Nuclear Waste Management of the Olkiluoto and Loviisa Power plants

Annual Review 2002

POSIVA

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 2002, a review of the communication activities pertaining to nuclear waste management, and an account of the provisions made for future waste management costs.

Studies of the final disposal of spent fuel progressed in accordance with the schedule confirmed by the Ministry of Trade and Industry (KTM). The main objective of the operations begun in 2001 is to bring the research, development and design work to the level that is required for the application for a construction licence and, further, to receive the construction licence from the Council of State. In accordance with the Decision in Principle ratified by Parliament on 18 May 2001, the final disposal site will be Olkiluoto in Eurajoki.

The site characterisation concentrated on defining the baseline and potential points of access to the underground rock characterisation facility known as ONKALO. The studies have helped confirm previous data and acquire increasingly detailed data to support the design of underground characterisation facilities.

With regard to safety studies, the performance of engineered barriers was studied extensively within the framework of several international co-operation projects. With respect to bedrock, the studies pertained to the migration and retention phenomena, and their modelling. In biosphere studies, the main emphasis was placed on the development of modelling. The work linked with safety analysis concentrated on establishing the disturbances caused by the ONKALO facility.

In the design of the final disposal canister, the main emphasis was placed on examining the opportunity for thinning the copper canister wall. With regard to sealing of the canister, a new test programme of electron beam welding was implemented. As a part of developing the canister manufacturing technology, an integrated copper canister cylinder and bottom end were manufactured with the “pierce and draw” method; a cylinder billet was also manufactured by die forging. The plans for an independent encapsulation plant located at Olkiluoto and for an encapsulation plant located as a part of the KPA Store were completed.

In designing the repository, the priorities included the development of groundwater control, the horizontal disposal concept and the backfilling methods, and co-ordination of the design of the repository and the ONKALO facility.

In the design work of the underground characterisation facility, the shaft and access tunnel alternatives were compared extensively, and on this basis a decision was taken to choose the access tunnel concept and to launch further studies into it.

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. Preparation for the research projects under the EU’s sixth framework programme progressed. A co-operation agreement was signed with the French waste management organisation, ANDRA.

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

By the end of 2002, 4 212 m^3 of operating waste had accumulated at the Olkiluoto Power Plant, and 2 512 m^3 at Loviisa; 3 834 m^3 of the Olkiluoto waste has been finally disposed of in the VLJ Repository; 1 089 m^3 of the Loviisa waste has been disposed of in the low- and intermediate-level waste repository at Hästholmen.

The overall costs of the research programme for nuclear waste management of the Loviisa and Olkiluoto Power Plants amounted to EUR 10.8 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 and 26 September 1995. 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 regarding 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 operating 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 2002 describes the status and operations of nuclear waste management in 2002. 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 2002, the load factors of OL1 and OL2 were 95.3% and 96.6%, 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 2002, the load factors of Lo1 and Lo2 were 89.3% and 82.2%, 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 Loviisa power plant, as well as that which will accumulate hereafter. The preparations are made according to the schedule requiring that the companies must be prepared to begin the final disposal of spent fuel 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 twenty-third refuelling of Olkiluoto 1 and the twenty-first refuelling of Olkiluoto 2 were carried out during the year under review. At the end of 2002, a total of 5 530 assemblies of spent fuel, equivalent to 973 tonnes of fresh uranium were stored at the Olkiluoto plant. The KPA Store housed 4 264 assemblies; the pools of OL 1 stored 617 assemblies and those of OL 2 stored 649 assemblies. The KPA Store has sufficient capacity for the spent fuel accumulated during about 30 years' operation of the plant units. To date, fuel racks have been installed in two of the three storage pools of the KPA Store. The store can be enlarged if necessary.

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 2008. In the future, it will be possible to substantially increase the capacity through the use of dense racks.

At the end of 2002, a total of 2 545 spent fuel assemblies, equivalent to about 305 tonnes of fresh uranium (estimated on the basis of the amount of uranium contained in the spent fuel, about 290 tonnes), were stored in the Loviisa plant's storage facilities. Lo1 housed 222 assemblies and Lo2 housed 209. The spent fuel storage facilities 1 and 2 held 450 and 1 664 assemblies, respectively.

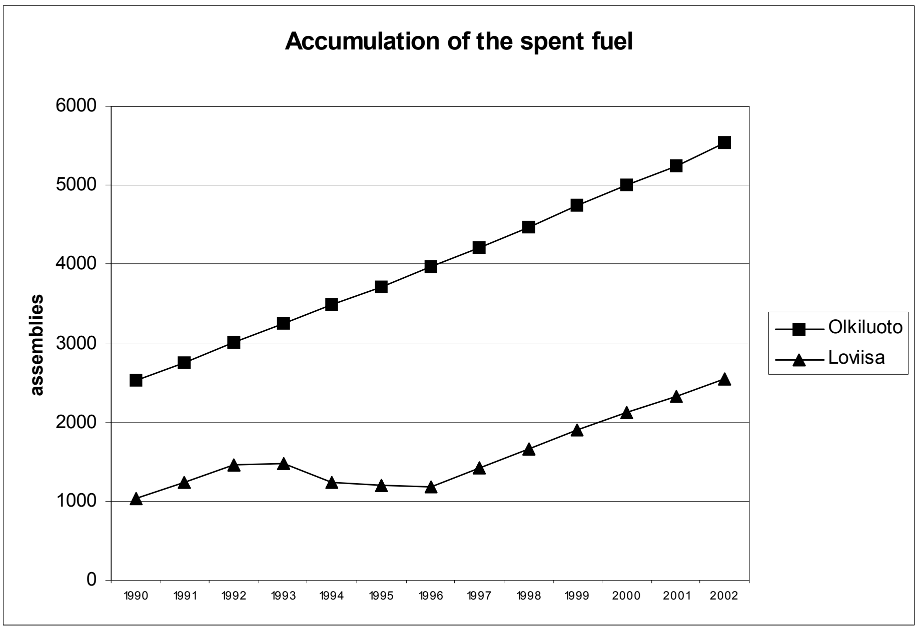
SITE CHARACTERISATION

In 2002, site characterisation was concentrated on defining the baseline and potential points of access to the ONKALO facility. The studies have helped confirm previous data and acquire increasingly detailed data to support the design of underground characterisation facilities.

Preliminary, detailed models were generated on the basis of the bedrock model for the alternative points of access by re-gathering and re-interpreting previous results and by adding new data to them.

Studies into the geological evolution at Olkiluoto have shifted from examination of the plastic deformation phases to research focusing on brittle fracture. The results will help increase understanding of the interdependence of the geological features and fracturing.

Five new boreholes were drilled and two existing holes were deepened. The new drillings were performed using what is called the 'triple tube method', which enables a good sample to be obtained even from the fractured parts of rock. Additional boreholes, with sections of about 40 m fitted with a casing, were drilled near these boreholes. This provided essential information on the



properties of the surface rock. Borehole investigations were carried out in both the old and new boreholes.

Investigations at Olkiluoto

Selection of the access tunnel location

Towards the end of 2002, five new deep investigation boreholes were drilled and one old borehole was deepened to compare potential location areas of the access tunnel. Of the new boreholes, three are located in the north-western part of the investigation area and two in the south-eastern part, where deepened borehole KR8 is also located. Geophysical standard measurements and hydraulic conductivity measurements were carried out in the boreholes with the detailed flow logging method. The seismic refraction sounding and re-interpretation of the results from the vertical seismic profiling (VSP) of borehole KR5 also complemented data on the north-western area. Furthermore, about a 600-metre-long investigation trench was dug in the area, from which geological mapping and soil logging were performed. Vertical seismic profiling and borehole TV imaging of borehole KR19 also sharpened the picture of the bedrock in the area. Additional data on the surface part of the bedrock in the south-eastern part was obtained by complementing the seismic refraction soundings performed in 2001.

Acquisition of information on the bedrock structure and baseline

Investigation borehole KR15 was deepened to the "final disposal depth", and geophysical and hydrogeological measurements were carried out in the extended borehole section. Properties of the above-mentioned rock volume were studied by seismic tomography soundings between boreholes KR14 and KR15 and by interference tests conducted with the differential flow measurement equipment between boreholes KR15-KR18. Vertical seismic profiling and borehole TV imaging performed in old boreholes complemented geological knowledge.

Definition of the baseline at Olkiluoto continued by collecting the existing data and by carrying out supplementary investigations. Drilled wells located on the island of Olkiluoto were surveyed. Water samples will be taken from some of the wells during 2003. Differential flow measurements and hydraulic conductivity measurements complemented data on the hydraulic conductivity of deep bedrock. Hydraulic conductivity of the surface part of the bedrock was determined in the shallow boreholes and hydraulic conductivity of the earth in the standpipes installed in 2001. Multi-packer equipment was installed in the deep boreholes for the purpose of monitoring during construction of the ONKALO facility. The long-term pumping test in borehole KR6 continued with a view to establishing the interrelationships between the deep saline groundwater, sea water and the water permeating from the surface.

The microseismic measurement network was put into use after the installation and regulation phase of the equipment. Observations were hampered by problems with telecommunications in the beginning, the seismic soundings performed in the area and the thunderstorm that raged over the island in September. The thunderstorm broke some components of the measuring equipment. The measuring system has proved to be extremely sensitive.

Interpretations of the geophysical measurement data and the known geological features were compared to assess the reliability of the interpretations and to upgrade the interpretation methods. Drill core data on the principal structures was examined in order to verify the structural interpretations. Particular attention was focused on the methods of generating the structural model to improve the modelling and interpretations.

Development of the groundwater flow modelling continued. The new modelling method, which enables even local effects of, for instance, pumping or water seepage to be simulated, proved to be efficient. A detailed description of the groundwater flows is a precondition for modelling of the migration of substances as well.

Hydrogeochemical investigations

The water sampling performed in 2002 helped specify the regional distribution of the salinity and the baseline of the groundwater chemistry in the investigation area. The data material necessary to establish the paleohydrogeological courses of evolution and the chemistry of deep groundwaters was complemented. A total of 11 water samples and six gas samples were taken from deep boreholes. The results will be reported in 2003.

Water samples were taken from the shallow boreholes drilled in the bedrock and from the standpipes installed in the earth in early summer and in autumn 2002. The water sampling in early summer was performed in accordance with Posiva's extensive sampling and analysis programme. In autumn, the work concentrated only on the water sampling of such points with which problems had arisen during previous samplings. Water samples were taken from a total of seven boreholes drilled in the rock and from ten groundwater pipes. A monitoring programme will be drawn up for the water sampling from the shallow boreholes and groundwater pipes on the basis of the water sampling performed in 2001-2002. The water sampling will complete the description of the baseline and provide information on any seasonal variations. A report was completed on the water sampling performed in summer. The water sampling performed in autumn was reported in early 2003.

Four sea-water samples were taken off the Olkiluoto Island towards the end of the summer. The objective of the sampling was to furnish supplementary information for interpretation of the results of the water sampling performed during the long-term pumping of the boreholes and for description of the baseline. A report on the sea-water sampling was completed in early 2003.

Environmental studies

An aerial false-colour photograph was taken of the Olkiluoto area in May 2002 to monitor the vegetation. The photograph was processed into corrected digital images to facilitate further processing. During summer, the central area of the island was divided into figures formed by the vegetation. The vegetation in these figures was classified systematically on the basis of field visits. The work will be continued in the coming years by detailed studies into the tree stand and soil.

Posiva acquired the monitoring data on the radioactivity of the marine ecosystems and the environment gathered by Teollisuuden Voima Oy as well as the results of weather measurements for the past then years and launched their examination from the point of view of the final disposal project. At best, the data goes back as far as the 1970s. Monthly and yearly averages and parameters were calculated from the weather data, and they were published together with the snow and frost observations made at Olkiluoto during the corresponding period.

The occurrence of animals, particularly game and fairly large mammals, was assessed by means of a literature study and on the basis of interviews with local hunters. As part of this work, an English summary was made of the survey of birds carried out in 1997 for international readers.

Water sampling continued with a view to examining the hydrological and chemical properties of groundwater occurring in the soil cover and the chemical properties of the upper part of the rock, and to studying the seasonal variation. The samples were taken from groundwater pipes and shallow rock holes.

Investigations in Loviisa

When the field investigations at Hästholmen ended in 2000, multi-packer equipment was installed in investigation borehole KR1 to enable water sampling from the borehole. The first sampling was performed in early 2002 and the results were reported in early 2003. The purpose of water sampling is to obtain reference material for studies into the Olkiluoto groundwater and to establish any effects on the quality of groundwater detected in the borehole as a result of the long-time plugging of the borehole.

Equipment and method development

New electronics cards were installed in the borehole probe of the hydraulic testing unit. The upgraded unit was put into measurement use.

The joint project launched in 2000 with the Geological Survey of Finland (GTK) aims at constructing a measuring transducer to measure the thermal properties of the bedrock *in situ* in deep boreholes. The equipment to be constructed is based on the conduction of heat from a cylindrical heat source. During the year under review, the development work continued by, for example, studying heating foils and temperature detectors suitable for this purpose. Construction of the actual prototype measuring transducer in a borehole with a diameter of 56 mm was launched on the basis of the studies. Preparation of the interpretation software of the measurements will begin in 2003. Underground measurements will also be taken into account in designing the transducer.

The construction of a new differential flow measurement unit launched in 2001 was completed and the unit was put into production use after acceptance tests. Electronics cards containing the new measuring software were installed in the old borehole transducers as well, and as a result differential flow measurements can be taken in the same manner with all the measurement units that are being used. For the purpose of site characterisation, a simple calliper transducer was installed in the new measurement unit. This transducer helps detect reference marks made in the borehole and thus helps calculate depth corrections for the hydraulic conductivity results. The integration of an additional function into the new unit enabling *in-situ* pressure measurement was also launched in 2002. In measuring saline groundwaters, pressure measurement conducted deep in the borehole can replace the time-consuming pressure measurement carried out with the aid of a freshwater hose. The software modifications and equipment tests required for operation of the pressure transducer will be carried out during 2003.

Simple measuring equipment based on what is called the “slug test” was designed and constructed with a view to measuring the hydraulic conductivity in shallow boreholes and groundwater pipes. The test section to be measured is separated by two plugs which are inflated, and the pressure transducer located in the measuring/support tube functions as a piston. The equipment can be moved fairly easily in the field. In late summer, the drillholes and standpipes most suitable for the measurements were measured with the equipment.

The development work on rock stress measurement based on the overcoring method, launched in 2001 with SKB, continued. The measurement contractor was informed of the problems with the measuring equipment encountered during the work, and equipment improvements have been promised. The development work will be continued by anisotropic examination of the Olkiluoto bedrock. The purpose is to also extend the built quality assurance system as part of this work.

The valves of the pressurised water sampling equipment (PAVE) were replaced by three ball valves connected in series. The valve modifications have substantially improved the reliability of the PAVE equipment. Push-pull couplings replaced the threaded joints used previously for attachment of the pressure vessels. The smaller pressure vessels, which facilitate further processing of the gas samples and analysis of the gases, were put into use. The internal ends of the pressure vessels were rounded with a view to preventing the gas phase from being formed in the upper parts of the pressure vessels during the lifting of the equipment. Larger pressure vessels with a volume of about 500 ml were also designed for the PAVE equipment. They enable larger sample quantities to be obtained in order to determine the parameters sensitive to air contamination.

The new hydrogeochemical field measurement equipment, which monitors the preliminary pumping of a water sample, was completed in early 2002. The equipment maintains the groundwater pumping and conducts continuous measurements of the pH, electrical conductivity, redox potential, dissolved oxygen and temperature. The representativeness of a water sample is assessed on the basis of the measurement results. The newly completed equipment makes it possible to take an increasingly great number of water samples and to operate the existing PAVE equipment more efficiently.

Measurements of the hydraulic conductivity in shallow boreholes and standpipes installed in the earth were carried out with the new equipment constructed for this purpose.

Equipment testing continued for the purpose of gas sampling from the groundwater pumped onto the ground. The first prototype was completed, but its development work must be further continued.

Method development work was launched to determine the gases dissolved in the groundwater using the mass spectrometry (MS) determination method. The objective of the work is to introduce a method that enables gases to be analysed from both the gas phase and the liquid phase. The purpose is to utilise membrane technology in analysing the liquid phase.

The prototype of new capillary electrophoresis equipment was completed. The equipment upgrades the analysis method of the cations and anions of groundwater samples.

The field work instructions for Posiva's water sampling, including instructions for groundwater sampling in the field, and sampling and analysis methods, were updated. The reliability of the analysis results with respect to, for example, isotope analyses, was monitored during the year by ordering parallel determinations from different laboratories.

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. These analyses also provide background material and basic data for future safety assessments and design of the final disposal system. In addition to spent fuel, the canister and bentonite, the studies pertained to the requirements that must be fulfilled in designing the repository and tunnels, shafts and backfilling materials, and sealing structures. The studies are conducted to a great extent under international co-operation programmes.

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. Studies are conducted to establish the degradation rate of the fuel matrix both under oxidising conditions and under reducing conditions buffered by iron. The tests conducted in Finland have shown that iron has a reducing effect on uranium.

To specify the solubility values of radionuclides so as to be more realistic, the solubility of thorium was studied in Olkiluoto groundwaters with different salinities.

The joint project launched by SKB and Posiva concerned experimental research and theoretical studies on the corrosion of copper in a saline groundwater environment. The corrosion investigations will be carried out under conditions that correspond as closely as possible to the repository conditions. With regard to the corrosion behaviour of copper, it is essential to know the length of the oxygenous period and the oxygen-consuming mechanisms of bentonite and their behaviour over time. SKB and Posiva jointly launched a project to investigate the redox conditions prevailing in bentonite and the components affecting the redox conditions of bentonite.

On the basis of current knowledge, cement might impair the performance of bentonite and consequently the use of ordinary cement in the neighbourhood of disposal holes and bentonite-based sealing structures should be limited. Any harmful effects could probably be avoided by using low-alkaline cement types (pH < 11), which are currently being developed. Posiva is studying low-alkaline cement types and their suitability for different purposes (sealing structures, grouting, shotcreting) in the repository jointly with SKB and NUMO. To date, materials and recipes have been developed, and basic testing of the grouting properties of the materials has been performed.

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 2002 concerned preliminary modelling of the geochemical balance of bentonite and the tunnel backfilling material (30% bentonite/70% crushed rock), the interface of bentonite and bedrock and the interface of the tunnel backfilling material and bedrock, and the development of this balance.

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 2000–2002, Posiva and SKB jointly studied the ability of existing models to theoretically explain the swelling pressures of bentonite measured in the tests. The studies pertained to measurements of the swelling pressures in Na bentonite as a function of the density and ionic strength of the NaCl solution. The Finnish contribution consisted of studies into the pore-water chemistry, which plays a part in the formation of swelling pressure. On the basis of the tests it can be concluded that ions present in external water penetrate into bentonite, thus reducing the swelling pressure. The results have been interpreted on the basis of different modelling alternatives. The model generated in Sweden, which assumes that some of the dissolved ions exist in ion pairs, is capable of predicting both the swelling pressure and the salinity of pore water fairly well. The approach used in Finland, in which the salinity of pore water is calculated on the basis of the microstructure of bentonite, also gives results consistent with those obtained in the above tests. The need to continue the studies will be assessed on this basis.

FEBEX

The EU's Nuclear Fission Safety programme (1994-1998) included the FEBEX project (Full-Scale Engineered Barriers Experiment), which demonstrated construction of the repository and investigated the thermohydromechanical and thermohydrogeochemical processes that occur in bentonite. The project included a full-scale test at the Grimsel Hard Rock Laboratory in Switzerland (an in-situ test), a large-scale laboratory test in Spain (a mock-up test), and laboratory investigations that supported these tests. Studies were being continued under the EU's framework programme for 2000-2003. The follow-up project includes partial completion of the in-situ test in summer 2002 and its continuation on a smaller scale, continuation of the mock-up test, and the laboratory investigations and the modelling that support them. The Spanish Ca-Mg-Na bentonite employed in the research differs in composition from the Na bentonite most commonly investigated in Finland, and thus extends the knowledge about the opportunities of using alternative bentonite types.

Posiva is taking part in the new 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. 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, the parties involved are Japan, Canada and the USA. The purpose of the project is to gather and assess the experience gained with the construction of underground characterisation facilities and with the research and tests conducted in them. In 2002, Posiva drew up a description of the assessment of the performance of engineered barriers and a report on the aspects linked with development of final disposal concepts.

GAMBIT

Development of the model that describes the migration of gas through compacted bentonite continued in the co-operation group named "GAMBIT Club". The third phase of the project consisted of the development of the model that seeks also to take account of the porosity produced through the compression of bentonite and the removal of water from the structures. The co-operation group stated, however, that the models used for interpreting the results obtained in the different gas migration tests still contained uncertainties that should be examined by supplementary tests. To acquire additional information, SKB and Posiva have in fact launched the design of a large-scale gas injection test (LASGIT). The purpose is to carry out the test at the Äspö Hard Rock Laboratory.

BENIPA

The EU project named "Bentonite barriers in integrated performance assessment (BENIPA)" completed the databases that deal with the features, events and processes (the FEPs) occurring in backfilling materials and affecting them, and the extensive literature reviews. VTT Processes acted as the leader of the subproject on crystalline rock. Migration analyses of radionuclides were carried out for both the KBS-3V concept and ENRESA's horizontal disposal concept. The REPCOM model employed in Posiva's safety analyses and ENRESA's GOLDSIM model yielded consistent results in both cases. The commercially available PC model named PORFLOW was also tested as part of the BENIPA project with good results. A working report on the use of this model for migration analyses of radionuclides in the KBS-3V and KBS-3H final disposal holes will be drawn up in 2003.

ECOCLAY

In 2002, the ECOCLAY project gathered experience and opinions about the handling of matters linked with the effects of cement in safety analyses. The ECOCLAY project will analyse the results of the inquiry in 2003. The project investigates interaction processes of bentonite and cement in the environments of clay and crystalline rock, particularly geochemical reactions, effects on the sorption of radionuclides, and coupled geochemical and migration phenomena. Posiva's contribution consists of examining the reactions and phenomena linked with the system formed by bentonite, cement and crystalline rock.

The NEA's EBS project

Groundwork was laid for the NEA's "Engineering barrier systems" project by an exhaustive inquiry, which examined requirements for the performance of engineered barriers and their handling in safety analyses. The NEA will publish a summary of the results of the inquiry in 2003. In the planning meeting of the EBS project, Posiva's proposal for the systematic management of design and performance requirements attracted extensive interest. The design and performance requirements were chosen as the topic of the first actual working meeting of the EBS project, and Posiva was asked to host the meeting.

Functioning of the bedrock as a barrier

An extensive questionnaire study was completed as the first work package in the EU project named "RETROCK", which studies the modelling methods and concepts of migration and retention in the bedrock. A summary of the results will provide a basis for the assessment of further investigation needs in accordance with opinions of the organisations operating in the different fields of nuclear waste management.

Studies into the migration phenomena continued jointly with other waste management organisations at the Äspö Hard Rock Laboratory. The tests concentrated on the system formed by several fractures or a small fracture zone. The work done in Finland concerned the modelling and interpretation of the results. The joint modelling project within the Task Force also continued. The Task Force considers extrapolation of the test results for a situation corresponding to the safety analysis. These co-operation projects are discussed below in the section entitled "The Äspö Hard Rock Laboratory".

Sorption tests and the modelling of sorption phenomena continued with a view to increasing the mechanistic and theoretical understanding of sorption. The tests concerned, for instance, the effects of the different concentrations of caesium on the retention of the tracer caesium. The kaolinite research aimed at defining the sorption mechanisms of europium and americium continued. Posiva continued to be involved in the work of the NEA's "Sorption Forum II" project, and took a decision to participate in the third phase of the TDB (Thermodynamic Data Base) project. A migration project (named KULKE) is being planned jointly with migration researchers and sorption and migration modelling engineers with a view to developing compatible and consistent experimental migration investigations and modelling methods. The project will cover experimental studies and modelling methods concerning both the near-field and the far-field. The KULKE project will form part of the Finnish nuclear waste research programme (KYT).

The joint project launched in 2001 under the direction of the Geological Survey of Finland (GTK) dealing with permafrost continued. For instance, two boreholes were drilled below the edge of the permafrost in the mine named "Lupin-Mine" in Canada. Results of the drilling, sampling and analyses will be considered during 2003.

Hydrogeochemical conditions and their relation to the prevailing flow conditions at the Olkiluoto investigation site were studied with the aid of 3D modelling. The work will be reported in 2003. The hydrogeochemical baseline was defined by updating the geochemical model where necessary. The work is being continued in 2003 and it will be reported as part of the reporting on the baseline in the summer of 2003.

Seashore landscape typical of Olkiluoto.

Biosphere studies

Guidelines for the biosphere-modelling project were laid down at the expert seminar held in December 2002. The project pertains to the biosphere of the groundwater discharge areas possibly located on dry land or of the areas that receive soil water from them. A model development project was launched jointly with SKB on the basis of the follow-up discussions of the seminar.

The international BIOPROTA project partly financed by Posiva was launched. The joint project of the nuclear waste management organisations and some official parties concentrates on establishing the key issues of biosphere modelling.

Posiva supports Studsvik Eco & Safety AB's participation in the EU's project entitled "Biosphere Models for Safety Assessment of radioactive waste disposal based on the application of the Reference Biosphere Methodology (BioMoSA)". In addition, Posiva monitored progress of the projects linked with international biosphere modelling (e.g. FASSET, BIOCLIM).

Safety analysis

Supported by Posiva, VTT Processes participated in the EU project entitled "Testing of safety and performance indicators (SPIN)", which was carried out in 2000–2002, with a view to studying optional performance and safety indicators of final disposal. VTT's contribution consisted of visualisation of the provisional and final results of the TILA-99 safety analysis (for instance, activity flows and radiation toxicity of radionuclides in the different parts of the final disposal system). In 2002, VTT was involved in drawing up the final report to be published in the EUR (European Utility Requirements) series and in making a popularised brochure about the subject.

Assessment of the disturbances caused by ONKALO continued and will be finished after completion of the assessment of the hydrological and geochemical disturbances. The assess-ment of disturbances forms part of the reporting to be submitted to STUK Radiation and Nuclear Safety Authority before construction of the ONKALO facility.

Posiva and VTT Processes have taken part it in the EU project named GASNET (a thematic network on gas issues in safety assessment of deep repositories for nuclear waste). The project assesses gas generation, the migration of gases, and their treatment in safety analyses. In November 2002, GASNET arranged an international working meeting, which presented the results of the project. The feedback received during the meeting provides a basis for GASNET's final report, which will be drawn up in 2003.

Co-operation and the exchange of information consisted, for instance, of participation in the work of the OECD/NEA and the international Crystalline Group. Within the OECD/NEA, Posiva was involved in the work of, for instance, the "Integration Group for Safety Case" (IGSC).

FINAL DISPOSAL TECHNOLOGY

Canister design

The canister design was studied jointly with SKB. The need to update the canister design report was assessed during 2002, and a decision was taken to update the report in 2003. The progress of the studies linked with the design bases, such as corrosion studies, was monitored and the importance of their results on the canister design and further on other factors was assessed. In particular, SKB and Posiva jointly pondered significance of the thinning of the copper canister wall with respect to the other factors. The integrity requirement of the canister material and joints appeared to be the most restrictive factor with respect to the thinning of the canister wall thickness. The limited scope of resolution of the inspection techniques so far causes the integrity requirement of the canister material to be rather rough, for which reason it is not possible to dimension the canister wall with smaller safety factors. The thinning of the wall from 50 mm to about 35–40 mm is considered to be a realistic target, however.

Canister sealing and inspection technology

The new test programme of electron beam welding (EB welding) was implemented in 2002. The test programme involved the welding of full-scale lids at both ends of two short copper cylinders. A spiral "labyrinth" was constructed of steel plate inside the short cylinder to represent the high gap volume that exists inside a full-scale canister. In this manner it was possible to simulate the formation of a vacuum necessary for the welding inside a closed piece to be welded. The quality of the vacuum was monitored inside the canister by means of instrumentation. The tests succeeded well in this respect. On the other hand, the welding chamber of a German welding equipment manufacturer (Steigerwald) was too small for these tests, for which reason equipment failures occurred during the tests, which partly spoiled their performance. During 2002, EB welding tests were also launched on a small plate scale with the equipment of another German welding equipment manufacturer (Präzisionstechnik GmbH). Preliminary results show that faultless EB welds can probably be made onto 50 mm copper with this equipment as well.

Development and studies of other welding methods also continued. The preliminary narrow-groove TIG welding tests, which are underway at Helsinki University of Technology, were delayed owing to equipment problems and the highly challenging task. However, reporting is anticipated in 2003. Sealing techniques, as well as other factors of the sealing technology, are being developed jointly with SKB through involvement, for instance, in the operations of SKB's canister laboratory. New Friction Stir Welding (FSW) equipment has recently been installed in SKB's welding laboratory. Plans have been made to join the copper canister lid to the casing in the encapsulation phase using the equipment. Compared with fusion welding methods, FSW gives the advantage that the joint produced consists of conditioned microgranular material, whose inspectability and corrosion properties are near the properties of hot-formed base material. Posiva will take part in the commissioning phase of the equipment as a joint project with SKB in 2003.

Concurrently with the welding tests, Posiva and SKB are jointly improving the suitability and resolution of the inspection techniques of the copper canister and welds as well as the inspection criteria utilising Finnish and foreign equipment and know-how resources. The results of the EB welding tests and copper canister hot-forming test described above were examined with the radioscopy and ultrasonic test equipment at SKB's canister laboratory.

Canister manufacturing technology

With regard to canister manufacturing technology, one of the principal subjects of development is the manufacture of the cylindrical part of the copper canister from one piece with several optional hot-forming methods. The development work was extended to also include casting of the canister billet in order to fulfil the canister quality requirements. Development work on billets was done with a view to upgrading the casting process of Outokumpu in such a manner that the oxygen content of the casting is in accordance with the specifications along the entire casting length, the micro-alloying of phosphor is more accurately controlled, the surface quality of casting is improved and the shrinkage damage caused inside the billet is minimised. Some of the development results have already been implemented in the form of equipment modifications, but a major modification of the casting system in Pori cannot be carried out until later. The castings performed have shown that even the partial modification to the casting process substantially improves the quality of the final result.

In 2002, a manufacturing test of the first seamless copper canister fitted with an integrated bottom end was conducted with the "pierce and draw" method at the pipe factory of Vallourec & Mannesmann Tubes in Germany. The final result was fairly good. A long pipe sufficient even for a canister of the BWR type was obtained with the method for the first time. An integrated bottom end was achieved at the same time. The method is extremely promising with a view to mass production as well. This time, quality problems only arose with the grain size of the integrated bottom end and with some internal material failures. The pipe factory is carrying on the development work to raise the hot-forming grade of the bottom end in the manufacturing process. The purpose is to continue carrying out similar manufacturing tests in 2003, so that the manufacturing process would become routine. This development work is also conducted jointly with SKB, which has already previously ordered several copper canisters made with the above "pierce and draw" method from the same manufacturer.

The technical and economic suitability of the alternative copper canister manufacturing methods and the equipment available for the manufacturing methods were studied further. On the basis of the studies, a new alternative manufacturing method, backward extrusion, is being examined. The

The first canister casing fitted with an integrated bottom manufactured at the factory of Vallourec & Mannesmann Tubes after pre machining.

testing of methods of the spinning type had to be abandoned, since suitable equipment was available nowhere in the world.

A joint project of Posiva and SKB concerned the manufacture of a copper canister and copper lids with open forging or more exactly die forging at a Swedish steel factory. When suitable forging equipment had been found (Scana AB), a manufacturing test was planned and performed, in which a cylinder of the canister casing was forged from a flattened and pierced copper billet. Tens of copper canister lids were also manufactured with the same equipment by the die forging of a 500-mm cylindrical billet into the lid mould. The purpose was to further improve the press tools and to forge the cylindrical billet that remained slightly short with the improved tools so as to reach the required measurements.

Development work on the canister insert continued by designing a new casting test. The casting test will be carried out at Metso Paper Oy's Rautpohja Foundry concurrently and in co-operation with SKB's similar casting tests in Sweden. Consistent quality requirements and objectives have been set for SKB's and Posiva's casting tests. The design of the casting test was launched in 2002, but the actual casting took place in early 2003. Compared with the previous casting test carried out at the Rautpohja Foundry (in 1998), the modifications were as follows:

– the stabilisation holes found in the edge zone (4 pcs.) were omitted
– casting of the bottom end (t 50 mm) was integrated
– toughness and tensile properties of the casting are sought to be improved (by subjecting the casting to an extensive destructive inspection and testing programme, whose results will be compared with the results obtained at Swedish foundries).

Design of the encapsulation plant

With regard to design of the encapsulation plant, the main objective set for 2002 was to adapt the plant to the Olkiluoto conditions. Comparison plans and cost estimates were made for the alternative locations of the encapsulation plant, i.e. location as a part of the KPA Store or location of the plant elsewhere on the island, as a part of the repository. With respect to location as a part of the KPA Store, two alternative systems of a different type were designed for the encapsulation plant: either linking the encapsulation plant with a water pool connection to the KPA Store or linking based on the use of a transfer cask. In designing both alternatives, the infrastructure on the island was utilised as effectively as possible. Transportation aspects and costs were also taken into account in the comparison. The comparison material was reported during 2002, but a final choice was not yet made.

Fuel transportation

The choice of the transfer cask type was studied as part of the design of the encapsulation plant. What is called the wet transport alternative seems better, since in this system the temperature of old spent fuel is not caused to rise, the loading and unloading operations are simpler, immediate releases are smaller in the event of an accident, etc.

Final disposal technology

In the field of final disposal technology, the focus areas in 2002 were the following:

- development and design of the groundwater control techniques;
- development of the horizontal disposal concept jointly with SKB;
- design of the research and development work on backfilling methods;
- preliminary design of the repository, focused on the facilities and systems that affect the design of ONKALO.

Co-operation with SKB was deepened, and particularly matters linked with development of the concept and the related verification were designed and implemented as joint projects. Furthermore, uncertainties linked with rock construction essential in respect of the repository were investigated jointly with the Swedish party.

Basic data for design 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. Rock behaviour models were examined and developed, considering particularly the conditions at Olkiluoto, which are characterised by anisotropy of the rock and the dependence of the deformation and strength properties on schistosity. The damage-controlled laboratory analyses performed previously for the Olkiluoto micaceous gneiss were utilised in what is called the brittle friction-cohesion material model, in which the material becomes weaker as the damage increases (non-linearity). The effect of foliation on the rock strength and deformation properties was examined with the aid of numerical modelling using particle mechanical program PFC3D. Uniaxial compression tests to be carried out at a laboratory were simulated by modelling, and the results were compared with the laboratory analyses performed for tonalite. The comparison showed that the results were similar. A report on this work was completed in 2002 in the Posiva series of reports and the results of the work were presented at two international meetings. In addition, a project was launched concerning the generation of a material model that takes the anisotropy of rock into account. The work is being implemented by making a macro for the FLAC calculation code. Furthermore, the work involves consideration of the hypotheses and limitations of the modelling methods based on different material models. The objective of the studies into rock behaviour is to produce basic data for design of the rock facilities and to make increasingly reliable assessments of the rock mechanical behaviour of the ONKALO facility and the repository.

The purpose of the work on the analysis method of fracturing is to establish the effect of fracturing on the behaviour of rock and, in particular, on the orientation and the need for bolting of the tunnels. The method can be adapted to the needs of ONKALO and the repository in such a manner that unfavourable excavation directions can already be avoided in the layout design phase and the best tunnel directions with respect to rock mechanics can be taken into account, thus minimising the need for reinforcement. A draft report on the work was drawn up during 2002, and a paper on the subject was written for the international SARA 2003 conference.

At Helsinki University of Technology, a master's thesis based on a literature survey was launched at the Laboratory of Rock Engineering. The thesis studied rock mechanical investigations carried out at underground research laboratories, concentrating mainly on the use of acoustic emission (AE) during excavation of the rock facilities. In addition, the thesis studied the experience gained with the method in monitoring measurements taken at the underground research laboratories in Sweden (HRL) and in Canada (URL). The purpose is to utilise the results obtained and the experience gained in the work for the design of ONKALO. A working report on the thesis was completed in 2002.

Design and development work aimed at controlling seepage waters in the rock facilities was launched in 2001. With respect to groundwater control, the objective is to produce basic data for a preliminary plan for the repository adapted to the Olkiluoto conditions and for the design and the preparation of contract documents of ONKALO. Within the project, the main packages of tasks include assessment of the amounts of seepage water and the feasibility for grouting, description of the geochemical and hydrogeological disturbance caused by seepage waters, development and testing of the grouting methods, and preparation of the basic plans linked with groundwater control.

A preliminary assessment of the amounts of seepage water and the feasibility of rock for grouting at the Olkiluoto disposal site was completed in 2002.

A prototype of the equipment that generates a dynamic grouting pressure was manufactured, and its functioning was tested in early 2002 by a pilot test in the boreholes drilled in the rock tunnel wall. Development of the grouting method based on a dynamic pulse has been interrupted for the time being.

Commercially available cement-based grouting materials were tested in the Technical Research Centre of Finland (VTT). Gelling occurs particularly with fine-grained grouting material compounds, and as a result the testing of their penetrability properties under laboratory conditions may be hampered. For this reason, different methods will be examined during 2003 with a view to analysing grouting cements and comparing them with the results obtained in the field.

Posiva took part in the INTE project, whose purpose is to draw up consistent domestic grouting instructions for fieldwork during 2003.

Development work on cement-based materials that generate a low pH continued as a co-operation project of Posiva and SKB on the laboratory scale. The objective is to verify that the pH of the groundwater will not rise above 11 resulting from the use of cement. During 2002, a summary was drawn up, describing the chemistry of the low-pH cement and the behaviour of the additions in cement and examining the interaction between the manufactured low-pH test pieces and the different groundwaters. Laboratory tests were also conducted to study the manufacture of the grouting mortar for rock bolts, grouting cement and binder compounds, and the properties to be achieved. The work was mainly done at CBI (Cement och Betong Institutet) and KTH in Sweden. During the project, it was detected that adding blast-furnace slag to cement was worth studying.

A working report was drawn up on the application of the observational method to the design and construction of the access route to ONKALO. The fields of application of the method include the reinforcement of rock, the sealing of rock by grouting, rock excavation using the drilling and blasting technique, and geometrical factors of the facilities to be excavated (e.g. depth of the facilities). In this study, a shaft was chosen as the access route, but the principles can also be applied to the access tunnel alternative. The report gives descriptions of the conditions, drawings and specifications defined on the basis of the preliminary investigations, which illustrate application of the method.

Posiva was involved in the planning of 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:

1) 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 purpose is to apply the linked program FLAC2D/PFC2D as a completely new one.
2) to acquire practical experience in the monitoring of rock damage using 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.
3) to demonstrate and further improve opportunities to control growth of the EDZ zone. The test will examine the effect of the backfilling pressure on the propagation of fractures.

During 2002, Posiva took part in the planning of the practical implementation of the failure test and preliminarily modelled the test by performing thermomechanical analyses with the FLAC3D program. A report on this work was completed in early 2003. The aim is to perform detailed modelling in 2003, and the actual failure test is scheduled to be conducted towards the end of 2003.

Development of the basic concepts for final disposal and verification of the feasibility of the developed technology

During 2002, Posiva and SKB jointly carried out a feasibility study project 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). The installation technique involves a concept in which the canisters and bentonite blocks packed into perforated steel drums are installed in about 200-metre-long horizontal disposal holes. Considerably less rock needs to be excavated in this concept than in the vertical disposal hole concept. Posiva's contribution, on which a working report was completed in 2002, consisted of, for example, drawing up layout designs for Olkiluoto, assessing the effects of rock factors on the orientation of the disposal hole, assessing the number and properties of structures that intersect the disposal holes, and assessing the amounts of seepage water during the construction and operation phases. The feasibility study also incorporated a preliminary performance and safety assessment. 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. A decision to launch the development programme on the basis of the feasibility study was taken at the end of 2002. The basic design of the KBS-3H concept will be performed during 2003 on the basis of the feasibility study. The principal areas of development include the drilling technique of disposal tunnels, installation of the bentonite/canister package in the tunnel, and performance of the bentonite plug planned between the packages. After the basic design, the purpose is to launch full-scale tests at the Äspö Hard Rock Laboratory, if this concept is further considered worth developing.

As for studies into the properties of buffer bentonite in 2002, 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".

The plans concerning the backfilling and sealing of the repository must be updated during 2003 for the purpose of preliminary design. The present plans have not necessarily been optimised for the Olkiluoto conditions and, when installed in accordance with the basic concept, crushed bentonite will not perform as designed if the design value is TDS 35 g/l. Optional backfilling materials were studied jointly with SKB. In spring, Posiva participated in the conference on the backfilling of repositories organised in Belgium. An optional compartmental backfilling method was demonstrated during the conference. In this method, the crushed stone sections are isolated by bentonite plugs instead of crushed bentonite to eliminate hydraulic conductivity. Towards the end of the year, SKB and Posiva planned the joint long-term repository backfilling programme, which was launched in the beginning of 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. Smectite contents of different clay types were determined in 2002, and examination of the geotechnical properties of the most promising deposits is being continued in 2003.

The Finnish Environment Institute is co-ordinating a project with a view to studying the performance of salt resistance materials especially for the needs of road and environmental construction. Friedland clay has been included in the study as a reference material. Posiva is involved in the project by monitoring the development work concerning the behaviour of materials on the national level. The geotechnical properties and, in particular, the compressibility of Friedland clay were investigated on a laboratory scale in Sweden.

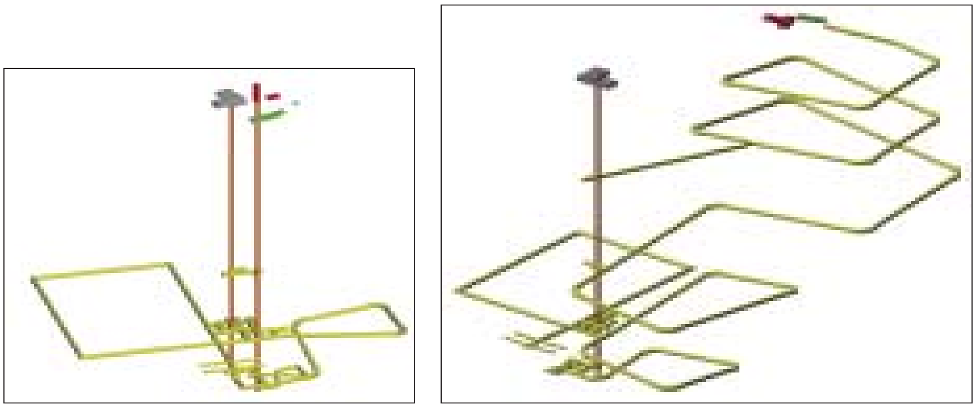
In 2002, discussions were held about the effects of permafrost on the performance of the backfilling material and the resulting processes in the repository environment. The Technical Research Centre of Finland (VTT) conducted a literature survey, which reviewed alterations in the different clay materials through the effect of the drying and shrinkage that occurs as a consequence of the freezing-thawing cycle.

Formulation of the technical plans for the repository

With regard to the repository design, the next interim target is to draw up a preliminary plan that is adapted to the Olkiluoto conditions; the plan will be completed by the end of 2003. During 2002, plans were made for the facilities of the KBS-3 type in the uncontrolled area of the repository where the access tunnel is used as the access route. The design enables the final disposal tunnels to be located on one level or two levels. The system design of the repository ensures that the design of the ONKALO facility and systems will take the future needs of the repository into account. During 2002, preliminary layout plans were drawn up for a fuel amount of 6 500 tU.

Design of the technology and systems for the operation phase

Logistic systems of the final disposal facility were examined during 2002.



The draft designs on which the evaluation of ONKALO was based: on the left, the shaft alternative and, on the right, the access tunnel alternative, which was chosen as the basis for further development.

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.

The preliminary design for ONKALO was drawn up in 2001. On this basis, the alternatives that included at least two separate access routes were considered feasible in terms of operational safety. In addition, alternatives with an access tunnel steeper than 1:10 were excluded because it was considered necessary to include the opportunity for the transport of waste packages in the access tunnel from the ground surface to the repository.

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.

In 2002, two alternative areas were investigated at Olkiluoto to establish a rough location for ONKALO. The investigated areas were an area in the south-east around borehole KR8 and an area in the north-west around borehole KR5. No decision on the location was taken.

INTERNATIONAL CO-OPERATION

Posiva monitored the work of international organisations and participated in this work through permanent group memberships and separately arranged meetings. These organisations included, in particular, the IAEA, the OECD/NEA, the European Commission and EDRAM.

Posiva attended the meetings organised by the IAEA and the meetings of the European Commission's Club of Agencies. EDRAM is a top-level forum for co-operation formed by nuclear waste management organisations. Its meeting was held in Finland in 2002.

Posiva has representatives in the NEA's nuclear waste committee (RWMC) and in the expert groups IGSC (Integration Group for Safety Case) and FSC (Forum for Stakeholders Confidence) under it. The NEA is preparing a new form of co-operation to enhance the exchange of information concerning engineered barriers and their performance. This matter was prepared at the working meeting held in Oxford in 2002. The next meeting dealing with this topic is scheduled to be held in Finland in 2003.

Posiva is a contracting party to ten projects included in the EU's fifth framework programme and, in addition, provides financing for some projects (e.g. SPIN and BENIPA). During 2002, Posiva was involved in preparation of the sixth framework programme. As part of this preparation, Posiva is involved in the Netexcel project. The parties involved in this project include the leading nuclear waste management organisations in Europe (Andra, DBE/GRS, Enresa, Nagra, Nirex, Ondraf, Posiva and SKB). The objective is to summarise and assess the research and development work on nuclear waste management that is currently underway, and to provide a basis for the design of projects integrated into the sixth framework programme.

The European Commission requested parties interested in the sixth framework programme to submit their "Expressions of Interest" to the Commission, which were closely connected with the Networks of Excellence planned for the sixth framework programme and with the integrated projects. The participants in the Netexcel project drew up a joint "Expression of Interest", in which the network of top expertise, named GEODISNET, forms an essential element. The Commission opened the first round of applications for the sixth framework programme in December, and jointly with the Netexcel group Posiva began to prepare proposals.

Posiva has made agreements on the exchange of information with the Canadian OPG, the Swiss Nagra, the Czech Rawra, the French Andra and the Japanese RWMC and Numo. Within the scope of these agreements, a research project concerning the properties of smectite clays was launched jointly with Rawra and a development project concerning the investigation methods of granitic bedrock was launched jointly with Andra. Communication with the Japanese parties was active during 2002. Posiva launched regular co-operation in the exchange of information and research with SKB and Andra, which relates to systems of the final disposal facility and to bedrock investigations. The topics considered at the meetings held during 2002 dealt mainly with the transport technology of waste packages/canisters from the ground surface to the repository along the shaft or the access tunnel.

Owing to the agreement signed in 2001, the co-operation between SKB and Posiva has extended and intensified. The co-operation with SKB has resulted in the formation of several tens of joint projects. In the field of technical design, efforts have been made to include all essential sub-areas of the final disposal system in the scope of co-operation. The content of the joint projects is described in more detail in the sections dealing with encapsulation and final disposal technology. In the field of encapsulation technology, several tests on the canister manufacturing and sealing technology were jointly carried out in 2002. A decision was taken to increase the number of tests on copper corrosion to supplement the tests that are currently being conducted in Finland. In the field of final disposal technology, the most significant joint project was the feasibility study on the horizontal disposal concept, i.e. KBS-3H. The next development phase of the concept was launched on the basis of this study. This phase will concentrate on further developing the installation and drilling technology, assessing the performance and preparing for the full-scale tests. In 2002, the long-term programme concerning the backfilling technology of the repository was also being planned jointly with SKB. A decision was taken to launch its first phase. The programme is aimed at selecting the backfilling method in 2007–2008.

Co-operation at the Äspö Hard Rock Laboratory is an essential element of the co-operation with SKB.

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 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.

At Olkiluoto, Posiva is mainly concentrating on research into the bedrock conditions and into the assessment of site-specific or site-dependent factors, while at Äspö it is performing the general testing and demonstration linked with engineered barriers and final disposal technology. Co-operation within the Äspö Hard Rock Laboratory project included bilateral (Posiva-SKB) studies, such as the "Hydrochemical Stability" project, and international EU projects, such as the "Prototype Repository" test. Within the scope of a separate agreement, Posiva was also involved in the large-scale TRUE (Tracer Retention Understanding Experiment in Block Scale) test jointly with Nirex, ANDRA, ENRESA, JNC and SKB.

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

- detailed investigation methods and their application to the modelling of the repository sites;
- testing of models that describe the barrier function of the bedrock;
- demonstration of the technology and performance of important parts of the repository concept.

The COLLOID project was launched at the Äspö Hard Rock Laboratory in 2000 to examine the stability and mobility of colloids. The purpose of the project is to establish the role bentonite plays in forming colloids, the amount of colloids in the deep groundwaters at Äspö, and the formation and migration of colloids under the groundwater conditions. Posiva became involved in the project in 2001. No actual research linked with the project was conducted during 2002, but Posiva took part in the workshop on colloids arranged by SKB in spring. Furthermore, Posiva was involved in the design and testing of colloid reactors necessary for field tests. The field tests will be launched in both the Äspö characterisation tunnel and the VLJ Repository at Olkiluoto in 2003.

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 2002, 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. Practical modelling work was conducted at the Technical Research Centre of Finland (VTT).

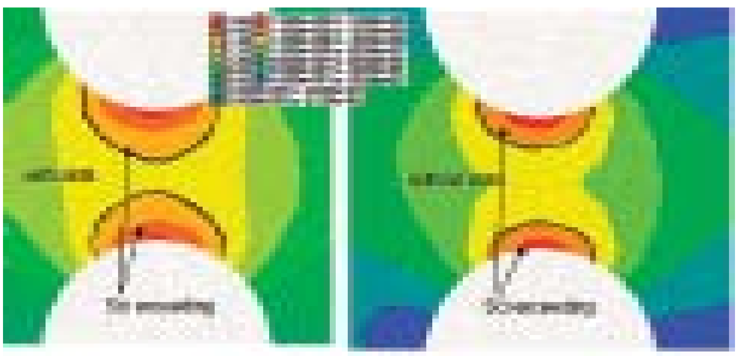
The objective of the large-scale (10-50 m) TRUE Block Scale test was to provide deeper insight into groundwater flows and the migration of the tracer in the fracture network. Posiva took part in the test by making predictions about the migration for certain parts of the test. A research group from the Technical Research Centre of Finland (VTT) was also involved in drawing up the final report on the TRUE Block Scale test by Posiva's commission.

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 2002, the purpose was to install canisters in two empty boreholes of the tunnel section of the second phase and to backfill the tunnels after instrumentation and fit the test tunnel mouth with a concrete plug. The test is behind schedule, however, since operating problems were detected with the canister heaters, and it was considered necessary to settle the matter before the installation phase. In practice, installation of the canisters and backfilling of the tunnel will take place in the spring of 2003.

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 metres, 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 planned a project linked with backfilling of the repository, which is scheduled to begin in early 2003. The backfilling programmes of both companies have many similarities and, to avoid overlapping work, plans were made to conduct some of the studies together, concerning, e.g., backfilling technology and backfilling materials. In the first phase, the parties will review the design bases and optional backfilling methods, and assess the most feasible methods for further development.

The Äspö Pillar Stability Experiment is a large-scale failure test on the pillar between two final disposal holes, which studies the behaviour of rock and the damage caused by stress. The test will be performed in a tunnel to be excavated at Äspö in 2003. During 2002, Saanio & Riekkola Consulting Engineers preliminarily modelled the failure test using the FLAC3D program.



The above picture compares the horizontal main stress calculated in accordance with the model 1.5 metres below the tunnel floor after the pillar has been heated for 120 days. There is a slot in the model shown on the left, while there is no slot in the model shown on the right. In the FLAC3D program, the maximum in-situ stress is 25 MPa.

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). 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

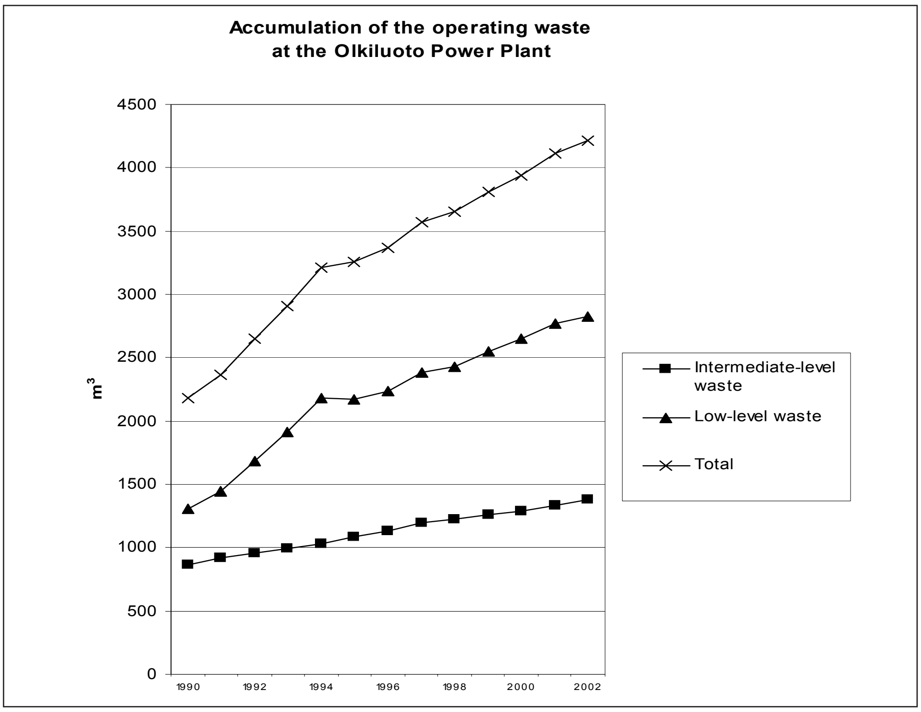
The table below shows the current status of storage and final disposal at the end of 2002. The waste has been packed into drums (200 litres each, or about 100 litres in compacted form), steel containers (1.3 or 1.4 m^3 each) and concrete boxes (net 5.2 m^3 each). In addition, Studsvik Energiteknik AB 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, used ventilation filters and other unpacked operating waste are stored at the plant units. The unpacked waste also included non-bituminised resins and waste oil. 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 2002, the amount of such waste oil was 4.5 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 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 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	6915	1383	6467		1294
Other operating waste					
– in drums	6005	1065		5880	1041
– in steel containers	455	632	2	450	625
– in concrete boxes	170	884	2	166	874
– unpacked		248			
Total		**4212**			**3834**



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 2002, 41 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. After the first test year, the average rate of gas generation corresponded to some 70 dm^3/month, whereas the value used in the FSAR safety analysis of the VLJ Repository is 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 10 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, but the small amount of reference data on the nucleotide sequence still hindered the identification with the otherwise promising method.

The studies are progressing in accordance with the research plan revised in 2002 in such a way that the focus of sampling is shifted 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 2002 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 accordance with the monitoring programme of the VLJ Repository, the pH and electrical conductivity values, redox potential, temperature and dissolved oxygen content of the groundwater have been monitored continuously before the water sampling. In 2002, field measurements were conducted at all the three groundwater stations. The results were reported in early 2003 together with the results of the groundwater analyses.

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 that the cement mortar that protected the bedrock bolts had completely lost 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. Samples will be taken and their corrosion rate under the Olkiluoto groundwater conditions will be analysed next time in the autumn of 2003. Some of the samples installed in 1998 were left in the original "Bolt 7" borehole for long-term monitoring.

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. As the storage capacity is still sufficient, a solidification plant has not yet been built.

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.

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 2002.

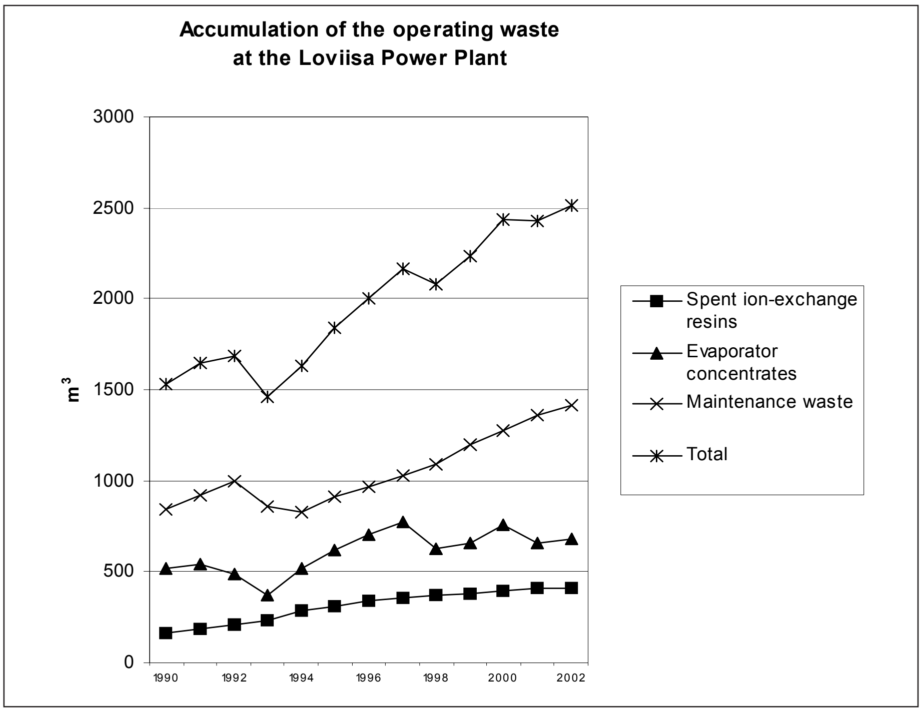
The final disposal facility

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

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	411		48	15664
Evaporator concentrates	683		65	461
Maintenance waste	329	1089		477
Total	**1423**	**1089**		**16602**



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. On the basis of the current estimate, it 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 2002, a total volume of over 900 m^3 of evaporator concentrates was treated at the caesium separation facility with 14 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 test results on the solidification products of evaporator concentrates 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 almost 20 years old.

Owing to the entry into force of the European cement standard and, at the same time, to the modification of the burning process, grinding and raw-material base of cement clinker made by the only Finnish cement manufacturer, 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. For 15 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 2002 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 was interrupted for the past year and no water sampling or analysis was thus performed. However, the hydrogeochemical studies conducted in 2001 were reported in early 2002. 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 2002.

According to the findings of 2002, 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 800 and 1 400 mS/m in the 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 140 l/min at the end of 2002. 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, 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

During the year under review, the studies pertained to groundwater flows of the repository for operating waste and to the effects of the arrangement of waste packages on the radionuclide contents of water using the CFD calculation code called FLUENT.

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 25).

DECOMMISSIONING INVESTIGATIONS

OLKILUOTO POWER PLANT

The operation of the Olkiluoto Power Plant results in the accumulation of intermediate- and low-level nuclear waste consisting of used reactor internals (e.g., control rods, core instruments, core grids, moderator tank lids and steam separators). Given that these items will be disposed of during the decommissioning of the plant, the matter is discussed in this section.

By the end of 2002, 244 control rods, 211 core instruments, two core grids and two moderator tank lids with their steam separators had accumulated at the Olkiluoto Power Plant. Used reactor internals are stored in the pools of the plant units.

The decommissioning plan for the Olkiluoto Power Plant is to be updated every five years. Next time the plan is updated in 2003. 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.

During 2002, studies were continued concerning the filling of the reactor pressure vessels with concrete before their decommissioning in one piece.

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. Calculation of the activity inventories and radiation levels of the activated decommissioning waste continued. Design was launched 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.

Preparations were made with a view to verifying the amounts of waste for the next update of the decommissioning plan.

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 2002. 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. On the basis of the study conducted in 2002 it has in fact been concluded that especially the sulphate-reducing bacteria may cause rapid corrosion of the carbon steel under reducing groundwater conditions.

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 2002, 146 used shielding elements, 199 absorbers, 188 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. During the year under review, provision continued for updating the decommissioning plan, which will be made in 2003. An operational life of 50 years was chosen as the basis for the updating. The work conducted in 2002 specified the amounts and cost estimates of the components and packages to be disposed of, launched preparation for the updating of the activity inventory, and examined the decommissioning costs of nuclear power in various countries. During the year under review, the IAEA also published the report IAEA-TECDOC-1322, Decommissioning costs of WWER-440 nuclear power plants; Posiva was involved in drawing up the report in 1999–2002.

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 (formerly owned by Fortum Technology). The research project co-ordinated by Posiva concerns both the operating waste and decommissioning waste management. The results will be used for the performance assessments of the final disposal of operating and decommissioning waste. 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 the accelerated laboratory conditions. Special emphasis will be placed on establishing the most durable concrete compositions under the prevailing conditions that will meet the requirements set for the lifespan.

The field and laboratory tests were begun in 1998. During 1999-2002, the research 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 also carried out. In 2002, microbes were also analysed during the field test sampling from the concrete test samples and water. The concrete test samples were washed owing to their black deposits. The black deposits of the test samples contained sulphate-reducing bacteria (SRB). On the other hand, very few SRB were detected in the water samples. 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. The tests will continue in accordance with Posiva's R&D Report published in 2000.

REPORTING, COMMUNICATIONS AND CONTACTS

A total of seven reports were published in the Posiva series of reports in 2002. 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 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.

With regard to Posiva's communications during the year under review, the major issues related to the final disposal of spent nuclear fuel from the fifth nuclear power plant unit and to the choice of an access tunnel concept for the implementation method of the access route to the underground rock characterisation facility, ONKALO. The progress made in the final disposal project in Sweden was also monitored, and information about it was provided at a press conference organised jointly with SKB at Olkiluoto.

International interest in Finland's final disposal project continues to be fairly extensive. During the year under review, 64 groups visited Olkiluoto to become acquainted with the nuclear waste management operations. More than 70% of the visitors were foreigners.

A survey of the initial situation with a view to enhancing Posiva's communications was launched during the year under review. The enhancement is based on the significant changes that have taken place in the Company's operating environment, such as the ratification of the decisions in principle concerning final disposal and the centralisation of Posiva's operations at Olkiluoto in Eurajoki. The survey of the initial situation in communications launched during the year under review concerned the views of the principal stakeholder groups of the final disposal project, the residents in the Eurajoki area and the Company personnel about communications and its improvement needs. The survey of the initial situation supports the long-term planning of Posiva's communications, and the survey results can be used in the future in setting the targets for communications.

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. The favourable decision rendered on the Yucca Mountain final disposal project in the USA was the most significant step forward in this field. 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.

CO-OPERATION PARTNERS

List of research institutes, universities and consultants engaged in nuclear waste management operations in 2002

AECL (Canada)
Alan Auld Associates (United Kingdom)
ALARA Engineering AB (Sweden)
Astrock Oy
Australian National University (Australia)
Ayotte Consulting and Management Services (ACMS) (Canada)
BNL Euro RSCG
Computer-aided Fluid Engineering AB (Sweden)
Conrox Ab (Sweden)
Consulting Engineers Esko Hämäläinen
Consulting Engineers Paavo Ristola Ltd
Contesta Oy
Diskurssi Oy
EnvirosQuantiSci (United Kingdom)
EP-Logistics Oy
Evata Finland Oy
Finnish Consulting Engineers Ltd
Finnish Environment Institute
Finnish Forest Research Institute
Parkano Research Station
Finnish Geodetic Institute
Fintact Oy
FM-Kartta Oy
Fortum Nuclear Services Oy
Fortum Engineering Oy
Gascoyne Geoprojects Inc. (Canada)
GEA Consulting (Sweden)
Geokeskus Oy
Geological Survey of Finland (GTK)
Espoo Unit
Geoservice Centre
Kuopio Unit
Geopros Oy
Golder Associates Inc. (Sweden)
Gridpoint Finland Oy
G.R. Simmons & Associates Consulting Services Ltd (Canada)
Helsinki University of Technology
Inspecta Testing Oy
Integrity Corrosion Consulting Ltd (Canada)
JA Streamflow AB (Sweden)
Kaisaniemen Dynamo Oy
Kalliosuunnittelu Oy Rockplan Ltd (KSOY)
Karinta Consulting Ab (Sweden)
Kivitieto Oy
Laine & Fire Safety Office Ltd
Lapela Oy
Libenter Oy
Metsätähti Ltd.
Outokumpu Engineering Services Oy
Outokumpu Mining Oy
Outokumpu Poricopper Oy
PRG-Tec Oy
Ramse Consulting Oy
Research Center Vinco Ltd
Robertson Geologging Ltd (United Kingdom)
Rock Engineering Consultants (United Kingdom)
Rollcon Oy
Saanio & Riekkola Consulting Engineers
Safety Assessment Management (SAM) (United Kingdom)
Safram Oy
Serco Assurance (United Kingdom)
SF GeoLogic AB (Sweden)
SKB International Consultants AB (Sweden)
Streamflow AB (Sweden)
Studsvik Scanpower Ab (Sweden)
Suomen Malmi Oy
Suomen Paprico Oy/Viestintä-Paprico Oy
Suomen Teknohaus Oy
Svensk Kärnbränslehantering AB (SKB) (Sweden)
Swedish Corrosion Institute (Sweden)
SwedPower AB (Sweden)
Tampere University of Technology
Laboratory of Engineering Geology
Tauno Nissinen Consulting Engineers Ltd
Technical Research Centre of Finland (VTT)
VTT Biotechnology
VTT Building and Transport
VTT Industrial Systems
VTT Processes
TVO Nuclear Services Oy
UK Nirex Ltd
University of Helsinki
Department of Chemistry
University of Jyväskylä
Department of Physics
Vesihydro Oy
Vibrometric Oy
Water and Environment Research of South-West Finland
Weizmann Institute of Science (Israel)

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, and that the quality system complies with the principles of the international ISO 9001 standard.

In 2002, the upgrading of the operating system continued in the direction of the ISO 9001:2000 standard, also taking the requirements of the environmental standard into account. Furthermore, studies pertaining to the significance of and opportunities for the safety culture in Posiva's operations were conducted. These studies were a continuation of the upgrading of the safety culture launched in 2001.

During the year under review, 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 subcontracting and the quality of field measurements and investigations. The auditing of subcontracting pertained to compliance with the regulations. Furthermore, the results of the audits gave ideas to further enhance the operations. In the auditing of the field measurement and investigation operations, the key areas were subcontracting, calibration of the measuring equipment, quality assurance of the measurements and investigations, and quality assurance linked with the operation and maintenance of the measurement database.

The capability of some sub-suppliers to fulfil the technical, economic, quality and environmental requirements was assessed during 2002. 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 an inspection visit.

Instructions with a view to assuring the quality of research, development and design work were specified. The planning of an instruction manual for construction of the ONKALO facility continued.

To enhance expertise, training was given on the basis of the studies into the personnel's know-how and training needs conducted in 2001. Besides professional training, the personnel were given common training in operating systems and improvement of the work community. Induction training was given to new Posiva employees. Annual development discussions were held according to plan.

COSTS

RESEARCH

The total cost of the nuclear waste management research programme was some EUR 10.8 million. Cost estimates for the research programme in 2002 were about EUR 10.9 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 2002

Research area	Costs (EUR million)
Planning, co-ordination, information activities and general studies	0.7
Management of spent fuel and high-level waste	9.6
Management of intermediate-level and low-level waste	0.2
Decommissioning and decommissioning waste	0.2
Total	10.8

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 693.2 million was assessed as the fund target for TVO in 2002, the corresponding amount for Fortum being EUR 515.2 million.

A liability amount of EUR 732.2 million was confirmed for TVO's nuclear waste management at the end of 2002 and, based on this amount, a fund target of EUR 732.2 million was confirmed for 2003. For Fortum, a liability amount of EUR 545.1 million was confirmed and, accordingly, a fund target of EUR 545.1 million for 2003.

LIST OF REPORTS 2002

POSIVA 2002-01
Copper corrosion under expected conditions in a deep geologic repository
Fraser King, Integrity Corrosion Consulting Ltd, Calgary, Canada
Lasse Ahonen, Geological Survey of Finland
Claes Taxén, Swedish Corrosion Institute, Stockholm, Sweden
Ulla Vuorinen, VTT Chemical Technology
Lars Werme, Svensk Kärnbränslehantering Ab, Stockholm, Sweden
January 2002
ISBN 951-652-108-8

POSIVA 2002-02
Estimation of rock movements due to future earthquakes at four candidate sites for a spent fuel repository in Finland
Paul La Pointe
Golder Associates Inc., Washington, USA
Jan Hermanson
Golder Associates AB, Sweden
February 2002
ISBN 951-652-109-6

POSIVA 2002-03
Fracture calcites at Olkiluoto – Evidence from Quaternary Infills for Palaeohydrogeology
Seppo Gehör, Kivitieto Oy
Juha Karhu, University of Helsinki
Aulis Kärki, Kivitieto Oy
Jari Löfman, VTT Processes
Petteri Pitkänen, VTT Building and Transport
Paula Ruotsalainen, TUKES
Olavi Taikina-aho, Kivitieto Oy
February 2002
ISBN 951-652-110-X

POSIVA 2002-04
Structure and geological evolution of the bedrock of southern Satakunta, SW Finland
Seppo Paulamäki, Markku Paananen, Seppo Elo
Geological Survey of Finland
February 2002
ISBN 951-652-111-8

POSIVA 2002-05
Rock strength and deformation dependence on schistosity – Simulation of rock with PFC3D
Toivo Wanne
Saanio & Riekkola Oy
June 2002
ISBN 951-652-112-6

POSIVA 2002-06
Solubility of thorium in 0.1 M NaCl solution and in saline and fresh anoxic reference groundwater
Jussi Jernström
University of Helsinki
Laboratory of Radiochemistry
Ulla Vuorinen
VTT Processes
Martti Hakanen
University of Helsinki
Laboratory of Radiochemistry
August 2002
ISBN 951-652-113-4

POSIVA 2002-07
Establishing baseline conditions and monitoring during construction of the Olkiluoto URCF access ramp
Bill Miller, John Arthur, Jordi Bruno, Paul Hooker, Phil Richardson, Cynthia Robinson, David Arcos
EnvirosQuantiSci, Melton Mowbray, UK
Julia West
British Geological Survey, UK
December 2002
ISBN 951-652-114-2

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