Nuclear Waste Management of the Olkiluoto and Loviisa Power Plants

Annual Review 2003

The front cover shows a split copper canister billet, with its crystal structure in view.

SUMMARY

This report describes the nuclear waste management of the Olkiluoto and Loviisa nuclear power plants. The report includes a description of the status and operations of nuclear waste management of the power companies in 2003, a review of the communication activities pertaining to nuclear waste management, and an account of the provisions made for future waste management costs.

The Ministry of Trade and Industry revised the schedule for the final disposal of spent fuel in such a way that, in accordance with the new schedule, the material required to apply for a construction licence must be ready by the end of 2012. At the same time, the Ministry set a new intermediate target at 2009, at which time an overview of the material intended for the application for a construction licence must be submitted. On the whole, preparations for the final disposal of spent fuel progress in accordance with the programme for the pre-construction phase of the final disposal facility published in 2000. The first three-year programme "TKS-2003" pertaining to research, development and technical design was drawn up during the year under review. The report also included a survey of the results of the work done during the past 3–4 years.

With regard to bedrock investigations at Olkiluoto, the main emphasis was on studies into the area of access and alignment of the access tunnel to the underground rock characterisation facility known as ONKALO. Extensive investigations into bedrock structures and the baseline at Olkiluoto continued, employing various methods and, at the same time, provision was made for monitoring ONKALO during construction and operation.

In the assessment of long-term safety, the proportion of international co-operation projects remained high. Several projects with a view to studying the performance of engineered barriers, implemented within the scope of the EU's fifth framework programme, are in the phase of final reporting. With respect to bedrock, the studies pertained to the migration and retention phenomena, and their modelling. In biosphere studies, the development of modelling continued.

The first plant description of the entire final disposal facility that takes the infrastructure and environmental conditions at Olkiluoto into account was completed during the year under review. Furthermore, the description took preliminarily account of the impact of the third plant unit at Olkiluoto (OL3) on final disposal.

In the design of the final disposal canister, Posiva's and SKB's plans were harmonised and drafting of a canister suitable for the OL3 fuel began. With regard to canister manufacturing technology, one of the principal development subjects continued to be the manufacture of the cylindrical part of the copper canister from one piece, with several optional methods. In the development work on canister sealing technology, an agreement was reached which enables future test programmes to be mostly implemented in Finland. Detailed design of the main equipment of the encapsulation plant continued. With respect to canister transportation, studies focused on the consequences of an accident where the lift falls with a canister in the transport shaft.

In designing the repository, the priorities included developing the low-pH grouting material, the horizontal disposal concept and the backfilling methods, and co-ordinating the design of the repository and the ONKALO facility.

The main drawing stage plan for the ONKALO facility and four other reports linked with the implementation of ONKALO were submitted to STUK Radiation and Nuclear Safety Authority for consideration. The municipality of Eurajoki granted a building permit in accordance with the Building Act for ONKALO on 12 August 2003 and the invitations for tenders for the first tunnel contract were sent to the excavation contractors in November. Area work above ground began towards the end of the year.

In international co-operation, the most significant projects were implemented, on the one hand, within the framework of the extensive agreements signed with SKB in 2001 and, on the other hand, within the scope of the EU's fifth framework programme. Three research projects under the EU's sixth framework programme progressed to the agreement phase. Posiva signed an agreement in principle on co-operation with the United States' Department of the Environment (DOE).

With regard to operating waste, the established monitoring and long-term investigations and practical measures continued.

By the end of 2003, 4 335 m^3 of operating waste had accumulated at the Olkiluoto Power Plant, and 2 685 m^3 at Loviisa; 3 918 m^3 of the Olkiluoto waste has been finally disposed of in the VLJ Repository; 1 180 m^3 of the Loviisa waste has been disposed of in the low- and intermediate-level waste repository at Hästholmen.

The decommissioning plans for the power plants were updated by the end of 2003.

The overall costs of the research programme for nuclear waste management of the Loviisa and Olkiluoto Power Plants amounted to EUR 13.1 million. On the whole, the research programme was implemented according to plan.

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INTRODUCTION

In Finland, two companies utilise nuclear energy to generate electrical power – Teollisuuden Voima Oy (TVO) and Fortum Power and Heat Oy (hereafter referred to as Fortum). In compliance with the Nuclear Energy Act, TVO and Fortum are liable for all activities associated with management of the nuclear waste they produce, for the appropriate preparation of these activities and for all related costs incurred.

In accordance with the Nuclear Energy Act, the Ministry of Trade and Industry (KTM) makes decisions on the principles that must be applied to nuclear waste management. KTM formulated these principles in its decisions of 19 March 1991, 26 September 1995 and 23 October 2003. The decisions provide a basis for both the practical implementation of nuclear waste management and the research and development related to future measures.

Each company is separately responsible for all measures necessary for the treatment and final disposal of low- and intermediate-level operating waste, and for the decommissioning of the power plants. Posiva Oy, a company jointly owned by TVO and Fortum, is in charge of the research and development of the final disposal of spent nuclear fuel and, ultimately, of the construction and operation of the final repository itself.

Posiva is also in charge of compiling the plan for and report on nuclear waste management of the Olkiluoto and Loviisa nuclear power plants, both of which are to be prepared annually. As prescribed by the Nuclear Energy Act and Decree, this Annual Review 2003 describes the status and operations of nuclear waste management in 2003. The report also reviews communication activities pertaining to nuclear waste management and the provisions made for future nuclear waste management costs.

At its Olkiluoto Power Plant in Eurajoki, Teollisuuden Voima Oy operates two boiling water reactors with a nominal output of 840 MWe (net) each. Olkiluoto 1 (OL1) was connected to the Finnish grid in September 1978, and Olkiluoto 2 (OL2) in February 1980. In 2003, the load factors of OL1 and OL2 were 97.0% and 95.5%, respectively. The operating licences for plant units OL1 and OL2, the storage facility for low-level waste (MAJ Store), the storage facility for intermediate-level waste (KAJ Store) and the interim store for spent fuel (KPA Store) will be valid until the end of 2018. The operating licence for the repository for operating waste (VLJ Repository) will be valid until the end of 2051.

Fortum Power and Heat Oy's Loviisa Power Plant has two pressurised water reactors with a nominal output of 488 MWe (net) each. Commercial operation of Loviisa 1 (Lo1) began in May 1977, and that of Loviisa 2 (Lo2) in January 1981. In 2003, the load factors of Lo1 and Lo2 were 92.4% and 87.9%, respectively. The operating licences for plant units Lo1 and Lo2, and the related nuclear fuel and nuclear waste management facilities will be valid until the end of 2007. With respect to the repository for operating waste (VLJ Repository), the operating licence will be valid until the end of 2055.

SPENT FUEL MANAGEMENT

PRINCIPLES AND SCHEDULE

In compliance with the Nuclear Energy Act and the KTM decisions, preparations are underway for the final disposal in Finland's bedrock of all spent fuel from the Olkiluoto power plant and the spent fuel stored to date at the Lo-viisa power plant, as well as that which will accumulate hereafter. In its decision of 23 October 2003, KTM revised the schedule for preparations for the final disposal of spent fuel in such a way that the preliminary studies and plans required for a construction licence of the final disposal facility must be submitted in 2009. Provision must be made to submit the final studies and plans by the end of 2012 instead of the previous deadline of 2010. The schedule target set for the beginning of final disposal was kept unchanged, in 2020. In the meantime, spent fuel is stored temporarily at the power plant sites.

In December 2000, the Council of State took a Decision in Principle concerning the final disposal of spent nuclear fuel at Olkiluoto in Eurajoki. Parliament ratified the decision nearly unanimously in May 2001. The final disposal facility, consisting of an encapsulation plant and a repository, will be built in the 2010s. In accordance with the Decision in Principle, an application for a construction licence must be submitted in 2016 at the latest.

In 2002, a Decision in Principle was taken to construct a new nuclear power plant unit in Finland. At the same time, a Decision in Principle was taken on the extended construction of a final disposal facility for spent nuclear fuel in such a way that the spent fuel from the new plant unit can also be disposed of in the facility. The waste management obligation of the new plant unit will not begin until the commissioning of the plant towards the end of the decade.

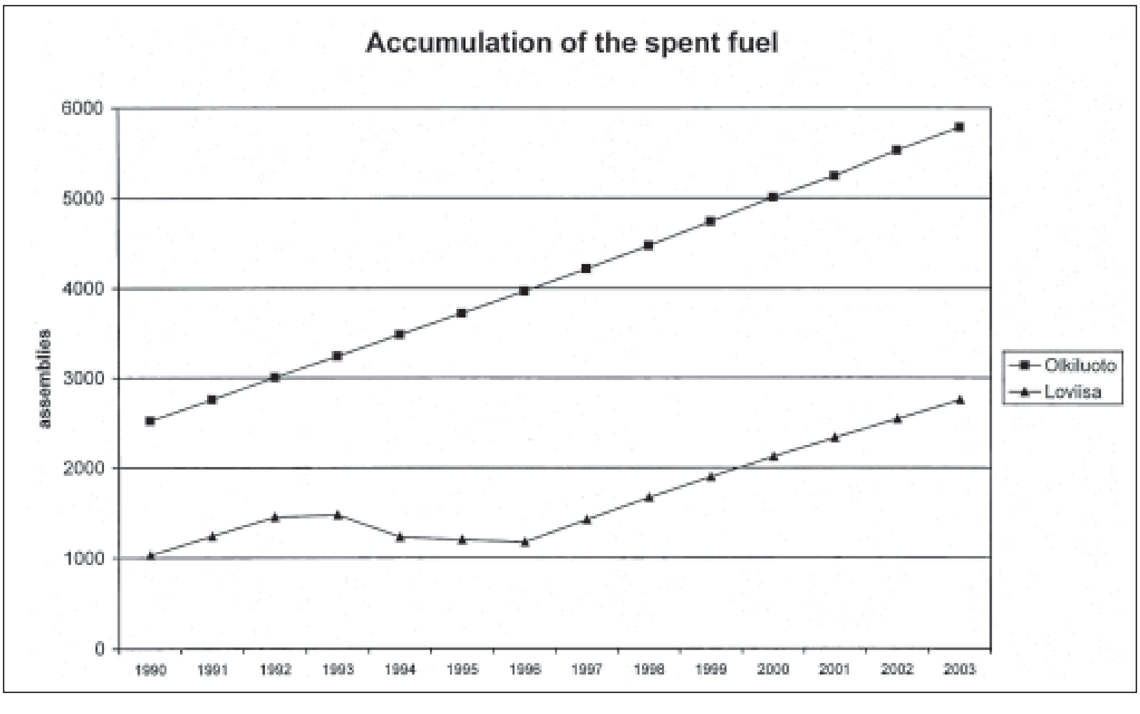
CURRENT STATUS OF STORAGE

Spent fuel from the Olkiluoto plant is stored temporarily at the plant units and in the interim store for spent fuel (KPA Store). The installation of new fuel racks in the pools of the KPA Store was completed during 2003. Owing to renovation of the racks, the storage capacity increased from 4 536 to 7 146 positions. The KPA Store has sufficient capacity for the spent fuel accumulated during about 30 years' operation of the plant units. The store can be enlarged if necessary.

The twenty-fourth refuelling of Olkiluoto 1 and the twenty-second refuelling of Olkiluoto 2 were carried out during the year under review. At the end of 2003, a total of 5 786 assemblies of spent fuel, equivalent to 983 tonnes of fresh uranium were stored at the Olkiluoto plant. The KPA Store housed 4 428 assemblies; the pools of OL1 stored 746 assemblies and those of OL2 stored 612 assemblies.

Return transports of spent fuel from the Loviisa plant to Russia terminated at the end of 1996 owing to an amendment to the Nuclear Energy Act. Subsequently, the storage capacity at the Loviisa plant was increased in such a way that, using racks of the current type, the capacity will be sufficient until 2010. In the future, it will be possible to substantially increase the capacity through the use of dense racks.

At the end of 2003, a total of 2 755 spent fuel assemblies, equivalent to about 330 tonnes of fresh uranium (estimated on the basis of the amount of uranium contained in the spent fuel,



about 314 tonnes), were stored in the Loviisa plant's storage facilities. Lo1 housed 240 assemblies and Lo2 housed 221. The spent fuel storage facilities 1 and 2 held 450 and 1 844 assemblies, respectively.

FINAL DISPOSAL PROJECT

Preparation for the final disposal of spent fuel continued in accordance with the Decision in Principle. The schedule for the project was defined by the decision of the Ministry of Trade and Industry taken in October 2003 in such a way that the studies and plans required for a construction licence of the final disposal facility must be submitted by the end of 2012 and the preliminary versions of them must be submitted as early as 2009. On the whole, however, the project continues to progress in accordance with the programme for the pre-construction phase of the final disposal facility published in 2000 (report POSIVA 2000-14).

In accordance with the programme, operations during the year were characterised by preparations for the beginning of the construction of the underground rock characterisation facility, known as ONKALO, in the middle of 2004. The design progressed to the phase of the preparation of implementation designs and the requests for tenders. The main drawing stage plan was also reported to STUK Radiation and Nuclear Safety Authority. At the same time, four other reports linked with the implementation of ONKALO were submitted to STUK for consideration. They deal with the following subjects:

- description of the baseline at Olkiluoto
- programme for the underground investigations
- the monitoring plan
- assessment of the disturbances caused by ONKALO in the immediate vicinity of the repository.

The first three-year programme "TKS-2003" pertaining to research, development and technical design was also completed towards the end of the year. In addition to the operating programme for the next few years, the report includes a fairly comprehensive survey of the results of the work done during the past three to four years. The purpose of the three-year programme is to promote the medium-term planning of operations and, on the other hand, to increase transparency of the planning from the viewpoint of outside evaluation.

Bedrock investigations at Olkiluoto

Studies into the access area to ONKALO

Five new deep investigation boreholes (KR24–KR28) were drilled in the access area to ONKALO. The boreholes helped establish the structures of the bedrock in the area of ONKALO and their significance to the layout of the access tunnel to ONKALO.

Furthermore, four shallow boreholes (PP36–PP39) were drilled and six groundwater observation tubes (PVP11–PVP16) were installed in the investigation area.

Borehole KR24 was drilled to the centre of the planned ventilation raise. As the aim was to keep the borehole inside the raise profile (diameter 6 m), it was necessary to employ steered drilling. Stress measurements were also carried out in the investigation borehole with the overcoring method using Swedpower AB's modernised Borre probe. It was possible to carry out the measurements only at two measurement levels, instead of the planned three to four levels, owing to equipment problems and the presence of drill cuttings and pieces of rock in the borehole, despite flushing. Furthermore, indications of damage were detected in the overcored core samples, for which reason a decision was finally taken to terminate the measurements. Sixteen measurements in all were attempted between depths of 288 m and 390 m, but only three measurements results can be considered relatively successful.

Investigation trench TJ7 was dug above the access tunnel along the tunnel line. The investigation trench helped verify the surface rock properties of the first part of the access tunnel and, in particular, the properties of structure RH24. Soil logging was also performed in the trench. Before digging the trench, short drillholes were made along the access tunnel line at intervals of about 10 m to verify the status (thickness of the soil cover) and quality of the rock surface. Towards the end of the year, the first pilot borehole was drilled to the profile of the access tunnel to ONKALO. The borehole was completed in early 2004.

Acquisition of information on the bedrock structure and baseline, and preparation for the monitoring

About a 600-m-long investigation trench, TK4, was dug in the central investigation area to establish the deformation phases and structures of the Olkiluoto bedrock. Furthermore, short investigation trenches were dug parallel to the two new deep boreholes in the vicinity of the point of access to ONKALO. The investigation trench and the borehole together help provide information on how to interpret local structures of the surface rock. Geological mapping along the profile in the north-south direction in the central investigation area provided insight into large structures of the bedrock.

With regard to geophysical investigations, emphasis was increasingly placed on interpretations of the old and new measurement results and on geological modelling. Interpretations of the results of the electrical soundings and the electromagnetic Gefinex 400S measurements performed in autumn 2002 provided additional information on, for instance, the continuity of structures R20A, R20B and R21. The remodelling of the old results of vertical seismic profiling (VSP) confirmed the existence of some structural features (nearly vertical structures) detected from the data provided by magnetic measurements on the ground surface.

In the near-field of ONKALO, mise à la masse measurements helped monitor the continuity of electrically conductive zones (and structures) between the different boreholes and from the boreholes onto the ground surface. Furthermore, walk-away vertical seismic profiling and seismic crosshole soundings were performed in the surroundings of ONKALO to sharpen the picture of the geological structure.

The borehole TV imaging was complemented in such a way that at the end of 2003 the latest borehole imaged by borehole TV is KR24. Normal geophysical borehole measurements were carried out in boreholes KR23–KR28.

Differential flow measurements and hydraulic conductivity measurements helped verify and complement data on the hydraulic conductivity of the bedrock. The basic principle has been to measure new boreholes systematically with the aid of a flow meter either by detailed flow logging, which has given a preliminary view of the hydraulic conductivity in the different parts of the borehole, or by complete differential flow measurement, which has enabled comprehensive analysis of the hydraulic conductivity and flow conditions in the borehole. In addition to these, the purpose of differential flow measurements was to explore poorly hydraulically conductive areas deep in the bedrock. The measurements were aimed at detecting highly saline zones or fractures suitable for water sampling. Furthermore, the flow meter was employed to specify and complement the values of hydraulic head, particularly in such borehole sections from which the previous results had been defective or uncertain owing to fracturing or other technical reasons. Hydraulic conductivity measurements with the hydraulic testing unit (HTU) mainly focused on characterising the poorly hydraulically conductive rock at the final disposal depth and in its vicinity (300–700 m).

Monitoring measurements continued. Measurements that have been launched previously include, for instance, measurement of the pressure head, measurement of the thickness of snow and frost, monitoring of the temperature and precipitation, and hydrogeochemical measurements. New monitoring measurements that complement the baseline include, for instance, measurement of the amount of dust and the amount of water infiltrating into the soil. Water permeability of the soil was also studied by means of test pits, from which soil samples were taken. The samples were analysed to determine the water permeability, chemistry, organic impurity, water content, and grain size distribution.

With regard to surface hydrology, long-term monitoring measurements of the groundwater level continued within the same scope as previously. Systematic measurements of the surface runoff began in the spring at four measuring weirs.

The measuring system of small movements of the bedrock, known as the GPS network, consists of a permanent station and nine local stations. The network was extended by two stations located north of the strait of Olkiluo-donsalmi. Station GPS10 on the island of Olkiluoto is located at the construction site of the new nuclear power plant unit and must therefore be closed. Consequently, a new station was built at Otpää, which will replace the old one in the measurements to be conducted in 2004. Measurements in autumn 2003 were made at both stations.

The extension of the microseismic station network was also launched. The present network of six stations was designed on the basis of the previous location plan for the ONKALO facility.

Interpretation of the hydrogeological data was performed, for instance, by analysing properties of individual hydraulically conductive fractures, combining data from the results of detailed flow logging of flow measurements, optical borehole TV imaging and core samples. The distribution of the salinity of groundwater was analysed on the basis of water samples and flow measurement results. The results of the interference test carried out in 2002 between boreholes KR14–KR18 were interpreted by both analytical methods and digital flow models.

The main objective of the flow modelling was to assess the effect of ONKALO on the groundwater level and on the distribution of saline groundwater. In these assessments, the principal tool was the computer software called FEFTRA, which has been especially developed to deal with problems with the free surface boundary condition. The main conclusions relating to the effects of ONKALO were based on a few calculated cases, one of which assumed that the amount of water seeping into ONKALO would not be reduced by any technical measures. The calculated cases also included an extreme case corresponding to very successful grouting. The results show that without any grouting at all, the amount of water seeping into ONKALO stabilises at a level of about 100 l/min, in which case the maximum reduction in the groundwater table would be about 300 m. In the case corresponding to very successful grouting, the amount of water seeping into ONKALO would be about 20 l/min, the reduction in the groundwater table thus being about 30 m. On the basis of the results, saline groundwater (having a concentration of 40–55 g/l, depending on the case) would seep into ONKALO.

Hydrogeochemical investigations

The hydrogeochemical description of Olkiluoto was updated by the hydrogeochemical result material gathered in 1999–2002. Deeper insight was gained particularly into groundwaters in the soil layer and the upper part of the bedrock and into the salinity distribution and dissolved gases of deep groundwaters. The description represents the current baseline at Olkiluoto before the construction of ONKALO begins. During 2003, the distribution of the groundwater types occurring at Olkiluoto was described for the first time with the aid of a 3D model as well.

Hydrogeochemical investigations further concentrated on studies into the regional distribution of the salinity, the definition of dissolved gases and the baseline in the investigation areas, since the aim is to update the description of the hydrogeochemical baseline once more using the result material on what is called the undisturbed status gathered before beginning the construction of ONKALO. A total of 27 groundwater samples were taken from deep boreholes. Of these, ten water-sampling points were chosen in such a way that their results primarily contribute to detailed planning of the monitoring programme for ONKALO to be launched in 2004. In selecting the sampling points, however, attention was also drawn to the fact that the results would be available for verification and finishing of the description of the hydrogeochemical baseline at Olkiluoto. A total of 14 gas samples were taken. The results will be reported for the first time in English in the first part of 2004.

Water samples were taken from the shallow boreholes drilled in the bedrock and from the standpipes installed in the ground in early summer and in autumn. In summer, samples were taken from 14 sampling points in all. The sampling in autumn mainly concentrated on water sampling from the shallow boreholes drilled in the bedrock and from the standpipes, both in late autumn. In addition, the purpose of the water sampling was to examine the seasonal variations and, with respect to the new sampling points, to acquire water samples of the undisturbed status before the construction of ONKALO begins. The results will also be reported in English in the first part of 2004.

The condition of the multi-packer equipment installed in borehole KR1 at Hästholmen in 2000 was checked in autumn 2003, and the pH and electrical conductivity values of the groundwater in the sampling sections were measured at the same time. The need for water sampling will be assessed on the basis of the results in 2004.

Environmental studies

The first summary of the environmental studies at Olkiluoto that covered the different fields was drawn up and included in the report on the baseline. Future environmental studies were defined for the monitoring programme. To help interpret the changes, a study was commissioned on the predictions of climate change for the Olkiluoto area.

The basic survey of the forest ecosystems launched in 2002, which will last for several years, continued with a forest inventory by vegetation type compartments. The results obtained will help assess, for instance, the species, age and size distribution of the tree stand with a view to monitoring any changes and providing basic data for the modelling of the biosphere. A regular network of observation points was marked in the field for forest studies to be conducted the following year.

Continuous long-term monitoring of precipitation was begun by establishing eight observation areas, in which the amount and composition of rainfall is monitored inside a forest stand and in clearings. The purpose of the monitoring of precipitation is to examine the effects of treetops on rainfall and, in a later phase, to monitor the spreading of dust caused by surface development and crushing work. A lysimeter network was also established in one of these intensive observation areas to help acquire information on the amount and quality of water moving in the surface layers of the soil. In addition, regular snow and frost observations continued as before, and two new frost observation points were established as part of the lysimeters.

The monitoring data for the past year on the weather conditions, the marine ecosystems and the radioactivity of the environment gathered by Teollisuuden Voima Oy were also stored in Posiva's archive for use and later reporting in accordance with the monitoring programme. Furthermore, water sampling from the groundwater pipes and shallow boreholes continued.

Equipment and method development

The absolute pressure transducers installed in the differential flow measurement units were tested and put into use. The transducers were found to be direction-dependent, and consequently magnetometers were also installed in the borehole probes, thus enabling the deviation caused by the direction-dependence to be taken into account in the results. New electronics cards were made for all the differential flow measurement units. The computer used for the older differential flow measurement unit was replaced to better meet the needs of the sophisticated measuring software. The flow guides in the old differential flow measurement unit were replaced as well. The measuring equipment will possibly also be used as part of the excavation of ONKALO for hydraulic conductivity measurements in the probe boreholes to be drilled in the tunnel drift after every third round. A study was therefore launched with a view to building a new, slightly lighter version of the equipment for use in the ONKALO facility.

The new transverse flow measurement equipment was completed at the end of 2003, but its testing was postponed to 2004. The electronics of the measuring equipment is now similar to that of the differential flow measurement unit. In addition, a magnetometer was installed in the equipment, which enables the direction of the equipment in the borehole to be determined accurately. The equipment also includes the Single Point Resistance measurement property. The structure of the flow guide of the transverse flow meter was renewed, and as a result it was possible to remove the solenoid valves that are damaged easily. The flow guide now has two sectors instead of the four sectors before. In building the new transverse flow measurement equipment, its possible use for measurements in the tunnels was also taken into account (e.g. the high hydrostatic pressure).

The Single Point Resistance measurement property was added to the hydraulic testing unit (HTU), thus facilitating the depth calibration of measurements. The function is similar to that of the differential flow measurement units, and consequently the results obtained with the units are better comparable with respect to the measurement depth. Tests showed that the unit functioned as expected.

Development work on the equipment known as TERO intended to measure the thermal properties of the bedrock *in situ* continued by constructing a prototype transducer. The equipment was tested in the test borehole of the Geological Survey of Finland (GTK) and its technical performance was found good. Some minor teething problems must be resolved before field tests, however. The beginning of preparation of the interpretation software for the measurements was delayed and will begin in 2004.

The development work on rock stress measurement based on the overcoring method, carried out jointly with SKB, could be utilised in the quality assurance of the measurements in KR24. The development work continued by anisotropic examination of the Olkiluoto bedrock: Laboratory analyses (modulus of elasticity and compressive strength) show that the degree of anisotropy of mica gneiss is 1.4.

Renovation of the sampling equipment for deep groundwaters, known as the PAVE equipment, was completed, and as a result there are now four sets of equipment in all. Three sets of equipment were operated, for which reason a new, third motorised hose winch was also manufactured. This makes installation of the equipment in the borehole easier and faster. Two new large pressure vessels with a volume of 500 ml were manufactured for the PAVE equipment, but their testing was postponed to 2004.

Three slim membrane pumps to be installed in the measuring hoses of the multi-packer equipment were manufactured during the year. The structure of the pumps was simplified at the same time, and as a result the manufacture also became slightly easier. The pumps were put into use in summer and they have functioned well.

Mass spectrometry equipment was acquired to determine the gases dissolved in the groundwater. The equipment enables gases to be analysed from both the aqueous phase and the gas phase using different sampling methods. During autumn, development of the analysis method mainly focused on the analysis of gases from the gas phase. The results of the first phase of method development were reported in February 2004.

Studies of the investigation equipment and measuring methods suitable for use in ONKALO were launched, and development work on some methods began. These include, for instance, borehole video imaging, measuring seepage water weirs, and instrumentation of the groundwater stations. Studies were also launched to investigate the effects of changing the material used for the packer equipment connecting rods from steel to carbon fibre.

ASSESSMENT OF LONG-TERM SAFETY

Studies on the performance of engineered barriers

The objective of performance analyses is to study the functioning of engineered barriers and to adapt the details of the final disposal concept to the conditions at Olkiluoto. This background material and basic data will be used both for the interim report on the safety analyses to be submitted to STUK in 2006, and for design and requirements management of the final disposal system. The studies are conducted to a great extent under international co-operation programmes at the Äspö and Grimsel Hard Rock Laboratories and under EU projects. The phenomena affecting the performance that particularly depend on the conditions at Olkiluoto will be later investigated in ONKALO.

The joint project launched by SKB and Posiva concerning the corrosion of copper in a saline groundwater environment continued, including both experimental research and theoretical studies. Corrosion investigations were carried out in Canada, Sweden and Finland. The purpose has been to create test conditions that correspond as closely as possible to the final disposal conditions. The capacity of bentonite to resist and retard the transmission of unfavourable corrosive conditions from the bedrock onto the canister surface is of great importance in the potential corrosion process. Investigations into the redox conditions prevailing in bentonite and the components affecting the redox conditions of bentonite and their measurement therefore continued.

Prototype repository

The KBS-3 final disposal concept is being tested and demonstrated under the EU's "Prototype Repository" project by constructing a full-scale long-term test for a sealed final disposal tunnel. Posiva and VTT are involved in developing the conceptual and mathematical modelling of engineered barriers. The work done in 2003 concerned modelling changes in the pore water of the buffer and backfilling material.

Swelling pressure

It is characteristic of bentonite that in saline water its swelling pressure and expansion capacity are reduced. To ensure a sufficient swelling pressure, the bentonite must be initially compacted to a sufficient density. In 2000–2003, Posiva and SKB jointly conducted experimental studies into the swelling pressure as a function of the bentonite density and the ionic strength and ionic form of the solution, and interpreted the results on the basis of theoretical models. Posiva's contribution consisted of studies into the importance of pore-water chemistry as a determining variable for swelling pressure. The need to continue the development of modelling and the experimental research will be assessed on the basis of the summary report, which is being completed.

Release mechanisms of uranium

The EU's project named "Rates and mechanisms of radioactive release and retention inside a waste disposal canister (IN CAN PROCESSES)" investigates canister-internal processes during the potential release of radionuclides from spent fuel. The degradation rate of fuel has been studied both under oxidising conditions and under reducing conditions buffered by iron. In Finland, the effect of alpha radiolysis was studied with the aid of ^{233}U-doped UO_2, which simulated the alpha activity of spent fuel 3 000 and 10 000 years after the final disposal. Some indications of an increase in the dissolution caused by alpha radiolysis were detected in short-term tests in bicarbonate waters under reducing conditions. Chemical and electrochemical measurements show that the reduction of uranyl-carbonate complexes also occurs in a solution that contains corrosive iron; in other words, the reduction need not necessarily occur through sorption on the surface of iron/iron oxide. (Several SKB-TR reports have been published on this work, and corresponding reports in the Posiva series of reports are being completed).

In 2003, Posiva and SKB jointly studied the release mechanisms of uranium from, for instance, gadolinium-doped uranium dioxide, which had been oxidised to the predetermined oxidation state $UO_{2,3}$ under controlled conditions. This helped simulate the oxidation of uranium (UO_2) contained in spent fuel to the cubical U_4O_{9+x} state. The detected increase in the lattice parameter of cubical oxide during the dissolution reaction in oxygen-free bicarbonate water suggests the selective dissolution of uranium with valence 6 from the solid phase. A report on this work was published in the Posiva series of reports.

FEBEX

Posiva is taking part in the FEBEX II project by examining, from the samples of the *in-situ* test, the chemical effects caused by concrete on bentonite near the interface of these materials. The samples of the *in-situ* test were taken in the spring of 2002 and the results were reported in spring 2003. After five test years, the effects of concrete could be detected in bentonite at a distance of over 10 cm from the interface.

CROP

Posiva is involved in the EU's project named "Cluster Repository Project – A Basis for Evaluating and Developing Concepts of Final Repositories for High-level Radioactive Waste (CROP)". Besides the EU countries, others involved are Japan, Canada and the USA. Towards the end of the project, data and experience were gathered from the performance analyses of engineered barriers. The working meeting of the CROP project was held at Olkiluoto in autumn 2003.

LASGIT

In 2003, SKB and Posiva jointly launched the LASGIT project. This project aims at studying the migration of gas through compacted bentonite by means of a large-scale test. The results obtained from the test will increase understanding of the gas migration process and enable the testing of migration models on a large scale. Installation work of the test is being completed in the first part of 2004.

LOT

Posiva is involved in the LOT test (Long-Term Test of Buffer Material) to be carried out at the Äspö Hard Rock Laboratory. The test pertains to validating the hypotheses and models of long-term processes occurring in the buffer material, and the closely linked processes concerning microbiology, the migration of radionuclides, copper corrosion and the migration of gas. The tests are performed at a depth of about 500 m, in boreholes drilled in the tunnel bottom; the boreholes have a diameter of 30 cm and a depth of 4 m. The tests to be performed in five boreholes were begun in 1999, and they have been planned to last for 1, 5 and 20 years. The results of the chemical studies were reported in 2003 (Posiva's working report 2003-32); they were obtained by analysing the samples of the first test borehole. Pore waters were pressed from the bentonite samples; pH, Eh, S(-II), Fe^{2+}, Na^{+}, K^{+}, Ca^{2+}, Mg^{2+}, Cl^{-}, SO_4^{2-} and HCO_3^{-} were determined from the pore waters. The exchangeable cations and water content of bentonite were determined as well. The exchangeable calcium content of bentonite had increased in comparison with the original MX-80 bentonite. This was consistent with the low calcium contents detected in the pore water. The effects of additions on the exchangeable cations mostly remained within the scope of normal variation.

BENIPA

The EU project named "Bentonite barriers in integrated performance assessment (BENIPA)", included in the fifth framework programme, was completed in 2003. VTT Processes, supported by Posiva, was responsible for compiling the databases that deal with the features, events and processes (the FEPs) and for gathering the data on crystalline rock. A working report was drawn up on the use of the commercially available PC model named PORFLOW for the migration analyses of radionuclides in the KBS-3V and KBS-3H final disposal holes and on its comparison with the REPCOM model. The European Commission will publish a final report on the BENIPA project.

ECOCLAY

In 2000–2003, Posiva was involved in the EU project named "ECOCLAY II (Effects of Cement on Clay Barrier Performance Phase II)", which investigated interaction between bentonite and cement in the environments of both clay and crystalline bedrock. The Finnish contribution consisted of studying particularly the effect of the salinity and high pH of groundwater in the system formed by compacted bentonite and crushed rock. The alteration of bentonite and crushed rock and the sorption and migration of the tracers (Na, Ca) were monitored as a function of the ionic strength and pH. The final report of ECOCLAY II will be completed in the first part of 2004.

The NEA's EBS project

The NEA's "Engineering barrier systems" project consists of a series of workshop meetings, which have been planned to be held annually. The first meeting was arranged in Oxford in 2002. It was preceded by an inquiry that examined requirements for the performance of engineered barriers and their handling in safety analyses. The topics for future meetings were agreed on in the first meeting.

Posiva hosted the second meeting in the series. The topic was the requirements for the design and performance of engineered barriers. The meeting was held in Turku from 27 to 29 August 2003. The meeting concluded that the design, construction and operation of a final disposal system form a complicated project, in which the requirements set by several parties must be taken into account. Tools are available for managing the requirements, which can be applied to the final disposal project to help systematise the work and to verify that the requirements set for the design will be fulfilled in a satisfactory manner. Management of the requirements and systematisation of the safety analysis complement each other. They partly utilise the same basic data and methods (e.g. official requirements, site-specific information, iterative working methods, change management), and they have similar needs (traceability, quality assurance, interaction). Active interaction was found to be an important factor in considering the waste management options and in developing design concepts.

NF-PRO

During 2003, Posiva was involved in the preparation of and application for the IP project entitled "Understanding and physical and numerical modelling of the key processes in the near-field, and their coupling, for different host rocks and repository strategies" (NF-PRO). Besides Posiva, the project involves VTT Processes and 44 other organisations. The project is included in the EU's sixth framework programme and consists of six subprojects, of which VTT and Posiva actively participate in four. The special subjects of their own include the dissolution of UO_2 doped by alpha activity, the evolution of pore water chemistry of bentonite (particularly pH, Eh and salinity), the corrosion products of iron and copper in bentonite, the THM behaviour of bentonite in the KBS-3V concept, and the integrated examination of all the sub-phenomena from the viewpoint of safety analysis. The project was launched in the beginning of 2004 and will continue until the end of 2007.

Functioning of the bedrock as a barrier

In 2003, the EU project named "RETROCK", which studies the modelling methods and concepts of migration and retention in the bedrock, arranged an international expert seminar to assess previous achievements of the project and to outline future work. The European Commission will publish a summary of the workshop.

Studies into the migration phenomena continued jointly with other waste management organisations at the Äspö Hard Rock Laboratory. The TRUE Block Scale tests continued in the follow-up project, in which the measurement of the tracers with the strongest sorption continued to determine the tails of the penetration curves. At the same time, additional modelling work was done with a view to interpreting the previous and new results. The work done under the joint modelling project within the Task Force focused on additional studies linked with the heterogeneity of the migration path. The effects of he-terogeneity with respect to the safety analysis were considered by extrapolating the test results for a situation corresponding to the final disposal conditions. These co-operation projects are discussed below in the section entitled "The Äspö Hard Rock Laboratory".

Sorption tests continued with a view to increasing the theoretical understanding of sorption and developing the mechanistic modelling. The tests with different concentrations of caesium have shown non-linear effects on the retention of the tracer caesium. The exposure of a sample to caesium before the retention test may have reduced the retention significantly, but in some cases a considerable alteration occurred in the rock, which resulted in intensified retention.

Examination of the migration in a fracture by means of tests carried out in a natural fracture brought to a laboratory continued by studying, for instance, the hydraulic conductivity of the fracture and the location of flow paths. Preliminary migration tests of radionuclides were carried out using tracers with negligible sorption (^{99m}Tc, sodium fluorescein) and sodium with low sorption.

Research aimed at defining the sorption mechanisms of europium and americium continued by studying their retention in kaolinite. In 2003, Posiva continued to be involved in the work of the NEA's "Sorption Forum II" project and the third phase of the TDB (Thermodynamic Data Base) project.

Investigation of the compatible and consistent migration modelling methods began under the migration project (named KULKE), formed jointly with sorption and migration modelling engineers and experimental migration researchers. The project covered experimental studies and modelling methods of both the near-field and the far-field. In the future, some of the investigations under the KULKE project will receive financing from the State Nuclear Waste Management Fund, forming part of the Finnish nuclear waste research programme (KYT). Some of the investigations have been proposed to form part of the FUNMIG project, which is included in the EU's sixth framework programme, now in its preparation phase. The project could begin from the beginning of 2005 at the earliest. Before launching the FUNMIG project, Posiva continues to provide financing for the investigations.

Potential changes in the prevailing flow conditions and hydrogeochemical conditions at the Olkiluoto investigation site caused by waters seeping into the ONKALO facility were studied by modelling both the entire area and the assumed flow path in detail. The studies form part of the assessment report on the disturbance caused by ONKALO, and detailed reporting on both studies is being completed in the first part of 2004.

Biosphere studies

Guidelines for the biosphere studies were defined in the three-year research programme (TKS-2003) and in the monitoring programme. A summary that covered all the different sectors of biosphere studies, vital for the assessment of long-term safety as well, was drawn up as a part of the report on the baseline.

The modelling project on the ecosystems that are located on dry land and receive potentially contaminated groundwater progressed particularly at the expert seminar arranged by SKB in May 2003.

The first version of the versatile and flexible biosphere-modelling tool (BIOMAT) tailored for the Matlab/Simulink calculation environment was commissioned jointly with SKB, and the development work is being continued in 2004.

The second year of operation of the BIOPROTA project, partly financed by Posiva, began in the autumn of 2003. The joint project of the nuclear waste management organisations concentrates on establishing the key issues of biosphere modelling. A considerable amount of work material on central sub-areas was already produced during the first year.

Posiva continued to monitor the progress of other international projects linked with biosphere modelling (e.g. BioMoSA, BIOCLIM, FASSET). In addition, Posiva's representative attended the conference organised by the IAEA in Stockholm in October, which considered preconditions for the implementation of radiation protection and opportunities for the practical arrangements.

Snow collectors erected in an intensive observation area inside a forest stand, which help examine, for instance, the effects of treetops on the chemical composition of falling rain and snow.

Leena Hamberg of the Finnish Forest Research Institute making an inventory of the coverage of undergrowth species with the aid of a portable frame. Photo: Maija Salemaa

Safety analysis

Assessment of the disturbances caused by ONKALO was completed, which also took account of the hydrological and geochemical disturbances within the scope of the separate studies performed. The assessment report on the disturbances was submitted to STUK and the members of the international assessment group, first as a draft in August and as a final version in late autumn, for evaluation before construction of the ONKALO facility begins. Posiva was also involved in drawing up and commenting on other reports to be submitted to STUK from the point of view of safety assessment.

As an expert in safety analysis, VTT Processes was involved in the groundwater control project, which produced a working report on the principles of groundwater control and the effects of seepage waters and, on the other hand, their reduction measures, as well as the final report on the entire project.

The experts in safety analysis were also involved in drawing up a new three-year programme for the research, development and technical design, and in planning the material necessary for the interim report to be drawn up in 2006.

As one of the preparatory phases of safety analysis, the Process Report of SR 97 was localised to correspond to Posiva's plans and the conditions at Olkiluoto. The Process Report also took the Finnish research findings into account as supplementary factors. The report was ready for publication in February 2004.

Co-operation and the exchange of information concerning safety analysis in particular consisted of, for instance, participation in the work of the OECD/NEA. Within the OECD/NEA, Posiva was involved in the work of the "Integration Group for Safety Case" (IGSC). During 2003, the IGSC arranged, for example, the first meeting of the international AMIGO project "Approaches and Methods for Integrating Geological Information in the Safety Case".

During 2003, Posiva and SKB jointly implemented the basic design phase concerning the horizontal location of the canister. This basic concept is called the KBS-3H concept, to distinguish it from the concept in which the canister is placed in the vertical position (KBS-3V). This installation technique would involve a new type of concept in which the canisters and bentonite blocks packed into perforated steel drums would be installed in about 200-m-long horizontal disposal holes. The work is being done in several phases. The objective of the many-year development programme is to enhance the KBS-3H concept so as to reach the level of the KBS-3V concept in technical terms, and to demonstrate the drilling of disposal holes and the installation of canisters and bentonite blocks in the long horizontal holes. The objective of the work conducted in Finland is to draw up the Safety Case of the KBS-3H concept in 2007, with Olkiluoto as the model site.

FINAL DISPOSAL TECHNOLOGY

General

During 2003, the preliminary planning phase was completed and plans for the final disposal facility were collected together in a consistent form as a plant description (Posiva's working report 2003-64). The plant description is the first plant design that has taken the infrastructure at Olkiluoto into account. Moreover, the plant design preliminarily took account of the effects of the OL3 plant, whose construction was confirmed in 2003, on the final disposal. The design system of the plant was developed during 2003 by introducing the numbering and nomination systematics for the future systems.

Development of the factors highly significant for the final disposal system was monitored in the design work. These factors include, for instance, burnup of the uranium fuel and the resulting radiation and decay heat properties. They were updated during the year under review and taken into account in developing the final disposal system and designing the plant.

Development of the management system of the design requirements continued. The requirements defined for the ONKALO facility acted as a model case. The management system was developed under a joint project co-ordinated by the Technical Research Centre of Finland (VTT).

The development and design work linked with encapsulation and the repository is described in more detail below.

Canister design

The study and comparison of the canister design jointly with SKB continued. On the basis of the studies, details of the designs for the copper canister and insert were slightly changed and the modifications were recorded in a memorandum. The canisters intended for BWR fuel are now practically similar in SKB's and Posiva's designs.

The canister design for the new nuclear power plant was drafted on the basis of the negotiated plant type, but as the plant type was confirmed towards the end of 2003 as being an EPR plant, the canister design will be specified during 2004. The greatest modifications result from the fact that the fuel assembly is longer than the assemblies of the OL1 and OL2 plants, and that the PWR assembly is larger in other respects as well. Consequently, a much lower number of assemblies can be placed in one canister, four pieces at most on the basis of preliminary calculations. A report will be drawn up on the design of the new canister and on the updated designs of the previous canisters.

It has been assessed that the canister will be subjected to a maximum pressure of about 45 MPa at the final disposal depth; the 3-km-thick ice layer that can form during the potential future glaciation was considered in the assessment. The mechanical strength of the canister was determined experimentally and, furthermore, SKB launched a project to prove with the aid of methods based on probability calculation that the probability of canister failure is low.

The acceptance criteria for canister manufacturing technology were considered jointly with SKB, but the preparation of a proposal was postponed to 2004.

Canister manufacturing technology

With regard to canister manufacturing technology, one of the principal development subjects continued to be the manufacture of the cylindrical part of the copper canister from one piece with several optional manufacturing methods. Manufacturing methods were developed both under the TEKES product development project of Posiva and Outokumpu Poricopper, and as a co-operation project with SKB. The TEKES product development project was originally planned to be completed at the end of 2003, but owing to some delays the project will continue until the end of June 2004.

Development work on the copper canister material continued jointly with Outokumpu Poricopper. The billet casting process was upgraded with a view to achieving a longer billet that meets the specifications. In the casting process, the feeding of melt into the mould was modified, thereby reducing the oxygen content to a sufficiently low level even in the beginning of the casting. The micro-alloying of phosphor was improved in such a manner that the phosphor content is in accordance with the specifications along the entire casting length. Solidification of the cast is now controlled better in the beginning of the casting, and as a result the centre crack of the base of the billet is reduced and the wastage of material is thus smaller. Owing to the better control of the casting process, the billet surface quality has also improved, which means there is less need to machine the surface of the billet. Sampling from the billet was modified, which further contributed to a smaller wastage of material. After modifications of Outokumpu Poricopper's casting equipment and process, Posiva and SKB jointly ordered eight billets for the three different canister manufacturing processes, the "pierce and draw" method, the extrusion method and the forging process. The billets met the specifications for composition and weight, but no specifications exist yet for permissible cracks or other flaws and the surface quality.

Manufacturing tests of the seamless copper canister fitted with an integrated bottom continued with the "pierce and draw" method at the pipe factory of Vallourec & Mannesmann Tubes in Germany. One canister was manufactured with this method and the first hot-forming phases of the second canister were performed during 2003. The research team formed by Vallourec & Mannesmann had planned modifications to the hot-forming process in order to make the grain structure of the bottom finer. The hot-forming process of the first canister was modified after the previous test carried out in 2002 in such a way that at the end of the hot-forming the canister bottom was hot-formed against a blind flange. Destructive inspection of the bottom showed, however, that the grain structure in the centre of the bottom continues to be rougher than elsewhere, which proved that the hot-forming grade of the bottom had remained too low. The research team carried on the development work by planning modifications to the last phases of the hot-forming process with a view to raising the hot-forming grade of the bottom. The canister was hot-formed after these modifications, and the canister investigations are being completed in the first part of 2004, when the hot-forming of the second canister can be continued. The manufacturing tests have been planned and carried out jointly with SKB.

Forging tests of the copper canister and copper lids continued under a joint project of Posiva and SKB at the factory of Scana Steel Components AB in Sweden. The forging of the pipe forged in 2002, which remained slightly short, was continued using new forging tools that better corresponded to the form of the pipe. The pipe now reached full length, but cracks were detected at its ends. In 2003, one new pipe was forged using the same new tools. The measurements and grain structure of this pipe fulfilled the requirements specified for the canister pipe. However, the inner diameter of the pipe has grown too large during the hot-forming and the form of the pipe is not completely even. A new tool was ordered for the last phase of the pipe hot-forming to improve the method further. Kungliga Tekniska Högskolan (KTH) in Stockholm was involved in the development work on the manufacturing process of copper lids, whose aim was, for instance, to make the grain structure of the lid finer and to increase the yield of the process. Copper lids have already been forged in serial production, their grain structure now meets the specifications throughout and the wastage of material has decreased.

SKB continued development work on the extrusion method of the copper canister at Wyman & Gordon in Scotland. In 2003, three pipes were extruded, one with a wall thickness of 40 mm and two with a wall thickness of 50 mm. All pipes fulfilled the requirements set for them.

Comparison of the different canister manufacturing methods and preparation of their cost estimates began jointly with SKB. The cost comparison will be completed in the first part of 2004.

A casting test of the canister insert made of nodular cast iron was carried out at Metso Paper Oy's Rautpohja Foundry. The casting test was designed jointly with SKB, which simultaneously had similar casting tests carried out by three foundries in Sweden. Compared with Posiva's previous casting test (in 1998), the stabilisation holes were omitted from the insert and casting of the bottom was integrated. The targets and quality requirements of the casting tests were consistent. One of the targets of the tests was to improve the toughness and tensile properties of the casting. The results of the manufacturing test fulfilled the requirements in all other respects except for the mechanical properties of the material and the cast structure. The tensile strength, breaking strength and ultimate elongation values remained below the requirements. Metallographic examinations showed that this was due to a wrong type of cast structure. The graphite had not been nodulised in accordance with the requirements, which apparently resulted from a malfunction or a fault in the casting process. A new casting test has been planned to be carried out to manufacture an insert that fulfils the requirements in all respects.

Canister sealing and inspection technology

Posiva continued development of the high-vacuum electron beam welding (EBW) method intended for sealing the copper lid of the canister by re-implementing the welding test programme of 2002, which failed owing, for instance, to equipment failures and problems linked with the joint surfaces of the lids. The welding equipment employed in the previous test programme had been transferred to ISF in Aachen, and consequently the new tests were carried out there. To verify the welding parameters, two series of plate tests were performed first, of which the latter succeeded better, thanks to the modified welding parameters. Two lid weldings were made after this. The gaps of the lid and the pipe joint surface had been dimensioned nil, and thus the pipe had to be preheated both times to about 70°C to be able to install the lid in its place. During the weldings, it was necessary to use a working distance different from that of the previous plate welding tests, but no new 'focus tests' were carried out, however. Both pipes were subjected to a radiographic inspection at SKB's canister laboratory, which showed that the welds were extremely porous throughout the weld area. The analysis of the test results and the reporting are underway.

In the course of the development programme of the electron beam welding method it has been detected that the implementation of test programmes abroad and with constantly changing equipment is rather laborious and slow. Owing to the co-operation agreement concluded with Patria Aviation Oy, Posiva has been offered an opportunity to implement the welding test programmes at Linnavuori, at the electron beam welding equipment employed by Patria Aviation. During 2004, the equipment will be modified for this purpose; for instance, the welding power will be raised to 50 kW. Posiva will be able to implement its subsequent test programme immediately after the equipment is ready for use, possibly in the autumn of 2004.

Posiva increased its resources in the sub-areas of the sealing and inspection technology of encapsulation technology to intensify its co-operation with SKB and to enable increasingly active involvement in SKB's EBW and FSW (Friction Stir Welding) projects. SKB aims at selecting the sealing method to be used for encapsulation and at proving its performance in the first part of 2005, for which reason SKB's development programme of sealing technology is progressing at a hectic pace. New FSW equipment, developed by The Welding Institute (TWI) and supplied by ESAB, was installed and put into use at SKB's canister laboratory in Oskarshamn. Furthermore, the EB welding equipment of the canister laboratory was modified.

Posiva continued to be involved in the domestic TEKES/EU project implemented by Helsinki University of Technology and the Technical Research Centre of Finland (VTT) with a view to increasing expertise and resources in the field of FSW technology. The project will continue until the autumn of 2004.

The narrow-gap TIG welding tests, commissioned by Posiva from Helsinki University of Technology and their reporting were completed. Using the equipment at Helsinki University of Technology, it was possible to weld a 15-mm-thick copper plate with reasonable preheating, whereas the welding of a 50-mm-thick plate did not succeed at all despite preheating. In accordance with calculations, the welding of so thick a material using the narrow-gap TIG welding equipment would require the preheating of approximately 500–700ºC, which will be practically out of the question in the encapsulation of spent nuclear fuel.

In the field of inspection technology, groundwork was laid for development work on processing the results of the inspection methods by ordering assessment of Posiva's and SKB's development work on canister inspection technology to date and, on this basis, a follow-up plan for the development work. Potential co-operation partners were considered to create a domestic expert and equipment network of inspection technology.

The results of the EB welding tests were examined at Inspecta Oy with what is called the phased array ultrasonic method and at SKB's canister laboratory with both the ultrasonic and radioscopy method. Destructive methods were applied to verify that the results obtained with SKB's NDT methods were very accurate in their resolution. The resolution or the interpretation of results of the comparison inspections conducted by Inspecta on the same test samples did not reach the same level at the first attempt, but further studies and interpretations have helped improve the resolution of Inspecta's inspection results as well.

Development work on the inspection methods and equipment of SKB's samples welded with the FSW method was launched in Sweden. Posiva aims to participate in this work as well.

Posiva was involved in SKB's development programme whose objective is to draw up a preliminary proposal for validation plans for the entire canister production chain. The proposal will provide a basis for a quality system to be submitted to the authorities for approval and to be certified. Posiva will build the system on the basis of the inspection and monitoring methods that are used as a tool for approval of the canister manufacture or sealing. SKB postponed presentation of the proposal to early 2004.

Equipment based on laser measurement has been developed at Kungliga Tekniska Högskolan (KTH) in Stockholm to verify the accuracy of shape and measurement of the copper canister manufacture; SKB ordered the equipment for its canister laboratory in Oskarshamn. Posiva was involved in development work of the equipment.

Design of the encapsulation plant and canister transportation

A description was drawn up on the plant site arrangements of the Olkiluoto final disposal facility in 2020. The description took account of the ONKALO facilities that would be built by that time.

Detailed design of the main equipment of the encapsulation plant continued. A transfer trolley has been designed to help transfer the canister in the canister transfer passage of the encapsulation plant from one work stage to another, lift the canister onto the work stations and even rotate it during welding and inspection. Furthermore, an automatic guided vehicle has been designed in detail, which can transfer the canister from the transfer trolley to the buffer store and from there further to the lift,

Assuring the fire safety is one of the bases for design of the canister transport vehicle.

and from the lift to the loading station of the repository. The automatic guided vehicle has been designed to function so that it is not necessary to lift the canister more than a couple of centimetres and such that the vehicle moves so slowly that the canister will not fall off even if the vehicle should stop suddenly or bump into an obstacle. Thanks to the reduction in the number of lifts, it has been possible to halve the height of the buffer store, which means the radiation protection conditions are better than before since no labyrinth shields open at the top are needed. The bridge crane of the buffer store will no longer be needed, either.

The canister gripping device has been designed to lift the canister by the lid. At the same time, a gripping device has been designed to enable the canister to be lifted by the cylinder surface in the event that it is not possible to grasp the lid.

In the design of the final disposal facility, provision is also made for malfunctions and accident situations in addition to normal operation. The stages of normal operation and their durations have been described for dose calculation and to be able to identify and describe the risky stages of operation in which malfunctions may arise or that may lead to an accident. The description of the Romuvaara site in Kuhmo, originally drawn up in 1999, was updated to take account of the location of the final disposal facility at Olkiluoto and development of the plans for the final disposal facility.

In the current plant design, a canister ready for final disposal is planned to be transferred to the repository located at a depth of about 500 m with a lift along a shaft. The consequences of an accident where the lift falls with a canister were studied by canister shock absorber tests. The tests showed that even a water cushion of several tens of metres at the shaft bottom would not sufficiently reduce the falling speed of the canister, but a 20-m-thick LECA cushion was assessed to be a suitable shock absorber and the canister to remain intact in all situations, as long as the LECA cushion does not float on the water surface.

Alternatively, a sealed canister can be transferred to the repository along the inclined access tunnel with a canister transport vehicle. In that case, the canister must be closed inside a transfer cask of the B(U) type fitted with shock absorbers. The transport vehicle could be, for instance, of the same type as the canister transfer and installation vehicle to be used in the repository. The heating of a final disposal canister placed inside transfer and radiation-shielding casks during a vehicle fire occurring in the tunnel was simulated. The study showed that a final disposal canister placed inside a transfer cask or a radiation shield of the installation vehicle and the nuclear fuel contained in the canister did not reach so high a temperature during the potential vehicle fire that they would be damaged.

Fuel transportation

The road, rail and sea transportation alternatives to transport the spent fuel from the Loviisa plant to Olkiluoto were updated during 2003. In addition to examination of the method of transportation, routes and transfer casks, the study of the necessary permits was updated. This time, the main emphasis was placed on assessment of the risks involved in sea transportation. The study assessed the risks posed by the transportation of spent fuel from the Loviisa nuclear power plant to the final disposal facility planned at Olkiluoto, both in terms of traffic and radiation. The studied routes included road, rail and sea routes or combinations of them depending on the necessary feeder traffic. The study included calculation of the radiation doses caused to the transport staff and population by normal transports and calculation of the radiation doses caused by any incidents and accidents to the population. The risk involved in the transportation of spent fuel caused by radiation is smaller than the ordinary risk posed by transportation. The ordinary maximal annual risks posed by the vehicle mileage in accordance with the basic case of spent fuel transportation are $4x10^{-5}$ (by road), $2x10^{-4}$ (by train) and $9x10^{-5}$ (by ship).

Safeguards of nuclear materials

A preliminary technical plan was drawn up for arrangement of the safeguards of nuclear materials in the entire area of the final disposal facility. International development in the safeguards of nuclear materials was monitored by, for instance, participating in meetings in this field, e.g. in the arrangements of the Experts' Group Meeting convened by STUK at Olkiluoto and in Rauma.

Basic data for design of the repository and the construction methods

The basic data for design constitutes, to a great extent, the data required during the construction phase, which is utilised in the design of ONKALO and the repository. Basic data is needed, for instance, to design the layout of the rock facilities, and to design and implement the excavation, reinforcement and grouting work. This package of tasks is divided into the development work linked with rock construction and the work linked with design of the actual repository.

To date, rock mechanical studies into the repository have been conducted assuming simple material models for the rock, which are based on the continuous, homogeneous, isotropic, linear and elastic behaviour of rock. Of the rock types occurring in the Olkiluoto area, a significant proportion is foliated, and the deformation and strength properties of the rock are anisotropic, i.e. different in different directions. Methods and ways of taking the anisotropic behaviour of rock into account in design were studied during 2003. Furthermore, description of the mechanical anisotropy of the rock was examined with the FLAC modelling program.

In 2003, the analyses performed pertained to the effect of fracturing detected at the assumed final disposal depth on the orientation and on the need for bolting the tunnels. The work was done with both the KBTunnel calculation code based on the block theory and distinct element code 3DEC, which helped assess the effect of fracturing more accurately by considering, e.g., the rock stress prevailing at the final disposal depth. Posiva's working report on the work was completed in 2003 and the results of the work were presented at the international SARA 2003 conference in summer 2003.

Posiva is involved in SKB's APSE project (Äspö Pillar Stability Experiment), in which the rock pillar between two full-scale, differently pressurised disposal holes is fractured. The objective is to verify in full scale the behaviour of rock described with the aid of models and, in particular, to establish the effect of the backfilling support pressure on the failure. Another objective is to acquire practical experience of the rock breaking and its detection with measuring devices with a view to monitoring the facilities during excavation. During 2003, Posiva took part in the implementation planning of the failure test and modelled the test by performing thermomechanical analyses with both the FLAC3D program and the linked FLAC2D/PFC2D program based on particle mechanics. The PFC2D (Particle Flow Code) method was employed to simulate the generation and expansion of fractures in fractured areas. The preliminary FLAC3D analyses were reported in SKB's series of IPR reports published in 2003. The actual failure test was launched towards the end of 2003 by making the first final disposal hole.

Excavation using the drilling and blasting technique and mechanical excavation both result in a zone around the repository where the rock becomes damaged by fracturing. Owing to this, the properties of the zone differ from those of intact rock. The quality and extent of the damage can be substantially affected by the choice of the excavation methods and the planning of excavation. During 2003, studies were conducted to establish the qualitative and quantitative properties of the Excavation Damaged Zone (EDZ) and its significance for operation of the repository. The studies concerned rock samples taken from both the Äspö Hard Rock Laboratory in Sweden and the characterisation tunnel at Olkiluoto. Results of the studies were presented, for example, at the MRS 2003 (Material Research Society) conference held in Kalmar, Sweden, and at the CLUSTER conference entitled "Impact of the EDZ on the performance of radioactive waste geological repositories" held in Luxembourg.

The project aimed at controlling seepage waters was underway from 1999 to 2003 to help establish the best methods and techniques for sealing the Olkiluoto bedrock with a view to the construction phase of the ONKALO facility and the design of the repository. Within the project, assessments of the water seepage and the feasibility for grouting of the Olkiluoto bedrock were made for ONKALO and the repository. Olkiluoto-specific basic concepts for groundwater control and the description of disturbances were completed towards the end of 2003. The properties of the cement-based grouting materials were tested as part of the project.

Development work on grouting materials that generate a low pH is underway as a co-operation project of Posiva, SKB and NUMO. The development work consists of studies into the use of cement, slag, fly ash and silica with additions. To ensure a tight final result, the objective is to develop grouting materials whose penetrability is better than that of cement. The development of materials with the best penetrability concentrates on the assessment of long-term safety and usability of silica sol and periclase. Field tests will be carried out as part of the project in Finland and Sweden.

Development of the basic concepts for final disposal

Posiva and SKB are jointly carrying out a long-term project (2002–2007) concerning the horizontal location of the final disposal canister. This basic concept is called the KBS-3H concept, to distinguish it from the concept in which the canister is placed in the vertical position (KBS-3V). The installation technique involves a new type of concept in which the canisters and bentonite blocks packed into perforated steel drums would be installed in about 200-m-long horizontal disposal holes. Considerably less rock needs to be excavated in this concept than in the vertical disposal hole concept. The work is being done in several phases. The objective of the development programme is to enhance the KBS-3H concept so as to reach the level of the KBS-3V concept in technical terms, and to demonstrate the drilling of disposal holes and the installation of canisters and bentonite blocks in the long horizontal holes.

The basic design of the KBS-3H concept was performed during 2003 using the feasibility study completed in 2002. The principal areas of basic design included development of the drilling technique of disposal tunnels, design of the installation equipment of the bentonite/canister package, and assessment of the performance of the bentonite plug between the packages.

As for studies into the properties of buffer bentonite in 2003, Posiva was mainly involved in international co-operation. These projects are described in more detail in the sections entitled "The Äspö Hard Rock Laboratory" and "Studies on the performance of engineered barriers". For the purpose of the quality assurance of buffer bentonites, the Geological Survey of Finland (GTK) studied the suitability of the different mineralogical investigation methods for the determination of expansive clay types. The mineralogy of the different bentonite deposits and commercially available bentonites was examined at the same time.

The plans concerning the backfilling and sealing of the repository were updated during 2003 for the purpose of preliminary design. The first phase of SKB's and Posiva's joint long-term repository backfilling programme was launched. Descriptions of the different backfilling alternatives were drawn up and their performance with respect to long-term safety was assessed during the year under review. Requirements set for the backfilling of the repository were presented in the workshop arranged by the OECD/NEA in autumn 2003.

It has been planned that European Ca-Mg bentonites can be used for tunnel backfilling, and Posiva is co-operating with, for instance, the Czech RAWRA to characterise montmorillonite-rich clay deposits in the Czech Republic. The studies conducted in 2003 concerned the geotechnical properties of the Rokla and Strance bentonites.

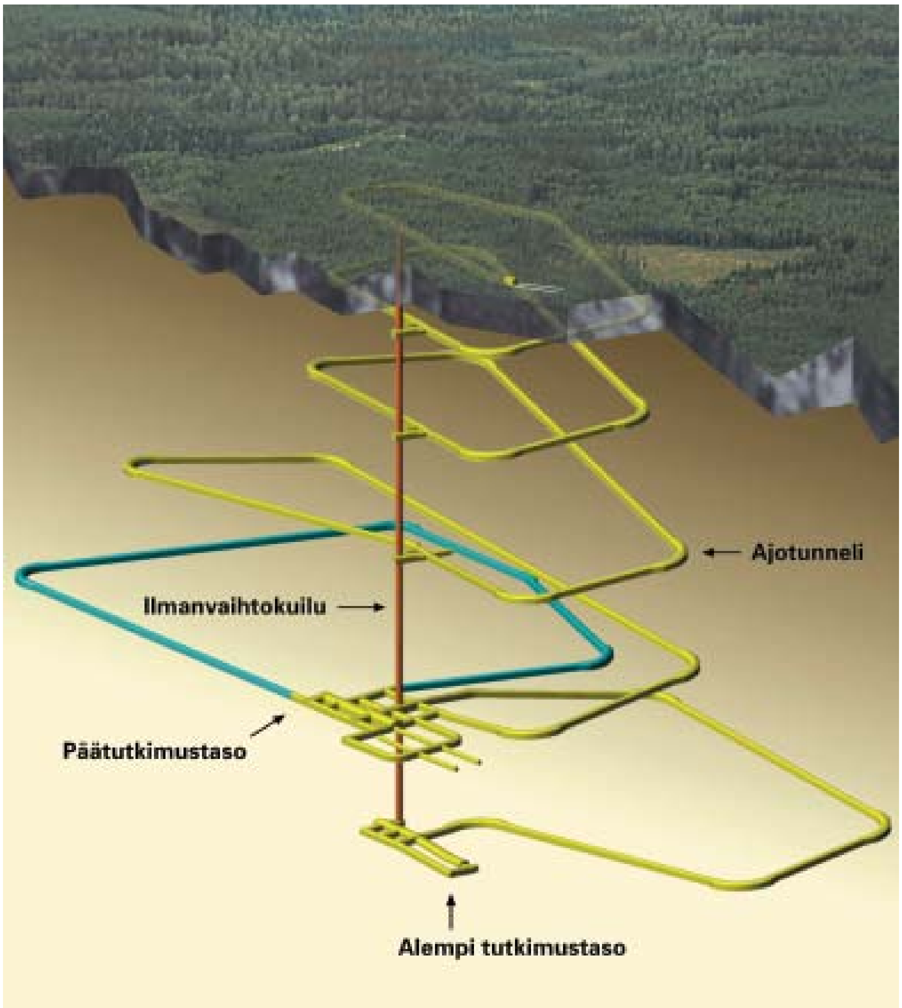
The Finnish Environment Institute is co-ordinating a project with a view to studying the performance of salt-resistant materials especially for the needs of road and environmental construction. Friedland clay has been included in the study as a reference material. Compilation of the final report on the project was underway in 2003.

Formulation of the technical plans for the repository

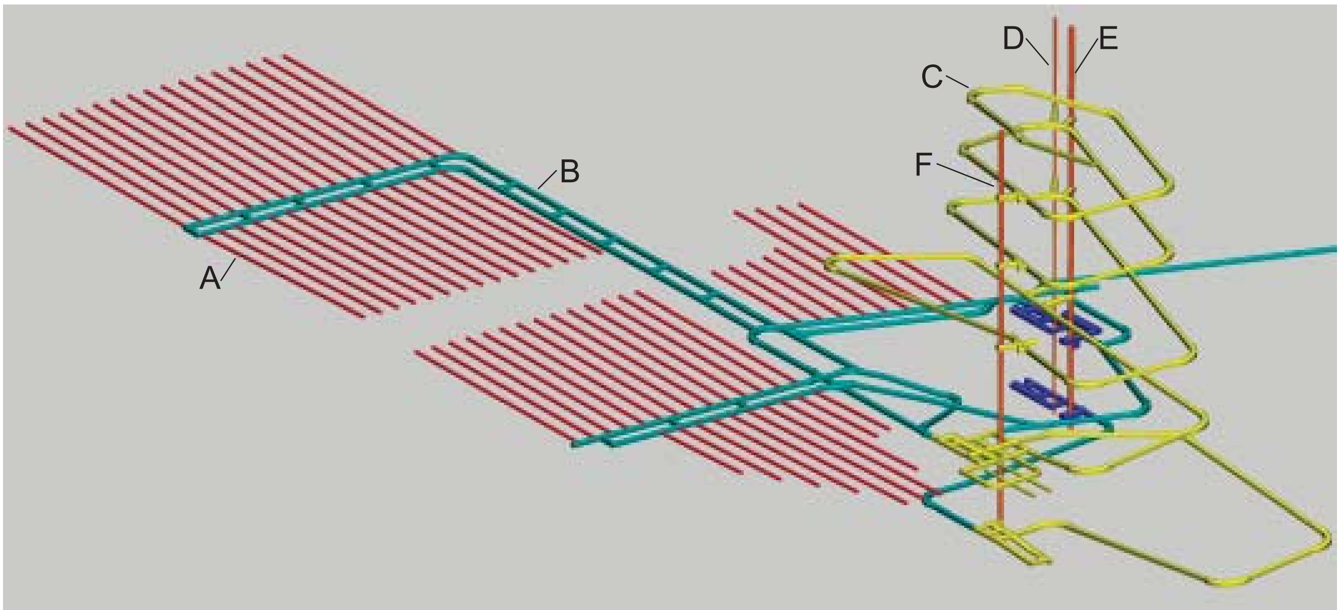
The first phase of the preliminary design of the repository was completed in 2003. The report on the preliminary plan dealt with the design concept of the repository, layout in the Olkiluoto bedrock, stage-wise implementation of the facilities, and the construction, operation and sealing of the repository. Of the functions in the operation phase, the safeguards of nuclear materials, radiation protection, normal operation and operation in the event of incidents and accidents have also been planned and reported.

Linked with the canister transport technology, new plans were drawn up for the transport and installation vehicles, the consequences of a potential fire damaging the transport vehicle in the repository or the access tunnel were considered, and the shock absorber to be made at the bottom of the canister shaft was developed. Models were made for the repository layout in the Olkiluoto bedrock. For some models, a description was drawn up of how the construction and sealing of the facilities could progress in stages during the long period of operation of the repository. A report was drawn up on the design of the repository and the most common technical constructions of the facilities were documented. Foreign materials remaining in the repository after sealing were assessed as well. Separate descriptions were drawn up of the repository systems and operations in the operation phase. Heat generation by the canisters and the restrictions placed on the maximum temperature have a fundamental effect on the repository designs. Thermal analyses were carried out for the facilities, utilising the most recent data on, for instance, thermal conductivity measurements of the bedrock.

The repository can be built on one or several levels. The preliminary plan comprises the facility alternatives placed on one level and on two levels. The plans for the repository were presented in the form of layout in the Olkiluoto bedrock. The total excavation volume of the repository is some 1.3–1.4 million cubic metres. Since the facilities will be excavated and backfilled in stages during the period of repository operation, the volume open at a given time will be some 0.5 million cubic meters. An access tunnel with a steepness of 1:10 and vertical shafts will provide connections between the underground facilities and the ground surface. The central tunnels of the repository will be implemented on what is called the parallel tunnel principle, in which two parallel central tunnels are linked to each other by means of connecting tunnels located at fixed intervals. The parallel tunnel principle improves the fire safety of the facilities and provides a flexible opportunity to backfill and seal disposal tunnels in stages during the period of repository operation.



A building permit in accordance with the Building Act was granted for the ONKALO facility on 12 August 2003.



The principle of the repository in the one-layer alternative after the final disposal operations of about 30 years. A = Disposal tunnels, B = Central tunnel, C = Access tunnel, D = Passenger shaft, E = Canister shaft and F = Ventilation raise.

DESIGN AND CONSTRUCTION OF THE ONKALO FACILITY

Design of the underground rock characterisation facility

Before a decision to construct a repository is taken, supplementary bedrock investigations will be carried out at Olkiluoto for the implementation design of the facilities. An underground rock characterisation facility, known as ONKALO, will be constructed for the investigations and design. The construction is scheduled to begin during 2004.

ONKALO should be constructed to allow underground investigations for site confirmation without jeopardising long-term safety of the repository site (Posiva 2000). In addition, it should be possible to later link ONKALO to the repository so as to form a part of it.

In the preliminary design phase of ONKALO in 2001, the alternatives that included at least two separate access routes were considered feasible in terms of operational safety. In the draft design phase in 2002, two alternative draft designs were drawn up on the basis of the preliminary design: the shaft alternative and the access tunnel alternative. After the evaluation, the access tunnel alternative was chosen as the basis for further development of the ONKALO facility owing to, for instance, the higher flexibility, the greater feasibility for investigations and the better working conditions.

The main drawing phase ended with submission of the application for a building permit to the municipality of Eurajoki on 20 May 2003. This outlined implementation plan material was sent to STUK for evaluation. In the licence material, the location of the ONKALO facility was confirmed to be south of the Korvensuo basin.

The implementation design phase began after the granting of the building permit (12 August 2003). Plans and supply documents were drawn up for the invitation for tenders for the first tunnel contract. The facilities, volumes and quality were determined on their basis for submission of the tender. The first tunnel contract includes excavation and structures of the access tunnel (to level –417 m) near the main characterisation level and raise boring of the shaft to level –287 m. The invitations for tenders were sent to the excavation contractors on 21 November 2003.

Construction above ground

The purpose of area planning above ground is to reserve sufficient areas and routes necessary for the repository for spent nuclear fuel and for the operations that prepare its implementation. In 2003–2004, the area planning projects are primarily linked with the construction of ONKALO.

In 2003, the area planning concentrated on the planning of a general layout of the ONKALO area (roads, site areas), the heating, plumbing and electricity trunk routes of municipal engineering and the support building for field studies to be built for investigation purposes. Earth works of the municipal engineering conduit began towards the end of 2003. A building permit was granted for the support building for field studies on 9 December 2003.

In 2004, the area planning and construction will concentrate on implementation of the facilities and structures necessary for the tunnel excavation of ONKALO.

INTERNATIONAL CO-OPERATION

A significant proportion of Posiva's research, development and technical design work is conducted under bilateral or multilateral international joint projects. In the development of encapsulation and final disposal technology, Posiva mainly co-operates with the Swedish SKB, and a large part of this work was done at the Äspö Hard Rock Laboratory (see the following chapter) and at the canister laboratory in Oskarshamn. Research that supports the assessment of long-term safety is currently conducted to a great extent under the framework programmes of the European Commission, the sixth of which is being launched. Furthermore, Posiva has extensive connections with nuclear waste programmes in other countries through either international organisations (OECD/NEA, EDRAM) or bilateral agreements. Posiva signed a new memorandum of understanding on co-operation with the United States' Department of the Environment (DOE).

The Commission's fifth framework programme has included a number of joint studies, which involved taking a joint stand or procedure with a view to facing future challenges posed by nuclear waste management. In the NET.EXCEL study, the implementation organisations of nuclear waste management assessed the current status of final disposal studies, prioritisation of the studies and enhancement of the future opportunities for networking. A report on the studies is being completed in the first part of 2004. Another similar group considered the long-term monitoring of final disposal, its technical opportunities and implementation methods in the light of current knowledge. This report is being completed in the first part of 2004 as well.

Posiva also supported the organisation of international seminars and conferences by being involved in their preparation and implementation. In addition to the previously mentioned working meeting of the OECD/NEA, which studied engineered barriers, Posiva supported the EDZ meeting arranged by the EC in Luxembourg and took part in the preparation of the OECD/NEA seminar on the handling of risks and uncertainties, which is held in the first part of 2004.

The Äspö Hard Rock Laboratory

SKB and Posiva mostly operated within the co-operation framework as in previous years. In addition to this, several joint projects were launched or planned during the year, which are not directly included in the co-operation programme at Äspö, but in which it will be possible to utilise the Äspö Hard Rock Laboratory or the ONKALO facility for making demonstrations in the future. These joint projects include, for instance, development work on the KBS-3H concept, development work on the low-pH cement and the joint project on backfilling technology (further information on the above-mentioned projects under, e.g., "Final disposal technology").

At Olkiluoto, Posiva is mainly concentrating on research into the bedrock conditions and into the assessment of site-specific or site-dependent factors. General development of the rock construction methods for the repository can also be implemented in ONKALO. At Äspö, it is performing the general verification and demonstration of operations linked with engineered barriers and final disposal technology. Field tests that provide a basis for the assessment of long-term safety are carried out at Äspö linked with the performance of the bedrock as a natural barrier.

The investigations to be carried out at the Äspö Hard Rock Laboratory within the framework of international co-operation have been grouped as follows:

- investigations linked with technology
- investigations linked with geosciences
- investigations linked with natural barriers
- investigations linked with operations of the research institute.

The COLLOID project was launched at the Äspö Hard Rock Laboratory in 2000 to examine the stability and mobility of colloids. During 2003, the project focused on studying the role bentonite plays in forming colloids. The field tests linked with the project were carried out in both the Äspö characterisation tunnel and the VLJ Repository at Olkiluoto. The amount and quality of colloids occurring in the natural state in the groundwaters at Olkiluoto were also investigated during the field test. The investigation results will be reported in 2004.

Posiva was involved in the tasks of the Task Force aimed at studying groundwater flow and migration. The purpose of Task 6, which was performed during 2003, was to combine the site evaluation and modelling processes linked with the migration of fluids in fractured rock on the scale of 50 m to 100 m. From Posiva's point of view, it is highly useful to explore the compatibility of the results of site characterisation with the modelled migration paths. The project utilises test results obtained from previous work packages by modelling the migration in certain fracture systems. The practical modelling work was conducted at the Technical Research Centre of Finland (VTT).

The objective of the large-scale (10–50 m) TRUE Block Scale test was to provide deeper insight into groundwater flows and the migration of the tracer in the fracture network. The second phase of the test, TRUE Block Scale continuation (TBS2), concentrated on establishing the retention and sorption properties of a structure that contains smectite. The test consists of modelling and tracer tests during 2003 and 2004.

Posiva is involved in the "Prototype Repository" project, which is implemented at SKB's Äspö Hard Rock Laboratory. The project has been accepted into the EU's framework programme for 2000-2003. The KBS-3 final disposal concept is being tested and demonstrated in the project by constructing a full-scale long-term test for a sealed final disposal tunnel. During 2001, canister models fitted with heaters and surrounded by compacted bentonite were placed in four full-scale final disposal holes. In addition, the tunnel was equipped with instrumentation, and a sampling system was also installed. Finally, the tunnel was filled with a mixture of crushed stone and bentonite, and closed by a solid concrete structure. In 2003, canisters were installed in the tunnel section of the second phase in two final disposal holes lined with bentonite and the open tunnel section was filled with a mixture of crushed stone and bentonite.

Posiva is involved in the LOT test (Long-Term Test of Buffer Material) to be carried out at the Äspö Hard Rock Laboratory. The test pertains to validating the hypotheses and models of long-term processes occurring in the buffer material, and the closely linked processes concerning microbiology, the migration of radionuclides, copper corrosion and the migration of gas. The tests are performed at a depth of about 500 m, in boreholes drilled in the tunnel bottom; the boreholes have a diameter of 30 cm and a depth of 4 m. The tests to be performed in five boreholes were begun in 1999, and they have been planned to last for 1, 5 and 20 years.

Posiva and SKB jointly launched the first phase of the project linked with backfilling of the repository. The objectives of the first phase were to describe the optional backfilling methods that had been determined together and to assess their performance from the viewpoint of the requirements; to select the most feasible methods for further development and to assess the volume of the required research and development work before commissioning of the repository. The first phase consisted of the following work packages: a description of the current technological development level, studies into the clay materials as part of the backfilling, preliminary plans for development of the backfilling technology, a description of the backfilling concepts, the role packer structures play in the repository, assessment of the optional backfilling methods and planning of a follow-up programme.

Posiva was involved in SKB's APSE project (Äspö Pillar Stability Experiment), whose purpose is to carry out a large-scale failure test on the pillar between two final disposal holes.

The objectives of the work are:

– to test the opportunities for predicting the strength behaviour of crystalline, hard rock on the tunnel scale and in an intense stress field using numerical modelling programs FLAC3D and PFC2D. In addition, the linked program FLAC2D/PFC2D was applied as a completely new one.
– to acquire practical experience in the monitoring of rock damage using, for instance, acoustic emission (AE) measurements and to compare the measured responses with the modelled results. AE is a highly feasible and interesting method to use during construction of the ONKALO facility as well.
– to demonstrate and further improve opportunities to control growth of the EDZ zone. The test will examine the effect of the pressure prevailing in one hole on the propagation of fractures.

During 2003, Posiva took part in the practical implementation and design of the failure test. In addition, Posiva was involved in the excavation project of the APSE tunnel, which also investigated issues linked with the feasibility for grouting and the effect of blasting diagrams on the excavation result. The failure test was modelled by performing thermomechanical analyses with both the FLAC3D program and the linked FLAC2D/PFC2D program. The preliminary FLAC3D analyses were reported in SKB's IPR series of reports published in 2003. A report on the detailed analyses was completed in early 2004. The actual failure test was launched at the end of 2003.

MANAGEMENT OF OPERATING WASTE

In addition to high-level spent fuel, the Olkiluoto and Loviisa Power Plants produce intermediate- and low-level nuclear waste, comprising used reactor internals (e.g., control rods and core instruments) and plant operating waste (e.g., ion-exchange resins and miscellaneous maintenance waste). The management of used reactor internals is discussed in the section entitled "Decommissioning investigations". The management of operating waste is discussed below.

OLKILUOTO POWER PLANT

Principles and schedule

Most of the operating waste is packaged immediately for handling, storage and final disposal. The intermediate-level ion-exchange resins used to clean the process water are solidified into bitumen, and the mixture is cast into steel drums. Some of the low-level waste (compressible miscellaneous maintenance waste) is compacted into the steel drums with a hydraulic press, and some (metal scrap and filter rods) is packed as such into steel containers, concrete boxes and steel drums. Drums containing compressible waste are further compacted so that the final height of the drums is approximately one half of the original (the diameter, however, does not change). Metal scrap can also be compacted before packaging. Miscellaneous liquid waste and sludge are solidified by mixing the waste and a binding agent in a drum that serves as a package for the solidified mixture.

Operating waste is stored temporarily at the plant units, in the storage facility for intermediate-level waste (KAJ Store), in the storage facility for low-level waste (MAJ Store), in the enclosed storage area and, to a minor extent, in the KPA Store, at the Olkiluoto plant site.

Intermediate- and low-level waste produced during power plant operation is disposed of in the present waste silos of the repository for operating waste (VLJ Repository). Very low-level waste is exempted from regulatory control and is either transported to the dump at the Olkiluoto plant site or handed over, for example, to be processed for reuse.

Current status of storage and final disposal

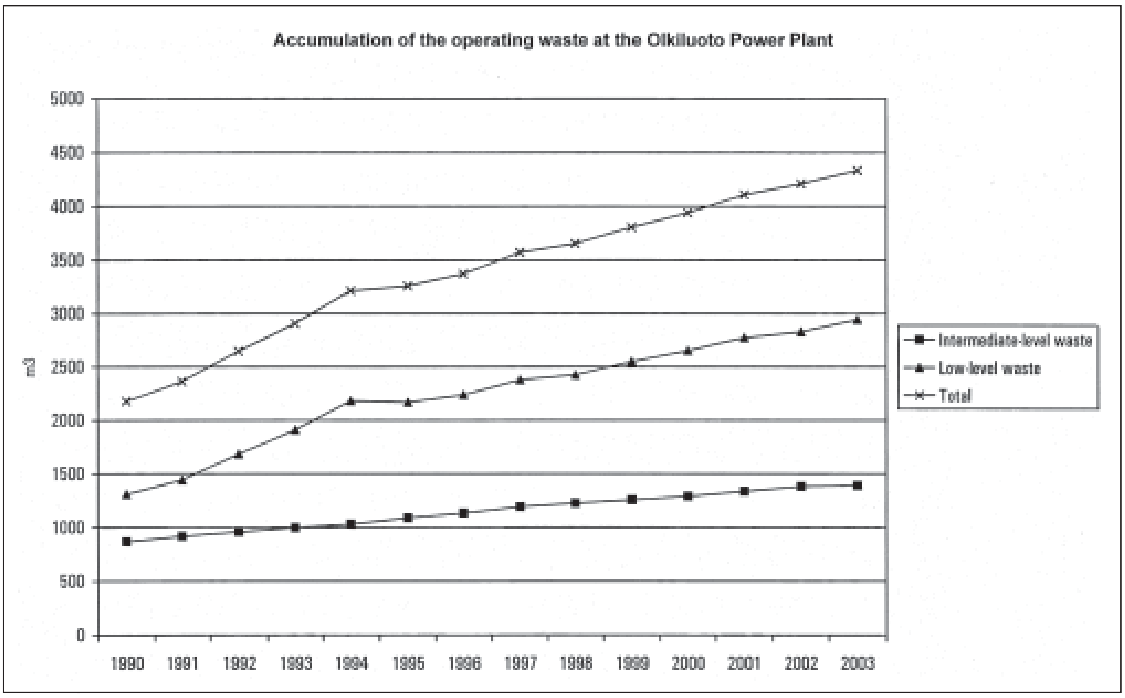
The table below shows the current status of storage and final disposal at the end of 2003. The waste has been packed into drums (200 litres each, or about 100 litres in compacted form), steel containers (1.3 or 1.4 m^3 each) and concrete boxes (net 5.2 m^3 each). In addition, Studsvik Energiteknik AB held five drums of low-level ash generated in an incineration test in their storage facility in Studsvik, Sweden. If necessary, the drums and containers are stored in the storage facilities of the plant units and the KAJ Store before final disposal in the VLJ Repository. Before transfer to the VLJ Repository, the drums and steel containers were placed in large (net 5.2 m^3 each) or small (net 3.9 m^3 each) concrete boxes, the large boxes housing 16 drums or 7 drums and 2 steel containers, and the small boxes 12 drums. Correspondingly, the concrete boxes will house twice as many compacted drums.

Bulky contaminated metal components are stored in the KAJ Store and the adjoining enclosed storage area. In addition, unpacked operating waste, such as used ventilation filters and non-bituminised resins, are stored at the plant units, and waste oil in the KPA Store. Some of the metal scrap will be disposed of as such in the concrete boxes used in the VLJ Repository. Some of the unpacked waste will later be exempt from regulatory control and will either be reused or transported to a dump. For example, very low-level waste oil may be exempt and reused. At the end of 2003, the amount of such waste oil was 13 m^3.

The waste storage facilities of the power plant units can house some 1 000 drums each. The MAJ Store mainly houses only very low-level maintenance

Operating waste produced at the Olkiluoto Power Plant

	Total volume of waste		In the VLJ Repository		
			KAJ Silo	MAJ Silo	Total
	(pcs)	(m^3)	(pcs)	(pcs)	(m^3)
Bituminised waste	6953	1391	6703		1341
Other operating waste					
– in drums	6142	1092		5880	1041
– in steel containers	455	632	5	450	632
– in concrete boxes	174	904	2	172	904
– unpacked		316			
Total		**4335**			**3918**



waste bags and scrap, which will be exempt from regulatory control. The KAJ Store can house drums, containers and bulky, contaminated metal components, the total volume of which comprises some 6 000 drums. The capacity of the intermediate-level waste silo in the VLJ Repository is 17 360 drums (200 litres each) and that of the low-level waste silo 24 800 drums, i.e. about 8 400 m^3 of operating waste packed in drums, or the equivalent of the waste accumulated during 40 years of operation of the two power plant units at Olkiluoto. Additional repository facilities can be built in the same bedrock area, if necessary.

Radioactive wastes from small producers are stored in the VLJ Repository at Olkiluoto. STUK Radiation and Nuclear Safety Authority has so far been in charge of these wastes, which consist of radioactive material used mainly in hospitals, research institutes and industrial plants. By the end of 2003, 42 m^3 of this waste had accumulated in the VLJ Repository.

Studies on operating waste

A large-scale test of the microbiological degradation of low-level maintenance waste is being conducted in the construction tunnel of the VLJ Repository. The project was launched as part of the PROGRESS project of the EU's nuclear fission safety programme in 1997. These studies are conducted to determine more exact estimates of the volume of gases generated by maintenance waste, and in order to gain a better understanding of the entire degradation process under the conditions that correspond to the situation after the sealing of the VLJ Repository. This project also involves monitoring the migration of activity from the waste drums to the surrounding water. One concrete box from the VLJ Repository with drums containing compacted waste was placed in a 20 m^3 steel tank. When the air originally found in the drums had been let out, the amount of the generated gas was found to be low compared with the value used in the safety analysis. The monthly rate of gas generation is 50 to 100 dm^3, whereas the value used in the FSAR safety analysis of the VLJ Repository was some 900 dm^3/month, when proportioned to the scale of the test.

Hydrochemical, microbial and gas analyses show that the test conditions are clearly reducing. Methane continues to dominate the gas phase. The conditions prevailing outside the drums, at the bottom of the test tank, on the lid level of the drums and inside the drums differ considerably. The pH outside the drums is about 9 while it is neutral and even slightly acid inside them. The DGGE (Denaturing Gradient Gel Electrophoresis) method was tested to identify the main microbe species. However, the small amount of reference data on the nucleotide sequence hindered identification of the species.

The studies are progressing in accordance with the research plan revised in 2003 in such a way that the focus of sampling has shifted to inside the drums.

Studies during the operating period of the VLJ Repository

Operation-time monitoring of the VLJ Repository (rock mechanics, hydrogeology, groundwater chemistry, repository air) continued in 2003 in accordance with the research and monitoring programme drawn up previously. The water quality at the groundwater stations of the VLJ Repository at Olkiluoto has been monitored since the latter part of the 1980s.

In spring 1993, ten test bolts were installed in the research tunnel of the VLJ Repository at Olkiluoto to establish the corrosion rate of the bedrock bolts. The objective of the test is to obtain information on the corrosion resistance of galvanised reinforcement bolts in the bedrock under the conditions of the VLJ Repository at Olkiluoto, with the hypothesis of the cement mortar that protects the bedrock bolts completely losing its protective property. The first test bolt was removed by core drilling in 1996. The next bedrock bolt will be removed for testing in 2004.

Since the bedrock bolts had remained unchanged, support tests were launched in 1998 to study the corrosion behaviour of galvanised steel in the borehole of the bedrock bolt removed from the research tunnel ("Bolt 7"). Thin galvanised steel plates and concrete cylinders were installed in the borehole, thus seeking to regulate the groundwater pH so as to make it more alkaline, and thereby simulating the actual environment of the reinforcement bolts in the operating conditions. Since the water chemistry in the above borehole has not been stable and the corrosion rate of the samples was contrary to expectations, a decision was taken to transfer the samples to the borehole located in the construction tunnel (VLJ-KR9). The water chemistry and conditions of the new disposal hole were studied in spring 2002, and 18 new zinc-coated steel plates and 16 zinc plates were installed in the borehole with the concrete cylinders in September 2002. In the autumn of 2003, samples were taken from the one-year-old test samples. The results of their analyses showed that the corrosion rate had been extremely slow.

LOVIISA POWER PLANT

Principles and schedule

Intermediate- and low-level operating waste is conditioned and stored at the plant site. Spent ion-exchange resins and evaporator concentrates are stored temporarily without solidification in a tank storage facility.

Compilation of the preliminary safety analysis report (PSAR) of a cementation-based solidification plant began towards the end of 1997. The preliminary safety analysis report was submitted to STUK for approval in the beginning of 2000 and it was approved in the spring of 2001. Preliminary design of the solidification plant began in 2002 and the implementation design towards the end of 2003. The solidification plant is scheduled for completion at the end of 2006.

Fortum has invested heavily in the development of new waste-treatment methods. These efforts have resulted in a waste-treatment method that separates caesium from the evaporator concentrate and reduces the waste to a very small volume. The evaporator concentrate is then so clean that a larger volume than previously can be exempt from regulatory control without increasing the annual activity release.

Dry maintenance waste from power plant service and repair work is packed in steel drums of 200 litres each. Compressible waste is compacted into drums with a hydraulic press, thereby reducing the volume by a factor of 3 to 4.

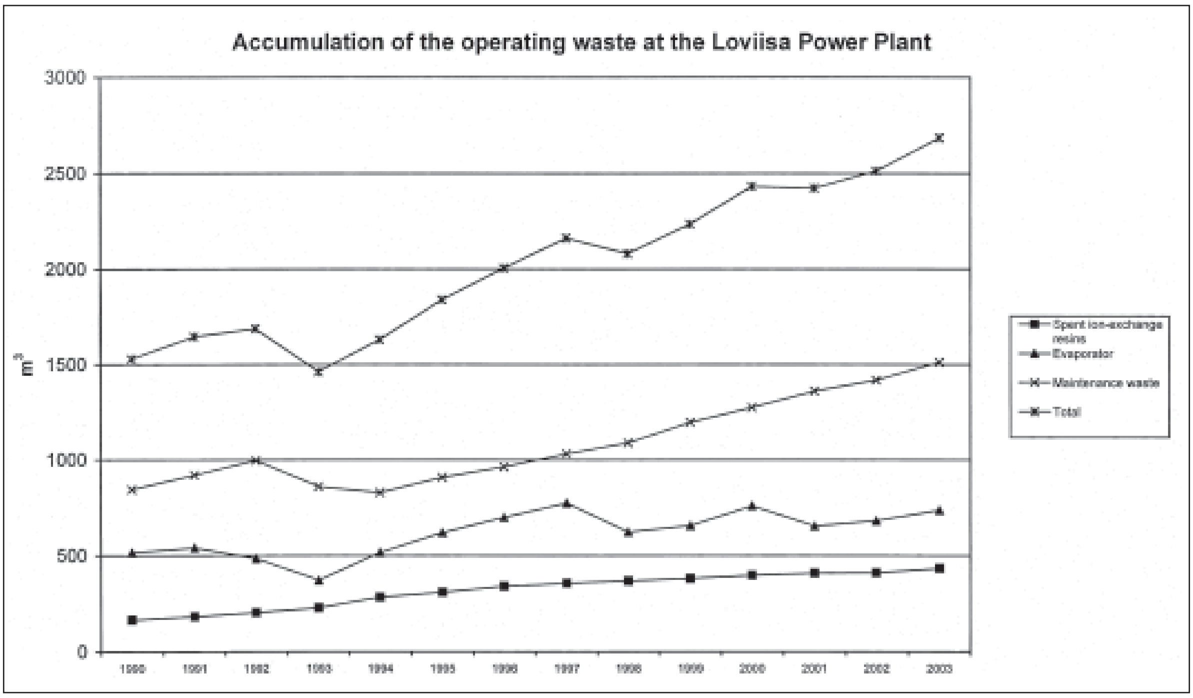
Intermediate- and low-level operating waste from the Loviisa Power Plant will be disposed of in an underground repository built in the bedrock at the power plant site. The repository was put into operation as an interim store in the spring of 1997. The repository received an operating licence in the spring of 1998, and the repository has been used for the final disposal of maintenance waste since the summer of 1999.

Current status of storage

The table below shows the current status of storage and final disposal at the end of 2003.

Operating waste produced at the Loviisa Power Plant

	Total volume of waste		**Share of the storage capacity**	**Activity**
	At the plant/ in the storage building (m^3)	In the repository (m^3)	(%)	(GBq)
Spent ion-exchange resins	434,5		51	14901
Evaporator concentrates	738		70	451
Maintenance waste	332,4	1180		487
Total	**1504,9**	**1180**		**15839**



The final disposal facility

Intermediate- and low-level operating waste produced at the Loviisa Power Plant will be disposed of in a repository constructed in the bedrock of Hästholmen Island. Fortum has been conducting studies on the suitability of the bedrock in the power plant area for the final disposal of waste since the early 1980s. A preliminary safety analysis report on the final disposal facility was completed in 1986. In 1988, STUK Radiation and Nuclear Safety Authority approved the safety analysis report and granted permission, in accordance with the power plant operating licence, for the construction of a repository. Preparatory construction activities began in 1992, and construction started in February 1993.

Excavation work begun in spring 1993 was completed on schedule in December 1995. Construction and installation work was started in November 1995. The installation work was completed on schedule in late 1996, at which time an application for the operating licence of the repository was also submitted. The repository was put into operation as an interim store in spring 1997 and as a final disposal facility in summer 1999.

The final repository comprises a transport tunnel of about 1 100 metres in length, tunnel and hall spaces built at a depth of about 110 metres, and stair and ventilation shafts. The construction of the repository is implemented in two stages. During the first construction stage, all repository spaces and access routes were excavated. These included two final disposal tunnels for maintenance waste and a final disposal hall for solidified waste. Only one maintenance waste tunnel and the systems serving the entire repository were completed during this stage. During the second stage, construction and installation work relating to the second maintenance waste tunnel and to the room for solidified waste will be carried out. The implementation time of the second stage is determined by the building schedule of the solidification plant, which is scheduled for 2004–2006.

Separate research programmes have been planned for the study of the transport tunnel and hall areas during operation.

Caesium separation facility

By the end of 2003, a total volume of over 1 100 m^3 of evaporator concentrates was treated at the caesium separation facility with 20 ion-exchanger columns, each with a volume of 8 litres. The efficient separation of caesium from evaporator concentrates is a normal operating procedure at the power plant.

Studies on solidification methods

Solidification with cement has been selected as the basic conditioning method for Loviisa's wet operating waste. Verification of the solidification recipes for bottom deposits and ion-exchange resins with new building cements continued and the test results on the solidification products of ion-exchange resins were reported during the year under review. In addition, test data was obtained from solidification product samples in long-term storage, the oldest of which are now as old as 20 years.

Owing to the entry into force of the European cement standard and, at the same time, to the modification made by the only Finnish cement manufacturer in the burning process, grinding and raw-material base of the cement clinker, the Finnish building cement types have changed considerably. As a result of the development work, which comprised materials tests, preliminary tests and actual solidification tests, the solidification formulations of the waste have been verified in such a way that the properties of the fresh and hardened end product fulfil the requirements set.

The durability test on ion-exchange resins solidified in half-scale containers in 1987 continued and the test results were reported in 2003. For 16 years now, the waste containers have been immersed in tanks filled with groundwater at the Loviisa Power Plant; as expected, they are still in good condition. No damage to the concrete walls of the containers has been detected, and the composition of the groundwater has remained relatively stable. Activity measurements for the groundwater have not indicated any signs of nuclide release from the solidification products in the concrete containers.

Studies during the operating period of the VLJ Repository

Operation-time studies on the repository for operating waste (VLJ Repository) continued in 2003 in accordance with the monitoring programme. The objective of the programme is to study and monitor long-term changes in the properties and the behaviour of the groundwater and bedrock in the repository and in its immediate vicinity.

The monitoring programme included monitoring the groundwater table in the investigation holes above ground once a month. The location of fresh and saline groundwater in the holes was measured four times during 2002. In the repository, the conductivity and pressure of groundwater, and the amount of seepage water were measured once a month, with the measurement of pressure and the amount of seepage water being partly continuous. The measurements concentrated on seepage water pools and on five groundwater stations built especially for this purpose. The hydrogeochemical research programme included water sampling and analysis from groundwater station LPVA2. Compared with the previous years, there were no significant changes in the results. The stability of the bedrock was mainly monitored by an automatic rock mechanical measurement system. Visual checking of the excavated and reinforced rock surfaces for maintenance purposes also continued in 2003.

According to the findings of 2003, the groundwater table follows variations in the sea-water level fairly closely. During construction, the groundwater table lowered a few metres in the immediate vicinity of the repository, but a distinct rise was observed after completion of the repository. Owing to the dry summer, however, the groundwater table lowered slightly. The interface between fresh and saline groundwater was between the levels of about -10 and -80 m in the repository area, in other words, distinctly above the repository.

The electrical conductivity measurements of seepage water show that the seepage water is slightly fresher than in the previous year, with the conductivity varying between 700 and 1 300 mS/m in different parts of the repository.

The pressure values of the groundwater clearly reflect the effect of variations in the sea-water level. At the five groundwater stations, the pressure varies between 1 and 11 bar as in the previous years.

The amounts of seepage water were measured at seven points on different sides of the repository. After completion of the excavation in 1996, the total amount of seepage water was about 300 l/min at its highest, from which it has steadily reduced, and was about 110 l/min at the end of 2003. About half of the seepage water comes from the transport tunnel and the rest from other facilities. The measurement results show that the maintenance waste rooms are practically dry.

The preliminary results of rock mechanical measurements suggest very stable conditions. As in the previous years, the displacements that have taken place in the repository ceilings and walls are very small, distinctly of the order of less than 0.1 mm. Visual examinations also show that the repository is in good condition, and the subsurface drains perform as intended.

Safety of final disposal of operating waste

With regard to the final disposal of operating waste, the activities during the year under review consisted of monitoring the international development by means of a conference visit and trade journals. The comparison of the sorption parameters used for the safety analysis of the Loviisa repository, which was conducted as part of the decommissioning investigations, and the corrosion studies and studies into filling materials also contribute to the readiness for the safety analysis of the final disposal of operating waste.

JOINT STUDIES

The long-term durability of concrete under final disposal conditions is being studied as a joint project by TVO and Fortum in the VLJ Repository at Olkiluoto and at the Materials and Concrete Laboratory of Contesta Oy (formerly owned by Fortum Technology). The research project pertains to both the operating waste and decommissioning waste management. The studies are discussed in the section entitled “Decommissioning investigations” (Page 29).

DECOMMISSIONING INVESTIGATIONS

OLKILUOTO POWER PLANT

Used reactor internals, which are classified as being intermediate-level operating waste, will not be disposed of until during the decommissioning of the plant. The used reactor internals are stored in the pools of the plant units and a separate inventory is kept of them. By the end of 2003, for instance 255 control rods, 217 core instruments, two core grids and two moderator tank lids with their steam separators had accumulated at the Olkiluoto Power Plant.

The decommissioning plan for the Olkiluoto Power Plant was updated during the year under review. According to the decommissioning plans, the reactor pressure vessels of the power plant units will be removed and disposed of in one piece. The plans are based on a power plant unit operating period of about 40 years and on controlled storage of about 30 years before decommissioning. The final decommissioning plan will be drawn up well before the power plant units cease energy generation. According to the present plan, the intermediate- and low-level waste from the decommissioning and the used reactor internals from power plant operation will be disposed of in an extension of the VLJ Repository.

The decommissioning investigations are aimed at technical and economic development of the decommissioning plan and specification of the basic data for the safety assessment of final disposal.

Activity measurements of various systems within the plant were continued as a means of further developing the activity inventory of the power plant's decommissioning waste. The updated inventory of activated material was completed at the end of 2003. In the updated decommissioning plan, its results have only been used in the dismantling plan for the thermal insulation plates and biological shields that surround the pressure vessels. Design was completed concerning the reactor's biological shield, thermal insulation plates and decommissioning of the fuel pools in the event of the reactors being removed in one piece. A new method of dismantling based on diamond wire cutting is employed in the new plan. The database built as a part of the decommissioning plan for the contaminated plant section, which was completed in 1989, was transferred to another database application. The database helps calculate the amounts of materials, the amounts of radioactive isotopes, the working hours required for dismantling, dose rates and committed doses of the workers, and the costs.

Long-term corrosion tests of carbon steel began towards the end of 1998 in the construction tunnel of the VLJ Repository. The tests are performed jointly with the concrete research in such a way that some of the pieces of carbon steel are placed in the same borehole as the test samples of concrete. Laboratory tests in the concrete-water and bedrock-groundwater environments were launched in spring 1998. The corrosion rate of the carbon steel samples is determined by the loss in weight and by the volumetric measurement of hydrogen gas. The planned periodic sampling and measurements of the laboratory and field tests were carried out in 2003. The black deposits detected (in the concrete test samples and carbon steel samples and the water) during the studies conducted in the VLJ Repository at Olkiluoto over several years have been found to contain, for instance, sulphate-reducing bacteria, which have been assessed to cause a higher corrosion rate than expected.

LOVIISA POWER PLANT

Operation of the Loviisa Power Plant results in the accumulation of intermediate- and low-level nuclear waste that will not be disposed of until during the decommissioning of the plant. This waste includes, e.g., used shielding elements, absorbers, neutron flux transducers, intermediate rods of control rods and fission chambers.

By the end of 2003, 146 used shielding elements, 199 absorbers, 195 neutron flux transducers, 128 intermediate rods and nine fission chambers had accumulated at the Loviisa Power Plant. Of these items, the shielding elements have been placed in the plant pools in the spent fuel store, and the absorbers and fission chambers have been stored in specially built channels in the spent fuel store. The neutron flux transducers and intermediate rods have been stored in corresponding channels located in the reactor halls.

In 1987, Fortum drew up a plan and cost estimate for the decommissioning of the Loviisa Power Plant. The decommissioning plans were updated in 1993. The plan was based on 30 years of commercial power plant operation, which is equivalent to the designed technical life of the power plant. However, technical measures may be undertaken to extend the operational life of a nuclear power plant. New studies were completed at the end of 1998, which focused on the effects of revised spent fuel management and the power plant modernisation project on the decommissioning plans and schedules. The operational life of the power plant has also been planned to be extended to 45 years, and this was considered in the studies. According to the updated decommissioning plan, all the radioactive systems not necessary for the remaining nuclear operation (i.e. storage of the spent fuel, solidification of the wet waste and final disposal of low- and intermediate-level waste) at Hästholmen will be dismantled immediately after the shutdown of the power plant.

The plans are revised every five years. The new decommissioning plan was updated during the year under review. An operational life of 50 years was chosen as the basis for the updating. The updating consisted of the verification of the activity inventory, dismantling measures, radiation dose estimates, amounts of the components and packages to be disposed of, safety of the final disposal, and estimates of the workload and costs.

It is not expedient, however, to make any decisions regarding decommissioning or continued operation until towards the end of the designed technical operational life. It is also advisable to take a final stand on whether the plant will be decommissioned immediately or after a certain delay, just upon termination of the power plant operation, before the beginning of the decommissioning.

JOINT STUDIES

The long-term durability of concrete under final disposal conditions is being studied as a joint project by TVO and Fortum in the VLJ Repository at Olkiluoto and at the Materials and Concrete Laboratory of Contesta Oy at Myyrmäki, Vantaa. The research project originally co-ordinated by Posiva concerns both the operating waste and decommissioning waste management. In 2003, TVO assumed responsibility for co-ordination of the project. The purpose of the studies is to realistically assess the long-term behaviour and degradation of concrete in the bedrock-groundwater environment that corresponds to operating conditions. The objective is to establish, using modern concrete technology, the durability and lifespan of the planned concrete types with different compositions under the real final disposal conditions and under accelerated laboratory conditions. Special emphasis will be placed on establishing the most durable concrete compositions under prevailing conditions, which will meet the requirements set for the lifespan.

The field and laboratory tests were begun in 1998. During 1999-2003, the research conducted annually included periodic water chemistry analyses of storage solutions of the test samples and groundwater in the boreholes. Periodic analyses of the test samples with respect to the penetration depth of corrosive components were carried out in 1999, 2000 and 2002, and analyses of the microstructures in 2001 and 2003. Furthermore, microstructural maps were determined for the nine concrete types tested at the laboratory, and microbes were analysed during the field test sampling from the surface of the concrete test samples and water in 2003. The black deposits formed on the test samples contained sulphate-reducing bacteria (SRB), whereas very few SRB were detected in the water samples. Before being reinserted to the borehole, the concrete test samples were washed owing to their black deposits. In 2002, geochemical data on the bedrock groundwaters of the repository for operating waste at Hästholmen and the VLJ Repository at Olkiluoto were compared with respect to the long-term durability of concrete, particularly with respect to concrete-corroding components and microbial activity. On the basis of the tests it was assessed that differences between the groundwaters were so small that it would not be necessary to begin field tests at Hästholmen.

The tests will continue in accordance with the updated research plan included in the summary report published in early 2004.

REPORTING, COMMUNICATIONS AND CONTACTS

A total of eleven reports were published in the Posiva series of reports in 2003. A list of these reports is appended. In addition, company-specific reports dealing with the research results were published.

In Finland, close co-operation continued with the research institutes, universities and consulting firms engaged in studies on nuclear waste management. During the year under review, the Ministry of Trade and Industry and STUK Radiation and Nuclear Safety Authority, as regulatory authorities, were kept informed of the measures taken in nuclear waste management and of the progress made in research.

Lectures were held in Finland at meetings intended for both experts and the general public. Representatives from the power companies and from Posiva participated as experts in the work conducted by the leading and joint groups of the publicly financed nuclear waste management research programme.

As regards communications during the year under review, the main emphasis was placed on issues related to the construction of ONKALO and to final disposal technology.

In spring, a press conference was organised at Olkiluoto concerning the submission of an application for a building permit for ONKALO. A brochure about the construction of ONKALO and the final disposal project was published in Finnish, English and Swedish in autumn.

Natural analogues and technology of the final disposal were demonstrated at the exhibition mounted as a part of the Yläne Nature Cabinet during the summer. More than 3 000 people visited the exhibition.

The welding and inspection technology of the final disposal canister lid was demonstrated to a group of journalists from the Satakunta area during a visit to SKB's canister laboratory in Oskarshamn. During the visit, the group also became acquainted with the investigations that were underway at the Äspö Hard Rock Laboratory.

In early 2004, an information meeting was arranged for journalists from the Satakunta area concerning the design of the final disposal project and implementation of the final disposal at Olkiluoto on the basis of the plant description.

International interest in Posiva's operations was manifested in the great number of foreign visitors. More than 40 foreign groups visited Olkiluoto to become acquainted with Posiva's operations and investigations there.

Co-operation between Posiva and the municipality of Eurajoki continued along the same lines as before.

Close co-operation with other Nordic organisations involved in nuclear waste research continued both through direct contacts and within the framework of various joint groups.

The progress made in international research projects related to nuclear waste management was monitored by participating in conferences and joint projects. Close co-operation in the Äspö Hard Rock Laboratory project and in numerous EU research projects continued.

The progress of research programmes in various countries was followed closely. Presentations were given on Finland's nuclear waste management programme and research results in international conferences regarding nuclear waste. Participation in the OECD/NEA expert working groups involved, for example, discussion and assessment concerning site characterisation and safety studies, and the decommissioning of power plants.

CO-OPERATION PARTNERS

List of research institutes, universities and consultants engaged in nuclear waste management operations in 2003

ALARA Engineering AB (Sweden)
Astrock Oy
Australian National University (Australia)
Concave Oy
Conrox Ab (Sweden)
Consulting Engineers Paavo Ristola Ltd
CT Heikkinen Oy
Enprima Engineering Oy
Enterpris Limited (United Kingdom)
Enviros Consulting Ltd (United Kingdom)
Enviros Spain S.L. (Spain)
EP-Logistics Oy
Evata Finland Oy
Facilia AB (Sweden)
Finnish Consulting Engineers Ltd
Finnish Forest Research Institute
Parkano Research Institute
Finnish Geodetic Institute
Finnish Meteorological Institute
Meteorological Research
Fortum Nuclear Services Oy
Gascoyne Geoprojects Inc. (Canada)
GEA Consulting (Sweden)
Geokeskus Oy
Geological Survey of Finland (GTK)
Espoo Unit
Geoservice Centre
Kuopio Unit
Geopros Oy
Geosigma AB (Sweden)
Gridpoint Finland Oy
Helsinki University of Technology
Laboratory of Materials Technology
Integrity Corrosion Consulting Ltd (Canada)
JA Streamflow AB (Sweden)
JP-Fintact Oy
JP-Suoraplan Oy
Kalliosuunnittelu Oy Rockplan Ltd (KSOY)
Karinta Consulting Ab (Sweden)
Kivitieto Oy

Lapela Oy
Libenter Oy
Marintel Ky
Metso Paper, Inc.
AB Nonlinear Solutions Oy
Outokumpu Technology Oy
Outokumpu Poricopper Oy
PRG-Tec Oy
Rock Engineering Consultants (United Kingdom)
Rollcon Oy
Saanio & Riekkola Consulting Engineers
Safety Assessment Management (SAM) Ltd (United Kingdom)
Safram Oy
Serco Assurance (United Kingdom)
Suomen Malmi Oy
Suomen Paprico Oy/Viestintä-Paprico
Suomen Teknohaus Oy
Svensk Kärnbränslehantering AB (SKB) (Sweden)
Swedish Corrosion Institute (Sweden)
SwedPower AB (Sweden)
Tampere University of Technology
Institute of Materials Science
Laboratory of Engineering Geology
Technical Research Centre of Finland (VTT)
VTT Biotechnology
VTT Building and Transport
VTT Industrial Systems
VTT Processes
TVO Nuclear Services Oy
University of Bern (Switzerland)
University of Gothenburg (Sweden)
University of Helsinki
Department of Chemistry
Department of Geology
Department of Pharmacy
University of Jyväskylä
Department of Physics
Vibrometric Oy

QUALITY MANAGEMENT AND ENVIRONMENTAL MANAGEMENT

Posiva's operations are aimed at the safe implementation of nuclear waste management in accordance with the needs of its owners and other clients, while protecting the environment and fulfilling the requirements set by society. Posiva has been upgrading quality ever since the Company was established. The purpose of the quality system is to verify the systematisation of Posiva's operations.

In 2003, the upgrading of the operating system continued in the direction of the ISO 9001 standard, also taking the requirements of environmental standard ISO 14001 into account. During 2003, the Company also succeeded in outlining the main and support processes essential from the viewpoint of Posiva's operations.

The efficiency and reliability of the system in relation to the set targets were assessed by Posiva's internal audits. The internal audits were concerned with the consideration of legislation, and safety and environmental aspects in the operations. The results of the audits brought important subjects of development to light to improve the efficiency of operations.

The capability of some sub-suppliers to fulfil the technical, economic, quality and environmental requirements was assessed during 2003. The operating systems that are being applied and their development potential were surveyed. In addition, the functioning of some organisations was assessed by means of the audits of suppliers.

Instructions with a view to assuring the quality of research, development and design work were specified. In assuring the quality, Posiva also employed an outside expert group to audit the material produced by Posiva. The quality management of the ONKALO project concentrated on determining the processes and defining the quality requirements to be established for the main contractor.

Induction training was given to new Posiva employees; they were also offered a five-day introductory course in nuclear waste management to enhance their expertise. The entire personnel received training in quality issues in spring 2003. Annual development discussions continued as before.

The significance of corporate security will increase substantially when the construction of ONKALO begins. With regard to occupational safety, the principal subjects of development in 2003 included the implementation design of risk management and occupational safety within the ONKALO project. In developing the operating system, a decision was taken to also consider the occupational health and safety management system in accordance with OHSAS 18001.

Fortum's and TVO's nuclear waste management operations comply with the quality and environmental management systems applied in the companies' nuclear power operations. The business sectors of Fortum Power and Heat have received various certifications (ISO 14001 and ISO 9001). TVO's environmental management system has been awarded a certificate in accordance with the ISO 14001 standard. TVO was accepted into the EMAS register in 2001.

COSTS

RESEARCH

The total cost of the nuclear waste management research programme was some EUR 13.1 million. The cost estimates for the research programme in 2003 were about EUR 11.4 million. The research programme was mostly implemented as planned.

The above-mentioned costs do not include Posiva's research assignments sponsored by Tekes, the National Technology Agency of Finland.

SUMMARY OF THE RESEARCH COSTS IN 2003

Research area	Costs (EUR million)
Planning, co-ordination, information activities and general studies	0.5
Management of spent fuel and high-level waste	12.1
Management of intermediate-level and low-level waste	0.3
Decommissioning and decommissioning waste	0.2
Total	13.1

FINANCIAL PROVISION FOR NUCLEAR WASTE MANAGEMENT

Funds for the future costs of nuclear waste management are collected by the State Nuclear Waste Management Fund. The fund target is determined according to the liability of nuclear waste management to be confirmed each year. The liability comprises the future costs of the management of all wastes accumulated by the end of the year in question.

EUR 732.2 million was assessed as the fund target for TVO in 2003, the corresponding amount for Fortum being EUR 545.1 million.

The Ministry of Trade and Industry (KTM) confirmed a liability amount of EUR 763.8 million for TVO's nuclear waste management at the end of 2003 and, based on this amount, a fund target of EUR 763.8 million for 2004. For Fortum, KTM confirmed a liability amount of EUR 570.2 million and, accordingly, a fund target of EUR 570.2 million for 2004.

LIST OF REPORTS 2003

POSIVA 2003-01
Vertical and Horizontal Seismic Profiling Investigations at Olkiluoto, 2001
Calin Cosma, Nicoleta Enescu, Erick Adam, Lucian Balu
Vibrometric Oy
March 2003
ISBN 951-652-115-0

POSIVA 2003-02
Baseline Conditions at Olkiluoto
Posiva Oy
September 2003
ISBN 951-652-116-9

POSIVA 2003-03
ONKALO Underground Characterisation and Research Programme (UCRP)
Posiva Oy
September 2003
ISBN 951-652-117-7

POSIVA 2003-04
Thermal Analyses of Spent Nuclear Fuel Repository
Kari Ikonen
VTT Processes
June 2003
ISBN 951-652-118-5

POSIVA 2003-05
Programme of Monitoring at Olkiluoto During Construction and Operation of the ONKALO
Posiva Oy
December 2003
ISBN 951-652-119-3

POSIVA 2003-06
Assessment of Disturbances Caused by Construction and Operation of ONKALO
Timo Vieno, Jarmo Lehikoinen, Jari Löfman, Henrik Nordman
VTT Processes
Ferenc Mészáros
The Relief Laboratory
October 2003
ISBN 951-652-120-7

POSIVA 2003-07
Hydrochemical Interpretation of Baseline Groundwater Conditions at the Olkiluoto site.
Petteri Pitkänen, Ari Luukkonen, Sami Partamies
VTT Building and Transport
March 2004
ISBN 951-652-121-5

POSIVA 2003-08
Air-oxidation Tests with Gd-doped UO_2 Preliminary Dissolution Experiments with pre-oxidized Gd-doped UO_{2+x}
Kaija Ollila
VTT Processes
Kristian Lindqvist
Geological Survey of Finland
October 2003
ISBN 951-652-122-3

POSIVA 2003-09
Narrow Gap Arc Welding Experiments of Thick Copper Sections
Rami Pohja, Heikki Vestman, Petra Jauhiainen, Hannu Hänninen
Helsinki University of Technology Laboratory of Engineering Materials
October 2003
ISBN 951-652-123-1

POSIVA 2003-10
Glacial Rebound and Crustal Stress in Finland
Kurt Lambeck, Anthony Purcell
Research School of Earth Sciences, The Australian National University
November 2003
ISBN 951-652-124-X

POSIVA 2003-11
Thermal Analysis of KBS-3H Type Repository
Kari Ikonen
VTT Processes
November 2003
ISBN 951-652-125-8

Fortum Power and Heat Oy, TJATE-G12-81
Decommissioning of the Loviisa NPP
Ilpo Kallonen, Tapani Eurajoki and Elias Mayer
Fortum Nuclear Services Ltd
Vantaa, December 2003
ISSN 1457-3342 Summary Report
ISBN 951-591-081-1

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