International Progress Report

IPR-99-31

Äspö Hard Rock Laboratory

Prototype Repository

Hydraulic tests in exploratory holes
Injection tests

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Geosigma

May 1999

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Foreword

This International Progress Report is one out of seven reports presenting the results from the hydrogeological field characterisation work prior to boring of the six deposition holes in the Prototype Repository tunnel in the Äspö Hard Rock Laboratory. The field investigations have been conducted in seven test campaigns between November 1997 and August 1999. The results from each campaign are described in a separate report and the following seven ones have been published.

Gentzschein, B. 1997: Äspö Hard Rock Laboratory. Prototype Repository. Hydraulic Tests in Pilot Holes. Drill campaign 1. SKB International Progress Report IPR 99-27, December 1997.

Gentzschein, B. 1998: Äspö Hard Rock Laboratory. Prototype Repository. Hydraulic Tests in Exploratory Holes. Drill campaign 2. SKB International Progress Report IPR 99-28, May 1998.

Gentzschein, B. 1999: Äspö Hard Rock Laboratory. Prototype Repository. Hydraulic Tests in Exploratory Holes. Drill campaign 3a. SKB International Progress Report IPR 99-29, June 1999.

Gentzschein, B. 1999: Äspö Hard Rock Laboratory. Prototype Repository. Hydraulic Tests in Exploratory Holes. Drill campaign 3b. SKB International Progress Report IPR 99-30, June 1999.

Gentzschein, B. 1999: Äspö Hard Rock Laboratory. Prototype Repository. Hydraulic Tests in Exploratory Holes. Injection Tests. SKB International Progress Report IPR 99-31 , May 1999.

Gentzschein, B. 1999: Äspö Hard Rock Laboratory. Prototype Repository. Hydraulic Tests in Exploratory Holes. Interference Tests A after drill campaign 3. SKB International Progress Report IPR 99-32, May 1999.

Gentzschein, B. 1999: Äspö Hard Rock Laboratory. Prototype Repository. Hydraulic Tests in Exploratory Holes. Interference Tests B after drill campaign 3. SKB International Progress Report IPR 99-33, November 1999.

The reports include technical specifications and description of the equipment used, measurement procedures, results of the flow and pressure measurements, relevant test data and all the background data necessary for interpretation and evaluation of field data.

Each test produces a great number of diagrams showing responses in test sections or observation boreholes caused by pressure draw-downs. Each report comprises between 120 and 600 diagrams sorted in appendices after the describing text. Due to the great number, the diagrams are not included in the printed versions of the reports. But the reports, including the diagrams are also stored as Word documents on a CD-R. In addition each diagram is stored as a file (GIF – format). The Word-documents, converted to PDF-format, as well as the diagram-files are available at the Äspö Hard Rock Laboratory.

ABSTRACT

The Prototype Repository in the Äspö Hard Rock Laboratory aims at simulating conditions in the future Deep Repository as realistically as possible. Some of many tasks are to observe the water saturation and homogenisation of the bentonite buffer and the backfill, and their interaction with the rock as well as to compare developed codes and material models with the observations. These tasks among other things need information on the hydraulic properties of the rock. The geohydraulic characterisation of the rock around the Prototype Repository is made in three stages. Each stage is intended to contribute to more details useful for determination of the localisation of the deposition holes and the boundary and rock conditions needed for the interpretation of the experimental data. The three stages are focused on:

1. Mapping of the tunnel
2. Pilot and exploratory holes
3. Deposition holes

This International Progress Report is report number 5 out of seven in a series which presents the results from stage 2, i e hydrogeological characterisation in pilot and exploratory holes, which have been obtained during seven test campaigns between November 1997 and August 1999. More precisely the present International Progress Report presents the results from the constant pressure injection tests in 13 holes between sections 3/542 and 3/578. Four of the hole are approximately 30 m and eight approximately 12 m deep. (The first four reports concerned in-flow and pressure build-up studies in the 33 exploratory drillholes in the Prototype Repository rock volume, supplemented with interference tests in hole sections with high in-flows.)

The tests were performed using the Underground Hydraulic Test system, UHT. Packers were installed in the studied holes so that three sections of 0.5 m each were obtained down to a depth of 1.75 m. Consequently 39 sections could be tested. During the flow phase the pressure in the test section was increased by 0.2 to 0.4 MPa over the ambient pressure. The pressure response in all the other 38 sections were registered with respect to magnitude and increase by time.

SAMMANFATTNING

Prototypförvaret i Äspölaboratoriet byggs för att simulera förhållandena så naturnära som möjligt i det framtida djupförvaret. Några av många uppgifter är att observera bentonitbuffertens och återfyllens vattenmättnad och homogenisering liksom den interaktion mellan materialen och berget som sker. samt att jämföra utvecklade koder och materialmodeller med de gjorda observationerna. För dessa uppgifter behöver bl a bergets hydrauliska egenskaper kunna beskrivas. Denna geohydrauliska karakteriseringen av berget omkring Prototypförvaret görs i tre steg. Varje steg ska bidra med mer användbar detaljinformation om lokalisering av deponeringshål samt randvillkor och bergegenskaper som behövs för tolkning av framtida observationer. De tre stegen inriktas på:

1. Kartering av tunneln
2. Pilot-och undersökningshål
3. Deponeringshål

Denna International Progress Report utgör rapport nummer 5 av sju i en serie som presenterar resultaten från Steg 2, dvs de hydrogeologiska karakteriseringar i pilot-och undersökningshål som gjorts i sju testkampanjer mellan november 1997 och augusti 1999. Mer precist redovisar föreliggande International Progress Report resultaten från mätningar i 13 hål mellan sektion 3/542 0ch 3/578. Fyra av hålen är ca 30 m och åtta ca 12 m djupa. (Den fyra första rapporterna redovisade resultaten från inflödes-och tryckuppbyggnadstester i de 33 undersökningshålen i prototypförvarsområdet kompletterade med interferenstester i borrhålssektioner med stort inflöde.)

I testerna användes systemet Underground Hydraulic Test, UHT. Manschetter installerades i de studerade borrhålen så att tre sektioner om 0,5 m vardera avskildes ner till et djup av 1.75 m. Följdaktligen kunde 39 sektioner testas. Under flödesfasen ökades trycket i den testade sektionen med mellan 0,2 och 0,4 Mpa jämfört med det naturliga vattentrycket i sektionen. Tryckresponsen i alla de andra 38 sektionerna registrerades i fråga om storlek och uppbyggnad med tiden

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1. BACKGROUND

Within the scope of SKB's program for R&D 1995, SKB has decided to carry out a project named ”Prototype Repository ” at the Äspö Hard Rock Laboratory. The aim of the project is to test important components in SKB' deep repository system in full scale and in a realistic environment.

The Prototype Repository is focused on testing and demonstrating the function of SKB's deep repository system. Activities aimed at contributing to development and testing of the practical engineering measures required to rationally perform the steps of a deposition sequence are also included. However, efforts in this direction are limited, since these matters are addressed in the Demonstration of Repository Technology project and to some extent in the Backfill and Plug test.

The characterisation of the test site, located in the TBM-drilled part of the Äspö HRL-tunnel, will be made in three stages. Each stage is intended to contribute to more details useful for the determination of the localisation of the deposition holes and also the boundary and rock conditions needed for the interpretation of the experimental data. The three stages are focused on:

1. Mapping of the tunnel
2. Pilot and exploratory holes
3. Deposition holes

Stage 1 is now completed. Stage 2 has been divided into three drilling campaigns:

1. Drilling of pilot holes
2. Drilling of exploratory holes-short boreholes
3. Drilling of exploratory holes-long boreholes

Ten pilot holes were drilled between October 14th and October 20th 1997 in the tunnel interval 3/539 m - 3/593 m. Ten of the short exploratory boreholes were drilled in the tunnel interval 3/544 m - 3/588 m between March 16th and March 24th 1998. Hydraulic tests were performed in these boreholes in November 1997 and in April 1998. Two short exploratory holes were drilled April 25th and 26th 1998. Nine long exploratory (30 m) boreholes were drilled June 3rd - June 28th 1998. Further more four of the older boreholes were extended to 30 m depth during May 1998. In July and August 1998 two c 50 m long exploratory boreholes where drilled from the G-tunnel towards and above the prototype tunnel. During the summer and autumn 1998 flow measurements and hydraulic tests (PBT's and interference tests) were performed in the long exploratory holes. The last tests were completed in December 1998.

This report describes the constant pressure injection tests, carried out in 13 exploratory boreholes in the prototype tunnel during January 1999.

2. OBJECTIVES

2.1 General objectives

The Prototype Repository is aimed at simulating a real repository in as many aspects as possible regarding geometry, materials and rock environment. The Prototype Repository is a demonstration of the integrated function of the repository components. Results will be compared with models and assumptions to their validity.

The major objectives for the Prototype Repository are:

- To demonstrate the integrated function of a full-scale prototype of the repository System.
- To provide a full-scale reference for testing/scrutinization of models, experiments and assumptions.
- To develop, test and demonstrate appropriate engineering standards, quality standards and quality assurance systems.
- To demonstrate technology for monitoring of the repository system.

The objectives for the characterisation program are:

- To provide a basis for determination of localisation of the deposition holes
- To provide data on boundary and rock conditions to enable interpretation of the experimental data.

2.2 Objectives of the hydraulic tests injection tests

The objectives of the injection tests in the exploratory holes is to obtain data for the geological and hydrogeological models. Another objective is to see if the hydraulic characteristics in the near field of the upper part of the depositions will change due to drilling of the deposition holes. In order to observe any changes the tests have to be made in exactly the same manner prior to and after drilling of the deposition holes.

The objectives of the hydraulic tests in the long exploratory boreholes are:

- The hydraulic tests in the exploratory holes shall provide hydrogeological data useful for setting up a hydrogeological model of the rock volume around the TBM tunnel.

- Data shall together with the geological and other investigations, constitute a basis for interpretation of changes of the rock characteristics around the upper part of the rock volume due to drilling of the deposition holes.

3. SCOPE

The injection tests were performed, using the Underground Hydraulic Test system, UHT, in 13 boreholes located in the TBM drilled part of the tunnel between section 3/542 m and section 3/578 m. Nine of the boreholes are vertical or subvertical, four have an inclination of 45 degrees. The nominal diameter is 76 mm. The borehole lengths and the dates of drilling are presented in Table 3-1.

Prior to the injection tests UHT 1 was mobilised. The mobilisation included transfer to the test site, calibration of flow meters and transducers and evacuation of air from the flow system. The preparations were conducted 16-17th of December 1998 and 7-8th of January 1999.

Table 3-1 Drilling data and borehole data of 13 injection tested exploratory boreholes in the Prototype Repository

Borehole	Drilling completed (Date)	Borehole length (m)	Comment
KA3542G01	980623	30.04	inclination 45º
KA3542G02	980616	30.01	“
KA3544G01	980324	12.00	
KA3546G01	980323	12.00	
KA3548G01	980323	12.01	
KA3550G01	980322	12.03	
KA3552G01	980321	12.01	
KA3554G01	980623	30.01	inclination 45º
KA3554G02	980616	30.01	“
KA3572G01	980320	12.00	
KA3574G01	980425	12.00	
KA3576G01	980426	12.01	
KA3578G01	980319	12.58	

Four tests with section length 0.5 m were planned to be performed in the interval 0.25 to 2.25 m in each borehole. However, since the length of the packer tool specially made for this occasion was too short, only three tests down to 1.75 m depth in each borehole were conducted. Consequently 39 sections were tested, see Table 3-2. The test period started January 8th and ended 16th of January 1999.

The demobilisation of the UHT 1 system was carried out January 16th and 20th.

Table 3-2 A list of injection tests conducted in exploratory boreholes. Prototype Repository - January 1999

Borehole	Date of test	Test No		Section	Start Test (kl.)	V. 0pen (kl.)	V Close (kl.)	End of Test (kl.)
KA3542G02	990108	1		0.25 - 0.75	19.23(7/1)	11:19.14	11:41.15	13.09
KA3542G02	990108	2		0.75 -.1.25	13.21	14:06.21	14:27.52	14.19
KA3542G02	990108	3		1.25 - 1.75	15.36	17:03.45	17:50.04	09.20 (9/1)
KA3542G01	990109	4		0.25 - 0.75	11.36	12:02.47	12:43.56	14.47
KA3542G01	990109	5		0.75 -.1.25	14.51	15:22.46	15:55.03	16.14
KA3542G01	990109	6		1.25 - 1.75	16.45	17:22.20	17:52.35	09.23 (10/1)
KA3544G01	990110	7		0.25 - 0.75	10.58	11:40.57	12:07.46	14.05
KA3544G01	990110	8		0.75 -.1.25	14.16	14:48.22	15:17.26	15.38
KA3544G01	990110	9		1.25 - 1.75	15.41	16:13.03	16:33.51	17.14
KA3546G01	990111	10		0.25 - 0.75	17.20(10/1)	10:28.08	10:54.42	11.10
KA3546G01	990111	11		0.75 -.1.25	11.18	11:54.56	12:15.26	13.29
KA3546G01	990111	12		1.25 - 1.75	13.24	14:11.10	14:32.29	14.55
KA3548G01	990111	13		0.25 - 0.75	15.22	16:02.46	16:31.37	16.49
KA3548G01	990111	14		0.75 -.1.25	16.55	17:26.18	17:49.02	18.06
KA3548G01	990111	15		1.25 - 1.75	18.12	18:46.08	19:08.12	08.18
KA3550G01	990112	16		0.25 - 0.75	08.57	09:39.05	10:03.51	10.17
KA3550G01	990112	17		0.75 -.1.25	10.25	11:08.56	11:31.39	13.42
KA3550G01	990112	18		1.25 - 1.75	13.52	14:39.27	15:01.00	15.15
KA3552G01	990112	19		0.25 - 0.75	15.40	16:30.13	16:51.41	17.12
KA3552G01	990112	20		0.75 -.1.25	17.35	18:05.07	18:25.10	18.37
KA3552G01	990112	21		1.25 - 1.75	18.44	19:16.47	19:36.43	08.27 (13/1)
KA3554G02	990113	22		0.25 - 0.75	09.10	09:53.51	10:20.09	10.32
KA3554G02	990113	23		0.75 -.1.25	10.40	11:17.33	11:43.04	12.59
KA3554G02	990113	24		1.25 - 1.75	13.08	14:55.09	15:17.11	15.33
KA3554G01	990113	25		0.25 - 0.75	16.17	16:52.47	17:14.04	17.29
KA3554G01	990113	26		0.75 -.1.25	17.40	18:15.17	18:37.15	18.49
KA3554G01	990113	27		1.25 - 1.75	19.05	19:38.52	20:12.58	08.00 (14/1)
KA3572G01	990114	28		0.25 - 0.75	10.24	11:47.58	12:10.42	13.22
KA3572G01	990114	29		0.75 -.1.25	13.30	14:14.25	14:34.25	14.51
KA3572G01	990114	30		1.25 - 1.75	14.58	15:48.31	16:19.31	16.33
KA3574G01	990114	31		0.25 - 0.75	16.55	17:35.01	17:58.14	18.11
KA3574G01	990114	32		0.75 -.1.25	18.25	19:04.21	19:31.13	08.17 (15/1)
KA3574G01	990115	33		1.25 - 1.75	08.26	09:01.50	09:33.59	09.52
KA3576G01	990115	34		0.25 - 0.75	10.17	10:53.43	11:14.23	12.31
KA3576G01	990115	35		0.75 -.1.25	12.39	13:28.13	13:50.54	14.05
KA3576G01	990115	36		1.25 - 1.75	14.14	15:01.26	15:23.44	15.35
KA3578G01	990115	37		0.25 - 0.75	16.10	16:55.33	17:16.14	17.29
KA3578G01	990115	38		0.75 -.1.25	17.36	18:12.13	18:32.27	18.45
KA3578G01	990115	39		1.25 - 1.75	18.51	19:25.22	19:46.10	09.31 (16/1)

4. EQUIPMENT USED

Parts of the underground hydraulic test system (UHT 1) were used for the injection tests. This was the first occasion when injection tests were performed using the UHT 1 equipment.

UHT 1, developed by SKB (Almén and Hansson, 1996) is constructed for underground hydraulic testing in boreholes with 56 mm and 76 mm diameter. Maximum borehole length is 300 m and the maximum working depth is 500 metres below sea level.

The main parts of the system (Figure 4-1) are :

- Down-hole equipment with packers and pipe string
- Hoisting rig
- Mini container including a system control unit, a measurement control unit and a data export and plotting unit

When conducting the injection tests only the mini container was utilised. The ordinary inflatable polyurethane packers and the pipe string were replaced by a specially made mechanical packer, which was lowered manually in the borehole and not by the rig. The packer was fixed in position with the help of a pipe wrench.

The mechanical double packer was manufactured by LIVINSTONE AB. The length of the packer is 2.3 m, see Figure 4-2. The test interval of 50 cm is limited by rubbers on both sides. The rubber length is 0.10 m. At the top the packer pipe is branched into two pipe ends. One is connected to the test interval between the sealing rubbers, the second pipe end is in hydraulic contact with the space below the lower packer.

On the pipe end connected to the test section a valve arrangement, consisting of a three-way coupling, a number of quick couplings and a valve, was mounted. To this device the injection hose and a hose to a pressure transducer (P) positioned in the mini container could be connected. The valve was used as a test valve. When opened, the injection started (after a delay due to the start of the regulation valves in UHT 1). The test interval was shut in and the injection stopped by closing the valve. The second pipe end was connected to a pressure line establishing hydraulic contact between the borehole interval below the packer and a pressure transducer (P_a) in the container.

The mini container is made of steel and has the outer dimension 2.5 x 1.7 x 2.6 m. Its walls are insulated using covered white plates and the floor is covered with an aluminium sheet. It is furnished with a table, cupboards and shelves for keeping tools, spare parts etc. The container accommodates the monitoring equipment the computers and the printer necessary to retrieve and plot data, respectively.

The electrical system of the container is connected to 16 A three-phase AC. The inside of the container is supplied with two 230 V electrical systems. One of them is directly connected to the power net, the second, which feeds the measurement instruments is also connected to an UPS-unit (auxiliary power supply) to avoid data losses during a power failure.

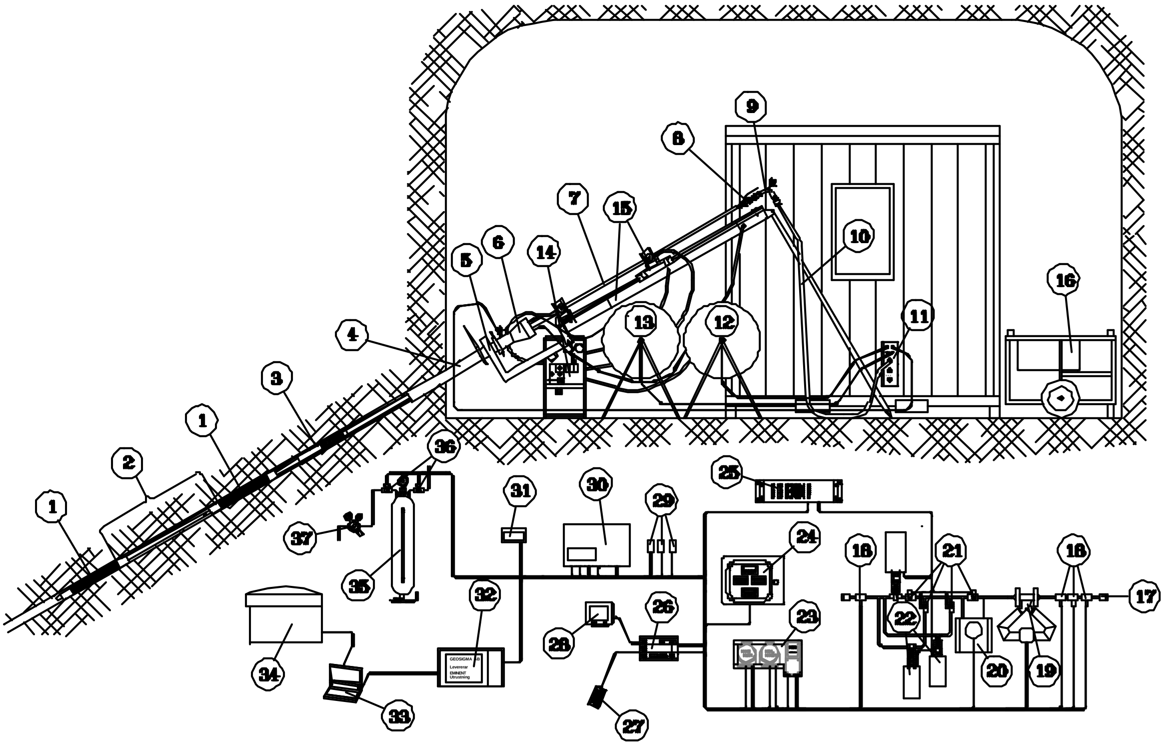


Figure 4-1 Overview of the UHT 1-system

1. Packer
2. Measurement section
3. Test valve
4. Casing
5. Extension beam
6. Sealing device
7. Pipe string
8. Adapter
9. Tube bend with air evacuation valve
10. Measurement hose from borehole
11. Wall lead-in
12. Hose reel, packer
13. Hose reel, section pressure
14. Control board, hoisting rig
15. Feed beam, hoisting rig
16. Power unit, hoisting rig
17. Inlet to container
18. Sensors, pressure, temperature, electrical conductivity
19. Flow meter BIG
20. Flow meter small
21. Valves
22. Regulation valves
23. Amplifier to Flow meter unit
24. Display for Flow meter unit
25. Stepping motor
26. Regulation computer
27. Regulation computer, key board
28. Regulation computer, monitor
29. Pressure transducers
30. Data scan box
31. External display
32. Measurement computer (SPC Rab-bit)
33. Evaluation computer (Compaq)
34. Laser Jet printer
35. Pressure tank, packer inflation
36. Solenoid valves
37. N_2-gas governor

The pipe system within the container is connected to a lead-through in the wall. On the outside of the lead-through, different hoses from the borehole are connected with the help of quick-couplings. The standard UHT 1 equipment includes an injection hose of polyurethane with a steel inforced cord (Φ=3/4 “). During the injection tests polyamide hoses (Tecalan 6/4 mm) were used as injection hoses as well as for pressure conducting.

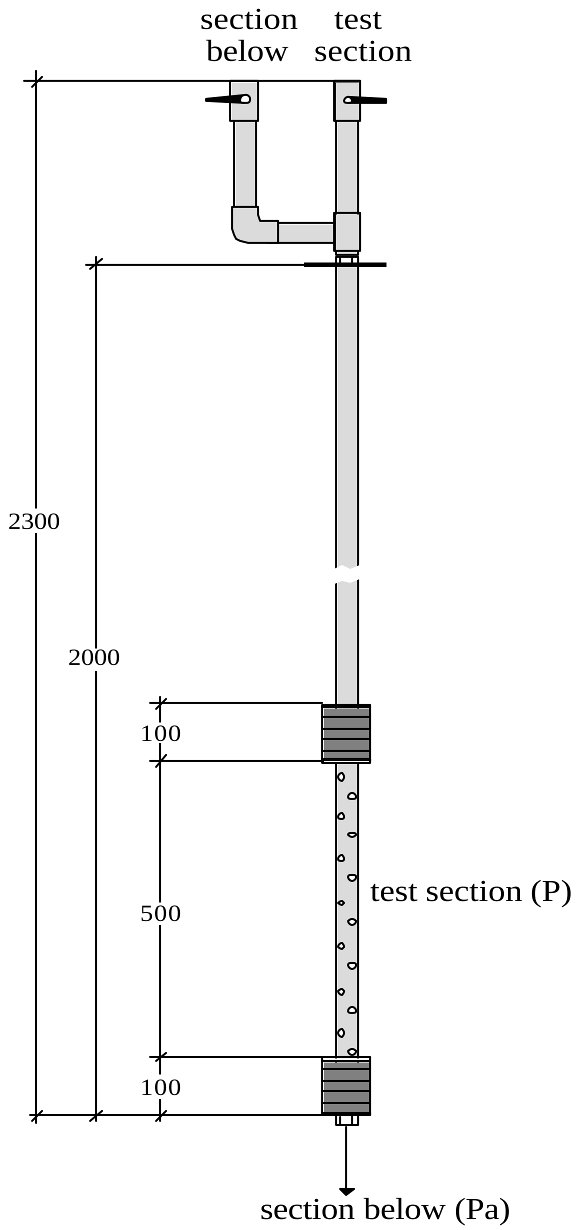


Figure 4-2 Mechanical double packer used in the Injection tests of 13 exploratory bore holes of the Prototype Repository, January 1999

The maximum injection pressure of the UHT 1 is 10 bar. If the undisturbed ambient pressure exceeds 10 bar injection tests using UHT 1 are not possible to perform.

The pressure transducers, of type Druck PTX 630, monitoring absolute pressure, are mounted on a board on one of the container walls. Two sets of transducers with different pressure ranges are operable. The standard set of pressure transducers are, cf. section 5.4:

Interval/packer	**Number**	**Transducer id**	**Range (alternative range)**		
Test section	2	P and P_b	6	MPa	(1 MPa)
Borehole	1	P_a	6	MPa	(1 MPa)
Packers	1	P_{pack}	8	MPa	(2 MPa)

6 MPa transducers were used for P, P_b and P_a. P_{pack} was not used at all.

The pressure transducers are connected to the borehole through cannula tubes, hydraulic hoses and polyamide hoses.

The technical specifications of the pressure transducers are:

Type :	Druck Transmitter PTX 630 abs.
Supply voltage:	9 - 30 VDC
Output current:	4 - 20 mA
Linearity and hysteresis:	± 0.1 % of full scale
Temperature error :	± 0.3 % of full scale in the range -2 ^{o}C - +30 ^{o}C

The flow meter unit enables monitoring and regulation of the flow during constant pressure tests and constant flow tests, respectively. The flow regulation is operated and controlled using a digital computer. The main parts of the flow meter unit are:

- Two mass flow meters of type Coriolis-meters, flow range: 0.001-100 l/min
- Valves to regulate the flow rate
- A water filter
- Two pressure transducers, measuring the pressure at the inlet and the outlet of water, respectively.
- A temperature sensor.

Further components are:
- A display unit with four displays
- A cylinder with an electric conductivity sensor
- An amplifier to the flow meter unit and the conductivity sensor.

The water flow is conducted via the large flow meter (Q_{big}) irrespective if the small flow meter (Q_{small}) is in use or not. The measurement system selects flow data from one of the two flow meters according to the following criteria:

Q_{small} is selected if (Q_{big} <Q2L2 and Q1L1< Q_{small} ≤Q1L2) or (Q_{big} ≤Q2L1 and Q_{small} >Q1L1).
Q_{big} is selected if (Q_{small} ≤Q1L1 and Q_{big} >Q2L1) or (Q_{small} >Q1L2 and Q_{big} >Q2L1)

QIL1 = Low limit for Q_{small} connected, set to $-5.0 * 10^{-7}$ during the injection tests.
Q1L2 = Upper measure limit for Q_{small}, set to $1.18 * 10^{-5}$ during the injection tests.
Q2L1 = Low limit for Q_{big} connected, set to $-5.0 * 10^{-5}$ during the injection tests.
Q2L2 = Lower measure limit for Q_{big}, set to $1.16 * 10^{-5}$ during the injection tests.

The system changes between the two flow meters during a test, depending on the variation of the flow rate. Which one used is known only by opening the *HT2 data file.

The technical data of the main components of the flow meter unit are as follows:

Flow meter Q_{small}

Type :	Micro Motion mass flow meter
Range:	0 - 1.00 kg/minute
Accuracy:	±0.4 % of current value ± zero stability (0.0001 Kg/minute)
Pressure drop at max.flow:	c. 500 kPa
Maximum working pressure:	7 MPa

Flow meter Q_{big}

Type :	Micro Motion mass flow meter
Range:	0 - 100 kg/ minute
Accuracy:	± 0.15 % of current value ± zero stability (0.003 Kg/minute)
Hysteresis:	< 0.1 %
Pressure drop at max. flow:	c. 500 kPa
Maximum working pressure:	5 MPa

Pressure transducers, inlet and outlet

Type :	Druck Transmitter PTX 1400
Range:	0 - 6 MPa
Linearity and hysteresis:	± 0.15 % typical value ± 0.25% maximum, Best Straight Line Definition

Temperature sensors

Type :	GEOSIGMA BG01 Semiconductor type
Range:	0 - +32 ^{o}C
Accuracy:	±0.25 ^{o}C

Electrical Conductivity meter

Type :	Kemotron 2911
Sensor:	Kemotron 9221, 4-electrode
Range:	Adjustable, 14 intervals within the range 0 - 20 000 mS/m
Accuracy, amplifier:	±0.25 % of current value
Accuracy, cell constant:	±0.5 %
Maximum working pressure:	5 MPa
Temperature sensor:	Pt 1000

When performing constant pressure injection tests, the constant pressure is maintained by a standard PC (Intel 486, 100 MHz, 4MB RAM and 200 MB HDD, CRT monitor). The pressure is kept constant by regulating the water flow rate. Specially designed software opens and shuts regulation valves such that a constant pressure according to a pre-set value is achieved. The program is written in TURBO-C and runs on a DOS platform.

The UHT 1 measurement system is controlled by, and operated from a 120 MHz Pentium laptop computer. The software used is DM2 (Datascan Technology) , which also constitutes the platform for the Hydro Monitoring System (HMS) at the Äspö HRL. DM2 is a standard program, but has been supplemented with additional programs.

All sensors are connected to the AD-converter unit (Datascan 7320)
In addition there is a Datascan-unit for digital I/O (Datascan 7035).

The data produced by UHT 1 are evaluated in a second computer, a portable Compaq 100 MHz Pentium. The operating system is Windows 95, but the evaluation programs run on a DOS platform. Data files from the test are transferred to the evaluation computer during or after each test.

The UHT 1-system also includes a HP Laser Jet 5p, which is printing either evaluation plots from the evaluation computer, or display images from the measurement computer.

5. PERFORMANCE AND EVALUATION

5.1 Test principles

The tests were performed as constant pressure injection tests. During the flow phase the ambient pressure in the test section was generally increased with c. 0.2 MPa to 0.4 MPa. Subsequently the test section was shut in and the pressure was allowed to recover to ambient pressure.

In the test section 1.25 m – 1.75 m in borehole KA3542G02 the borehole pressure was higher than the maximum pressure of the injection pump. Therefore a constant pressure outflow test was performed in this section.

The pressure was measured within the test section as well as in the borehole interval below the packers. The surrounding boreholes were packed of and closed during the test period.

5.2 Test cycle and procedures

The test cycle was performed as follows:

- The double packer was lowered into position and the sealing rubbers were expanded to delimit the test interval.
- The measurement section and the packer pipes were filled up with water.
- The injection hose and the pressure hoses (all filled up with water) were connected via quick-couplings.
- The measurement system of UHT 1 was started.
- The undisturbed pressure was measured for at least 20 minutes.
- The injection was started, by opening the test valve.
- Regulation of a constant injection pressure for 20 minutes.
- The injection was stopped, by closing the test valve.
- Pressure recovery during 10 minutes.
- The UHT 1 measurement was ended and the packer released.
- Transfer to next borehole section.

The different stages of a test were regulated and controlled from the measurement computer in the UHT 1 container. The flow phase was started according to the following procedure:

- The injection pump was started.
- The data processing system was initiated to begin the flow phase
- Within 45 seconds the test valve was manually opened .

The recovery period was initiated in a corresponding way. In the diagrams the start of the flow and recovery periods, respectively, are determined by pre-set criteria (Crit4 and Crit5 respectively on the A0-flyleaf).

During the injection, the pressure initially increased far more than the pre-set value. Since most of the test sections were low conductive or impermeable, the pressure was decreasing during the entire flow period without reaching down to the reference level. To achieve a more constant pressure the automatic regulation was interrupted when the pressure was close to the pre-set value, and then restarted after c. 30 seconds. In some cases, if the initial pressure value did not deviate too much, the reference level was changed to be more equal to the actual pressure.

The constant pressure during the injection was achieved prior to the injection start by pre-setting a reference pressure on the display of the regulation computer. The display value P_{ref} was not compensated for the vertical distance between the transducer and the test section as was the case with the pressures P, P_a and P_b , see section 5.4, p.14.

5.3 Calibration

The flow meters Q_{small} and Q_{big}, see chapter 4, were calibrated using graduated cylinders and a stop watch. Two flow values were measured for each flow meter for the purpose of calibration, and each level was measured twice.

The pressure transducers P , P_b and P_a, see chapter 4, were calibrated with the help of the reference pressure system established in the Äspö HRL tunnel. The transducers were connected to two hoses, filled with water of known density. The water column of each hose ends at a well defined reference water level (at KK0120 and KK2850) enabling calculation of the calibration constants. The position of the pressure sensors and the barometric pressure are also used in the calibration process. The elevation of the sensors were surveyed prior to the tests and the barometric pressure was measured with a Druck DPI 700 digital pressure indicator, which have a factory-listed accuracy of 0.05% of full scale (2 bar).

The temperature sensor and the electric conductivity sensor were only zero-point calibrated. The temperature sensor was compared with a high-accuracy portable spirit thermometer of good quality (the accuracy was ±0.2 °C in the range -10 °C - +50°C). The conductivity sensor was calibrated using a liquid solution with a well determined electric conductivity.

The results of the calibrations were entered into the measurement computer and the calibration constants were automatically calculated.

5.4 Data processing

The parameters, measured by the UHT-1 measurement system are:

P	Pressure of the test section
P_a	Pressure of the borehole intervals above and/or below the test section
P_{pack}	Packer pressure
T_{surf}	Water temperature (surface)
Q_1	Water flow rate Q_{small}
Q_2	Water flow rate Q_{big}
P_b	Pressure of the test section (same as P)
Elcond	Electrical conductivity

Since a mechanical packer was used, P_{pack} was not measured during the injection tests. P_a was equal to the pressure of the borehole interval below the test section, see Figure 4-2.

The operative system of the measurement computer is OS9000. The measurement program is based on a program called
- DM2-386

Additionally there are three modules (standard programs):

- CALC-386 (for special transformation of data)
- SEQ-386 (creates automatic sequenses of measurements, data storing.)
- MIMICMAN (creates graphical interfaces with process images)
- CONTR-386 (controller for regulation of flow/pressure)

These programs are supplemented with a number of application programs.

- Menu programs for entering data (calibration constants, background data)
- Report generator which creates an out put file (MIO-format)
- Drive routine for extra display
- Calibration programs

The program ”KERMIT” is used to transfer data from the measurement computer to the evaluation computer.

The program SHELL.EXE starts all the programs in the evaluation computer. SHELL.EXE is a commercial program from WordPerfect. The data file transferred from the measurement computer has a MIO-format (Appendix 2 p.3). This file is converted to a number of files, which enables plotting of the different diagrams. The same plot program creates plots both on the screen and on the printer. The programs in the evaluation computer are:

- IPPLOT.EXE Conversion program from ERGO-data (B. Johansson)
- SKBPLOT.EXE Plot program from ERGO-data (B. Johansson)
- PLTCNV.EXE File selection program. From GEOSIGMA (G. Nyberg)
- RUNBAT.EXE File selection program and start of BATCH file. From GEOSIGMA (G. Nyberg)

The plot program generates three types of diagrams :

- A diagrams (**A1 - A5**) illustrating pressure, flow and temperature variations during the whole test cycle. **A0** is a flyleaf displaying background data as well as measured and calculated data from the test.

- B diagrams (**B1 - B6**) representing pressure and flow variations during the flow phase in logarithmic and semilogarithmic scale. Also other parameter transformations are plotted.

- C diagrams (**C1 - C9**) showing pressure and flow variations during the pressure build up phase in logarithmic and semi-logarithmic scale. Also other transformations of parameters and time are plotted.

The pressure values of the diagrams are corrected for the vertical distance between the transducer and the test section (upper limit). This is achieved by entering basic data such as length to the test section, borehole inclination and the height of the transducer, into the measurement computer, before each test.

The format of the section limits in the diagrams only allows one decimal, which entails that the section limits 0.25 m, 0.75 m, 1.25 m and 1.75 m are written 0.3 m, 0.8 m, 1.3 m and 1.8 m respectively

A more detailed description of the diagrams is found in Appendix 1. In Appendix 2 the symbols and the parameters of the diagrams are described.

5.5 Preliminary evaluation

The UHT 1 system automatically calculates a steady-state value of the hydraulic conductivity of the test sections using Moye´s formula (Moye 1967):

$$K = \frac{Qp \times 1000 \times 9.81}{L \times dP_{om}} \cdot C$$

where

Qp = flow rate of the test section at the end of the flow phase(m^3/s)
dP_{om} = Average of $P - P_o$ during the flow phase (kPa)
P = hydraulic head of the test section
P_o = hydraulic head of the test section before flow start.

$C = [1 + \ln(L/2r_w)]/2\pi$
L = Length of the test section (m)
r_w = borehole radius (m)

The steady-state hydraulic conductivity is printed on the flyleaf of each test section (as K_{OSS}).

5.6 Sources of error

The accuracy of the pressure transducers, the flow meters, the temperature sensor and the electrical conductivity sensor is described in chapter 4.

The zero stability of the “small “ flow meter is $\pm 1.67 \cdot 10^{-9}$ m^3/s (0.0001 kg/min), see chapter 4. In the majority of the injection tests the flow rate is close to or less than the zero stability and often negative. In most tests the flow values are scattered around the zero flow line. This means that in many tests the flow values and the calculated conductivity values, section 5.5, have low accuracy.
In a number of tests the pressure increases after the injection stop. This could be an effect of a too short pressure stabilisation period or possibly due to high pressure in the borehole interval below the packers, which influences the section pressure.

6. Test data and results of the injection tests

In this chapter background data and important key data of each test are presented. In Table 6-1 data are summarised.

The pressure values P_0, P_p and P_f are compensated for the vertical distance between the pressure transducer and the test interval, see section 5.4. The pre-set section pressure, P_{ref} , however is not compensated .

Borehole KA3542G02, section 0.25 m - 0.75 m

Date:	99-01-08	Field Crew:	B. Gentzschein
Valve opened:	990108 111914	Valve closed:	990108 114115
Total flowing time :	22.0 min.	Tot. Pr. Build-up time	87.1 min.

Pressure before injection start	(P_0, kPa)	:	119.0
Pressure just before closing the valve	(P_p, kPa)	:	309.8
Pressure at the end of the recovery	(P_f, kPa)	:	346.6

Pre-set section pressure (during injection) (P_{ref}, kPa) : 303.3

Initially the pressure increases to >320 kPa. Thereafter it decreases to a level below the pre-set value ! Approximately 25 minutes after the valve closing the pressure increases, possibly due to the high pressure in the borehole interval below the packer.

The measured flow rate before and after the injection phase is internal within the flow meter system and does not impact the test section (since the test valve is closed). It is probably an effect of air in the flow meter system. The flow at the end, Qp, is negative ($-3.22 \cdot 10^{-10}$ m^3/s). This is within the limits of the zero stability, $\pm 1.67 \cdot 10^{-9}$ m^3/s (0.0001 kg/min), see chapter 4.

Borehole KA3542G02, section 0.75 m – 1.25 m

Date: 99-01-08 Field Crew: B. Gentzschein

Valve opened: 990108 140621 Valve closed: 990108 142752
Total flowing time : 21.5 min. Tot. Pr. Build-up time 29.9 min.

Pressure before injection start (P_0, kPa) : 120.2
Pressure just before closing the valve (P_p, kPa) : 315.8
Pressure at the end of the recovery (P_f, kPa) : 368.8

Pre-set section pressure (during injection) (P_{ref}, kPa) : 308.5

Initially the pressure increased to >570 kPa. By opening a valve the pressure fell to a level close to the pre-set value.

As in the preceding test the pressure increased after valve closing

The measured flow rate before the injection phase is of internal nature, see section 0.25 – 0.75 m.

Borehole KA3542G02, section 1.25 m – 1.75 m

Date: 99-01-08 Field Crew: B. Gentzschein

Valve opened: 990108 170345 Valve closed: 990108 175004
Total flowing time : 46.5 min. Tot. Pr. Build-up time 929.3 min.

Pressure before valve opening (P_0, kPa) : 3056.3
Pressure just before closing the valve (P_p, kPa) : 1045.7
Pressure at the end of the recovery (P_f, kPa) : 3130.5
Pre-set section pressure (during injection) (P_{ref}, kPa) : 1042

Because of the high section pressure the test was performed as a constant pressure outflow test. The recovery lasted over night.

Borehole KA3542G01, section 0.25 m - 0.75 m

Date: 99-01-09 Field Crew: B. Gentzschein

Valve opened: 990109 120247 Valve closed: 990109 124356
Total flowing time : 41.2 min. Tot. Pr. Build-up time 118.1 min.

Pressure before injection start (P_0, kPa) : 137.4
Pressure just before closing the valve (P_p, kPa) : 512.3
Pressure at the end of the recovery (P_f, kPa) : 474.7

Pre-set section pressure (during injection) (P_{ref}, kPa) : 500
Initially the pressure increased to >1000 kPa, then it slowly decreased to the pre-set value.
During the recovery the pressure initially fell off, then increased slowly.

Borehole KA3542G01, section 0.75 m – 1.25 m

Date: 99-01-09 Field Crew: B. Gentzschein

Valve opened: 990109 152246 Valve closed: 990109 155503
Total flowing time : 32.3 min. Tot. Pr. Build-up time 18.6 min.

Pressure before injection start (P_0, kPa) : 119.1
Pressure just before closing the valve (P_p, kPa) : 524.1
Pressure at the end of the recovery (P_f, kPa) : 546.9

Pre-set section pressure (during injection) (P_{ref}, kPa) : 500

Initially the pressure increased to c. 600 kPa. Then it didn't reach the pre-set value before recovery start. After valve closing the pressure didn't fall, but increased, possibly due to the high pressure in the borehole interval below the packer.

Borehole KA3542G01, section 1.25 m – 1.75 m

Date: 99-01-09 Field Crew: B. Gentzschein

Valve opened: 990109 172220 Valve closed: 990109 175235
Total flowing time : 30.3 min. Tot. Pr. Build-up time 928.7 min.

Pressure before injection start (P_0, kPa) : 118.8
Pressure just before closing the valve (P_p, kPa) : 540.5
Pressure at the end of the recovery (P_f, kPa) : 742.6

Pre-set section pressure (during injection) (P_{ref}, kPa) : 500

Initially the pressure increased to >1000 kPa. By opening a valve the pressure decreased. Again the pressure increased during the recovery (over night).

Borehole KA3544G01, section 0.25 m - 0.75 m

Date: 99-01-10 Field Crew: B. Gentzschein

Valve opened: 990110 114057 Valve closed: 990110 120746
Total flowing time : 26.8 min. Tot. Pr. Build-up time 116.5 min.

Pressure before injection start (P_0, kPa) : 162.0
Pressure just before closing the valve (P_p, kPa) : 690.9
Pressure at the end of the recovery (P_f, kPa) : 500.1

Pre-set section pressure (during injection) (P_{ref}, kPa) : 500

Initially the pressure increased to >1100 kPa. By opening a valve the pressure decreased.

Borehole KA3544G01, section 0.75 m – 1.25 m

Date: 99-01-10 Field Crew: B. Gentzschein

Valve opened: 990110 144822 Valve closed: 990110 151726
Total flowing time : 29.1 min. Tot. Pr. Build-up time 13.9 min.

Pressure before injection start (P_0, kPa) : 126.7
Pressure just before closing the valve (P_p, kPa) : 574.8
Pressure at the end of the recovery (P_f, kPa) : 613.6

Pre-set section pressure (during injection) (P_{ref}, kPa) : 500

Initially the pressure increased to c. 550 kPa. Shortly after the injection start, P_{ref} was changed to 550 kPa. The pressure increased during the recovery.

Borehole KA3544G01, section 1.25 m – 1.75 m

Date: 99-01-10 Field Crew: B. Gentzschein

Valve opened: 990110 161303 Valve closed: 990110 163351
Total flowing time : 30.3 min. Tot. Pr. Build-up time 928.7 min.

Pressure before injection start (P_0, kPa) : 131.4
Pressure just before closing the valve (P_p, kPa) : 529.5
Pressure at the end of the recovery (P_f, kPa) : 652.9

Pre-set section pressure (during injection) (P_{ref}, kPa) : 500

Pressure increase during recovery !

Borehole KA3546G01, section 0.25 m - 0.75 m

Date: 99-01-11 Field Crew: B. Gentzschein

Valve opened: 990111 102808 Valve closed: 990111 105442
Total flowing time : 26.6 min. Tot. Pr. Build-up time 14.5 min.

Pressure before injection start (P_0, kPa) : 124.5
Pressure just before closing the valve (P_p, kPa) : 694.5
Pressure at the end of the recovery (P_f, kPa) : 619.0

Pre-set section pressure (during injection) (P_{ref}, kPa) : 500

Initially the pressure increased to >800 kPa. Thereafter it decreased, but the pre-set value was not reached before the end of the flowing period.

Borehole KA3546G01, section 0.75 m – 1.25 m

Date: 99-01-11 Field Crew: B. Gentzschein

Valve opened: 990111 115456 Valve closed: 990111 121526
Total flowing time : 20.5 min. Tot. Pr. Build-up time 71.9 min.

Pressure before injection start (P_0, kPa) : 127.3
Pressure just before closing the valve (P_p, kPa) : 520.1
Pressure at the end of the recovery (P_f, kPa) : 403.9

Pre-set section pressure (during injection) (P_{ref}, kPa) : 500

Shortly after the injection start P_{ref} was changed to 520 kPa.

Borehole KA3546G01, section 1.25 m – 1.75 m

Date: 99-01-11 Field Crew: B. Gentzschein

Valve opened: 990111 141110 Valve closed: 990111 143229
Total flowing time : 21.2 min. Tot. Pr. Build-up time 10.6 min.

Pressure before injection start (P_0, kPa) : 130.8
Pressure just before closing the valve (P_p, kPa) : 579.2
Pressure at the end of the recovery (P_f, kPa) : 562.5

Pre-set section pressure (during injection) (P_{ref}, kPa) : 500

Shortly after the injection start P_{ref} was changed to 550 kPa.

Borehole KA3548G01, section 0.25 m - 0.75 m

Date: 99-01-11 Field Crew: B. Gentzschein

Valve opened: 990111 160246 Valve closed: 990111 163137
Total flowing time : 28.7 min. Tot. Pr. Build-up time 16.4 min.

Pressure before injection start (P_0, kPa) : 122.8
Pressure just before closing the valve (P_p, kPa) : 518.6
Pressure at the end of the recovery (P_f, kPa) : 489.2

Pre-set section pressure (during injection) (P_{ref}, kPa) : 500

Borehole KA3548G01, section 0.75 m – 1.25 m

Date: 99-01-11 Field Crew: B. Gentzschein

Valve opened: 990111 172618 Valve closed: 990111 174902
Total flowing time : 22.8 min. Tot. Pr. Build-up time 16.0 min.

Pressure before injection start (P_0, kPa) : 124.0
Pressure just before closing the valve (P_p, kPa) : 820.4
Pressure at the end of the recovery (P_f, kPa) : 701.4

Pre-set section pressure (during injection) (P_{ref}, kPa) : 500

Initially the pressure increased to >800 kPa. Then it didn't reach down to the pre-set value before recovery start.

Borehole KA3548G01, section 1.25 m – 1.75 m

Date: 99-01-11 Field Crew: B. Gentzschein

Valve opened: 990111 184608 Valve closed: 990111 190812
Total flowing time : 22.1 min. Tot. Pr. Build-up time 788.5 min.

Pressure before injection start (P_0, kPa) : 126.9
Pressure just before closing the valve (P_p, kPa) : 527.9
Pressure at the end of the recovery (P_f, kPa) : 308.1

Pre-set section pressure (during injection) (P_{ref}, kPa) : 500

The recovery lasted over the night.

Borehole KA3550G01, section 0.25 m - 0.75 m

Date: 99-01-12 Field Crew: B. Gentzschein

Valve opened: 990112 093905 Valve closed: 990112 100351
Total flowing time : 24.8 min. Tot. Pr. Build-up time 11.6 min.

Pressure before injection start (P_0, kPa) : 121.5
Pressure just before closing the valve (P_p, kPa) : 520.0
Pressure at the end of the recovery (P_f, kPa) : 386.0

Pre-set section pressure (during injection) (P_{ref}, kPa) : 500

The injection pressure is relatively stable and the recovery is c. 34 %

Borehole KA3550G01, section 0.75 m – 1.25 m

Date: 99-01-12 Field Crew: B. Gentzschein

Valve opened: 990112 110856 Valve closed: 990112 113139
Total flowing time : 22.7 min. Tot. Pr. Build-up time 129.9 min.

Pressure before injection start (P_0, kPa) : 130.1
Pressure just before closing the valve (P_p, kPa) : 563.5
Pressure at the end of the recovery (P_f, kPa) : 505.7

Pre-set section pressure (during injection) (P_{ref}, kPa) : 500

P_{ref} was changed to 540 kPa at 11:10.30:

Borehole KA3550G01, section 1.25 m – 1.75 m

Date: 99-01-12 Field Crew: B. Gentzschein

Valve opened: 990112 143927 Valve closed: 990112 150100
Total flowing time : 21.6 min. Tot. Pr. Build-up time 11.9 min.

Pressure before injection start (P_0, kPa) : 126.9
Pressure just before closing the valve (P_p, kPa) : 679.6
Pressure at the end of the recovery (P_f, kPa) : 663.2

Pre-set section pressure (during injection) (P_{ref}, kPa) : 500

Initially the pressure increased to >700 kPa. . Thereafter it decreased, but the pre-set value was not reached before the end of the flowing period

Borehole KA3552G01, section 0.25 m - 0.75 m

Date: 99-01-12 Field Crew: B. Gentzschein

Valve opened: 990112 163013 Valve closed: 990112 164151
Total flowing time : 21.5 min. Tot. Pr. Build-up time 20.0 min.

Pressure before injection start (P_0, kPa) : 127.2
Pressure just before closing the valve (P_p, kPa) : 560.7
Pressure at the end of the recovery (P_f, kPa) : 538.4

Pre-set section pressure (during injection) (P_{ref}, kPa) : 540

The injection pressure is relatively stable, but the recovery is only c. 5%.

Borehole KA3552G01, section 0.75 m – 1.25 m

Date: 99-01-12 Field Crew: B. Gentzschein

Valve opened: 990112 180507 Valve closed: 990112 182510
Total flowing time : 20.1 min. Tot. Pr. Build-up time 11.2 min.

Pressure before injection start (P_0, kPa) : 125.1
Pressure just before closing the valve (P_p, kPa) : 788.3
Pressure at the end of the recovery (P_f, kPa) : 762.8

Pre-set section pressure (during injection) (P_{ref}, kPa) : 500

Initially the pressure increased to >870 kPa. Then it didn't reach down to the pre-set value before the injection stop.

Borehole KA3552G01, section 1.25 m – 1.75 m

Date: 99-01-12 Field Crew: B. Gentzschein

Valve opened: 990112 191647 Valve closed: 990112 193643
Total flowing time : 20.0 min. Tot. Pr. Build-up time 769.8 min.

Pressure before injection start (P_0, kPa) : 129.1
Pressure just before closing the valve (P_p, kPa) : 528.4
Pressure at the end of the recovery (P_f, kPa) : 552.9

Pre-set section pressure (during injection) (P_{ref}, kPa) : 500

The flow at the end, Qp, is negative (-6.496e-10 m^3/s). This is within the limits of the zero stability, $\pm 1.67 \cdot 10^{-9}$ m^3/s (0.0001 kg/min), see chapter 4. During the recovery, lasting over night, the pressure is increasing.

Borehole KA3554G02, section 0.25 m - 0.75 m

Date: 99-01-13 Field Crew: B. Gentzschein

Valve opened: 990113 095351 Valve closed: 990113 102009
Total flowing time : 26.3 min. Tot. Pr. Build-up time 11.2 min.

Pressure before injection start (P_0, kPa) : 116.5
Pressure just before closing the valve (P_p, kPa) : 600.2
Pressure at the end of the recovery (P_f, kPa) : 452.8

Pre-set section pressure (during injection) (P_{ref}, kPa) : 500

P_{ref} was increased to 590 kPa.

Borehole KA3554G02, section 0.75 m – 1.25 m

Date: 99-01-13 Field Crew: B. Gentzschein

Valve opened: 990113 111733 Valve closed: 990113 114304
Total flowing time : 25.5 min. Tot. Pr. Build-up time 74.5 min.

Pressure before injection start (P_0, kPa) : 117.6
Pressure just before closing the valve (P_p, kPa) : 517.4
Pressure at the end of the recovery (P_f, kPa) : 653.4

Pre-set section pressure (during injection) (P_{ref}, kPa) : 500

The pressure increased during the recovery period, possibly due to the high pressure in the borehole interval below the packers.

Borehole KA3554G02, section 1.25 m – 1.75 m

Date: 99-01-13 Field Crew: B. Gentzschein

Valve opened: 990113 145509 Valve closed: 990113 151711
Total flowing time : 22.1 min. Tot. Pr. Build-up time 14.8 min.

Pressure before injection start (P_0, kPa) : 118.1
Pressure just before closing the valve (P_p, kPa) : 571.2
Pressure at the end of the recovery (P_f, kPa) : 574.7

Pre-set section pressure (during injection) (P_{ref}, kPa) : 500

P_{ref} was increased to 550 kPa. A small pressure increase occurred during the recovery period.

Borehole KA3554G01, section 0.25 m - 0.75 m

Date: 99-01-13 Field Crew: B. Gentzschein

Valve opened: 990113 165247 Valve closed: 990113 171404
Total flowing time : 21.3 min. Tot. Pr. Build-up time 14.2 min.

Pressure before injection start (P_0, kPa) : 117.1
Pressure just before closing the valve (P_p, kPa) : 514.2
Pressure at the end of the recovery (P_f, kPa) : 120.5

Pre-set section pressure (during injection) (P_{ref}, kPa) : 500

A stable flow and pressure and a nice recovery!

Borehole KA3554G01, section 0.75 m – 1.25 m

Date: 99-01-13 Field Crew: B. Gentzschein

Valve opened: 990113 181517 Valve closed: 990113 183715
Total flowing time : 22.0 min. Tot. Pr. Build-up time 10.8 min.

Pressure before injection start (P_0, kPa) : 114.6
Pressure just before closing the valve (P_p, kPa) : 607.4
Pressure at the end of the recovery (P_f, kPa) : 573.7

Pre-set section pressure (during injection) (P_{ref}, kPa) : 550

P_{ref} was increased to 590 kPa. A small pressure increase during the recovery.

Borehole KA3554G01, section 1.25 m – 1.75 m

Date: 99-01-13 Field Crew: B. Gentzschein

Valve opened: 990113 193852 Valve closed: 990113 201258
Total flowing time : 34.1 min. Tot. Pr. Build-up time 706.6 min.

Pressure before injection start (P_0, kPa) : 116.9
Pressure just before closing the valve (P_p, kPa) : 520.8
Pressure at the end of the recovery (P_f, kPa) : 2466.4

Pre-set section pressure (during injection) (P_{ref}, kPa) : 500

The pressure increased during the long recovery period. After c. nine hours of recovery the pressure below the packers declined. It is unknown why.

Borehole KA3572G01, section 0.25 m - 0.75 m

Date: 99-01-14 Field Crew: B. Gentzschein

Valve opened: 990114 114758 Valve closed: 990114 121042
Total flowing time : 22.8 min. Tot. Pr. Build-up time 70.4 min.

Pressure before injection start (P_0, kPa) : 129.1
Pressure just before closing the valve (P_p, kPa) : 519.5
Pressure at the end of the recovery (P_f, kPa) : 380.1

Pre-set section pressure (during injection) (P_{ref}, kPa) : 500

A constant injection pressure was achieved after more than 16 minutes.

Borehole KA3572G01, section 0.75 m – 1.25 m

Date: 99-01-14 Field Crew: B. Gentzschein

Valve opened: 990114 141425 Valve closed: 990114 143425
Total flowing time : 20.0 min. Tot. Pr. Build-up time 15.8 min.

Pressure before injection start (P_0, kPa) : 122.1
Pressure just before closing the valve (P_p, kPa) : 974.1
Pressure at the end of the recovery (P_f, kPa) : 883.7

Pre-set section pressure (during injection) (P_{ref}, kPa) : 500

P_{ref} was changed to 950 kPa.

Borehole KA3572G01, section 1.25 m – 1.75 m

Date: 99-01-14 Field Crew: B. Gentzschein

Valve opened: 990114 154831 Valve closed: 990114 161931
Total flowing time : 31.0 min. Tot. Pr. Build-up time 12.1 min.

Pressure before injection start (P_0, kPa) : 136.1
Pressure just before closing the valve (P_p, kPa) : 529.5
Pressure at the end of the recovery (P_f, kPa) : 522.2

Pre-set section pressure (during injection) (P_{ref}, kPa) : 500

The recovery is less than 10 kPa.

Borehole KA3574G01, section 0.25 m - 0.75 m

Date: 99-01-14 Field Crew: B. Gentzschein

Valve opened: 990114 173501 Valve closed: 990114 175814
Total flowing time : 23.2 min. Tot. Pr. Build-up time 11.7 min.

Pressure before injection start (P_0, kPa) : 123.7
Pressure just before closing the valve (P_p, kPa) : 539.9
Pressure at the end of the recovery (P_f, kPa) : 535.7

Pre-set section pressure (during injection) (P_{ref}, kPa) : 500

P_{ref} was changed to 520 kPa. The recovery is less than 5 kPa.

Borehole KA3574G01, section 0.75 m – 1.25 m

Date: 99-01-14 Field Crew: B. Gentzschein

Valve opened: 990114 190421 Valve closed: 990114 193113
Total flowing time : 26.9 min. Tot. Pr. Build-up time 764.3 min.

Pressure before injection start (P_0, kPa) : 123.4
Pressure just before closing the valve (P_p, kPa) : 524.7
Pressure at the end of the recovery (P_f, kPa) : 337.6

Pre-set section pressure (during injection) (P_{ref}, kPa) : 500

The recovery lasted over night.

Borehole KA3574G01, section 1.25 m – 1.75 m

Date: 99-01-15 Field Crew: B. Gentzschein

Valve opened: 990115 090150 Valve closed: 990115 093359
Total flowing time : 32.2 min. Tot. Pr. Build-up time 15.1 min.

Pressure before injection start (P_0, kPa) : 123.4
Pressure just before closing the valve (P_p, kPa) : 560.6
Pressure at the end of the recovery (P_f, kPa) : 556.8

Pre-set section pressure (during injection) (P_{ref}, kPa) : 500

P_{ref} was changed to 530 kPa. The recovery is less than 5 kPa.

Borehole KA3576G01, section 0.25 m - 0.75 m

Date: 99-01-15 Field Crew: B. Gentzschein

Valve opened: 990115 105343 Valve closed: 990115 111423
Total flowing time : 20.7 min. Tot. Pr. Build-up time 75.8 min.

Pressure before injection start (P_0, kPa) : 122.3
Pressure just before closing the valve (P_p, kPa) : 519.9
Pressure at the end of the recovery (P_f, kPa) : 396.7

Pre-set section pressure (during injection) (P_{ref}, kPa) : 500

Borehole KA357601, section 0.75 m – 1.25 m

Date: 99-01-15 Field Crew: B. Gentzschein

Valve opened: 990115 132813 Valve closed: 990115 135054
Total flowing time : 22.7 min. Tot. Pr. Build-up time 13.6 min.

Pressure before injection start (P_0, kPa) : 127.9
Pressure just before closing the valve (P_p, kPa) : 524.4
Pressure at the end of the recovery (P_f, kPa) : 517.3

Pre-set section pressure (during injection) (P_{ref}, kPa) : 500

Borehole KA357601, section 1.25 m – 1.75 m

Date: 99-01-15 Field Crew: B. Gentzschein

Valve opened: 990115 150126 Valve closed: 990115 152344
Total flowing time : 21.3 min. Tot. Pr. Build-up time 10.3 min.

Pressure before injection start (P_0, kPa) : 134.8
Pressure just before closing the valve (P_p, kPa) : 529.4
Pressure at the end of the recovery (P_f, kPa) : 523.9

Pre-set section pressure (during injection) (P_{ref}, kPa) : 500

Borehole KA3578G01, section 0.25 m - 0.75 m

Date: 99-01-15 Field Crew: B. Gentzschein

Valve opened: 990115 165533 Valve closed: 990115 171614
Total flowing time : 20.7 min. Tot. Pr. Build-up time 12.0 min.

Pressure before injection start (P_0, kPa) : 133.7
Pressure just before closing the valve (P_p, kPa) : 543.3
Pressure at the end of the recovery (P_f, kPa) : 520.0

Pre-set section pressure (during injection) (P_{ref}, kPa) : 500

P_{ref} was changed to 524 kPa. The flow at the end, Qp, is negative (-1.689e-10 m^3/s). This is within the limits of the zero stability, $\pm 1.67 \cdot 10^{-9}$ m^3/s (0.0001 kg/min), see chapter 4.

Borehole KA357801, section 0.75 m – 1.25 m

Date: 99-01-15 Field Crew: B. Gentzschein

Valve opened: 990115 181213 Valve closed: 990115 183227
Total flowing time : 20.3 min. Tot. Pr. Build-up time 12.3 min.

Pressure before injection start (P_0, kPa) : 122.8
Pressure just before closing the valve (P_p, kPa) : 563.0
Pressure at the end of the recovery (P_f, kPa) : 543.3

Pre-set section pressure (during injection) (P_{ref}, kPa) : 500

P_{ref} was changed to 540 kPa.

Borehole KA3578G01, section 1.25 m – 1.75 m

Date: 99-01-15 Field Crew: B. Gentzschein

Valve opened: 990115 192522 Valve closed: 990115 194610
Total flowing time : 20.8 min. Tot. Pr. Build-up time 823.6 min.

Pressure before injection start (P_0, kPa) : 130.2
Pressure just before closing the valve (P_p, kPa) : 529.9
Pressure at the end of the recovery (P_f, kPa) : 241.5

Pre-set section pressure (during injection) (P_{ref}, kPa) : 500

Recovery over night!

Table 6-1 Test data from injection tests conducted in the exploratory boreholes. Prototype Repository - January 1999

Borehole	Date of test	Test No	Section (m)	Flowing Time (min)	Recovery time (min)	P_o (kPa)	P_p (kPa)	P_f (kPa)
KA3542G02	990108	1	0.25 - 0.75	22.0	87.1	119.0	309.8	346.6
KA3542G02	990108	2	0.75 -.1.25	21.5	29.9	120.2	315.8	368.8
KA3542G02	990108	3	1.25 - 1.75	46.5	929.3	3056.3	1045.7	3130.5
KA3542G01	990109	4	0.25 - 0.75	41.2	118.1	137.4	512.3	474.7
KA3542G01	990109	5	0.75 -.1.25	32.3	18.6	119.1	524.1	546.9
KA3542G01	990109	6	1.25 - 1.75	30.3	928.7	118.8	540.5	742.6
KA3544G01	990110	7	0.25 - 0.75	26.8	116.5	162.0	690.9	500.1
KA3544G01	990110	8	0.75 -.1.25	29.1	13.9	126.7	574.8	613.6
KA3544G01	990110	9	1.25 - 1.75	20.8	12.7	131.4	529.5	652.9
KA3546G01	990111	10	0.25 - 0.75	26.6	14.5	124.5	694.5	619.0
KA3546G01	990111	11	0.75 -.1.25	20.5	71.9	127.3	520.1	403.9
KA3546G01	990111	12	1.25 - 1.75	21.2	10.6	130.8	579.2	562.5
KA3548G01	990111	13	0.25 - 0.75	28.7	16.4	122.8	518.6	489.2
KA3548G01	990111	14	0.75 -.1.25	22.8	16.0	124.0	820.4	701.4
KA3548G01	990111	15	1.25 - 1.75	22.1	788.5	126.9	527.9	308.1
KA3550G01	990112	16	0.25 - 0.75	24.8	11.6	121.5	520.0	386.0
KA3550G01	990112	17	0.75 -.1.25	22.7	129.9	130.1	563.5	505.7
KA3550G01	990112	18	1.25 - 1.75	21.6	11.9	126.9	679.6	663.2
KA3552G01	990112	19	0.25 - 0.75	21.5	20.0	127.2	560.7	538.4
KA3552G01	990112	20	0.75 -.1.25	20.1	11.2	125.1	788.3	762.8
KA3552G01	990112	21	1.25 - 1.75	20.0	769.8	129.1	528.4	552.9
KA3554G02	990113	22	0.25 - 0.75	26.3	11.2	116.5	600.2	452.8
KA3554G02	990113	23	0.75 -.1.25	25.5	74.5	117.6	517.4	653.4
KA3554G02	990113	24	1.25 - 1.75	22.1	14.8	118.1	571.2	574.7
KA3554G01	990113	25	0.25 - 0.75	21.3	14.2	117.1	514.2	120.5
KA3554G01	990113	26	0.75 -.1.25	22.0	10.8	114.6	607.4	573.7
KA3554G01	990113	27	1.25 - 1.75	34.1	706.6	116.9	520.8	2466.4
KA3572G01	990114	28	0.25 - 0.75	22.8	70.35	129.1	519.5	380.1
KA3572G01	990114	29	0.75 -.1.25	20.0	15.8	122.1	974.1	883.7
KA3572G01	990114	30	1.25 - 1.75	31.0	12.1	136.1	529.5	522.2
KA3574G01	990114	31	0.25 - 0.75	23.2	11.7	123.7	539.9	535.7
KA3574G01	990114	32	0.75 -.1.25	26.9	764.3	123.4	524.7	337.6
KA3574G01	990115	33	1.25 - 1.75	32.2	15.1	123.4	560.6	556.8
KA3576G01	990115	34	0.25 - 0.75	20.7	75.8	122.3	519.9	396.7
KA3576G01	990115	35	0.75 -.1.25	22.7	13.6	127.9	524.4	517.3
KA3576G01	990115	36	1.25 - 1.75	21.3	10.3	134.8	529.4	523.9
KA3578G01	990115	37	0.25 - 0.75	20.7	12.0	133.7	543.3	520.0
KA3578G01	990115	38	0.75 -.1.25	20.3	12.3	122.8	563.0	543.3
KA3578G01	990115	39	1.25 - 1.75	20.8	823.6	130.2	529.9	241.5

7. REFERENCES

Almén, K-E and Hansson, K., 1996: Hydrotestutrustning för underjordsmätningar i Äspölaboratoriet – Konstruktion och tillverkning. Tekniskt Dokument IPR-97-03, SKB Äspölaboratoriet, Stockholm. (In Swedish)

Gentzschein, B. 1994: ÄSPÖLABORATORIET. Manual för tryckuppbyggnadstester.SKB-MD: 324.002-01

Gentzschein, B. 1997: PROTOTYPE REPOSITORY. Hydraulic Tests in Pilot Holes. Drill campaign 1. SKB IPR 99-27

Gentzschein, B. 1998: PROTOTYPE REPOSITORY. Hydraulic Tests in Exploratory Holes. Drill campaign 2. SKB IPR 99-28

Hansson, K. 1997: Manual för Underground Hydraulic Testsystem UHT1 Del 1, Handhavande (in Swedish)

Johansson, B., and Olsson, O., 1997: IPPLOT, Konverterings- och plottprogram för data från injektions- och pumptester. Användarhandledning. Ver. 1.5 .ERGODATA AB. (In Swedish)

Rhén, I. and Nilsson, L., 1991: Pressure build-up tests in sounding boreholes - performance and evaluation. SKB-Technical Document No. 25-91-010

Olsson O. 1998: PM for authors of SKB Reports. Directions for formatting. Swedish Nuclear and Waste Management Co., Figeholm Sweden. January 1998.

APPENDICES

Appendices 4-16 are not included as hard copies in the report, but stored on CD-ROM which is available at Äspö Hard Rock Laboratory.

APPENDIX 1 Description of the UHT 1 diagrams

APPENDIX 2 Symbols and calculations of the UHT 1 diagrams and description of the MIO-file

APPENDIX 3 List of data files

APPENDIX 4 Diagrams from transient injection tests in three test intervals between 0.25 m and 1.75 m in borehole KA3542G02. January 8th 1999

APPENDIX 5 Diagrams from transient injection tests in three test intervals between 0.25 m and 1.75 m in borehole KA3542G01. January 9th 1999

APPENDIX 6 Diagrams from transient injection tests in three test intervals between 0.25 m and 1.75 m in borehole KA3544G01. January 10th 1999

APPENDIX 7 Diagrams from transient injection tests in three test intervals between 0.25 m and 1.75 m in borehole KA3546G01. January 11th 1999

APPENDIX 8 Diagrams from transient injection tests in three test intervals between 0.25 m and 1.75 m in borehole KA3548G01. January 11th 1999

APPENDIX 9 Diagrams from transient injection tests in three test intervals between 0.25 m and 1.75 m in borehole KA3550G01. January 12th 1999

APPENDIX 10 Diagrams from transient injection tests in three test intervals between 0.25 m and 1.75 m in borehole KA3552G01. January 12th 1999

APPENDIX 11 Diagrams from transient injection tests in three test intervals between 0.25 m and 1.75 m in borehole KA3554G02. January 13th 1999

APPENDIX 12 Diagrams from transient injection tests in three test intervals between 0.25 m and 1.75 m in borehole KA3554G01. January 13th 1999

APPENDIX 13 Diagrams from transient injection tests in three test intervals between 0.25 m and 1.75 m in borehole KA3572G01. January 14th 1999

APPENDIX 14 Diagrams from transient injection tests in three test intervals between 0.25 m and 1.75 m in borehole KA3574G01. January 14th 1999

APPENDIX 15 Diagrams from transient injection tests in three test intervals between 0.25 m and 1.75 m in borehole KA3576G01. January 15th 1999

APPENDIX 16 Diagrams from transient injection tests in three test intervals between 0.25 m and 1.75 m in borehole KA3578G01. January 15th 1999

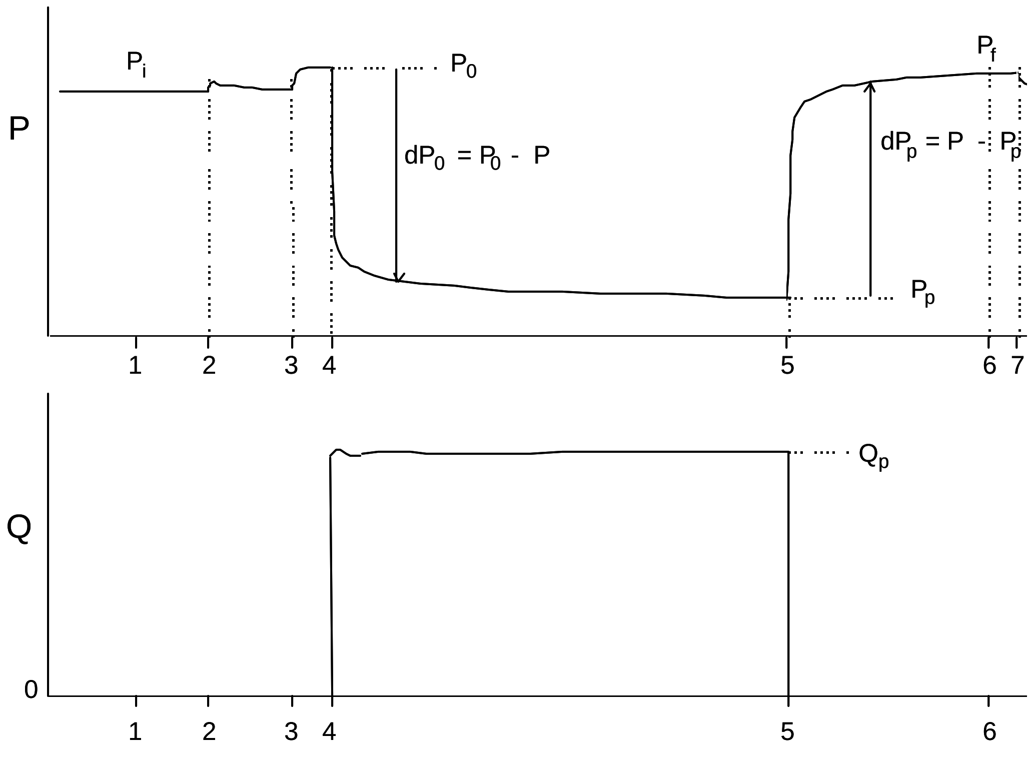
APPENDIX 1

Description of test diagrams produced by the UHT 1-system.

A flow and pressure build-up test with the UHT 1-equipment comprises 7 stages:

Stage 0: Start of registration
Stage 1: Storing of initial values
Stage 2: Start of packer inflation
Stage 3: Evacuation of air from the pipe string and the measurement hose.
Stage 4: The test valve is opened, the flowing phase is started
Stage 5: The test valve is closed, the flowing phase is stopped, and the pressure recovery phase is started
Stage 6: The recovery ends.
Stage 7: The packers are deflated. Stabilisation of the borehole pressure after the test.

In the two figures below, the variation of the test section pressure (P) and the flow rate (Q) of a typical (outflow-) test are illustrated. The numbers on the x-axis indicate the start of the different stages respectively.



P_i = The first pressure value of stage #1
P_0 = Average of the four last pressure values of stage #3
P_p = Average of the five last pressure values of stage #4 (the last one is excluded)
P_f = The last pressure value of the recovery (stage #5)
Q_p = Average of the five last flow values of stage #4 (the last one is excluded)

Appendix 1

A-diagrams show flow-, pressure-, electric conductivity- and temperature variations during the entire test cycle.

A0 A flyleaf showing background data as well as measured and

calculated data from the test.

A1
X : Absolute time, stage 0 - 3
Y1: P

A2
X : Absolute time, stage 1 - 7
Y1: Q
Y2: Elcond

A3
X : Absolute time, stage 0 - 7
Y1: P
Y2: Pa
Y3: Pb

A4
X : Absolute time, stage 0 - 7

Y1: Tsec
Y2: Tsurf
Y3: Tair

A5
X : Absolute time, stage 0 - 7
Y1: Ppack
Y2: Pair
Y3: W

B-diagrams show test parameter variations during the flowing phase (stage 4).

B1
X : log (t)
Y1: P
Y2: Tsec
Y3: Elcond

B2
X : $t^{1/4}$ and t
Y1: 1/Q

B3
X : $t^{1/2}$ and t
Y1: 1/Q

B4
X : log (t)
Y1: 1/Q
Y2: der(1/Q)

B5 X : log (t)
Y1: log (Q)
Y2: log(der(1/Q))

B6 X : $t^{1/2}$ and t
Y1: Q

C-diagrams show test parameter variations during the recovery phase (stage 5).

C1 X : $t^{1/4}$ and dt
Y1: P

C2 X : $t^{1/2}$ and dt
Y1: P

C3 X : $(tpp + dt)^{1/2} - dt^{1/2}$ and dt
Y1: P

C4 X : log(dt) and dt
Y1: P
Y2: der(P)
Y3: Q

C5 X : log(dt/ (tp+dt)) and dt
Y1: P
Y2: Tsec

C6 X : log(dte) and dt
Y1: log(P-Pp)
Y2: log(der(P-Pp))

C7 X : $(1/dt)^{1/2} - (1/(tpp+dt))^{1/2}$ and dt
Y1: P

C8 X : log(dt)
Y1: P
Y2: der(P)
Y3: Q

C9 X : log(dt)
Y1: log(P-Pp)
Y2: log(der(P-Pp))

APPENDIX 2: Symbols and calculations of the UHT 1 diagrams and description of MIO-files

Symbols

(from Johansson and Olsson 1997)

TT	Test type
DW	Borehole diameter
X	x-coordinate, top of casing
Y	y-coordinate, top of casing
Z	altitude, top of casing
AW	Borehole azimut
IW	Borehole inclination
TC	Test crew
EC	Equipment code
TB	Time (YYMMDDhhmmss) when PB and BB are measured
PB	Barometric pressure at time TB (measured by P-the test section sensor)
BB	Barometric pressure at time TB (measured by Pair, not in use)
tabs	time
t	elapsed time from pump start
dt	elapsed time from pump stop
tp	duration of flow phase
tpp	corrected tp
dte	equivalent time
dtf	duration of the pressure recovery
Vtot	total flowing volume during the flowing phase
Crit 4	criteria of the start of the flow phase
Difft 4	the start time of the flow phase is set "Difft 4" seconds before (negative) or after (positive) the time point when the criteria Crit4 is accomplished.
Crit 5	criteria of the start of the recovery period
Difft 5	the start time of the recovery period is set "Difft 5" seconds before (negative) or after (positive) the time point when the criteria Crit5 is accomplished
IPRiffstart	time difference between the time, when the data processing system is initiated to begin the flow phase and the time when the flow phase really starts according to the criteria Crit 4.
IPRiffstop	time difference between the time, when the data processing system is initiated to begin the recovery period and the time when the recovery period really starts according to the criteria Crit 5.
dl4	Smoothing for derivative calculations, flow phase
dl5	Smoothing for derivative calculations, recovery phase

Crit 4, Difft 4, Crit 5, Difft 5, dl4 and dl5 are input values to the plot program IPPLOT:

Measured variables

P	ground-water pressure of the test section
P_a	ground-water pressure of the borehole interval below the test section
P_b	ground-water pressure of the test section
P_{pack}	Packer-pressure

P_w	Pressure of the ground-water level sensor (not in use)
Q1	flow rate of the small flow meter (Q_{small})
Q2	flow rate of the big flow meter (Qbig)
Q	Flow rate from the test section, one of Q1 or Q2. It is not possible to know which one of Q_{small} or Qbig that is used unless you study the data file *.HT2
Tsec	Temperature of the test section (not in use)
Tsurf	Temperature of the injection water at surface.
Tair	Air temperature in the measurement container (not in use)
Pair	Barometric pressure (not in use)
W	Ground-water level (not in use)

Calculations

Vtot = the integral of the flow rate (Q) during the flowing phase (stage 4)
All values are integrated, the negative values as well.

tpp = (Vtot/Qp) or = tp. When processing the Prototype injection test data, tpp was set equal to tp

dte = dt * tp/ (dt + tp)

From the variables P, P_a, P_b, W and Q constants, with indices i, o, p, f and e, are determined according to:

i	The first value of stage 1
o	Average of the 4 last values of stage 3.
p	Average of the 5 last values of stage 4, excluding the last value.
f	The last value of stage 5
e	The last value of stage 7

Transformation of the pressure values in the diagrams have been carried out according to:

P (diagram) = P (measured) + LK * sin(IW) * 9.807

P_a (diagram) = P_a (measured) + LM * sin(IW) * 9.807

P_b(diagram) = P_b (measured) + LK * sin(IW) * 9.807

LK, LM = Distance from the pressure transducers to the top of the test section.

dP_{im} = Average of differential pressure ($P - P_i$) during the flow phase (stage 4) with the open hole pressure (P_i) as a reference.

dP_{om} = Average of differential pressure ($P - P_o$) during the flow phase (stage 4) with the section pressure before the flow start(P_o) as a reference.

$$Koss = \frac{Qp \times 1000 \times 9.81}{L \times dP_{om}} \cdot [1 + \ln(L/2r_w)]/2\pi$$

L = Length of the test section (m)

r_w = borehole radius (m)

$$Kiss = \frac{Qp \times 1000 \times 9.81}{L \times dP_{im}} \cdot [1 + \ln(L/2r_w)]/2\pi$$

L = Length of the test section (m)

r_w = borehole radius (m)

Appendix 2

Description of the MIO - file

The MIO-file consists of two parts, one command part and one data part. The data part has a table structure with columns. The first column is as rule a time column followed by the parameters defined in the command part.

The commands are in the beginning of the file. Only one command on each line is allowed and the commands are first in the lines. Commands and parameters are separated by a space character.

The data types of the parameters are:

s - string of ASCII symbols
d - integer
f - decimal number
e - floating point
D - date (YYMMDD)
t - time (hhmmss) or [(YY)YYMMDDhhmmss]

The commands used are as follows:

Commands	(data type)	Description
l	d	number of command rows(including this row)
hs	[s . .]	general head line
t	s	name of table
f	s	file name of the data part (if data are in a sepa rate files)
s	d	number of rows to skip before reading data
c	s c d d d	column description, the parameters are : name of
	the	
		column, data type, offset (position on the row,
	first	
		pos.= 0), width of column, number of decimals(-1
	if	
		no decimal number). This description is repeated
	for	
		each column.
cm	s e e	name of column, min. value, max.value.
cu	s s	unit of column
;	s[ss. .]	comment row

APPENDIX 3: List of data files Injection tests, Prototype Repository - January 1999

Borehole	Test No	Section (m)	Start of test	End of Test	Raw data files	Data files Flow rates	Data files Pressures
KA3542G02	1	0.25 - 0.75	990107 19.23	990107 13.09	3542G2_1.HT2	42G2_1A2.DAT	42G2_1A3.DAT
KA3542G02	2	0.75 -.1.25	990108 13.21	990108 14.19	3542G2_2.HT2	42G2_2A2.DAT	42G2_2A3.DAT
KA3542G02	3	1.25 - 1.75	990108 15.36	990109 09.20	3542G2_3.HT2	42G2_3A2.DAT	42G2_3A3.DAT
KA3542G01	4	0.25 - 0.75	990109 11.36	990109 14.47	3542G1_1.HT2	42G1_1A2.DAT	42G1_1A3.DAT
KA3542G01	5	0.75 -.1.25	990109 14.51	990109 16.14	3542G1_2.HT2	42G1_2A2.DAT	42G1_2A3.DAT
KA3542G01	6	1.25 - 1.75	990109 16.45	990110 09.23	3542G1_3.HT2	42G1_3A2.DAT	42G1_3A3.DAT
KA3544G01	7	0.25 - 0.75	990110 10.58	990110 14.05	3544G1_1.HT2	44G1_1A2.DAT	44G1_1A3.DAT
KA3544G01	8	0.75 -.1.25	990110 14.16	990110 15.38	3544G1_2.HT2	44G1_2A2.DAT	44G1_2A3.DAT
KA3544G01	9	1.25 - 1.75	990110 15.41	990110 17.14	3544G1_3.HT2	44G1_3A2.DAT	44G1_3A3.DAT
KA3546G01	10	0.25 - 0.75	990110 17.20	990110 11.10	3546G1_1.HT2	46G1_1A2.DAT	46G1_1A3.DAT
KA3546G01	11	0.75 -.1.25	990111 11.18	990111 13.29	3546G1_2.HT2	46G1_2A2.DAT	46G1_2A3.DAT
KA3546G01	12	1.25 - 1.75	990111 13.24	990111 14.55	3546G1_3.HT2	46G1_3A2.DAT	46G1_3A3.DAT
KA3548G01	13	0.25 - 0.75	990111 15.22	990111 16.49	3548G1_1.HT2	48G1_1A2.DAT	48G1_1A3.DAT
KA3548G01	14	0.75 -.1.25	990111 16.55	990111 18.06	3548G1_2.HT2	48G1_2A2.DAT	48G1_2A3.DAT
KA3548G01	15	1.25 - 1.75	990111 18.12	990111 08.18	3548G1_3.HT2	48G1_3A2.DAT	48G1_3A3.DAT
KA3550G01	16	0.25 - 0.75	990112 08.57	990112 10.17	3550G1_1.HT2	50G1_1A2.DAT	50G1_1A3.DAT
KA3550G01	17	0.75 -.1.25	990112 10.25	990112 13.42	3550G1_2.HT2	50G1_2A2.DAT	50G1_2A3.DAT
KA3550G01	18	1.25 - 1.75	990112 13.52	990112 15.15	3550G1_3.HT2	50G1_3A2.DAT	50G1_3A3.DAT
KA3552G01	19	0.25 - 0.75	990112 15.40	990112 17.12	3552G1_1.HT2	52G1_1A2.DAT	52G1_1A3.DAT
KA3552G01	20	0.75 -.1.25	990112 17.35	990112 18.37	3552G1_2.HT2	52G1_2A2.DAT	52G1_2A3.DAT
KA3552G01	21	1.25 - 1.75	990112 18.44	990113 08.27	3552G1_3.HT2	52G1_3A2.DAT	52G1_3A3.DAT
KA3554G02	22	0.25 - 0.75	990113 09.10	990113 10.32	3554G2_1.HT2	54G2_1A2.DAT	54G2_1A3.DAT
KA3554G02	23	0.75 -.1.25	990113 10.40	990113 12.59	3554G2_2.HT2	54G2_2A2.DAT	54G2_2A3.DAT
KA3554G02	24	1.25 - 1.75	990113 13.08	990113 15.33	3554G2_3.HT2	54G2_3A2.DAT	54G2_3A3.DAT
KA3554G01	25	0.25 - 0.75	990113 16.17	990113 17.29	3554G1_1.HT2	54G1_1A2.DAT	54G1_1A3.DAT
KA3554G01	26	0.75 -.1.25	990113 17.40	990113 18.49	3554G1_2.HT2	54G1_2A2.DAT	54G1_2A3.DAT
KA3554G01	27	1.25 - 1.75	990113 19.05	990114 08.00	3554G1_3.HT2	54G1_3A2.DAT	54G1_3A3.DAT
KA3572G01	28	0.25 - 0.75	990114 10.24	990114 13.22	3572G1_1.HT2	72G1_1A2.DAT	72G1_1A3.DAT
KA3572G01	29	0.75 -.1.25	990114 13.30	990114 14.51	3572G1_2.HT2	72G1_2A2.DAT	72G1_2A3.DAT
KA3572G01	30	1.25 - 1.75	990114 14.58	990114 16.33	3572G1_3.HT2	72G1_3A2.DAT	72G1_3A3.DAT
KA3574G01	31	0.25 - 0.75	990114 16.55	990114 18.11	3574G1_1.HT2	74G1_1A2.DAT	74G1_1A3.DAT
KA3574G01	32	0.75 -.1.25	990114 18.25	990115 08.17	3574G1_2.HT2	74G1_2A2.DAT	74G1_2A3.DAT
KA3574G01	33	1.25 - 1.75	990115 08.26	990115 09.52	3574G1_3.HT2	74G1_3A2.DAT	74G1_3A3.DAT
KA3576G01	34	0.25 - 0.75	990115 10.17	990115 12.31	3576G1_1.HT2	76G1_1A2.DAT	76G1_1A3.DAT
KA3576G01	35	0.75 -.1.25	990115 12.39	990115 14.05	3576G1_2.HT2	76G1_2A2.DAT	76G1_2A3.DAT
KA3576G01	36	1.25 - 1.75	990115 14.14	990115 15.35	3576G1_3.HT2	76G1_3A2.DAT	76G1_3A3.DAT
KA3578G01	37	0.25 - 0.75	990115 16.10	990115 17.29	3578G1_1.HT2	78G1_1A2.DAT	78G1_1A3.DAT
KA3578G01	38	0.75 -.1.25	990115 17.36	990115 18.45	3578G1_2.HT2	78G1_2A2.DAT	78G1_2A3.DAT
KA3578G01	39	1.25 - 1.75	990115 18.51	990116 09.31	3578G1_3.HT2	78G1_3A2.DAT	78G1_3A3.DAT

The ***.HT2-files** require the program IPPLOT for data conversion (Johansson and Olson 1997)

The ***A2.DAT-files** contain:
- Column #1: Date and time (YYMMDDhhmmss)
- Column #2: Flow rate (m^3/s)
- Column#3: Electric conductivity (mS/m)

The ***A3.DAT-files** contain:
- Column #1: Date and time (YYMMDDhhmmss)
- Column #2: Section pressure P (kPa)
- Column #3: Pressure below section (kPa)
- Column #4: Section pressure P_b (kPa