation releases into the environment together with personnel monitors. On the basis of the licensee's test records and documents and its own checks in the plant, the Inspectorate is satisfied that instruments are tested regularly by plant personnel as specified and are in good working order.

In addition to controls carried out by the Inspectorate, selected measuring systems are checked each year in the course of comparative measures involving various national laboratories and measuring stations:

- The quarterly control measurements carried out by the Inspectorate and the half-yearly comparison measurements by the Section for Radiation Monitoring in Freiburg (SUeR) on aerosol and iodine filters and on waste water samples, showed good agreement between the Inspectorate's readings and those of KKG.
- As required under its operating approval, the KKG Dosimetry Department again participated in the annual comparison measurements for personnel dosimetry departments organised jointly by the Swiss Federal Office of Public Health and the Inspectorate and furnished proof of the required measuring accuracy at the reference point of ±10%.

Maintenance work on an air lock in the containment.
Photo: KKG

3.4 Personnel and organisation

3.4.1 Organisation and management

KKG underwent no organisational changes during the year and at the end of 2003 had a workforce of 394 (2002: 381).

During the year, the KKG Management and the Inspectorate held their annual meetings to discuss issues ranging from the generic aspects of important projects to the strategy, objectives and development plans associated with investment in nuclear safety. KKG indicated that it favours a long service life for the plant and so requires highly skilled and motivated personnel. As a result, the plant places a high value on systematic staff development and promotion. The strong reliance on staff expertise was also discussed in the context of quality management. KKG considers that regulation should be kept to the minimum necessary. Over-regulation robs staff of individual responsibility, which in turn demotivates them and impacts on their daily work. As a result, KKG has adopted a streamlined Quality Management System whilst still complying with the requirements of the IAEA Quality Assurance Code (No. 50-C-Q "Quality Assurance") – as demanded by the Inspectorate.

The Inspectorate had previously asked all plants to perform a systematic self-assessment (self-assessment by Management) and a joint working group of plants in Switzerland was set up to create a model that can now be used by all of them. KKG found this a useful process and will conduct such self-assessments regularly in future.

The Inspectorate can confirm that safety issues are not the subject of economy measures. Similarly, KKG has no plans for savings on human resources. KKG has not found it difficult to recruit well qualified younger personnel to replace staff about to retire.

3.4.2 Personnel and training

Operating staff, subject to compulsory licensing, receive basic and development training. This consists of initial training in a specific plant operation, regular refresher courses to maintain skills and training associated with plant development and changes in the regulatory framework. The basic training includes a course for nuclear power technicians at the Technician School run by the Paul Scherrer Institute as well as a comprehensive plant-specific technology course on the design and operation of major systems of relevance to plant operators. KKG has a plant-specific simulator and its use by licensed personnel is an essential element of their basic and development training. In particular, it allows them practice rare operational situations or those of particular importance to nuclear safety. The simulator provides comprehensive training on the various aspects of normal operation together with the main accident and emergency situations. These issues are then discussed in class so that personnel gain an understanding of plant behaviour even in complex situations and so can take the right action. In-house development training includes management courses for all supervisory staff. Amongst operational personnel, it is particularly shift leaders and picket engineers who benefit from this form of training.

The Inspectorate assessed thoroughly procedures used by KKG to select new operating staff, staff selected for training in more senior functions and the periodic refresher courses for licensed personnel. In addition, it inspected the training programme, a group training session on the simulator and the didactic approach to exercises dealing with various accident scenarios.

As part of an IAEA project, the Inspectorate reviewed the strategies employed by KKG to retain expertise and transfer knowledge to new personnel. KKG has comprehensive plans to ensure that staff due to retire are replaced in good time together with effective mechanisms for the transfer of their knowledge and skills. KKG has already successfully completed its first generational change and is well prepared for the next wave of staff changes.

During the year, one picket engineer passed the practical element of the licence examination as part of an emergency exercise with the Inspectorate in attendance. The engineer will take the theory element at the beginning of 2004. Five KKG staff successfully completed the Basic Nuclear Technology Course at the PSI Technician College, again with the Inspectorate in attendance. Guideline R-27 regulates the training and testing of operating staff subject to licensing requirements. The number of licensed personnel is shown in Table A2.

3.5 Overall judgement by the Inspectorate

In terms of nuclear safety, radiation protection and management, the Gösgen plant is in good condition. The operation of the plant complied with current regulations. Neither the extremely high temperatures in summer 2003 nor the power failure in Italy had a significant effect on plant operation. The only unscheduled reduction in power – near the end of the year – had no impact on safety.

There were two notifiable incidents. However, they were of minor importance in terms of nuclear safety and in both cases, KKG identified and remedied the cause immediately.

As part of its supervisory role, the Inspectorate scrutinised plant modifications, system/component checks together with training, operation, radiation protection and radioactive waste. It conducted some 55 inspections during the year, the majority during the annual maintenance shutdown. The licensee was advised of the results of the inspections and carried out improvements where indicated. The Inspectorate identified no deficiencies in terms of technical safety that could have threatened the safe operation of the plant.

Several of the improvements suggested following the PSR in 1999 were completed during the year. There was a delay in the work to improve earthquake protection in the emergency-feed water building that could have been avoided had planning been more careful.

The initial and development training of operating personnel subject to licensing requirements was provided with the requisite care and was well structured. Particular emphasis was given during training to the need for a safety-oriented culture. KKG conducts a comprehensive assessment of reactor operators, shift leaders and picket engineers at least every two years using sophisticated simulator training techniques and so ensures that the plant is operated exclusively by qualified staff with the requisite team skills. Based on the results of exams taken at the end of the Basic Nuclear Technology Course and the licensing exams, the Inspectorate can confirm that staff subject to compulsory licensing have the required specialist skills.

In terms of operational radiation protection, both routine work and the work associated with the in-service inspections specified in safety regulations were carried out successfully. The release of radioactive materials to the environment was significantly below the officially prescribed limits. The radiation dose for the general public, over and above the exposure to naturally occurring radiation, was therefore insignificant.

4. LEIBSTADT NUCLEAR POWER PLANT

4.1 Operational data and results

The Leibstadt Nuclear Power Plant (KKL), a boiling water reactor, started commercial operations in 1984. The net electrical output in 2003 was 1165 MW. Further details on the plant can be found in Tables A1 and B3 of the Appendix; Figure B2 shows a functional diagram of a boiling water reactor.

In its 19th year of operation, KKL achieved a load factor of 91.5% and an availability of 93.7%. The annual maintenance shutdown lasted 22 days.

Availability and load factors for the last ten years are shown in Figure A1.

The Leibstadt plant experienced no unscheduled reactor scrams during the year. The reactor was shutdown for one day after the maintenance shutdown to allow operating personnel to enter the drywell and remedy a leak in the area of the control air system of a safety relief valve. Reactor power was reduced to 55% for 25 hours after faults developed in the feed water pumps that required immediate repair by operating personnel.

Aerial view of the Leibstadt nuclear power plant.
Photo: KKL

On several hot days in June and July, power had to be reduced because the cooling water temperature was unduly high. Following the power failure in Italy on 28 September 2003, power was reduced to 70% as a precautionary measure and in order to maintain grid stability.

4.2 Plant safety

4.2.1 Particular events

The Inspectorate categorised four events as Class B as defined in its Guideline R-15, "Reporting on the operation of nuclear power plants". They were given the Level 0 on the International Nuclear Event Scale INES (see Appendix, Table B 2).

Inspecting an impeller of a main cooling water pump.
Photo: KKL

- At periodic intervals, KKL transports containers containing drums filled with radioactive waste to ZWILAG, the central interim radwaste storage facility for further processing. In February, KKL transported containers in breach of the associated transport regulations because measurements revealed a maximum surface dose rate of 3.5 mSv/h on the underside of the transport vehicle. Under the transport regulations, the dose rate on all external surfaces of container may not exceed 2 mSv/h and so KKL were in breach of the regulations. This resulted in no risk to either the environment or transport staff.
- During a functionality test of the emergency feed water system, it was impossible to open the feed valve from the control room. If the system had been activated, it would probably not have worked. After replacement of the drive control card, the feed valve operated as designed.
- During preparations for a system function test of the emergency system 61, the power breaker supplying the 380 V voltage distribution from the 6.6 kV bus bar failed to operate. When an attempt was made to restore the original power supply, the breaker for this system similarly failed to operate. An initial examination of the breakers showed that in both cases the excess current circuit breaker had been tripped. Further examination revealed evidence of wear in the area of the excess current trip. After fitting two backup breakers the system function test was repeated, this time successfully. Further clarification is being sought from the breaker manufacturer on an appropriate maintenance strategy.
- During a system function test of the nuclear island closed cooling water system, the relevant pump was switched on; it operated briefly but then stopped. It was found that a heat exchanger outlet valve had received an erroneous close command during the opening process. However, it was not possible to reproduce the error, i.e. a new system start was initiated and the train changeover was successful. It has not yet been possible to identify the cause of the fault and so, to facilitate identification, the relevant signals are being constantly recorded and evaluated.

The first incident was the result of human error and the other three were caused by technical faults during system checks.

The classified events over the last ten years are shown in Figure A2.

4.2.2 Work during the refuelling shutdown

The maintenance shutdown from 3–25 August 2003 covered routine work such as refuelling, electrical and mechanical inspections, non-destructive material testing, periodic testing of systems and components as well as maintenance and modification work.

Below is a list of the main non-destructive tests on vessels and pipes:

– Tests were conducted on six welds on the high-pressure core spray system and the emergency system. Indications for two welds were such that they were subject to compulsory reporting requirements but on evaluation neither was found to impact on safety.
– Tests were conducted on 11 welds on the top and bottom of the reactor pressure vessel. The indications for four welds were such that they were subject to compulsory reporting requirements. Similarly, on evaluation none was found to impact on safety.
– The results of eddy-current testing on 18 screw holes on the flange of the reactor pressure vessel identified no deficiencies.
– X-ray testing of 16 welds on the emergency feed water system and the steam/air pressure vessels produced no indications subject to compulsory reporting requirements.
– As in previous years, the internal surfaces of the reactor pressure vessel and core internals were inspected with underwater cameras in accordance with the test programme. The cameras check for cracks and any change from the original shape. No indications were found.

The following important maintenance work was carried out:

– 15 control rod drives on the control rod drive system were replaced with spare reconditioned drives. The decision to replace was based on identified friction coefficients and the maintenance interval. Maintenance work was also done on 12 hydraulic control units and their inlet and outlet valves.
– The mechanical seal on circulating pump A was replaced after an increase in pressure between the first and second part of the seal had been identified during the 19th cycle. In addition, the settings on both circulating pumps were checked.
– Seven of the 16 safety and relief valves (SRV) were replaced in rotation by spare reconditioned units. For the first time, three of the new SRVs recently approved for use by the Inspectorate were fitted. When the system was restarted for the 20th cycle, all SRVs were seal-tight.
– During the "cold" pressure test of the reactor pressure vessel (RPV), which is performed before the system is restarted, minor leaks were found on three of the control rod drive flanges. After the test had been completed, the drives were removed, new seals fitted and the drives reinstalled.
– The suction sieves on all three feed water pumps were removed, inspected, cleaned and refitted. The deposits, in particular the fine metal fragments that caused the fuel assembly damage in earlier cycles have declined each year. The long-term programme introduced by KKL designed to prevent foreign debris getting into water systems and consisting of improved training of maintenance personnel and systematic controls has had a sustained effect.
– Feed water pump RL22: As specified in the long-term programme, the mechanical seals on both the pre-pump and main pump were replaced, the hydraulic gearbox overhauled and for the first time an oil-aerosol separator was fitted.
– One of the main condenser pumps was thoroughly overhauled. The pump runner had suffered cavitation erosion and was replaced by a new runner specially designed for hydraulic use.
– The levelling of the turbine platform and its extension were checked in the warm state. The axial shaft elevation and the concentricity of the couplings were checked.
– The block transformer in Phase R of the high-voltage systems was replaced with a spare transformer that had been fully reconditioned prior to the maintenance shutdown.
– The required calibrations and tests were performed on I&C systems that for safety reasons can only be done during the maintenance shutdown. The behaviour of electronic control circuits, including their instrumentation, was tested and recorded.

No defects of relevance to plant safety were found during the remaining maintenance work, tests and inspections.

Functionality checks performed in accordance with the System and Logic Function Test Programme revealed no defects of relevance to plant safety. This also applied to the functionality tests performed on completion of modifications to the plant.

Before, during and after the maintenance shutdown, the Inspectorate conducted more than 30 inspections and technical discussions and reviewed documents in order to evaluate the extent and quality of the works, the state of operational readiness and the tests carried out by KKL during the restart programme. The Inspectorate noted with satisfaction that the shutdown programme was professionally planned and organised, the work of the required quality and complied with radiation protection requirements.

However, the Inspectorate also found that in three instances KKL failed to comply fully with clearance and reporting requirements during the maintenance shutdown. The Inspectorate emphasised that compliance with the clearance and reporting requirements specified in its guidelines is an important element of the Inspectorate's responsibilities and strict compliance is required in future.

4.2.3 Plant modifications

One of the main modifications during the year was the replacement of two low-pressure preheaters after a thinning had been identified in the cladding in 1999. The cladding for the new pre-heaters is made of erosion-resistant austenitic material.

The diesel monitors for the high pressure core spray system (HPCS) and the emergency cooling system A had been upgraded in 2000 and 2001. In 2003, similar work was done to the safety logic for the emergency cooling system B.

In order to improve the running of the dampened feed water non-return valves, new internals, with a modified design and a hardened surface, were fitted to two of the valves in the steam tunnel and drywell. Considerable work was required to modify the steel supports located above the valves to gain adequate clearance for the fitting of these components. Similar modifications were made to two other valves in 2001. Leak tests and free-running tests confirmed that the modifications had been effective.

The position indicators for testable non-return valves were replaced using a new design and more appropriate materials and so increasing the reliability of the indicators.

In the past, the hydrogen recombiner, which is a mobile unit, had to be connected to one of two possible power supplies if it were needed. The same applied to the numerous control cableing for the associated valves. The recombiner is now permanently connected to the power supply for emergency cooling system A and the electrical cables are permanently in situ.

To improve safety, additional fire detectors were fitted in the drywell. In the event of a fire, an alarm is sounded in the control room. As a result, it is now possible to detect even a smouldering fire in the drywell.

A range of preparatory work connected with the "Process Computer System Modernisation" was undertaken. The work, which for safety reasons can only be done during the maintenance shutdown, included the installation of various network cabling and the installation of the master cables for the instrumentation and control equipment.

4.2.4 Fuel and assemblies control rods

There was no damage to fuel assemblies during the 19th operating cycle (2002/03). This positive result was the result of two factors. Firstly, the plant regularly carries out a "System and Component Cleanliness" programme during the maintenance shutdown and this prevents foreign debris from penetrating the cooling system. Secondly, almost all fuel assemblies are fitted with debris filters and some 20% of assemblies have particularly effective filters capable of retaining even wire-type debris.

During the fuel change, a total of 116 fresh SVEA96-Optima2 assemblies were loaded together with 16 fresh fuel assemblies of the new type ATRIUM-10XP. The latter is approved by the Inspectorate for trial purposes. The Inspectorate is satisfied that all fuel assemblies used are of a quality that satisfies quality requirements.

Boric acid concentrations in the reactor water were elevated in 2003 indicating leaking control rods. The licensee submitted a strategy for dealing with control rod replacement and this formed the basis of work during the maintenance shutdown to replace 18 highly irradiated control rods. Although the effect of this work has been good, the boric acid concentration has not yet returned to its normal level. The Inspectorate is kept informed on a regular basis of the levels of boric acid concentration in the reactor water. Despite these deficiencies, the control rods have sufficient shutdown capacity.

4.3 Radiation protection

4.3.1 Protection of personnel

In the calendar year 2003 (values for 2002 in brackets), the collective doses determined for KKL were as follows:

Plant status	Collective dose Person-Sv	
Scheduled shutdown	0.60	(0.22)
Power operation	0.27	(0.23)
Total annual collective dose	0.87	(0.45)

In 2003, the work in the radiation field was more extensive than in 2002 and so the annual collective dose was correspondingly higher. The highest individual dose accumulated at KKL was 8.7 mSv (4.6 mSv), which is below the annual dose limit of 20 mSv set by the Radiation Protection Order for persons occupationally exposed to radiation. Further details are to be found in the Tables A5–A10 and Figures A5–A8.

The use of screening monitors revealed no evidence of incorporation. There were no instances of personal contamination that could not be removed in the usual way (hand washing, showering).

No cases of unacceptable contamination occurred in the plant – this was confirmed by regular control measurements of air and surface samples. The average dose rate at the recirculation loops was slightly lower for the third year in succession and during the maintenance shutdown in 2003 was 1.71 mSv/h (1.89 mSv/h), i.e. below the guide value in the operating licence (2 mSv/h). Whereas the dose rates at the reactor internals subject to monitoring have been more or less constant in the last five years, dose rates declined in the secondary loop. Operating the plant at a higher output has had no measurable effect on the dose received by personnel.

During the maintenance shutdown in 2003, approximately 43 t of temporary shielding was installed in the plant, 25 t of which was in the drywell. In addition, the customary shielding (about 450 lead mats and two water shields) was erected in the steam tunnel.

The measurement programmes set up after earlier fuel defects and designed to detect contamination from α-radiation were continued. Results were comparable with those in 2002.

For all work expected to produce a collective dose in excess of 10 Pers.-mSv, detailed radiation protection plans were compiled. In the year under review, this applied to work on the feedwater non-return valves and on the reactor water cleaning system as well as the work to replace the two low-pressure pre-heaters and the hydraulic snubbers. The planned dose limit was not exceeded during any of this work and in some cases it was under the limit. In contrast, the job dose rate resulting from the replacement of control rods and the remote-control ultrasound testing of the RPV primary housing was significantly higher than the planned rate. In future, KKL will monitor the workstations even more carefully and take remedial action as required.

As a result of its numerous inspections (including one unannounced), the Inspectorate can confirm that KKL has an effective system of radiation protection.

4.3.2 Releases to the environment and direct radiation

Listed in Table A4a are the limits for releases of radioactive substances from KKL, the releases for the year 2003 and the dose values for individuals in the vicinity, calculated on the basis of Guideline R-41. Radioactive releases via the exhaust-gas system in the form of aerosols, iodine and noble gases were well below the limits specified in the operating licence. This was also true of radioactive releases in wastewater for tritium and the other radioactive releases. Table A4b shows the releases over the past five years of noble gases and iodine via the exhaust-gas system, and of tritium and other radioactive sub-

View of the steam turbine. An opened low pressure turbine is in the foreground.
Photo: KKL

stances in wastewater. Release values below 0.1% of the specified limits are not shown.

The yearly dose for individual members of the public in the vicinity of KKL is based, assuming unfavourable circumstances, on the amount of radioactive substances actually released by way of the stack and in wastewater. At approximately 0.0033 mSv for adults and 0.0059 mSv for infants it is well below the source-related guide value of 0.3 mSv per year contained in the revised Guideline R-11. The dose results primarily from the identified release of carbon-14 (C-14). This nuclide is produced in the reactor when neutrons react with nitrogen, carbon and oxygen. KKL carries out random checks of C-14 and tritium concentrations in the waste gas on a routine basis. Articles 5 and 6 of the Radiation Protection Order state that activities that result in an effective dose of less than 0.01 mSv per year for the persons concerned are deemed justified and optimised. As a result, no further action is required to reduce radioactive releases and the resultant dose for the population. Moreover, this remains true even after account is taken of PARCOM Recommendation 91/4 because liquid releases from KKL are extremely low based on international comparisons.

The dose-rate monitoring network (MADUK) located around the plant and operated by the Inspectorate showed no increase in values as a result of reactor operation (see Figure A10). The ambient dose rate in the immediate vicinity of a boiling water reactor is increased by direct and scattered radiation from the turbine building. Measurements carried out quarterly by the Inspectorate at the plant perimeter detected no significant increase compared with previous years. The thermoluminescent dosimeters (TLD), which are evaluated by KKL, measure the dose at several points along the perimeter fence. They showed a maximum dose of 3.85 mSv (including natural background radiation of approximately 0.7 mSv). The limits for direct radiation outside the site of 1 mSv per year for residential, recreational and work premises and 5 mSv per year for other areas, specified in Article 102 Paragraph 3 of the Radiation Protection Order were not exceeded during the year.

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4.3.3 Radiation protection instrumentation

The Inspectorate uses a system of random sampling to check instruments for monitoring activity and radiation levels in the plant and radiation releases into the environment together with personnel monitors and personnel dosimetry systems. On the basis of the licensee's test records and documents and its own checks in the plant, the Inspectorate is satisfied that instruments are tested regularly by plant personnel as specified and are in good working order.

In addition to controls by the Inspectorate, certain measuring systems are checked each year in the course of comparative measurements involving other national laboratories and calibration services:

– The quarterly control measurements carried out by the Inspectorate and the half-yearly comparison measurements by SUeR on aerosol and iodine filters and on wastewater samples, showed a good correlation with the results produced by the Leibstadt plant.
– As required under its operating approval, the KKL Dosimetry Department again participated in the annual comparison measurements for personnel dosimetry departments organised jointly by the Swiss Federal Office of Public Health and the Inspectorate and furnished proof of the required measuring accuracy at the reference point of ±10%.

4.4 Personnel and organisation

4.4.1 Organisation and management

KKL underwent no organisational changes during the year. The workforce at KKL has now stabilised and at the end of the year under review it was 413 persons (2001: 395).

In 2002, AXPO acquired a 100% holding in Watt AG and its subsidiaries. As a result, EGL, which previously was responsible for the management of KKL, was integrated into AXPO Holding. At the beginning of 2003, the management of KKL was transferred to the "Nuclear Energy business group of NOK, the North-East Switzerland Power Company (an AXPO company). This transfer had no effect on the operational management and internal structures and procedures of KKL but as part of the same process of integration the fuel offices of KKB and KKL were combined. With both KKB and KKL now in the same NOK business group this will further strengthen the existing well-established co-operation between the two plants in various technical fields and in the area of safety culture.

Costs and investment in the area of nuclear safety are a standard agenda item at the annual discussions between the KKL Management and the Inspectorate. KKL has indicated that cost savings are practical in its view but only if they are not to the detriment of safety. No savings are planned in terms of human resources.

In recent years, KKL has progressively transformed its quality management system into a "Total Quality Management" system (TQM) and this took effect in October 2003. The system can be accessed by all staff in a very user-friendly format on the KKL Intranet. The TQM system introduced by KKL can be classified as an integrated management system in as much as it encompasses all aspects of power plant operation. KKL is planning to apply for certification of the "quality" aspect of the system in 2004 in accordance with ISO 9001:2000.

4.4.2 Personnel and training

Operating staff subject to compulsory licensing receive basic and development training. This consists of initial training in a specific plant operation, regular refresher courses to maintain skills and training associated with plant development and changes in the regulatory framework. Operational training plays a crucial role in determining the skill levels of operating personnel and so KKL is training two additional picket engineers to act as simulator instructors and teachers. The way in which staff manage changes to shift patterns impacts significantly concentration and motivation levels and so the health care curriculum for shift workers included a seminar on sleep.

The Inspectorate assessed thoroughly the procedures used by KKL to select new operating staff, staff selected for training in more senior functions and the periodic refresher courses for licensed personnel. In addition, it inspected the training programme and a simulator exercise in which a shift team had to deal with various operating faults. The plant-specific simulator at KKL is a valuable tool that allows shift personnel to practice under realistic conditions plant operation in times of normal running and emergencies.

As part of an IAEA project, the Inspectorate reviewed the strategies employed by KKL to retain expertise and transfer knowledge to new personnel. KKL has comprehensive plans to ensure that staff due to retire are replaced in good time together with effective mechanisms for the transfer of their knowledge and skills. KKL has already successfully completed its first generational change and is well prepared for the next wave of personnel changes.

During the year, two picket engineers at KKL received their licenses under the supervision of the Inspectorate. A total of four employees successfully completed their exams at the end of the Basic Nuclear Technology Course at the PSI Technician School and a further four at the Nuclear Power School (Kraftwerksschule) in Essen, similarly under the supervision of the Inspectorate. Guideline R-27 regulates the training and testing of operating staff subject to licensing requirements. The number of licensed personnel is shown in Table A2.

4.5 Overall judgement by the Inspectorate

In terms of nuclear safety, radiation protection and management, the Leibstadt plant is in good condition. During its 19th operating cycle, KKL recorded a high load factor of 91.5%. There were no unscheduled reactor scrams during the year and for the first time in many years there was no damage to fuel assemblies. The long-term programme introduced by KKL to prevent debris entering water systems, which consists of improved training for maintenance personnel and systematic checks, is having an effect.

During the year, there were four notifiable incidents based on Guideline R-15: one during the transport of a container carrying radioactive drums and the other three during functional tests of safety systems. The incidents were of minor importance in terms of nuclear safety.

Because of control rod leaks, boric acid concentrations in the reactor water were ele-

Replacement of a low pressure preheater.
Photo: KKL

vated. For this reason, the licensee replaced 18 highly irradiated control rods during the maintenance shutdown. The effect of this has been positive but boric acid concentrations have not yet returned to normal levels. The control rods still have sufficient shutdown capacity.

The maintenance shutdown lasted 22 days and was planned and executed professionally. The main activity was the ultrasonic testing of welds, which is part of a long-term test programme. As in previous years, the internal surfaces of the RPV and the core internals were inspected with an underwater camera. Non-destructive material testing, plant modifications, inspections and functional checks of systems and components produced no significant findings.

As part of its supervisory activities, the Inspectorate conducted some 80 inspections during the year, the majority during the maintenance shutdown. The inspections focussed on operational issues, radiation protection and in-service inspections. The licensee was advised of the results of these inspections and carried out improvements where indicated. The Inspectorate identified no deficiencies in terms of technical safety that could have threatened the safe operation of the plant.

The Inspectorate found that in three instances KKL failed to follow the correct release and reporting procedures during the maintenance shutdown. The Inspectorate stressed to KKL that it must comply fully with the Inspectorate's release and reporting requirements in future.

The initial and development training of operating personnel subject to licensing requirements was given the requisite care and was well structured. During training, particular emphasis was placed on the need for a safety-oriented culture. KKL conducts a comprehensive assessment of reactor operators, shift leaders and picket engineers at least every two years using sophisticated simulator techniques and so ensures that the plant is operated solely by qualified staff with the requisite team skills. Based on the results of exams taken at the end of the Basic Nuclear Technology Course and the licensing exams, the Inspectorate can confirm that staff subject to compulsory licensing have the required specialist skills.

In terms of operational radiation protection, both routine work and the work associated with the in-service inspections specified in safety regulations were carried out successfully. The release of radioactive materials into the environment was significantly below the officially prescribed limits. The radiation dose for the general public, over and above exposure to naturally occurring radiation, was therefore insignificant.

5. ASPECTS COMMON TO SWISS NUCLEAR INSTALLATIONS

5.1 Probabilistic safety analysis (PSA) and accident management (AM)

5.1.1 Probabilistic safety analysis

The purpose of a probabilistic safety analysis (PSA) is to evaluate severe accidents and their resulting consequences. A severe accident is a hazardous incident such that the reactor core can no longer be cooled and consequently, begins to melt. Only a severe accident has the potential to release large amounts of radioactive material into the environment surrounding the nuclear power plant. Severe accidents are extremely unlikely as they require the failure of numerous safety equipment. The following paragraphs describe the main PSA work that has been carried out or submitted to the Inspectorate by the Swiss plant licensees in 2003:

– The licensee of the Beznau nuclear power plant (KKB) had revised and expanded its PSA as part of the periodic safety review (PSR). At the request of the Inspectorate, and in connection with the appraisal of KKB's application for an indefinite operating license for Unit 2, KKB supplied in 2003 additional information required for the regulatory review of its PSA. The results of the KKB-PSA and the review by the Inspectorate are summarised below in Chapter 5.1.2.
– The licensee of the Gösgen nuclear plant (KKG) submitted at the end of 2003 a revised PSA for full power operation. Primarily, KKG had incorporated into the PSA model (a) recent plant modifications and operating experience, (b) revised analyses for fire and earthquake initiating events and for operator actions, and (c) new thermo-hydraulic analyses.
– The licensee of the Leibstadt nuclear power plant (KKL) continued work on implementing a "Living PSA" toward achieving the capability to more efficiently revise the PSA also at intervals of less than ten years. KKL developed special software and used it in 2003 to update its component reliability data. In addition to this data, KKL also submitted to the Inspectorate an improved probabilistic analysis for operator actions.
– The licensee of the Mühleberg nuclear power plant (KKM) initiated a series of tasks designed to implement the potential improvements indicated in the Inspectorate's evaluation of the KKM PSR. At the end of 2003, KKM submitted to the Inspectorate revisions of parts of its PSA.

The Inspectorate reviews each PSA submittal. If potential improvements in the analyses or with respect to plant operation or hardware are identified they are documented in review reports that must be considered by the licensees. Simultaneously with its review of a revised PSA, the Inspectorate updates its own plant-specific PSA model. Having such an updated regulatory model allows the Inspectorate to perform its own risk analysis in order to perform an independent assessment of safety issues.

The findings of the PSA studies reveal that nuclear power plants in Switzerland have comparatively high levels of safety compared to plants worldwide. For example, they are significantly above the targets set by the International Atomic Energy Agency (IAEA). Risk profiles are largely balanced, i.e. no dominant plant weaknesses have been identified.

5.1.2 Review of Beznau PSA

As part of its PSR, the licensee of the Beznau plant submitted a PSA to the Inspectorate covering both full power operation and shutdown/low power operation. The full-power study is a revision of the previous study and encompasses the analysis of the sequence of events of a severe accident from the time of the initial event up to and including core damage and the failure of the containment, as the final retention barrier preventing a possible release of radioactive materials into the environment. The study of the shutdown and low power operation has been conducted for the first time. In this study the sequence of accident events only up to and including damage to fuel assemblies is analysed. PSAs are less common for shutdown and low power operation than for full power operation.

The PSA submitted by KKB shows that KKB's safety level is high based on international comparisons both for full power and shutdown/low power operation. The core damage frequency at KKB is now lower than identified in the previous PSA. This further reduction is due primarily to the back fitting of an additional system for steam generator feed (emergency feedwater system) and good operating experience in both KKB units.

As a result of its policy of targeted back-fitting, KKB has a balanced safety concept for both full power and shutdown/low power operation. The frequencies of core and fuel assembly damage specified in the PSA are not linked unduly to a specific initiating event or the failure of a single safety system. From an overall perspective, KKB's emergency power supply system has the highest safety relevance in the management of severe accidents.

For full power operation at KKB, there has been a significant decline in the mean frequency of an early large release of radioactive materials into the environment compared with the previous PSA. Reasons for this reduction include that accident management measures have now been considered for the first time, that new strategies to mitigate the effects of severe accidents have been implemented, and that systems have been improved technically (e.g. containment isolation).

On the basis of its independent examination, the Inspectorate concludes that the KKB PSA provides a plausible and comprehensive depiction of plant behaviour at KKB in the event of a severe accident.

5.1.3 New probabilistic seismic hazard analysis

The Inspectorate asked the licensees of the Swiss nuclear power plants to conduct new seismic hazard analyses to reflect recent improvements in the methodology underlying such studies. The licensees responded with a project called PEGASOS ("Probabilistische Erdbebengefährdungsanalyse für die KKW-Standorte in der Schweiz"). The aim of this project is to calculate the seismic hazard based on geoscientific data that reflects the state of knowledge of the informed technical community.

The workshops and structured expert elicitations planned for 2003 were carried out on schedule. On these occasions the large number of experts involved put forward, discussed and

Assembly of new batteries. Photo: KKG evaluated additional models to describe specific physical relationships in the process of developing and propagating seismic ground motions. After evaluation, the detailed models were integrated into the overall numerical model. The overall model takes the form of a logic tree in which each complete branch represents a hazard curve and an associated probability. After completion of the overall model, in the spirit of a know-how transfer the hazard computations will be carried out in co-operation with a US company in Switzerland.

The Inspectorate is continuously monitoring the course of the project. As soon as PEGASOS results will exist and be reviewed by the Inspectorate, the new findings and knowledge will be incorporated into the PSAs of the Swiss licensees. Furthermore, any necessary measures will be implemented.

5.1.4 Implementation of Severe Accident Management Guidance

Severe Accident Management Guidance (SAMG) serves to systematically master or mitigate the effects of a severe accident. The implementation of SAMG by the nuclear power plants in Switzerland represents an extension to the existing system of accident and emergency procedures to include accidents resulting in serious core damage. The aim of SAMG is to stop the process of core meltdown or at least to minimise the release of radioactive materials into the environment. By requiring that SAMG covers not only full-power but also shutdown operation, Switzerland has gone beyond the international state-of-the-art.

In recent years, all nuclear power plants in Switzerland have carried out extensive work on the implementation of SAMG for full power operation and in some cases for shutdown operation as well. This development work has continuously been reviewed by the Inspectorate. In particular, the technical fundamentals for the management of a severe accident (basis of SAMG) are now ready to use. The plants are required to implement SAMG by the end of 2004.

5.1.5 Accident analysis system ADAM

If a hazardous incident occurs in a nuclear power plant in Switzerland, the Inspectorate receives up to 25 relevant plant parameters ("Anlageparameter", ANPA) every two minutes via a dedicated communication network. These parameters are processed by the ADAM System (Accident Diagnostics, Analysis and Management). ADAM consists of three modules with the following functions:

- *Online PI Module (PI = picket engineer):* The PI Module processes the ANPA parameters and presents them in graphic form allowing the PI to grasp quickly the sequence of events and the severity of the incident.
- *Online Diagnostic Module:* The diagnostic module interprets the ANPA parameters, in some cases by use of thermo-hydraulic analyses. The diagnostic module provides indications of possible causes of the incident, of compliance with limits and of the status of important plant components.
- *Offline simulation module:* The simulation module examines a wide range of accident sequences. It can also be used to estimate the quantity of radioactive substances released in the event of a severe accident.

In 2003, ADAM was used several times in online mode in order to evaluate reactor safety, including as part of the KKB overall emergency exercise IRIS. This showed that the system is highly reliable and can provide valuable information for evaluating the status of the plant. In addition, the Inspectorate also used ADAM for its own internal training in reactor safety and the ADAM simulation module was used to ran simplified thermo-hydraulic analyses, e.g. in order to briefly check PSA success criteria.

5.1.6 Probabilistic event analysis

Using the PSA models, the probabilistic event analysis evaluates the impact of events on plant risks. The term event has a broad meaning here and includes not only unscheduled plant shutdowns/scrams and unavailability of safety relevant components, but also scheduled maintenance and functional tests. The main use of the probabilistic event analysis is for the annual evaluation of operating experience. It can also be used for the classification of events in terms of their impact on nuclear safety.

Last year, with the objective to gather experience, the Inspectorate performed a probabilistic event analysis for all nuclear power plants in Switzerland for the year 2000. The plant licensees supported the collection of the data required for this purpose. In order to evaluate the events, the Inspectorate used its own PSA models for internal events. This case study has demonstrated an efficient approach for the identification and probabilistic evaluation of relevant events. The study showed that a probabilistic event analyses can produce valuable insights on the plant operation. With the annual number of risk peaks and the annual accumulated risk, the study identified two probabilistic safety indicators pointing to both instantaneous and overall increases in risk. These indicators ought to be used in future for the evaluation of operating experience.

5.2 Ageing surveillance

During 2003, work continued on the comprehensive documentation for the process of ageing surveillance in Swiss nuclear power plants and the central interim storage facility. The documentation contains the main information necessary for assessing ageing mechanisms and provides an important basis for the verification of ageing surveillance conducted as part of the regular periodic safety reviews of each installation. The Ageing Surveillance Programme (ASP) is a continuous and systematic process designed to identify and assess the effects of ageing on materials and structures and if necessary to take action to remedy or prevent damage caused by ageing. The results of research into the ageing mechanisms are used to plan maintenance programmes and are also used for training purposes during the non-destructive material testing of mechanical components.

Civil engineering: Both the nuclear power plants and the central interim storage facility conducted further basic inspections. These inspections identified and documented the condition of structural elements and the results will facilitate the assessment of modifications in future. KKM and KKG have completed basic inspections for all their classified buildings and to a large extent these have been documented and assessed by the Inspectorate. Still outstanding are the basic inspections for structural elements such as fixings, fire barriers, paintwork, joint tapes/seals, penetrations and at KKG inspections are also outstanding for other specific items such as inlet structures and cooling water ducts. KKB has completed the basic inspections for reactor buildings and auxiliary buildings A, B, C, D, E and these have been documented and assessed by the Inspectorate. The base inspections for the turbine hall, emergency building, other auxiliary buildings and the hydroelectric power plant are planned, scheduled and in part already completed but not yet documented. At KKL, documentation is now available for all classified buildings, although the results of basic inspections have not yet been recorded. During the year, maintenance work was carried on structures such as expansion joints and facades. The structural condition of elements of relevance to safety is good. The ageing surveillance of structures is on schedule.

Electrical components: The ASP documents for Class 1E equipment such as cables, motors, solenoid valves, etc. in the containment area are almost complete and those for the remaining Class 1E components largely drafted. The focus during the year at KKB, KKG and KKL was the drafting of further documents on Class 1E components outside the containment. At KKM, the focus was on the importance in safety terms of a component's function irrespective of the location where it is fitted. Taking Swiss nuclear power plants as a whole, the written characterisation for the relevant Class 1E components is more than 80% complete. In connection with improvements in the surveillance and prevention of age-related deterioration, several gaps were found in plant maintenance and they were remedied by measures such as additional checks and a shorter maintenance interval. The ASP documents for the relevant components have been revised accordingly. No further action is required at this stage. The situation is also helped by the fact that components in electrical and control systems are often changed for economic reasons or technical obsolescence before they reach the end of their technical life.

Mechanical components: The development of two small leaks caused by material fatigue, one in a flow meter on a feedwater line and the other on the reactor pressure vessel nozzle in the control rod return system at the Mühleberg plant (see Chapter 2.2.1) again underlines the importance of the ageing surveillance programme. In both these instances, the damaged components had either not yet been included in the ASP or not adequately recorded, despite the fact that KKM is well advanced with the process of ASP documentation. In 2003, KKM submitted documentation on nine cooling and safety systems and revised documentation on the containment. KKB also compiled improved documentation on the containment, which reflected the findings of recent research and internally, it processed the ASP for outstanding safety systems. This documentation is due for submission to the Inspectorate in 2004. KKL submitted documentation on a further four cooling and safety systems. Ageing surveillance is now firmly anchored as a process in the KKL Management System. KKG focussed its efforts on transient surveillance, which serves to identify and check for material fatigue. It largely adhered to the timetable for the production of ageing surveillance documents for the numerous mechanical components in Safety Classes 2 and 3. In terms of general safety systems, the Inspectorate has received from KKB, KKL and KKM the required documents for about 60% of the mechanical components and about 40% of those required from KKG. ASP work on Safety Class 1 components, such as the reactor pressure vessel is largely complete. The Inspectorate has kept a close watch on any damage occurring in plants outside Switzerland and the results of the non-destructive testing of Swiss reactor pressure vessels (e.g. testing of RPV head penetrations at KKB) to see whether modifications are required to the Swiss ASP. Recent damage to plants outside Switzerland has involved systems already covered by the programme of in-service inspections conducted in Swiss nuclear power plants.

The ageing surveillance programme involving all Swiss nuclear power plants and the central interim storage facility is largely on schedule and is proceeding reasonably well. Ageing surveillance includes not only an assessment of component condition by an appropriate method but also the regular evaluation of international experience in the field of material ageing. The Inspectorate monitors the results on a continuous basis and can confirm that ageing phenomena have so far not impaired the safety of Swiss nuclear power plants in any way. The ageing surveillance programme is one of the mechanisms used to ensure that Swiss nuclear plants maintain their high safety level even after a lengthy service life of several decades.

5.3 Radioactive waste

Maintenance work and modifications to an operational nuclear power plant give rise to material that is either radioactively activated or contaminated with radioactivity. To minimise the amount of radioactive waste, material that has been contaminated but is not in itself radioactive is taken for decontamination and then cleared as inactive. The conditions for passing materials from controlled zones as inactive are laid down in Guideline R-13, which came into effect in February 2002. In 2003, a total of 90 tonnes of material (mostly steel, concrete, oil and building rubble) from Swiss nuclear power stations (including the experimental nuclear power plant at Lucens) passed as inactive was cleared for further use or conventional disposal and reported to the Inspectorate. The secondary waste arising from decontamination is treated as radioactive raw waste.

Radioactive raw waste derives mainly from water purification systems and the treatment of stack gas and recirculation air. This form of waste also derives from the replacement of components during maintenance work, modifications or back fitting. The radioactive raw waste is collected, conditioned in batches (campaigns) and held in the plant's own interim storage or the Central Interim Storage Facility (ZZL) at Würenlingen until its transfer to a geological repository. The amount of radioactive raw waste in all nuclear power plants was similar to last year. Comparisons over several years show a slight reduction in the volume of waste (see Table A11a).

When the waste is conditioned, it is solidified, bound in a matrix and packed in a form suitable for transport and both interim and final storage. During 2003, the following conditioning campaigns were conducted by Swiss nuclear power plants:

– KKB – cementation of slurries from the waste-water treatment system,
– KKM – cementation of ion-exchange resins,
– KKG – bitumination of concentrates and final conditioning by means of cementation of previously compressed filter elements,
– KKL – cementation of resins and concentrates.

In addition, several power plants repackaged waste in compliance with the current acceptance conditions for the incineration and melting plant at ZWILAG. After conditioning, each waste package and its characteristics are recorded in an electronic database. During 2003, the Inspectorate examined the conditioning work carried out by all four nuclear power plants and with satisfaction was able to confirm that all had complied with the regulations.

PSI closed down its furnace in 2002 after the 46th and final campaign to incinerate combustible mixed waste. The resultant ash products were returned to the power plants (KKL and KKM) in 2003. It had been intended that the incineration and melting plant at ZWILAG would take over the low-level combustible waste from 2003. However, the plant was unable to commence actual operations (see Chapter 6). The

Bird's eye view of the ZWILAG buildings in Wuerenlingen.
Photo: ZWILAG

waste casks produced by the plants since the end of 2002 and intended for the new furnaces at ZWILAG were initially stored at the plant's own interim storage facility. Since then, some casks have been transferred to ZWILAG where they are being stored in the high-bay racking store in the conditioning plant.

The licensee is required to provide a detailed specification in compliance with Guideline R-14 for each conditioning process and the types of resultant waste casks. In addition, they must be examined and approved by the Inspectorate. The Inspectorate has approved all the waste cask types currently produced by the plants. In 2003, the Inspectorate assessed and approved one further type of cask. In addition, the Inspectorate checked and approved the final redocumentation required for types of waste casks previously produced by the plants. This process provides evidence that waste casks of a type no longer produced in this form comply with current requirements. The Inspectorate welcomes the completion of this lengthy process of redocumentation. It means that documentation containing the information required for further disposal is available for every type of waste cask produced by nuclear power plants.

In all nuclear power plants, raw waste is held in specially designated locations in the controlled zone awaiting subsequent treatment. Conditioned waste casks are stored in the plant's own interim storage facility. Records are kept of the contents of the interim storage sites and reports filed every month. During the year, the Inspectorate visited the interim storage sites at KKB, KKG and KKL and the inspections confirmed compliance with regulations.

5.4 Emergency preparedness

Emergency preparedness embraces all organisational and technical measures inside and outside the plant to protect employees and the general public in the case of an accident impacting on the immediate surroundings of a nuclear power plant.

The prime aim of the licensee of a nuclear plant and the relevant supervisory body is the safe operation of the plant. There are technical and organisational concepts designed to prevent and limit the effects of accidents. Well-developed emergency structures play an important role in this respect and in the context of emergency preparedness, the effects of such accidents can be minimised if appropriate decisions and actions are taken at the right time.

5.4.1 Emergency exercises

Emergency preparedness is maintained at a high level by targeted training for emergency organisations and verified by means of emergency exercises.

The Inspectorate's requirements in terms of the planning and execution of emergency exercises in Swiss nuclear power plants are laid down in Guideline R-45. This Guideline was revised during 2003 and the new edition reflects experience gained from previous exercises. It came into force on 1 August 2004. As a rule, there will be one emergency exercise, including an official inspection, in each plant per year.

The following exercises were held during the year under review:

– *Beznau nuclear power plant (KKB): general emergency exercise "IRIS".*
  For this exercise, it was assumed that Unit 1 was shut down and as Unit 2 was being shut down, there was an explosion in the turbine hall. The explosion caused a fire and flooding in the turbine hall resulting in a failure of the auxiliary cooling water system, which in turn meant that it was not possible to guarantee the cooling of various auxiliary systems. Further failures and incidents escalated the emergency in Unit 2. Remedial action was initially successful but further problems threatened this work and subsequently caused damage to the core and endangered containment. In order to protect the containment, it was eventually necessary to perform a filtered venting of the containment.
  The exercise was conducted under the direction of the Chairman of KomABC (Swiss Federal Commission for NBC Protection). Participants also included relevant Federal bodies who are members of the EOR (Task Organisation for Increased Radioactivity), representatives from the relevant bodies in the cantons of Aargau and Zurich and from Germany. The exercise allowed participants to work through the process of notification, decision-making and implementation as required under RABE, the system for the rapid alarming of the population.
– *Gösgen nuclear power plant (KKG): works security exercise "FEUERBALL" (fireball).*
  For this exercise, it was assumed that a vehicle loaded with explosives had gained access via a temporary site entrance and was parked in the area of the emergency diesel generator building, auxiliary systems building and switchgear building and was being used as blackmail. An accident occurred during evacuation of the area resulting in fire, deaths and injuries. The purpose of the exercise was to test the interaction between the KKG emergency management team and external bodies and also between the KKG emergency management team and internal emergency teams.
– *Leibstadt nuclear power plant (KKL): staff emergency exercise "FAST".*
  In this instance, it was assumed that a large aircraft with a full tank of fuel had crashed into the turbine hall and reactor building. This had resulted in a massive fire over a wide area and in part serious damage to buildings and components. Debris had damaged a main steam line and a small amount of radioactive material had leaked into the environment. The exercise consisted of two phases: the actual staff exercise and the resultant round table discussion with plant managers and external federal experts specialising in disaster management (including the Swiss Air Accident Investigation Bureau) and cantons (including the canton police in Aargau). This exercise focussed on management and organisational issues, fire fighting, security, alarm concept, information and communication, medical and care services.
– *Mühleberg nuclear power plant (KKM): works emergency exercise "EKLAT" based on initial security incident.*
  For the exercise, it was assumed that there had been a demonstration outside the power plant. An armed demonstrator had forced his way into the turbine hall and damaged one of the turbine oil tanks. The turbine was isolated. The intruder was detected by the plant's own guards. The police were summoned and apprehended the culprit as he was trying to escape. In order to bring the oil leak under control, the oil brigade was deployed. An oil fire at two places in the turbine hall impeded its work. In addition to bringing the emergency situation under control, the exercise focussed on the associated internal and external co-operation and a review of the information function.
– *Central Interim Storage Facility Würenlingen (ZWILAG): staff security exercise "TROJA".*
  The scenario here was that two members of a legitimate visitor group had sought to gain

access to restricted parts of the building. The emergency team called in to deal with the matter had to assume that a hostage had been taken. They were required to develop suitable solutions in consultation with the police.

– *Paul Scherrer Institut (PSI): institute security exercise "TERO".*

  The scenario in this instance was a series of arson attacks timed at intervals in two different buildings, the second targeting the Diorite reactor, which was in a decommissioned state. The exercise involved teamwork between all staff in the emergency organisation called in to resolve this challenging emergency situation. In addition to a review of the readiness of PSI's entire emergency organisation, it also served as a review of co-operation with the canton police in Aargau.

The Inspectorate found that plants maintained a high state of emergency preparedness during the year under review. Potential improvements identified during the emergency exercises were accepted, evaluated and implemented. For example, during IRIS, the general emergency exercise held at Beznau it was found that the criteria for triggering a "warning" and an "alarm" needed clarification.

5.4.2 Emergency preparedness in the neighbourhood

Emergency preparedness in the vicinity of nuclear plants is an integral part of general measures to protect the Swiss population. After a plebiscite had endorsed new legislation designed to protect the population, the way was clear in 2003 for appropriate measures to protect it against disasters and emergency situations.

The following ordinances relating to emergency preparedness in the vicinity of nuclear plants were revised in consultation with the Inspectorate:

1. Swiss Ordinance on the supply of iodine tablets

The Ordinance on the supply of iodine tablets of 26 February 2003 states that iodine tablets must be issued as a precaution in sufficient quantities in Zone 1 and now in Zone 2 (up to a distance of 20 km from a nuclear power plant) to households, industry, schools, government and other public and private organisations. This means that iodine tablets will be available immediately to all those living in Zones 1 and 2 if an alarm is given.

2. Swiss Ordinance on alert procedures

The Ordinance on alert procedures, which took effect on 1st January 2004 changes the organisation with responsibility for triggering the siren alarm in Zone 1. Under the Swiss Ordinance on emergency protection, it was the nuclear power plant itself that was responsible for triggering sirens. This responsibility now rests with the canton. This change is designed to simplify the co-operation between the nuclear power plant and federal bodies in the event of an accident because the licensee is now only responsible for ensuring compliance with the alarm criteria and notification to the authorities. The alarm itself is triggered by the cantons, although for technical reasons this change will not take effect until 1st January 2006. From 1st January 2004, the siren "Radioactivity Alarm NPP" will no longer be used. The plants and the cantons started work on the associated organisational changes during 2003.

The Inspectorate was involved in the drafting of both ordinances.

In addition, the Inspectorate supported the cantons with their training in emergency preparedness at nuclear power plants.

In 2003, there were a total of 23 external training courses in emergency protection, in some cases in co-operation with other training establishments. The courses included 9 at federal level and 12 at canton or community level. The training focussed on emergency protection in the event of increased radioactivity in the vicinity of a Swiss nuclear power plant. Depending upon the target group, the courses also dealt with subjects such as the principles of radiation protection, how a nuclear power plant works and accident scenarios.

5.5 Inspections in 2003

Inspections play a crucial role in the process to monitor nuclear safety and radiation protection at nuclear installations as they provide evidence for an independent assessment of a plant's general condition and operations. On the one hand, they provide the Inspectorate with information on whether a licensee is running its facility as required by law (conformity check). On the other hand, they provide early warning of possible shortcomings in nuclear safety and radiation protection so that prompt remedial action can be taken (preventive safety check).

In 2003, the Inspectorate carried out the following inspections as part of its role to supervise nuclear power plants:

Plant	KKB	KKM	KKG	KKL	Total
Total	76	58	56	80	270

These inspections took place during the operation of the plant and during maintenance shutdowns.

The table does not include inspections by the SVTI, the Swiss Association for Technical Inspections. Working on behalf of the Inspectorate, the SVTI verifies the in-service inspections of pressurised, safety-classified components at nuclear power plants. In 2003, SVTI conducted some 150–200 such inspections at each nuclear power plant.

In most cases, licensees are advised of official inspections in advance so that a timetable can be agreed for the relevant inspections and plant staff can make themselves available to answer questions by the inspectors. However, some inspections are unannounced, e.g. to verify general plant and operating documents.

Overall, the results of inspections were good and the Inspectorate only identified a few minor defects, e.g. Guidelines not implemented in full or requested additional clarification on issues such as the implementation of plant modifications. With several inspections, the results of observations and tests by the Inspectorate failed to comply with official guidelines, e.g. the implementation of fire prevention measures and balancing of radioactive releases. However, there was no evidence of any deficiency that could have jeopardised the safe operation of the plants. In terms of organisation and human resources, no deficiencies were found that could have adversely affected safety.

5.6 Security of Swiss nuclear power plants in the event of a deliberate aircraft crash

The terrorist attacks of 11th September 2001 on the New York World Trade Center (WTC) and the Pentagon in Washington created a new dimension in global terrorism: For the first time in history, passenger aircraft with a full fuel load had been used as a weapon to attack people and civilian buildings. The resultant destructive force was enormous resulting in the collapse of both WTC towers and the collapse of one side of the Pentagon building. The attacks claimed more than 3,000 lives. This new type of threat quickly triggered concerns throughout the world on the effect of a deliberate crash of an aircraft on a nuclear power plant. The question was whether such an attack could lead to a nuclear disaster. In autumn 2001, the Swiss Federal Council received a request for a postulate on this question.

In order to conduct a detailed and comprehensive evaluation of the actual threat posed by this new scenario, the Inspectorate asked nuclear power plants at the end of September 2001 to carry out an analysis of plant safety in the event of a deliberate aircraft crash. The Inspectorate evaluated the subsequent reports submitted by licensees, which for understandable reasons remain confidential. The Inspectorate announced the results of its evaluation in a public report at a press conference on 3rd April 2003. This report can be viewed on the Inspectorate's website at http://www.hsk.ch.

The main findings can be summarised as follows:

The consequences of a deliberate aircraft crash are determined primarily by general conditions such as the type of aircraft and its flight path and so, the type of aircraft, the engine type, the angle of impact and the topography in the immediate vicinity of a nuclear power plant would have a major impact on the consequences. Investigations have shown that an attack on a nuclear power plant using a civilian aircraft would only be possible, if the angle of impact were relatively flat and the aircraft was flying at a reduced speed. This conclusion was derived from flight simulator exercises and interviews with experienced pilots. In contrast, the report did not comment on the likelihood of an aircraft being used by terrorists to attack a Swiss nuclear power plant as for the purposes of the investigation, this was assumed.

In addition, the structural and technical design of an individual plant would also be crucial in determining the consequences of a deliberate crash by an aircraft.

The design of nuclear power plants is based on a comprehensive and systematic safety concept, which would also apply if an aircraft were to crash. This includes the *concept of staged independent barriers*. If an aircraft were to crash, the reactor building would act as an *external* barrier and play a central role in resisting penetration by aircraft components, in particu-

Inspection of the aerosol monitors in the Muehleberg nuclear power plant at their commissioning. Photo: KKM

lar the engines, tail and fuel. However, the second important barrier is *internal*, i.e. storey separation and the numerous vertical and horizontal divisions of individual areas and the concrete radiation protection walls inside the reactor building. Typically, these massive structures are 1–2 m thick and the walls serve to reinforce the external design. The thickness of the concrete is several metres and these two barriers serve to protect the reactor core, i.e. the reactor pressure vessel, the reactor cooling system and most of the safety systems.

The *Concept of Spatial Separation* protects the plant against external events as it ensures that redundant safety systems are placed in different buildings or located at a distance from one another.

Nuclear power plants have several *redundant* and *diverse safety systems*, i.e. multiple systems based on several different technologies. In addition, Swiss nuclear power plants have their own bunker-type autarkic emergency systems and so have redundancy-based, spatially-separated shutdown and cooling systems in the reactor building to protect them against an aircraft crash and penetration by third parties.

Based on a comprehensive analysis that considered in detail the aspects referred to above, the Inspectorate is now in a position to comment as follows on the situation with regard to the Swiss nuclear power plants:

- If a civilian passenger aircraft were deliberately crashed into a Swiss nuclear power station, the damage to people and property at the plant is likely to be serious.
- In order to penetrate the reactor building, the speed of the aircraft on impact would have to be in the range of elevated or above. At such speeds, it would be difficult to target and hit the reactor building with any accuracy. This applies particularly to the Mühleberg plant because of its valley location with surrounding hills, which would make it almost impossible for a civilian aircraft to hit it at high speed with any degree of accuracy.
- The results of studies relating to the Gösgen and Leibstadt plants show that – at all the investigated speeds – the plants are so well protected that it would not be possible to penetrate the reactor building. As a result, the likelihood of a release of radioactive substances into the surrounding area if an airline were to crash into these plants is very low and would be in the per thousand range.
- The licensee of the Beznau plant has shown that the plant has effective protection against penetration of the reactor building if the speed were average or elevated. At Mühleberg, it was found that the reactor building had a high level of protection against penetration if the speed were average. In addition, the massive internal structures mean that the plant has a high level of protection against a failure of systems of relevance to cooling of the core even if the external building suffered serious damage.
- Analyses by the licensees of the Beznau and Mühleberg plants showed that the likelihood of releases of radioactive substances in the event of an aircraft crash is low, i.e. in the per cent range.

Other countries have also investigated the risks associated with a deliberate aircraft crash (including Belgium, USA, Sweden). The results are consistent with the results of the Swiss study. The study carried out in Germany by GRS (Association for Installation and Reactor Safety, Germany) is confidential and has not been made available to the Inspectorate. However, based on a confidential memorandum compiled by the BMU (German Federal Ministry for the Environment, Nature Conservation and Reactor Safety) and published by BUND, the German environmental organisation, it is clear that the analytical methods and models adopted in both the Swiss and German studies are very similar and in many aspects identical. Both studies were based on a comparatively conservative approach. In Switzerland, this approach was refined further and the results include a quantitative assessment of the actual level of protection of nuclear power plants against an airline crash. In addition, the Swiss study comments on the likelihood of a more serious release of radioactive substances in the event of an assumed deliberate airline crash, i.e. the Swiss study identifies the conditional risk in the event of a crash whereas this is not included in the German study.

5.7 Operational life of Swiss nuclear power plants

The operating licenses granted to Gösgen, Leibstadt, and Beznau 1 have always been for an unlimited period whereas Beznau 2 and Mühleberg are currently licensed for a specific period. The new nuclear energy legislation (KEG), which was approved by the Swiss Parliament in March 2003 and takes effect from the beginning of 2005, does not specify a limit on service life. This means that nuclear power plants can be operated for as long as they remain in a safe condition. There is no pre-determined operating life. The safety requirements are based on the one hand on the original design criteria. Certain components – see below – are designed for a specific service life of 40 operating years. On the other hand, the requirements state *that all necessary precautionary measures based on experience and the state of the art in science and technology must be taken* (Article 5 KEG). In other words, a nuclear plant must be back-fitted on a permanent basis in line with new developments. This is a specific requirement under Article 22.2g of the KEG, which reads: *Plants shall undergo the necessary back-fitting based on experience and the state of back-fitting technology, and beyond that if this helps to reduce hazard further and is proportionate.* Swiss nuclear power plants have always attached great importance to back-fitting, improvements, and replacement of components in order to improve safety.

The safety status of a nuclear power plant is subject to continuous review by the supervisory body, and it also undergoes a comprehensive systematic review every ten years. This raises the question, therefore, of how – from a safety perspective – the service life of a nuclear power station should be limited. If it is assumed that a plant is operated with care and well maintained, that ageing mechanisms are effectively monitored, structures, systems and components are replaced when necessary and no incidents occur that limit its service life, this then raises the further question of which structures, systems and components cannot be replaced. Experts in the field all agree that the only components that cannot be replaced with reasonable means are the reactor pressure vessel (RPV) and the primary containment.

In terms of the RPV, the two unavoidable ageing mechanisms limiting service life are *embrittlement caused by neutron irradiation and material fatigue*, with embrittlement being the more important.

Neutron irradiation on the RPV wall of the reactor core zone causes lattice defects in the metal, which makes it brittle. This means that the safety margin in respect of brittle fractures is reduced as service life is increased. In practical terms, this does not affect normal power operation but for the start-up and shutdown of a plant, pressure tests and in the event of an accident, there must be sufficient protection against brittle fractures. The level of embrittlement is monitored by a programme, which includes the irradiation of probes in the RPV and their subsequent analysis in laboratory tests. This forms the basis of evidence showing whether the RPV is protected against brittle fractures. Results to date of the irradiation probe programme show that RPVs in all Swiss nuclear power plants comply with international standards on protection against brittle fractures. In addition, it is also possible to extrapolate the results beyond the original design service life of 40 years and this extrapolation shows that based on current knowledge, protection against brittle fractures can be maintained beyond the originally assumed design life of 40 years.

Material fatigue is caused by cyclical loads such as start-up/shutdown or a reactor scram. For the purposes of material fatigue, the RPV and other components in Safety Class 1 were also designed for a service live of 40 years. This was based on a specific number of different cyclical loads known as design transients. The design criteria stipulate that the usage factor must remain less than 100% at all times. However, a 100% usage factor does not necessarily mean that a component will actually fail or fatigue cracks develop. Compared with the number of fatigue load cycles that lead to failure in laboratory tests, there is a safety factor of 20. This is a conservative reflection of possible uncertainties in the transfer of test results to actual usage in the plant. As long as the design calculations show that the usage factor is less than 100%, component failure because of fatigue can be excluded, provided all relevant origins of fatigue have been taken into account.

Operating experience has shown that actual transients are generally less common and result in less stress than had been assumed at the time of the design. As a result, actual usage factors have so far been less in most cases than expected. In addition, if usage factors were recalculated using the more accurate methods now available, this would further reduce the usage factor in many cases.

However, there are also instances, where degradation mechanisms such as localised frequent thermal cycles were not foreseen at the time of design. One such example are the RPV feedwater nozzles at the Mühleberg plant. Here, leakage developed between the internal nozzle wall and the inserted thermal sleeve, which was actually designed to provide thermal protection for the nozzle wall. This resulted in highly cyclical thermal loads and to an usage factor of 90%, i.e., contrary to the design basis. The nozzles have now been modified and the source of fatigue eliminated. The feedwater nozzles now undergo regular ultrasonic tests, the most recent during the 2003 maintenance period and these showed no evidence of cracks.

To sum up: The fatigue usage of the RPV – not including replaceable components – is generally far lower than the design basis. Regular non-destructive testing has not produced any unacceptable findings. From today's perspective, there is no evidence, therefore, that fatigue would be an obstacle preventing the operation of RPVs for more than 40 years. In addition, in-service inspections and international findings have not produced evidence of other active degradation mechanisms in non-replaceable components of the RPV.

In addition to the RPV, the primary containment is also deemed non-replaceable. In this case, corrosion could represent a damage mechanism capable of limiting service life. With regard to the containment at the Mühleberg plant, leaks have developed in the reactor well area and so corrosion must be regarded as an active degradation mechanism. Tests and controls to date have not revealed any evidence of significant damage. However, targeted measures are required to protect the long-term structural integrity of the primary containment. Similarly, the primary containment in Unit 1 of the Beznau nuclear power plant has also experienced corrosion. In the short term, this does not represent a safety problem but its importance for the longer term is being investigated. No active degradation mechanisms have been identified in the primary containment of other plants.

From today's perspective and assuming that ageing is managed effectively, the Swiss nuclear power plants could be operated for longer than 40 years even from the standpoint of nuclear safety.

However, comprehensive safety evidence of a formal nature would be required if nuclear power plants were to extend their service life beyond 40 years. For this purpose, nuclear power plants would have to provide safety evidence for the proposed extension to their service life, similar in its scope to that submitted for the original 40-year period. Of course, the evidence would also have to reflect experience since that date and the state of the art in science in technology.

In the United States, this type of evidence has already been submitted for 23 nuclear power plants and the US Nuclear Regulatory Commission (NRC) has approved service lives of up to 60 years. The same process will be completed for a further 18 plants during 2004/05, and a further 20 or so plants are due to submit the relevant applications this year or in the next few years. It is likely, therefore, that most plants currently in operation will seek a service life of 60 years, including the R.E. Ginna and Point Beach plants, both of which are similar to the Beznau plant and the Hatch and Monticello plants, which are similar to the Mühleberg NPP.

6. CENTRAL INTERIM STORAGE FACILITY, WÜRENLINGEN

The Central Interim Storage Facility (ZZL) of the "Zwischenlager" Würenlingen AG (ZWILAG) consists of several interim storage buildings, a conditioning plant as well as an incineration and melting plant. In this section, the status of the commissioning and operation of the different parts of the facility and issues relating to radiation protection, personnel and organisation are explained and evaluated. In addition, it discusses issues relating to the return of reprocessed waste and the procurement of transport and storage casks.

6.1 Interim storage facilities

The interim storage halls at ZZL are designed for the storage over several decades of spent fuel assemblies and all levels of radioactive waste. They include a cask storage hall for spent fuel assemblies and vitrified high-level waste from reprocessing (vitrified residue packages), a storage hall for intermediate-level waste and a storage hall, currently still under construction, for low- and intermediate-level radioactive waste. In addition, the interim storage element includes a reception building and a hot cell. Storage operations started in 2001.

At the end of 2002, a total of 10 transport and storage casks (TL casks) were stored in the cask storage hall. During 2003, a further 2 TL casks were added making a total of 12 casks at the end of 2003: 4 casks of type CASTOR HAW 20/28 CG, each with 28 vitrified residue packages from reprocessing by COGÉMA of KKB and KKG fuel assemblies, 4 casks of type TN97L, each with 97 spent fuel assemblies from the operation of KKL and 4 casks of type

The anti-crash lid is fitted onto a TL-container in the storage hall of ZWILAG.
Photo: ZWILAG

Fuel elements are being loaded into a TL-container in the hot cell by remote control.
Photo: ZWILAG

TN24G, each with 37 fuel assemblies from KKG. Prior to granting approval, the Inspectorate scrutinised the corresponding storage applications and made several inspections of the storage work. The Inspectorate found that work had been done appropriately.

KKM delivered spent fuel assemblies in transport casks with a capacity of 7 fuel assemblies. At ZZL, the fuel assembles are transferred to storage casks of type TN24BH. This takes place in the hot cell. This type of storage cask, which holds 69 fuel assemblies, is also approved as a transport cask so that when transferred at a later date, no further handling will be required. The first transport/transfer campaign took place in 2003 (9 transports each with 7 fuel assemblies and a 10th and final transport with 6 fuel assemblies. No problems arose during the transfer of the fuel assemblies to the storage casks. These casks were hermetically closed in January 2004 and on successful completion of leak tests were taken to the cask storage hall.

ZZL was designed from the outset so that – in addition to the transport and storage of casks containing spent fuel assemblies and vitrified residue packages – the cask storage hall could also be used for the interim storage of the six large casks of decommissioning waste from the former experimental nuclear power plant at Lucens (VAKL), which since decommissioning has been stored at Lucens. In September 2003, these casks – some of which weigh up to 95 tonnes – were transported from Lucens to ZZL (see Chapter 9.5) for storage in the cask storage hall. This work was completed as scheduled and in accordance with the guidelines of the Inspectorate.

In the year under review, no waste was deposited in the intermediate-level storage hall and so the inventory for this type of waste remains unchanged at 134 packages.

Construction of the storage hall for low-level and intermediate-level waste continued during the year. ZWILAG intends to use this building for several years as a conventional store for non-radioactive equipment and material. The current construction work is limited, therefore, to the structures required for this type of storage. As part of the approval procedure, the Inspectorate is supervising the construction and installation of any equipment that will be required at a later date, when this storage facility is used for radioactive waste. In 2003, this storage hall was completed to the extent that it can now be used by ZWILAG. Since autumn 2003, some 3000 empty containers no longer required by PSI and taken over by ZWILAG in the framework of an agreement have been deposited in the storage hall. During the next few years, these containers will be filled with radioactive waste and used to load waste into the incineration and melting plant.

6.2 Conditioning plant

The licence to build the conditioning plant at ZZL was issued by the Swiss Federal Council on 21st August 1996 and the operating licence on 6th March 2000. The conditioning plant is designed to treat low-level waste from the operation and later decommissioning of Swiss nuclear power plants as well as, if required, radioactive waste without α-emitters from medicine, industry and research. In 2000, ZWILAG completed the installation of systems and instrumentation (with a few exceptions) and began preparations for start-up. The Inspectorate monitored the work of ZWILAG by examining submitted documentation and on-site inspections and found that ZWILAG had complied with guidelines.

In 2002, ZWILAG decided that for the time being it would refrain from operating certain equipment in the conditioning plant, in particular the waste cementation facility. The reason being that the expected volume of waste could be treated in the next few years in the incineration and melting plant. As a result, in July 2002 it submitted an application to operate only part of the conditioning plant. The Inspectorate carried out the necessary examinations and inspections required for this partial approval and granted it in February 2003. Following that, operational waste from Swiss nuclear power plants was transported to ZZL and stored in the high rack storage area in the conditioning plant. As soon as approval has been granted for the first active trial run of the incineration and melting plant, this waste will be transferred to the incineration/melting plant and conditioned by incineration there.

During 2003, ZWILAG commissioned the remaining unapproved equipment in the conditioning plant individually and on an inactive basis. The Inspectorate conducted numerous inspections and defects identified were remedied. On completion of the commissioning work, ZWILAG applied in November 2003 for approval to operate the entire conditioning plant. The Inspectorate granted operating approval in December 2003 based on the documents submitted and the results of its own inspections.

6.3 Incineration and melting plant

The Federal Council approved the construction of the incineration and melting plant at ZZL on 21st August 1996 and licensed its operation on 6th March 2000. The plant is designed for the incineration and melting of low-level radioactive waste from the operation of Swiss nuclear plants and from medicine, industry and research, so reducing its volume and converting it into an inorganic state suitable for interim and final storage. The Inspectorate supervised the construction and assembly of those parts of plant that are important for safety and radiation protection.

Inactive trial operations between 2000 and 2002 identified several defects in the plant and ZWILAG completed the necessary technical modifications to remedy these defects. Problems arose with the centrifugal bearing during further inactive trials in April and May 2003 and an immediate reworking of the bearing only produced a limited improvement with the result that ZWILAG suspended the trials at the end of May. The bearing was redesigned and refitted and in December 2003, ZWILAG commenced further inactive trials. However, these trials also had to be suspended before completion because other complications arose. In contrast, the new centrifugal bearing worked as designed during these latter trials.

As in previous years, the Inspectorate supervised the trial runs relating to the commissioning of the incineration and melting plant. Most of the defects identified in 2002 were resolved to the satisfaction of the Inspectorate. The Inspectorate is insisting that the first active trial run must wait until all the outstanding items on the Pending List have been dealt with and the plant has run inactively for a continuous period of about three weeks without significant problems.

In May 2003, ZWILAG tested a new sampling procedure designed to specify the types of waste containers produced by the plant and their compatibility with Guideline R-14. The physical and chemical parameters of representative samples taken from the plant are used to verify and approve the types of waste produced and the continuous quality control demanded for active operation.

6.4 Radiation protection

In 2003, the collective accumulated dose was 2.7 mSv (2002: 6.2 mSv). The principle of optimisation was consistently applied. There were no instances of personal contamination.

Specialists in radiation protection are routinely involved in the deposit of transport and storage casks in the cask storage hall. The Inspectorate can confirm that the preparation and execution of the delivery checks for one transport/storage cask was carried out with the requisite care. Similarly, in terms of radiation protection, the condition of this storage hall and the storage hall for medium-level waste already in operation together with the associated reception building and hot cell is good. The radiation protection specialists had no difficulty in discharging their supervisory and control responsibilities relating to the operation of the hot cell. 69 fuel assemblies from KKM were transferred in the hot cell to a larger transport and storage cask.

With the exception of the high rack storage area, the conditioning plant is not yet in active operation. With regard to the incineration and melting plant, ZWILAG provided training – based on radiation protection criteria – for certain functions that will be important for the future active operation of the plant.

ZWILAG has a very good stock of the hardware required for operational radiation protection and has the resources required to carry out any modifications required for future operations. Human resources for radiation protection functions are in short supply. The Inspectorate considers that ZWILAG meets is priority tasks in terms of radiation protection.

6.5 Personnel and organisation

As a result of various discussions with ZWILAG, the Inspectorate has identified that staff at ZWILAG are extremely stretched as the current start-up of the plant coincides with the completion of important systems. Despite the increase in personnel to deal with this demanding phase of the plant's operation and the simultaneous commissioning of systems, the Inspectorate considers that the plant has insufficient human resources. The Inspectorate will continue to pay particular attention to this issue.

At the end of the year under review, auditors from Swiss TS audited the Quality Management System of ZWILAG. The auditors commended the level of commitment displayed by staff in implementing the management system. It also found that the system was being used in normal daily operations although only just introduced on a definitive basis. Based on the good results of this audit, the SQS awarded ZWILAG certification of compliance with Quality Standard ISO 9001:2000.

The Inspectorate has monitored the introduction of the Quality Management System from the outset and can confirm that ZWILAG's understanding of formal management systems has increased significantly in recent years. Despite its greater formality, the system is not regarded as a constraint but is seen as an aid to daily operations.

Compliance with the requirements of the non-industry specific ISO standard does not mean that the System satisfies the requirements for nuclear plants as specified by international bodies. These requirements are laid down in an IAEA document – Safety Series 50-C/SG-Q "Quality Assurance". From the outset, the Inspectorate has insisted that this document should form the basis of evaluations of nuclear safety. As these aspects of nuclear safety are not covered by the ISO-Norm, the Inspectorate will continue to monitor the various processes at ZWILAG with relevance to nuclear safety.

6.6 Waste from reprocessing

Spent fuel from Swiss nuclear power stations is processed by COGÉMA at La Hague (France). In addition, it is now being processed by BNFL at Sellafield as well (United Kingdom). Under the terms of the contracts signed with these companies, waste resulting from the reprocessing of fuel assemblies from Swiss nuclear power stations by COGÉMA and BNFL must be returned to Switzerland. Highly active vitrified waste (vitrified residue packages) resulting from the reprocessing by COGÉMA is ready for return. That from the reprocessing by BNFL is not yet available.

The first vitrified residue packages resulting from the reprocessing of spent fuel assemblies from the Gösgen plant were returned in 2001. In 2002 and 2003, three further consignments containing vitrified waste from the reprocessing of spent fuel from Beznau were returned to ZZL. COGÉMA is responsible for the handling and control of the residue packages due for return and for loading them into a TL cask. The Inspectorate was present at this work and can confirm that it complied with the relevant requirements. The three casks were transported and subsequently stored in the cask storage hall at ZZL as planned and in accordance with regulations.

6.7 Procurement of transport and storage casks

The approved concept for the interim storage of spent fuel assemblies and vitrified residue packages is to enclose the waste in massive transport and storage casks (TL casks). These casks are transported from nuclear power plants or reprocessors to ZZL for storage in the cask storage hall. These casks must ensure safe storage during the period of interim storage. Drawing on its previous experience, the Inspectorate drafted Guideline R-52, which specifies the requirements for the design of transport and storage casks and the supervisory procedure to be followed during the design and manufacture of these casks. The Guideline took effect in July 2003. Apart from a few minor modifications to reflect the current state of the art in science and technology, it adopted the reference specifications for TL casks contained in the Inspectorate's report on ZZL in December 1995.

ZWILAG's owners started acquiring suitable TL casks in 1996. Supervision of the procedure used to procure these casks is a two-stage process: The Inspectorate first evaluates the choice (specification) of cask type and then it assesses compliance with the reference specifications on the basis of a safety report submitted by ZWILAG. In terms of Stage 1, the Inspectorate had already approved the selection of five types of cask (three for spent fuel assemblies and two for vitrified residue packages) by the end of 2002. During 2003, the nuclear plant licensees selected no additional types of casks but ordered additional casks of the types for which selection approval had already been granted by the Inspectorate. During the year under review, the Inspectorate monitored the design, construction details and manufacture of the TL casks ordered. At the Inspectorate's request, the Swiss Association for Technical Inspections (SVTI) supervised the acceptance tests.

For the purposes of determining compliance with the reference requirements, the Inspectorate evaluated in 2003 one further type of cask (TN24BH) for spent fuel assemblies from the Mühleberg plant on the basis of the relevant safety report. It concluded that this type of cask also complied with the requirements laid down for safe interim storage at ZZL. This means that the Inspectorate has so far confirmed that four types of casks satisfy the requirements of the reference specifications and are suitable for interim storage at ZZL: Three are designed for spent fuels and come from France (Types TN24G, TN97L and TN24BH manufactured by COGÉMA Logistics, previously Transnucléaire) and one is designed for vitrified residue packages and comes from Germany (Type CASTOR HAW 20/28 CG manufactured by GNB). Testing of a fifth type of cask (Type TN81CH from COGÉMA Logistics and designed for vitrified residue packages) was still in progress at the end of 2003 and is likely to be completed in 2004. Experienced gained during this and previous tests will be incorporated into the approval procedure governing the storage of individual TL casks.

6.8 Overall impression

Transport and storage casks are deposited in the cask storage hall on a routine basis. In terms of nuclear safety and radiation protection, the condition of this store as well as the storage hall for medium-level waste already in operation together with the associated reception building and hot cell is good. Operational management complies with regulations.

The Inspectorate granted full operating approval to the conditioning plant in December 2003. However, with the exception of the high rack storage area, the plant is not yet in active operation.

There were renewed problems in 2003 during the inactive test phases of the incineration and melting plant and active commissioning has been further delayed. Because of this delay, there is a build-up in the number of waste containers awaiting treatment in the plant and emanating from nuclear power plants as well as medicine, industry and research.

The plant has appropriate procedures for operational radiation protection. ZWILAG has resources capable of being adapted to accommo-

One of six containers with radioactive waste from the former nuclear research reactor Lucens is being delivered to the Central Interim Storage Facility. Photo: ZWILAG

date changing responsibilities. The Inspectorate awarded a “good” rating to the plant in terms of its compliance with radiation protection requirements.

Despite an increase in staff, the Inspectorate considers that the plant has only just enough personnel to deal simultaneously with both the commissioning of the incineration and melting plant and the storage operations.

The Quality Management System at ZWILAG has been certified in accordance with ISO-9001:2000. It has now been introduced, is running well and is regarded as beneficial to daily operations.

7. PAUL SCHERRER INSTITUTE (PSI)

7.1 Nuclear facilities at PSI

PSI is the largest research institute for natural and engineering sciences in Switzerland. Together with Swiss and foreign universities, institutes, clinics and industry, PSI works in the fields of material sciences, elementary particle physics, environmental and energy research as well as the biosciences. Its nuclear facilities are supervised by the Inspectorate and consist of the research reactor PROTEUS, a Hot Laboratory designed for the investigation of nuclear fuels and radioactive waste, facilities for the processing and storage of radioactive waste and the research reactors SAPHIR and DIORIT, now being dismantled.

7.2 Research reactor PROTEUS

The second test campaign of Phase II of the experimental programme continued successfully without incident during 2003 with a nuclear configuration consisting of light-water reactor fuel assemblies (LWR-PROTEUS). The work focussed on investigations into the high burn-up of pressurised water reactor fuel assemblies. Samples of high burn-up fuel were irradiated in PROTEUS and their reactivity was then compared with both fresh and calibrated fuel samples. Similar to the situation in 2002, the investigations this year produced interesting evidence of the decline in reactivity with increasing burn-up. In a repeat of the first test campaign, PWR fuel segments with a high burn-up rate were measured. This time, in addition to H_2O and a H_2O/D_2O mixture, a third moderator consisting of H_2O mixed with 2000 ppm boron was used in the central tank of PROTEUS. The Inspectorate gave prior approval to the changes to the composition of the moderator. In the autumn, a third test campaign was completed with four newly manufactured samples of fuel segments with one of the samples having a burn-up rate of more than 100 GWd/t. Two other samples came from a boiling water reactor. Phase II of the LWR PROTEUS experimental programme was concluded with the investigation of 13 fuel segments. It examined the high burn-up of fuel in terms of neutronics and reactor physics. The results were compared with the computed results of theoretical models and the findings will facilitate improvements to the simulation codes used for nuclear power stations (see also the annual reports from PSI).

During 2003, the reactor was in operation for 647 hours (2002: 713 hours; 2001: 416 hours), of which 3 hours were power operation (2002: 4 hours; 2001: 9 hours). Power operation means output from 200 W_{th} to the maximum permissible level of 1000 W_{th}.

The collective dose to the operating personnel (7 persons) was 1.3 Person-mSv (2002: 8 persons with 0.4 Person-mSv). The number of licensed personnel increased to 5 following the licensing of a reactor physicist.

Dismantling of radioactive waste from the reactor core during the decommissioning of the experimental reactor SAPHIR.
Photo: PSI

7.3 Dismantling of research reactors SAPHIR and DIORIT

Stage 2 in the dismantling of SAPHIR was completed at the end of October 2003: The equipment fitted in the reactor pool was detached, dismantled and stored outside the pool pending future disposal. The work was carried out in compliance with radiation protection requirements. Activated components were detached and broken up under water using tools with extension pieces. After the activated components had been removed from the reactor pool, preparations were made to drain the reactor water. In this connection, PSI submitted details of its measurements guaranteeing compliance with release limits. The Inspectorate verified the measurements and calculations and gave approval for the reactor water to be discharged into the River Aare (see Table A4a). In addition, before the reactor water was drained, a shield consisting of concrete blocks and steel plates was erected in the pool. As a result the dose rate from the remaining activated parts of the pool lining was reduced to such an extent that it was possible to remove non-activated components manually. The collective dose for Stage 2 was 4.94 person mSv (6 persons), which was very close to the planned rate of 5 person mSv. This was due to careful planning and compliance with radiation protection requirements.

In tandem with the work on Stage 2, preparations were started for Stage 3. In this stage, the final highly activated components in the biological shield will be removed. During this work the activity concentrations in the groundwater have to be monitored. For this purpose well borings outside and inside the SAPHIR building are prepared to monitor the groundwater for traces of artificial radioactivity. The Inspectorate scrutinised the groundwater monitoring programme and approved the work. As a result, work on Stage 3 of the dismantling work was able to start at the beginning of November 2003.

In terms of dismantling the DIORIT reactor, the inner concrete ring including the sheet-steel thermal shield was cut away and then broken into individual segments with hydraulic presses. The boronated aluminium sheet forming part of the thermal shield was detached from the steel segments without difficulty and is now ready for separate conditioning. In addition, a diamond circular saw was used on site to cut the inner and outer steel bearing rings supporting the reactor graphite. These ring segments were removed from the reactor and placed directly into concrete containers suitable for final storage. Because of difficulties during the cutting of the bearing rings, the collective dose for the five individuals working on the dismantling of DIORIT was 18 person mSv. The planned dose rate was 12 person mSv. A deviation of this level is admissible with this prototype of work.

7.4 Hot Laboratory

The Hot Laboratory is a specially equipped building designed for the investigation and processing of highly radioactive substances (e.g. nuclear fuels, accelerator targets or strong medical or industrial sources). Following completion of the renovation work in 2002, which improved the building's fire, earthquake and radiation protection, the Inspectorate could finally examine the fire alarm and fire protection systems and gave them a positive rating. Work on the experimental programme was restarted in the renovated building and no problems arose. In addition to work on fuel manufacture, the main focus was the design of new systems to examine how materials behave under extreme radiation.

During its supervisory work, the Inspectorate established that the office building associated with the laboratory building no longer complied with legal requirements. As a result, PSI submitted a concept for the redesign of the building.

The collective dose to PSI personnel (58 in total) was 33.3 person mSv.

7.5 Processing of radioactive waste

PSI processes radioactive waste from federal and cantonal research institutes, medical and industrial sources and in some cases from Swiss nuclear power stations. The waste undergoes appropriate conditioning in order to convert it into a form suitable for interim and final storage.

7.5.1 Approval procedures for waste package types

After a thorough review of specifications submitted by PSI, the Inspectorate approved a further three waste package models:

- incorporation using cement of waste from the decommissioned SAPHIR reactor into concrete containers,

– cementation of fuel waste from the Hot Laboratory in 1-litre packages (partial conditioning),
– redocumentation of waste from the Hot Laboratory lightly contaminated with plutonium and already conditioned.

During the year, PSI submitted the following three specifications, which the Inspectorate is currently reviewing:
– accelerator waste conditioned prior to 1992 (redocumentation),
– new conditioning of accelerator waste with a view to type approval,
– modified procedure for the final conditioning of fuel residues from the hot laboratory, similarly with a view to type approval.

7.5.2 Incineration plant and waste management laboratory

No further incineration campaigns took place in the PSI incineration plant during 2003 as the plant was taken out of service in 2002 after Campaign 46. The remaining incineration residues (ash) and the ceramic filters used for stack-gas cleaning, which had been generated by the final incineration campaigns were conditioned in full in the waste management laboratory using cement mortar and returned in the appropriate proportions to the individual nuclear power plants or the federal interim storage facility. PSI has not yet submitted plans to the Inspectorate for decommissioning those parts of the plant requiring approval.

7.5.3 Further waste conditioning in PSI East

A concrete-casting plant was installed in the "lower level passage" of the DIORIT building, which can be used to fill small containers containing stored raw waste (from the reactors SAPHIR, DIORIT and from the accelerator plants of PSI West) with cement. In particular, this plant will be used to produce a mortar with an

Top view of the experimental reactor PROTEUS: The nine fuel elements in the central test tank and the support structure of the transfer container can be seen.
Photo: PSI

additive from the graphite removed from the DIORIT reactor in 2002 and subsequently shredded. PSI has already conducted successful research into the use of graphite instead of quartz sand as a mortar additive and the plant is likely to be commissioned for active operation in spring 2004.

During the year, PSI collected radioactive waste from research, medicine and industry totalling just under 8.5 m^3 and weighing a total of 8.3 t. As in previous years, the main nuclide from this waste in terms of activity was tritium. The waste is being kept in storage halls AB and C at the PSI East site pending subsequent conditioning.

7.5.4 Clearance of materials

In 2003, the radiation protection group approved for unrestricted further use inactive materials from PSI controlled zones (those supervised by the Inspectorate) weighing a total of 105 t, including 43 t scrap metal. To confirm compliance with the required parameters, the Inspectorate took random samples to check these figures.

Transfer container for radioactive aluminum components from the experimental reactor SAPHIR.
Photo: PSI

7.6 Storage of radioactive waste

7.6.1 Federal interim storage facility

Since 1992, the Federal Interim Storage Facility (BZL) has routinely stored conditioned radioactive waste. The approved storage capacity is intended for the storage of standard barrels (200 Litres) of conditioned waste and small containers (maximum of 4.5 m^3). These small containers are used for unconditioned components, primarily from the DIORIT reactor and PSI West. In addition, the Inspectorate has granted restricted and conditional approval for the storage of further unconditioned waste provided that it meets optimisation requirements (Article 6 of StSV, the Swiss Radiation Protection Order).

During the year, PSI checked for corrosion and contamination the 89 concrete barrels (1 m^3) originally conditioned for disposal on the sea bed and which, pending final storage at BZL, had been stored in open depots at PSI East. On completion of this work, the barrels were transported to BZL for storage. In addition, two containers conditioned for final storage and containing waste from DIORIT and a container containing beryllium and beryllium oxide reflector elements from the decommissioned research reactor SAPHIR were transferred to BZL. At the end of 2003, the area housing the standard barrels was 75% full. The inventory of radioactive waste stored by PSI at the end of the year is shown in Table A11.

In order to make optimum use of its available storage capacity, PSI has applied for an amendment to its operating license that would give it greater flexibility in terms of acceptance conditions and the Inspectorate evaluated the associated safety report compiled by PSI for BZL. The application to amend BZL's operating license, the safety report compiled by PSI, the Inspectorate's report and the associated comments by KSA, the Swiss Federal Nuclear Safety Commission were put into the public domain in November and December 2003. Two objections have been lodged and the approval procedure is likely to be concluded in 2004.

7.6.2 Other storage facilities in PSI East

Storage halls AB and C, the depot and the transhipment area are used for the short- and medium-term storage of low- and intermediate-level waste before or after conditioning. The waste stored in these halls is likely to vary considerably. During the year, PSI made great efforts to empty storage areas, which are not covered and so in part are exposed to the weather.

Storage hall AB contains unconditioned radioactive waste from medicine, industry and research pending subsequent processing. In addition to the special waste, which cannot be conditioned with methods already approved, the hall contains waste from collections by BAG, the Swiss Federal Office of Public Health in the years 1999–2003. In addition, storage hall AB serves as decay storage for waste that contains radioactive iodine.

Storage hall C is currently used to store packages with cemented solutions containing plutonium and DIORIT waste pending final conditioning. The depot is used for the temporary storage of unconditioned waste, including scrap metal from the former experimental nuclear power plant at Lucens and material generated by the decommissioning of SAPHIR together with a series of packages that have undergone final conditioning but are not yet specified and which for shielding purposes are placed in 1m^3 concrete barrels. The transhipment area is currently used for the storage of six wastewater tanks from the hot laboratory pending subsequent decontamination or conditioning.

During 2003, some 3,000 empty standard barrels that had previously been used for the transport of combustible waste from nuclear power plants to the PSI incineration plant and since then stored at the federal collection site at PSI were transferred to ZWILAG.

As a result of several inspections, the Inspectorate can confirm that the storage of radioactive waste at PSI complies with regulations.

7.7 Particular events

During the year under review, PSI reported no classifiable events.

In 2002, the faulty adjustment of a safety rod pair had resulted in a notifiable event. The defect was remedied in 2003 by replacing the rod positioner and the associated electronics. This work was cleared by the Inspectorate.

7.8 Radiation protection

In 2003, the collective dose experienced by the entire PSI workforce was 181.7 Person-mSv (2002: 179.2 Person-mSv). With the return of the radio-chemistry section of the Hot Laboratory to full operation and the dismantling of SAPHIR and DIORIT with its associated implications for radiation protection, the collective dose in areas supervised by the Inspectorate increased from 47.0 Person-mSv in 2002 to 59.5 Person-mSv in 2003. Further information on the personnel dose is contained in Tables A5–A10.

The release of radioactive materials through the exhaust air and wastewater systems of PSI was assessed and the results used to calculate the dose in accordance with Guideline R-41. Using conservative conversion factors, it was found to be 0.06 mSv per year at the most unfavourable position outside the controlled areas of PSI. This dose is well below the source-related dose guideline value of 0.15 mSv per year for radioactive releases specified in the PSI regulations.

Following intervention by the Inspectorate, the attempt by PSI to allow unrestricted access to the East site and the associated removal of personnel controls at access points was not realised. The conditions required for the adequate control of personnel entering several controlled zones within the site do not yet exist.

7.9 Personnel, organisation and training

The previous year had been characterised by personnel and organisation changes within the PSI management. In addition, the generic safety functions of the Department for Radiation Protection and Safety had been fundamentally restructured. In contrast, 2003 was a period of consolidation. From the Inspectorate's perspective, the recognition of a radiation protection expert and the training of other staff in radiation protection were welcome developments. The Inspectorate welcomed the increase in radiation protection staff at the PSI East site.

The services of PSI were presented to a wider public during several Open Days. In terms of radiation protection, PSI displayed a professional approach to preparations for these events both before and on the days themselves.

During the year, an audit was performed of the Quality Management System in the Department for Radiation Protection and Safety, part of which has certification. The Inspectorate participated in this audit and can confirm that it was properly carried out.

7.10 Training

During the year under review, the Inspectorate approved the training course for radiation protection staff developed by the PSI Radiation Protection School in accordance with the Swiss Ordinance on radiation protection. In addition to reviewing the course documents, the competence of teaching staff and the examination board, the Inspectorate confirmed the quality of the teaching and the oral and practical examinations.

At the beginning of 2003, UVEK, the Swiss Federal Department for Environment, Transport, Energy and Communication approved the PSI Radiation Protection School as an examination venue for personnel involved in the transport of hazardous radioactive substances. The Inspectorate had previously drafted a report on this issue. At the same time, the Inspectorate approved a course for training specialists in radiation protection in transport issues.

In addition to full-time teaching staff, the PSI School also has visiting lecturers from nuclear power plants and the Inspectorate, so allowing practical experience and details of the legislative framework to be included in the radiation protection courses.

7.11 General impression

PSI operates its complex installations responsibly and professionally. The diversity of its tasks is also reflected in the activities of the Department for Radiation Protection and Safety (ASI). In particular, the re-organisation in 2002 significantly strengthened the radiation protection function as the Inspectorate had demanded. The increase in the number of personnel and the training of specialists in radiation protection are positive developments. In addition, the audit performed by ASI will help to develop the QMS further. The development by PSI of a database to monitor written correspondence has made it easier to control requests and information from the supervisory bodies. For example, it ensured that scheduled work demanded by the Inspectorate in its report on the licensing application for the BZL was implemented in full and on time. Worthy of particular recognition is the professional and well-documented work on decommissioning SAPHIR and DIORIT.

PSI has found invaluable the monitoring of new projects by ASI. In this respect, the Inspectorate requires specific evidence of a detailed review of proposals, plant modifications and the revision of documents. The Inspectorate expects a more critical and searching approach to projects such as the removal of access controls.

Overall, the condition of the PSI plants under the supervision of the Inspectorate in terms of operational radiation protection and nuclear safety is good.

8. OTHER NUCLEAR INSTALLATIONS

8.1 Ecole Polytechnique Fédérale de Lausanne (EPFL)

EPFL, the Swiss Federal Institute of Technology in Lausanne has several nuclear facilities. They are the research reactor CROCUS, the neutron experiment CARROUSEL, the neutron source LOTUS together with the associated laboratories. These facilities are assigned to LRS (Laboratoire de physique des réacteurs et de comportement des systèmes – Laboratory for reactor physics and systems behaviour), which in turn is part of IPEP, the Institute of Physics of Energy and Particles. In 2003, the CROCUS reactor was run for 364 hours at low output (less than 100 W) and was used to train engineering and physics students from EPFL, students attending the PSI Radiation Protection School and those at the School of Engineering in Geneva. The total output of thermal energy was 163 watt-hours. CARROUSEL was used for practical training in the effects of different moderators and absorbers on neutron flux. The neutron source LOTUS was not operated during the year under review. During the year, there were no notifiable events as specified in Guideline R-25. The dose rate for personnel was below the detection limit. The release of radioactive materials into the air and wastewater was insignificant. During an inspection in December 2003, the Inspectorate found that facilities were in a clean and orderly condition.

During the year, one reactor manager (chef d'exploitation) and one reactor operator (opérateur) were licensed at the training reactor CROCUS.

8.2 University of Basel

The research reactor at the University of Basel is also used for teaching purposes. In addition to practical training in reactor physics for students of physics, the reactor was used by students at

Departure of a heavy transport with radioactive waste from the decommissioned experimental reactor Lucens.
Photo: HSK

the Fachhochschule Aargau and the PSI Radiation Protection School. Samples were irradiated for use on courses run by a radiation protection school and for use by the Basel-Stadt laboratory. During the year under review, the reactor operated without problem for 47 hours at a thermal output of 1 kW. Individual and collective doses were below the detection limit. The release of radioactive materials into the air and wastewater was insignificant.

As part of a survey by a canton laboratory of earthquake protection, the Inspectorate evaluated the radiological effects of the destruction in an earthquake of the entire building, including the reactor. This showed that the resultant radiation doses for both the local population and personnel would be below the statutory limit for accidents.

Improvements are planned in respect of fire protection.

Custom made hoisting tools for the safe transport of the steel containers with radioactive waste from the decommissioned plant of the experimental nuclear reactor Lucens. Photo: HSK

8.3 Experimental reactor at Lucens

During the year, six steel containers with radioactive waste from the decommissioned experimental reactor at Lucens (VAKL) were transferred to the Central Interim Storage Facility (ZZL) at Würenlingen (see also Chapter 9.5). After its removal, the land on which the containers had been stored for several decades was examined for possible residue radioactivity. This revealed evidence of slight, strongly adhesive contamination of up to two guide values on the concrete framework acting as a shield. These slightly contaminated components were transported immediately to ZZL for decontamination. Following this, the licensee rechecked the site and the Inspectorate then conducted its own tests. It found that the soil and building on it were free from contamination and so the entire property, which is owned by NGA, the National Association for the Promotion of Industrial Nuclear Technology, was discharged from the requirements of radiation protection legislation. In December, NGA submitted an application to the Swiss Federal Council seeking its removal from the supervision required under nuclear legislation.

Since the order by the Federal Council on 12 April 1995, the rest of the VAKL site, with its below and above ground buildings and owned by the Canton of Waadt, is no longer subject to nuclear legislation and is being used for other purposes.

During the year, the sole remaining employee of the VAKL monitoring group exposed to radiation in the course of his occupation, accumulated a whole-body dose of 0.7 mSv. There were no radiological or safety incidents. The Section for Radiation Monitoring (SUeR), which is part of BAG, the Swiss Federal Office of Public Health is mandated to conduct radiological monitoring of water percolating from the caves for 30 years. The results of this monitoring are published by BAG in its annual report "Umweltradioaktivität und Strahlendosen in der Schweiz" (Environmental Radioactivity and Radiation Doses in Switzerland).

9. TRANSPORT OF RADIOACTIVE MATERIALS

9.1 Approvals under legislation on the transport of hazardous materials

Swiss regulations on the transport of radioactive materials by road and rail are based, inter alia, on international legislation on the transport of hazardous materials by road (ADR[1]) or by rail (RID[2]). The IAEA recommendations (TS-R-1[3]) on the safe transport of radioactive materials apply to all means of transport and international transport legislation is revised regularly to reflect these recommendations. The national transport of Class 7 hazardous materials is covered by the SDR[4] and the RSD[5].

Primary responsibility for complying with transport regulations and for safety rests with the consignor. If nuclear fuels or other highly radioactive materials are to be transported, the consignor must first obtain an approval certificate from the competent authority. The approval certificates apply, depending upon the circumstances, to the packages to be transported and/or the shipment itself. The certificate is, therefore, a prior requirement for authorisation under atomic energy legislation.

In Switzerland, the Inspectorate is responsible for the issue of approval certificates required under legislation on the transport of hazardous materials, irrespective of whether the radioactive material to be transported is from nuclear installations or other operations. In the case of approval for packages used in Switzerland, the Inspectorate is mainly involved in the validation of certificates, issued by the competent authority in the country of origin and relating to the design of the package. The Inspectorate checks that the safety report on the package design is complete, in particular that the proof of compliance accords with the requirements of ADR/RID and TS-R-1. In certain cases, shipment approval is required and this applies in particular to goods transported on the basis of a special agreement. In this case, the transport itself is subject to special measures laid down by the Inspectorate. In addition, the Inspectorate also checks the documents provided to ensure that the package and its contents comply with the regulations.

In the year under review, the Inspectorate assessed 17 requests under legislation on hazardous materials and issued the appropriate approval. Of these, 13 related to applications for the validation of package approval certificates (2 transport and storage casks, 2 transport casks for spent fuel assemblies, 6 transport casks for fresh fuel assemblies and 3 special containers for nuclear and other radioactive material). The remaining four requests were for one shipment approval and three special arrangements.

9.2 Authorisations under radiation protection legislation

Under Article 2 of the Swiss Radiation Protection Law of 22 March 1991, the transport of radioactive materials requires authorisation. The conditions governing such authorisations are laid down in this legislation and in the Ordinance on Radiation Protection of 22 June 1994. The Inspectorate is mandated by the Federal Office of Energy (BFE) to issue such authorisations in relation to nuclear installations.

During the year under review, no authorisations of this type were issued.

9.3 Authorisations under atomic energy legislation

Under Article 4 of the Atomic Energy Law of 23 December 1959, Federal authorisation is required for the transport, delivery, procurement and any other form of possession, import, transit or export of radioactive nuclear fuels and residues. In addition, under Article 11 of the Ordinance on Atomic Energy of 18 January 1984, authorisation is required for the import, export and transit of radioactive waste from nuclear installations. The Federal Office of Energy is responsible for the issue of these authorisations. With regard to the authorisation of transports of packages requiring approval, the Inspectorate verifies each application to ensure compliance

[1] European Agreement on the Transport of Dangerous Goods by Road.

[2] Ordinance for the International Rail Transport of Dangerous Goods.

[3] IAEA Safety Standards Series: Regulations for the Safe Transport of Radioactive Material, 1996 Edition (Revised).

[4] Order from 17 April 1985 concerning the Transport of Dangerous Goods by Road (SR 741.621).

[5] Order from 3 December 1996 concerning the Transport of Dangerous Goods by Rail (SR 742.401.6).

with nuclear and radiological safety requirements and regulations on the transport of hazardous materials. The Federal Office of Energy only issues authorisation if the Inspectorate has given a positive assessment.

During the year under review, the Inspectorate carried out 19 assessments for transport authorisations under atomic energy legislation: 1 for the export of spent fuel assemblies for reprocessing, 1 for the transport of spent fuel assemblies to the Central Interim Storage Facility (ZZL) of ZWILAG, 7 for the import of fresh fuel assemblies for nuclear power stations, 1 for the transport of decommissioning waste from the Lucens experimental nuclear power station to ZZL (see Chapter 9.5), a further 8 for the transport of nuclear materials to and from PSI and finally 1 for the transport of fuel samples from KKG to the Institute for Transuranium Elements in Karlsruhe (D).

9.4 Transport of spent fuels and high-level vitrified waste

In the period under review, there were 15 transports of spent fuel assemblies from Swiss nuclear power stations. Of these, 2 transports were from KKG to the COGEMA reprocessing plant in France and 2 from KKB to the BNFL reprocessing plant in England – all 4 by rail. A total of 11 casks containing spent fuel assemblies were transported by road to the Central Interim Storage Facility ZZL (10 from KKM, 1 from KKL). The Inspectorate carried out the required inspections and can confirm that the transport complied in all cases with the limits specified in legislation on hazardous materials, in particular those relating to radiation protection.

In September 2003, the COGEMA reprocessing plant returned high-level vitrified waste. The transport casks were transported by rail to

Proper fixation and declaration of the heavy transport of a steel container with radioactive waste from the former experimental nuclear reactor Lucens.
Photo: HSK

the ZWILAG loading stop where they were transferred to a special ZWILAG transporter and then transported by road to the ZWILAG site. This transport also complied with the limits specified in the legislation on hazardous materials.

9.5 Transport of decommissioning waste from Lucens experimental nuclear power station

Between 18 and 25 September 2003 six consignments with decommissioning waste from the Lucens experimental nuclear power station (VAKL) were transported from the works site of VAKL to the ZZL of ZWILAG. The six transport casks, which had been stored at Lucens since 1972, were transported by road and were covered by a transport approval issued by the Inspectorate. Total activity from all six consignments was estimated to be in the order of 6 terabecquerel with about 5 terabecquerel from one cask containing fuel residues (about 55 kg).

Preparations by all those involved in the transport (consignor, consignee, transport company and transport co-ordinator) were good. The transports complied with the limits specified in the legislation on hazardous materials. The Inspectorate kept a close watch on these consignments through its inspection programme and although minor discrepancies arose, they had no effect on safety.

9.6 Inspections and audits

To ensure the safety of transport personnel and the general public, the transport of radioactive materials must comply with the relevant legislation on radiation protection and transport. The quality assurance programmes of designers and manufacturers of packages as well as those of carriers, consignors and consignees of radioactive materials aim at ensuring compliance with the regulations.

All Swiss nuclear power plants, as well as ZZL and PSI have quality assurance programmes for the transport of radioactive materials that are recognised by the Inspectorate or certified by another accredited body. In order to maintain or renew the required approval, regular audits are performed at nuclear installations. During the year under review, no such audit was due.

In addition to checking the transport of spent fuels, the Inspectorate also scrutinised several consignments of fresh fuel assemblies delivered to nuclear power stations as well as the transport of radioactive waste and other radioactive materials from and to Swiss nuclear installations. The contamination limits were never exceeded. In one case a dose rate limit was exceeded. During the transport of waste from KKL to ZZL, the maximum admissible dose rate was exceeded by a factor of 1.7 on the underside – a difficult area to access – of a vehicle. There was no danger to personnel or the environment. The Inspectorate classified the event in accordance with Guideline R-15[6] (see Chapter 4.2.1).

9.7 Training and information

For the 13th time, training was provided in November to plant staff responsible for the dispatch of radioactive materials. The five-day course was run by the Radiation Protection School of the Paul Scherrer Institute (PSI) with the Inspectorate providing some of the instructors.

[6] Reporting on the operation of nuclear power plants – December 1999, Guideline R-15

10. GEOLOGICAL REPOSITORIES FOR RADIOACTIVE WASTE

10.1 Repository for low- and intermediate-level waste

In 1995, after a broadly based evaluation of sites that was gradually narrowed down to four possible sites, Nagra, the national co-operative for the disposal of radioactive waste selected Wellenberg in the Canton of Nidwalden as a potential site of a final storage facility for low- and intermediate-level waste (L+ILW). The authorities responded by approving the choice. GNW, the consortium for nuclear waste disposal at Wellenberg, which was set up in 1994, submitted an application for outline approval. The Inspectorate compiled a report in which it recommended further investigation of the site. It was suggested that first of all an exploratory gallery should be constructed in order to confirm the suitability of the underlying rock.

Work on the project was suspended in 1995 when the canton of Nidwalden refused to grant GNW the required concession to use the subsoil and in 1997, UVEK, the Swiss Federal Department for Environment, Transport, Energy and Communication adjourned the outline approval procedure. In March 2000, discussions were held between the head of UVEK and the Nidwalden government. They agreed the conditions for a continuation of the project and the timetable leading up to the construction of an exploratory gallery. In December 2000, the expert working group for Wellenberg established by the canton of Nidwalden and the Political Coordination Committee came out in favour of allowing a further application for a concession. In January 2001, GNW applied to the canton of Nidwalden for a concession to construct an exploratory gallery at Wellenberg. In September 2001, the governing council of the canton of Nidwalden granted the concession thereby rejecting the objections that had been raised. However, this decision was overturned on 22 September 2002 in a cantonal plebiscite with the result that Wellenberg had to be abandoned as a possible site for a L+ILW repository.

The properties of opalinus clay are being examined in the rock laboratory Mont Terri in the Canton of Jura.
Photo: Nagra

After the cantonal plebiscite, GNW stopped work on the project, except for certain closure activities. The observation equipment installed in the area was gradually dismantled. During 2003, the deep boreholes were filled with special concrete under the supervision of the Inspectorate. The site will be returned to cultivation or transformed into a state agreed with the owners for use in some other way. Several of the shallow piezometric boreholes were handed over to the canton for further use. The decision to wind up GNW was announced in the Swiss "Handelsamtsblatt" (official journal of commerce) in August 2003 and the final balance sheet was prepared on 30 November 2003.

The elimination of Wellenberg as a possible site has delayed plans for the construction of a geological repository by many years. It will be necessary to repeat the selection procedure in order to find a suitable location. For various reasons, the three other sites previously identified – Bois de la Glaive, Oberbauenstock and Piz Pian Grand – are no longer under consideration.

In addition, the rules governing the selection procedure have changed and the changes will be reflected in this new selection process; in particular, cantons and local authorities will be involved at an earlier date. The overriding priority remains the long-term safety of the population and the environment. Under recent legislation on nuclear energy approved by the Swiss Parliament on 21 March 2003, the responsibility for waste disposal remains with the generator of that waste, i.e. primarily the licensees of nuclear power stations. Nagra, acting on behalf of licensees, is responsible for the required preparations, i.e. including the new search for a site.

10.2 Repository for high-level waste, preparatory actions

10.2.1 Demonstration of disposal feasibility

During 2003, work on a geological repository for high-level waste focussed primarily on the verification of disposal feasibility. This demonstration of disposal feasibility is based on a Federal decision arising from atomic energy legislation dating from 1978, under which general license for a nuclear power plant may only be granted if there is a guarantee of permanent secure disposal and final storage of radioactive waste. This proof of disposal feasibility is still outstanding for high-level waste (HLW) and long-life intermediate level waste (LL-ILW)

At the end of 2002, Nagra submitted an application for a model storage facility in the Zurich Weinland. The host rock in this case would be Opalinus Clay, which forms a layer some 110 m thick in this area. The demonstration of disposal feasibility consists of three parts:

– *Demonstration of safety:* This must show that the selected host rock, with its geological and hydro-geological qualities verified by the results of field investigations, combined with artificial barriers are capable of guaranteeing the long-term safety of the final storage facility.
– *Demonstration of site suitability:* Investigations, substantiated by appropriate documentary evidence must show with high probability that the host rock with the qualities referred to in the proof of safety exists in sufficient quantities to ensure that if a final storage facility were developed on this site, it is likely to be successful.
– *Demonstration of engineering feasibility:* This must show that a final storage facility could be built, operated and kept secure in the selected host rock using current technology and in compliance with safety regulations.

At the start of 2003, Nagra focussed on the completion and publication of the demonstration-of-disposal reports. The three main reports, which summarise the extensive documentation on the investigations, were published in hardcopy at the end of April 2003. They were as follows:

– NTB 02-02: Concept for installation and operation of geological repository
– NTB 02-03: Synthesis of the results of the geo-scientific investigations
– NTB 02-05: Safety Report (in English).

The Inspectorate examined the project documentation in detail and evaluated the proof of disposal using evaluation criteria specified in advance. In its evaluation of the geo-scientific evidence, the Inspectorate was assisted by the Commission for Nuclear Waste Disposal (KNE). After an initial review of the reports, the Inspectorate commissioned numerous experts to verify certain aspects of the evidence. These experts started work in the second half of 2003 and the technical evaluation of the proof of disposal is expected to be finished by the end of 2004.

In addition, as part of the evaluation by the competent federal authorities, the Swiss Federal Office of Energy (BFE) commissioned a group of nine acknowledged experts assembled by the Nuclear Energy Agency (NEA) of the OECD to examine the safety element of the demonstration of disposal feasibility. The group, from countries in Europe as well as Australia and Canada, held their first meeting in Wettingen from 30 June to 2 July 2003, Nagra presented the project and the Inspectorate gave details of the evaluation required. In response to the documents made available to the group, the latter submitted 400 questions of clarification, which were then answered by Nagra. It held its second meeting from 23 to 28 November 2003, also in Wettingen to discuss outstanding issues. On the final day of the meeting, the group of experts gave a very positive oral assessment of the relevant safety analysis. The group's written report will be published in spring 2004. The Inspectorate closely observed the work of the experts.

10.2.2 Exploratory bore Benken

Long-term hydraulic tests continued at the exploratory borehole at Benken. The Benken Coordination Commission, which has been monitoring the work, met on 22 January 2003 for their last scheduled meeting. It approved its final report on the work by Nagra and in particular confirmed compliance with the requirements specified in the relevant approval document of 15 May 1996, pending those relating to the subsequent filling or sealing of the borehole.

The three communities of Marthalen, Benken and Trüllikon in conjunction with the Zürich Weinland planning group has set up the "Opalinus Forum". The aim of this forum is to safeguard local interests with regard to a possible geological repository and to act as a point of contact for the public. The public will be able to put questions to the forum who will then arrange for them to be answered by the appropriate body.

10.2.3 Public Relations

On 18 February 2003, the environmental groups "Igel" and "Bedenken" held a joint press conference at which it was alleged that Nagra and the regulatory authorities had withheld information on the loss of drilling fluid into the Opalinus Clay during the sinking of the special borehole at Benken. This allegation, in addition to other alleged discrepancies in site data, was contained in a report by the Öko-Institut (Institute of Applied Ecology) in Darmstadt. In order to clarify the situation, the Inspectorate organised two meetings attended by experts from relevant or interested organisations (Benken Coordination Commission, cantons of Zurich and Schaffhausen, the local "Bedenken" action group, the Öko-Institut Darmstadt, the Commission for Nuclear Waste Disposal and Nagra). As a result of these discussions, it was established that many statements in the Öko-Institut report were incorrect. In particular it was clearly shown that there has been no loss of drilling fluid into the Opalinus Clay. The Inspectorate produced a record of the findings of this meeting and advised the public in press releases issued on 8 May and 6 August 2003. The Öko-Institut initially planned to revise its report but this work was suspended in January 2004. The allegations relating to site data and the loss of drilling fluid were found to be groundless.

On 17 March 2003, BMU, the German Federal Ministry for the Environment, Nature Conservation and Reactor Safety held an information seminar in Jestetten (Baden Württemberg) for representatives of local authorities in the communities close to the German/Swiss border. The seminar focussed on the selection procedure that led in 1993 to Zürich Weinland being selected as an exploratory region and the Opalinus Clay as a potential host rock and, in particular, on the assessment by representatives of AkEnd, the German working group looking at the selection procedure for potential final storage sites. In its comments, AkEnd had stated that the selection procedure complied with the relevant international guidelines in force at the time and had rejected as unfounded allegations that selection of this site had been unduly influenced by its proximity to the German border. However, its comments made no reference to the suitability of the location. The BMU distanced itself from the comments by AkEnd. In November 2002, the Inspectorate prepared its own assessment of the selection procedure and the comments by AkEnd. This was published in spring 2003 (HSK 23/74).

At a meeting in Marthalen on 6 June 2003, some 100 representatives from local authorities in the cantons of Zürich, Schaffhausen, Thurgau and Aargau together with their German counterparts located close to the border, including representatives from the Land of Baden-Württemberg were briefed by BFE, the Inspectorate and Nagra on the technical progress and the political process. In particular, the meeting focussed on the selection procedure and the review process of the demonstration of disposal feasibility. In addition, BFE announced the creation of three groups designed to ensure the inclusion of authorities in both Switzerland and Germany: firstly, a committee consisting of government representatives from the relevant cantons and the German Land of Baden-Württemberg to consider political issues associated with the demonstration of disposal feasibility. Secondly, a technical forum chaired by the Inspectorate, where specialists from the cantons and the Land of Baden-Württemberg would discuss technical issues and suggestions emanating from the general public. Thirdly, an Information and Coordination group to coordinate public relations. The Information and Coordination group met several times in 2003. The technical forum met twice and it also has its own website at www.technischesforum.ch.

On 25 October, the Baudirektion of the Canton of Zürich and Swiss Federal Office for Energy organised a public meeting at Trüllikon. In addition to representatives from the cantons of Zürich, Schaffhausen, Thurgau and Aargau, their counterparts in Southern Germany, safety authorities and commissions (the Inspectorate, the Swiss Federal Nuclear Safety Commission and the Commission for Nuclear Waste Disposal) and Nagra, the participants included the Opalinus Forum and KLAR ("No living with nuclear risks"). The event was well attended and also generated lively press coverage.

10.2.4 Rock laboratory

In addition to work to strengthen political support for the geological repository and inform the public, work also continued on scientific and technical investigations. The rock laboratories at Mont Terri (Jura) and Grimsel (Bern) made great strides in improving the quality of data for the project.

The rock laboratory at Mont Terri studied the properties of the Opalinus Clay. This work supplements the geological understanding of the Zürich Weinland region obtained from in-situ testing of rock properties. The Mont Terri Project now has twelve partner organisations from six countries (Switzerland, France, Germany, Spain, Belgium and Japan). The Inspectorate joined the Mont Terri Project in summer 2003. Together with external experts, it will validate computer models and tools against concrete data records obtained in the rock laboratory. The models and tools will be used for the independent verification of projects submitted in connection with the geological repository.

In essence, the main work conducted by the Mont Terri rock laboratory during the year was as follows: The drafting of a new research programme was completed in May at a meeting attended by all partners, and the government of the canton of Jura has now approved its implementation. This long-term programme consists of 22 new experiments during the next five to ten years. In co-operation with the Engineering Geology group at the Swiss Federal Institute of Technology in Zürich, the Inspectorate has started work on an experiment to examine, characterise and model fracture generation in the excavation damage zone of the gallery triggered by stress changes in the surrounding rock. New niches have been drilled to extend the rock laboratory. In addition, a start niche have been established in preparation for a future gallery.

The Grimsel rock laboratory also continued its research. Experiments included the in-situ behaviour of artificial barriers and the migration of radionuclides under conditions similar to final storage.

The Grimsel rock laboratory is also a partner of the "ITC School of Underground Waste Storage and Disposal". This international centre, established on 4 May 2003, provides education and training in the field of geological repositories. It thus aims for the preservation and transfer of knowledge and expertise in final storage technology. The Inspectorate supported the founding of the ITC and there are now more than 40 organisations from Switzerland and elsewhere involved in the school. It offered its first courses in autumn 2003 and they were very well received. The IAEA was among those that took advantage of the courses.

The Inspectorate has responsibility for the issue of approvals required under radiation protection legislation for experiments involving radioactive material, as well as for their supervision. In October 2003, it approved the use of radionuclides in order to calibrate new test equipment at the Grimsel rock laboratory. In September and November 2003, it approved tracer experiments with short-lived radionuclide mixtures as part of an experiment to examine the influence of cement water on the sorption of nuclides in the rock. In this connection, the Inspectorate carried out two inspections at the rock laboratory, which confirmed compliance with the requirements. Safety bodies in the cantons are advised of both the approvals and the performance of the experiments.

11. INSTRUCTIVE EVENTS IN NUCLEAR INSTALLATIONS ABROAD

None of the incidents reported in 2003 by nuclear facilities outside Switzerland was such that immediate action was required in order to improve the safety of Swiss nuclear facilities.

The following section gives details of several important incidents with an impact on safety, which could provide lessons for Swiss nuclear facilities and so improve their safety. The section starts with a brief description of the process that exists for the international exchange of experience.

11.1 Information sources for incidents in foreign nuclear installations

The main source of information for foreign incidents is the "Advanced Incident Reporting System" (AIRS) operated by the IAEA to which all nuclear regulatory bodies adhere. The operators have their own organisation, the "World Association of Nuclear Operators" (WANO), which informs its global membership of any incident. In addition, operators also belong to owner groups and other larger groupings (e.g. VGB Power Tech, the association for power plant operators and manufacturers in Europe) from whom they obtain information or who prepare incident analyses on their behalf.

All the organisations providing an international exchange of operating experience have a common goal, i.e. to learn from incidents in other facilities and so increase safety and availability in their own facilities.

In order to evaluate incidents in other facilities, the operators have agreed procedures as part of their management systems and these are checked regularly for validity. In addition, the Inspectorate monitors how Swiss nuclear plants learn from incidents abroad and put into practice what they have learned. In turn, the operators of nuclear facilities provide reports to the Inspectorate on foreign incidents that have been investigated in detail.

In addition, the Inspectorate conducts a systematic analysis of foreign incidents. If it considers that an incident abroad might have relevance for the safety of one or several nuclear plants in Switzerland, it asks the operators to conduct an appropriate investigation and report back in detail.

The value of this mutual exchange of information on incidents and their evaluation is clear if we compare incidents outside Switzerland with the number of actual abnormal incidents with a similar cause in Switzerland. From experience, we know that the number is very small.

The procedure under which the supervisory body and the operators independently evaluate incidents in foreign nuclear facilities in terms of their relevance to Swiss nuclear power plants and if necessary take appropriate action plays a major role in ensuring ongoing improvements to nuclear safety.

11.2 Damage to irradiated fuel assemblies caused by a defective cleaning device

An incident in a Hungarian nuclear power plant in April 2003 was categorised as INES 3 under the International Nuclear Event Scale (INES). A special cleaning device was used to clean the fuel assemblies, which resulted in radioactive noble gases escaping into the reactor building and some into the environment. An inspection of the cleaning device and the fuel assemblies within it revealed that the upper part of the fuel assemblies had been seriously damaged and in part completely destroyed.

The fuel assemblies required cleaning because during previous decontamination of the primary system it had been found that magnetite had come away from the surface of the steam generator heating tubes and been deposited on the fuel rods. This had reduced the heat transfer of the fuel rods and rendered power operation more difficult. In order to remove the magnetite deposits, a service firm – well respected in the nuclear industry – had developed a special cleaning technique that had been used successfully for several years. It consisted of a special tank, which could be installed in the fuel assembly storage pond of a nuclear power plant. However, the maximum number of fuel assemblies that could be cleaned at any one time was seven. In order to speed up the process, a similar system was developed that allowed the simultaneous cleaning of up to 30 fuel assemblies. Trials of this system by the service firm had been successful. Following its approval by the operator and the supervisory body, it was installed in the fuel assembly storage pond and was used several times successfully for cleaning purposes.

Similarly, the fourth load had been successfully cleaned and was awaiting removal. The large crane required for this work was unavailable for several hours and so the system was switched to a special cooling mode (hereafter called "Mode B"). After some five hours of cooling in Mode B, a high level of Kr-85 activity was noted in the cleaning system and the alarm limit for noble gas activity in the reactor building reached. The level of noble gas activity in the exhaust air stack also increased significantly and at this point the supervisory body was advised. When the cover of the cleaning device was opened, an escape of gas took place and the dose rate increased significantly. An inspection with a video camera revealed that the upper section of all the 30 fuel assemblies had been damaged and in part completely destroyed. At this point, an emergency was declared both by the plant and the supervisory body. The latter advised the IAEA and neighbouring countries and the incident – originally classified as INES 2 – was categorised as INES 3 because fuel had been destroyed.

The incident was investigated thoroughly in order to determine the causes. These investigations involved the supplier, plant operator and the supervisory body. In addition, experts from IAEA conducted a separate independent examination. In tandem with this, the Director of the Hungarian supervisory body commissioned a further independent investigation by experts to determine whether the supervisory activities carried out by his own body had been appropriate in the circumstances. A key concern underlying the investigations was whether and to what extent the IAEA Nuclear Safety Standards (NUSS) and other nuclear safety standards had been breached. The investigations also sought to identify why the independent checks of technical safety conducted by supplier, operator and supervisory body had not identified and remedied the weaknesses in time. The investigations identified the following weaknesses:

– The cooling system design was not suitable for "Mode B" operation. In this mode, adequate cooling of fuel assemblies with a high residual heat output can only be guaranteed for about two hours. If operated continuously in "Mode B" for a longer period, steam will develop and so cause overheating and damage to the upper section of the fuel assemblies. The manufacturer had only provided evidence that cooling would be sufficient for normal operation (no lengthy delay in "Mode B").
– The instrumentation monitoring the cooling of the fuel assemblies was inadequate. The cleaning tank had no temperature gauge in the upper section with the result that there was no indication that steam was being produced or that cooling was insufficient. Although there was a small pipe to take away the steam, its outlet was below the surface of the water in the fuel assembly pond and it was impossible from the edge of the pond to see the steam escaping.
– Cleaning of the fuel assemblies was done exclusively by personnel from the service firm whose main priority had been the speed of the cleaning process. Because previous experience with this system had been good, workers were not aware of the risks inherent in inadequate cooling. When the operating engineer from the nuclear power plant took over management of the emergency, those involved had insufficient knowledge of the process and so the decisions had been taken in response to the immediate situation. This did not make for good decision-making. The order to open the cover resulted in water coming into contact with the extremely hot fuel rods. This resultant thermal shock caused further damage to the fuel rods, which in turn triggered a significant release of radioactivity.

Comparison of these weaknesses with the safety requirements of the IAEA Nuclear Safety Standards reveals the following crucial discrepancies:

– The design of nuclear power plant systems must be such that adequate removal of residual heat must be guaranteed not only for normal operation but also for other possible operational occurrences and accidents. Therefore, important process parameters must be adequately monitored by measurements, displays and alarms. In addition, the relevant staff

must be provided with appropriate operating instructions designed to avoid or control any accidents and staff must be given the required training. This procedure was not followed adequately in this case.
– Under the IAEA Safety Standard "Design Requirement", the manufacturer is responsible for ensuring that a design is safe. The manufacturer must provide not only a safe design but also a procedure that affords safety the highest priority. This principle was not followed in this case.
– The same standard requires an operator to assume overall responsibility for the operation of a system. The operator must ensure, therefore, that accident prevention and control are handled and implemented in compliance with IAEA Standards and that personnel at a nuclear power plant involved in this work are trained in the safety aspects of process control and the use of procedures for abnormal occurrences. Similarly, this requirement was not met in this case.
– The IAEA Nuclear Safety Standards recommend that supervisory authorities verify whether the relevant Safety Standards can be maintained even if conditions are extremely unfavourable. In the case in question, incidents with a maximum release potential should have been analysed and the relevant safety arrangements reviewed. This was not done.

In Switzerland, there has been no special cleaning of fuel assemblies and there are currently no plans to use a cleaning process to remove fuel rod deposits. However, lessons can be learned from this incident.

Swiss nuclear power plant licensees have established Quality Management Systems (QMS) in compliance with the IAEA NUSS Standard for QMS. This standard requires a specific procedure for the individual project phases with a relevance to safety and which guarantee that priority is given to safety. Provided this quality-assured process is followed, it would be almost impossible for an incident to occur in Switzerland similar to that described above.

In Switzerland, the Inspectorate would be required to give its approval to any extraordinary cleaning campaign involving newly discharged fuel assemblies as such work would require extensive radiation protection planning. However, the regulatory framework laid down by the Inspectorate contains no mandatory requirement for approval to be given in respect of mobile cleaning equipment for fuel rods, as this would not be classed as a modification to the fuel rods or a modification or a repair to mechanical equipment with a safety classification. The following lesson must, therefore, be learned from the incident. Nuclear Safety Standards must also apply to mobile auxiliary equipment used in the power plant by the operator – irrespective of the expertise, experience and reputation of the service firm carrying out the work. The operator has full responsibility for the safe operation of the plant. The supervisory body must ensure in the course of an approval procedure that the operator has carried out the relevant analyses and safety review and provided evidence that the process is harmless. The evidence submitted must be the subject of a critical and searching review and if necessary additional checks demanded.

11.3 Unintended initiation of safety injection and opening of relief valves during start-up

During the normal restart of a French pressurised water reactor (PWR) after fuel assembly replacement at about 25–30 bar and a primary temperature of 170 °C, the system was switched from residual heat removal system to heat removal via the steam generator. As start-up proceeded, the high-pressure safety injection pumps were switched on incorrectly causing borated water to be fed into the primary circuit and a rapid rise in primary circuit pressure. Pressure increased to 166 bar, which in turn triggered the operation of the safety valve on the primary side and coolant was released into the specially designed tank. The operators realised that the high-pressure safety injection pumps had been switched on incorrectly and reversed the relevant injection signal. Additional action by operators to reduce pressure and normalise plant operation was not in compliance with accident procedures. As a result, when pressure dropped below 118 bar, the high-pressure safety injection pumps were switched on again causing a further discharge of primary coolant into the pressure-relief tank. This undue load caused a fracture of the rupture disc in the pressure-relief tank and the release of radioactive coolant into the containment. There was no release of activity into the environment.

The incident was triggered by faulty operator actions and non-compliance with operating procedures. In the case of the initial faulty actuation of the high-pressure safety injection pumps, an operator erroneously reversed the blocking of the safety injection as required by the operating instructions in the event of low pressure prevailing in the primary circuit. As part of efforts to reduce the pressure and normalise the state of the plant following the pressure transient, operators did consult the accident instructions but failed to perform one of the main switching procedures specified in the operating manual. As a result the high-pressure safety injection pumps were switched back on.

The incident indicates that during the start-up of a PWR, systems are sensitive to faulty operator behaviour. Normally, switching operations during system start-up are not a problem, as sufficient time is available to complete them. The operator is still investigating the precise reasons for the errors. The supervisory body carried out its own inspection after the incident in order to obtain an independent assessment of the sequence of events. Initial results show that the operator errors and non-compliance with the operating instructions were due to ergonomic and organisational factors.

The PWRs used in Switzerland are also equipped with a system that blocks safety injection from a specific moment during shutdown or unblocks it again on start-up. However, the design of Swiss plants differs in one fundamental respect in that the high-pressure safety injection pumps cannot exceed a pressure of 110 bar, i.e. the system cannot reach the pressure required to open the safety and pressure-relief valves. Moreover – in addition to administrative procedures to prevent faulty injection – there are other automatic safety mechanisms to prevent the unintended actuation of an erroneous injection. Furthermore, simulator training is provided on a regular basis, which pays particular attention to start-up and shutdown procedures, particularly as these tend to happen but rarely and mostly only on an annual basis. However, incidents involving operator error cannot be excluded from Swiss nuclear power plants. As part of its supervisory activities, the Inspectorate seeks to ensure that operators have access to operating instructions that meet modern ergonomic requirements.

11.4 Faulty thermal pipe sleeves in the feedwater system of a boiling water reactor

Thermal pipe sleeves are used to limit the stress on load-bearing pipes caused by temperature shocks if there is a sudden injection of cold emergency coolant into a hot pipe. At a boiling water reactor in Sweden, it had been necessary to replace the thermal pipe sleeves on pipes exiting the residual heat/emergency feedwater system and entering the feedwater system. The aim was to reduce the impact of thermal shock and improve conditions for in-service non-destructive testing. A design, new to the nuclear industry, was used for this purpose: it involved the use of support pins, which were fitted to the outer pipe and which retained the inner pipe sleeves. This design had already been used in a conventional thermal power station.

After the plant had operating at power for a certain time, differences developed in the feedwater flow and pressure conditions in two parallel trains of the feedwater system. Despite investigations, it was not possible to identify the cause. An attempt was made to reduce the differences by throttling back the valve and increasing the pump pressure. However, a result of this was non-compliance with the design specification for the admissible feedwater flow. After several months, the differences increased even further with the result that the plant had to be shutdown to inspect the pipe sleeves. It was found that the support pins had broken and so were no longer retaining the sleeves with the result that they had moved in the feedwater line in the direction of the reactor and so had blocked the flow openings. This had damaged parts of the pipework. Fragments of the support pins were found in the reactor pressure vessel. Investigations identified that the cause was fatigue fracturing of the support pins produced by the high speed of the flow and the resultant vibrations. The thermal pipe sleeves were replaced with a similar but improved design and the damaged pipework was replaced. In terms of its relevance to safety, the incident was initially classified as INES 0.

The operator prepared two reports on the incident: one relating to the use of the poorly designed thermal pipe sleeves and the other on its own investigations to determine the cause of the feedwater problems. The supervisory body examined these reports and carried out additional investigations. As a result of these investigations, it asked the operator to carry out certain improvements before restarting the plant after the next replacement of fuel assemblies:

– Improvements to various internal instructions on procedures to be observed in the event of the following; abnormal operating states, changes to reactor system components within pressurised enclosures and independent safety reviews.
– Introduction of a programme to improve the culture of safety and correct management weaknesses.

The authorities subsequently revised the event classification to INES 1 because the investigation of the incident had identified defects in the operator's safety culture. In addition, the operator was asked to take the following action:

– To improve procedures relating to the procurement and control of nuclear components and the handling of any departure from official parameters.
– To provide training to personnel in respect of the resultant changes to procedural requirements.

In addition, the incident has had legal consequences for the operator. The Swedish supervisory authority has filed a complaint under criminal law because it considers that the plant was in contravention of statutory and official regulations.

In certain respects, the philosophy adopted by the Swedish supervisory authority differs fundamentally from that of the approach in Switzerland. In Sweden, particular importance is attributed to "process-oriented supervision". This means that the supervisory body primarily checks and reviews processes that an operator has established as part of its management system. The assumption being that there is a high probability that the product of a process will be of good quality, if the underlying process has been thoroughly checked. In this case, the Swedish supervisory body did not examine in detail changes to the plant as the process applicable to the change was regarded as proven.

In Switzerland, all changes to components with relevance to safety require approval. This means that the Inspectorate must approve the concept, layout, design, manufacture, fitting and commissioning of systems in a multi-stage process. This procedure provides independent, detailed and official verification and so ensures that all aspects of nuclear safety are taken into consideration. The Inspectorate does apply a process-oriented approach to certain aspects of its supervisory role but for important or major changes of relevance to safety, the product of a process is also scrutinised as a matter of course.

12. REGULATORY SAFETY RESEARCH

Nuclear safety involves a broad range of complex technical questions. This is further complicated by differing viewpoints and perceptions of safety and risk combined with political and social influences. The recent nuclear energy legislation (KEG), passed but not yet in force, requires nuclear facilities which are used for the peaceful exploitation of nuclear energy to comply with the state of the art (Article 4a KEG). The federal government encourages research to this purpose, in particular research into the safety of nuclear facilities and into nuclear waste disposal (Article 86 KEG).

As part of regulatory safety research, the Inspectorate commissions and co-ordinates research designed to determine current scientific and technological know-how and then to expand this knowledge and use it for its supervisory functions. In addition to national research projects, Switzerland also participates in international projects and co-operates with foreign universities and official bodies. Despite a restricted budget, Switzerland thus benefits from well-funded research and the resultant increase in knowledge. In addition it can also exploit synergies and retain the attractiveness of Switzerland as a center for research and industry. Cost efficiency and medium-term planning security for research partners also play an important role.

Specific areas of regulatory safety research

Due to the increasing operation time of the nuclear facilities, the physical ageing of components and technical obsolescence of methodology and processes are of increasing importance. In particular, this affects materials, risk analyses and control systems. Other important areas of research relate to operational changes, such as those resulting from the introduction of higher burn-up and MOX fuels designed to optimise fuel usage. Regulatory safety research is currently focussing on the following areas:

Reactor safety: Important issues are mechanical, thermal, chemical and radiation-induced ageing and embrittlement as well as incident and accident research. The RIKORR II project (crack corrosion in pressurised ferritic components in the primary circuits of BWRs) is looking at ageing phenomena in boiling water reactors in order to evaluate the structural integrity of the reactor pressure vessel (RPV). During the year under review, research was conducted into the effects of temporary increases of chloride in the primary water on stress corrosion cracking behavior in various ferritic RPV steels operated under normal water chemistry (NWC) conditions. The "Diagnostic" project is developing methods that can be used for the early diagnosis of material fatigue in stainless steel pipes. Neutron-diffraction experiments and magnetic tests indicate how the degree of fatigue respectively the number of load cycles can increase the martensite content. During the next few years, material characteristics combined with measurements at the Beznau plant will be used to develop a thermo-dynamic material model for the deformation-induced formation of martensite in stainless austentic steels.

The STARS project (transient analysis of reactors in Switzerland) is designed to assist the deterministic safety analyses of fuel and burn-up behaviour. An analysis of the parametric uncertainties occurring in high burn-up and neutron fluence calculations based on Monte Carlo simulations has enabled an improvement in the evaluation of thermo-hydraulic issues.

Under a co-operation with the US regulatory authority, Switzerland has been participating for several years in the research into severe accidents. The aim of the "Cooperative Probabilistic Risk Assessment Research" project is to exchange the findings of research into probabilistic safety analyses (risks from shutdown, fire PSAs, risk-informed decision-making and operating variables). The "Cooperative Severe Accident Research" project uses analytical and experimental techniques to investigate plant behaviour and the interaction between core meltdown, water and the reactor vessel.

Radiation protection: The following projects deal with the protection of personnel and the environment in the vicinity of nuclear installations from ionising radiation, the optimisation of radiation clearance tests and the radiological and nuclear safety aspects of water chemistry: The "Dosimetry" project is continuing its work to develop standard test methods to facilitate the comparison and interpretation of test results. A portable surface contamination monitor, which incorporates calibrations and comparability calculations, has been evaluated for its sensitivity and detection levels. The radio-analysis project looks into the gauging and calibration of test equipment used to analyse soil and water samples for the monitoring of both, the environment and individuals exposed to radiation. Projects in the medical field include the "Evaluation of a combined therapy with tumour vascular-specific reagents and ionising radiation", which looks into the formation of blood vessels and the behaviour of associated cells under the influence of radiation.

Interdisciplinarial research: The safety of nuclear facilities is also determined by non-nuclear issues, such as safety at work, human performance, organisational culture, ergonomics, selection of suitable personnel and the issue of human error. The OECD Halden Reactor Project, set up in 1958 and involving 18 countries, is looking at two specialist areas: The first is "Nuclear Safety and Reliability – Fuels and Material", which looks into the lifetime of various materials used in nuclear components both under stationary and transient conditions. The second is "Man Machine Systems Research", which looks into human performance and limits to the ability of humans to monitor and control complex systems. The "Human Reliability Analysis" project looks into influences on human behaviour and thus will enable a more accurate determination of the likelihood of human error and so improve probabilistic safety analyses.

13. INTERNATIONAL ACTIVITIES

The Inspectorate is an active member within a range of international organisations with the aim of harmonising the basis of its regulatory role and participating in the exchange of knowledge. As a member of the International Atomic Energy Agency (IAEA), the Inspectorate is involved in decision-making bodies and working groups, such as the CSS (Commission on Safety Standards), NUSSC (Nuclear Safety Standards Committee), RASSC (Radiation Safety Standards Committee), TRANSSC (Transport Safety Standards Advisory Committee) and WASSC (Waste Safety Standards Committee).

Within the OECD/NEA, the Inspectorate is an active member of the following committees: CNRA (Committee on Nuclear Regulatory Activities), CSNI (Committee on the Safety of Nuclear Installations), CRPPH (Committee on Radiation Protection and Public Health) and RWMC (Radioactive Waste Management Committee). It is also involved in other important international associations such as the WENRA (Western European Nuclear Regulators' Association), NRWG (Nuclear Regulatory Working Group of the European Commission) and NERS (Network of Regulators of Countries with Small Nuclear Programmes).

In 2003, staff from the Inspectorate participated in numerous international seminars and conferences, with the aim of maintaining and developing important contacts with foreign regulatory authorities. For example, in February experts from NUPEC, the Japanese regulatory authority visited the Inspectorate to inform themselves about probabilistic safety aspects and the management of severe accidents. Five members of the Russian regulatory authority held discussions with the Inspectorate on progress with their own quality management system developed as part of the SWISRUS III project which was financed by DEZA, the Swiss agency for development and co-operation and which was supervised by the Inspectorate. Two of their personnel completed their doctorates in 2003 during the SWISRUS project. Quality management was also the subject of a workshop in Vienna in March 2003 on "Regulatory Management Systems" organised by the Inspectorate, by CENS ("Center for Nuclear Safety in Eastern Europe") and by the IAEA. The workshop included presentations on the management systems in Switzerland, Finland, Canada, Hungary and the USA and drew up recommendations.

As part of its programme of assistance to East European countries, the Inspectorate supported the governmental nuclear regulatory authorities in those countries in their work to complete safety analyses and so contributed indirectly to the safety of nuclear power plants of Russian design. The CENS Institute (http://www.censee.org) was set up in 2002 with the support of DEZA in order to co-ordinate the numerous technical co-operative projects with the various nuclear safety authorities in Eastern and Central Europe. CENS, acting as a regional training centre for personnel working in nuclear regulatory authorities, organises workshops and courses to train personnel in the field of nuclear safety.

The annual 2003 assembly of DSK, the German-Swiss consortium for the safety of nuclear installations was held from October 29th to 31st in Garching (Germany). In addition to an exchange of information on the safety of nuclear facilities and radiation protection in the two countries, the main topics under discussion

Members of the "French-Swiss Commission for the Safety of Nuclear Installations" (CFS) visited the Beznau nuclear power plant on June 2nd, 2003.
Photo: KKB

were emergency protection of the public in the vicinity of nuclear facilities close to the border, the current organisational changes to authorities and operations in Baden-Württemberg, the impact of the new Swiss nuclear energy legislation and current work on the proof-of-disposal evidence in Switzerland.

Delegations from Switzerland and Austria exchanged information on approval procedures, in particular the status of the approval procedures for KKB II, ZWILAG and the wet storage at Gösgen. In addition, information was provided on the operation of nuclear facilities, the doses for personnel and the number of notifiable events. The information on the decommissioning of nuclear facilities (DIORIT and SAPHIR) and the disposal of radioactive waste was received with particular interest.

In July 2003, CFS, the Commission Franco-Suisse de Sûreté des Installations Nucléaires held its 14th session at Würenlingen, Switzerland. Delegates discussed, inter alia, current trends in nuclear energy policy and exchanged information on important safety and radiation protection issues arising from the supervision of nuclear installations.

In June, the chairman of the Nuclear Regulatory Commission (NRC, the US regulatory authority) visited the Inspectorate to discuss the "Integrated Supervision" system being implemented by the Inspectorate. The NRC is seeking closer co-operation with the Inspectorate in this area.

From 23–24 June 2003, a workshop on "Redefining the Large Break LOCA" was held in Zürich, organised jointly by PSI, the Inspectorate and NEA. The Inspectorate reported on the results of the plebiscite on the 18th of May 2003 and its implications for nuclear energy in Switzerland. The presentation by the director of the NRC was a clear affirmation of risk-informed supervision.

In 2000, Switzerland ratified the "Joint Convention on the safety of spent fuel management and on the safety of radioactive waste management" (Joint Convention). Under the terms of this Convention, it is required to report to subsequent review meetings attended by other signatories on the implementation of the safety requirements specified in the Convention. The first "Review Meeting" on the "Joint Convention" was held in November 2004 at the IAEA in Vienna. The first country report was completed in April 2003 and deposited with the IAEA. 33 additional country reports were discussed and it was found that the Swiss disposal programme for spent fuel elements and radioactive waste was in accord with the Joint Convention. Several areas were considered to be exemplary, such as ISRAM, the electronic waste database and the close involvement of the Swiss public and the neighbouring countries in the outline approval procedure.

WENRA meets twice yearly. At the November meeting in Stockholm, the main topics under discussion were the harmonisation of regulatory functions and requirements for nuclear facilities and the harmonisation of the regulatory functions and requirements for decommissioning and disposal. These requirements are based on the IAEA Safety Standards. At present, a list of questions is being compiled that will subsequently be answered by each country. Based on their answers, action may be taken to introduce a harmonised safety policy in all European countries. In addition, inspection teams in the various countries will verify that standards are implemented and maintained.

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Table A1

Performance of the Swiss nuclear power plants in 2003

	KKB 1	KKB 2	KKM	KKG	KKL
Thermal energy produced [GWh]	9543	9109	8457	24820	28929
Net electrical energy supplied [GWh]	3062	2920	2744	7926	9309
Thermal energy supplied [GWh]	138.6	9.4	1.9	164	0
Availability factor[1] [%]	97.3	92.5	91.7	94.7	93.7
Non-availability due to annual revision [%]	2.7	6.9	6.3	5.5	6.1
Load factor[2] [%]	95.9	91.4	88.2	94.5	91.5
Number of unplanned scrams	0	3	1	0	0
Other unplanned shutdowns	0	0	1	0	1
Load reductions due to events or failures (>10% P_N)	1	2	0	1	2

[1] Availability (in%): Time in which the nuclear power plant was in operation or in a usable condition.

[2] Load factor (in %): Energy produced relative to the nominal power and 100% availability.

Table A2

Numbers of licensed personnel and grand totals of all personnel in the Swiss nuclear power plants at the end of 2003 (Numbers in brackets: 2002).

Job title	KKB 1+2	KKM	KKG	KKL
B operator	14 (14)	7 (8)	4 (4)	5 (5)
A operator	14 (14)	10 (9)	18 (19)	10 (10)
Shift chief and deputy	27 (28)	11 (11)	19 (21)	17 (21)
Picket and operations engineers	11 (9)	8 (7)	12 (13)	13 (12)
Radiation protection expert	5 (5)	4 (4)	7 (7)	10 (9)
Radiation protection technician	5 (5)	6 (6)	3 (3)	5 (5)
Total personnel	497 (481)	305 (295)	394 (381)	413 (395)

Table A3

Classified events in 2003

Date	Plant	Event	INES Classification
29.1.2003	KKB 2	Reactor trip following fail-opening of main steam relief valves	0
6.2.2003	KKM	Leakage on the flow measurement of a feedwater line	0
20.2.2003	KKL	Exceeding of a dose limit at a transport of radioactive waste	0
19.3.2003	KKB 2	Inadvertent reactor trip during a functional test	0
16.4.2003	KKL	Failure to open of an injection valve of the RCIC during a functional test	0
20.5.2003	KKG	Failure to close of a containment isolation valve during a functional test	0
20.5.2003	KKG	Failure to start a nuclear service water pump during a functional test	0
21.5.2003	KKB 1	Unregistered release of radioactive gas out of an auxiliary building	0
31.5.2003	KKM	Leakage of a gasket at a reactor recirculation pump	0
31.05.2003	KKM	Leakage at a reactor pressure vessel nozzle of the control rod drive return system	0
19.8.2003	KKB 2	Reactor trip at 12% power after failure to change-over the feedwater pumps	0
1.9.2003	KKM	Reactor trip following loss of the main heat sink	0
9.10.2003	KKL	Failure of pump breaker during preparation of a SEHR functional test	0
16.10.2003	KKL	Trip of a NICCW pump during a functional test	0

Table A4a

Summary of the releases of radioactive materials to the environment in 2003 and the resulting calculated individual doses (see footnotes at the end of the table)

NPP	Medium	Type of releases[4]	Release limits[1]	Actual releases[2, 4]			Calculated effective equivalent doses[3]	
				Equivalent releases (compared with the limits)				
			Bq/year	Bq/year	Percent of limit	Bq/year	Adult mSv/year	Infant mSv/year
KKB 1 + KKB 2	Waste water ($4100\ m^3$)	Nuclide mixture (without tritium)	$4 \cdot 10^{11}$	$4.7 \cdot 10^{8}$	0.1%	$1.2 \cdot 10^{10}$	<0.001	<0.001
		Tritium	$7 \cdot 10^{13}$	$1.1 \cdot 10^{13}$	16%	$1.1 \cdot 10^{13}$	<0.001	<0.001
	Exhaust air	Noble gases	$1 \cdot 10^{15}$	$5.0 \cdot 10^{12}$	0.5%	$4.8 \cdot 10^{12}$	<0.001	<0.001
		Aerosols	$6 \cdot 10^{9}$	–	<0.1%	$2.5 \cdot 10^{5}$	<0.001	<0.001
		Iodine-131	$4 \cdot 10^{9}$	$5.3 \cdot 10^{6}$	0.1%	$5.3 \cdot 10^{6}$	<0.001	<0.001
		Carbon-14 (CO_2)	–	–	–	$4.0 \cdot 10^{10}$	0.0012	0.0020
	Total dose						0.0013	0.0022
KKM	Waste water ($5591\ m^3$)	Nuclide mixture (without tritium)	$4 \cdot 10^{11}$	$7.0 \cdot 10^{8}$	0.2%	$4.3 \cdot 10^{9}$	<0.001	<0.001
		Tritium	$2 \cdot 10^{13}$	$1.7 \cdot 10^{11}$	0.9%	$1.7 \cdot 10^{11}$	<0.001	<0.001
	Exhaust air	Noble gases	$2 \cdot 10^{15}$	$3.9 \cdot 10^{12}$	0.2%	$2.3 \cdot 10^{12}$	<0.001	<0.001
		Aerosols	$2 \cdot 10^{10}$	–	<0.1%	$1.1 \cdot 10^{7}$	0.0047	0.0040
		Iodine-131	$2 \cdot 10^{10}$	$1.3 \cdot 10^{8}$	0.7%	$1.3 \cdot 10^{8}$	<0.001	<0.001
		Carbon-14 (CO_2)	–	–	–	$2 \cdot 10^{11}$	<0.001	0.0012
	Total dose						0.0055	0.0053
KKG	Waste water ($7398\ m^3$)	Nuclide mixture (without tritium)	$2 \cdot 10^{11}$	–	<0.1%	$4.6 \cdot 10^{7}$	<0.001	<0.001
		Tritium	$7 \cdot 10^{13}$	$1.4 \cdot 10^{13}$	20%	$1.4 \cdot 10^{13}$	<0.001	<0.001
	Exhaust air	Noble gases	$1 \cdot 10^{15}$	$<7.5 \cdot 10^{12}$	<0.8%	$<6.5 \cdot 10^{12}$	<0.001	<0.001
		Aerosols	$1 \cdot 10^{10}$	–	<0.1%	$4.9 \cdot 10^{4}$	<0.001	<0.001
		Iodine-131	$7 \cdot 10^{9}$	–	<0.1%	–	<0.001	<0.001
		Carbon-14 (CO_2)	–	–	–	$3.0 \cdot 10^{11}$	0.0021	0.0035
	Total dose						0.0022	0.0037
KKL	Waste water ($15727\ m^3$)	Nuclide mixture (without tritium)	$4 \cdot 10^{11}$	–	<0.1%	$1.1 \cdot 10^{8}$	<0.001	<0.001
		Tritium	$2 \cdot 10^{13}$	$2.2 \cdot 10^{12}$	11%	$2.2 \cdot 10^{12}$	<0.001	<0.001
	Exhaust air	Noble gases	$2 \cdot 10^{15}$	–	<0.1%	$2.5 \cdot 10^{12}$	<0.001	<0.001
		Aerosols	$2 \cdot 10^{10}$	$3.5 \cdot 10^{7}$	0.2%	$3.5 \cdot 10^{7}$	<0.001	<0.001
		Iodine-131	$2 \cdot 10^{10}$	$4.8 \cdot 10^{8}$	2.4%	$4.8 \cdot 10^{8}$	<0.001	0.001
		Carbon-14 (CO_2)	–	–	–	$6.0 \cdot 10^{11}$	0.0032	0.0054
	Total dose						0.0033	0.0059

Table A4a (continued)

Releases from the Paul Scherrer Institute in 2003 and the resulting calculated individual doses (see footnotes at the end of the table)

	Main stack East (PSI-East)	Incinerator (PSI-East)	Saphir (PSI-East)	C-laboratory, laboratory for radio-active waste (PSI-East)	BZL	Central stack (PSI-West)	Injector I (PSI-West)	Injector II (PSI-West)	C-Laboratory (PSI-West)	Waste water PSI (2411 m^3)	Total PSI
Releases in waste water[2, 4] [Bq]											
Nuclide mixture (without tritium)	–	–	–	–	–	–	–	–	–	$2.2 \cdot 10^{7}$	$2.2 \cdot 10^{7}$
Tritium	–	–	–	–	–	–	–	–	–	$3.3 \cdot 10^{11}$	$3.3 \cdot 10^{11}$
Releases to exhaust air[2, 4] [Bq]											
Noble gases and other gases	$4.9 \cdot 10^{10}$	–	–	–	–	$1.1 \cdot 10^{14}$	$1.0 \cdot 10^{10}$	$1.0 \cdot 10^{10}$	–	–	$1.1 \cdot 10^{14}$
Beta/Gamma-Aerosols (without iodine, half-life >8 hrs.)	$4.6 \cdot 10^{5}$	–	$1.5 \cdot 10^{4}$	–	–	$1.3 \cdot 10^{10}$	–	$6.0 \cdot 10^{6}$	$3.2 \cdot 10^{5}$	–	$1.3 \cdot 10^{10}$
Alpha-aerosols	–	–	–	–	–	–	–	–	–	–	–
Iodine (I-131-equ.)	$3.9 \cdot 10^{8}$	–	$2.4 \cdot 10^{4}$	–	–	$1.2 \cdot 10^{7}$	–	$6.3 \cdot 10^{3}$	–	–	$4.0 \cdot 10^{8}$
Tritium (tritiated water)	$3.8 \cdot 10^{11}$	$9.6 \cdot 10^{9}$	–	$9.9 \cdot 10^{10}$	$1.4 \cdot 10^{9}$	$5.7 \cdot 10^{11}$	–	–	–	–	$1.1 \cdot 10^{12}$
Carbon-14 (CO_2)	–	–	–	–	–	–	–	–	–	–	–
Annual dose[3] [mSv/year] for:											
Adults	<0.00015	<0.00015	<0.00015	<0.00015	<0.00015	0.0035	<0.00015	<0.00015	<0.00015	<0.00015	**<0.004**
Infants	0.0002	<0.00015	<0.00015	<0.00015	<0.00015	0.0036	<0.00015	<0.00015	<0.00015	<0.00015	**<0.004**
Part of source-related dosis guideline[1]	0.1%	<0.1%	<0.1%	<0.1%	<0.1%	2.4%	<0.1%	<0.1%	<0.1%	<0.1%	<3%

Table A4a (Footnotes)

1 **Release limits** according to the operating license for the nuclear installation concerned. The release limits for the NPPs have been laid down to keep the off-site exposure of the critical population group in the vicinity below 0.3 mSv/year. For the Paul Scherrer Institute (PSI), the releases are directly limited to 0.15 mSv/year via the source-related dosis-guideline, according to the permit dated 6/2002.

2 **Measurement of releases** is carried out according to the requirements. "For the release of radioactive materials and the surveillance of radioactivity and direct irradiation in the environment of the..." (given NPP) and the PSI. The accuracy of the measurements is about 50%. Releases below 0.1% of the annual release limits are regarded by the Inspectorate as not being relevant.

3 **Annual dose** is calculated for persons who live permanently at the critical location and take their total food produced at the location and all water requirements at a location downstream from the NPP. The calculations are done according to the Inspectorate's Guideline HSK-R-41; this contains a model and the defined parameters to use.

Doses less than 0.001 mSv – equivalent to the dose accumulated in 10 h due to natural radioactivity – are, as a rule, not recorded. At PSI, the annual dose of the complete installation is shown as a total over all the release points although the critical locations of the single release points do not, in general, come together.

4 By the **type of release,** the following is noted:

Waste water: Releases in Bq/year are normalised to a reference exemption limit (LE) of 200 Bq/kg. The LE values for the individual nuclides are taken from Appendix 3 of the radiological protection ordinance (StSV). A LE value of 200 Bq/kg corresponds to a reference nuclide with an ingestion dosis-factor of $5 \cdot 10^{-8}$ Sv/Bq. The non-normalised total of the waste water releases is shown in the Table.

Noble gases: Radioactive releases in Bq/year, normalised to a reference CA value of $2 \cdot 10^5$ Bq/m^3, are given. The CA values for the noble gas nuclides are taken from Appendix 3 of the radiological protection ordinance (StSV). A CA value of $2 \cdot 10^5$ Bq/m^3 corresponds to a reference nuclide with an immersion dosis-factor of $4.4 \cdot 10^{-7}$ (Sv/year)/Bq/m^3. The non-normalised sum of the noble gas releases is shown in the Table.

For NPP Gösgen (KKG), a ß-total measurement was carried out for balancing the noble gases (see the values in brackets); for the equivalent-exchange calculation, for this case, a mixture of 80% Xe-133, 10% Xe-135 and 10% Kr-88 was taken. This mixture was also taken for calculating the dose.

Gases: At PSI it is mainly the nuclides C-11, N-13, O-15 and Ar-41 whose half-life times are less than two hours. For the releases here, it is the sum of the radioactivity, without standardising to a reference value, which are given.

Aerosoles: The releases given correspond to the total of aerosol activity without standardising to a reference value.

The dose contribution of aerosoles with a half-life time less than 8 days is negligible for the nuclear power plants.

In the case of NPP Mühleberg (KKM), the main contribution to the dose stems from soil-deposited aerosoles which were unintentionally released in 1986. The dose contribution through aerosole releases in the reporting period is small compared to this and lies within the order of magnitude of other Swiss nuclear power plants.

Iodine: The release of I-131 is limited for NPPs. Therefore, only this iodine isotope is given in the actual releases. The annual dose is, however, calculated using all available iodine isotopes. For example, for KKB, I-133 contributions are also taken into account.

At PSI, the release as I-131-equivalent through a weighted total of the activity of the released iodine nuclides is given. Here the weighting factor is derived from the relationship between the ingestion-factor of the particular nuclide to that of the ingestion-factor from I-131. The ingestion factors are taken from the StSV.

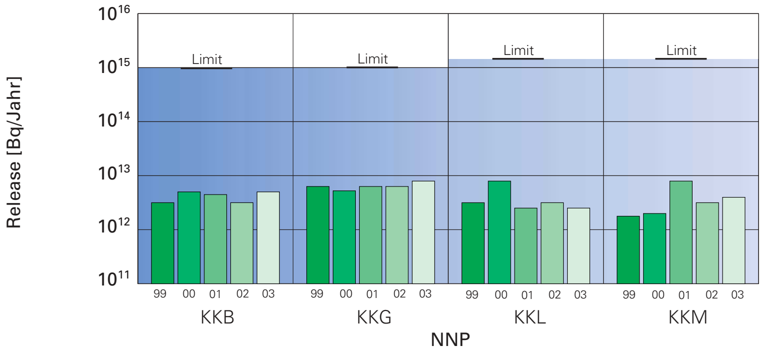
Carbon-14: The dosis-relevant part of C-14, present as carbon dioxide, is given in the Table. The C-14 values are based on actual measurements in the cases of KKG and KKL. At KKB and KKM they are based on published information and measurements from previous years.

Table A4b

Releases of the Swiss nuclear power plants in the last 5 years, compared to the release limits

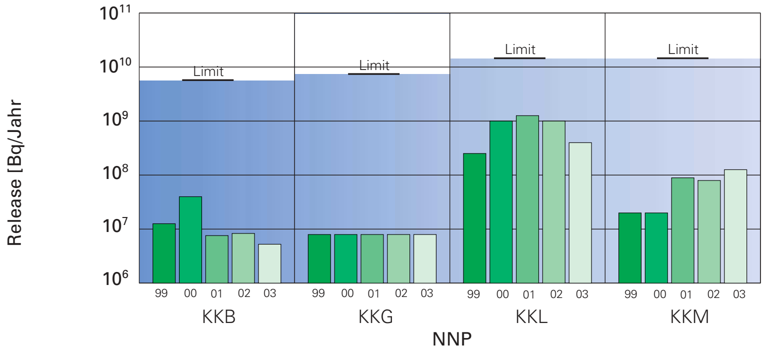
Exhaust air

Noble gases



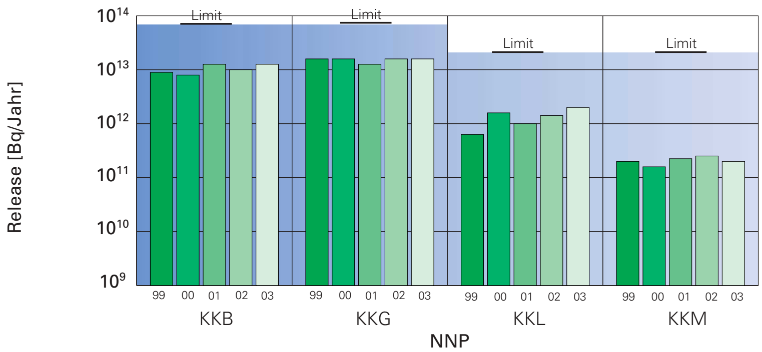
Exhaust air

Iodine



Waste water

Tritium in waste water



Waste water

Other liquid-type releases

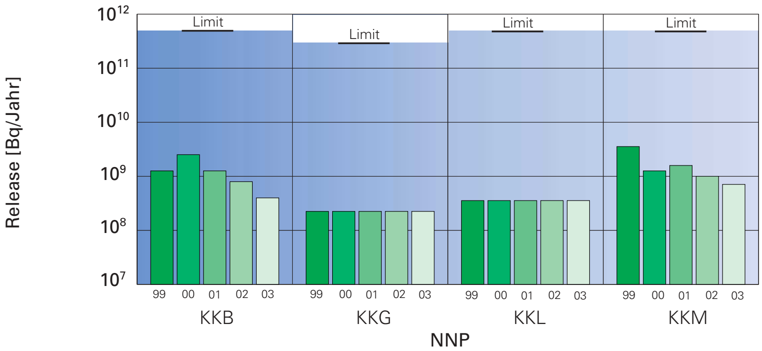


Table A5a

Nuclear power plants: Whole-body doses of occupationally exposed personnel from external irradiation in 2003. Number of persons and average annual dose

Dose distribution [mSv]	KKB 1 + 2			KKG			KKL			KKM			Total NPP[1]		
	E	F	E + F	E	F	E + F	E	F	E + F	E	F	E + F	E	F	E + F
>0,0–1,0	296	341	637	263	400	663	274	757	1031	153	508	661	986	1665	2651
>1,0–2,0	46	37	83	17	44	61	52	74	126	40	67	107	155	217	372
>2,0–5,0	29	27	56	31	47	78	36	92	128	52	78	130	148	243	391
>5,0–10,0	5	2	7	13	6	19	2	11	13	22	23	45	42	46	88
>10,0–15,0										7	5	12	7	5	12
>15,0–20,0															
>20,0–50,0															
>50,0															
Total persons	376	407	783	324	497	821	364	934	1298	274	681	955	1338	2176	3514
Average per person [mSv]	0.7	0.5	0.6	0.8	0.6	0.7	0.7	0.6	0.7	1.9	1.0	1.2	1.0	0.8	0.9

[1] External personnel who have worked in more than one plant are only counted once.

E = plant own personnel, F = external personnel; TL-dosimeters used in all plants.

Table A5b

Nuclear power plants and research: Whole-body doses of occupationally exposed personnel from external irradiation in 2003. Number of persons and average annual dose

Dose distribution [mSv]	PSI	University[3]	Total Research[1]	ZZL	Total NNP E + F	Total NPP and Research[2]
0.0–1.0	1083	13	1097	88	2651	3740
> 1.0–2.0	43		43		372	415
> 2.0–5.0	13		13		391	404
> 5.0–10.0	3		3		88	91
> 10.0–15.0					12	12
> 15.0–20.0						
> 20.0–50.0						
> 50.0						
Total persons	1142	13	1156	88	3514	4662
Average per person [mSv]	0.2	0.0	0.2	0.0	0.9	0.8

[1] This column contains the annual dose of one person from the experimental reactor at Lucens (0.7 mSv).

[2] Individuals from external personnel having worked successively in several installations are counted here only once.

[3] This column contains the total number of occupationally exposed personnel at PSI.

E = plant own personnel, F = external personnel; TL-dosimeters used in all installations and plants.

Table A6a

Nuclear power plants: Whole-body doses of occupationally exposed personnel from external irradiation in 2003. Annual collective doses in Person-mSv

Dose distribution [mSv]	KKB 1 + 2			KKG			KKL			KKM			Total NPP[1]		
	E	F	E + F	E	F	E + F	E	F	E + F	E	F	E + F	E	F	E + F
0.0–1.0	61.8	57.1	118.9	35.9	53.0	88.9	61.6	124.6	186.2	46.2	122.3	168.5	205.5	311.2	516.7
> 1.0–2.0	68.8	54.4	123.2	26.0	64.8	90.8	78.4	112.0	190.4	62.7	101.4	164.1	235.9	326.6	562.5
> 2.0–5.0	87.1	78.2	165.3	101.9	144.3	246.2	115.6	285.3	400.9	172.5	232.2	404.7	477.1	750.1	1227.2
> 5.0–10.0	36.4	10.6	47.0	90.7	38.0	128.7	12.7	71.9	84.6	149.2	154.9	304.1	289.0	311.2	600.2
> 10.0–15.0										81.5	56.8	138.3	81.5	56.8	138.3
> 15.0–20.0															
> 20.0–50.0															
> 50.0															
Total [Persons-mSv]	254.1	200.3	454.4	254.5	300.1	554.6	268.3	593.8	862.1	512.1	667.6	1179.7	1289.0	1755.9	3044.9
Highest individual dose [mSv]	9.5	5.3	9.5	9.8	7.7	9.8	7.3	8.7	8.7	12.8	13.1	13.1	12.8	13.1	13.1

[1] External personnel that work in more than one installation are only counted once. Through the addition of the varius doses collected in different NPPs, or the elimination of individual doses that have been reported on more than once, the collective doses change only slightly.

E = plant own personnel, F = external personnel

Table A6b

Nuclear power plants and research: Whole-body doses of occupationally exposed personnel from external irradiation in 2003. Annual collective doses in Person-mSv

Dose distribution [mSv]	PSI	Universities[3]	Total Research[1]	ZZL	Total NPP E + F	Total NNP and Research[2]
0.0–1.0	57.8	0.0	58.5	2.7	516.7	575.4
> 1.0–2.0	58.8		58.8		562.5	621.4
> 2.0–5.0	45.8		45.8		1227.2	1273.1
> 5.0–10.0	20.3		20.3		600.2	621.0
> 10.0–15.0					138.3	138.3
> 15.0–20.0						
> 20.0–50.0						
> 50.0						
Total [Pers.-mSv]	182.7	0.0	183.4	2.7	3044.9	3229.2
Highest individual dose [mSv]	7.8	0.0	7.8	0.3	13.1	13.1

[1] This column contains the annual dose of one person from the experimental reactor at Lucens (0.7 mSv).

[2] External personnel that work in more than one installation are only counted once. Through the addition of the various doses collected in different NPPs, or the elimination of individual doses that have been reported on more than once, the collective doses change only slightly.

[3] This column contains the doses of the total number of occupationally exposed personnel at PSI.

E = plant internal personnel, F = external personnel; TL-dosimeters used in all installations and plants.

Table A7

Nuclear power plants and research (own and external personnel): Whole-body doses of occupationally exposed personnel from external irradiation in 2003.
Number of individuals grouped according to age and sex

Dose distribution [mSv]	16–18 years		19–20 years		21–30 years		31–40 years		41–50 years		51–60 years		> 60 years		Total
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	
0.0–1.0	20		46	2	507	49	861	63	958	44	904	22	243	7	3726
> 1.0–2.0	1		4		59	2	116	2	128	1	87	2	13		415
> 2.0–5.0	1		2		43		100		150	1	94	2	11		404
> 5.0–10.0			1		12		28		23		22		5		91
> 10.0–15.0					1		3		4		4				12
> 15.0–20.0															
> 20.0–50.0															
> 50.0															
Total persons	22		53	2	622	51	1108	65	1263	46	1111	26	272	7	4648
Average per person [mSv]	0.42		0.54	0.00	0.63	0.09	0.79	0.08	0.83	0.13	0.66	0.40	0.42	0.01	0.69
Collective dose [Person-mSv]	9.3		28.8	0.0	392.1	4.4	872.5	5.2	1049.9	5.9	735.8	10.4	114.8	0.1	3229.2

M = male, F = female

Table A8

Nuclear power plants and research: Distribution of hand and foot doses in 2003

Dose distribution [mSv]	KKB 1 + 2			KKG			KKL			KKM			Total NPP			PSI			ZZL			Total NNP + PSI
	E	F	E+F	E	F	E+F	E	F	E+F	E	F	E+F	E	F	E+F	E	F	E+F	E	F	E+F	E + F
0–25	8	2	10	3	0	3	2	10	12	6	9	15	19	21	40	108	1	109	0	0	0	149
> 25–50																2		2				2
> 50–75																1		1				1
> 75–100																						
> 100–150																						
> 150–200																						
> 200–250																						
> 250–300																						
> 300–350																						
> 350–400																						
> 400–450																						
> 450–500																						
> 500																						
Total persons	8	2	10	3	0	3	2	10	12	6	9	15	19	21	40	111	1	112	0	0	0	152

E = plant internal personnel, F = external personnel

Table A9

Nuclear power plants and research: Committed effective dose E_{50} of occupationally exposed personnel resulting from incorporation in 2003

Committed effective dose E_{50}/Dose distribution [mSv]	KKB 1 + 2			KKG			KKL			KKM			Total NNP			PSI			ZZL			Total NNP + PSI
	E	F	E+F	E	F	E+F	E	F	E+F	E	F	E+F	E	F	E+F	E	F	E+F	E	F	E+F	E + F
< = 1.0	343	414	757	307	465	772	364	942	1306	627	1988	2615	1641	3809	5450	310	19	329	28	80	108	5887
> 1.0–2.0																						
> 2.0–5.0																						
> 5.0–10.0																						
> 10.0–15.0																						
> 15.0–20.0																						
> 20.0–50.0																						
> 50.0																						
Total persons	343	414	757	307	465	772	364	942	1306	627	1988	2615	1641	3809	5450	310	19	329	28	80	108	5887

Persons by which in the screening measurement did not exceed the predetermined threshold are noted in this Table in the E_{50} dose distribution between 0–1.0 mSv.

Table A10a

Nuclear power plants and research: Distribution of total accumulated doses (life-doses) of occupationally exposed own personnel[1] in 2003

Dose distribution [mSv]	KKB 1+2	KKG	KKL	KKM	Total NPP	PSI	ZZL	Total NPP+PSI
> 100–150	35	16	11	25	87	11	27	125
> 150–200	24	11	6	16	57	3	1	61
> 200–250	17	8	2	14	41	4		45
> 250–300	11	3		7	21	1	1	23
> 300–350	9	1		2	12	1		13
> 350–400	4			5	9			9
> 400–450	2			1	3			3
> 450–500	4			4	8			8
> 500–550				5	5			5
> 550–600	2			1	3			3
> 600	1				1			1
Total persons	109	39	19	80	247	20	29	296

[1] Includes persons who left during 2003.

Table A10b

Nuclear power plants and research: Life-dose according to age distribution of the occupationally exposed own personnel[1] in 2003

Dose distribution [mSv]	21–30 years	31–40 years	41–50 years	51–60 years	> 60 years	Total NPP + PSI
> 100–150		14	45	50	16	125
> 150–200			11	41	9	61
> 200–250		2	7	28	8	45
> 250–300		1	2	13	7	23
> 300–350			1	11	1	13
> 350–400			1	5	3	9
> 400–450				1	2	3
> 450–500				5	3	8
> 500–550				4	1	5
> 550–600			1	1	1	3
> 600					1	1
Total persons		17	68	159	52	296

[1] Includes persons who left during 2003.

Table A11a

Radioactive waste at the NPPs and PSI (for PSI are also included here waste from medicine, industry and research). Volume in m^3 (rounded values)

	unconditioned[1]			conditioned[2]	
	Amount arising[3]	In ZZL[4]	Total[5]	Production[6]	Total[7]
PSI	56	–	459	3	950
KKB	24	8	171	5	1 059
KKM	21	8	89	55	971
KKG	17	22	20	13	344
KKL	39	23	48	23	1 400
Total	157	61	787	99	4 724

[1] Unconditioned waste contains revision-work waste and process waste.

[2] A reduction in volume occurs during conditioning burnable and compressible wastes.

[3] Gross-volume in 2003 derived from the number of raw waste containers, excepting KKM (netto-volume of raw waste).

[4] Gross-volume of the containers with combustible and meltable waste which were transferred to ZWILAG in the reporting period 2003 for conditioning in the combustion and melting facility.

[5] Gross-volume in storage in the nuclear installations by the end of 2003 (derived from the number of raw waste containers, except for KKM, which shows the netto-volume of the raw waste).

[6] Gross-volume in reporting period 2003 (for KKB the exact package volume is considered).

[7] Gross-volume in storage at the nuclear installations at the end of 2003 (for KKB the exact package volume is considered).

Table A11b

Deposited radioactive waste at the Central Interim Storage Facility of ZWILAG.
Volumes rounded to m^3

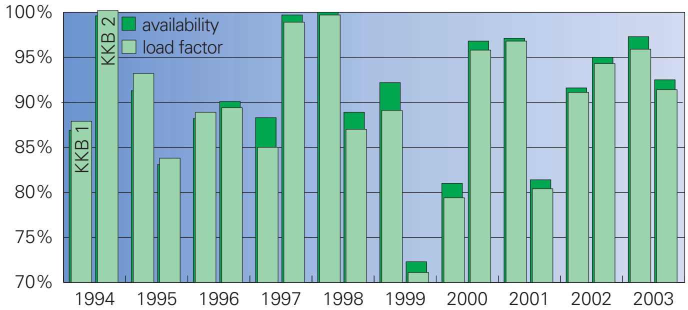
Storage	In Storage	Number
MAA-Storage (m^3) Waste Reception-Hall (m^3)	– –	29 8[1]
HAA-Storage – Number of containers with fuel elements HAA-Storage – Number of containers with vitrified waste HAA-Storage – Number of containers with radioactive waste of Lucens	1 1 6	8 4 6

[1] 38 Packages with slightly enriched uranium-containing material from the experimental reactor at Lucens.

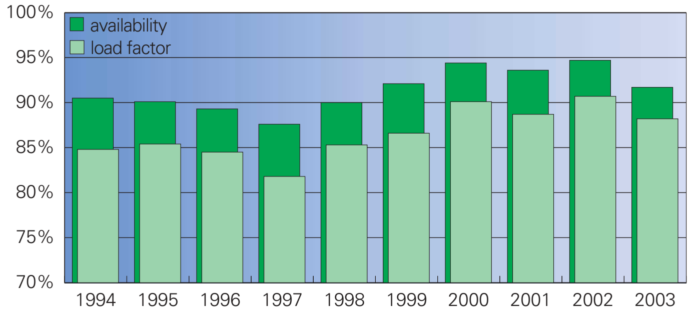
Figure A1

Availability and load factor 1994–2003

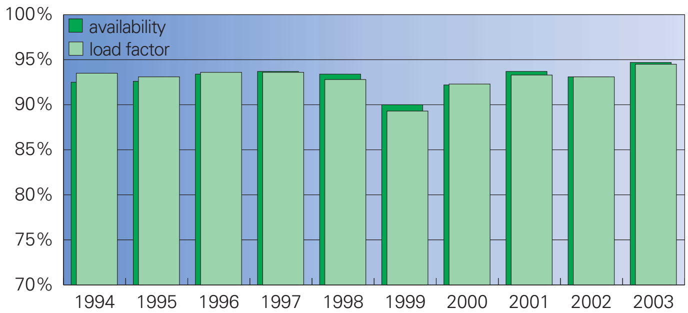
KKB 1, 2



KKM



KKG



KKL

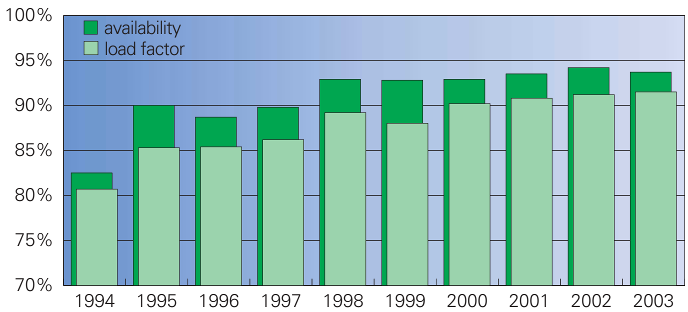
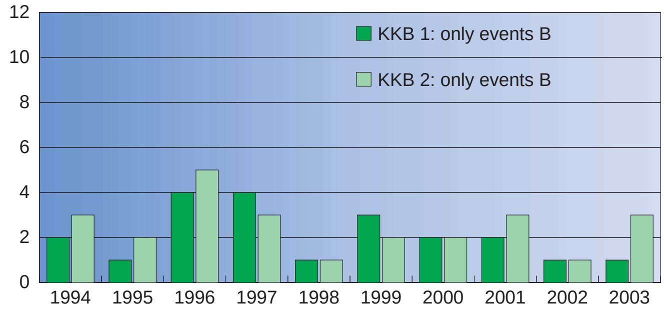


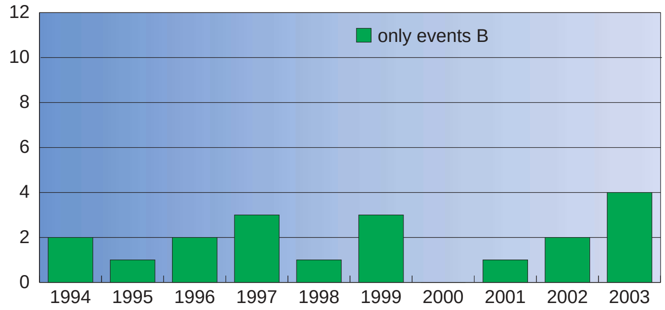
Figure A2

Notifiable, classified events, 1994–2003

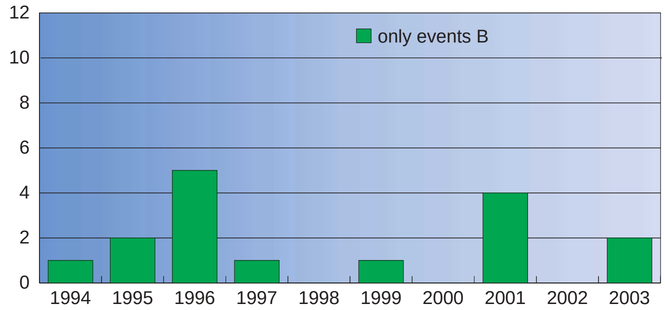
KKB 1, 2



KKM



KKG



KKL

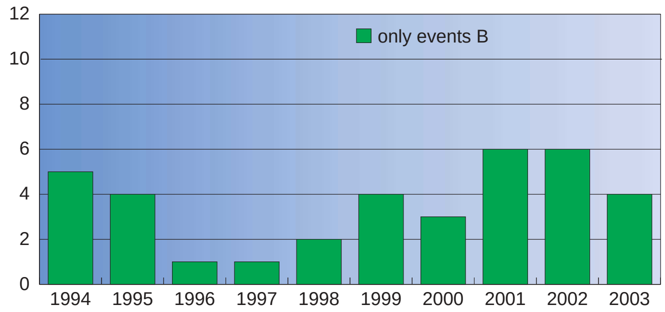
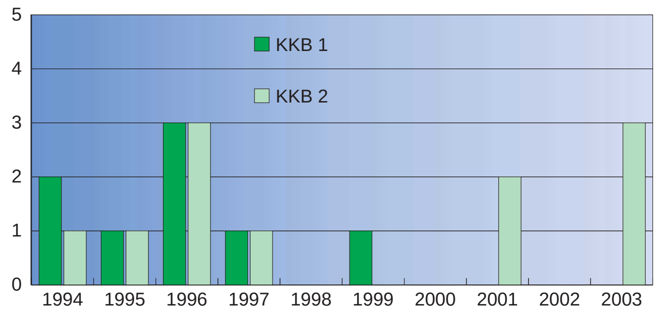


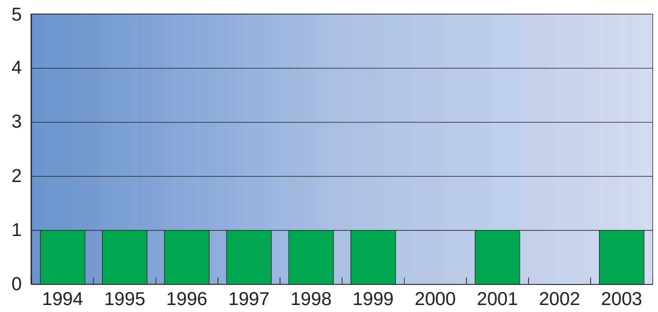
Figure A3

Number of reactor scrams (unplanned), 1994–2003

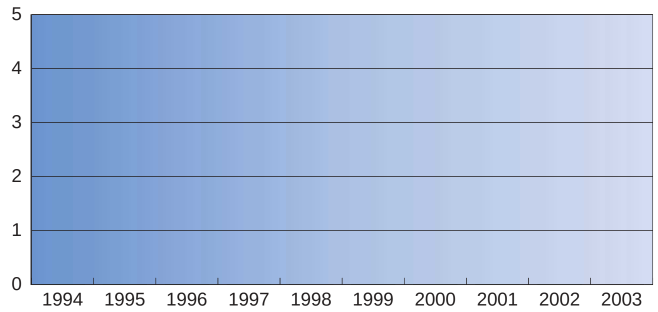
KKB 1, 2



KKM



KKG



KKL

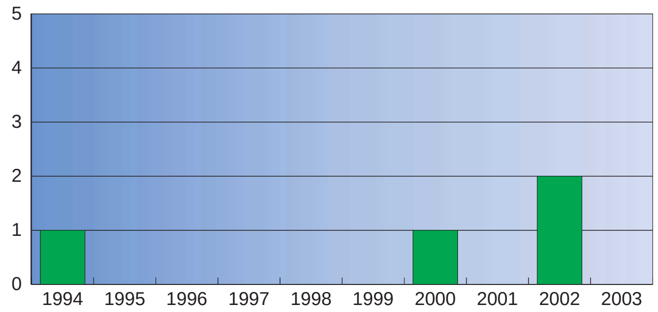


Figure A3a

Causes for classified events in the Swiss NPPs per year, 1994–2003

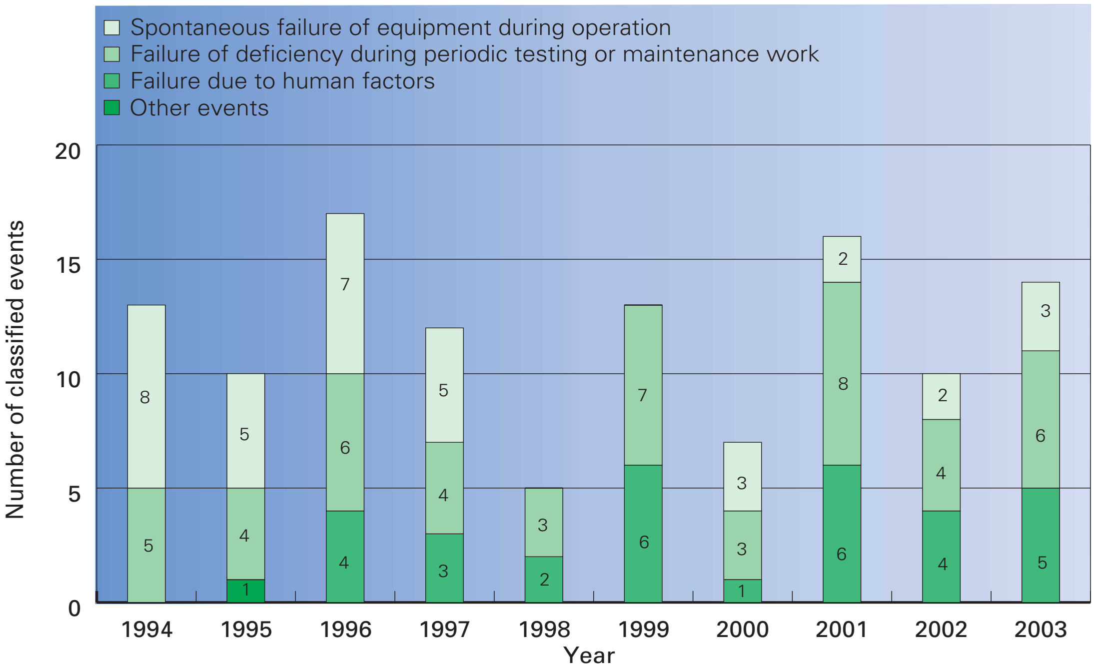


Figure A3b

Causes of unplanned reactor scrams per year, 1994–2003

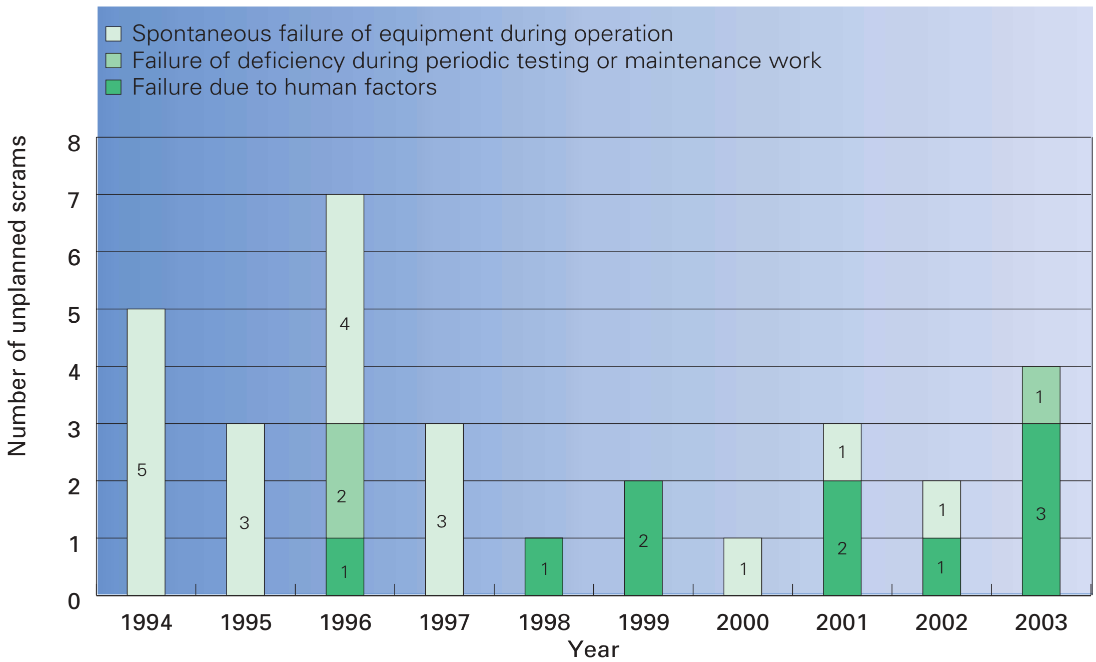
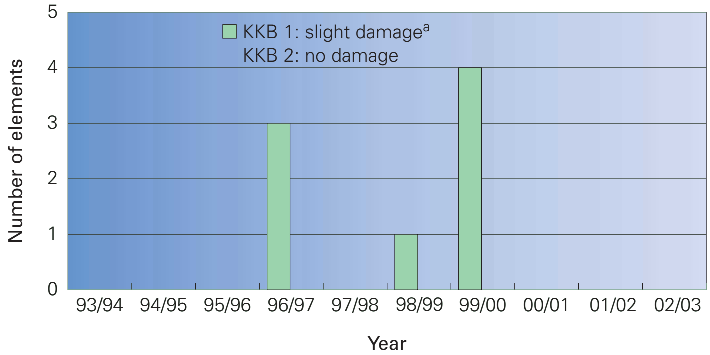


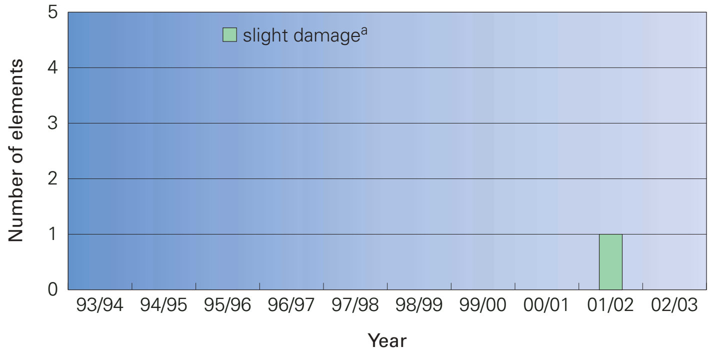
Figure A4

Fuel element defects (number of elements), 1993–2003

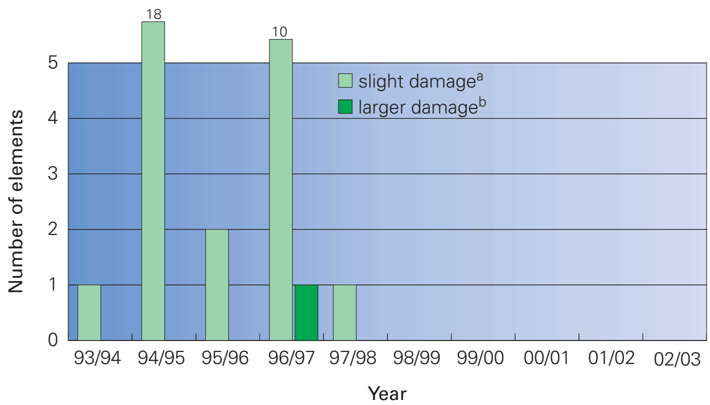
KKB 1, 2



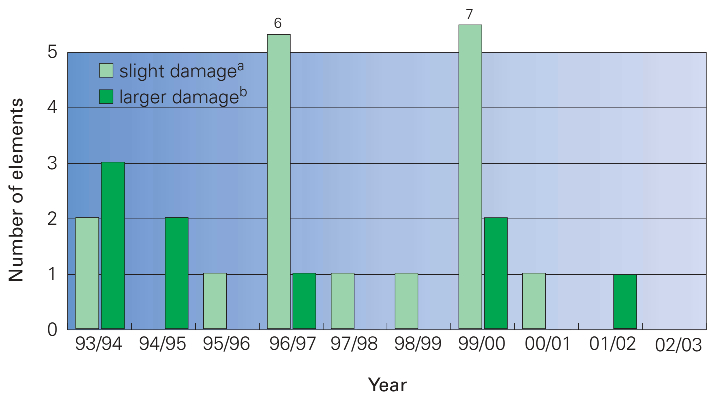
KKM



KKG



KKL



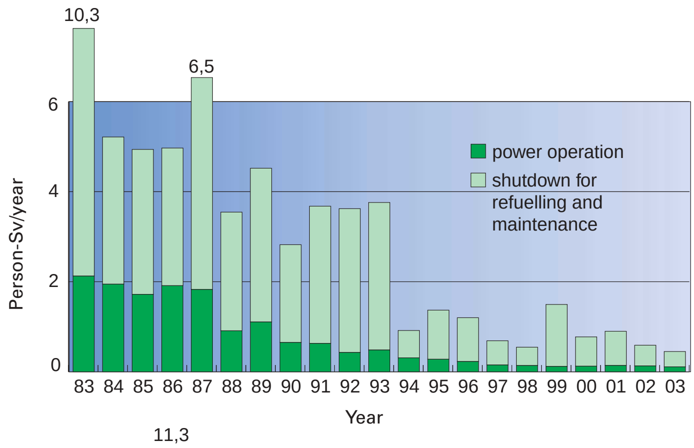
[a] e.g. hair cracks

[b] e.g. larger damage or breaks in the cladding with fuel washout

Figure A5

Annual collective doses (Person-Sv/year) in the NPPs, 1983–2003

KKB 1, 2



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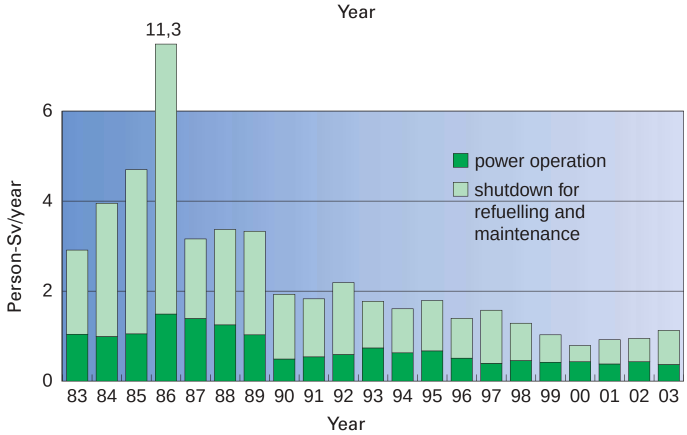

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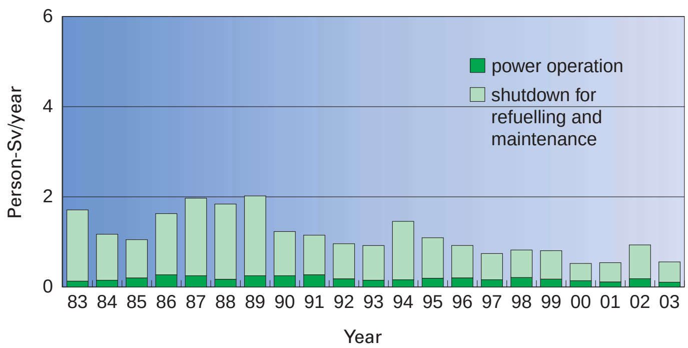

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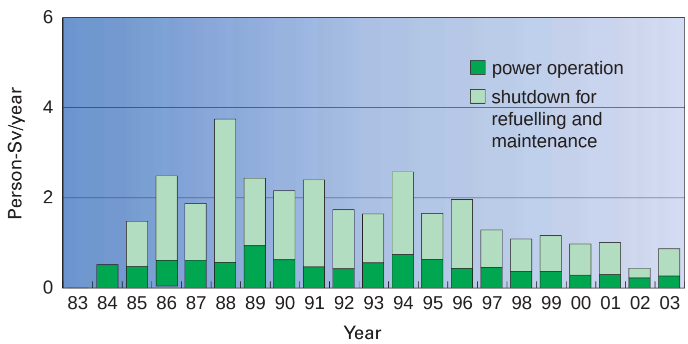


Figure A6

Annual collective doses (Person-Sv/year) in the nuclear installations: 1971–2003

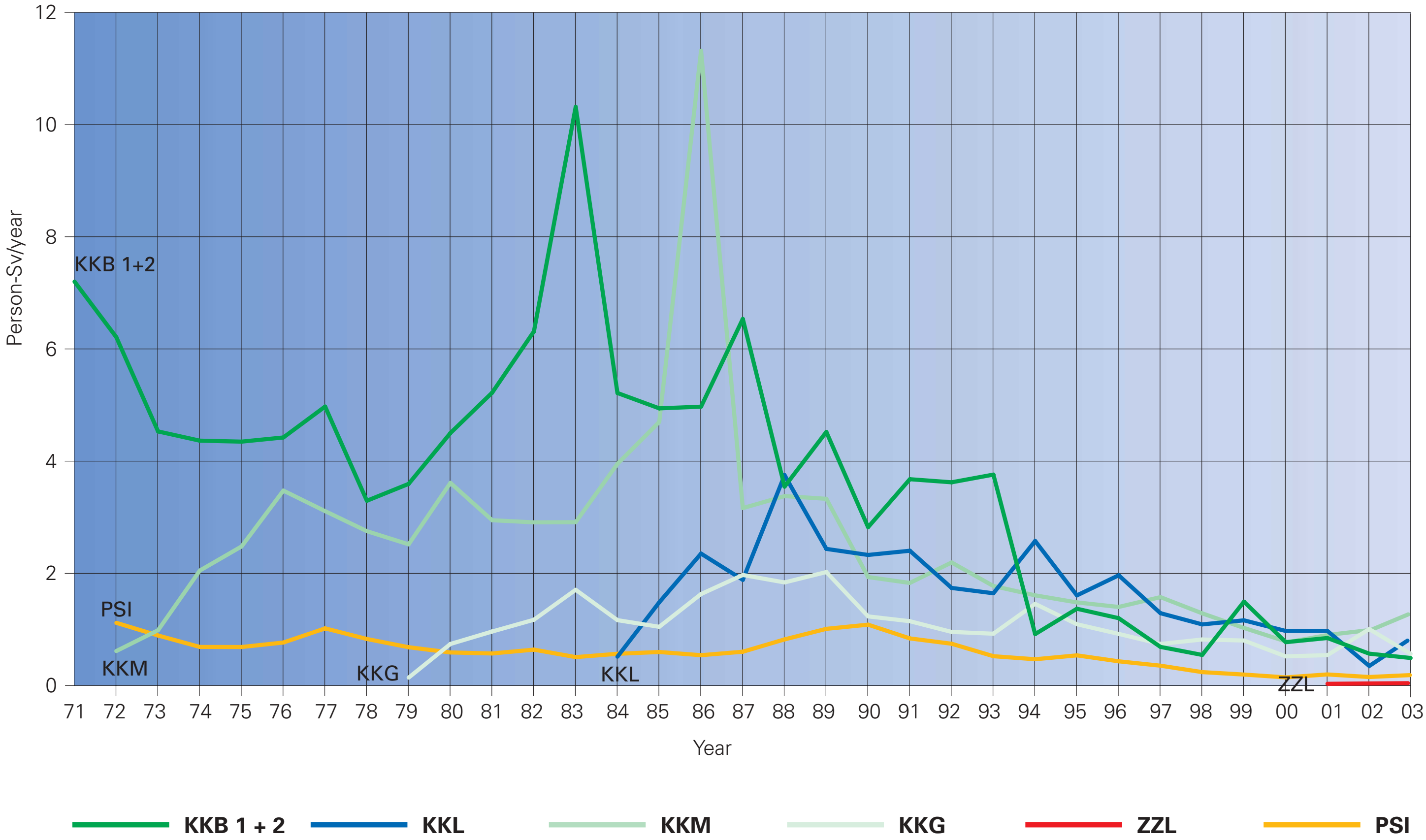
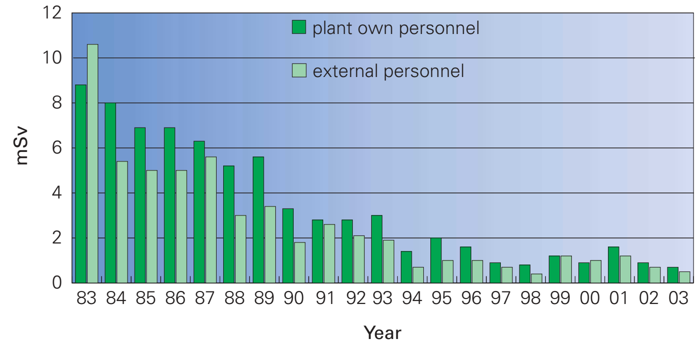


Figure A7

Nuclear power plants: Average annual individual doses (mSv); 1983–2003

KKB 1, 2



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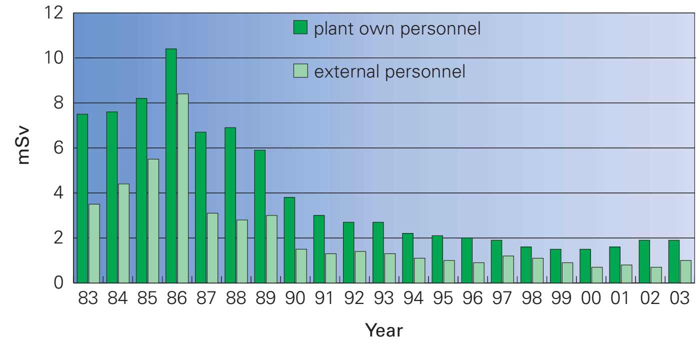

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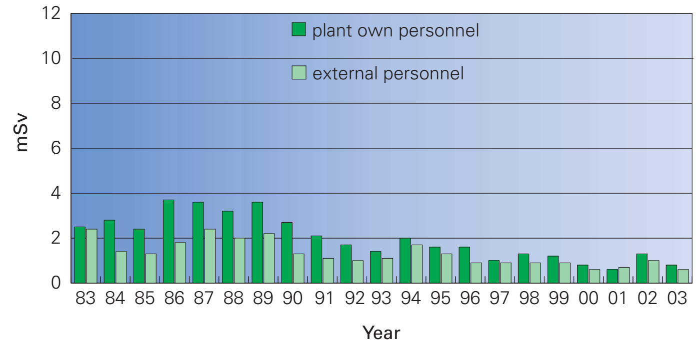

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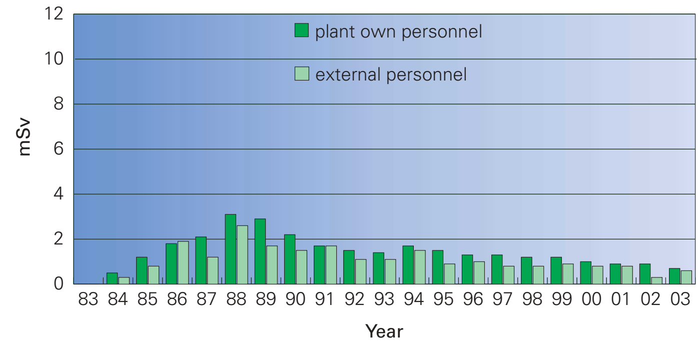
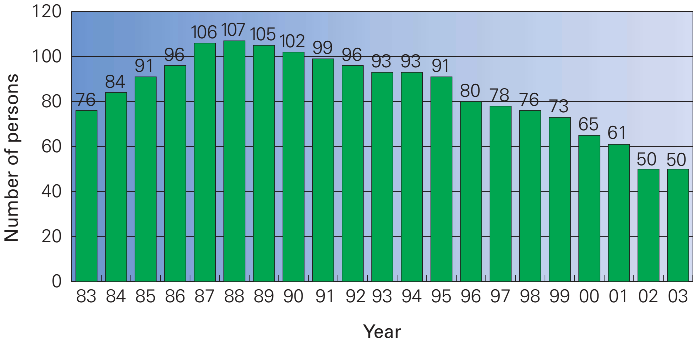


Figur A8

Nuclear power plants: Occupationally exposed personnel with a life-dose exceeding 200 mSv, 1983–2003

KKB 1, 2



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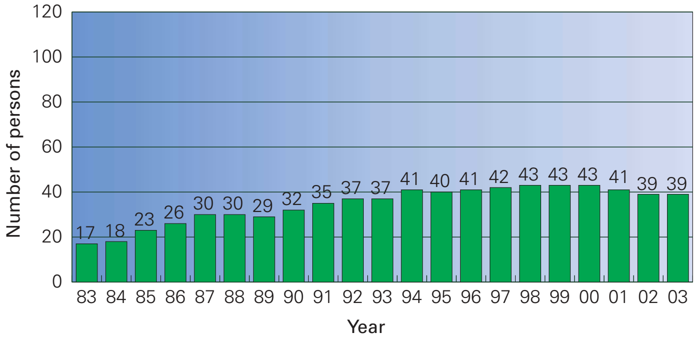

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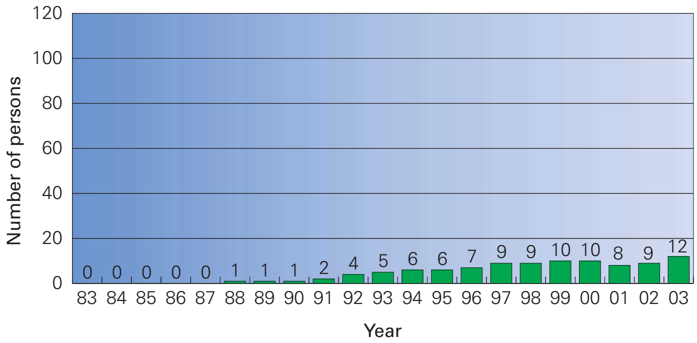

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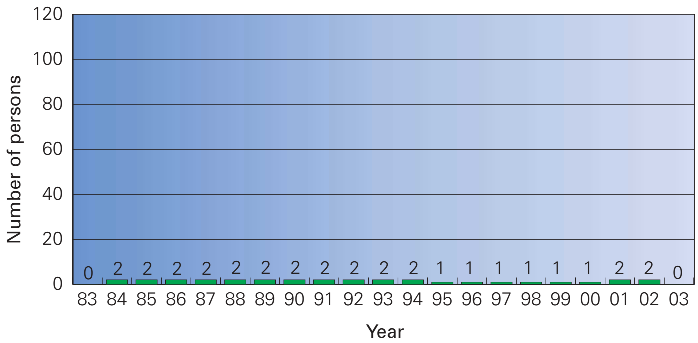
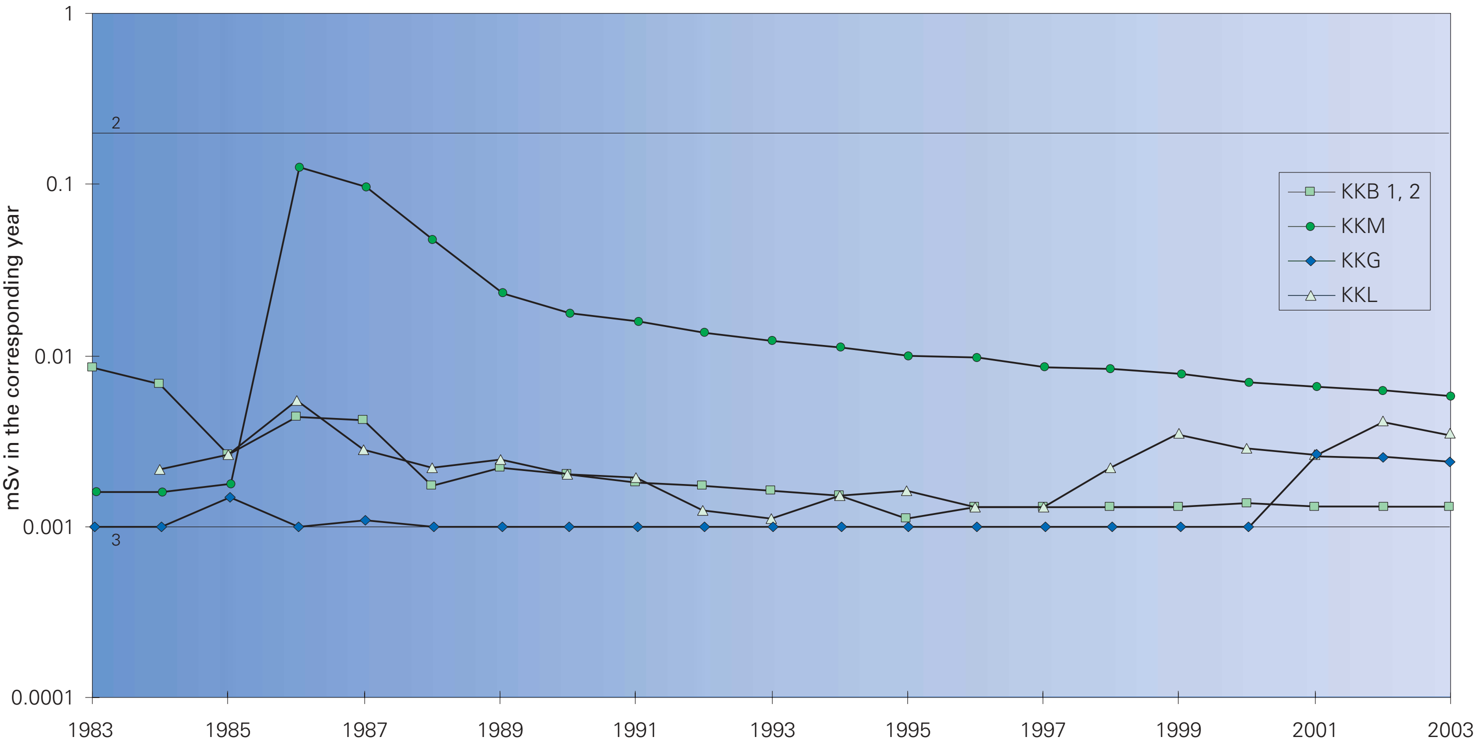


Figure A9

Calculated doses for the most affected persons (adults)[1] in the vicinity of the Swiss nuclear power plants



[1] Fictitious person, permanently located at the critical place, obtaining all food from the area and all drinking water from the river downstream of the nuclear power plant in question.

[2] Source-related dose guideline (StSV Art. 7, HSK-Guideline R-11).

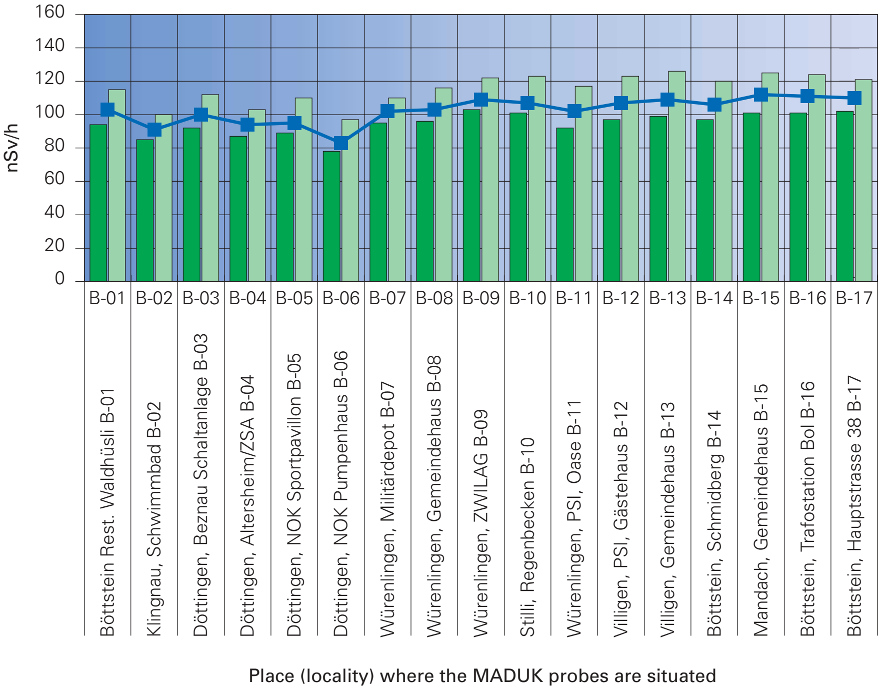
[3] Values below 0.001 mSv are not shown on the Figure.

Figure A10

Local dose rate in 2003, as measured by the MADUK probes

KKB

Legend
- Minimum daily value
- Maximum daily value
- Year's average value



KKL

Legend
- Minimum daily value
- Maximum daily value
- Year's average value

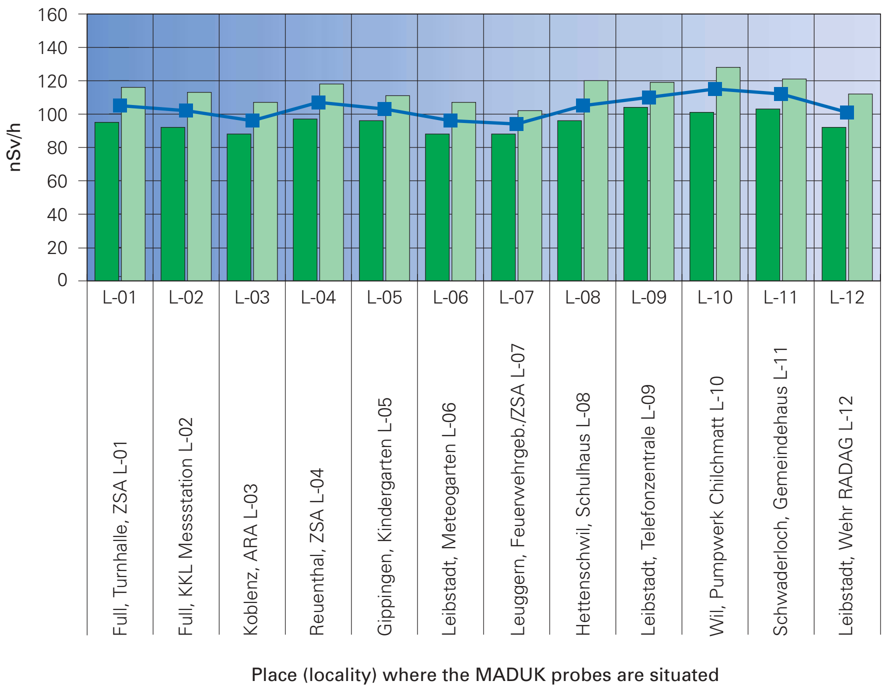
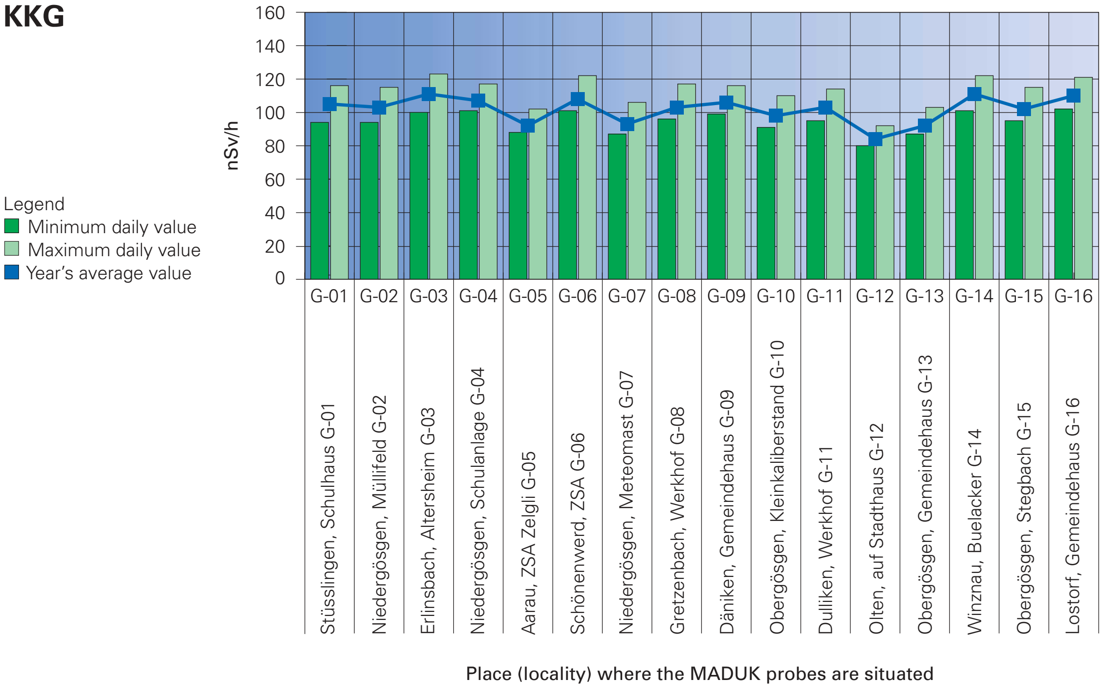


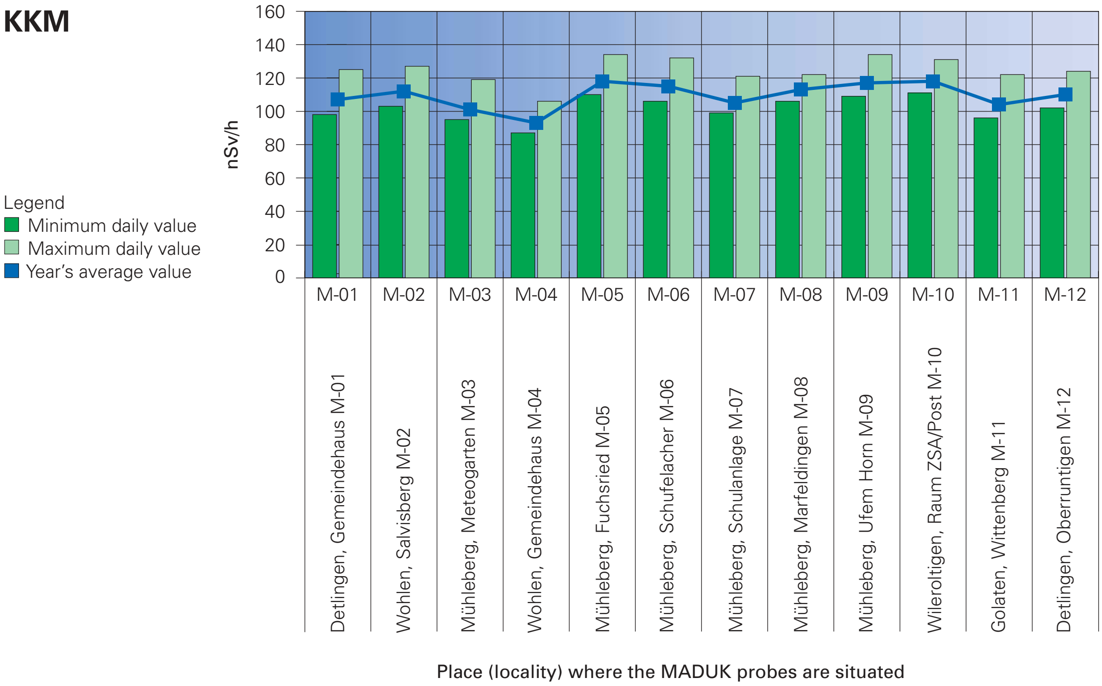
Figure A10 (cont.)

Local dose rate in 2003, as measured by the MADUK probes

KKG



KKM



APPENDIX B

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Table B1

List of the Swiss Guidelines and Recommendations
Languages: All guidelines originally written in German; guidelines noted /e, /f or /r have been also translated into English, French or Russian. Note: All guidelines are available on the HSK Internet website.

Guideline	Title of Guideline	Date of current issue
R-04/d	Aufsichtsverfahren beim Bau von Kernkraftwerken; Projektierung von Bauwerken (Supervisory procedures governing the construction of nuclear power plants: Design of buildings)	December 1990
R-05/d	Aufsichtsverfahren beim Bau von Kernkraftwerken; mechanische Ausrüstungen (Supervisory procedures governing the construction of nuclear power plants: Mechanical equipment)	October 1990
R-06/d	Sicherheitstechnische Klassierung, Klassengrenzen und Bauvorschriften für Ausrüstungen in Kernkraftwerken mit Leichtwasserreaktoren (Safety classification, interface between classes and construction regulations concerning equipment of light water reactor nuclear power plants)	May 1985
R-07/d	Richtlinie für den überwachten Bereich der Kernanlagen und des Paul Scherrer Institutes	June 1995
R-07/r	(Guideline for radiation protection zones in nuclear installations and in the Paul Scherrer Institute)	June 1995
R-08/d	Sicherheit der Bauwerke für Kernanlagen, Prüfverfahren des Bundes für die Bauausführung	May 1976
R-08/e	Safety of buildings for nuclear installations: Federal procedures for the construction supervisory	May 1976
R-11/d	Ziele für den Schutz von Personen vor ionisierender Strahlung im Bereich von Kernkraftwerken (Objectives of the protection of persons from ionising radiation in the vicinity of nuclear power plants)	May 1980
R-11/f	Objectifs de la protection des personnes contre les radiations ionisantes dans la zone d'influence des centrales nucléaires	July 1978
R-12/d	Erfassung und Meldung der Dosen des strahlenexponierten Personals der Kernanlagen und des Paul Scherrer Instituts	October 1997
R-12/e	Determining and reporting the doses of occupationally exposed personnel in nuclear installations and the Paul Scherrer Institute	October 1997
R-13/d	Inaktive Freigabe von Materialien und Bereichen aus kontrollierten Zonen (Freimessrichtlinie) (Release of inactive materials and zones from controlled areas [Clearance Guideline])	February 2002
R-14/d	Konditionierung und Zwischenlagerung radioaktiver Abfälle	December 1988
R-14/r R-14/e	Conditioning and Interim Storage of Radioactive Wastes	December 1988
R-15/d R-15/r	Berichterstattung über den Betrieb von Kernkraftwerken (Reporting guideline concerning the operation of nuclear power plants)	December 1999
R-16/d	Seismische Anlageninstrumentierung (Seismic plant instrumentation)	February 1980
R-17/d	Organisation und Personal von Kernkraftwerken	June 2002
R-17/e	Organisation and personnel of nuclear power plants	June 2002

Table B1 (cont.)

List of the Swiss Guidelines and Recommendations

Guideline	Title of Guideline	Date of current issue
R-18/d	Aufsichtsverfahren bei Reparaturen, Änderungen und Ersatz von mechanischen Ausrüstungen in Kernanlagen (Supervision of repairs, modifications and replacement of mechanical equipment in nuclear installations)	December 2000
R-21/d	Schutzziele für die Endlagerung radioaktiver Abfälle	November 1993
R-21/e	Protection Objectives for the Disposal of Radioactive Waste	November 1993
R-21/f	Objectifs de protection pour le stockage final des déchets radioactifs	November 1993
R-23/d	Revisionen, Prüfungen, Ersatz, Reparaturen und Änderungen an elektrischen Ausrüstungen in Kernanlagen (Revisions, testing, replacement, repair and modification of electrical equipment in nuclear installations)	January 2003
R-25/d	Berichterstattung des Paul Scherrer Instituts sowie der Kernanlagen des Bundes und der Kantone (Reporting guideline concerning the Paul Scherrer Institute and the nuclear installations of the Federation and the cantons)	June 1998
R-27/d	Auswahl, Ausbildung und Prüfung des lizenzpflichtigen Betriebspersonals von Kernkraftwerken (Selection, training and examination of NPP staff requiring a license)	May 1992
R-30/d	Aufsichtsverfahren beim Bau und Betrieb von Kernanlagen (Supervisory procedures for construction and operation of nuclear installations)	July 1992
R-31/d	Aufsichtsverfahren beim Bau von Kernkraftwerken, 1E klassierte elektrische Ausrüstungen (Supervisory procedures governing the construction of nuclear power plants: 1E classified electrical equipment)	January 1994
R-32/d	Richtlinie für die meteorologischen Messungen an Standorten von Kernanlagen (Guideline for meteorological measurement on sites of nuclear installation)	September 1993
R-35/d	Aufsichtsverfahren beim Bau und Änderungen von Kernkraftwerken, Systemtechnik (Supervisory procedures governing the construction of nuclear power plants: System engineering)	May 1996
R-37/d	Anerkennung von Strahlenschutz-Ausbildungen und -Fortbildungen im Aufsichtsbereich der HSK (Recognition of radiation protection and further training in the supervision areas of HSK)	July 2001
R-39/d	Erfassung der Strahlenquellen und Werkstoffprüfer im Kernanlagenareal (Registration of radiation sources and material testers on a nuclear installation site)	January 1990
R-40/d	Gefilterte Druckentlastung für den Sicherheitsbehälter von Leichtwasserreaktoren, Anforderungen für die Auslegung (Filtered containment venting for light water reactors: design requirement)	March 1993

Table B1 (cont.)

List of the Swiss Guidelines and Recommendations

Guideline	Title of Guideline	Date of current issue
R-41/d	Berechnung der Strahlenexposition in der Umgebung aufgrund von Emissionen radioaktiver Stoffe aus Kernanlagen	July 1997
R-41/e	Calculation of the radiation exposure in the vicinity of nuclear installations due to emissions of radioactive materials	July 1997
R-42/d	Zuständigkeiten für die Entscheide über besondere Massnahmen bei einem schweren Unfall in einer Kernanlage	February 2000
R-42/e	Responsibility for decisions to implement particular measures to mitigate the consequences of a severe accident at a nuclear installation	March 1993
R-45/d	Planung und Durchführung von Notfallübungen in den schweizerischen Kernkraftwerken	January 2004
R-45/e	Planning and Execution of Emergency Exercises in Swiss Nuclear Power Plants	February 1998
R-47/d	Prüfung von Strahlenmessgeräten (Testing of radiation measuring instruments)	October 1999
R-48/d	Periodische Sicherheitsüberprüfung von Kernkraftwerken (Periodic Safety Review of Nuclear Power Plants)	November 2001
R-49/d	Sicherheitstechnische Anforderungen an die Sicherung von Kernanlagen (Technical Safety Requirements for the Safety of Nuclear Installations)	December 2003
R-50/d	Sicherheitstechnische Anforderungen an den Brandschutz in Kernanlagen (Technical Safety Requirements for Fire Protection in Nuclear Power Plants)	March 2003
R-52/d	Transport- und Lagerbehälter (T/L-Behälter) für die Zwischenlagerung	Juli 2003
R-52/e	Transport and Storage Casks (T/S-Casks) for interim storage	November 2003
R-60/d	Überprüfung der Brennelementherstellung (Surveillance of Fuel Element Production)	March 2003
R-100/d	Anlagezustände eines Kernkraftwerks (Nuclear Power Plant Conditions)	June 1987
R-101/d	Auslegungskriterien für Sicherheitssysteme von Kernkraftwerken mit Leichtwasser-Reaktoren	May 1987
R-101/e	Design Criteria for Safety Systems of Nuclear Power Plants with Light Water Reactors	May 1987
R-102/d	Auslegungskriterien für den Schutz von sicherheitsrelevanten Ausrüstungen in Kernkraftwerken gegen die Folgen von Flugzeugabsturz	December 1986
R-102/e	Design Criteria for the Protection of Safety Equipment in NPP against the Consequences of Airplane Crash	December 1986
R-103/d	Anlageinterne Massnahmen gegen die Folgen schwerer Unfälle (Plant internal measures against severe accidents)	November 1989

Table B2

International Nuclear Event Scale (INES)

The international scale used to indicate accident severity in nuclear installations (International Nuclear Event Scale INES), jointly prepared by IAEA and NEA), was tested in a pilot scheme at the beginning of 1990 and has been in permanent use since 1992. The scale differentiates between the following seven levels of events, according to their relevance to safety.

It is now possible to access important information concerning events under the Internet address "www-news.iaea.org/news/". Due to administrative reasons, only the events over the last six months are given.

The event scale consists of seven levels, namely, 1–7, according to their importance to safety. (Level-0 events are those having no significance for safety.)

Level	Descriptor	Criteria	Examples
7	Major accident	• External release of a large fraction of the reactor core inventory typically involving a mixture of short- and long-lived fission products (in quantities radiologically equivalent to more than tens of thousands of terabecquerels of iodine-131). **Remark:** Possibility of acute health effects. Delayed health effects over a wide area, possibly involving more than one country. Long-term environmental consequences	Chernobyl, USSR, 1986
6	Serious accident	• External release of fission products (in quantities radiologically equivalent to the order of thousands to tens of thousands of terabecquerels of iodine-131). **Remark:** Full implementation of local emergency plans probably needed to limit serious health effects.	
5	Accident with off-site risk	• External release of fission products (in quantities radiologically equivalent to the order of hundreds to thousands of terabecquerels of iodine-131). **Remark:** Partial implementation of emergency plans (e.g. local sheltering and/or evacuation) required in some cases to lessen the likelihood of health effects. • Severe damage to a large fraction of the core and major plant contamination.	Windscale, UK, 1957 Three Mile Island, USA 1979
4	Accident without significant off-site risk	• External release of radioactivity resulting in a dose to the most exposed individual off-site of the order of a few millisieverts. **Remark:** Need for off-site protective actions generally unlikely except possibly for local food control. • Some damage to reactor core as a result of mechanical effects and/or melting. • Worker doses likely to have acute fatal consequences.	Saint Laurent, France, 1980 Tokaimura, Japan, 1999

Table B2 (cont.)

International Nuclear Event Scale (INES)

Level	Descriptor	Criteria	Examples
3	Serious incident	• External release of radioactivity above authorised limits, resulting in a dose to the most exposed individual off-site of the order of tenths of a millisievert. • Exposure of personnel sufficient to cause acute health effects. Severe spread of contamination inside the plant. • Incidents in which a further failure of safety systems could lead to accident conditions, or a situation in which safety systems would be unable to prevent an accident if certain initiators were to occur.	Vandellos, Spain, 1989
2	Incident	• Incidents with significant failure in safety provisions but with sufficient defence in depth remaining to cope with additional failures. These include events where the actual failures would be rated at level 1 but which reveal significant additional organisational inadequacies or safety culture deficiencies.[1] • An event resulting in a dose to a worker exceeding a statutory annual dose limit and/or an event which leads to the presence of significant quantities of radioactivity in the installation in areas not expected by design and which require corrective action.	
1	Anomaly	• Anomaly beyond the authorised regime but with significant defence in depth remaining. This may be due to equipment failure, human error or procedural inadequacies and may occur in any area covered by the scale e.g. plant operation, transport of radioactive material, fuel handling, waste storage.	
0	No safety significance	• Deviations where operational limits and conditions are not exceeded and which are properly managed in accordance with adequate procedures. **Examples include:** a single random failure in a redundant system, discovered during periodic inspections or tests, a planned reactor trip proceeding normally, spurious initiation of protection systems without significant consequences, leakages within the operational limits, minor spreads of contamination within controlled areas without wider implications for safety culture.	

[1] For reasons of clarity, inadequacies in Safety Culture are given as the following examples in the IAEA INES User Manual:
- A violation of operational limits and conditions (i.e. conditions for safe operation) or a violation of a procedure without justification;
- A deficiency in the Quality Assurance process;
- An accumulation of human errors;
- A failure to maintain proper control over radioactive materials, including releases into the environment, or a failure in the systems of dose control;
- The repetition of an event, indicating that either possible lessons have not been learnt or the corrective actions have not been taken after the first event.

Tabelle B3

Basic characteristics of the Swiss nuclear power plants

	KKB 1	KKB 2	KKM	KKG	KKL
Thermal power [MW]	1 130	1 130	1 097	3 002	3 600
Electrical power [MW]	380	380	372	1 020	1 220
Net electrical power [MW]	365	365	355	970	1 165
Reactor type	PWR	PWR	BWR	PWR	BWR
Reactor supplier	Westing-house	Westing-house	GE	KWU	GE
Turbine supplier	BBC	BBC	BBC	KWU	BBC
Generator rating [MVA]	2·228	2·228	2·214	1 140	1 318
Cooling	River-water	River-water	River-water	Cooling tower	Cooling tower
Start of commercial operation	1969	1971	1972	1979	1984

Figure B1

Functional diagram of a nuclear power plant with a **pressurised water reactor**

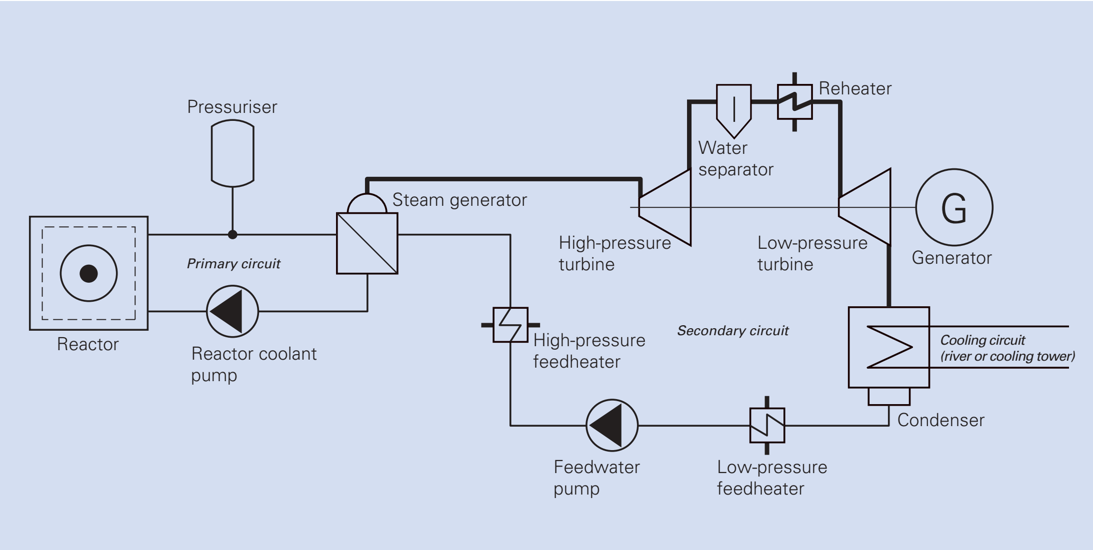
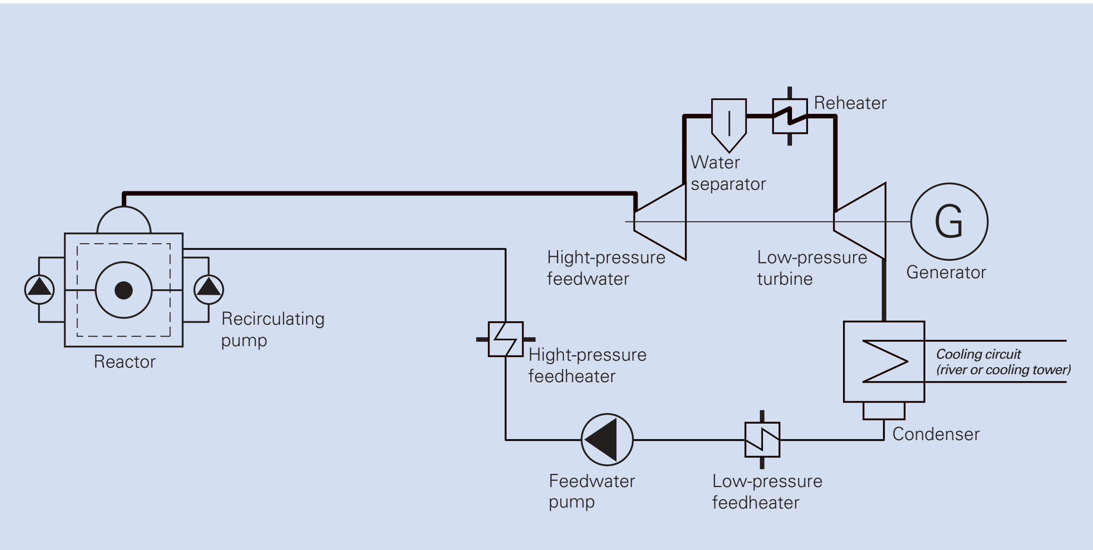


Figure B2

Functional diagram of a nuclear power plant with a **boiling water reactor**



LIST OF ABBREVIATIONS

ADR	European Agreement concerning the International Carriage of Dangerous Goods by Road
AGT	Waste package type
AM	Accident Management
ANPA	System for automatic transfer to HSK of the NPP parameters
ASP	Ageing Surveillance Programme
BAG	Swiss Federal Office of Public Health
BBT	Swiss Federal Office of Professional Development and Technology
BE	Fuel Assembly
BFE	Swiss Federal Office of Energy
BNFL	British Nuclear Fuels Ltd.
Bq	Becquerel
BWR (SWR)	Boiling Water Reactor
BZL	Swiss Federal Interim Storage Facility
CFS	Commission Franco-Suisse de Sûreté des Installations Nucléaires
CIS/DAISY	Chemical Information System/Data Analysis and Information System
COGEMA	Compagnie Générale des Matières Nucléaires, La Hague
CNS	Convention on Nuclear Safety
DSK	German-Swiss Commission for the Safety of Nuclear Installations
DWR (PWR)	Pressurised Water Reactor
EK (EC)	Earthquake or Seismic Event Class
EKRA	Expert Working Group Concepts for the Disposal of Radioactive Waste
EOR	Task Organisation for Increased Radioactivity
EPFL	Ecole Polytechnique Fédéral de Lausanne (Swiss Federal Institute of Technology, Lausanne)
EPRI	Electrical Power Research Institute, USA
ETH	Swiss Federal Technical University
EU	European Union
GfS	Reactor Simulator School, Essen, Germany
GNW	Consortium for Nuclear Waste Disposal, Wellenberg
GRS	Association for Installation and Reactor Safety, Germany
GSKL	Group of the Managers of Swiss NPPs
GWh	Gigawatt hour (= 10^9 Watt hour)
HAA	High Level Radioactive Waste
HRA	Human Reliability Analysis
HRP	Halden Research Project, Norway
HSK	Swiss Federal Nuclear Safety Inspectorate
HTR	High Temperature Reactor
IAEA	International Atomic Energy Agency, Vienna
IGA	Institut de Génie Atomique
INES	International Nuclear Event Scale

IRA	Institut de Radiophysique Appliquée, Lausanne (Institute of Applied Radiophysics)
IRS	Incident Reporting System

KGL	Controlled Geological Long-Term Storage
KKB	Nuclear Power Plant Beznau (2 Units, 1 and 2)
KKG	Nuclear Power Plant Gösgen
KKL	Nuclear Power Plant Leibstadt
KKM	Nuclear Power Plant Mühleberg
KKW/NPP	Nuclear Power Plant
KNE	Commission for Nuclear (Waste) Disposal
KOMABC	Swiss Federal Commission for NBC-Protection
KSA	Swiss Federal Nuclear Safety Commission
KSR	Swiss Federal Commission for Radiation Protection and Monitoring of Radioactivity
kV	Kilovolt (= 10^3 Volt); voltage unit

LAR	Leading Committee for Radioactivity
LMA	Long-lived Intermediate Level Radioactive Waste
LWR	Light Water Reactor

MAA	Intermediate Level Radioactive Waste
MADUK	Monitoring Network for Automatic Dose Rate Measurement in the Vicinity of NPPs
MeV	Mega-Electron Volt (= 10^6 Electron Volt)
MGy	Mega-Gray = 10^6 Gray (1 Gray = 100 rad)
MIF	Medicine, Industry and Research
MOX	Mixed Oxide Fuel (Uranium-Plutonium Mixture)
mSv	Milli-Sievert (= 10^{-3} Sievert)
µSv	Micro-Sievert (= 10^{-6} Sievert)
MW	Megawatt (= 10^6 Watt; power unit)
MW_e	Megawatt electrical power
MW_{th}	Megawatt thermal power

NADAM	Network for Automatic Dose-Alarm and Measurement
Nagra	National Co-operative for the Disposal of Radioactive Waste
NANO	Backfitted Emergency System, NPP Beznau
NAZ	National Emergency Operations Centre
NFO	Emergency Organisation
NOK	Nordostschweizerische Kraftwerke AG (North-East Switzerland Power Company)
NPP	Nuclear Power Plant
NRC	Nuclear Regulatory Commission, USA
nSv	nano-Sievert (= 10^{-9} Sievert)
NTB	Nagra Technical Report

OECD	Organisation for Economic Co-operation and Development
OSART	Operational Safety Review Team (from IAEA)

Person-mSv	Person-millisievert (= 10^{-3} Person-Sievert)
Person-Sv	Person-Sievert: collective Radiation Dose (1 Person-Sv = 100 Person·rem)
PSA	Probabilistic Safety Analysis
PSI	Paul Scherrer Institute, Würenlingen and Villigen (East and West)
PSR	Periodic Safety Review
PWR	Pressurised Water Reactor

QA	Quality Assurance
QM	Quality Management
REFUNA	Regional Heat Supply System of the Lower Aare Valley
RID	Regulations Concerning the International Carriage of Dangerous Goods by Rail
RPV	Reactor Pressure Vessel
SAA	Low-level radioactive waste
SBB	Swiss Federal Railway
SAMG	Severe Accident Management Guidance
seco	State Secretary for Economy
SG	Steam generator
SK	Safety Class
SMA	Low- and intermediate-level radioactive waste
SR	Systematic Collection of the Federal Law
StSG	Radiation Protection Law
StSV	Radiation Protection Ordinance
SUeR	Section for Radiation Monitoring, Freiburg
SUSAN	Special Independent System for Decay Heat Removal, NPP Mühleberg
SUVA	Swiss Accident Insurance Office, Luzern
Sv	Sievert (= radiation dose equivalent; 1 Sv = 100 rem)
SVA	Swiss Society for Atomic Energy
SVTI	Swiss Association for Technical Inspections
TBq	Terabecquerel (1 TBq = 10^{12} Bq)
THORP	Thermal Oxide Reprocessing Plant
TL	Cask for Transport and Storage
TLD	Thermoluminescent Dosimeter
UVEK	Swiss Federal Department for Environment, Transport, Energy and Communication
VAKL	Experimental Nuclear Power Plant, Lucens
VSE	Swiss Electricity Union
Wh	Watt-hour
ZWIBEZ	Interim Radwaste Storage Facility, NPP Beznau
ZWILAG	Interim Storage Facility, Würenlingen
ZZL	Central Interim Storage Facility, Würenlingen

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