International
Progress Report

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Äspö Hard Rock Laboratory

Status Report
October – December 2001

December 2001

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co
Box 5864
SE-102 40 Stockholm Sweden
Tel +46 8 459 84 00
Fax +46 8 661 57 19

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Laboratory

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Summary

Investigations and experiments

The barrier function of the host rock

The CHEMLAB probe has been constructed and manufactured for validation experiments in situ at undisturbed natural conditions. The second experiments with migration of actinides, lasting three months, was started in December**.**

The Matrix Fluid Chemistry experiment has the aim to determine the origin and age of matrix fluids and to establish to what extent diffusion processes have affected the composition of matrix fluid. In October the planned sampling from the sectioned-off borehole was made.

The Stability and Mobility of Colloids (SMC) Project has been initiated to investigate the potential for colloidal transport in natural groundwater. Studies aim at investigation of the colloid concentration in the Äspö HRL and the role of bentonite clay as a source for colloid generation. In October –November the sampling took place at several places along the Äspö ramp, with the expected result that the naturally occuring amount of colloids is very low in Äspö groundwater.

A set of microbiology research tasks for the performance assessment of high level nuclear waste (HLW) disposal has been identified. A test site at the 450 m level, called the MICROBE site, is in operation consisting of three core drilled holes intersecting water conducting fractures. Each bore hole is equipped with metal-free packer systems that allow controlled sampling from each fracture. The laboratory at 450 m level is still under development but an early biofilm build-up test has been conducted during the period.

Technology and function of important parts of the repository system

The Prototype Repository experiment is located in the last part of the TBM tunnel at the 450 m level and will include 6 deposition holes in full scale. The aims of the Prototype Repository are to demonstrate the integrated function of the repository components and to provide a full-scale reference for comparison with models and assumptions. Physical activities in the Prototype Repository tunnel have been the backfilling of the tunnel and successive installation of the instruments in the backfill. Before Christmas the inner plug was cast, whereby the inner section was successfully in place. The malfunction of the insulation in the electrical system to the heaters in the Canister Retrieval Test was later in 2002 discovered to be a fact also in the Prototype Repository.

The Backfill and Plug Test comprises full scale testing of backfill materials, filling methods, and plugging. The entire test set-up with backfilling, instrumentation and building of the plug was finished late September 1999 and the wetting of the 30/70 mixture through the filter mats started in November 1999. Water filling of the outer test sections (0/100) has continued and is still not completed. The plug has been post-grouted for final tightning and an increased water pressure is planned for speeding up the saturation process. Water saturation, water pressure and swelling pressure in the backfill and water pressure in the surrounding rock have been continuously measured

and recorded. Only the sensors placed in the first layers (about 200 mm from the mat) in the 30/70 section have been clearly water saturated, while the sensors 600 mm away indicate an increased water content.

Canister Retrieval Test aims at demonstrating the readiness for recovering of deposited canisters also after the time when the bentonite has swelled. The heaters as well as the system for artificial saturation were turned on in October 2000 and have been running during the period as planned. The temperature at mid-hight on the surface of the canister has been steadily at 94°C. Saturation of the buffer has been going on as planned. On November 3rd it was discovered that the insulation of all cables had a malfunction giving too low resistance to earth. A major investigation programme was launched in order to find the cause of the malfunction.

The Long Term Tests of Buffer Material aims to validate models and hypotheses concerning long-term processes in buffer material. Five bore holes have been filled with highly compacted bentonite and one heater. The bentonite parcels are equipped with instruments, bacteria, copper coupons and with radioactive tracers. The intended test temperatures of 90°C in the standard type parcels and 130°C in the adverse condition parcels have been reached. Saturation and heating has been going on. Parcel A0 (A=adverse conditions) was retrieved, samples taken and sent for analysis.

International Co-operation

Eight organisations from seven countries are currently (April 2002) participating in the Äspö HRL.

The EC project CROP, a Thematic Network project, focused the work on finalisation of the first two Work Packages, collecting data for Country Annexes on repository concepts and experimental procedures in URLs. Final drafts of EC deliverables were presented to the participants for review, discussion and approval. The work in Work Package 3 on models, codes and model application was initiated.

Facility Operation

The status of the facility is good.

The Äspö road and parking lot have been re-coated and completed with a layer of fine gravel mixed with bitumen.

A project for hands-free registration of underground visits is in progress. The main objective is to improve the safety in case of any incident/accident. After implementation the system will also help in energy conservation as the ventilation system then can operate in accordance to the need of personnel, equipment and vehicles actually being underground

Information activities

During the period October-December, 2001, 2 386 persons (2821 during last period) visited the Äspö HRL. These persons represented the public, municipalities where SKB performs feasibility studies, teachers, students, politicians, journalists and visitors from foreign countries. 1 102 persons (779 last period) represented the six municipalities where SKB has performed feasibility studies.

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1 General

The scientific investigations within SKB's research programme are part of the work conducted to develop and test methods for identification and characterisation of suitable repository sites, design of a deep repository as well as excavation and operation of such a repository. This requires extensive field studies of the active processes and properties of the geological barrier, the interaction between different engineered barriers and host rock, means of construction, and ways of disposal and backfilling. The Äspö Hard Rock Laboratory (Äspö HRL) provides an opportunity for research, development and demonstration of these issues in a realistic setting. Important tasks for the Äspö HRL are:

- to increase scientific understanding of the safety margins of the deep repository,
- to test and verify technology that provide cost reductions and simplifies the repository concept without compromising safety,
- to demonstrate technology that will be used in the deep repository,
- to provide experience and training of staff, and
- to inform about technology and methods to be used in the deep repository.

A set of Stage Goals have been defined for the work at the Äspö HRL. The Stage Goals were redefined in the SKB Research Development and Demonstration (RD&D) Programme 95, which was submitted to the Swedish Authorities in September 1995. An updated program RD&D Programme 1998 was submitted in September 1998. This programme is the basis for the planning and execution of the current work. The recent RD&D Programme 2001 (submitted to the Swedish Authorities in September 2001) suggests a continuation of the work along the plan that was outlined in 1995 and 1998.

The Stage Goals for the Operating Phase of the Äspö HRL are as follows:

1 Verify pre-investigation methods

demonstrate that investigations on the ground surface and in bore holes provide sufficient data on essential safety-related properties of the rock at repository level.

2 Finalise detailed investigation methodology

refine and verify the methods and the technology needed for characterisation of the rock in the detailed site investigations.

3 Test models for description of the barrier function of the host rock

further develop and at repository depth test methods and models for description of groundwater flow, radionuclide migration, and chemical conditions during operation of a repository and after closure.

4 Demonstrate technology for and function of important parts of the repository system

test, investigate and demonstrate on full scale different components of importance for the long-term safety of a deep repository system and to show that high quality can be achieved in design, construction, and operation of system components

2 Methodology for detailed characterisation of rock underground

Background

A programme for detailed characterisation will be devised before detailed characterisation is initiated on a selected site and construction of the surface and underground portions of the deep repository is commenced. In conjunction with the driving of the Äspö tunnel, several different investigation methods have been tried and the usefulness of these methods for detailed characterisation for a deep repository is being evaluated. Preliminary experience from Äspö shows that there is a need for refinement of these methods to enhance the quality of collected data, boost efficiency and improve reliability in a demanding underground environment. Furthermore, the detailed characterisation programme needs to be designed so that good co-ordination is obtained between rock investigations and construction activities.

The objectives are:

- to try out existing and new methods to clarify their usefulness for detailed characterisation. The methods to be tested are chosen on the basis of their potential use within the detailed characterisation programme,
- to refine important methods in a detailed characterisation programme to enhance data quality, efficiency and reliability.

Detailed characterisation will facilitate refinement of site models originally based on data from the ground surface and surface boreholes. The refined models will provide the basis for updating the layout of the repository and adapting it to local conditions. Due to the heterogeneity of the rock, the layout of the repository needs to be adapted to the gradually refined model of rock conditions. This approach has a long tradition in underground construction and it should be used also for a deep repository.

Results

No new results.

Planned work

A report on underground investigation methods used during the construction phase of the Äspö HRL will be published during mid 2002. The report will describe the different methods used with regard to instrument or other working tools and measurement methodology. Resolution and accuracy of the measured values as well as general aspects of errors will be discussed. The evaluation part will address the usefulness and feasibility of the methods. Recommendations on possible modifications etc. will also be given.

3 Test of models for description of the barrier function of the host rock

3.1 Natural Barriers

General

The Natural Barriers in the deep geological repository for radioactive wastes are the bedrock, its properties and the on-going physical, chemical and biological processes in the rock. The function of the natural barriers as part of the integrated disposal system can be presented as *isolation, retention* and *dilution*. The common goal of the experiments within Natural Barriers is to increase the scientific knowledge of the safety margins of the deep repository and to provide data for performance and safety assessment calculations. The strategy for the on-going experiments on the natural barriers is to concentrate the efforts on those experiments which results are needed for the planning of the future candidate site investigations, planned to start in 2002.

3.2 Radionuclide retention

Background

The retention of radionuclides in the rock is the most effective protection mechanism if the engineering barriers have failed and the radionuclides have been released from the waste form. The retention is mainly caused by the chemical properties of the radionuclides, the chemical composition of the groundwater, and to some extent also by the conditions of the water conducting fractures and the groundwater flow.

Laboratory studies on solubility and migration of the long lived nuclides e.g. Tc, Np, and Pu indicate that these elements are so strongly sorbed on the fracture surfaces and into the rock matrix that they will not be transported to the biosphere until they have decayed. In many of these retention processes the sorption could well be irreversible and thus the migration of the nuclides will stop as soon as the source term is ending.

Laboratory studies under natural conditions are extremely difficult to conduct. Even though the experiences from different scientists are uniform it is of great value to demonstrate the results of the laboratory studies in situ, where the natural contents of colloids, organic matter, bacteria, etc. are present in the experiments. Laboratory investigations have difficulties to simulate these conditions and are therefore dubious as validation exercises. The CHEMLAB borehole-laboratory has been constructed and manufactured for validation experiments in situ at undisturbed natural conditions. Figure 3-1 illustrates the principles of the CHEMLAB 1 and CHEMLAB 2 units.

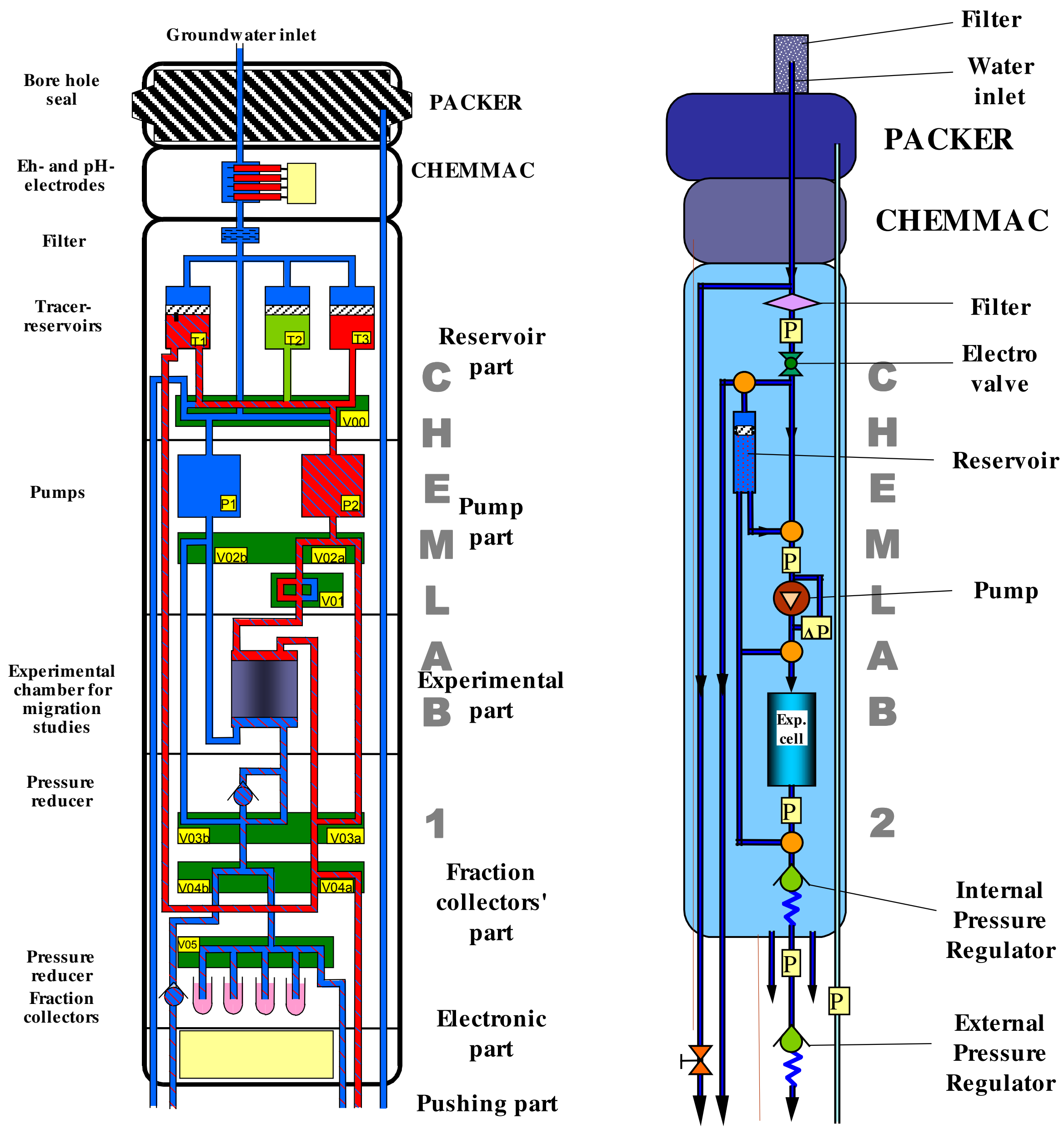

Figure 3-1 *Schematic illustration of CHEMLAB 1 and 2.*

Objectives

The objectives of the Radionuclide Retention (CHEMLAB) experiments are:

- To validate the radionuclide retention data which have been measured in laboratories by data from in situ experiments in the rock
- To demonstrate that the laboratory data are reliable and correct also at the conditions prevailing in the rock
- To decrease the uncertainty in the retention properties of relevant radionuclides

Experimental concept

CHEMLAB is a borehole laboratory built in a probe, in which migration experiments can be carried out under ambient conditions regarding pressure and temperature and with the use of the formation groundwater from the surrounding rock.

Initially one “all purpose” unit was constructed in order to meet any possible experimental requirement. This unit CHEMLAB 1 has been used for the “diffusion in bentonite” experiments and will now be used for similar experiments including the effects of radiolysis. Others to follow are:

- Migration from buffer to rock
- Desorption of radionuclides from the rock
- Batch sorption experiments

The CHEMLAB 2 unit is a simplified version of CHEMLAB 1, designed to meet the requirements by experiments where highly sorbing nuclides are involved. These are:

- Migration of redox sensitive radionuclides and actinides
- Radionuclide solubility
- Spent fuel leaching

New results

The second experiment with actinides was started in December and will be completed in February.

Planned work

The third actinide migration experiment is scheduled to start as soon as the previous experiment has been evaluated.

Experiment with radiolysis is also planned to start in March in CHEMLAB 1.

3.3 Matrix Fluid Chemistry

Background

Knowledge of matrix fluids and groundwaters from rocks of low hydraulic conductivity will complement the hydrogeochemical studies already conducted at Äspö, for example, matrix fluids are suspected to contribute significantly to the salinity of deep formation groundwaters. It will also provide a more realistic chemical input to near-field performance and safety assessment calculations, since deposition of spent fuel will be restricted to rock volumes of similar hydraulic character.

Objectives

The main objectives of the task are:

- to determine the origin and age of the matrix fluids,
- to establish whether present or past diffusion processes have influenced the composition of the matrix fluids, either by dilution or increased concentration,
- to derive a range of groundwater compositions as suitable input for near-field model calculations, and
- to establish the influence of fissures and small-scale fractures on fluid chemistry in the bedrock.

Experimental concept

The experiment has been designed to sample matrix fluids from predetermined, isolated borehole sections. The borehole was selected and drilled on the basis of: a) rock type, b) mineral and geochemical homogeneity, c) major rock foliation, d) depth, e) presence and absence of fractures, and f) existing groundwater data from other completed and on-going experiments at Äspö. Special equipment has been designed to sample the matrix fluids ensuring: a) an anaerobic environment, b) minimal contamination from the installation, c) minimal dead space in the sample section, d) the possibility to control the hydraulic head differential between the sampling section and the surrounding bedrock, e) in-line monitoring of electrical conductivity and uranine content, f) the collection of fluids (and gases) under pressure, and g) convenient sample holder to facilitate rapid transport to the laboratory for analysis.

Migration of matrix fluids will be facilitated by small-scale fractures and fissures. Therefore the matrix fluid chemistry will be related to the chemistry of groundwaters present in hydraulically-conducting minor fractures ($K= 10^{-10}$-$10^{-9}ms^{-1}$), since it will be these groundwaters that may initially saturate the bentonite buffer material.

New developments and results

Since the last status report the most important developments have been the sampling of the matrix groundwaters from the sectioned-off borehole KF0051A01 on October 15/16 and the Final Matrix Fluid Workshop held on October 17/18 in Stockholm.

<u>Sampling of matrix fluids</u>

The pressure monitoring curves for borehole sections 1-4 prior to sampling, shown in Figure 3-2, indicate that Section 4 (blue) in the Äspö diorite (previously sampled 2 years ago in December 1999) appears to have recovered, and Section 2 (green) in the Ävrö granite (unopened since the commencement of the experiment 3.5 years ago) continues to show a steady, although small, increase with time. Section 1 (red) also opened in December 1999 shows no change as might be expected because of the large borehole section volume involved, and Section 3 (yellow), located between the packed-off sections 2 and 4, shows a very slight increase over the 3.5 year period.

Sampling resulted in the following:

Section 1: No water or gas; underpressure in section
(Previous sampling in Dec. 1999 gave only gas)

Section 2: Some gas and small water volume (34.74 mL); only water sampled

Section 3: Gas and water (321.19 mL); both gas and water sampled

Section 4: Gas and water (195.02 mL); both gas and water sampled
(Previous sampling in Dec. 1999 gave 160 mL)

(Note: H_2S was detected from sections apart from Section 1)

Adequate water was collected from Sections 3 and 4; Section 2 produced a small but important volume which took several attempts to remove using evacuated glass vials. Surprisingly Section 1 was underpressurised and nothing was collected.

Of the three water samples, only Section 2 had to be prioritised as to what species to be analysed; major cations and anions, stable isotopes (^{18}O, ^{2}H), strontium isotopes (^{86}Sr, ^{87}Sr) and ^{37}Cl. Section 3 and 4 samples additionally will include: pH (field and laboratory), alkalinity, ^{13}C and ^{14}C, and ^{10}B. Other analyses will include gas samples (normal suite: N_2, O_2, CO_2, H_2, CH_3, CH_4 etc.) from Sections 3 and 4, and Section 3 also will be checked for microbe activity.

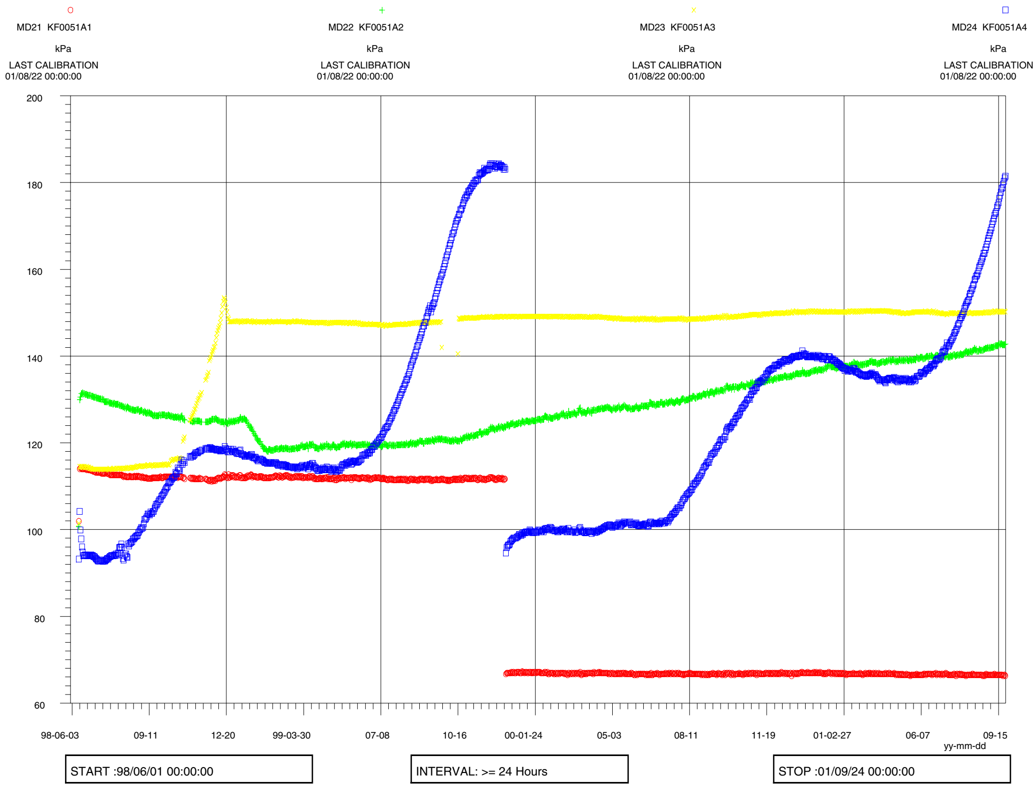

Figure 3-2 *Pressure monitoring curves for each of the four isolated borehole sections:1 (red), 2 (green), 3 (yellow) and 4 (blue). Sections 2 and 4 are specially equipped for matrix fluid sampling.*

Initial impressions from the *in-situ* and laboratory measurements of pH and alkalinity is that the samples may not differ too much from the Section 4 water sampled in December 1999.

<u>Final Matrix Fluid Workshop</u>

The Final Matrix Fluid Workshop was held in Stockholm to provide a last opportunity to present the status of on-going projects and to receive input from the participants prior to the conclusion of the project scheduled for December 31, 2001. Minutes of the Workshop will be compiled and published as an ITD report.

In addition to concluding the various projects, a series of topics were identified for potential future consideration following final reporting of the project in June, 2002:

a) Äspö Diorite fracture: Small-scale in- and out-diffusion studies

University of Bern, University of Waterloo, Terralogica: Depending on the outcome of a Pilot Study (presently being reported), plus available resources, a complete profile suite of samples could be analysed and interpreted.

b) *Matrix block: Large-scale in- and out-diffusion profile using helium*

For some time Nagra has shown interest in carrying out He in- and out-diffusion studies on a crystalline rock profile – along similar lines to the Mont Terri clay experiment which was very successful (^{37}Cl, ^{11}B and U-decay series measurements should also be carried out).

c) Fluid inclusions

Universities of Bern, Waterloo and Stockholm; Kivitieto: Potential to further use laser ablation techniques to characterise selected fluid inclusions of importance

- since theoretical diagrams are commonly used to estimate salinity, usually expressed as molar equivalent NaCl, it would be particularly interesting to know the exact composition of the important fluid inclusion phases

d) Permeability test

University of Waterloo: How long should the experiment continue? Should a post-mortem be carried out on the core? In particular, is there any evidence of mineral coatings having formed on the core surface which may represent evaporated matrix fluid compositions?

e) Future use of the matrix borehole

- Geosigma: Proposal to increase the hydraulic understanding of the matrix borehole
- Universites of Bern and Waterloo: Leaching experiment to be compared with laboratory leaching studies

This study is considered important since it will provide direct input into characterising/confirming the hydraulic nature of the matrix rock surrounding the sampled borehole.

Present status of reporting

Fluid inclusions

- University of Waterloo: Completed ITD
- University of Bern: Completed ITD
- Kivitieto and Stockholm University: Final preparation for ITD publication
- Stockholm University: Synthesis ITD draft being circulated for commment

Crush/leach experiments

A synthesis ITD of the work carried out by the Universities of Bern and Waterloo is being prepared by the University of Bern (available January, 2002)

Hydraulic character of the rock matrix

- Geosigma: Completed ITD

Äspö Diorite fracture: In- and out-diffusion studies (Pilot Study)

- Terralogica: Final preparation for ITD.

On-going studies

Permeability experiment

- University of Waterloo: Still on-going after 2 years and still no indication of matrix fluid extraction.

Post-mortem to be carried out on the drillcore in the near-future; may be supported by Ontario Power Generation.

Planned activities

Sampling and analysis of matrix fluid

Analysis and quality control of the sampled matrix groundwater data are presently on-going; full results are expected by February 2002.

International interest

Nagra/University of Bern are interested in conducting an in- and out-diffusion experiment in crystalline rock along similar lines to that conducted in clay bedrock at Mont Terri, Switzerland. They wish to coordinate with future drilling activities at Äspö to sample a rock core along a profile through a tight 'matrix rock' bedrock section.

Ontario Power Generation, Canada have shown interest in participating in some of the future activities listed above under section 1.4.4

Timetable

- Final reporting of project is scheduled for June, 2002.

3.4 Colloids

Background and objectives

Colloids are small particles in the size range 10^{-3} to 10^{-6} mm these colloidal particles are of interest for the safety of spent nuclear fuel because of their potential for transporting radionuclides from a faulty repository canister to the biosphere.

SKB has for more than 10 years conducted field measurements of colloids. The outcome of those studies performed nationally and internationally concluded that the colloids in the Swedish granitic bedrock consist mainly of clay, silica and iron hydroxide and that the mean concentration is around 20-45 ppb which is considered to be a low value (Laaksoharju et al., 1995). The low colloid concentration is controlled by the large attachment factor to the rock which reduces stability and the transport capacity of the colloids in the aquifer.

It has been argued that e.g plutonium is immobile owing to its low solubility in groundwater and strong sorption onto rocks. Field experiments at the Nevada Test Site, where hundreds of underground nuclear tests were conducted, indicate that plutonium is associated with the colloidal fraction of the groundwater. The $^{240}Pu/^{239}Pu$ isotope ratio of the samples established that an underground nuclear test 1.3 km north of the sample site is the origin of the plutonium (Kersting et al., 1999). Based on these results SKB decided year 2000 to initiate the project COLLOID at Äspö-HRL to study the stability and mobility of colloids at prevailing groundwater conditions. One important aspect was to study the potential for bentonite clay (surrounding the copper capsules) to generate colloids. The objectives of the colloid project is to:

1) Study the role of bentonite clay as a source for colloid generation
2) Verify the colloid concentration at Äspö-HRL
3) Investigate the potential for colloid formation/transport in natural groundwater concentrations.

Experimental concept

The experimental concepts for the Colloid project are: laboratory experiments, background measurements, borehole specific experiment and possibly fracture specific experiment. Theses concepts are described below:

<u>Laboratory experiments</u>:

The role of the bentonite clay as a source for colloid generation at varying water salinities has been studied in laboratory experiments conducted at KTH (Royal Institute of Technology, Stockholm). The results from the laboratory test indicate that the bentonite colloid formation is strongly correlated with the ionic strength of the solution. Very low concentration of colloids formed in suspensions with ionic strengths 0.1 and 1 M. This is valid for experiments both with dry (Figure 3-3) and wet prepared bentonite.

At 0 and 0.01 M colloids were formed in the experiments with wet prepared bentonite. In the case with dry prepared bentonite where the solutions are shaken initially, the sedimentation is slow and no measurement was possible. At high ionic strength the colloid formation is minor. At ionic strength 0.01 M where colloid formation is favourable the colloid formation seems to increase when using a temperature of 60 ° C for the solution compared with a solution of 20 ° C. The experiment has been extended to investigate in detail the chemical changes and the size distribution associated with colloid generation. These results will be compared with the parallel experiments conducted at the company Claytec. In addition a “washed” bentonite is used in order to avoid interference from the clay on the solution. The chemical changes in the solution and formation of small particles are studied in detail during the time period August-December 2001. The reporting of these experimental results is ongoing.

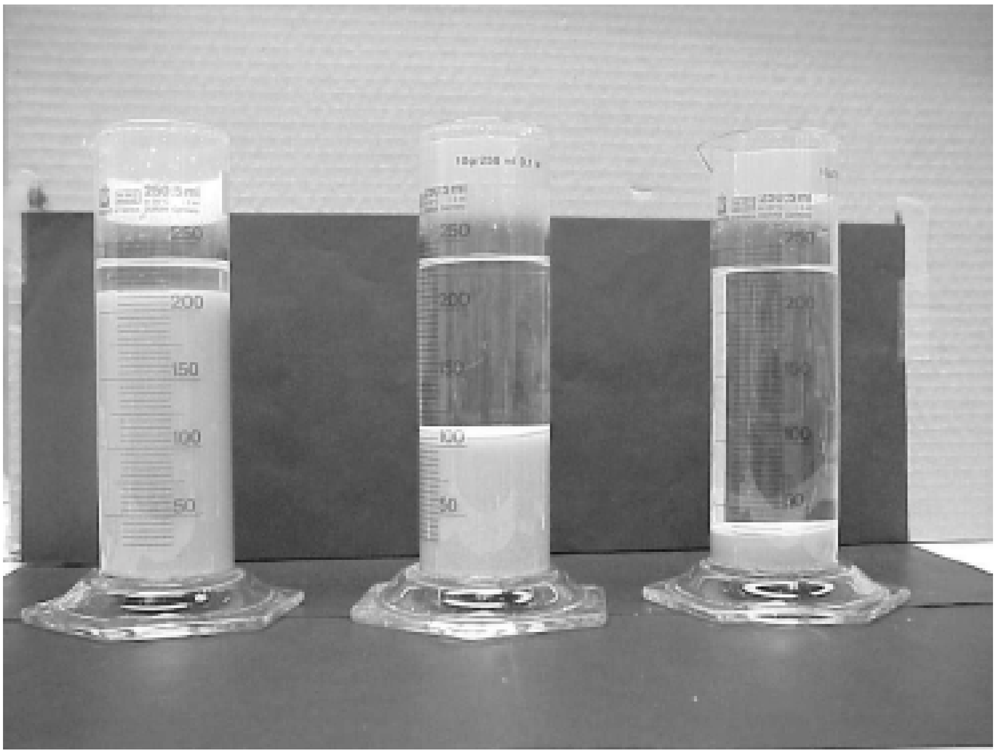

Figure 3-3 *The salinity of the water affects the colloid generation. The experiment show different degrees of sedimentations of bentonite clay dependent of the ion content in the water. The experimental conditions: Dry bentonite, 10 g/250 ml in contact with 0.01, 0.1 and 1 M solution at 20 °C after 1.5 weeks (Wold and Eriksen, 2001).*

<u>Background measurements:</u>

The aim of this activity is to measure the natural background colloid concentrations from 8 different boreholes along the Äspö HRL-tunnel (Figure 3-4). The boreholes represent different water types since it is well known that the colloid stability can change with the ion content of the groundwater. The measurements were performed during the time period October-November 2001. The work was performed by INE-team (Germany), Posiva-team (Finland) and SKB-team (Sweden) (see Figure 3-5). The colloid content was measured on-line from the boreholes by using a modified laser based equipment LIBD (Laser-induced Breakdown-Detection) which has been developed by INE in Germany (Figure 3-6). The advantage is that the resolution of this equipment is higher compared with standard equipment. It is therefore possible to detect the colloid contents at much lower concentrations than previously possible. The outcome of these measurements will be compared with standard type of measurements such as particle counting by using Laser Light Scattering (LLS) on pressurised groundwater samples. Standard type of filtration and ultra filtration was performed on-line/at-line of the boreholes. In addition samples for groundwater, microbes and humic material was collected from the selected boreholes in order to judge the contribution from these on the measured colloid concentration. The electrical conductivity was measured along the tunnel from water venues in order to reflect the variability of the groundwater composition which can affect the colloid stability. The results will be reported in March 2002.

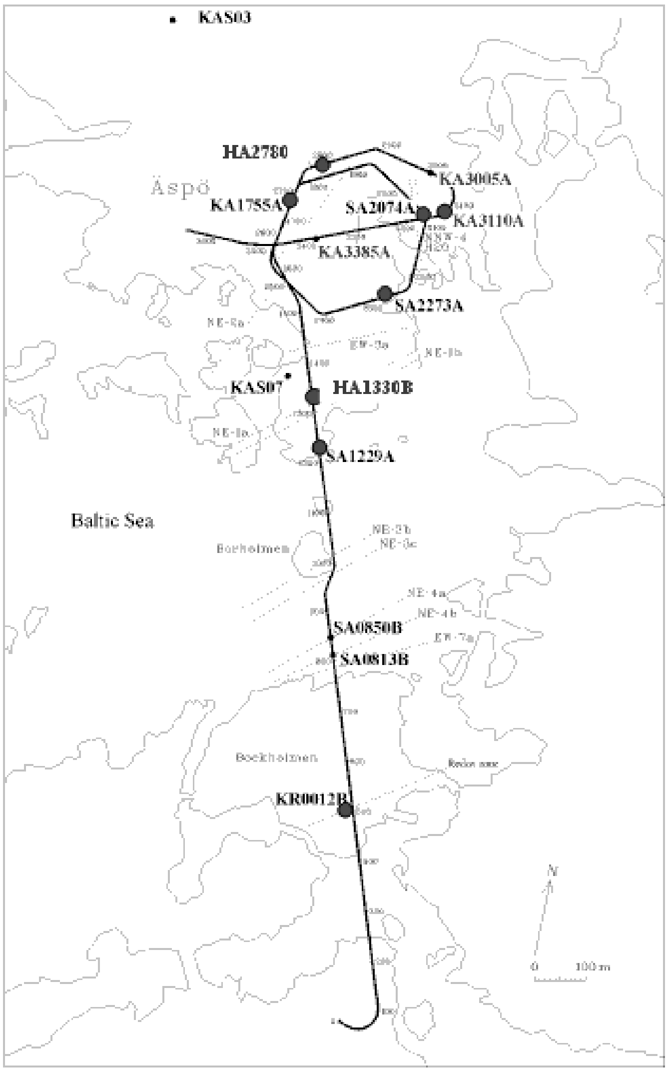

Figure 3-4 *Boreholes with circles are sampled for colloids along the Äspö tunnel.*

Figure 3-5 *Backgorund measurements of colloids performed by the INE-team (Germany), POSIVA-team (Finland) and SKB-team (Sweden) at Äspö-HRL.*

Figure 3-6 *The equipment for Laser-induced Breakdown-Detection (LIBD) of colloids is installed in a van in order to allow mobility and on-line measurements at boreholes.*

Borehole specific experiment:

The aim of the experiment is to determine the colloid generation properties of the bentonite clay in contact with the prevailing groundwater conditions at Äspö. For the borehole specific measurements 3 boreholes along the Äspö tunnel will be investigated. The boreholes are selected so the natural variation in the groundwater composition at Äspö is covered. The groundwater is in contact with the bentonite clay adapted in a container/packer equipment in the borehole and the colloid content is measured prior and after in contact with the bentonite clay (see Figure 3-7) by using LIBD/LLS and conventional filtering. This activity will be performed in field during the time period April-August 2002.

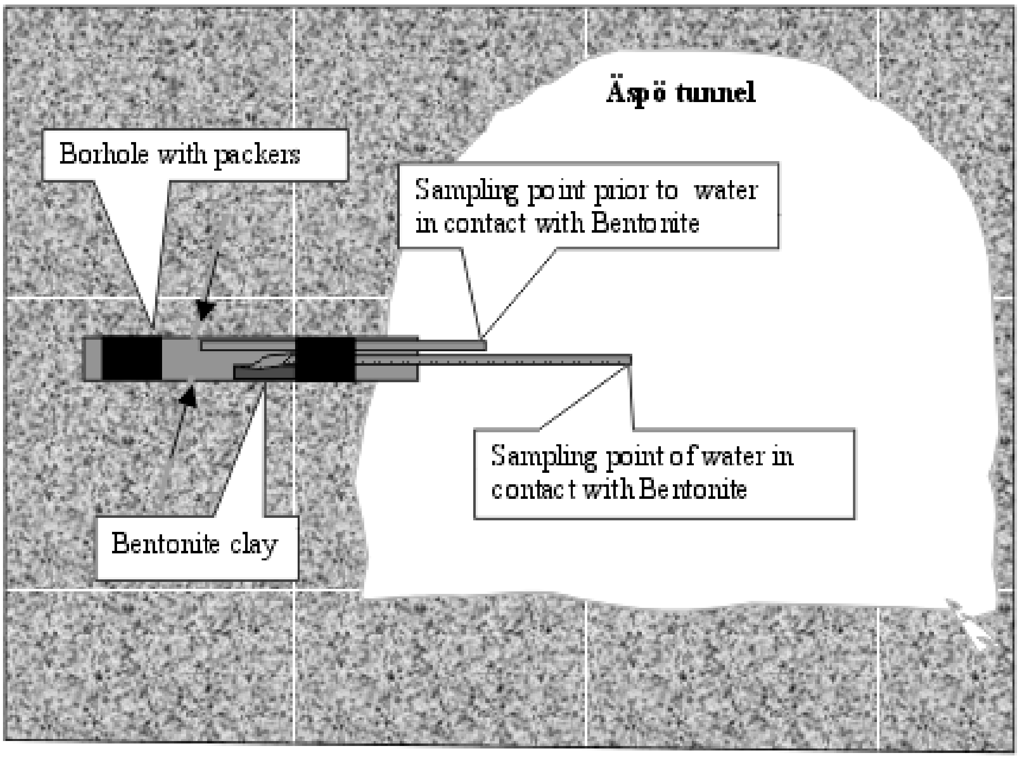

Figure 3-7 *The groundwater is in contact with the bentonite clay in a container. The bedrock fracture is sealed off with packers and the colloid content is measured in the groundwater prior and after being in contact with the bentonite to determine its colloid generation potential.*

Fracture specific experiment:

This experiment is dependent of the results from the previous experiments. A final judgement will therefore be taken during the summer of 2002. For the fracture specific measurements two nearby boreholes at ÄHRL will be selected for the experiment to be possibly conducted January-June 2003. One of the boreholes will be used as an injection borehole and the borehole downstream will be used as a monitoring borehole. The boreholes intersect the same fracture and have the same basic geological properties. After assessing the natural colloid content in the groundwater, bentonite clay will be dissolved in ultra pure water to form colloidal particles. The colloids are labelled with a lanthanide (i.e europium) and the fluid is labelled with a water conservative tracer. The mixture will be injected into the injection borehole (Figure 3-8). From the monitoring borehole the colloidal content will be measured with laser (LIBD/LLS), the water will be filtered and the amount of tracers will be measured.

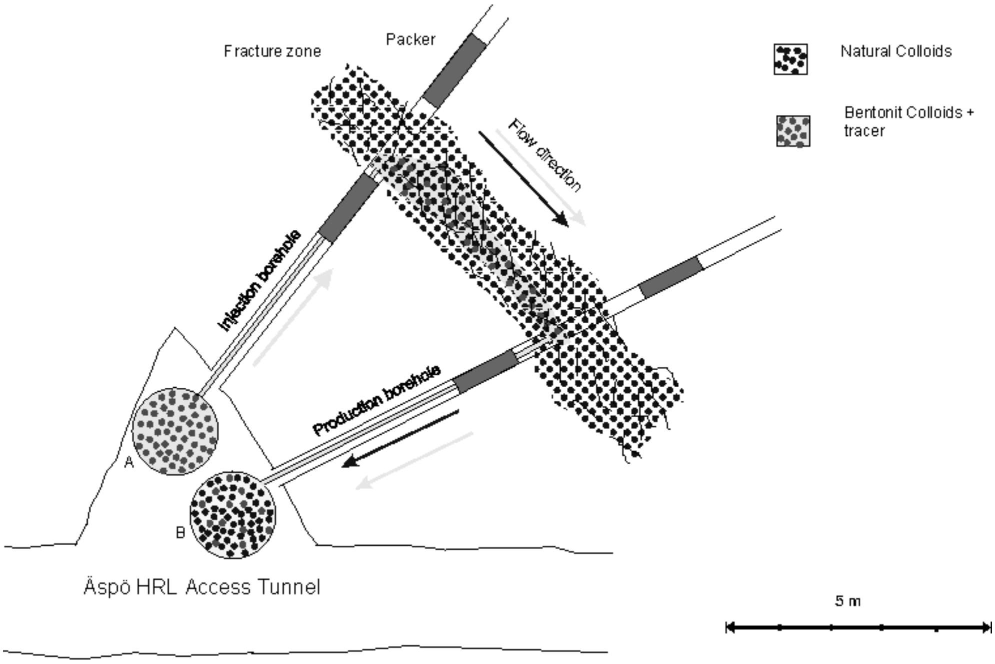

__Figure 3-8__ Injection of bentonite colloids and monitoring of the injected and natural colloids in the production borehole.

The result of interest is to monitor the changes in the colloid content prior and after the transport. The outcome of the experiment is used to check the calculations in the safety assessment reports (such as TR 91-50) and to used the results in future colloid transport modelling.

Time table

The project is conducted during the time period 2000-2003. The time plan for the project is:

- Laboratory tests January-December, 2001
- Field measurements, background colloid content October 2001 – November 2001
- International Äspö Colloid workshop 5:th of March 2002 in Stockholm
- Borehole specific experiment, January-August 2002
- Fracture specific experiment, January-July 2003
- End of project December 2003

Specific work performed during the 4th quater of 2001

The work performed during the 4th quaternary of 2001 consists of finalising the laboratory studies, performing the background measurements and planning and initiating the borehole specific experiment.

3.5 Microbe

Background

Microorganisms interact with its surroundings and in some cases they greatly modify the characteristics of their environment. Several such interactions may have a significant influence on the function of a future high level radioactive waste repository. Interactions with a potential for study at the MICROBE sites are:

Bio-mobilisation of radionuclides. To what extent can bacterial dissolution of immobilised radionuclides and production of complexing agents increase radionuclide migration rates?

Bio-immobilisation of radionuclides. What are the retention effects from microbial biofilms forming on groundwater conducting fracture surfaces and in the biological iron-oxidising systems (BIOS) forming in ground surface outflow of groundwater?

Microbial corrosion of copper. Bio-corrosion of the copper canisters, if any, will be a result of microbial sulphide production. Two important questions arise: Can sulphide-producing microbes survive and produce sulphide in the bentonite surrounding the canisters? Can microbial sulphide production in the surrounding rock exceed a performance safety limit?

Microbial effects on the chemical stability. Microorganisms can have an important influence on the chemical situation in groundwater. Especially, they may execute reactions that stabilise the redox potential in groundwater at a low and, therefore, beneficial level for the repository. Another very important bio-effect is the microbial reduction of oxygen with hydrogen, methane and organics carbon. In situ data are required for proper modelling.

These tasks have been addressed in a range of projects, of which several are ongoing. Important conclusions have been obtained based on laboratory and field data. While some results seem very solid with general applicability, others are pending inspection at in situ conditions. This is especially true for data generated at the laboratory only. In situ generated data must be obtained for microbial activities in the far- and near-field environment at realistic repository conditions. This can only be achieved at underground sites, developed for microbiological research, using circumstantial protocols for contamination control during drilling and operation. An in situ site allows experiments at high pressure with a proper gas content and biogeochemical situation. This is of great importance for modelling true subterranean microbial activity and very difficult to obtain in vitro.

Objectives

The major objectives for the MICROBE sites are:

- To provide in situ conditions for the study of bio-mobilisation of radionuclides.
- To present a range of conditions relevant for the study of bio-immobilisation of radionuclides.

- To enable investigations of bio-corrosion of copper under conditions relevant for a high level radioactive waste repository.
- To offer proper circumstances for research on the effect of microbial activity on the long-term chemical stability of the repository environment.

Experimental concept

The deepest MICROBE site is on the 450 m level and consists of three core drilled boreholes, KJ0050F01, KJ0052F01 and KJ0052F03, intersecting water conducting fractures at 12.7, 43.5 and 9.3 m respectively. Each borehole is equipped with metal free packer systems that allow controlled sampling of respective fracture. An underground laboratory, approximately 7 x 2.5 m is installed close to the boreholes and is equipped with a large anaerobic chamber and basic laboratory equipment. Tubings and circulation pumps connect this boreholes with the laboratory.

Two additional MICROBE sites have been opened in the Äspö tunnel for experiments. A side vault at tunnel length 1127B has a constructed, shallow pond (2000 x 1000 x 10 cm) with unique populations of sulphur oxidizing bacteria. The 1127B site will be used for investigations of microbial stable isotope fractionation of sulphur in sulphate, sulphur and sulphide. The 2200A m site, at 296 m depth will be equipped with open flow channels feed from a packed off borehole used earlier for rock tension measurements (BSP 2200). Trace element retention by the biological iron oxide systems (BIOS) will be studied. BIOS are commonly forming when ferrous iron containing groundwater comes under oxidising conditions, such as outflow into an oxygenic atmosphere. Earlier results indicated a significant metal retention effect from the biological part of naturally occurring iron oxides.

New results

Bio-mobilisation of radionuclides.

Biofilm build-up in KJ0052F03 has been investigated. The number of attached microorganisms was 10^7 cells/cm^2 after 65 days (Figure 3-9).

Bio-immobilisation of radionuclides.

The 2200 m vault roof has been secured and the BSP borehole has been equipped with a packer.

Microbial corrosion of copper.

The results obtained are consistent with earlier results. Microbial production of sulphide ceases under full bentonite swelling pressure (2 g/cm^2). Migration of sulphide producing microorganisms through bentonite does not occur at repository density (2 g/cm^2).

Microbial effects on the chemical stability.

No new results.

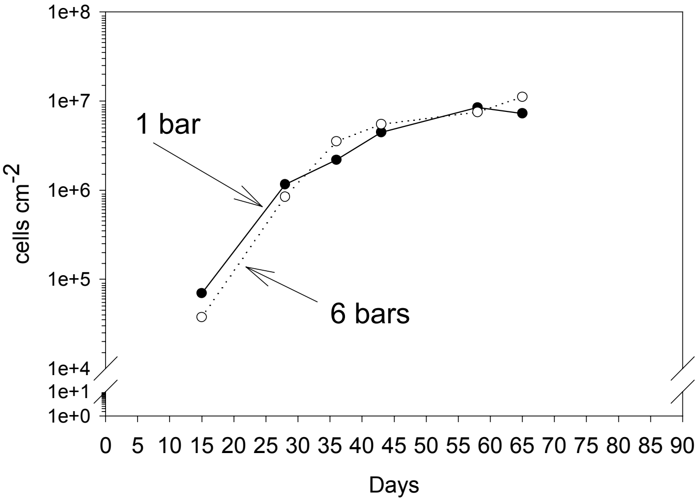

Figure 3-9 *Biofilm build-up is studied in KJ0052F03. The experiment started 26 September 2001 and will be closed 24 January 2002. Two pressure levels were analysed.*

Planned work

Bio-mobilisation of radionuclides

Constructed surfaces with defined concentrations of trace elements will be exposed to microbial biofilms after summer 2002, when the circulation systems are running.

Bio-immobilisation of radionuclides

Flow through tanks (2000 x 300 x 200 cm) will be installed on the 2200 BIOS site. They will be equipped with an array of different supports for BIOS attachment and growth. Oxygen and pH profiles will be shed and measured. Trace element analysis and groundwater chemical composition will be analysed. Retention of naturally occurring trace elements will be investigated.

Microbial corrosion of copper

A second round of bentonite incubations will preliminary start summer 2002. Details will be planned after final evaluation of the 2001 experiments.

Microbial effects on the chemical stability.

Work is ongoing to build and install temperature controlled circulation systems on the MICROBE 450 m site. The systems should be up and running in June/July. A field gas chromatograph and gas extraction systems will be developed for dissolved hydrogen and methane in groundwater during spring 2002. Biofilm experiments will start after summer 2002. Those biofilms will be used for trace element immobilisation and mobilisation experiments and for redox experiments as listed above.

4 Demonstration of technology for and function of important parts of the repository system

4.1 General

Stage goal 4 of the Äspö HRL is to demonstrate technology for and function of important parts of the repository system. This implies translation of current scientific knowledge and state-of-the-art technology, into engineering practice applicable in a real repository.

It is important that development, testing and demonstration of methods and procedures, as well as testing and demonstration of repository system performance, is conducted under realistic conditions and at appropriate scale. A number of large-scale field experiments and supporting activities are therefore conducted in the Äspö HRL. The experiments focus on different aspects of engineering technology and performance testing, and will together form a major experimental program.

With respect to *technology demonstration* important overall objectives of this program are:

- to furnish methods, equipment and procedures required for excavation of tunnels and deposition holes, near-field characterisation, canister handling and deposition, backfilling, sealing, plugging, monitoring and also canister retrieval, and
- to integrate these methods and procedures into a disposal sequence, that can be demonstrated to meet requirements of quality in relation to relevant standards, as well as practicality.

With respect to *repository function*, objectives are:

- to test and demonstrate the function of components of the repository system, and
- to test and demonstrate the function of the integrated repository system.

4.2 The Prototype Repository

Background

Particular aspects of the repository concept have previously been tested in a number of in situ and laboratory tests. There is a need to test and demonstrate the integrated function of the repository in full scale and with state-of-the-art technology. It is envisaged that this technology can be tested, developed and demonstrated in the Prototype Repository. The design, construction and testing of the Prototype Repository is aimed at a simulated deposition sequence starting from detailed characterisation of the host rock to re-saturation of the backfilled deposition holes and tunnel. The

Prototype Repository experiment is located in the inner part of the TBM tunnel at 450 m level and will include 6 deposition holes in full scale.

The aims of the Prototype Repository are:

- to demonstrate the integrated function of the repository components and to provide a full-scale reference for comparison with models and assumptions, and
- to develop and test appropriate engineering standards, quality criteria and quality systems.

The Prototype Repository will be a long-term test divided into two sections, separated by a concrete plug. One plug will also separate the test from the rest of the Äspö HRL. One section, the outer one – Section II, is planned to be decommissioned after about 5 years (the bentonite buffer saturated) and the second section, the inner one – Section I, after approximately 20 years.

New results

The project management core group continued to have planning meetings weekly for discussion and decision on activities during the following weeks. Those meetings are documented but considered to be internal meetings.

The backfilling continued during the period and reached the retaining wall in the plug position in late November, about two weeks in advance of the time schedule. The work went well without surprices or mistakes. Immediately thereafter the plug was cast and the annual goal of finalising Section I before Christmas was achieved.

The decision to use self-compacting concrete was successfully carried through, and the plug was cast to the specifications requested.

Heaters in all the four installed canisters have been turned on (the first on September 17^{th} and the fourth on October 22) with the initial power of 1800 W, which will be decreased in accordance to the decay curve of the spent fuel, i.e. with 30 W per canister and year the first 5 years and 24 W per canister and year the 5 years following thereafter.

No EC Milestones were due during the period. Either were any Deliverables coupled to the EC project due during the period. But as the installation was completed earlier than planned the following Milestones were met:

Milestone 4 Installation of Section I completed by month #19 (i.e. March 2002)

Milestone 6 Heaters in Section I turned on by month #20 (i.e. April 2002)

The following periodic reports were submitted:

- annual report on scientific and technical achievements covering the first year - September 2000-August 2001 - of the project,
- second 6-month presentation of progress in relation to work and time plans and
- first annual report on incurred costs.

The request to EC of accepting ANDRA as a contractor in the EC project without extra funding was prepared and communicated with the EC. The remaining activity is to formally submitt the request, which in draft was supported by the EC officer for the project.

The discovered short-circuit in the canister in the Canister Retrieval Test is a potential problem also to the Prototype Repository, because the design is the same. No immediate alarm was raised during the period but now in late February three of the canisters exibit a decrease in resistance to earth and the decision has been taken to investigate the cause of the observation by examine the canister in the Canister Retreival Test.

Planned work

The preparation of Section II prior to installation of bentonite blocks and canisters in the two deposition holes continues with installation of instruments and cables for rock mechanical measurements, packers and piezometres and hoses for water sampling as well as HM instruments measuring piezometric changes and displacements at the same time. Installation of cable packages will also start. All preparations will almost be completed during the first quarter of 2002, so that the first bentonite block can be lowered in mid April. (Today in April we know that the insulation problem in the Canister Retreival Test has postponed the start of installation for the time being.)

The following Deliverables and Milestone coupled to the EC project are due during the first quarter of 2002.

D13 Preparation of deposition holes prior to emplacement of buffer and canisters in Section II

D14 Installation of buffer and canisters in Section I

D19 Sensor data report #1

Milestone 3 Sensors and sampling equipment for installation in buffer, backfill, rock and plug in Section II delivered to AEHRL by month #18 (i.e February 2002)

4.3 Backfill and Plug Test

Background

The *Backfill and Plug Test* includes tests of backfill materials and emplacement methods and a test of a full-scale plug. It is a test of the integrated function of the backfill material and the near field rock in a deposition tunnel excavated by blasting. It is also a test of the hydraulic and mechanical functions of a plug. The test is partly a preparation for the Prototype Repository.

The entire test setup with backfilling, instrumentation and building of the plug was finished in the end of September 1999 and the wetting of the 30/70 mixture through the filter mats started in late November 1999. Wetting of the backfill from the filter mats and the rock has continued during the years 2000 and 2001.

New results

Figure 4-1 shows an illustration of the experimental setup. The following main events and results from the last quarter of 2001 can be mentioned:

- The water pressure in the permeable mats and the drained inner part of the drift have been increased with steps of 100 kPa to 400 kPa at the following times:

  100 kPa: 2001-10-03

  200 kPa: 2001-11-14

  300 kPa: 2001-11-28

  400 kPa: 2001-12-10

  The amount of water passing through the plug and the surrounding rock has been measured during this period by collecting the water outside the plug. Figure 4-2 shows the results with a direct response of each pressure increase and then a successive reduction in flow until steady state is reached. The results show that the leakage has increased from 0.02 l/min to 0.06 l/min when the pressure was increased from 100 kPa to 400 kPa. The leakage is not higher than what could be accepted for future flow tests.

- Water saturation, water pressure and swelling pressure in the backfill and water pressure in the surrounding rock have been continuously measured and recorded. Figure 4-3 and Figure 4-4 show example of measured results. Figure 4-3 shows the water pressure in the rock measured in the short bore holes about 30 cm below the floor of the tunnel. The strong increase at the end of the diagram is the result of the recent water pressure increase after grouting. Figure 4-4 shows the suction (negative pore water pressure) measured in the centre of different layers of 30/70. Only the sensors placed in the first layers (about 20 cm from the mat) have been clearly water saturated. Decrease in suction in transducers W17 and W20 (about 40 cm from the mat), which started in September 2000, has continued and can from July 2001 also be seen for the central transducers W19 and W22 (about 60 cm from the mats).

Planned work

In the first quarter of 2002 the water saturation will continue with consecutive measurement of water inflow, water pressure, total pressure and wetting.

The stepwise increase in water pressure in the permeable mats will also continue with one more step to 500 kPa, in order to reduce the time to reach saturation.

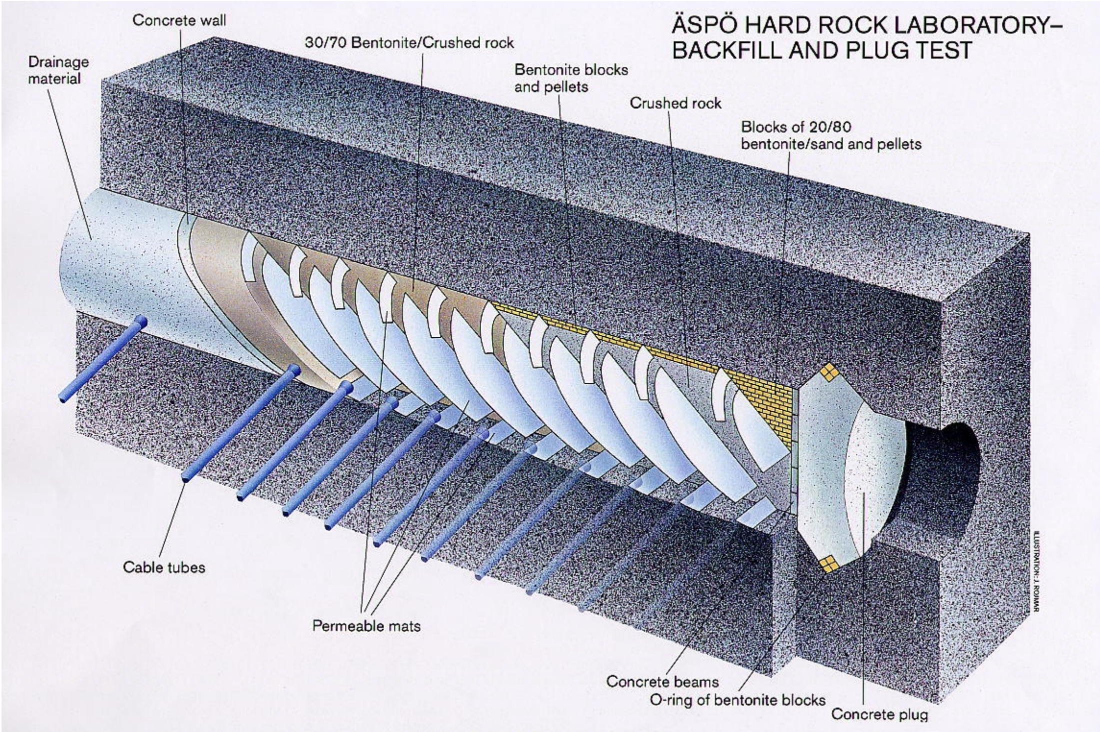

Figure 4-1 *Illustration of the experimental setup of the Backfill and Plug Test.*

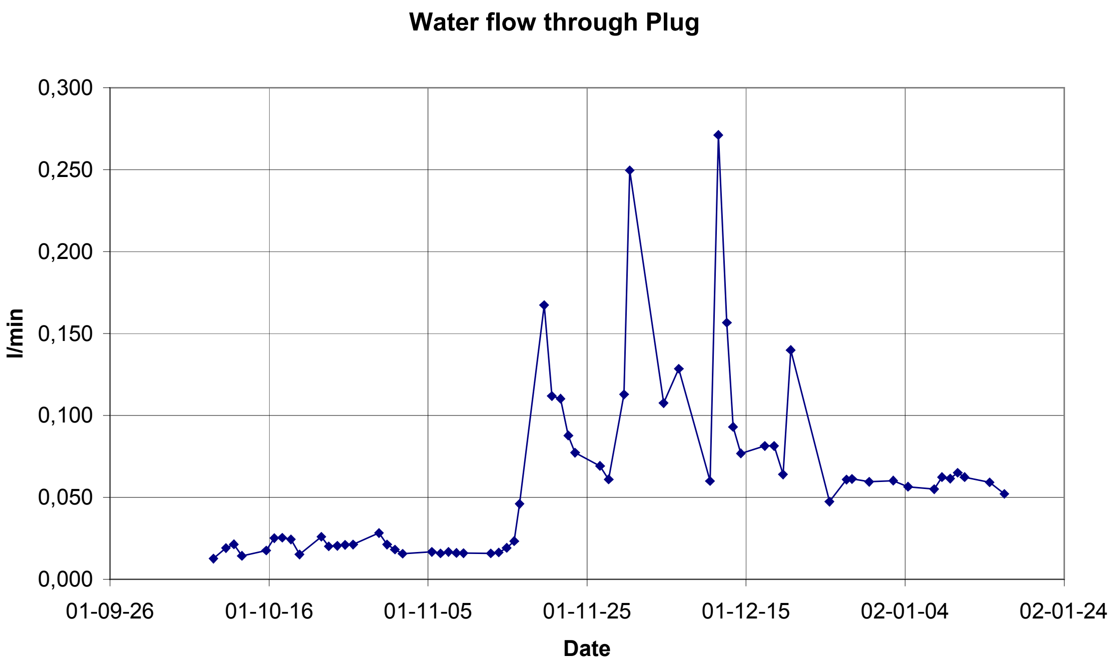

Figure 4-2 *Water flow through the plug and its surroundings. The first peak corresponds to the pressure increase from 100 to 200 kPa, the second to 300 kPa and the third to 400 kPa.*

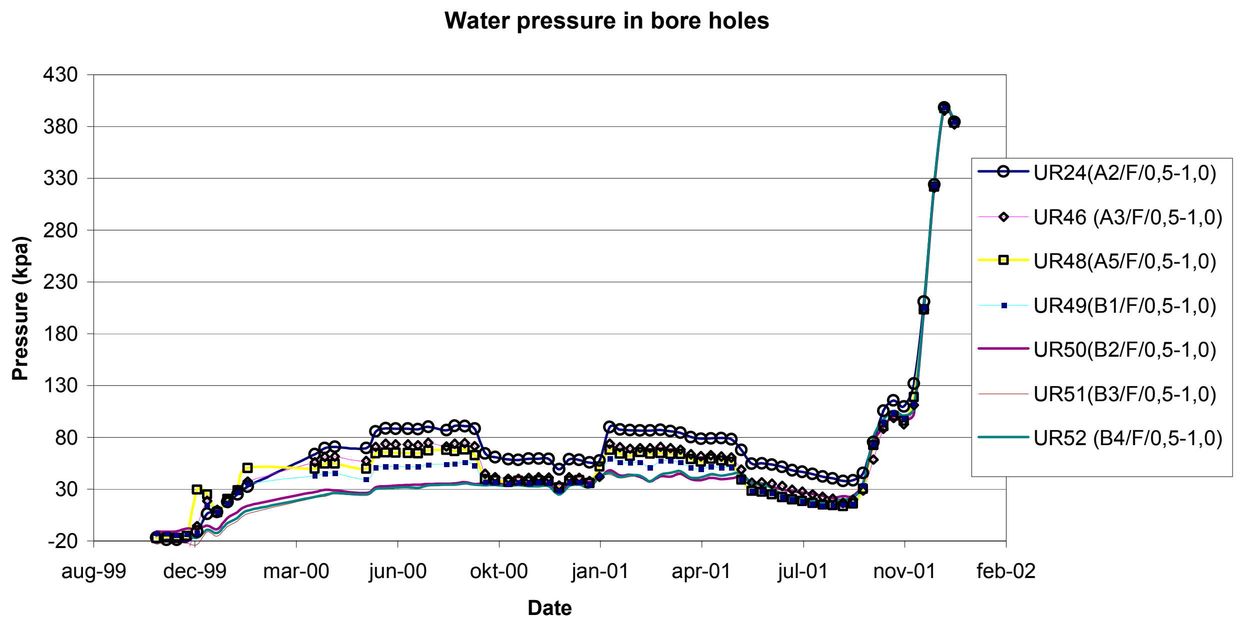

Figure 4-3 *Water pressure measured in the floor 30 cm below the rock surface. UR24, 46, 48 and 49 are placed in the 30/70 sections and the rest in the 0/100 sections.*

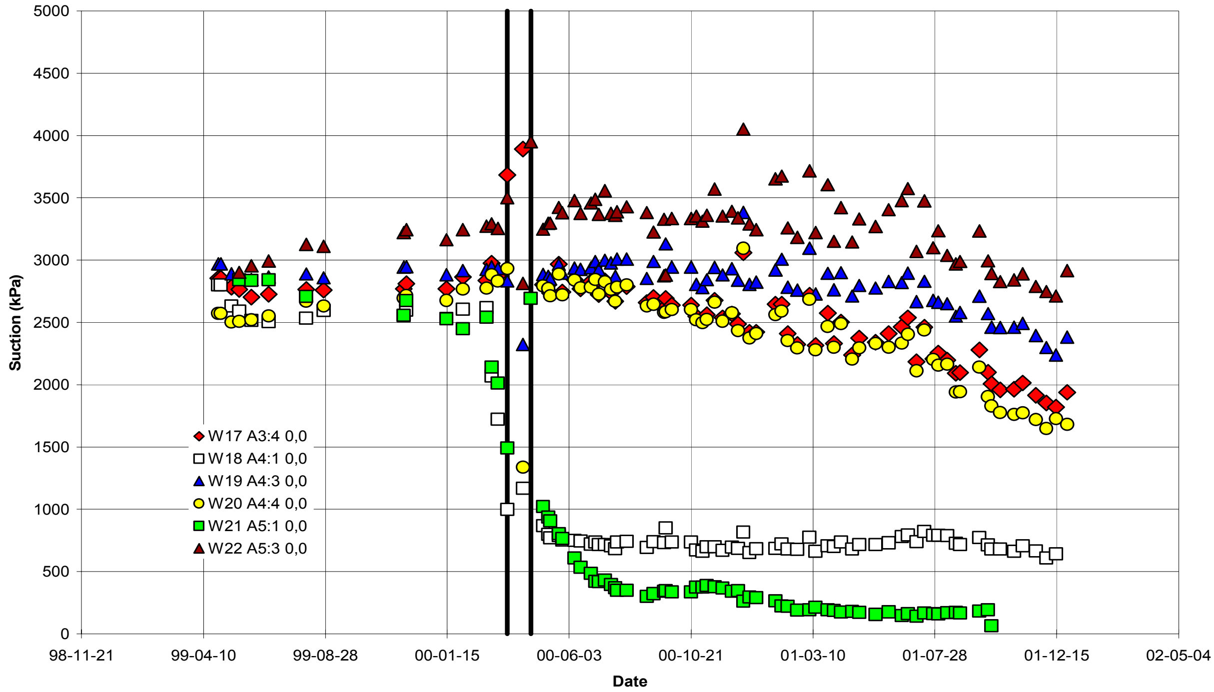

Figure 4-4 *Suction measured in the centre of different layers in the 30/70 backfill. W18 and W21 are placed in the first layer about 20 cm from the mats. W17 and W20 are placed 40 cm and W19 and W22 are placed 60 cm from the mats.*

4.4 Canister Retrieval Test

Background

SKB's strategy for the disposal of canisters with the spent nuclear fuel is based on an initial emplacement of about 10% of the number of canisters followed by an evaluation of the result before any decision is made on how to proceed. One outcome can be that the result is not accepted and that the canisters have to be recovered. In such case some, if not all, canisters can be surrounded by a saturated and swollen buffer, which holds the canister in such a grip that the canister can not just be pulled up. First the bentonite grip has to be released, for which two alternative principles can be applied; remove or shrink the bentonite. Then the canister is free to be lifted up to the tunnel and placed in a radiation shield. A concern is any type of radioactive contamination that the bentonite has been exposed to.

The retrieval test is aiming at demonstrating the readiness for recovering of disposed canisters also after the time when the bentonite has swelled. The process covers the retrieval up to the point when the canister is safely resting in a radiation shield and ready for transport to the ground surface. The test is separated into two phases; Design and Set-up, and the actual Retrieval Test.

The installation of the buffer material and the canister with instrumentation and heaters started mid September 2000 and was completed during October 2000 including the in situ casting of the concrete plug on top of the bentonite buffer. The heaters were turned on in October 2000 and the artificial saturation of the buffer material started a few days later. The operation of the Canister Retrieval Test is designed to continue for some 4 to

5 years, until the bentonite buffer has been fully saturated. The concrete plug on top of the bentonite buffer is held in position with help of 9 wire ropes that are secured in the rock by grouting. The wire ropes are designed for a maximum swelling pressure of 5 MPa from the buffer material. The experimental set up is shown in Figure 4-5.

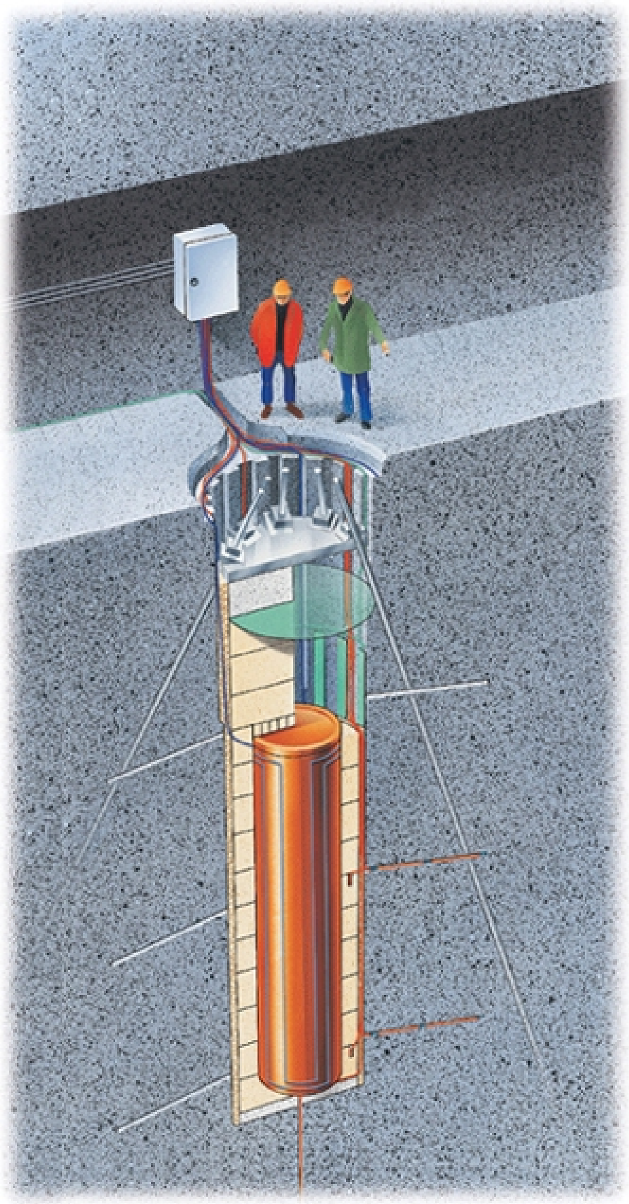

Figure 4-5 *Experimental set up. The horizontal holes are equipped with thermocouples and the sub-vertical holes indicate the anchoring ropes. Instruments in the buffer are placed on the same level as the three levels for thermocouples in the rock. Stripes of permeable mats are attached to the rock wall and fibre optical cables for temperature measurements are attached to the surface of the canister.*

Instruments are located in the buffer below, at mid hight and above the canister. They measure: temperature, pore pressure, total pressure and degree of saturation. At the same horisons also thermocouples are placed in horisontal holes as Figure 4-5 indicates.

Fibre optical cables are attached to the canister, and they register the temperature each half metre along the cables. Strain gages and thermocouples are installed inside the canister.

The rock mechanical instruments, which were installed in vertical holes prior to the boring of the deposition holes, are still in operation and continue to register stress and strain changes as well as the temperature.

The stresses in the cable ropes, which anchore the plug in the top of the hole, are also meassured by strain gauges.

New results

The artificial water supply to the surrounding permeable mats has continued and the flow registered. The final thermal load of 2600 W in the canister has been on since February 13th, and the sensor readings have continued.

A new data report has been compiled for publishing during the period. All sensors in operation in the beginning of the period are still in operation, and the measuring system and transducers have continued to work well.

The temperature on the surface of the canister has been steadily at 94^{o}C at mid hight, and there has been no attempt to decrease the thermal load with the approximately 150 W that would be required in order to decrease the temperature to exactly 90^{o}C. Inside the canister the temperature has been steadily approx 15^{o}C higher than on the copper surface.

In the buffer the temperature has developed in all measured point in accordance to expectations, which also has been the case in other similar experiments in Sweden and abroad.

The measurements of rock stresses and strain are based on the vibrating wire method and the readings need to be compensated for the temperature-induced effect on the instrument. A plausible compensation equation has been tested and used in evaluation of the results, Figure 4-6 shows the temperature and the readings from three of the strain gages compensated for the temperature. These gages are located 300 mm from the deposition hole with the B position on the axis of the tunnel and the C position on a line perpendicular to the tunnel axis.

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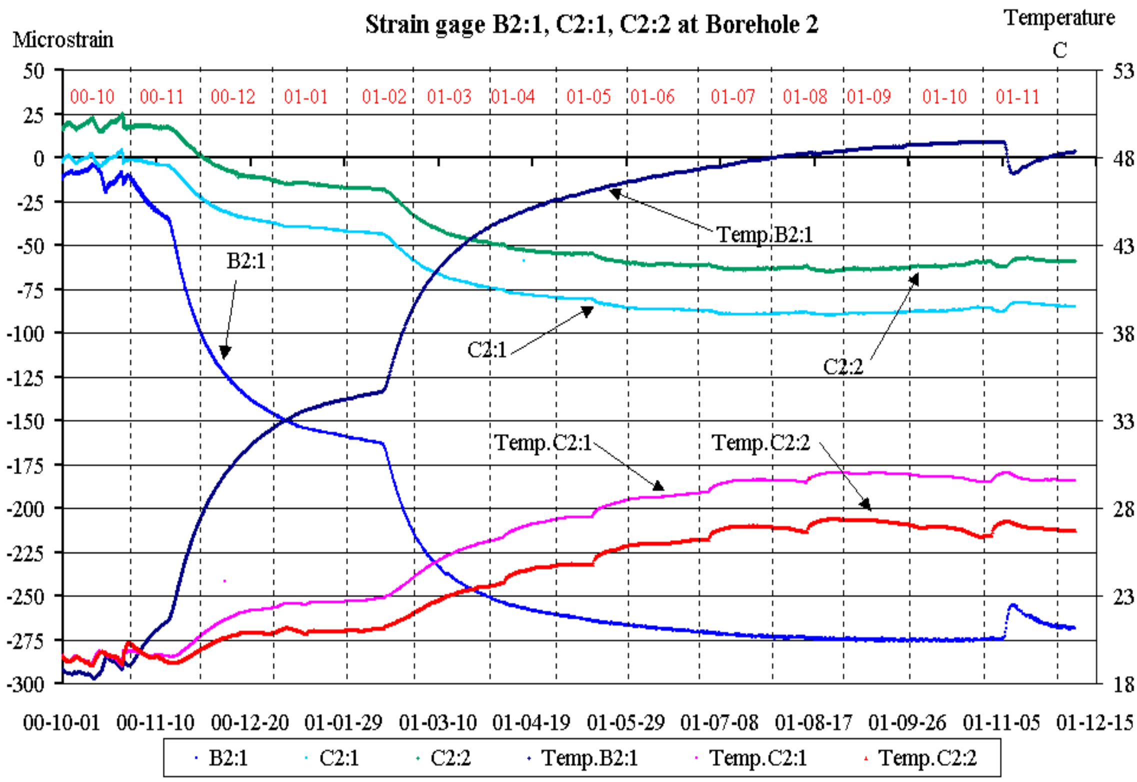

Figure 4-6 *Temperature and temperature compensated strain measurements in three positions around the Canister Retrieval Test Hole. B2:1 is located at mid hight of the canister and C2:1 and C2:2 both at the top of the canister.*

One major drawback came on November 3rd when a fuse brock indicating a short-circuit in the heater´s electrical system. The investigation revieled that two of the 36 heater elements had direct contact with earth. The others were in shape, not good but in shape. The general rule for an electrical installation is that the acceptable insulation is 500 000 ohm or higher. The 34 heaters were all below 500 000 ohm and varied between 50 000 and 250 000 ohm, when the resistance was measured at a voltage of 500 V. (The resistance at lower voltage was never measured, but would be expected to be higher.) After the quick measurements revieling the problem it was decided that the earlier operating heaters plus two new ones should be turned on in order to provide the needed experimental conditions until an alternative plan of retrieval had been developed in case all heaters would be short-circuited. So far (April) the heating has continued without problem.

A number of alternative causes have been investigated without revieling any clear evidence of the cause. Is it inside the canister or outside? What is the conducting medium, oil fog inside or salt water outside? The reality is that all 72 cables to the 36 heaters have developed a lower resistance to earth, despite the fact that they are separated on two water-tight plugs through the canister´s lid. And more confusing is that all cables to instruments inside the canister, which are taken through two additional plugs in the lid show the same low resistance to earth, though these cables have no contact with the electrical net. And, the plugs are not the cause of the problem. They were the first to be suspected and the first to be cleared after testing. The plug construction is shown in Figure 4-7, and Figure 4-8 shows how the cables are connected to the plug inside the canister.

Figure 4-7 *Gisma plugs of water-tight construction garanteed to withstand 125°C during 9000 hours.*

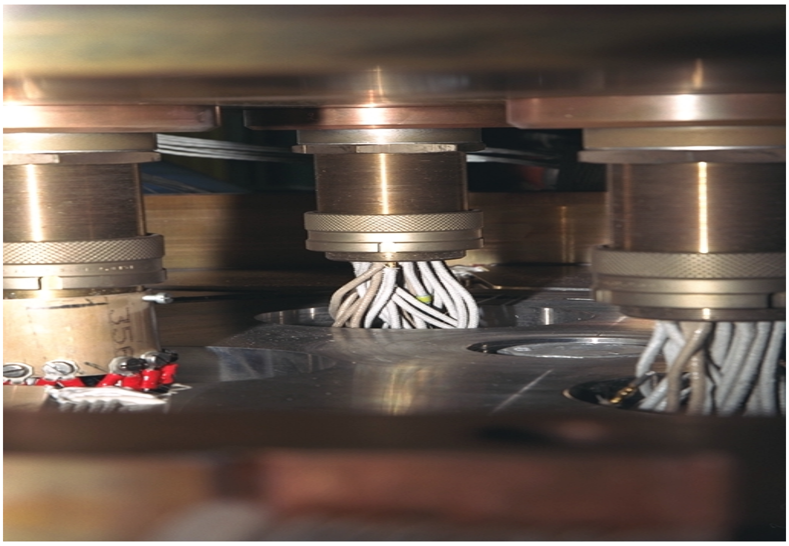

Figure 4-8 *The three plugs through the copper lid before lowering the copper lid. The inner lid consists of steel.*

Planned work

The plan in December 2001 was to continue the artificial water saturation of the bentonite and to continue the registration of sensor readings.

If all heaters would fail the plan was to lift up the steel and concrete plug in the top of the hole and to excavate the bentonite buffer with continous sampling. When the canister lid has been made free it is possible to determin whether the problem is inside the canister or outside. If the verdict is "inside" the canister has to be retrieved, while more samples from the bentonite buffer can be extracted, with major benefit for the modellers. If the verdict is "outside" the aim is to repair the failure and re-build the test with new bentonite blocks for continuing the saturation of the buffer.

Because of the discovery of the similar problem in the heaters in the Prototype Repository (in late February) a decison has been taken to act according to the plan above if this may shed light on the cause of the malfunction. So far (in April) this has not taken place.

4.5 Long Term Test of Buffer Material (LOT)

Background

Bentonite clay has been proposed as buffer material in several concepts for HLW repositories. In the Swedish KBS-3 concept the demands on the bentonite buffer are to serve as a mechanical support for the canister, reduce the effects on the canister of a possible rock displacement, and minimise water flow over the deposition holes.

The decaying power from the spent fuel in the HLW canisters will give rise to a thermal gradient over the bentonite buffer by which original water will be redistributed parallel to an uptake of water from the surrounding rock. A number of laboratory test series, made by different research groups, have resulted in various buffer alteration models.

According to these models no significant alteration of the buffer is expected to take place at the prevailing physico-chemical conditions in a KBS-3 repository neither during nor after water saturation. The models may to a certain degree be validated in long-term field tests. Former large scale field tests in Sweden, Canada, Switzerland and Japan have in some respects deviated from possible KBS-3 repository conditions and the testing periods have generally been dominated by initial processes, i.e. water uptake and temperature increase.

The present test series aims at validating models and hypotheses concerning physical properties in a bentonite buffer material and of related processes regarding microbiology, radionuclide transport, copper corrosion and gas transport under conditions similar to those in a KBS-3 repository. The expression ”long term” refers to a time span long enough to study the buffer performance at full water saturation, but obviously not ”long term” compared to the lifetime of a repository. The objectives may be summarised in the following items:

- Data for validation of models concerning buffer performance under quasi-steady state conditions after water saturation, e.g. swelling pressure, cation transport and gas penetration.
- Check of existing models concerning buffer-degrading processes, e.g. illitisation and salt enrichment.
- Information concerning survival, activity and migration of bacteria in the buffer.
- Check of calculation data concerning copper corrosion, and information regarding type of corrosion.
- Data concerning gas penetration pressure and gas transport capacity.
- Information that may facilitate the realisation of the full-scale test series with respect to clay preparation, instrumentation, data handling and evaluation.

The testing philosophy for all tests in the series (Table 4-1) is to place prefabricated units of clay blocks surrounding heated copper tubes in vertical boreholes. The test series are performed under realistic repository conditions except for the scale and the controlled adverse conditions in three tests.

Table 4-1. Lay out of the ongoing Long Term Test series.

Type	No.	T	Controlled parameter	Time
		°C		years
A*	0	120<150	T, $[K^+]$, pH, am	1
A	2	120<150	T, $[K^+]$, pH, am	5
A	3	120<150	T	5
S	2	90	T	5
S	3	90	T	>>5

*Parcel A0 has been terminated and the test materials are presently being examined in laboratory analyses and tests.

A	= adverse conditions	S	= standard conditions
T	= temperature	$[K^+]$	= potassium concentration
pH	= high pH from cement	am	= accessory minerals added

Adverse conditions in this context refer to high temperatures, high temperature gradients over the buffer, and additional accessory minerals leading to i.a. high pH and high potassium concentration in clay pore water. The central copper tubes are equipped with heaters in order to simulate the effect of the decay power from spent nuclear fuel. The heater effect are regulated or kept constant at values calculated to give a maximum clay temperature of 90°C in the standard tests and in the range of 120 to 150°C in the adverse condition tests. Test ”parcels” containing heater, central tube, clay buffer, instruments, and parameter controlling equipment are placed in boreholes with a diameter of 300 mm and a depth of around 4 m

Temperature, total pressure, water pressure and water content, are measured during the heating period. At termination of the tests, the parcels will be extracted by overlapping core-drilling outside the original borehole. The water distribution in the clay will be determined and subsequent well-defined chemical, mineralogical and physical testing will be performed.

New results

The power in parcel A0 was turned off in October and the parcel was released from the rock by overlapping percussion drilling, approximately 20 cm outside the bentonite, and by wire-sawing in the bottom. The use of water was minimised in order not to damage the parcel material. The release operation was thereby complicated and took around three weeks to complete. The parcel was fully released on November 27 and the uplift and first cut up was made on site (Figure 4-6). The material was sent to KTH, VTT,

Figure 4-6 *Check of radioactivity from the tracer material in the bottom part of the A0 parcel immediately after uplift and removal of the covering rock.*

Studsvik and Clay Technology laboratories for the various planned tests and analyses. Preliminary results concerning water content, degree of saturation and water chemistry are presently at hand.

The data acquisition concerning temperature, water pressure, total pressure, and moisture has in principle been well functioning. The results show that water uptake is still going on in the 4 remaining parcels.

Planned work

Tests and analyses of the A0 bentonite material, cupper coupons and tracer test material will continue during the spring and summer. Reporting is planned to be made during the fall of 2002. Continuous follow up of data from the remaining four parcels in Äspö will be made and reported every six month.

5 Äspö facility operation

The status of the facility is excellent both from an environmental and operational point of view.

In order to lower cost and increase operational efficiency the maintenance agreement with the main contractor (OKG) has been renegotiated. Maintenance contracts with other companies have been agreed upon and signed. It´s our belief that this will decrease operational cost and improve maintenance efficiency.

The Äspö road and the new parking lot, have been refurbished, coated and completed with a layer of fine gravel mixed with bitumen.

The project to improve fire safety is in progress. The project is based on suggestions from a fire risk analysis made in 1999. Traffic lights have been installed in a high-risk part of the tunnel. Additional installation of fire detectors in the 420-m level and installation of voice-alarm in strategic areas of the tunnel have been carried out. The work was completed in December.

The project for hands-free-registration in the underground facility is in progress. A Norwegian company has been chosen for delivery of the system. Delivery contract has been signed and installation of the system is to begin in January 2002.

Due to lack of office-space and reorganisation, a two-level barrack, housing 16 offices and 2 conference rooms has been built adjacent to existing buildings. The building was completed in March and was taken in use during week #15 2001. In addition to this, rebuilding or expansion of the existing facility is needed to meet the demands of site investigations in the Oskarshamn area. Planning for this is in progress.

5.1 Technical systems

Background

The monitoring of groundwater changes (hydraulic and chemical) during the construction of the laboratory is an essential part of the documentation work aiming at verifying pre-investigation methods. The great amount of data calls for efficient data collection system and data management procedures. Hence, the Hydro Monitoring System (HMS) for on-line recording of these data have been developed and will continuously be expanded along with the tunnelling work and the increased number of monitoring points.

New results

The new HMS(E) computer is in full operation in the G-tunnel to take care of data from hydro-sections in the Prototype Repository.

Planned work

A new weir in the G-tunnel is going to be installed in January 2002. This weir measures inflow from the G-tunnel. In February all weirs in the tunnel will be calibrated. All the brass couplings in the tunnel will be changed to couplings made of stainless steel, this will be done during January-March.

The surface borehole (KLX01) in the Laxemar area will be renovated during March.

5.2 Information

Background

The information group's main goal is to create public acceptance for SKB in co-operation with other departments at SKB. This is achieved by informing about SKB, the Äspö HRL and the SKB siting programme. The visitors are also guided on a tour of the Äspö HRL.

New results

During the fourth quarter of 2001 the Äspö HRL had 2 386 visitors. They have represented the general public, communities where SKB has performed feasibility studies, teachers, students, politicians, journalists and visitors from foreign countries. 1 102 visitors represented the six communities where SKB has performed feasibility studies.

The common booking system has finally been ordered and is under construction. Start of running test is 2002-01-01.

On December 9th an open house was arranged at the Äspö HRL. The open house was inspired by Christmas with Swedish Christmas buns and cookies, Father Christmas giving presents to the children. The open house generated more than 300 visitors.

Planned work

To test run the new booking system during the first quarter of 2002 and to take it in to use in April 2002.

6 International Cooperation

6.1 Current international participation in the Äspö Hard Rock Laboratory

Eight organisations from seven countries are currently (January 2002) participating in the Äspö HRL.

In each case the cooperation is based on a separate agreement between SKB and the organisation in question. Table 6-1 shows the scope of each organisation's participation under the agreements.

Most of the organisations are interested in groundwater flow, radionuclide transport and rock characterisation. Several organisations are participating in the Äspö Task Force on groundwater flow and radionuclide migration, which is a forum for cooperation in the area of conceptual and numerical modelling of groundwater flow and solute transport in fractured rock.

Table 6-1. Scope of international cooperation

Organisation	**Scope of participation**
Agence Nationale pour la Gestion des Déchets Radioactifs, **ANDRA**, France.	Detailed investigation methods and their application for modelling the repository sites Test of models describing the barrier function of the bedrock Demonstration of technology for and function of important parts of the repository system
Bundesministerium für Wirtschaft und Technologie, **BMWi**, Germany	Participation in the Task Force on modelling of groundwater flow and transport of solutes by using "German" computer codes Participation in the geochemical modelling efforts in the Äspö HRL Work related to transport and retention of radionuclides and colloids in granitic rock In-situ geoelectrical measurements with respect to water saturation of rock masses in the near field of underground tunnels Work on design and performance of in-situe tests using methods and equipment similar to those used in the Grimsel investigations
Empresa Nacional de Residuos Radiactivos, **ENRESA**, Spain	Test of models describing the barrier function of the bedrock Demonstration of technology for and function of important parts of the repository system
Japan Nuclear Cycle Development Institute, **JNC**, Japan. The Central Research Institute of the Electronic Power Industry**, CRIEPI,** Japan	The Tracer retention understanding experiments (TRUE) The detailed scale redox (REX) experiment Radionuclide retention experiments Task Force on modelling of groundwater flow and transport of solutes. Prototype repository project. Long-term test of buffer materials
Nationale Genossenschaft für die Lagerung Radioaktiver Abfälle,	Test of models describing the barrier function of the bedrock

Organisation	Scope of participation
NAGRA, Switzerland	Demonstration of technology for and function of important parts of the repository system
POSIVA , Finland.	Testing of models describing the barrier function of the bedrock Testing and demonstration of repository systems in full scale Verification of the function of repository system components
USDOE/**Sandia National Laboratories**, USA	Test of models describing the barrier function of the bedrock

6.2 Prototype Repository – EC project

The Prototype Repository is co-funded by the European Commission during a 42 months period starting September 2000 with SKB as the co-ordinator. The EC part coincide with the project work (see Section 4.2 above) during that specific time with minor exemptions. The participants are shown in Table 6-2.

Tabell 6-2. Participants in the Prototype Repository EC project

Principal contractors	Associated contractors
SKB (co-ordinator)	GeoDevelopment, VBB VIAK and Clay Technology
Posiva (FI)	VTT
ENRESA (E)	AITEMIN and CIMNE
GRS (G)	
BGR (G)	
UWC – Univ Wales Cardiff (UK)	
JNC (J)	
ANDRA (F) (in process of joining)	

6.3 CROP – Cluster repository project

The CROP is a Thematic Network with the intention to form a basis for evaluating and developing concepts of final repositories for high-level radioactive waste. The objects are primarily: to work out a document that can serve as an aid for future repository design and construction with focus on EBS, and to create a forum for exchange of information on repository design, construction and operation. The European Commission funds the participation of the European organisations but not the non-European ones. The project time is 36 months from the start in February 2001 and SKB/Äspö HRL is the co-ordinator.

The work is separated into four Work Packages:

WP1. Design and construction of engineered barrier systems (EBS)

WP2. Instruments and experimental procedures

WP3. Assessment of the function of EBS and understanding of their performance and the capability to model important processes

WP4. System assessment and development of improved HLW concepts

In each WP one country annex is compiled by each of the participants, see Table 6-3, and one summary text. They make together the deliverable for that WP.

WP #1 and #2 have been further worked at during the period. The deliverables are due12 months after the start of the project, i e February 2002. .

Contractor	Member to Contractor
SKB (co-ordinator)	**GeoDevelopment (S)**
SKC-CEN (B)	
POSIVA (FI)	
GRS (G)	
ENRESA (E)	
ANDRA (F)	
NAGRA (CH)	
OPG (CAN)	
USDOE CBFO (US)	
DBE (G) (expert)	

7 Documentation

During the period October-December 2001, the following reports have been published and distributed:

7.1 Äspö International Cooperation Reports

Dershowitz W, Eiben T, Busse R, Kluckow I, Wallman P
Simulation of the Äspö Tracer Understanding (TRUE-1) Experiment, Radially converging and dipole tracer experiments Äspö Task Force, Task 4C and 4D
ICR-01-05

7.2 Äspö International Reports

Pettitt, W, 1999.
Acoustic emission and ultrasonic monitoring during the excavation of deposition holes in the Prototype Repository.
IPR-01-01

Pettitt, W., Young, P., 2000.
Analysis of the in-situ principal stress field at the HRL using acoustic emission data.
IPR-01-09

Gunnarsson, D., Johannesson, L-E., Börgesson, L., 2001.
Backfilling of the tunnel in the Prototype Repository. Results of pre-tests. Design of material, production technique and compaction technique.
IPR-01-11

Autio, J, Johansson, E., Somervuori, P., 1999.
Modelling of an in-situ failure test in the research tunnel at Olkiluoto.
IPR-01-15

Autio, J, Johansson, E., Kirkkomäki, T., Hakala, M., Heikkilä, E., 2000.
In-situ failure test in the research tunnel at Olkiluoto.
IPR-01-16

Sandén, T., 2001.
Detailed design of lead-throughs and cable protections in the Prototype Repository, Section I.
IPR-01-18

Gentzschein, B., 2001.
Prototype Repository. Hydraulic tests in exploratory holes - Injection tests 2.
IPR-01-21

Pusch, R., Svemar, C., 2001.
Project description CLUSTER Repository Project. A basis for evaluating and developing concepts of final repositories for high level radioactive waste.
IPR-01-23

Ask, D., Stephansson, O., Cornet, F.H., 2001.
Integrated stress analysis of hydraulic stress data in the Äspö region, Sweden. Analysis of hydraulic fracturing stress measurements and hydraulic test in pre-existing fractures (HTPF) in boreholes KAS02, KAS03 and KLX02.
IPR-01-26

Kemppainen, M., Oila, E., Siitari-Kauppi, M., 2001.
Investigation of porosity and micro-facturing of granitic fracture wall rock and fault breccia specimens using the PMMA technique.
IPR-01-27

Goudarzi, R., Gunnarsson, D., Johannesson, L-E., Börgesson, L., 2001.
Sensor data report (Period 990601-010701). Backfill and Plug Test. Report No: 3.
IPR-01-28

Nyberg, G., Jönsson, S., Wass, E., 2001.
Hydro monitoring program. Report for 2000.
IPR-01-29

Morosini, M., 2001.
Äspö Task Force on modelling of groundwater flow and transport of solutes. Proceedings from the 14^{th} Task Force meeting at Särohus, Sweden, November 14-16, 2000.
IPR-01-30

Rhén, I., Forsmark, T., Torin, L., Puigdomenech, I., 2001.
Prototype Repository. Hydrogeological, Hydrochemical and temperature measurements in borehole during the operation phase of the Prototype Repository. Tunnel section I.
IPR-01-32

Börgesson, L., 2001.
Compilation of laboratory data for buffer and backfill materials in the Prototype Repository.
IPR-01-34

Makurat, A., Loset, F., 2001.
Results of Q- and RMR logging and tilt testing of cores from boreholes KA2511A, KAS02 and KA2598A at Äspö HRL.
IPR-01-35

Äspö Hard Rock Laboratory
Status report April-June 2001.
IPR-01-37

Mützel, W., Huth, E., Brausam, R., Keller, J., Pettersson, S., Bäck, R., 2001.
Demonstration deposition machine for canisters. Description and experience from design and test operation.
IPR-01-38

Cruz, B de la., Fernández, A.M., Rivas, P., Cózar, J., Labajo, M.A., 2000.
TRUE Block Scale Experiment. Tracer tests stage. Mineralogical and geochemical analyses of fracture filling materials (gouge and coutings) from drillcore samples.
IPR-01-59

Andersson, C., Pusch, R., 2001.
Preparation of deposition holes prior to emplacement of buffer and canisters in section I.
IPR-01-64

20 Technical Documents

4 International Technical Documents

References

Laaksoharju M, Degueldre C, Skårman C, 1995. Studies of colloids and their importance for repository performance assessment.
SKB Technical Report TR 95-24, Stockholm, Sweden.

Kertsting A, Efurd D, Finnegan D, Rokop D, Smith D, Thopmson J, 1999.
Migration of plotonium in the ground water at the Nevada Test Site.
Nature, Vol 397, January 1999, pp 56-59.

Allard, B., Karlsson, F., Neretnieks, I., 1991.
Concentrations of particulate matter and humic substance in deep groundwaters and estimated effects on the adsorption and transport of radionuclides.
SKB TR 91-50

Appendix A

MASTER SCHEDULE AESPOE

Christer Svemar

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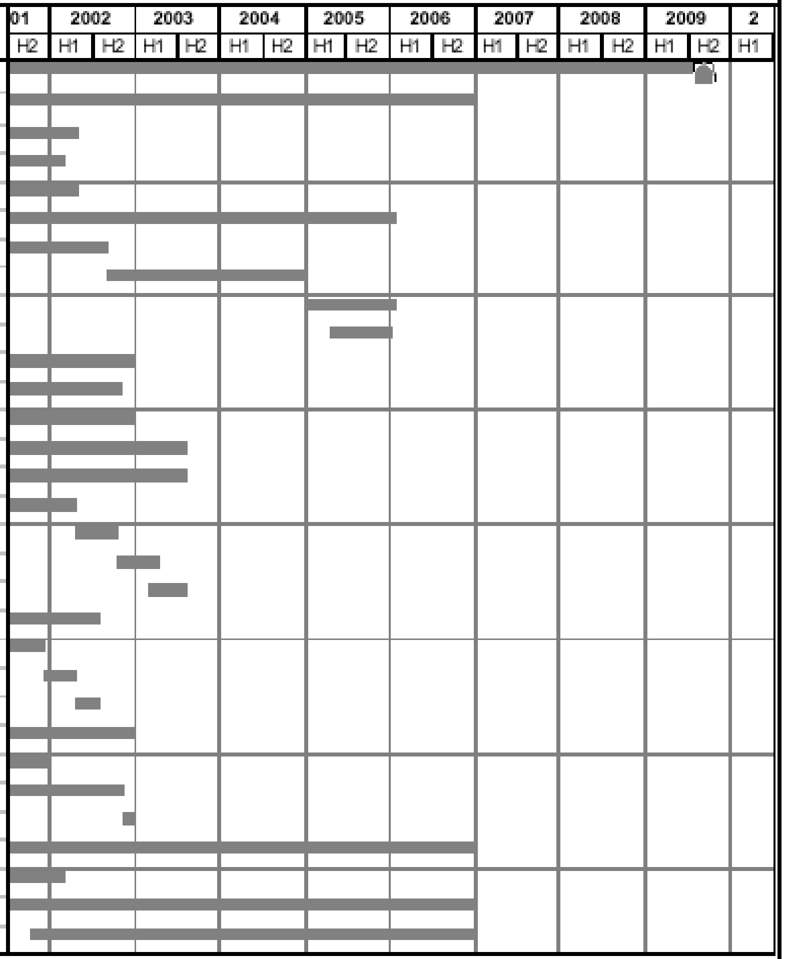
Version 2000.1

WBS	Namn	Start	Slut
0	MASTER SCHEDULE AESPOE	96-07-01	09-09-09
1	TEST OF MODELS OF THE BARRIER FUNCTION OF THE HOST F	96-07-01	06-12-22
1.1	Tracer Retention Understanding Experiments	96-07-01	02-04-30
1.1.1	Tracer test stage	96-07-01	02-02-28
1.1.2	Evaluation and reporting stage	00-10-20	02-04-30
1.2	Long Term Test of Diffusion in the Rock Matrix (LTDE)	01-01-01	06-01-20
1.2.1	Construction, installation, pre-tests and initiation	01-01-01	02-08-30
1.2.2	Analyses and modelling during exeriment	02-09-02	04-12-30
1.2.3	Overcoring and analyses of overcored rock	04-12-31	06-01-20
1.2.4	Integration and reporting	05-04-15	06-01-06
1.3	Numerical modelling of groundwater flow (NUMMOD)	96-07-01	02-12-23
1.3.1	Realization	96-07-01	02-10-23
1.3.2	Reporting	00-10-20	02-12-23
1.4	Radionuclide retention (CHEMLAB)	00-01-03	03-08-01
1.4.1	Actinideexperiment	00-01-03	03-08-01
1.4.1.1	Field experiments I	00-01-03	02-04-17
1.4.1.2	Field experiments II	02-04-18	02-10-07
1.4.1.3	Field experiments III	02-10-08	03-04-07
1.4.1.4	Reporting	03-02-26	03-08-01
1.4.2	Radiolysisexperiment	00-11-09	02-07-31
1.4.2.1	Laboratory work	00-11-09	01-12-03
1.4.2.2	Realization radiolysis	01-12-04	02-04-16
1.4.2.3	Reporting	02-04-17	02-07-31
1.5	Colloid	01-02-02	02-12-30
1.5.1	Laboratory tests	01-02-02	01-12-21
1.5.2	Field tests	01-04-04	02-10-31
1.5.3	Reporting	02-11-01	02-12-30
1.6	MICROBE	01-03-01	06-12-22
1.6.1	Preparation	01-05-21	02-02-20
1.6.2	Realization	01-03-01	06-12-22
1.6.3	Reporting	01-10-08	06-12-22



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MASTER SCHEDULE AESPOE

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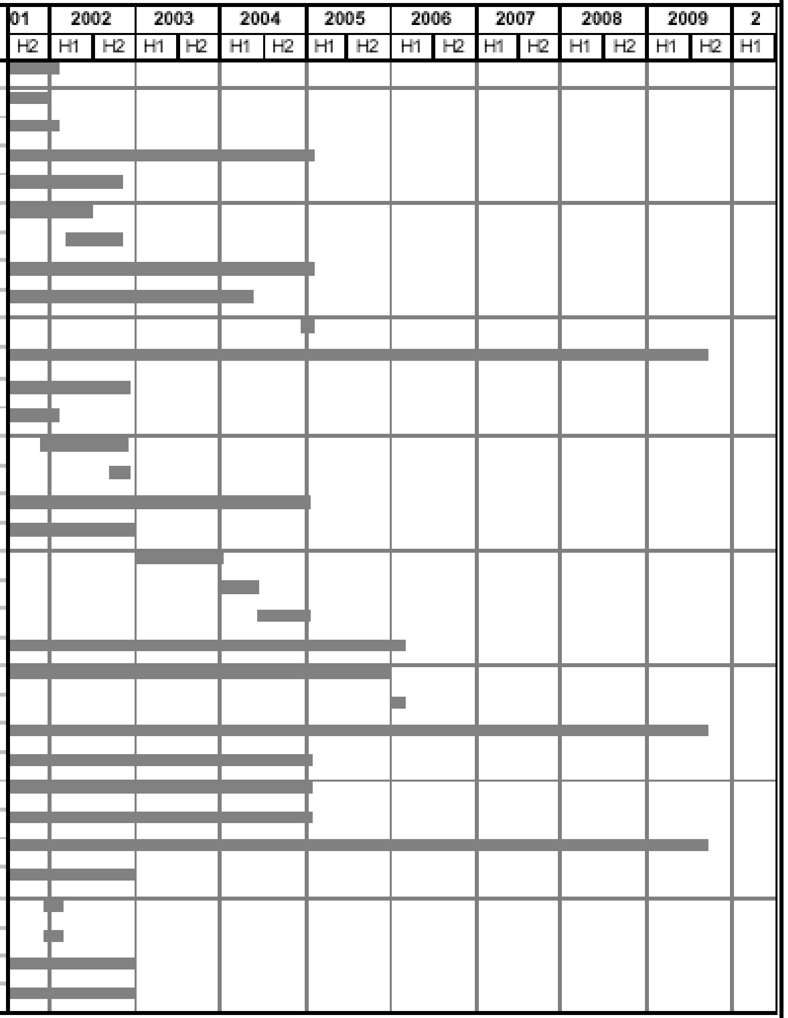
Version 2000.1

Christer Svemar

WBS	Namn	Start	Slut
1.7	MATRIX FLUID CHEMISTRY	97-10-20	02-01-31
1.7.1	Drillcore study	98-12-24	01-12-21
1.7.2	Fluid sampling	97-10-20	02-01-31
1.8	The Task Force on modelling of groundwater flow and transort of s	00-01-03	05-01-28
1.8.1	Task 5	00-01-03	02-10-25
1.8.1.1	Modelling	00-01-03	02-06-28
1.8.1.2	Reporting	02-03-08	02-10-25
1.8.2	Task 6	00-11-09	05-01-28
1.8.2.1	Modelling	00-11-09	04-05-17
1.8.2.2	Reporting	04-12-07	05-01-28
2	**DEMONSTRATION OF TECHNOLOGY FOR THE REPOSITORY SY**	**99-09-15**	**09-09-09**
2.8	The Prototype Repository	00-08-14	02-11-29
2.1.1	Installation of inner section	00-08-14	02-01-25
2.1.2	Installation of outer section	01-11-12	02-11-28
2.1.3	Test and comissioning	02-09-11	02-11-29
2.2	Backfill and Plug Test	99-11-22	05-01-07
2.2.1	Water saturation	99-11-22	03-01-03
2.2.2	Flow & Mechanical testing	03-01-06	04-01-02
2.2.3	Backfill excavation	04-01-05	04-06-04
2.2.4	Evaluation and reporting	04-06-07	05-01-07
2.3	Canister Retrieval Test	00-11-03	06-03-02
2.3.1	Saturation	00-11-03	05-12-30
2.3.2	Finish report	06-01-02	06-03-02
2.4	Long term tests of buffer material	99-09-15	09-09-09
2.4.1	A2 Heating Tests	00-01-20	05-01-20
2.4.2	A3 Heating Tests	00-01-20	05-01-20
2.4.3	S2 Heating Tests	00-01-20	05-01-20
2.4.4	S3 Heating Tests	99-09-15	09-09-09
3	**AESPOE FACILITY OPERATION**	**00-09-04**	**02-12-27**
3.1	EXTENTION FIRE ALARM UNDERGROUND	01-12-10	02-02-11
3.1.1	Reporting	01-12-10	02-02-11
3.2	ROCKA VISULATIZATION SYSTEM	00-09-04	02-12-27
3.2.1	Implementation of RVS	00-09-04	02-12-27



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