P-14-30

Prototype Repository – Sensor data report (Period 010917–140101) Report No 26

Reza Goudarzi, Clay Technology AB

May 2015

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co

Box 250, SE-101 24 Stockholm
Phone +46 8 459 84 00

ISSN 1651-4416
SKB P-14-30
ID 1463875
May 2015

Prototype Repository – Sensor data report (Period 010917–140101) Report No 26

Reza Goudarzi, Clay Technology AB

Abstract

The Prototype Repository Test consists of two sections. The installation of the first Section of Prototype Repository was made during summer and autumn 2001 and Section 2 was installed in spring and summer 2003. The retrieval of the outer section started at the end of November 2010 and finished at the end of December 2011. All measurements from the sensor in Section 2 have been presented in the last sensors data report SKB P-13-39 (Goudarzi 2014).

After the retrieval of the outer section, validation tests of the total pressure sensors of type Geocon were made. It was then discovered that, the up to 20120101 used calibration values (linear equation) gave inaccurate readings of the total pressure. The improvements of the readings were large when a polynomial calibration equation was used instead. At the presentation of the data in this report the polynomial equation was used.

This report presents data from measurements in the Prototype Repository Section I during the period 20010917–20140101. The report is organized so that the actual measured results are shown in Appendix 1–7, where Appendix 5 deals with measurements of canister displacements (by AITEMIN), Appendix 6 deals with geo-electric measurements in the backfill (by GRS), and Appendix 7 deals with measurement of water pressure in the rock (by VBB/VIAK). The main report and Appendix 1–4 deal with the rest of the measurements.

Section 1

The following measurements are made in the bentonite in each of the two instrumented deposition holes in Section 1 (1 and 3): Temperature is measured in 32 points, total pressure in 27 points, pore water pressure in 14 points and relative humidity in 37 points. Temperature is also measured by all relative humidity gauges. Every measuring point is related to a local coordinate system in the deposition hole.

The following measurements are made in the backfill in Section 1. Temperature is measured in 20 points, total pressure in 18 points, pore water pressure in 23 points and relative humidity in 45 points. Temperature is also measured by all relative humidity gauges. Furthermore, water content is measured by an electric chain in one section. Every measuring point is related to a local coordinate system in the tunnel.

The following measurements are made on the surface of the canisters in Section 1: Temperature is measured every meter along two fiber optic cables. Furthermore, displacements of the canister in hole 3 are measured with 6 gauges.

The following measurements are made in the rock in Section 1: Temperature is measured in 37 points in boreholes in the floor. Water pressure is measured in altogether 64 points in 17 boreholes all around the tunnel.

Conclusions

A general conclusion is that the measuring systems work well, but the number of sensors that has failed is increasing. 275 (excluding water pressure sensors in the rock, geo-electric measurements) out of totally 363 installed sensors in Section 1 are out of order, the majority being RH-sensors that fail at water saturation. Furthermore almost all suction sensors placed in the backfill is not giving reliable values due to high degree of saturation (RH 100%).

The drainages of the inner section together with the drainage of the outer plug were closed at the beginning of November 2004. The pressure (pore pressure and total pressure) both in the backfill and in some parts of the buffer in the six deposition holes increased after this date. At the beginning of December 2004 damages on the cables to the installed heaters in two of the canisters (canister No 2 and No 6) were observed. The power to all of the canisters was then switched off and the drainage of the tunnel was opened. The power of canisters was switched on again on December 15 except for canister No 2 where all of the installed heaters were out of order. The drainage of the tunnel was

kept open. The increase in pore pressure affected the saturation rate of the backfill and the buffer. The failure of the heaters in canister No 2 and the time when the power was switched off affected also the measurements especially the temperature measurements in the buffer. A packer installed in the rock in Section 1 was broken around the 18th of April 2006. The broken packer caused an increase in the measured total and pore pressure in the backfill in Section 1. The work with the new tunnel near by the Prototype site which started in April 2007 has affected the pressure, water outflow and saturation of the backfill.

Sammanfattning

Prototypförvaret består av två sektioner. Den första sektionen installerades under sommaren och hösten 2001 och Sektion 2 installerades under våren och sommaren 2003. I slutet av november 2010 började arbetet med att demontera den yttre sektionen av försöket och demonteringen har avslutat i decmber 2011.

I denna rapport presenteras data från mätningar i Prototypförvaret för Sektion I under perioden 20010917–20140101. Rapporten är uppdelad så att själva mätresultaten redovisas i Appendix 1–7, varvid Appendix 5 behandlar mätning av kapselförskjutningar (görs av AITEMIN), Appendix 6 behandlar geoelektriska mätningar i återfyllningen (görs av GRS) och Appendix 7 behandlar vattentrycksmätningar i berget (handhas av VBB/VIAK). I själva huvudrapporten och Appendix 1–4 behandlas alla övriga mätningar.

Efter demontering av yttre sektionen, utfördes en utvärdering av totaltrycksgivarna av fabrikatet Geocon. Då upptäckes att de använda kalibraringsparametrana och den linear ekvationen för totaltryck inte var optimala. Den alternativa polynoma ekvationen vid redovisning av data används i den här rapporten vilket gav högre tryck.

Sektion 1

Följande mätningar görs i bentoniten i vardera av de två instrumenterade deponeringshålen i Sektion 1 (1 och 3): Temperatur mäts i 32 punkter, totaltryck i 27 punkter, porvattentryck i 14 punkter och relativa fuktigheten i 37 punkter. Temperaturen mäts även med relativa fuktighetsmätare. Varje mätpunkt relateras till ett lokalt koordinatsystem i deponeringshålet.

Följande mätningar görs i återfyllningen i Sektion 1: Temperaturen mäts i 20 punkter, totaltryck i 18 punkter, porvattentryck i 23 punkter och relativa fuktigheten i 45 punkter. Temperaturen mäts även med alla relativa fuktighetsmätare. Varje mätpunkt relateras till ett lokalt koordinatsystem i tunneln. Dessutom mäts vatteninnehållet i en sektion med en geoelektrisk mätkedja.

Följande mätningar görs på ytan i kapselns kopparhölje i samtliga 4 kapslar i Sektion 1: Temperaturen mäts varje meter längs två fiberoptiska kablar från två håll. Dessutom mäts förskjutningar av kapseln i hål 3 med 6 givare.

Följande mätningar görs i berget i Sektion 1: Temperatur mäts i borrhål i 37 punkter i golvet. Vattentryck mäts i sammanlagt 64 punkter i 17 borrhål runt hela tunneln.

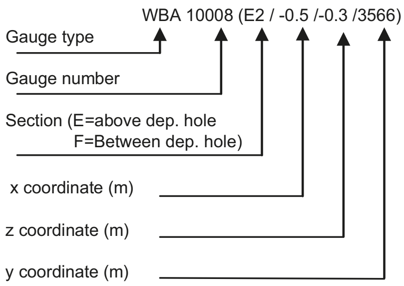
Slutsatser

En generell slutsats är att mätsystemen tycks fungera bra. 275 av totalt 363 installerade givare i Sektion 1 (med undantag av vattentrycksmätare i berget) fungerar inte. Många av dessa (64 stycken) är RH-mätare som slutar fungera vid vattenmättnad. Portrycket och totaltrycket både i återfyllnaden och i bufferten ökade markant efter stängningen av dränaget. Ökningen av portrycket påverkade också vattenmättnaden i vissa delar av buffert och återfyllnade. Skador observerades på kablarna till de installerade värmarna i två av kapslarna i början av december 2004, varefter effekten till samtliga kapslar stängdes av samtidigt som dräneringen av tunneln öppnades. Effekten till alla kapslar utom kapsel nr. 2 sattes på igen den 15:e december. Skadorna på kablarna till värmarna i kapsel 2 var så omfattande att det inte var möjligt att använda dessa. Dräneringen av tunneln förblev öppen. En packer installerad i berget i Sektion 1 gick sönder kring den 18:e april 2006. Den läckande packern medförde att totaltrycken och portrycken i återfyllningen i Sektion 1 ökade markant. Arbetet med den nya tunneln nära Prototype-tunneln vilket startade i april 2007 har påverkat tryckte, utflödet ur tunneln samt vattenmättnaden av återfyllningen i de båda tunnelsektionerna.

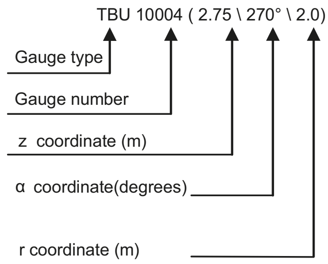
Contents

Quick guide

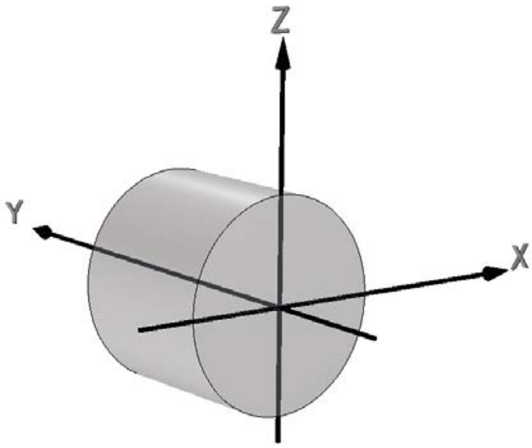
Transducers in the backfill



Transducers in dep. holes 1,3,5 and 6 and in the rock

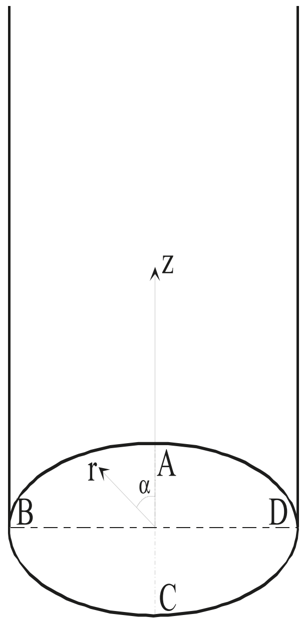


Coordinate system in backfill



End of tunnel at	Y =3599.8 m
Center dep.hole 1.at	Y =3587 m
Center dep.hole 2 at	Y =3581 m
Center dep.hole 3 at	Y =3575 m
Center dep.hole 4at	Y =3569 m
Inner plug surface at	Y=3561.4 m
Center dep.hole 5at	Y =3551 m
Center dep.hole 6at	Y =3545 m
Outer plug surface at	Y=3538.6 m
Tunnel radius	Z=X =2.5 m

Coordinate system in dep. holes



Tunnel direction	C-A
Bottom of hole	Z=0
Bottom of canister	Z=0.5
Top of canister	Z=5.400
Upper buffer surface	Z=7.125
Dep. hole radius	r=0.875
Canister radius	r=0.525

1 Introduction

The Prototype Repository Test consists of two sections. The installation of the first Section of Prototype Repository was made during summer and autumn 2001 and Section 2 was installed in spring and summer 2003.

Section 1 consists of four full-scale deposition holes, copper canisters equipped with electrical heaters, bentonite blocks and a deposition tunnel backfilled with a mixture of bentonite and crushed rock and ends with a concrete plug as shown in Figure 1-1. Section 2 consists of two full-scale deposition holes with a backfilled tunnel section and ends also with a concrete plug.

The bentonite buffer in deposition holes 1, 3, 5 and 6, the backfill and the surrounding rock are instrumented with gauges for measuring temperature, water pressure, total pressure, relative humidity, resistivity and canister displacement. The instruments are connected to data collection systems by cables protected by tubes, which are led through the rock in watertight lead throughs.

In general the data for Section 1 in this report are presented in diagrams covering the time period 2001-09-17 to 2014-01-01. The time axis in the diagrams represent number of days from start 2001-09-17, which is the day the heating of the canister in hole 1 was started. For Section 2 the data had presented in diagrams covering the time period 2003-05-08 to 2011-01-01 in the last data report "Prototype repository – Sensors data report No 25" (Goudarzi 2014).

This report consists of several parts. In Chapters 2, 3 and 4 a test overview with the positions of those measuring points and a brief description of the instruments are shown. In Chapter 5 the measured results from all measurements in Section 1, except canister displacement, water pressure in the rock and resistivity in the backfill and buffer, are presented and commented. The diagrams of those measured results are attached in Appendix 1-4. The results and comments of the measurements of canister displacement, resistivity in the backfill, and water pressure in the rock are presented separately in Appendix 5-7.

A quick guide to the position of the instruments in the buffer and backfill is shown on page 9.

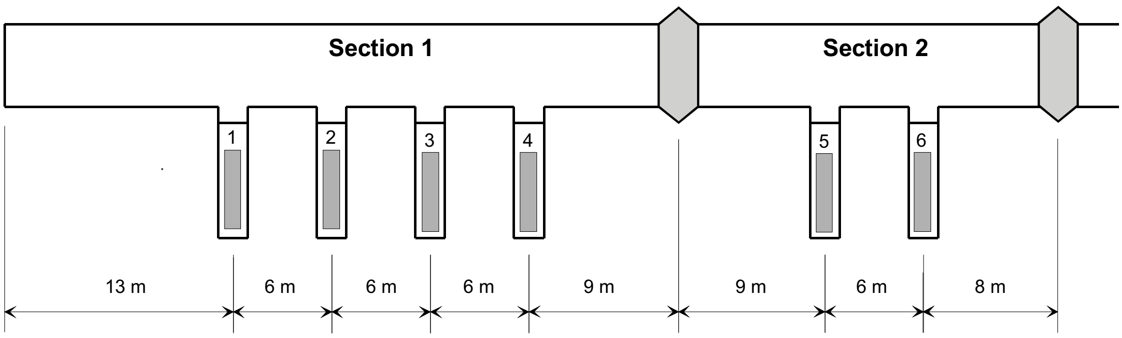


Figure 1-1. *Schematic view of the Prototype Repository.*

2 Geometry and coordinate systems

The Prototype Repository consists of two sections as shown in Figure 1-1. The geometry and the coordinate system for the sensors are different for the deposition holes and the tunnel. The temperature sensors in the rock are defined with the same coordinate system as the deposition holes.

Deposition holes

In Section 1 the deposition holes are termed 1-4 according to Figure 1-1. The coordinate system for these holes is shown in Figure 2-1. With the z-axis starting from the cement casting and the angle a counted anti-clockwise from direction A. Measurements are mainly made in four vertical Sections A, B, C and D according to Figure 2-1. Direction A and C are placed in the tunnels axial direction with A headed against the end of the tunnel i.e. almost towards West.

Tunnel

The coordinate system of the backfill in the tunnel is shown in Figure 2-2. The coordinate y starts at the entrance on ground, which means that the tunnel ends at y=3599.8. The y-axis runs in the centre of the tunnel, which means that the tunnel walls intersect the z and x-axes at +/–2.5 m. The z-coordinate is determined positive upwards and the x-coordinate is determined positive to the right when facing the end of the tunnel.

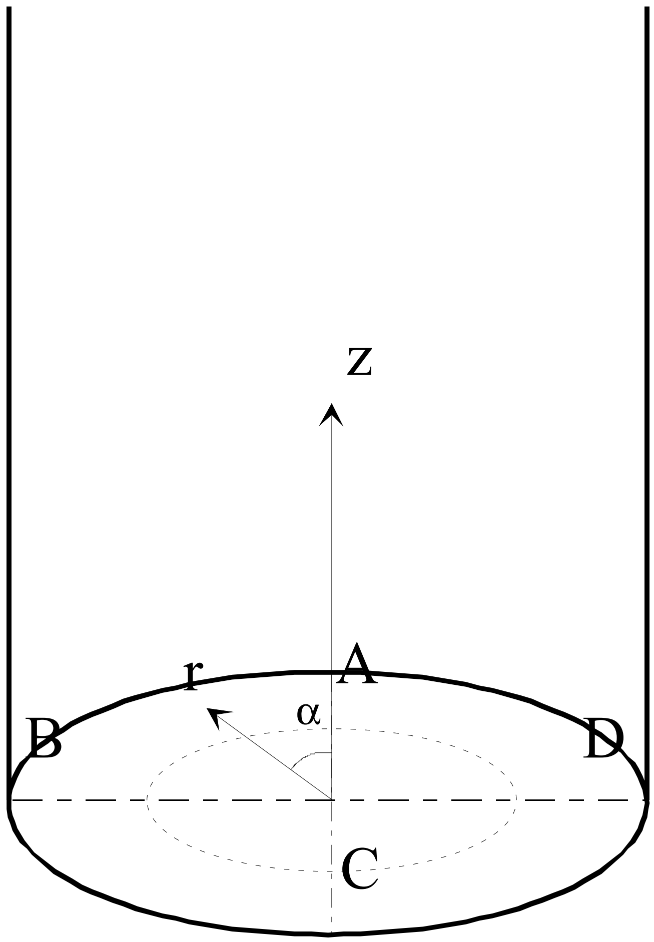


Figure 2-1. Figure describing the instrument planes (A–D) and the coordinate system used when describing the instrument positions.

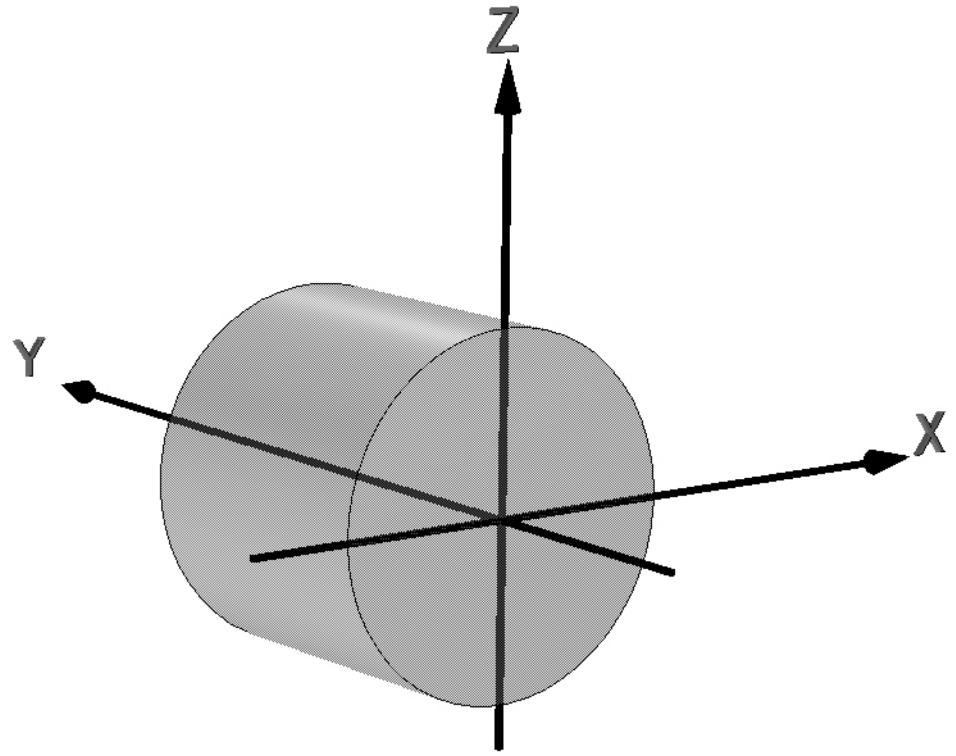


Figure 2-2. *Coordinate system of the tunnel.*

3 Brief description of the instruments

The different standard instruments that are used in the buffer, backfill and rock (temperature) are briefly described in this chapter.

Measurements of temperature

Buffer, backfill and rock

Thermocouples from Pentronic have been used to measure temperature. Measurements are done in 32 points in each instrumented hole (hole 1 and hole 3). In addition, temperature gauges are built into the capacitive relative humidity sensors and some of the other sensor types as well.

Canister

Temperature is measured on the surface of the canister with optical fiber cables. An optical measuring system called FTR (Fiber Temperature Laser Radar) is used.

Measurement of total pressure in the buffer and backfill

Total pressure is the sum of the swelling pressure and the pore water pressure. It is measured with the following instrument types:

- Geocon total pressure cells with vibrating wire transducers.
- Kulite total pressure cells with piezo resistive transducers.

Measurement of pore water pressure in the buffer and backfill

Pore water pressure is measured with the following instrument types:

- Geocon pore pressure cells with vibrating wire transducer.
- Kulite pore pressure cells with piezo resistive transducer.

Measurement of the water saturation process in the buffer and backfill

The water saturation process is recorded by measuring the relative humidity in the pore system, which can be converted to total suction (negative water pressure). The following techniques and devices are used:

- Vaisala relative humidity sensor of capacitive type. The measuring range is 0–100% RH.
- Rotronic relative humidity sensors of capacitive type. The measuring range is 0–100% RH.
- Wescor soil psychrometer. The sensor is measuring the dry and the wet temperature in the pore volume of the material. The measuring range is 95.5–99.6% RH corresponding to the pore water pressure –0.5 to –6 MPa. Psychrometers are placed in the backfill in Section I.

4 Location of instruments in Section 1

4.1 Strategy for describing the position of each device in the bentonite and rock in and around the deposition holes

The same principles are used for describing the position of all sensors in the bentonite inside the deposition holes as well as the thermocouples in the rock around the deposition holes. The principles are described in the quick guide inserted as a folded A3 page at the end of the report.

The type of instruments and their locations are described in detail in Börgesson and Sandén (2001).

Every instrument is named with a unique name consisting of 1 letter describing the type of measurement, 2 letters describing where the measurement takes place (buffer, backfill, rock or canister), 1 figure denoting the deposition hole (1–4) and 4 figures specifying the instrument according to a separate list (see Table 4-1 to 4-9). Every instrument position is then described with three coordinates according to Figure 4-1.

The r-coordinate is the horizontal distance from the centre of the hole and the z-coordinate is the height from the surface of the bottom casting of the hole (the block height is set to 500 mm). The a-coordinate is the angle from the vertical direction A (almost West).

Figure 4-1 shows an overview of the instruments in the buffer. The bentonite blocks are called cylinders and rings. The cylinders are numbered C1–C4 and the rings R1–R10 respectively.

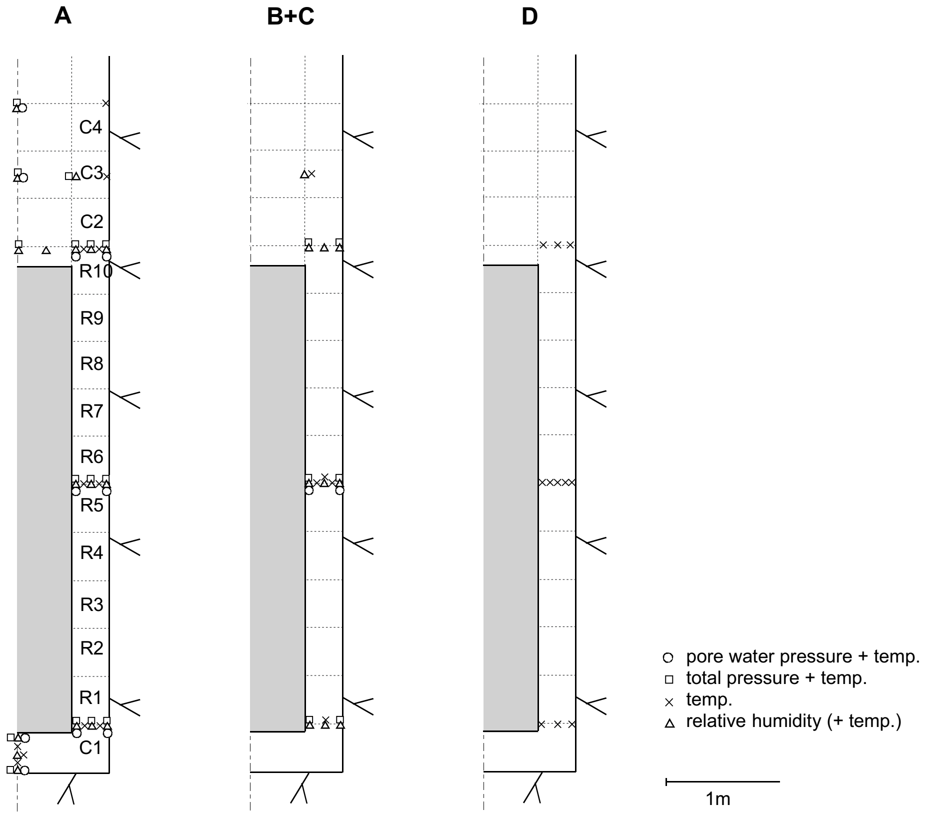


Figure 4-1. *Schematic view over the instruments in four vertical sections and the block designation.*

4.2 Position of each instrument in the bentonite in hole 1 (DA3587G01)

The instruments are located in three main levels in the blocks, 50 mm, 160 mm and 250 mm, from the upper surface. The thermocouples are mostly placed in the 50 mm level and the other gauges in the 160 mm level except for the Geokon type 1 pressure sensors and the Rotronic humidity sensors, which are placed in the 250 mm level depending on the size of the sensor house.

Exact positions of the sensors are described in Tables 4-1 to 4-4.

Table 4-1. Numbering and position of instruments for measuring temperature (T) in the buffer in hole 1.

Type and number	Block	Instrument position				Fabricate	Remark
		Direction	α	r	Z		
			degree	m	m		
TBU10001	Cyl. 1	Center	270	0,050	0,054	Pentronic	
TBU10002	Cyl. 1	Center	270	0,050	0,254	Pentronic	
TBU10003	Cyl. 1	Center	270	0,050	0,454	Pentronic	
TBU10004	Cyl. 1	A	355	0,635	0,454	Pentronic	
TBU10005	Cyl. 1	A	355	0,735	0,454	Pentronic	
TBU10006	On top of the canister in hole 2					Pentronic	
TBU10007	Cyl. 1	C	175	0,685	0,454	Pentronic	
TBU10008	Cyl. 1	D	270	0,585	0,454	Pentronic	
TBU10009	Cyl. 1	D	270	0,685	0,454	Pentronic	
TBU10010	Cyl. 1	D	270	0,785	0,454	Pentronic	
TBU10011	Ring 5	A	0	0,635	2,980	Pentronic	
TBU10012	Ring 5	A	0	0,735	2,980	Pentronic	
TBU10013	Ring 5	B	90	0,585	2,980	Pentronic	
TBU10014	Ring 5	B	90	0,685	2,980	Pentronic	
TBU10015	Ring 5	B	90	0,785	2,980	Pentronic	
TBU10016	Ring 5	C	175	0,585	2,980	Pentronic	
TBU10017	Ring 5	C	175	0,685	2,980	Pentronic	
TBU10018	Ring 5	C	175	0,735	2,980	Pentronic	
TBU10019	Ring 5	D	270	0,585	2,980	Pentronic	
TBU10020	Ring 5	D	270	0,635	2,980	Pentronic	
TBU10021	Ring 5	D	270	0,685	2,980	Pentronic	
TBU10022	Ring 5	D	270	0,735	2,980	Pentronic	
TBU10023	Ring 5	D	270	0,785	2,980	Pentronic	
TBU10024	Ring 10	A	0	0,635	5,508	Pentronic	
TBU10025	Ring 10	A	0	0,735	5,508	Pentronic	
TBU10026	Ring 10	D	270	0,585	5,508	Pentronic	
TBU10027	Ring 10	D	270	0,685	5,508	Pentronic	
TBU10028	Ring 10	D	270	0,785	5,508	Pentronic	
TBU10029	Cyl. 3	A	0	0,785	6,317	Pentronic	
TBU10030	Cyl. 3	B	95	0,585	6,317	Pentronic	
TBU10031	Cyl. 3	C	185	0,585	6,317	Pentronic	
TBU10032	Cyl. 4	A	0	0,785	7,026	Pentronic	

Table 4-2. Numbering and position of instruments for measuring total pressure (P) in the buffer in hole 1.

Type and number	Block	Instrument position				Fabricate	Remark
		Direction	α	r	Z		
			degree	m	m		
PBU10001	Cyl. 1	Center	0	0,000	0,000	Geokon	In cement
PBU10002	Cyl. 1	Center	0	0,100	0,504	Geokon	
PBU10003	Cyl. 1	A	5	0,585	0,504	Kulite	Vertical
PBU10004	Cyl. 1	A	5	0,685	0,504	Kulite	Vertical
PBU10005	Cyl. 1	A	5	0,785	0,504	Kulite	Vertical
PBU10006	Cyl. 1	B	95	0,635	0,504	Geokon	
PBU10007	Cyl. 1	B	105	0,735	0,504	Geokon	
PBU10008	Cyl. 1	C	185	0,635	0,504	Geokon	
PBU10009	Cyl. 1	C	195	0,735	0,504	Geokon	
PBU10011	Ring 5	A	5	0,685	2,780	Geokon I	
PBU10012	Ring 5	A	5	0,785	3,030	Kulite	In the slot
PBU10013	Ring 5	B	95	0,585	2,780	Geokon I	
PBU10014	Ring 5	B	95	0,785	2,780	Geokon I	
PBU10015	Ring 5	C	185	0,535	3,030	Geokon I	In the slot
PBU10016	Ring 5	C	185	0,825	2,870	Kulite	In the slot
PBU10017	Ring 10	Center	0	0,050	5,558	Geokon	
PBU10019	Ring 10	A	5	0,685	5,558	Kulite	Vertical
PBU10020	Ring 10	A	5	0,785	5,558	Kulite	Vertical
PBU10021	Ring 10	B	90	0,635	5,558	Geokon	
PBU10022	Ring 10	B	100	0,735	5,558	Geokon	
PBU10023	Ring 10	C	190	0,735	5,558	Geokon	
PBU10024	Ring 10	C	180	0,635	5,558	Geokon	
PBU10025	Cyl. 3	Center	0	0,050	6,317	Kulite	Vertical
PBU10026	Cyl. 3	A	5	0,585	6,567	Geokon	
PBU10027	Cyl. 4	Center	0	0,050	7,076	Kulite	Vertical

Table 4-3. Numbering and position of instruments for measuring pore water pressure (U) in the buffer in hole 1.

Type and number	Block	Instrument position				Fabricate	Remark
		Direction	α	r	Z		
			degree	m	m		
UBU10001	Cyl. 1	Center	90	0,050	0,054	Kulite	
UBU10002	Cyl. 1	Center	90	0,050	0,254	Geokon	Horizontal
UBU10003	Cyl. 1	A	355	0,585	0,344	Geokon	
UBU10004	Cyl. 1	A	355	0,785	0,344	Kulite	
UBU10005	Ring 5	A	355	0,585	2,780	Geokon	
UBU10006	Ring 5	A	355	0,785	2,870	Kulite	
UBU10007	Ring 5	B	85	0,535	2,870	Kulite	In the slot
UBU10008	Ring 5	B	85	0,825	2,870	Kulite	In the slot
UBU10009	Ring 5	C	175	0,535	2,780	Geokon	In the slot
UBU10010	Ring 5	C	175	0,825	2,780	Geokon	In the slot
UBU10011	Ring 10	A	355	0,585	5,398	Kulite	
UBU10012	Ring 10	A	355	0,785	5,308	Geokon	
UBU10013	Cyl. 3	Center	90	0,050	6,317	Geokon	
UBU10014	Cyl. 4	Center	90	0,050	6,916	Geokon	

Table 4-4. Numbering and position of instruments for measuring water content (W) in the buffer in hole 1.

Type and number	Block	Instrument position				Fabricate	Remark
		Direction	α	r	Z		
			degree	m	m		
WBU10001	Cyl. 1	Center	180	0,050	0,054	Rotronic	
WBU10002	Cyl. 1	Center	0	0,400	0,254	Rotronic	
WBU10003	Cyl. 1	Center	180	0,100	0,254	Rotronic	Horizontal
WBU10004	Cyl. 1	A	350	0,785	0,344	Vaisala	
WBU10005	Cyl. 1	A	350	0,685	0,344	Vaisala	
WBU10006	Cyl. 1	A	350	0,585	0,344	Vaisala	
WBU10007	Cyl. 1	B	80	0,585	0,344	Vaisala	
WBU10008	Cyl. 1	B	80	0,685	0,254	Rotronic	
WBU10009	Cyl. 1	B	80	0,785	0,254	Rotronic	
WBU10010	Cyl. 1	C	170	0,585	0,254	Rotronic	
WBU10011	Cyl. 1	C	170	0,685	0,254	Rotronic	
WBU10012	Cyl. 1	C	170	0,785	0,254	Rotronic	
WBU10013	Ring 5	A	350	0,585	2,870	Vaisala	
WBU10014	Ring 5	A	350	0,685	2,870	Vaisala	
WBU10015	Ring 5	A	350	0,785	2,870	Vaisala	
WBU10016	Ring 5	B	80	0,535	2,780	Rotronic	In the slot
WBU10017	Ring 5	B	80	0,685	2,780	Rotronic	
WBU10018	Ring 5	B	80	0,785	2,780	Rotronic	
WBU10019	Ring 5	C	180	0,535	2,870	Vaisala	In the slot
WBU10020	Ring 5	C	180	0,685	2,870	Vaisala	
WBU10021	Ring 5	C	180	0,785	2,780	Rotronic	
WBU10022	Ring 10	Center	0	0,050	5,418	Vaisala	
WBU10023	Ring 10	A	180	0,362	5,428	Vaisala	
WBU10024	Ring 10	A	350	0,585	5,398	Vaisala	
WBU10025	Ring 10	A	350	0,685	5,398	Vaisala	
WBU10026	Ring 10	A	350	0,785	5,398	Vaisala	
WBU10027	Ring 10	B	80	0,585	5,308	Rotronic	
WBU10028	Ring 10	B	80	0,685	5,308	Rotronic	
WBU10029	Ring 10	B	80	0,785	5,308	Rotronic	
WBU10030	Ring 10	C	170	0,585	5,398	Vaisala	
WBU10031	Ring 10	C	170	0,785	5,308	Rotronic	
WBU10032	Cyl. 3	Center	270	0,050	6,317	Vaisala	
WBU10033	Cyl. 3	A	350	0,585	6,317	Vaisala	
WBU10034	Cyl. 3	B	90	0,585	6,317	Vaisala	
WBU10035	Cyl. 3	C	180	0,585	6,317	Rotronic	
WBU10036	Cyl. 4	Center	180	0,050	6,916	Vaisala	
WBU10037	Cyl. 4	Center	270	0,050	6,756	Vaisala	

4.3 Position of each instrument in the bentonite in hole 3 (DA3575G01)

The instruments are located according to the same system as those in hole 1.

The positions of each instrument are described in Tables 4-5 to 4-9.

Table 4-5. Numbering and position of instruments for measuring temperature (T) in the buffer in hole 3.

Type and number	Block	Instrument position					Remark
		Direction	α	r	Z	Fabricate	
			degree	m	m		
TBU30001	Cyl. 1	Center	270	0,050	0,095	Pentronic	
TBU30002	Cyl. 1	Center	270	0,050	0,295	Pentronic	
TBU30003	Cyl. 1	Center	270	0,050	0,445	Pentronic	
TBU30004	Cyl. 1	A	355	0,635	0,445	Pentronic	
TBU30005	Cyl. 1	A	355	0,735	0,445	Pentronic	
TBU30006	Cyl. 1	B	85	0,685	0,445	Pentronic	
TBU30007	Cyl. 1	C	175	0,685	0,445	Pentronic	
TBU30008	Cyl. 1	D	270	0,585	0,445	Pentronic	
TBU30009	Cyl. 1	D	270	0,685	0,445	Pentronic	
TBU30010	Cyl. 1	D	270	0,785	0,445	Pentronic	
TBU30011	Ring 5	A	0	0,635	2,971	Pentronic	
TBU30012	Ring 5	A	0	0,735	2,971	Pentronic	
TBU30013	Ring 5	B	90	0,585	2,971	Pentronic	
TBU30014	Ring 5	B	90	0,685	2,971	Pentronic	
TBU30015	Ring 5	B	90	0,785	2,971	Pentronic	
TBU30016	Ring 10	A	329	0,410	5,394	Pentronic	Just above canister lid
TBU30017	Ring 5	C	175	0,685	2,971	Pentronic	
TBU30018	Ring 5	C	175	0,735	2,971	Pentronic	
TBU30019	Ring 5	D	270	0,585	2,971	Pentronic	
TBU30020	Ring 5	D	270	0,635	2,971	Pentronic	
TBU30021	Ring 5	D	270	0,685	2,971	Pentronic	
TBU30022	Ring 5	D	270	0,735	2,971	Pentronic	
TBU30023	Ring 5	D	270	0,785	2,971	Pentronic	
TBU30024	Ring 10	A	0	0,635	5,504	Pentronic	
TBU30025	Ring 10	A	0	0,735	5,504	Pentronic	
TBU30026	Ring 10	D	270	0,585	5,504	Pentronic	
TBU30027	Ring 10	D	270	0,685	5,504	Pentronic	
TBU30028	Ring 10	D	270	0,785	5,504	Pentronic	
TBU30029	Cyl. 3	A	0	0,785	6,314	Pentronic	
TBU30030	Cyl. 3	B	95	0,585	6,314	Pentronic	
TBU30031	Cyl. 3	C	185	0,585	6,314	Pentronic	
TBU30032	Cyl. 4	A	0	0,785	7,015	Pentronic	

Table 4-6. Numbering and position of instruments for measuring total pressure (P) in the buffer in hole 3.

Type and number	Block	Instrument position in block					Remark
		Direction	α	r	Z	Fabricate	
			degree	mm	mm		
PBU30001	Cyl. 1	Center	0	0	0	Geokon	In cement
PBU30002	Cyl. 1	Center	0	100	495	Geokon	
PBU30003	Cyl. 1	A	5	585	495	Kulite	Vertical
PBU30004	Cyl. 1	A	5	685	495	Kulite	Vertical
PBU30005	Cyl. 1	A	5	785	495	Kulite	Vertical
PBU30006	Cyl. 1	B	95	635	495	Geokon	
PBU30007	Cyl. 1	B	105	735	495	Geokon	
PBU30008	Cyl. 1	C	185	635	495	Geokon	
PBU30009	Cyl. 1	C	195	735	495	Geokon	
PBU30010	Ring 5	A	5	535	3021	Kulite	In the slot
PBU30011	Ring 5	A	5	685	2771	Geokon I	
PBU30012	Ring 5	A	5	825	3021	Kulite	In the slot
PBU30013	Ring 5	B	95	585	2771	Geokon I	
PBU30014	Ring 5	B	95	785	2771	Geokon I	
PBU30015	Ring 5	C	185	535	3021	Geokon I	In the slot
PBU30016	Ring 5	C	185	825	2971	Kulite	In the slot
PBU30017	Ring 10	Center	0	50	5556	Geokon	
PBU30018	Ring 10	A	5	585	5556	Kulite	Vertical
PBU30019	Ring 10	A	5	685	5556	Kulite	Vertical
PBU30020	Ring 10	A	5	785	5556	Kulite	Vertical
PBU30021	Ring 10	B	90	635	5556	Geokon	
PBU30022	Ring 10	B	100	735	5556	Geokon	
PBU30023	Ring 10	C	180	735	5556	Geokon	
PBU30024	Ring 10	C	190	635	5556	Geokon	
PBU30025	Cyl. 3	Center	0	50	6314	Kulite	Vertical
PBU30026	Cyl. 3	A	5	585	6564	Geokon	
PBU30027	Cyl. 4	Center	0	50	7065	Kulite	Vertical

Table 4-7. Numbering and position of instruments for measuring pore water pressure (U) in the buffer in hole 3.

Type and number	Block	Instrument position in block				Fabricate	Remark
		Direction	α	r	Z		
			degree	mm	mm		
UBU30001	Cyl. 1	Center	90	50	45	Kulite	
UBU30002	Cyl. 1	Center	90	100	245	Geokon	Horizontal
UBU30003	Cyl. 1	A	355	585	335	Geokon	
UBU30004	Cyl. 1	A	355	785	335	Kulite	
UBU30005	Ring 5	A	355	585	2771	Geokon	
UBU30006	Ring 5	A	355	785	2861	Kulite	
UBU30007	Ring 5	B	85	535	2861	Kulite	In the slot
UBU30008	Ring 5	B	85	825	2861	Kulite	In the slot
UBU30009	Ring 5	C	175	535	2771	Geokon	In the slot
UBU30010	Ring 5	C	175	825	2771	Geokon	In the slot
UBU30011	Ring 10	A	355	585	5396	Kulite	
UBU30012	Ring 10	A	355	785	5306	Geokon	
UBU30013	Cyl. 3	Center	90	50	6314	Geokon	
UBU30014	Cyl. 4	Center	90	50	6910	Geokon	

Table 4-8. Numbering and position of instruments for measuring water content (W) in the buffer in hole 3.

Type and number	Block	Instrument position				Fabricate	Remark
		Direction	α	r	Z		
			degree	m	m		
WBU30001	Cyl. 1	Center	180	0,050	0,045	Rotronic	
WBU30002	Cyl. 1	Center	0	0,400	0,215	Rotronic	
WBU30003	Cyl. 1	Center	180	0,100	0,245	Rotronic	Horizontal
WBU30004	Cyl. 1	A	350	0,785	0,335	Vaisala	
WBU30005	Cyl. 1	A	350	0,685	0,335	Vaisala	
WBU30006	Cyl. 1	A	350	0,585	0,335	Vaisala	
WBU30007	Cyl. 1	B	80	0,585	0,335	Vaisala	
WBU30008	Cyl. 1	B	80	0,685	0,245	Rotronic	
WBU30009	Cyl. 1	B	80	0,785	0,245	Rotronic	
WBU30010	Cyl. 1	C	170	0,585	0,245	Rotronic	
WBU30011	Cyl. 1	C	170	0,685	0,245	Rotronic	
WBU30012	Cyl. 1	C	170	0,785	0,245	Rotronic	
WBU30013	Ring 5	A	350	0,585	2,861	Vaisala	
WBU30014	Ring 5	A	350	0,685	2,861	Vaisala	
WBU30015	Ring 5	A	350	0,785	2,861	Vaisala	
WBU30016	Ring 5	B	80	0,535	2,771	Rotronic	In the slot
WBU30017	Ring 5	B	80	0,685	2,771	Rotronic	
WBU30018	Ring 5	B	80	0,785	2,771	Rotronic	
WBU30019	Ring 5	C	180	0,535	2,861	Vaisala	In the slot
WBU30020	Ring 5	C	180	0,685	2,861	Vaisala	
WBU30021	Ring 5	C	180	0,785	2,771	Rotronic	
WBU30022	Ring 10	Center	180	0,050	5,416	Vaisala	
WBU30023	Ring 10	A	352	0,262	5,396	Vaisala	
WBU30024	Ring 10	A	350	0,585	5,396	Vaisala	
WBU30025	Ring 10	A	350	0,785	5,396	Vaisala	
WBU30026	Ring 10	A	350	0,685	5,396	Vaisala	
WBU30027	Ring 10	B	80	0,585	5,306	Rotronic	
WBU30028	Ring 10	B	80	0,685	5,306	Rotronic	
WBU30029	Ring 10	B	80	0,785	5,306	Rotronic	
WBU30030	Ring 10	C	170	0,585	5,396	Vaisala	
WBU30031	Ring 10	C	170	0,785	5,306	Rotronic	
WBU30032	Cyl. 3	Center	180	0,050	6,314	Vaisala	
WBU30033	Cyl. 3	A	350	0,585	6,314	Vaisala	
WBU30034	Cyl. 3	B	90	0,585	6,314	Vaisala	
WBU30035	Cyl. 3	C	180	0,585	6,314	Rotronic	
WBU30036	Cyl. 4	Center	180	0,050	6,910	Vaisala	
WBU30037	Cyl. 4	Center	270	0,050	6,750	Vaisala	

4.4 Instruments on the canister surface in holes 1–4

The canisters are instrumented with optical fiber cables on the copper surface.

Figure 4-2 shows how two optical fiber cables are placed on the canister surface. Both ends of a cable are used for measurements. This means that the two cables are used for four measurements.

With this laying the cables will enter and exit the surface at almost the same position. Curvatures are shaped as a quarter circle with a radius of 20 cm. The cables are placed in a milled out channels on the surface. The channels have a width and a depth of just above 2 mm.

In additional to the optical cables one thermocouple (TBU 10006) is fixed to the lid of the canister in deposition hole 2 (see Table 4-1).

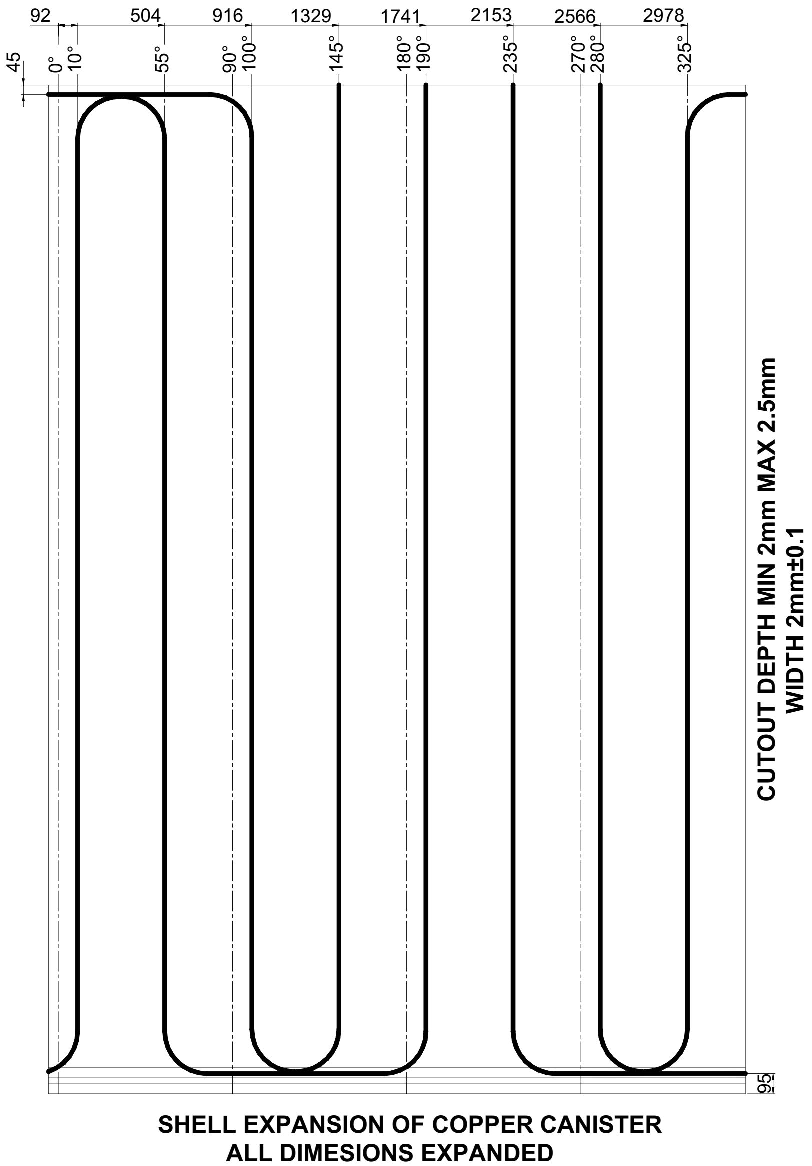


Figure 4-2. *Laying of the optical fiber cables with protection tube of Inconel 625 (outer diameter 2 mm) for measurement of the canister surface temperature (surface unfolded).*

4.5 Position of temperature sensors in the rock

The positions of the temperature sensors in the rock are termed in the same way as the sensors in the buffer in the deposition holes. Figure 4-3 shows an overview of the temperature sensors placed in the rock. The sensors are assigned to the closest deposition hole. The positions are described in Table 4-9.

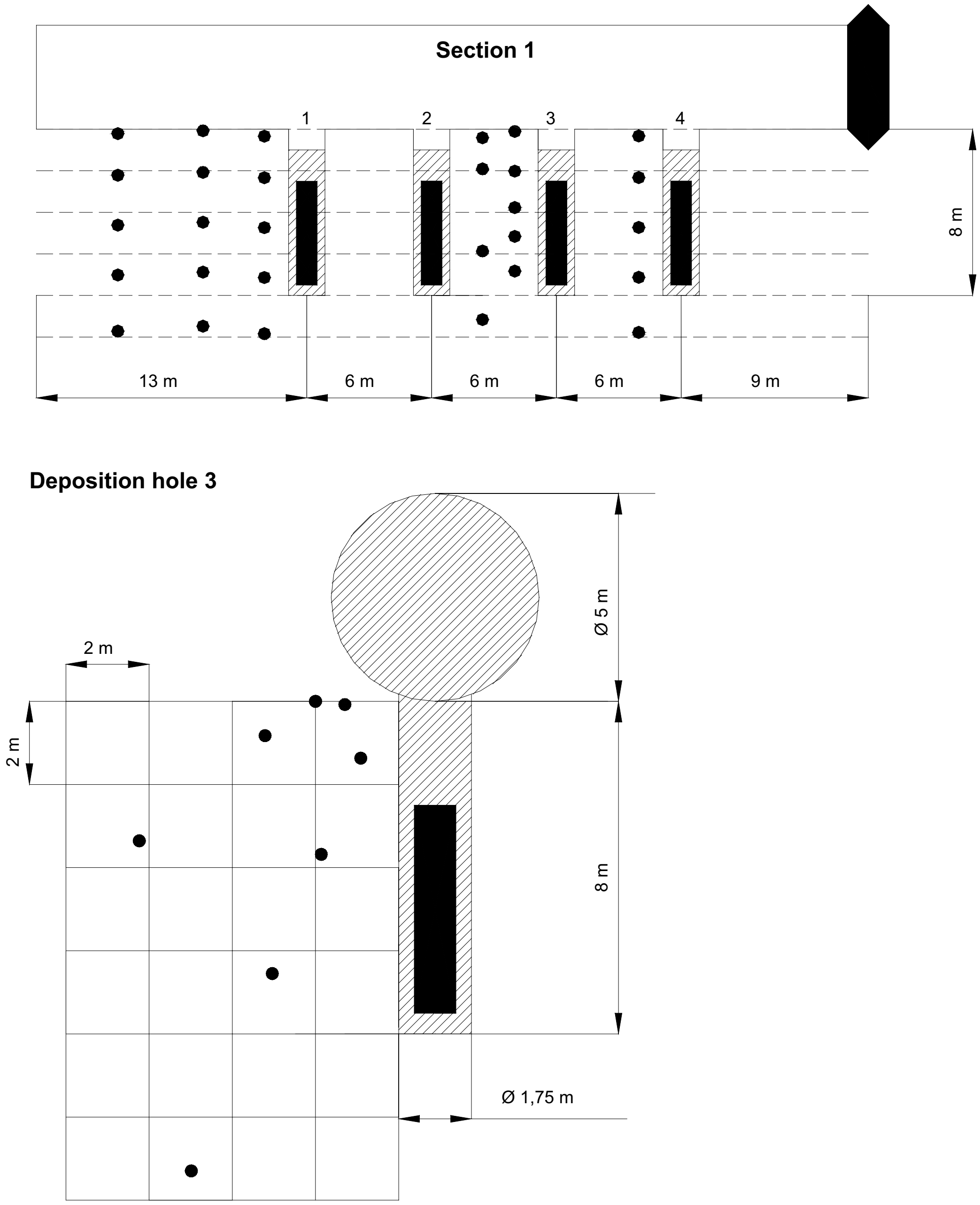


Figure 4-3. *Overview of the temperature sensors in the rock. Length section (upper) and cross section (towards the end of the tunnel).*

Table 4-9. Numbering and position of temperature sensors in the rock.

Instrument position in rock				
Type and number	α	r	Z	Fabricate
	degree	m	m	
Measured from DA3587G01(Hole 1)				
TROA0350	360	9,080	7,785	Pentronic
TROA0340	360	9,080	5,785	Pentronic
TROA0330	360	9,080	3,385	Pentronic
TROA0320	0	9,080	0,986	Pentronic
TROA0310	0	9,081	-1,714	Pentronic
TROA0650	360	4,990	7,922	Pentronic
TROA0640	360	4,982	5,922	Pentronic
TROA0630	360	4,972	3,522	Pentronic
TROA0620	360	4,961	1,122	Pentronic
TROA0610	360	4,951	-1,478	Pentronic
TROA1050	359	2,014	7,663	Pentronic
TROA1040	359	2,022	5,663	Pentronic
TROA1030	359	2,032	3,263	Pentronic
TROA1020	359	2,042	0,863	Pentronic
TROA1010	359	2,053	-1,837	Pentronic
Measured from DA3581G01(Hole 2)				
TROA1840	179	2,403	7,584	Pentronic
TROA1830	179	2,427	6,084	Pentronic
TROA1820	179	2,489	2,135	Pentronic
TROA1810	179	2,541	-1,165	Pentronic
Measured from DA3575G01(Hole 3)				
TROA2150	134	3,287	7,956	Pentronic
TROA2140	1	1,993	5,977	Pentronic
TROA2130	1	1,975	4,228	Pentronic
TROA2120	2	1,961	2,838	Pentronic
TROA2110	3	1,944	1,168	Pentronic
TROA1850	360	2,013	7,887	Pentronic
TROA2330	90	2,192	7,922	Pentronic
TROA2320	90	1,786	6,630	Pentronic
TROA2310	109	7,111	4,638	Pentronic
TROA2440	124	4,090	7,172	Pentronic
TROA2430	90	2,735	4,317	Pentronic
TROA2420	89	3,912	1,449	Pentronic
TROA2410	89	5,86	-3,297	Pentronic
Measured from DA3569G01 (Hole 4)				
TROA3050	359	2,013	7,665	Pentronic
TROA3040	359	2,020	5,665	Pentronic
TROA3030	358	2,030	3,265	Pentronic
TROA3020	357	2,040	0,865	Pentronic
TROA3010	357	2,051	-1,784	Pentronic

4.6 Strategy for describing the position of each device in the backfill in Section 1

The principles of terming the instruments are described in the quick guide inserted as a folded A3 page at the end of the report.

Every instrument is named with a unique name consisting of 1 letter describing the type of measurement, 2 letters describing where the measurement takes place (buffer, backfill, rock or canister) and 5 figures specifying the instrument according to separate lists (see Tables 4-10 to 4-13). Every instrument position is then described with three coordinates according to Figure 2-2. The x-coordinate is the horizontal distance from the centre of the tunnel and the z-coordinate is the vertical distance from the centre of the tunnel. The y-coordinate is the same as in the tunnel coordinate system, i.e. y=3599 corresponds to the end of the tunnel.

The backfill is mainly instrumented in vertical sections straight above and between the deposition holes (Figures 4-4 and 4-5).

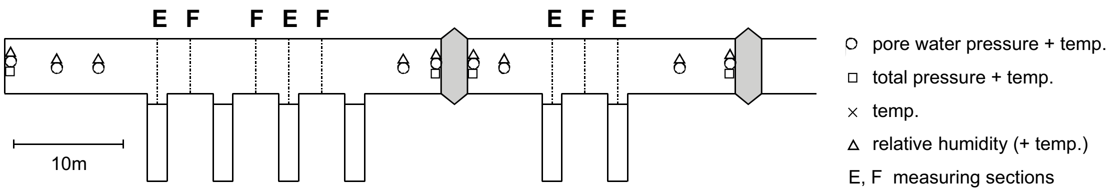


Figure 4-4. Schematic view over the instrumentation of the backfill.

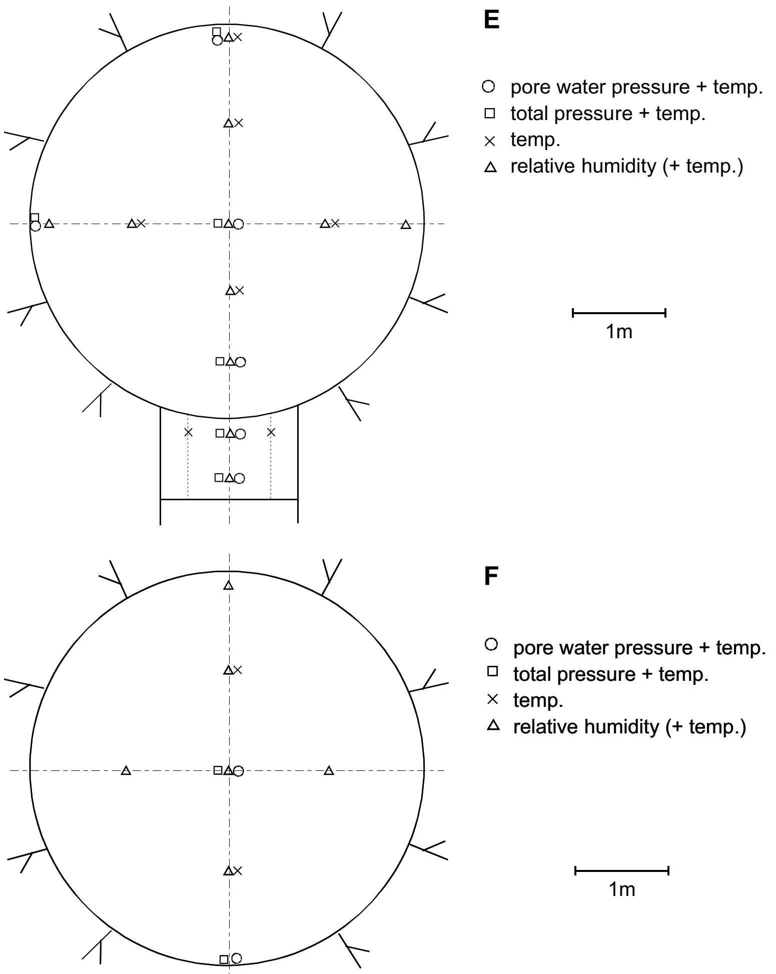


Figure 4-5. Schematic view over the sensors positions in the different sections.

4.7 Position of each instrument in the backfill

The positions of each instrument are described in Tables 4-10 to 4-13.

Table 4-10. Numbering and position of instruments for measuring temperature (T) in the backfill.

Type and number	Instrument position				Fabricate	Remark
	Section	x	z	y		
		m	m	m		
TBA10001	E, over dep.hole 1	-1,3	-0,1	3 587	Pentronic	
TBA10002	E, over dep.hole 1	0,1	1,3	3 587	Pentronic	
TBA10003	E, over dep.hole 1	0,0	-0,8	3 587	Pentronic	
TBA10004	E, over dep.hole 1	-0,5	-2,6	3 587	Pentronic	
TBA10005	E, over dep.hole 1	0,5	-2,6	3 587	Pentronic	
TBA10006	E, over dep.hole 1	-0,1	2,3	3 587	Pentronic	
TBA10007	E, over dep.hole 1	1,3	-0,1	3 587	Pentronic	
TBA10008	F, between dep.hole 1 and 2	0,0	1,3	3 584	Pentronic	
TBA10009	F, between dep.hole 1 and 2	-0,1	-1,3	3 584	Pentronic	
TBA10010	F, between dep.hole 2 and 3	0,0	1,2	3 578	Pentronic	
TBA10011	F, between dep.hole 2 and 3	0,0	-1,2	3 578	Pentronic	
TBA10012	E, over dep.hole 3	-0,1	2,3	3 575	Pentronic	
TBA10013	E, over dep.hole 3	0,0	1,3	3 575	Pentronic	
TBA10014	E, over dep.hole 3	0,0	-0,9	3 575	Pentronic	
TBA10015	E, over dep.hole 3	-0,5	-2,6	3 575	Pentronic	
TBA10016	E, over dep.hole 3	0,5	-2,6	3 575	Pentronic	
TBA10017	E, over dep.hole 3	-1,3	0,0	3 575	Pentronic	
TBA10018	E, over dep.hole 3	1,3	0,0	3 575	Pentronic	
TBA10019	F, between dep.hole 3 and 4	0,0	1,2	3 572	Pentronic	
TBA10020	F, between dep.hole 3 and 4	0,0	-1,3	3 572	Pentronic	

Table 4-11. Numbering and position of instruments for measuring total pressure (P) in the backfill.

Type and number	Instrument position				Fabricate	Remark
	Section	x	z	y		
		m	m	m		
PBA10001	Inner part	0,2	0,1	3589	Kulite	
PBA10002	E, over dep.hole 1	0,0	0,0	3587	Geokon	
PBA10003	E, over dep.hole 1	0,0	-1,8	3587	Geokon	
PBA10004	E, over dep.hole 1	0,0	-2,6	3587	Geokon	
PBA10005	E, over dep.hole 1	0,0	-3,1	3587	Kulite	
PBA10006	E, over dep.hole 1	-2,3	0,1	3587	Kulite	
PBA10007	E, over dep.hole 1	0,2	2,3	3587	Kulite	
PBA10008	F, between dep.hole 1 and 2	0,0	0,0	3584	Geokon	
PBA10009	F, between dep.hole 1 and 2	-0,1	-1,8	3584	Geokon	
PBA10010	F, between dep.hole 2 and 3	0,0	-0,2	3578	Kulite	
PBA10011	F, between dep.hole 2 and 3	0,0	-2,3	3578	Kulite	
PBA10013	E, over dep.hole 3	0,0	-1,8	3575	Kulite	
PBA10015	E, over dep.hole 3	0,0	-3,1	3575	Geokon	
PBA10016	E, over dep.hole 3	-2,3	0,0	3575	Geokon	
PBA10017	E, over dep.hole 3	0,0	0,0	3575	Geokon	
PBA10018	F, between dep.hole 3 and 4	0,0	0,0	3572	Geokon	
PBA10019	F, between dep.hole 3 and 4	0,0	-2,3	3572	Geokon	
PBA10020	In front of plug	0,0	0,0	3561	Kulite	

Table 4-12. Numbering and position of instruments for measuring pore water pressure (U) in the backfill.

Type and number	Instrument position				Fabricate	Remark
	Section	x	z	y		
		m	m	m		
UBA10001	Inner part	-0,2	-0,1	3589	Kulite	
UBA10002	Inner part	0,0	0,0	3592	Geokon	
UBA10003	Inner part	-0,2	-0,1	3590	Geokon	
UBA10004	E, over dep.hole 1	0,0	-0,1	3587	Geokon	
UBA10005	E, over dep.hole 1	-0,2	-1,8	3587	Kulite	
UBA10006	E, over dep.hole 1	0,1	-2,6	3587	Kulite	
UBA10007	E, over dep.hole 1	0,4	-3,2	3587	Kulite	
UBA10008	E, over dep.hole 1	-2,3	0,0	3587	Geokon	
UBA10009	E, over dep.hole 1	0,0	2,3	3587	Geokon	
UBA10010	F, between dep.hole 1 and 2	0,0	0,0	3584	Kulite	
UBA10011	F, between dep.hole 1 and 2	0,1	-1,8	3584	Kulite	
UBA10012	F, between dep.hole 2 and 3	0,0	-0,2	3578	Kulite	
UBA10013	F, between dep.hole 2 and 3	0,0	-2,3	3578	Kulite	
UBA10014	E, over dep.hole 3	0,0	0,0	3575	Kulite	
UBA10015	E, over dep.hole 3	0,0	-1,8	3575	Geokon	
UBA10016	E, over dep.hole 3	0,3	-2,6	3575	Geokon	
UBA10017	E, over dep.hole 3	-0,1	-3,1	3575	Geokon	
UBA10018	E, over dep.hole 3	-2,3	0,0	3575	Geokon	
UBA10019	E, over dep.hole 3	0,0	0,0	3575	Geokon	
UBA10020	F, between dep.hole 3 and 4	0,0	0,0	3572	Kulite	
UBA10021	F, between dep.hole 3 and 4	0,0	-2,3	3572	Kulite	
UBA10022	In front of plug	0,0	0,0	3565	Kulite	
UBA10023	In front of plug	0,1	0,0	3562	Kulite	

Table 4-13. Numbering and position of instruments for measuring relative humidity (W) in the backfill.

Type and number	Instrument position				Fabricate	Remark
	Section	x	z	y		
		m	m	m		
WBA10001	Inner part	0,0	0,0	3589	Wescor	
WBA10002	Inner part	0,0	0,0	3592	Wescor	
WBA10003	Inner part	0,1	-0,1	3590	Wescor	
WBA10004	E, over dep.hole 1	0,3	2,3	3587	Wescor	
WBA10005	E, over dep.hole 1	0,0	1,3	3587	Wescor	
WBA10006	E, over dep.hole 1	0,0	0,1	3587	Wescor	
WBA10007	E, over dep.hole 1	0,1	-0,8	3587	Wescor	
WBA10008	E, over dep.hole 1	0,0	-1,7	3587	Wescor	
WBA10009	E, over dep.hole 1	-0,1	-2,6	3587	Wescor	
WBA10010	E, over dep.hole 1	-0,5	-3,1	3587	Wescor	
WBA10011	E, over dep.hole 1	-2,3	-0,1	3587	Wescor	
WBA10012	E, over dep.hole 1	-1,3	0,0	3587	Wescor	
WBA10013	E, over dep.hole 1	1,3	0,0	3587	Wescor	
WBA10014	E, over dep.hole 1	2,3	0,0	3587	Wescor	
WBA10015	F, between dep.hole 1 and 2	0,0	1,3	3584	Wescor	
WBA10016	F, between dep.hole 1 and 2	0,0	2,3	3584	Wescor	
WBA10017	F, between dep.hole 1 and 2	0,0	0,0	3584	Wescor	
WBA10018	F, between dep.hole 1 and 2	0,0	-1,3	3584	Wescor	
WBA10019	F, between dep.hole 1 and 2	-1,3	0,0	3584	Wescor	
WBA10020	F, between dep.hole 1 and 2	1,3	0,0	3584	Wescor	
WBA10021	F, between dep.hole 2 and 3	0,0	2,3	3578	Wescor	
WBA10022	F, between dep.hole 2 and 3	0,0	1,2	3578	Wescor	
WBA10023	F, between dep.hole 2 and 3	0,0	-0,2	3578	Wescor	
WBA10024	F, between dep.hole 2 and 3	0,0	-1,2	3578	Wescor	
WBA10025	F, between dep.hole 2 and 3	-1,3	0,0	3578	Wescor	
WBA10026	F, between dep.hole 2 and 3	1,3	0,0	3578	Wescor	
WBA10027	E, over dep.hole 3	0,0	2,5	3575	Wescor	
WBA10028	E, over dep.hole 3	0,0	1,3	3575	Wescor	
WBA10029	E, over dep.hole 3	0,0	0,0	3575	Wescor	
WBA10030	E, over dep.hole 3	0,0	-0,9	3575	Wescor	
WBA10031	E, over dep.hole 3	0,0	-1,6	3575	Wescor	
WBA10032	E, over dep.hole 3	-0,3	-2,6	3575	Wescor	
WBA10033	E, over dep.hole 3	0,1	-3,1	3575	Wescor	
WBA10034	E, over dep.hole 3	-2,3	0,0	3575	Wescor	
WBA10035	E, over dep.hole 3	-1,3	0,0	3575	Wescor	
WBA10036	E, over dep.hole 3	1,3	0,0	3575	Wescor	
WBA10037	E, over dep.hole 3	2,3	0,0	3575	Wescor	
WBA10038	F, between dep.hole 3 and 4	0,0	2,3	3572	Wescor	
WBA10039	F, between dep.hole 3 and 4	0,0	1,2	3572	Wescor	
WBA10040	F, between dep.hole 3 and 4	0,0	0,0	3572	Wescor	
WBA10041	F, between dep.hole 3 and 4	0,0	-1,3	3572	Wescor	
WBA10042	F, between dep.hole 3 and 4	-1,3	0,0	3572	Wescor	
WBA10043	F, between dep.hole 3 and 4	1,3	0,0	3572	Wescor	
WBA10044	In front of plug	0,0	0,0	3565	Wescor	
WBA10045	In front of plug	-0,1	0,0	3562	Wescor	

5 Results and comments for Section 1

5.1 General

In this chapter short comments on general trends in the measurements are given. Sensors that are not delivering reliable data or no data at all are noted and comments on the data collection in general are given.

The heating of the canister in hole 1 started with an applied constant power of 1,800 W at 010917. This date is also marked as start date for the test. The backfilling started 010903 and was finished 011120 and the plug was cast at 011214. In order to simulate the radioactive decay, the power was decreased 20 W one year after start of the first heater. At the beginning of September 2004 the power was decreased with about 30 W to 1,710 W in deposition holes 1–4. Table 5-1 shows some important dates for Section 1. At the beginning of November 2004 the drainage of the inner part of Section 1 and the drainage trough the outer plug were closed. At the beginning of December 2004 damages on the cables for the installed heaters in one of the canisters in Section 1 (No 1) and one in Section 2 (No 6) were observed. The damages were probably caused by the high water pressure in the buffer and backfill. It was then decided to switch off the power to all canisters. This was done on December 2. The drainage of the tunnel was opened on December 6 and investigations of the damaged cables were initialized. The power to all the canisters, except for canister 2, was on December 15 switched on. The damages on heaters in canister 2 were so severe that it was impossible to apply any power on this canister. The drainage of the tunnel was kept open.

In December 2005, 2006, 2007 and in January 2009 and 2010 the power to the canisters was reduced with about 30 W. The applied power after the latest reduction is about 1,560 W. There were problems with the some electrical heaters in the canister in hole 1 (2013-03-06/day 4,188) and in the canister in hole 3 (2013-05-20/ day 4,264) during this measuring period. The power in the hole 1 has reduced to about 1,440 W and the power in the hole 3 has reduced to 490 W.

Table 5-1. Key dates for Section 1.

Activity	Date
Start backfilling	3/9 2001
Start heating canister 1	17/9 2001
Start heating canister 2	24/9 2001
Start heating canister 3	11/10 2001
Start heating canister 4	22/10 2001
Finish backfilling	20/11 2001
Plug casting	14/12 2001
Decreased power (–20 W)	17/9 2002
Decreased power (–40 W)	5/9 2003
Decreased power (–30 W)	8/9 2004
The drainage of tunnel was closed	1/10 2004
The power to all canisters was switched off	2/12 2004
The drainage of the tunnel was opened	6/12 2004
The power to the canisters was switched on	15/12 2004
Decreased power (–30 W)	2/12 2005
A packer installed in the rock was broken	18/5 2006
Decreased power (–30 W)	21/12 2006
Decreased power (–30 W)	11/12 2007
Decreased power (–30 W)	29/1 2009
Decreased power (–30 W)	21/1 2010
Start of the dismantling of the outer plug	29/11 2010
The dismantling of the Section2 has finished	20/12 2011
Decreased power in the canister 1 (–120W)	6/3 2013
Decreased power in the canister 3 (–1060W)	20/5 2013

Beside the above reported power reductions a change in power was made June 23 2003 due to additional calculations of the power from measurement of the energy. The power of the canisters was adjusted to 1,800 W. The most significant change was made for canister 2 (See Section 5.4.1 and Appendix 3 page 138).

After the retrieval of the outer section, validation tests of the total pressure sensors of type Geocon were made. It was then discovered that, the up to 20120101 used calibration values (linear equation) gave inaccurate readings of the total pressure. The improvements of the readings were large when a polynomial calibration equation was used instead. At the presentation of the data in this report the polynomial equation was used.

At present about 275 (excluding water pressure sensors in the rock and the displacement sensors for the canister) out of totally 363 installed sensors are out of order. In Figure 5-1 the numbers of still working sensors in the buffer and the backfill of Section 1 are plotted as function of time from September 2001. The figure shows that the majority of the broken sensors are RH-sensors and thermocouples (in deposition hole 3). The figure also shows that the numbers of broken sensors increased after the closing of the drainage of the tunnel.

The measured processes were slow up to about 20 days after the drainage of the tunnel was closed. Very small changes of the measured parameters occurred up to that date. After that the readings from some of the total and pore pressure sensors placed in the buffer reacted strongly (quick increase in pressure). Also the total and pore pressure sensors placed in the backfill recorded high pressures caused by the closing of the drainage. After the reopening of the drainage of the tunnel, both the pore pressures and the total pressures in the backfill were stabilized on almost the same level as before the closing of the drainage. At around day 1,670 both the total pressure sensors and the pore pressure sensors are measuring an increase in pressure. This is caused by a failure in one packer placed in the rock at the inner part of the tunnel causing an increase in out flow of water from the inner section from about 1.5 l/min to more than 9 l/min.

So far hole 1 has been strongly wetted and a very slowly wetting is observed in hole 3. A slow but obvious wetting of the backfill is noted until about 20 days after the closing of the drainage. After that a strong increase of the wetting rate was monitored by several psychrometers. The measurement of the temperature on the canister surface with the optical system has stopped functioning.

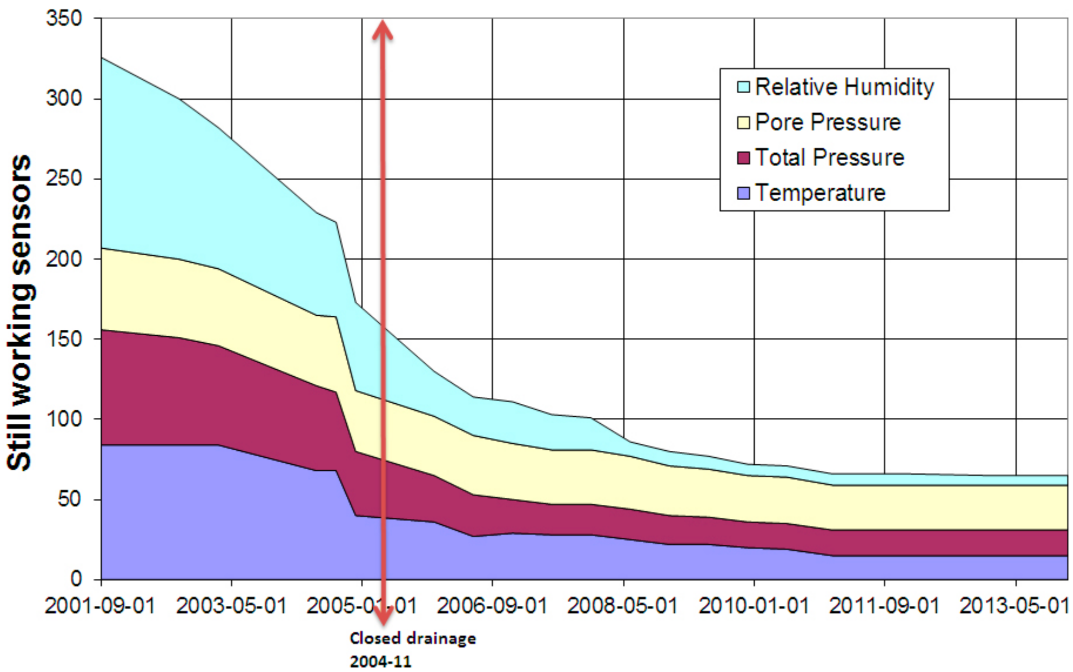


Figure 5-1. *The number of still working sensors placed in the buffer and backfill in Section 1 as function of date. The coloured fields are representing the four types of installed sensors.*

5.2 Deposition hole 1

5.2.1 Total pressure

Geokon (App. 1\pages 49–50)

The measured pressure range is from 1.4 to 8.5 MPa. The highest pressure is indicated from the peripheral sensors in the bottom block (C1). Four sensors in block R5 and block R10 yielded a high increase in total pressure when the drainage of the tunnel was closed. Most of the sensors yielded a drop in pressure when the heaters where switched off and the drainage of the tunnel was opened again and an increase in pressure when the heaters where switched on again.

All of the installed sensors are out of order.

Kulite (App. 1\page 50)

The highest pressure 7 MPa is indicated from the peripheral sensor (PBU 10012) in block R5. Three of the installed sensors indicated a rapid increase in pressure when the drainage of the tunnel was closed followed by a drop in pressure when the power was switched off and the drainage was reopened. After the power was switched on the pressure increased to the same level as before the closing of the drainage.

Two sensors were not installed and six of the installed sensors are out of order.

5.2.2 Relative humidity

Vaisala (App. 1\pages 51–52)

Since temperature is also measured with all relative humidity sensors, the diagrams include those measured temperatures. The temperature measurements start at about 16 degrees while the RH measurements start at about 70%RH.

The relative humidity measured in the buffer has not changed very much during the last 6 months, except for the sensors placed above the canister (in Cylinder 3 and 4) which are indicating a slowly wetting. The sensors have not reached 100 RH. The temperature measurements were effected when the power to the heaters was switched off but reached the same levels as before when the power was switched on again. A slow decrease in temperature is measured by all of the still working sensors

Sixteen sensors are out of order, most of them due to high water saturation of the buffer.

Rotronic (App. 1\pages 53–54)

All Rotronic sensors placed between the canister and the rock measured RH higher than 90% within 200 days after the start of the test. Two of the sensors placed in the central part of block C1 indicated a drying of the bentonite (decreasing in RH from about 75%) up to the time when they stopped working (after about 1,000 days).

All of the installed sensors have stopped giving reliable RH values, most of them due to high water saturation of the buffer. One of the temperature sensors is still working.

5.2.3 Pore water pressure

Geokon (App. 1\page 55)

The highest pressures 500–1,600 kPa are measured near the canister surface in block R5 (UBU10005) and in the periphery of block R5 (UBU10010). Two sensors in block C1 are also recording an increasing pressure (UBU10002, UBU10003) while the rest of the sensors are measuring very low pressures at the last reading before they were broken (day 3,639).

All sensors are out of order.

Kulite (App. 1\page 56)

Rather high water pressures have been measured by three sensors located in block R5 (1,200–3,500 kPa). One sensor placed in the outer slot started to react about 50 days after the start of the measurement. The pore pressure measured with two of the sensors reacted strongly during the period when the drainage of the tunnel was closed and during the period when the power to the canister was switched off. The sensors measured an increase of the pressure with about 100 kPa after the middle of May 2007. This change in pressure is probably cause by the preparation work done for a new tunnel near by the Prototype tunnel.

All of the installed sensors have stopped giving reliable values.

5.2.4 Temperature in the buffer (App. 1\pages 56–59)

The measured temperature after the power to the canister was switched on again ranges from 28.0°C (in the periphery of the upper bentonite cylinder C4) to 70.0°C in block R5 close to the canister. The highest temperature gradient measured in the buffer is 0.57°C /cm (block R5).

Thirty-two sensors are out of order.

The temperature in the buffer is also measured with the Geokon sensors (from day 1,350). The maximum temperature recorded with these sensors is about 40°C at the end of this measuring period (UBU10010 placed in block R5).

5.2.5 Canister power in dep. hole 1 (App. 1\page 61)

The power of the canister in whole 1 was kept constant during one year at 1,800 W since the start 010917. After one year the power was decreased with about 20 W. After another year the power was decreased with about 40 W. The next reduction of power was made at the beginning of September year 2004 (about 30 W). The power of the canister in hole 1 was about 1,710 W after this reduction. During the period between December 6 and December 15 2004 the power to the canister was switched off. After that period the power was adjusted to about 1,710 W again. At the beginning of December 2005, 2006, 2007 and January 2009 and 2010 the power was decreased with 30 W. After these reductions the power was about 1,560 W until 2013-03-06 (day 4188) when the power has reduced to about 1,440 W due to electrical heater failure.

5.2.6 Temperature on the canister surface (App. 1\page 62)

The first diagram shows the maximum temperature, measured with the optical cables placed on the surface of the canister, plotted as function of time. The maximum measured temperature on the canister surface is about 75°C. With no damages on the optical cables this plot should have four curves. Only one curve with relevant values is presented here up to December 24 which indicates that the optical cables are damaged. The second diagram shows the distribution of the temperature along the optical cables at December 1 2004. The length of the cables on the canister surface is about 20 m. The variation of a few degrees is caused by the difference in temperature in the centre and ends of the canister. At December 15 2004 the optical system for measuring the temperature on this canister stopped functioning.

5.3 Deposition hole 3

5.3.1 Total pressure

Geokon (App. 2\pages 63–64)

Most of the sensors placed in block C1 and block R10 yielded an increase in total pressure when the drainage of the tunnel was closed.

The total pressures measured in this deposition hole are significantly lower than those measured in deposition hole 1. The maximum pressure registered so far is 3 MPa (PBU30023). This value was obtained when the drainage was closed. The sensor is placed in block R10.

Twelve sensors are out of order.

Kulite (App. 2\pages 64–65)

The highest pressure, 2,0 MPa, is indicated from the peripheral placed sensors in block C1. Also two sensor placed in block R10 have measured a pressure higher than 1.5 MPa. The sudden change in pressure which occurred around day 180 was probably caused by early data logger problems.

Eleven sensors are out of order.

5.3.2 Relative humidity

Vaisala (App. 2\pages 65–67)

A significant drying of the bentonite close to the top of the canister was observed by the two sensors WBU30022 and WBU30023. After the closing of the drainage both sensors indicated an instant and significant increasing in relative humidity. The still working sensor (WBU30022) is measuring a slowly increasing in humidity, implying a wetting of the buffer close to the canister lid.

An increased wetting of the bentonite can be observed by sensors place in block R10 between the canister and the rock. One sensor placed in block R5 showed an increase in relative humidity from about 70% to 82% after the closing of the drainage.

Two sensors (WBU30019 and WBU30020) placed in block R5 measured a decrease in relative humidity (indicating a drying of the buffer) after the power was switched on again. During this measuring period the still working sensors (WBU30020, WBU30033) are measuring a slowly increase in relative humidity.

Seventeen sensors are out of order.

Rotronic (App. 2\pages 67–69)

All Rotronic sensors in hole 3 have failed or increased the measured RH to 100%. The reason for this is unclear. Since there are no other signs of strong wetting, malfunction are more probable than strong wetting. One sensor (WBU30016) placed close to the canister in block R5 was indicating a drying of the bentonite until it failed.

5.3.3 Pore water pressure.

Geokon (App. 2\page 70)

One sensor UBU30014 placed in C4 yields continue increasing to 350 kPa during this measuring period. All sensors yield very low pressures except for one sensor below the canister that yields a sudden increase to 220 kPa around day 300.

Kulite (App. 2\page 70)

UBU30004 yielded a maximum pressure of 440 kPa. This sensor is placed near the rock surface at the bottom of the deposition hole. The rest of the sensors yield low pressures.

5.3.4 Temperature in the buffer (App. 2\pages 71–74 and 75)

The measured temperature ranges from 38°C (in the periphery of the upper bentonite cylinder C4) to a temperature of 83.2°C in the centre close to the canister. These measurements are from the period just before the power to the canisters where switched off. The highest temperature gradient measured with the sensors is 0.59°C/cm (block R5). There have appeared some problems with some data scan units, which explains the noise in some curves.

30 sensors are out of order.

The temperature in the buffer is also measured with the Geokon sensors (from day 1,350). The maximum temperature recorded at the end of this measuring period with these sensors is about 39°C (UBU30015 placed in block R5 close to the canister). Temperature drops in the buffer during this measuring period are depending to power reduction (day 4,264).

5.3.5 Canister power (App. 2\page 76)

The power of the canister in hole 3 was kept constant at 1,800 W from the start 011011 until 020917, when the power was decreased with about 20 W. The power has been stepwise decreased according to Table 5-1. During the period between December 6 and December 15 the power of all canisters was switched off. After that period the power was adjusted to about 1,710 W. At the beginning of December 2005, 2006, 2007 and January 2009 and 2010 the power was decreased with 30 W. After these reductions the power was about 1,560 W until 2013-05-20 (day 4,264) when the power has reduced to about 490 W due to electrical heater failure.

5.3.6 Temperature on the canister surface (App. 2\pages 76–77)

The first diagram shows the maximum temperature plotted as a function of time. The maximum measured temperature on the canister surface was about 100°C just before the power to the canisters was switched off. The temperature recovered, but only to about 93°C after the power was switched on again and after that a slightly decrease in temperature was measured until the sensor stopped functioning at the end of August 2005. The second diagram shows the distribution of the temperature along the cables. See also Section 5.2.6.

5.4 Deposition hole 2

5.4.1 Canister power (App. 3\page 79)

The power of the canister in hole 2 was kept constant at 1,800 W from the start 010924 until 020917, when the power was decreased with about 20 W. After two years (September 2003) the power was decreased with about 40 W to 1,740 W. The interruption in the curve between days 409 and 456 is caused by data collection problems. At the beginning of September 2004 the power was decreased with about 40 W to 1,710 W. Since permanent damages on the heaters in the canister were observed on December 1 2004 the power to this canister has been switched off and not been restarted.

5.4.2 Temperature on the canister surface (App. 3\pages 80–81)

See Section 5.2.6. The maximum measured temperature on the canister surface was just before the power was switched off about 96°C. The reason for the unexpected increase in temperature after 450 days is the difficulties with the measurement of the power (see Section 5.2.5). The actual power at that time was probably higher than 1,800 W. After the power was switched off the temperature on the canister surface was stabilized on about 30°C. The sensor stopped giving reliable data at the beginning of June 2005.

5.5 Deposition hole 4

5.5.1 Canister power (App. 3\page 82)

The power of the canister in hole 3 was kept constant at 1,800 W from the start 011011 until 020917, when the power was decreased with about 20 W. Some initial problems with the control system for the power have been overcome. The power has been stepwise decreased according to Table 5-1.

During the period between December 6 and December 15 the power of all canisters was switched off. After that period the power was adjusted to about 1,710 W. At the beginning of December 2005, 2006, 2007 and January 2009 and 2010 the power was decreased with 30 W. After the latest reduction the power is now about 1,560 W.

5.5.2 Temperature on the canister surface (App. 3\pages 82–83)

See Section 5.2.6. The maximum measured temperature on the canister surface after the power was switched on again was 88°C. The sensor stopped giving reliable data at the beginning of April 2005.

5.6 Backfill in Section1

5.6.1 Total pressure in the backfill

Geokon (App. 4\page 85)

All these sensors yielded high increase in total pressure in connection with closing of the tunnel drainage. The maximum measured pressure was about 2.5 MPa. After the opening of the drainage the total pressure was stabilized on the same level as before the closing of the drainage (maximum pressure about 0.2 MPa). At around the 20th of April 2006, a packer placed in a borehole in Section I of the tunnel started to leak resulting in an increase of water drained out from the inner section from about 1.5 l/min to about 9 l/min. The damaged packer caused also an increase in the measured total pressure of about 300 kPa (around day 1,660). At the beginning of April 2007 some of the sensors indicated an increase in the measured pressure. The change in the measure pressures was probably related to the work with the excavation of a new tunnel near by the Prototype-tunnel which was initialized at that time. The measured total pressures at the end of this measuring period vary between 970–1,600 kPa at the end of this measuring period.

Three sensors are out of order.

Kulite (App.4 \page 86)

These measurements yielded rather small increase in total pressure until the drainage of the tunnel was closed. The maximum pressure recorded is with PBA10013, about 350 kPa. The sensor stopped functioning during a period of about 100 day after the rapid increase in pressure when the tunnel drainage was closed. Sensor PBA10013 is placed 1.7 m above the bentonite surface in hole 3.

All sensors are out of order.

5.6.2 Suction in the backfill (App. 4\pages 87–90)

The suction in the backfill is measured with Wescor psychrometers. The steady but slow wetting (decrease in suction) observed in about 50% of the sensors continues. 7 sensors close to the roof and walls of the tunnel and one sensor just above the buffer in hole 1 indicate fast wetting that has gone close to water saturation (less than 1,000 kPa suction). Also the sensor placed just inside the plug has reached a suction value that indicates saturation. In connection with the closing of the drainage, a very rapid decrease in suction was recorded by the installed psychrometers. Six of these sensors placed in the central part of the tunnel section yielded an increase in suction, after the reopening of the drainage, to the same level as before the closing. Seven of the sensors measured a decrease in suction after the packer was damaged.

All of these sensors have stopped giving reliable values due to high water saturation of the backfill.

5.6.3 Pore water pressure in the backfill

Geokon (App. 4\page 90)

All these sensors yielded high increase in pore pressure when the drainage of the tunnel was closed. Many of the sensors recorded pressures up to 2.5 MPa. After the opening of the drainage the pore pressure was stabilized at low pressures (below 0.1 MPa). Also these sensors reacted when the packer was broken by measuring an increase in pore pressure of about 200 kPa. At the beginning of April 2007 some of the sensors are indicating an increase in the measured pressure. The change in the measure pressures is probably related to the work with the excavation of a new tunnel near by the Prototype-tunnel which was initialized at that time. The measured pore pressures vary between 800–1,050 kPa at the end of this measuring period.

Kulite (App. 4\page 91)

Also some of these sensors recorded very high water pressure after the closing of the drainage. The still functioning sensors measured an increase in pore pressure of about 200 kPa at the time when the packer installed in the rock was broken. The sensors reacted also when the excavation of the nearby tunnel was initialized. Eight sensors are out of order.

5.6.4 Temperature in the backfill (App. 4\pages 92–94)

The measured temperature in the backfill over the whole test period ranges from 16 to 35°C. The highest temperature was as expected measured above the buffer in hole 3 just before the drainage was opened. Also these sensors reacted when the packer was broken (a decrease in temperature). The measured temperatures at the end of this measuring period vary between 16 and 25°C.

5.7 Temperature in the rock

5.7.1 Near hole 1 (App. 1\pages 60–61)

The maximum temperature measured in the rock is 38.6°C. This temperature was measured with the thermocouple TROA1030 located 2.038 m from the centre of the canister in deposition hole 1. The temperature in the rock close to the deposition hole decreased when the power to the canisters was switched off but increased again when the power was switched on to a temperature about 1°C lower than before the power was switched off. The temperature is continuing to drop and the maximum temperature at the end of this measuring period is about 33°C.

5.7.2 Near hole 2 (App. 3\page 79)

The maximum temperature in the rock (46.8°C) was measured by TROA1820 located 2.490 m from the centre of the canister in deposition hole 2 just before the power to the canisters was switched off. Since no power is applied to this canister anymore the temperature in the rock around the deposition hole is continuing to decrease and the maximum temperature at the end of this measuring period is about 27°C.

5.7.3 Near hole 3 (App. 2\pages 74–75)

The maximum temperature in the rock (48.8°C) was measured by TROA2120 located 1.967 m from the centre of the canister in deposition hole 3 just before the power to the canisters was switched off. Although the power was switched on again the temperature around the deposition hole is continuing to drop. This is most obvious for the sensors installed in the direction towards deposition hole 2. The maximum temperature measured temperature at the end of this measuring period is about 30°C. The temperature drop about 10°C during this measuring period caused by reduction of power (day 4,264) in the canister in hole 3.

5.7.4 Near hole 4 (App. 3\page 81)

The maximum temperature in the rock (46.5°C) is measured by TROA3030 located 2.034 m from the centre of the canister in deposition hole 4. Also for this deposition hole there was a drop in the temperature in the rock when the power was switched off. After the power was switched on again the temperature in the rock increased to almost the same level as before the power was switched off and has been remained relatively constant until this measuring period (day 4,264) after reduction of power in the canister in hole 3. The maximum temperature in the rock at the end of this measuring period is about 40°C.

5.8 Analyze of data from Section 1

5.8.1 Deposition hole 1

Before the drainage of the tunnel was closed and the power of the canister was switched off the saturation of the buffer at mid height of the canister in block R5 was considered (indicated both by the relative humidity sensors and total pressure sensors) to be high even close to the canister (PBU10015). Also installed pore pressure sensors placed in block R5 (e.g. UBU 10007) are measuring high pressures close to the canister which also is indicating that the bentonite is saturated. This was not changed when the drainage was opened and the power of the canister was switched on again. The degree of saturation in the solid blocks both under (Block C1) and above the canister (Blocks C2–C4) is much lower. However the degree of saturation interpretable from measurements of relative humidity, swelling pressure and pore pressure is increasing with time. This trend is continuing with the same rate after the drainage was opened and the power was switched on.

In Figure 5-2 the temperature in the buffer is plotted as function of the radius from the centre of the deposition hole. The measurements are made with different type of sensors in block R5 (at mid height of the canister). A straight line is fitted to the measured values. The temperature gradient is determined from the fitted line in the figure. This gradient together with the temperature on the canister surface and the temperature in the buffer close to the outer radius of the ring shaped block (r = 785 mm) are plotted as function of time in Figure 5-4. The shaded part of the plot represents the time when the power to the canister was switched off at the beginning of December 2004. The plot shows that the temperature after this is somewhat lower than before, probably due to the fact that no power is applied to canister 2 after December 2 2004. However the temperature gradient over the buffer is similar before and after the switch on/off the power of the canisters. The determination of the gradient was made up to the beginning of December 2005. After that the number of still working sensors are too few, to be able to determine the temperature gradient.

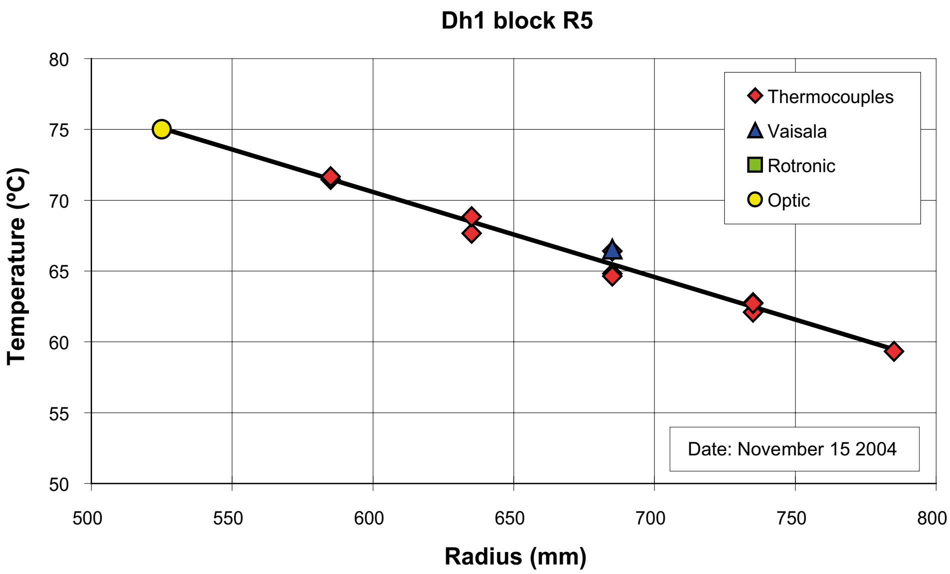


Figure 5-2. *The temperature in block R5 in Dh 1 as function of radius from the centre of the deposition hole on November 15, 2004.*

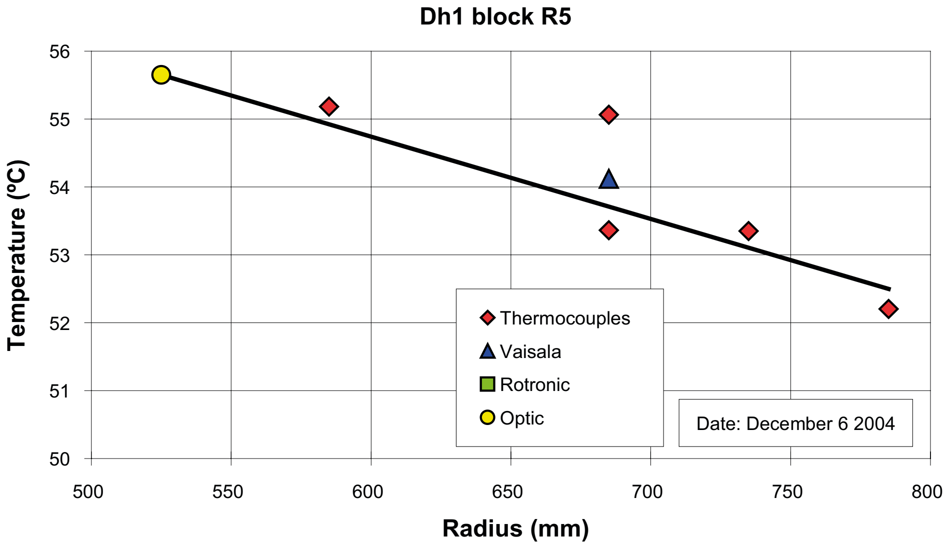


Figure 5-3. *The temperature in block R5 in Dh 1 as function of radius from the centre of the deposition hole on December 6, 2004.*

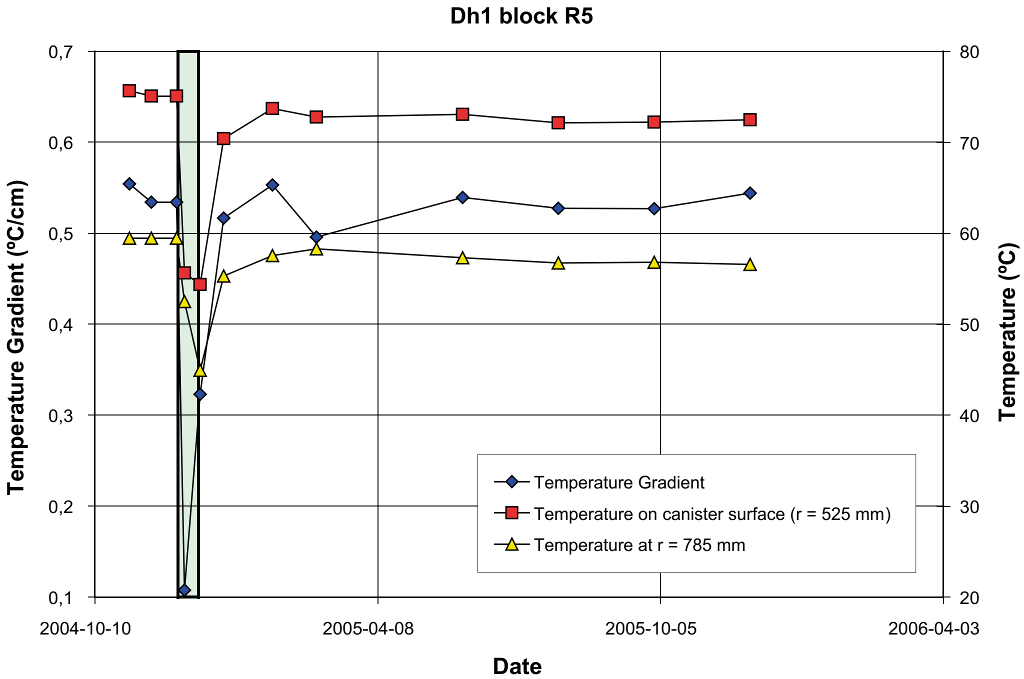


Figure 5-4. *The temperature and temperature gradient plotted as function the date in deposition hole 1 block R5.*

5.8.2 Deposition hole 3

The saturation of the buffer, as an average, indicated by both RH-transducers and total pressure transducers was before the closing of the drainage much lower compared to the buffer in deposition hole 1, although some total pressure sensors placed above and under the canister indicated rather high total pressures. When the drainage was closed those total pressure sensors which before had indicated high total pressure reacted with a rapid increase in pressure while the rest of the transducers did not react at all. When the drainage was opened again and the power to the canisters was switched off there was a decrease in the pressure. For most of the transducers the pressure went down to the same level as before the closing of the drainage. One RH sensor placed in block R5 at a radius of 785 mm reacted with a significant increase in RH (from 70% to 82%) when the drainage was closed. The RH was maintained on the higher level even after the opening of the drainage. Also some transducers placed in the buffer but close the canister top reacted with an increase in RH of about 5%. These transducers had before the closing of the drainage indicated a drying of the buffer. The rest of the RH transducers reacted very little at the closing/opening of the drainage. The buffer is today far from saturated (indicated both by RH-sensors, total pressure sensors and pore pressure sensors).

In Figure 5-5 the temperature in deposition hole 3 is plotted as function of the radial distance from the centre of the deposition hole. Compared with the corresponding plot for deposition hole 1 this plot shows a significant drop in temperature between the surface of the canister and the buffer (inner diameter of the ring). This indicates that the initial slot (of about 10 mm) between the canister and the buffer was still open.

The temperature gradient over the inner slot together with the temperature on the canister and the temperature on the inner radius of the ring shaped block are plotted as function of time in Figure 5-6. The shaded part of the plot represents the time when the power to canisters was switched off. Immediately after the power was switched off the temperature gradient increased which indicate that the slot was isolating the canister resulting in a much faster drop in temperature of the buffer than the canister surface. When the power was switched on again the temperature gradient over the slot reached the same level as before the closing of the drainage indicating an open slot between the canister and the buffer. The figure also shows that the gradient is decreasing with time which might be an indication that the gap is getting smaller. The sensors for measuring the temperature on the canister surface stopped functioning of August 2005. The temperature gradient over the inner slot could not be calculated after that date.

The temperature gradient over the buffer is plotted in Figure 5-7 together with the temperature on the inner surface of the block and the temperature at the radius of r = 785 mm. After the power was switched on again also this gradient stabilized on the same level as before the power was switched off.

A conclusion of the analyses is that even though the pressure in the backfill and in the surrounding rock was high (more than 2 MPa) when the drainage was closed, water did not enter the inner slot between the buffer and the canister. The fact that no water pressure acted directly on the canister surface can also explain the large vertical displacement of the canister measured when the drainage was closed (see Figure 5-8). If the increased pore pressure (2.5 MPa) would act directly on the canister surface the deformation should be much smaller than what was measured. The measured deformation was probably caused by large deformations of the solid bentonite block below the canister.

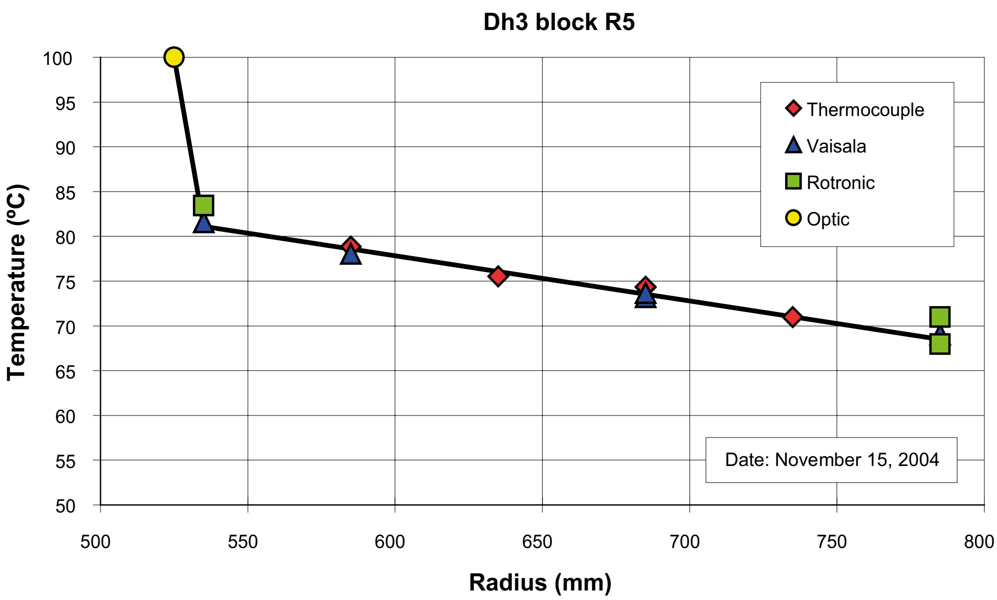


Figure 5-5. *The temperature in block R5 in Dh 3 as function of radius from the centre of the deposition hole on November 15, 2004.*

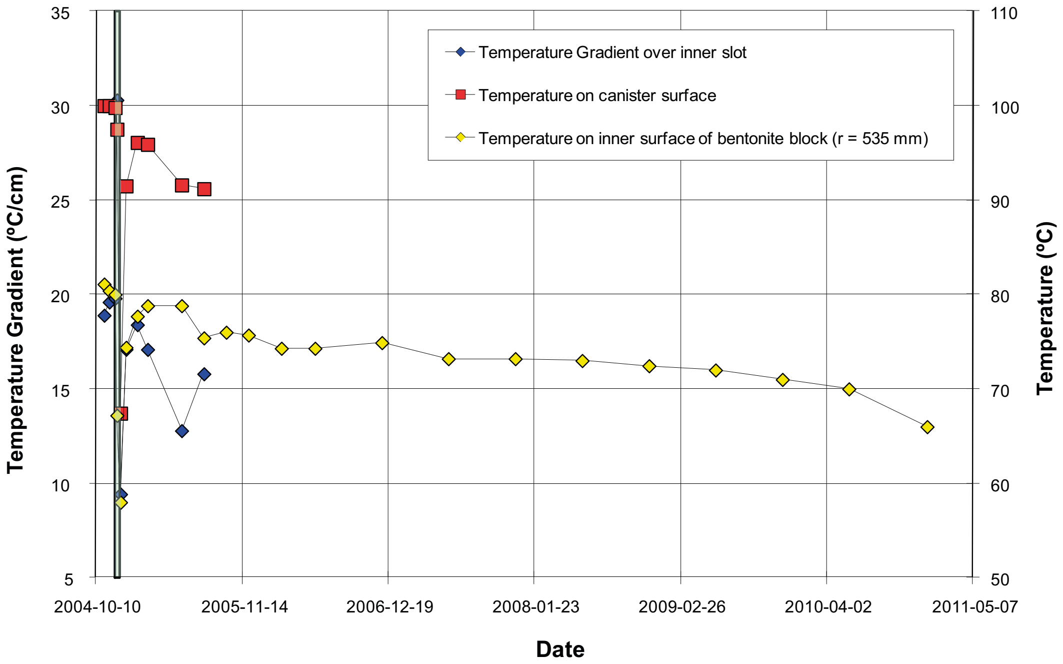


Figure 5-6. *The temperature and temperature gradient over the inner slot plotted as function the date in deposition hole 3 block R5.*

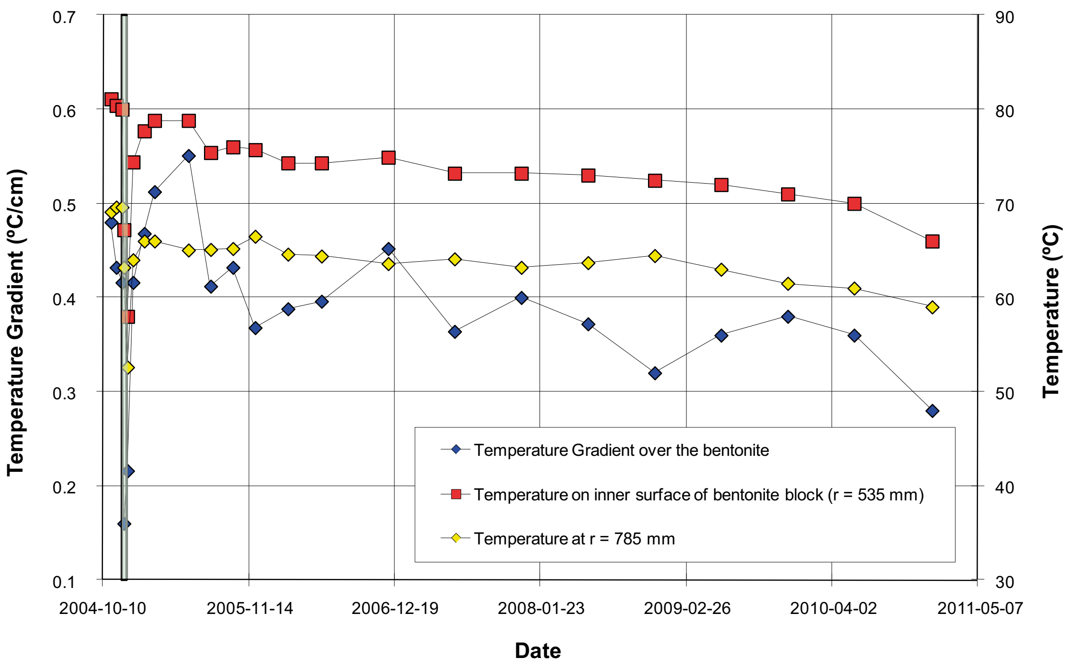


Figure 5-7. *The temperature and temperature gradient over the buffer plotted as function the date in deposition hole 3 block R5.*

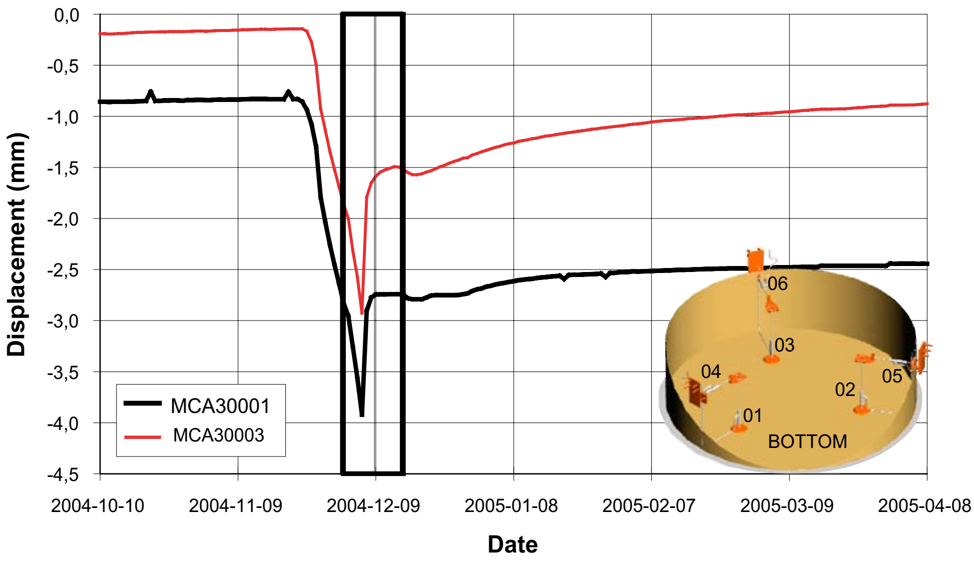


Figure 5-8. *Vertical displacement of the canister in Dh 3. Negative sign on the displacement means that the canister is moving downwards.*

5.8.3 Backfill

The pore pressure in the backfill increased fast from a low level when the drainage of the tunnel was closed. This affected the rate in which the backfill was saturated measured both with soil psychrometers and with resistivity measurements made by GRS. After the drainage was reopened the pore pressure stabilized on the same level as before it was close. The saturation rate (measured with both psychrometers and resistivity measurements) decreased to the same rate as before the closing of the drainage for most of the sensors.

When a packer placed in a borehole in Section I was broken (at the middle of April 2006) the pressure in the backfill (both total pressure and pore pressure) increased with about 300 kPa.

An increase of the total pressure and the pore pressure can also be observed around day 2,040 (corresponding to the date 2007-04-19). The increase in pressure is probably related to the work with the excavation of a new tunnel nearby the Prototype-tunnel which was initialized at that time. The pore pressure and total pressure are continuing to increase and the total pressure has at the end of this measuring period reach a maximum of about 900 kPa.

The change in pressure affected also the measured suction values (measured with soil psychcrometers). Eight of the sensors measured a decrease in suction of about 500 kPa due to the broken packer. All of the installed sensors have stopped giving reliable values after most of them have reached a suction value less than 1,000 kPa which is indicating that the backfill is saturated.

The outflow from the inner section of the Prototype tunnel as function of time is shown in Figure 5-9. The figure is showing that the outflow from Section I increased from about 1.8 l/min to about 9 l/min when the installed packer was broken. The large scatter and the increase in the outflow starting at the beginning of summer 2007 are probably caused by the work with the new tunnel placed close to the Prototype tunnel.

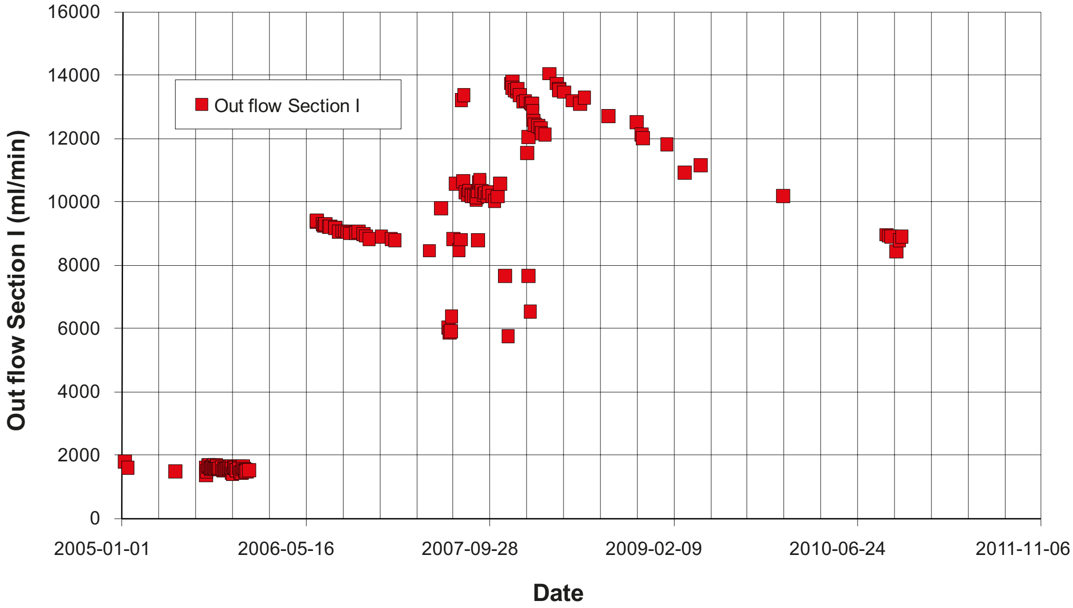


***Figure 5-9.** The measured outflow from the inner section of the Prototype tunnel.*

References

SKB's (Svensk Kärnbränslehantering AB) publications can be found at www.skb.se/publications.

Börgesson L, Sandén T, 2001. Äspö Hard Rock Laboratory. Prototype Repository. Report on instrument positions in buffer/backfill and preparation of bentonite blocks for instruments and cables in section I. SKB IPR-01-20, Svensk Kärnbränslehantering AB.

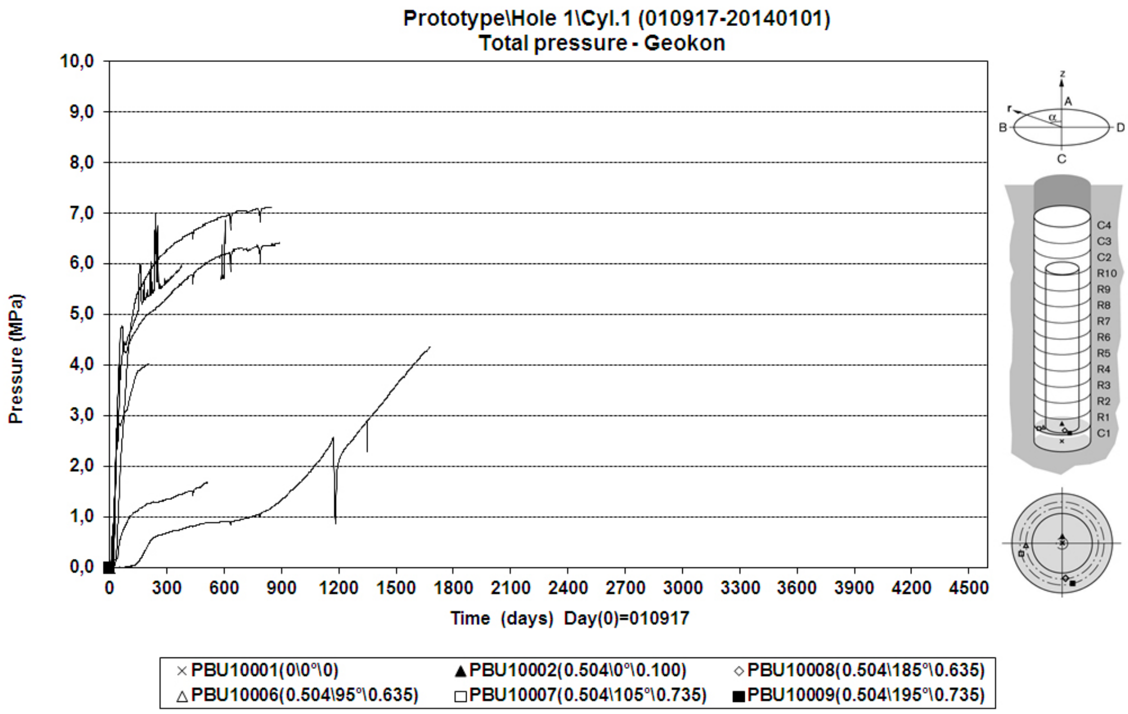
Goudarzi R, 2014. Prototype Repository – Sensor data report (Period 010917–130101). Report No 25. SKB P-13-39, Svensk Kärnbränslehantering AB.

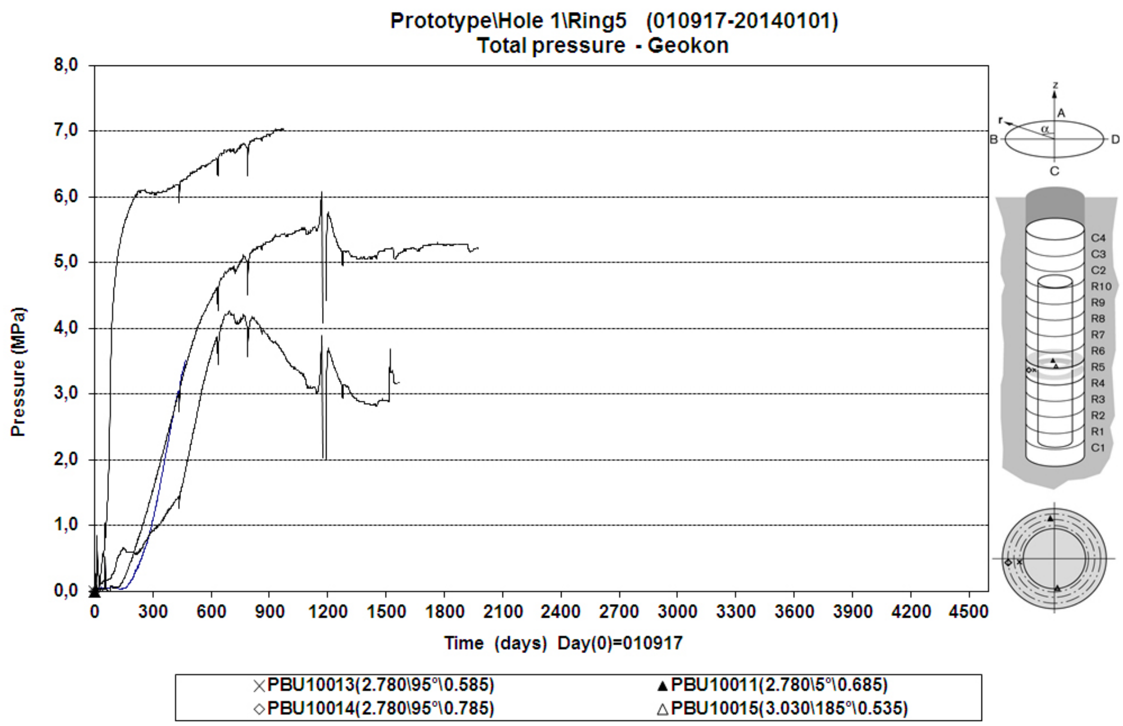
Forsmark T, Rhén I, Andersson C, 2001. Äspö Hard Rock Laboratory. Prototype Repository. Hydrogeology – Injection test campaign 2, Flow measurement of DA3575G01, groundwater salinity, ground water leakage into G-, I- and J-tunnels. SKB IPR-01-31, Svensk Kärnbränslehantering AB.

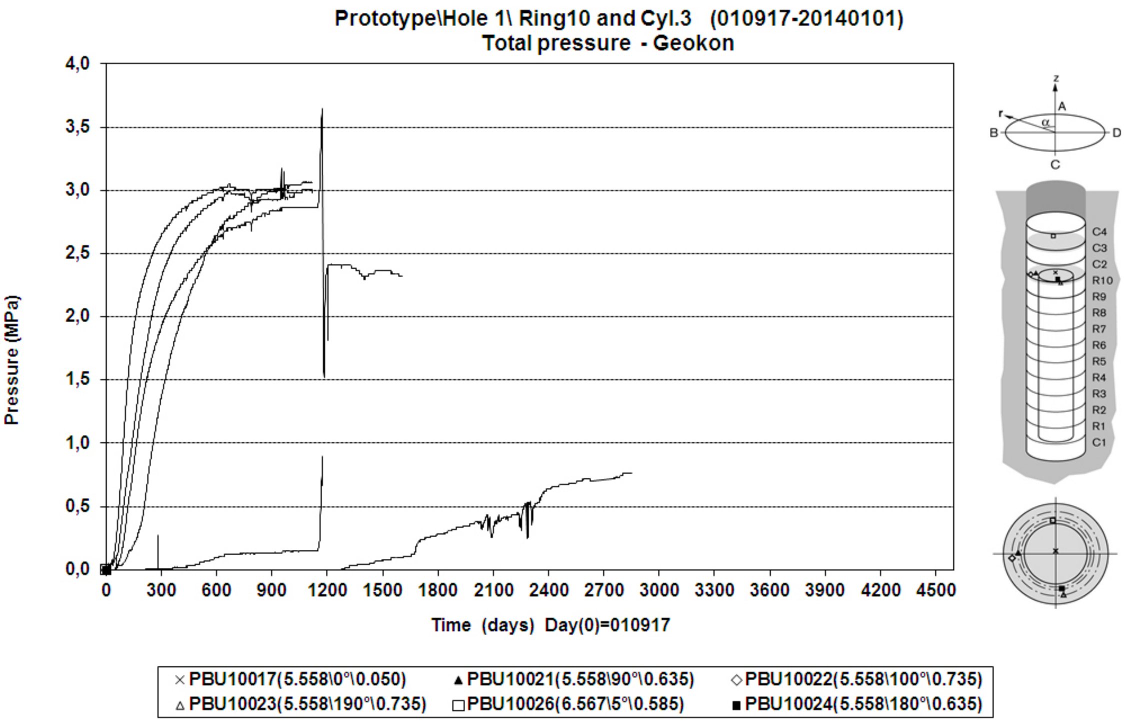
Rhén I, Forsmark T, 2001. Äspö Hard Rock Laboratory. Prototype Repository. Hydrogeology. Summary report of investigations before the operation phase. SKB IPR-01-65, Svensk Kärnbränslehantering AB.

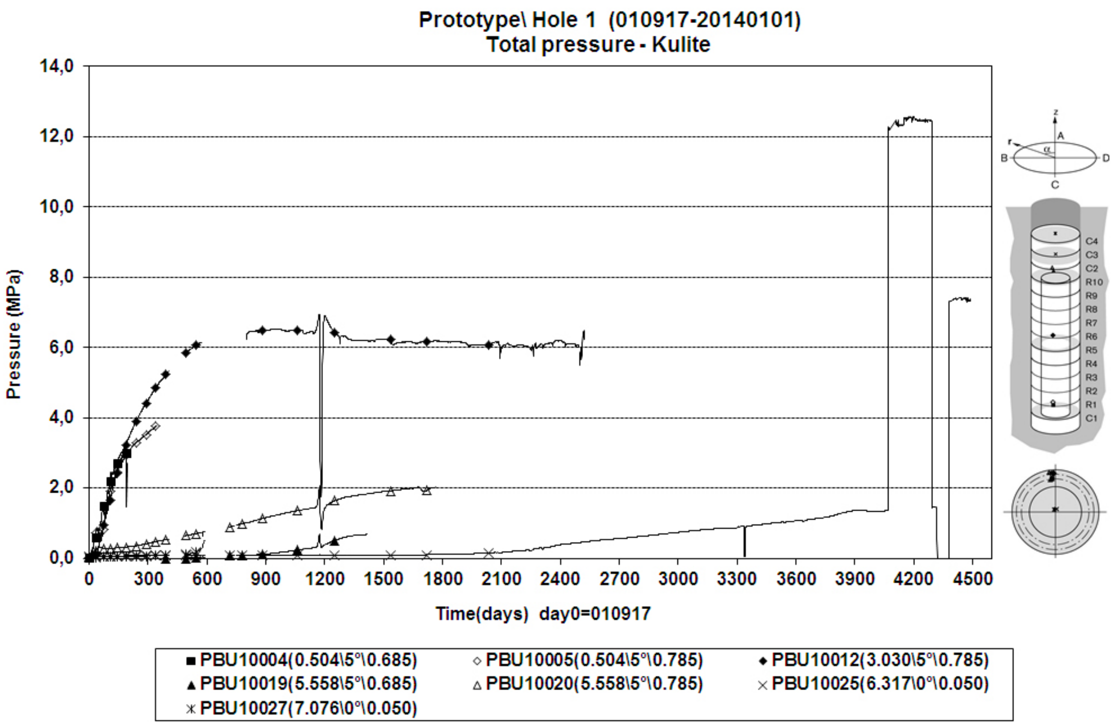
Rhén I, Forsmark T, Torin L, Puigdomenech I, 2001. Äspö Hard Rock Laboratory. Prototype Repository. Hydrogeological, hydro-chemical and temperature measurements in boreholes during the operation phase of the Prototype Repository. Tunnel section I. SKB IPR-01-32, Svensk Kärnbränslehantering AB.

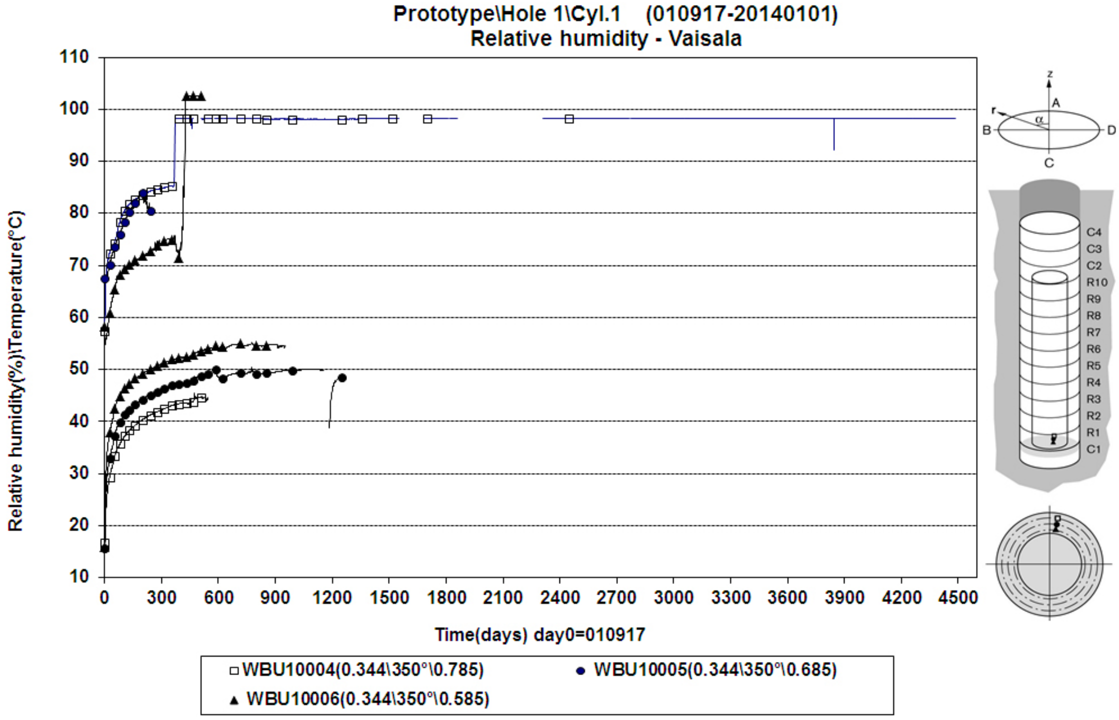
Dep. hole 1

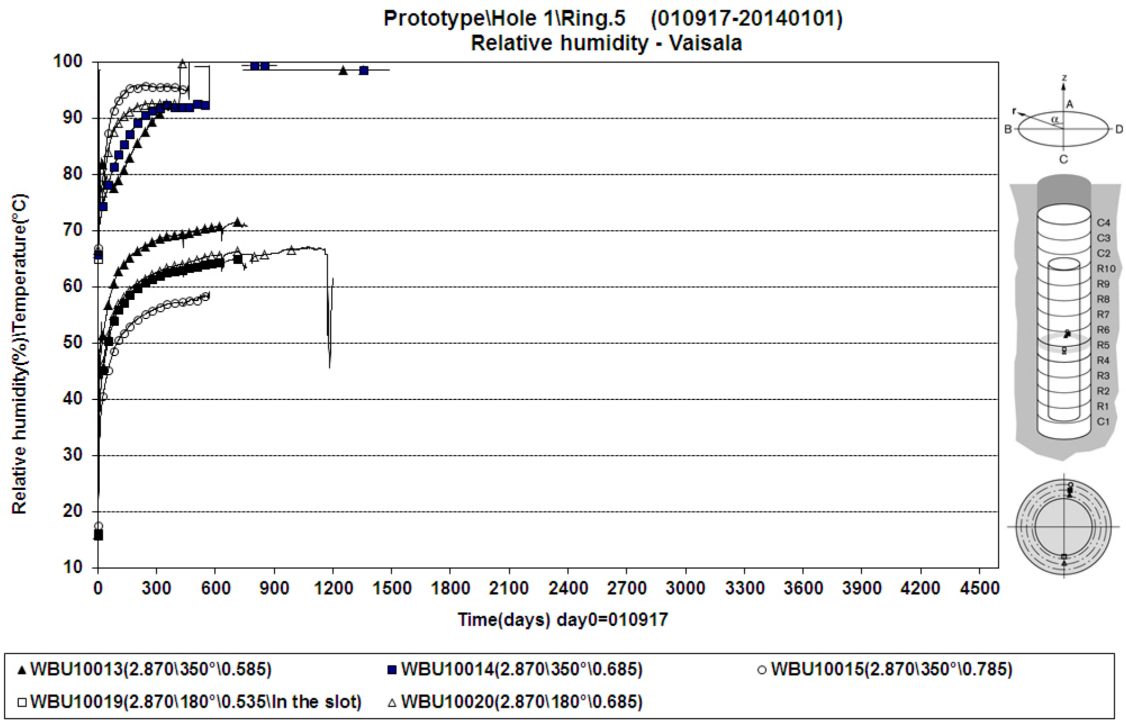

Prototype\Hole 1\Cyl.1 (010917-20140101)
Total pressure - Geokon
Pressure (MPa)
Time (days) Day(0)=010917
× PBU10001(0\0°\0)
▲PBU10002(0.504\0°\0.100)
◇PBU10008(0.504\185°\0.635)
△PBU10006(0.504\95°\0.635)
□PBU10007(0.504\105°\0.735)
■PBU10009(0.504\195°\0.735)

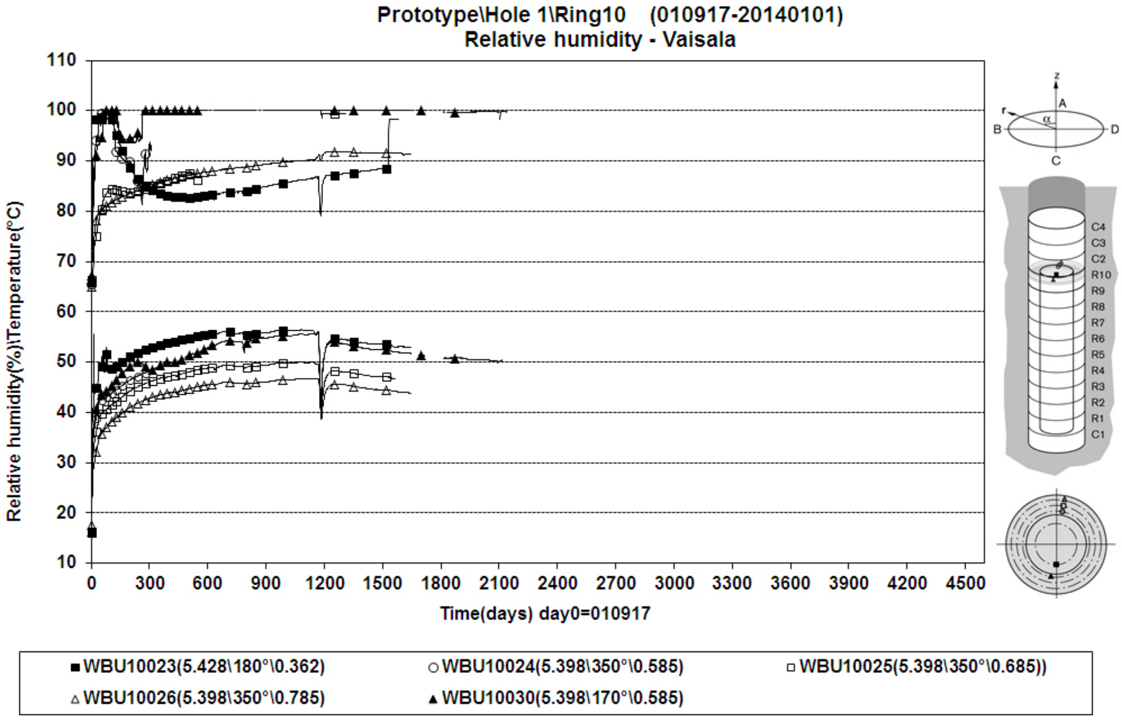

Prototype\Hole 1\Ring5 (010917-20140101)
Total pressure - Geokon
Pressure (MPa)
Time (days) Day(0)=010917
×PBU10013(2.780\95°\0.585)
▲PBU10011(2.780\5°\0.685)
◇PBU10014(2.780\95°\0.785)
△PBU10015(3.030\185°\0.535)


Prototype\Hole 1\ Ring10 and Cyl.3 (010917-20140101)
Total pressure - Geokon
Pressure (MPa)
Time (days) Day(0)=010917
PBU10017(5.558\0°\0.050)
PBU10021(5.558\90°\0.635)
PBU10022(5.558\100°\0.735)
PBU10023(5.558\190°\0.735)
PBU10026(6.567\5°\0.585)
PBU10024(5.558\180°\0.635)

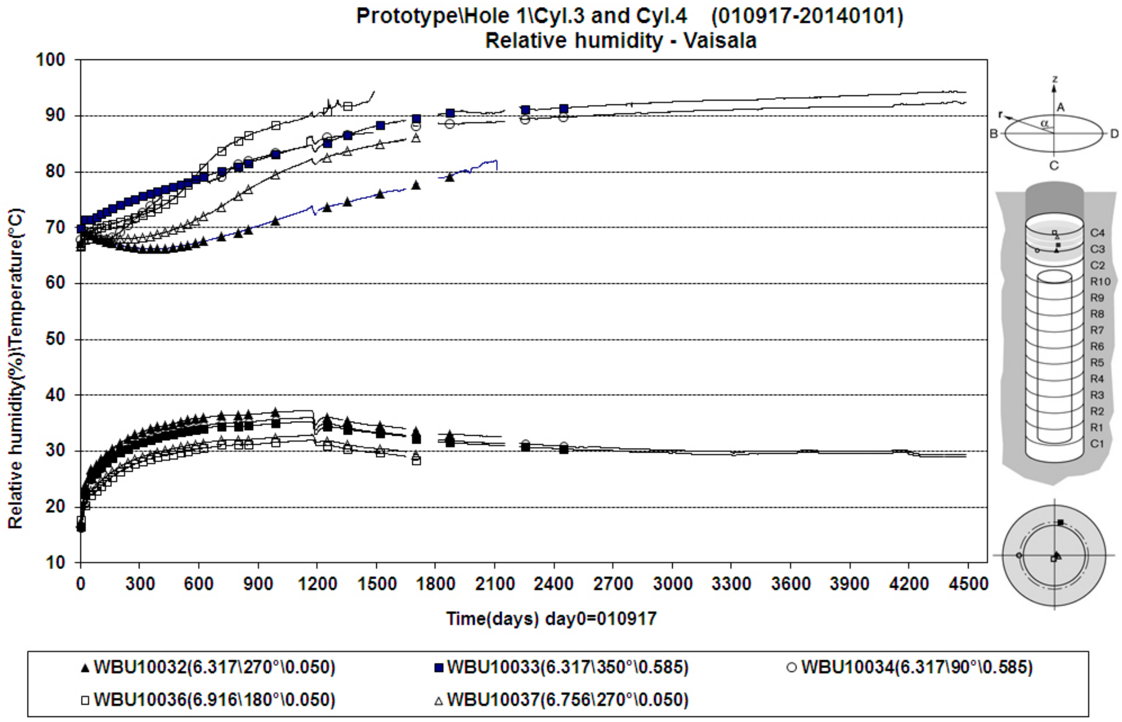

Prototype\ Hole 1 (010917-20140101)
Total pressure - Kulite
Pressure (MPa)
Time(days) day0=010917
PBU10004(0.504\5°\0.685)
PBU10005(0.504\5°\0.785)
PBU10012(3.030\5°\0.785)
PBU10019(5.558\5°\0.685)
PBU10020(5.558\5°\0.785)
PBU10025(6.317\0°\0.050)
PBU10027(7.076\0°\0.050)


Prototype\Hole 1\Cyl.1 (010917-20140101)
Relative humidity - Vaisala
Relative humidity(%)\Temperature(°C)
Time(days) day0=010917
WBU10004(0.344\350°\0.785)
WBU10005(0.344\350°\0.685)
WBU10006(0.344\350°\0.585)

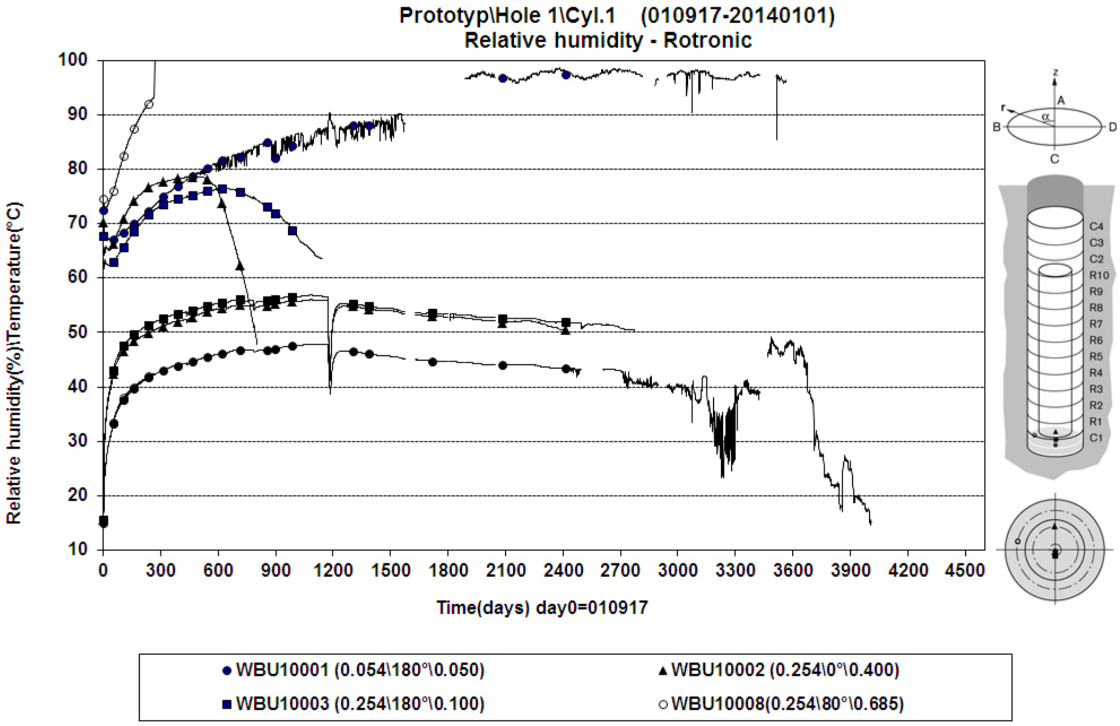

Prototype\Hole 1\Ring.5 (010917-20140101)
Relative humidity - Vaisala
Relative humidity(%)\Temperature(°C)
Time(days) day0=010917
WBU10013(2.870\350°\0.585)
WBU10014(2.870\350°\0.685)
WBU10015(2.870\350°\0.785)
WBU10019(2.870\180°\0.535\In the slot)
WBU10020(2.870\180°\0.685)

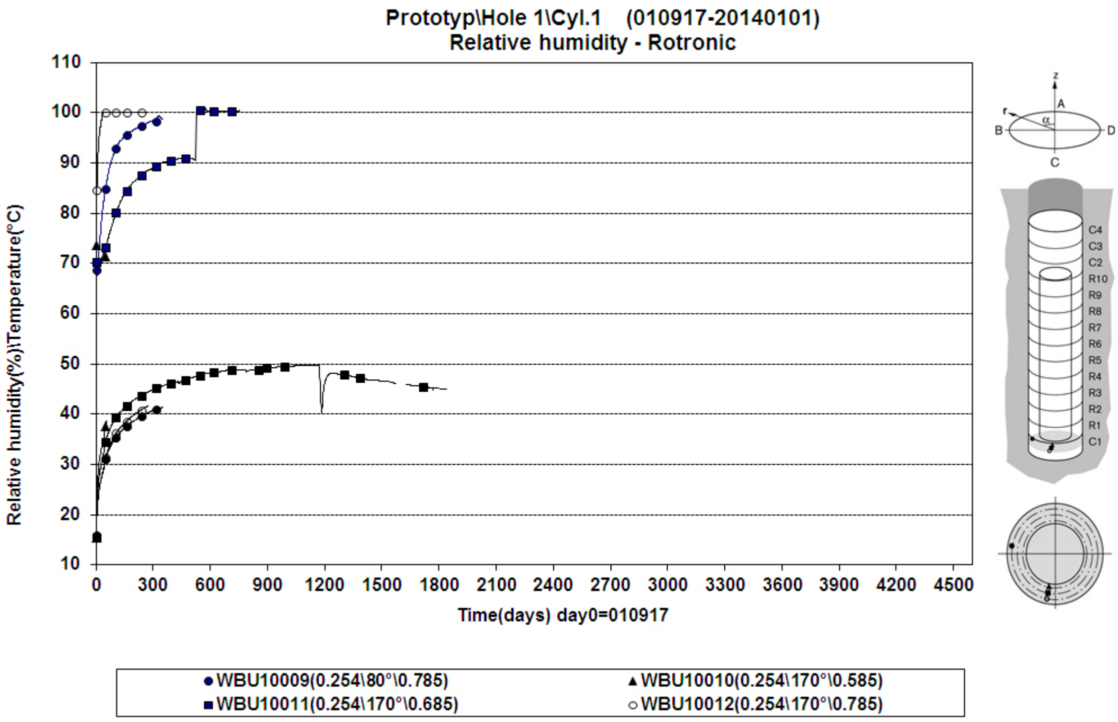


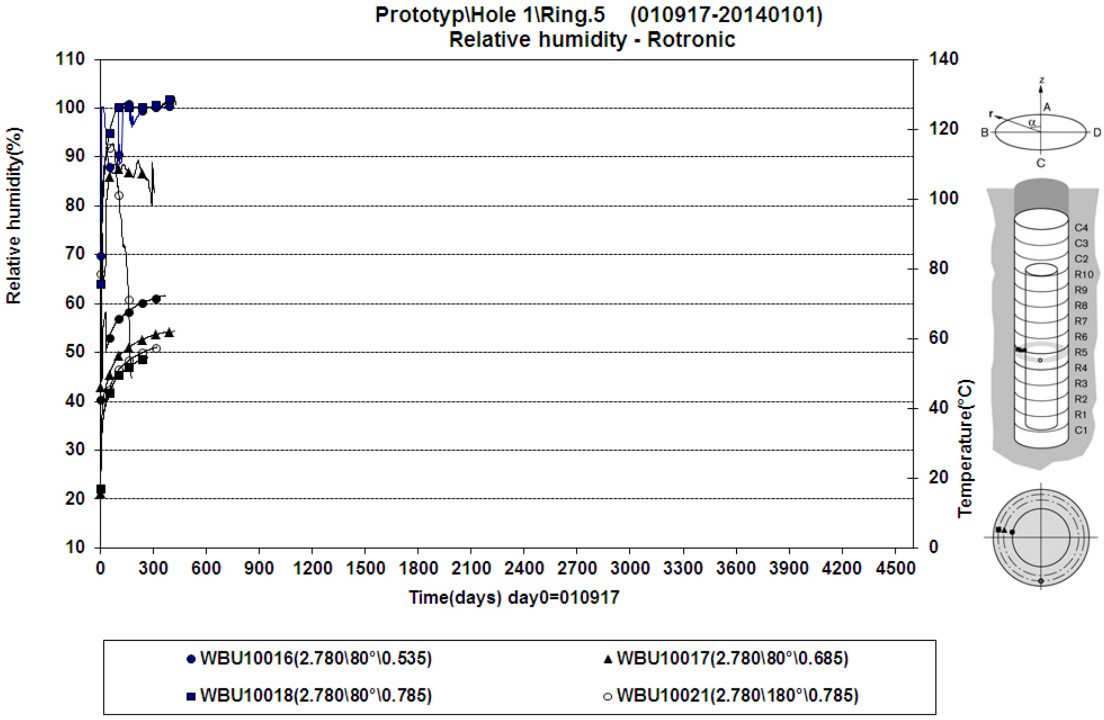
Prototype\Hole 1\Ring10 (010917-20140101)
Relative humidity - Vaisala
Relative humidity(%)\Temperature(°C)
Time(days) day0=010917
■ WBU10023(5.428\180°\0.362)
○ WBU10024(5.398\350°\0.585)
□ WBU10025(5.398\350°\0.685))
△ WBU10026(5.398\350°\0.785)
▲ WBU10030(5.398\170°\0.585)

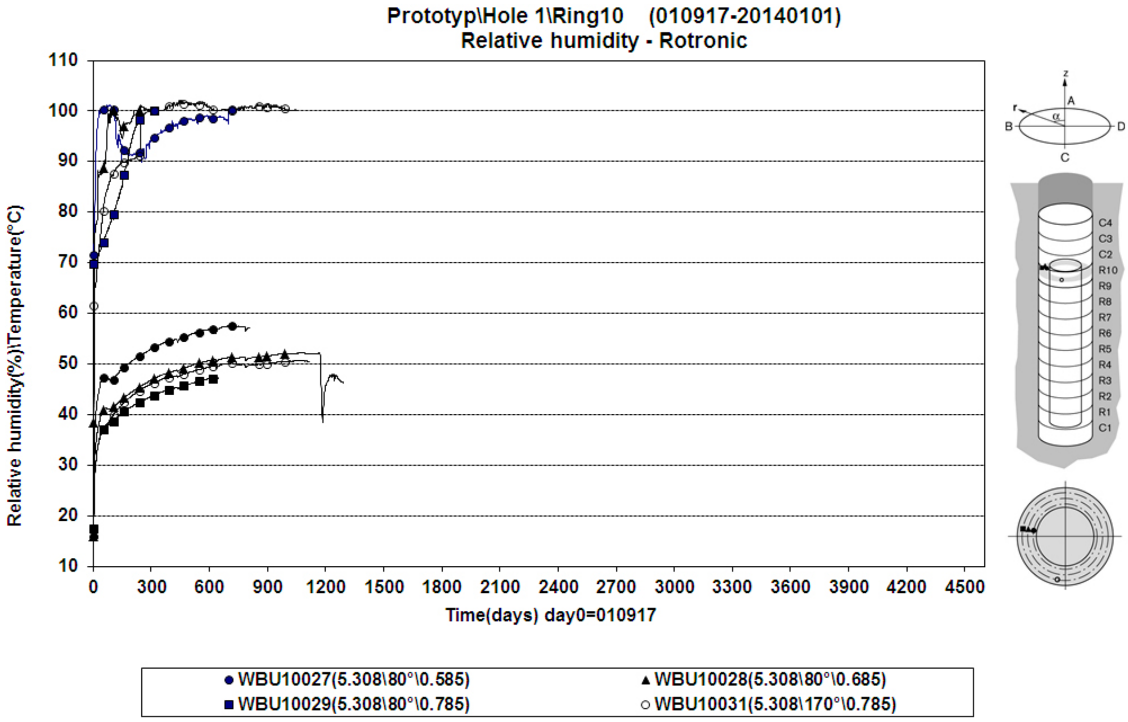


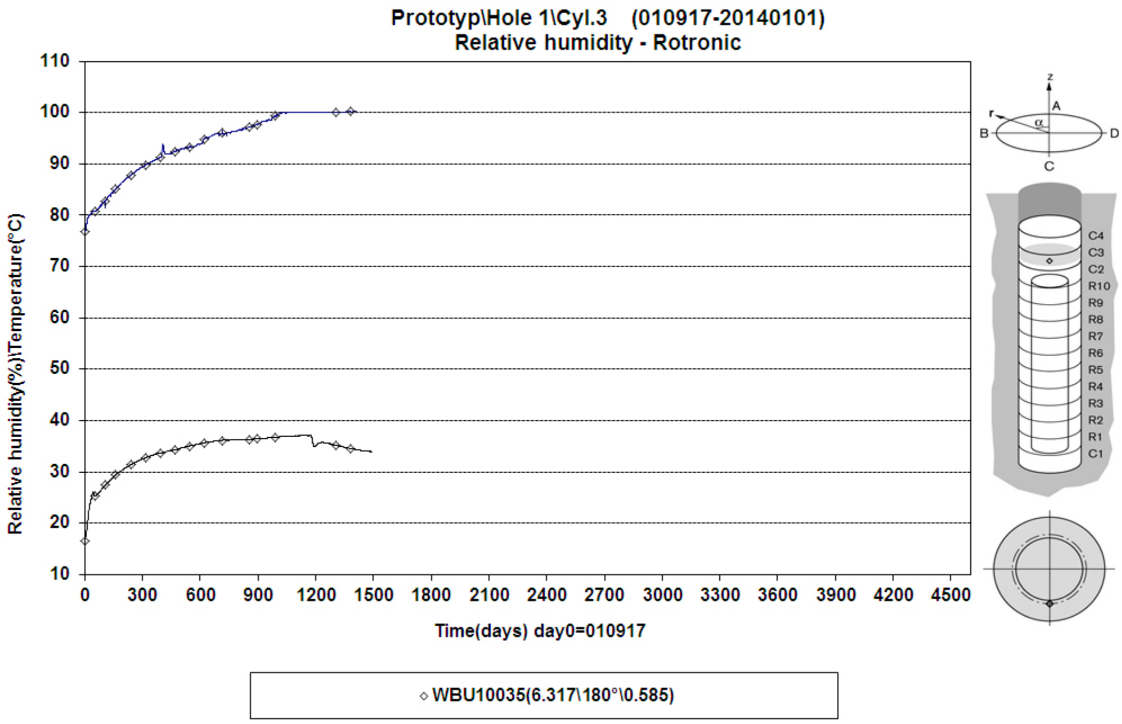
Prototype\Hole 1\Cyl.3 and Cyl.4 (010917-20140101)
Relative humidity - Vaisala
Relative humidity(%)\Temperature(°C)
Time(days) day0=010917
▲ WBU10032(6.317\270°\0.050)
■ WBU10033(6.317\350°\0.585)
○ WBU10034(6.317\90°\0.585)
□ WBU10036(6.916\180°\0.050)
△ WBU10037(6.756\270°\0.050)

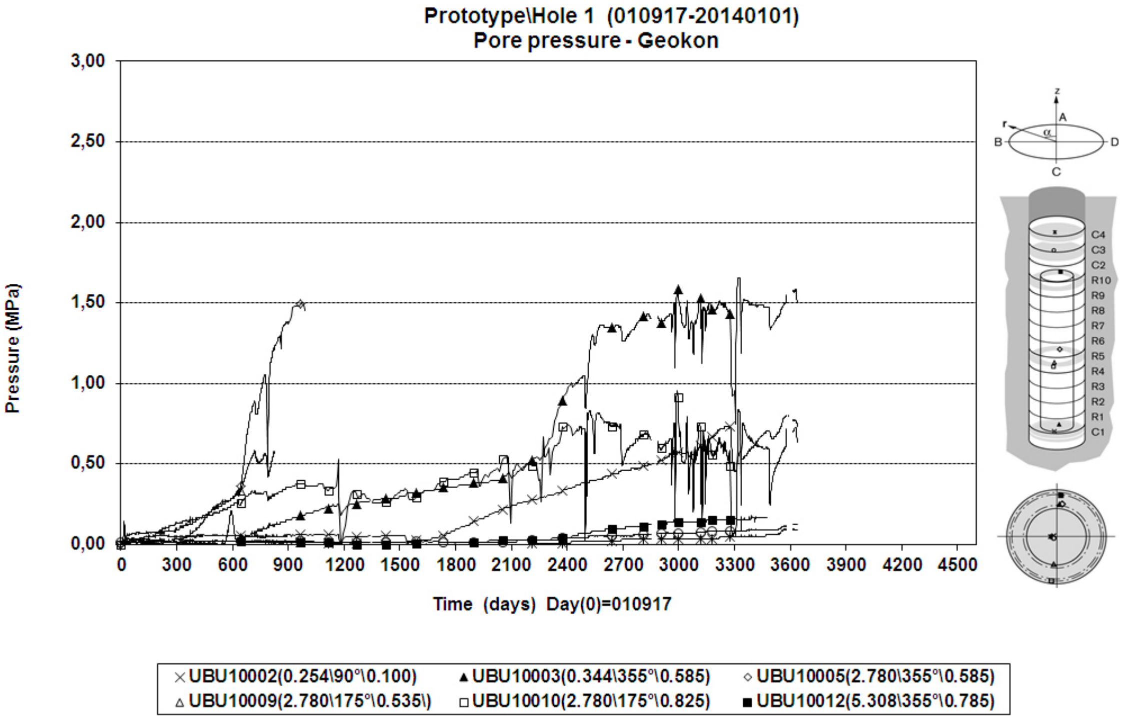

Prototyp\Hole 1\Cyl.1 (010917-20140101)
Relative humidity - Rotronic
Relative humidity(%)\Temperature(°C)
Time(days) day0=010917
WBU10001 (0.054\180°\0.050)
WBU10002 (0.254\0°\0.400)
WBU10003 (0.254\180°\0.100)
WBU10008(0.254\80°\0.685)

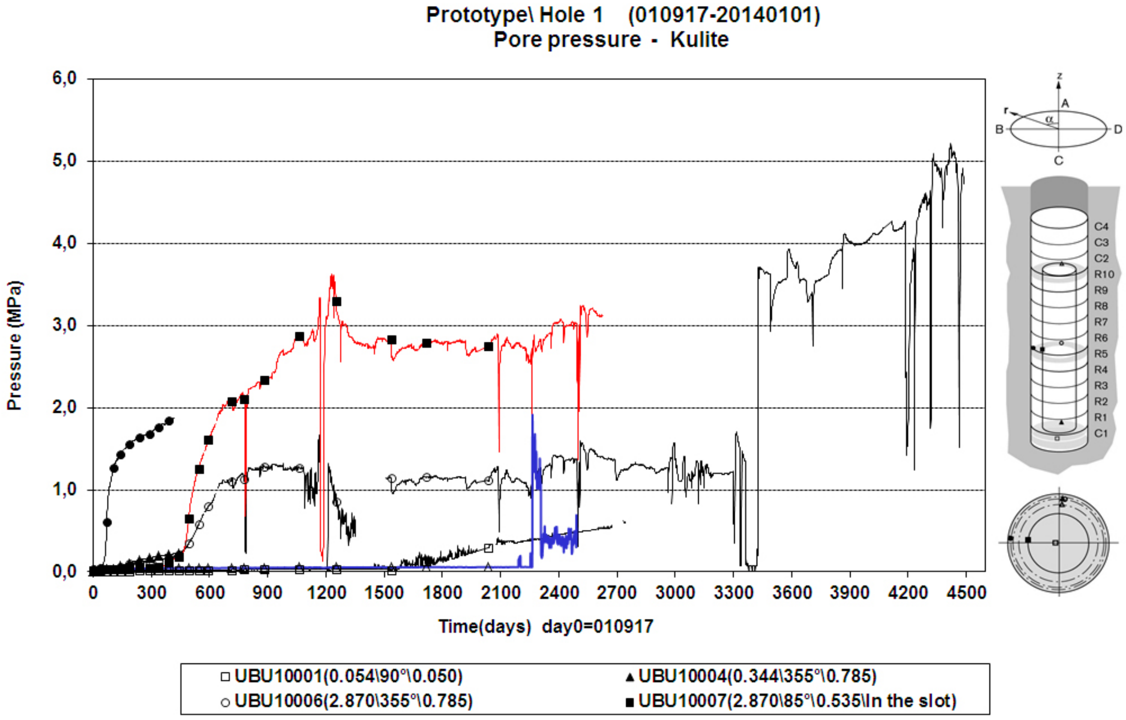

Prototyp\Hole 1\Cyl.1 (010917-20140101)
Relative humidity - Rotronic
Relative humidity(%)\Temperature(°C)
Time(days) day0=010917
WBU10009(0.254\80°\0.785)
WBU10010(0.254\170°\0.585)
WBU10011(0.254\170°\0.685)
WBU10012(0.254\170°\0.785)

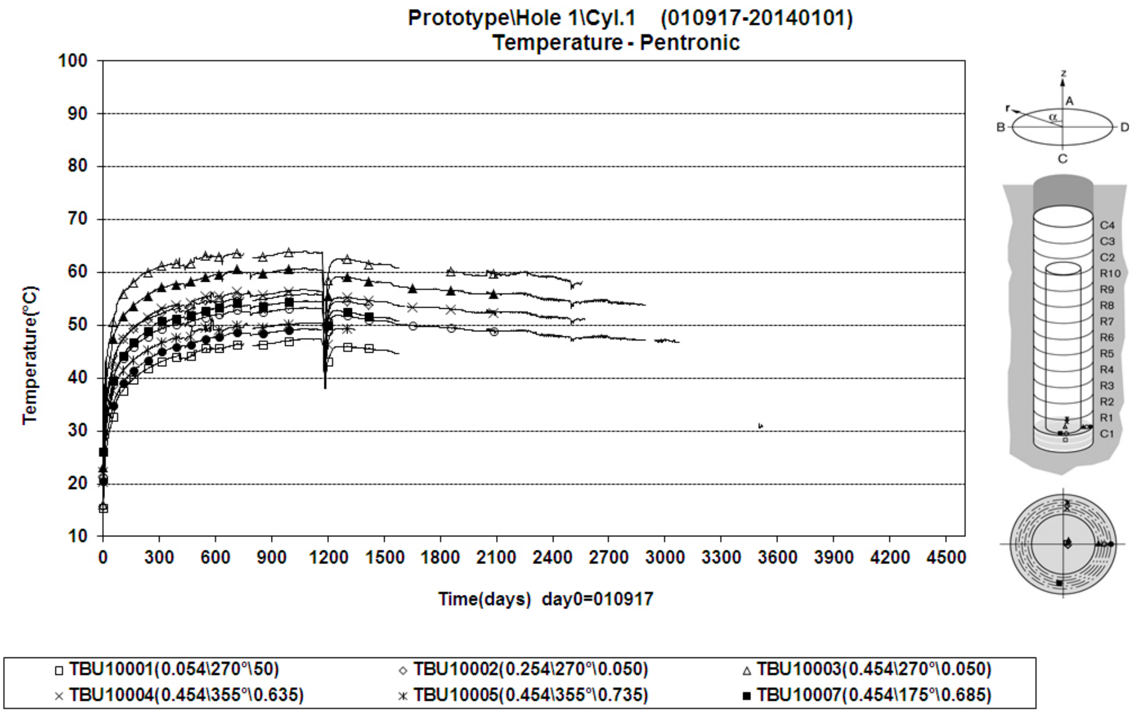

Prototyp\Hole 1\Ring.5 (010917-20140101)
Relative humidity - Rotronic
Relative humidity(%)
Temperature(°C)
Time(days) day0=010917
WBU10016(2.780\80°\0.535)
WBU10017(2.780\80°\0.685)
WBU10018(2.780\80°\0.785)
WBU10021(2.780\180°\0.785)

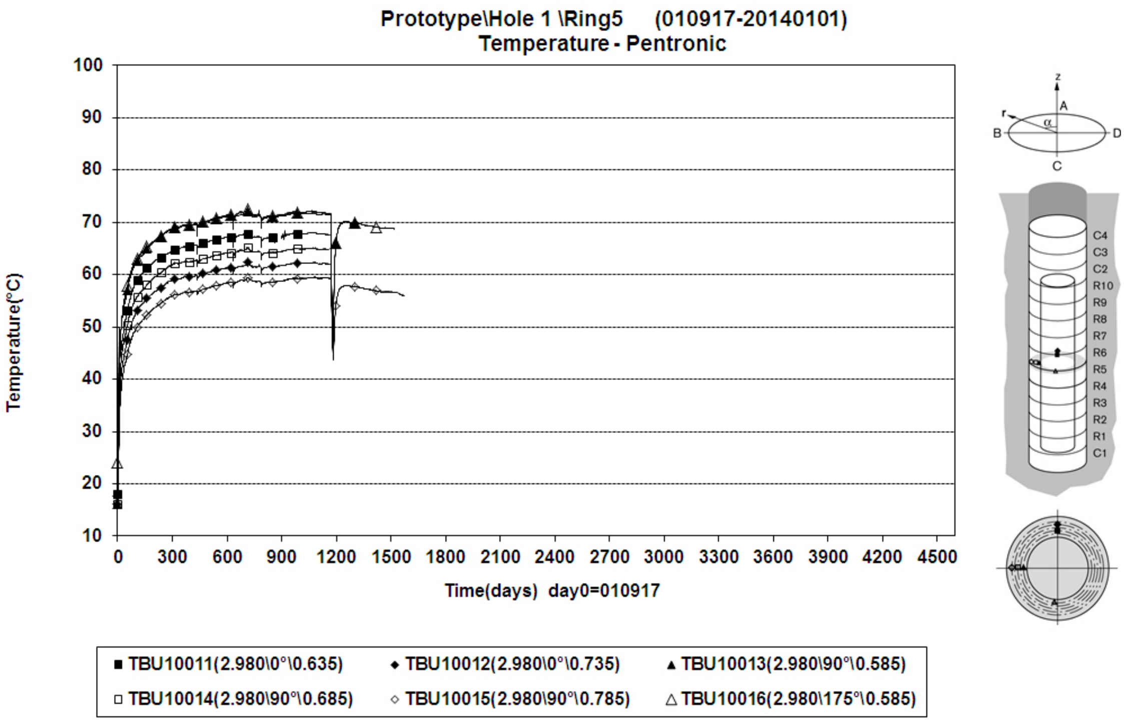

Prototyp\Hole 1\Ring10 (010917-20140101)
Relative humidity - Rotronic
Relative humidity(%)\Temperature(°C)
Time(days) day0=010917
WBU10027(5.308\80°\0.585)
WBU10028(5.308\80°\0.685)
WBU10029(5.308\80°\0.785)
WBU10031(5.308\170°\0.785)


Prototyp\Hole 1\Cyl.3 (010917-20140101)
Relative humidity - Rotronic
Relative humidity(%)\Temperature(°C)
Time(days) day0=010917
WBU10035(6.317\180°\0.585)

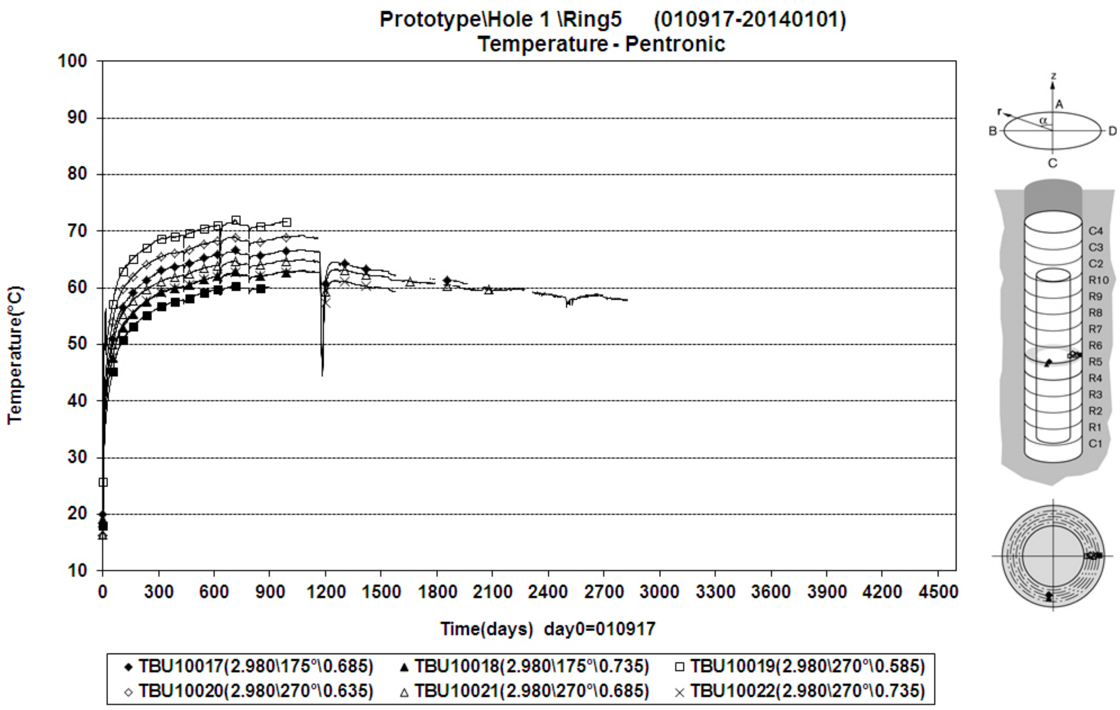

Prototype\Hole 1 (010917-20140101)
Pore pressure - Geokon
Pressure (MPa)
Time (days) Day(0)=010917
UBU10002(0.254\90°\0.100)
UBU10003(0.344\355°\0.585)
UBU10005(2.780\355°\0.585)
UBU10009(2.780\175°\0.535\)
UBU10010(2.780\175°\0.825)
UBU10012(5.308\355°\0.785)


Prototype\ Hole 1 (010917-20140101)
Pore pressure - Kulite
Pressure (MPa)
Time(days) day0=010917
UBU10001(0.054\90°\0.050)
UBU10004(0.344\355°\0.785)
UBU10006(2.870\355°\0.785)
UBU10007(2.870\85°\0.535\In the slot)

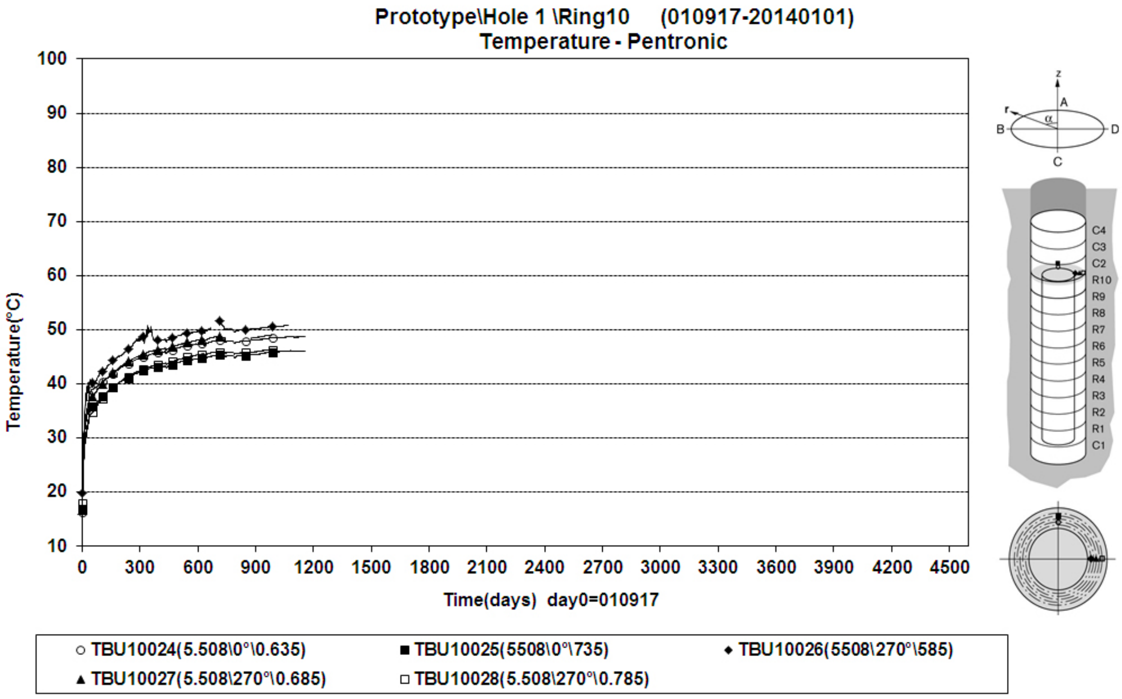

Prototype\Hole 1\Cyl.1 (010917-20140101)
Temperature - Pentronic
Temperature(°C)
Time(days) day0=010917
TBU10001(0.054\270°\50)
TBU10002(0.254\270°\0.050)
TBU10003(0.454\270°\0.050)
TBU10004(0.454\355°\0.635)
TBU10005(0.454\355°\0.735)
TBU10007(0.454\175°\0.685)

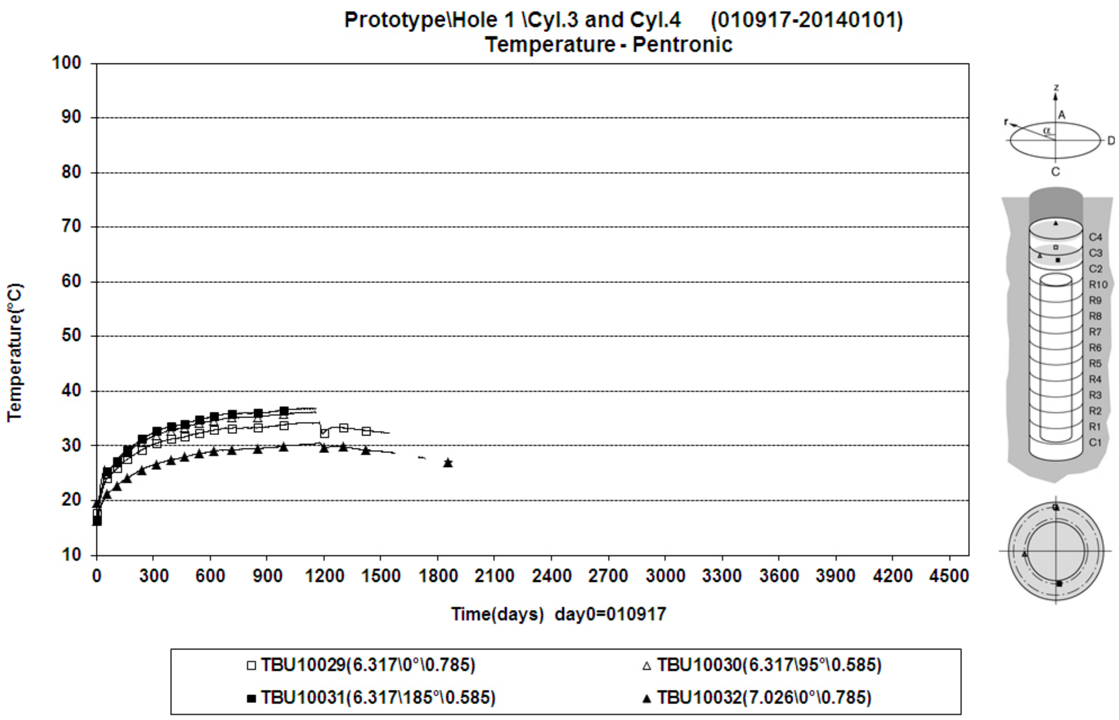


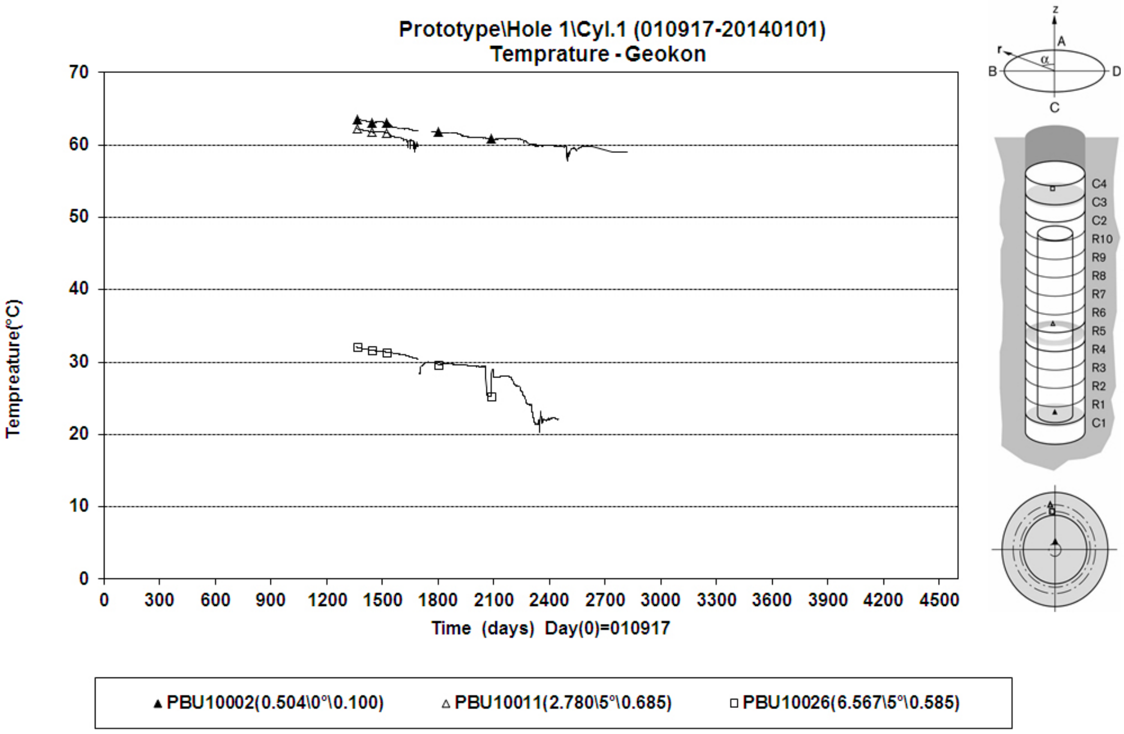
Prototype\Hole 1 \Ring5 (010917-20140101)
Temperature - Pentronic
Temperature(°C)
Time(days) day0=010917
TBU10011(2.980\0°\0.635)
TBU10012(2.980\0°\0.735)
TBU10013(2.980\90°\0.585)
TBU10014(2.980\90°\0.685)
TBU10015(2.980\90°\0.785)
TBU10016(2.980\175°\0.585)

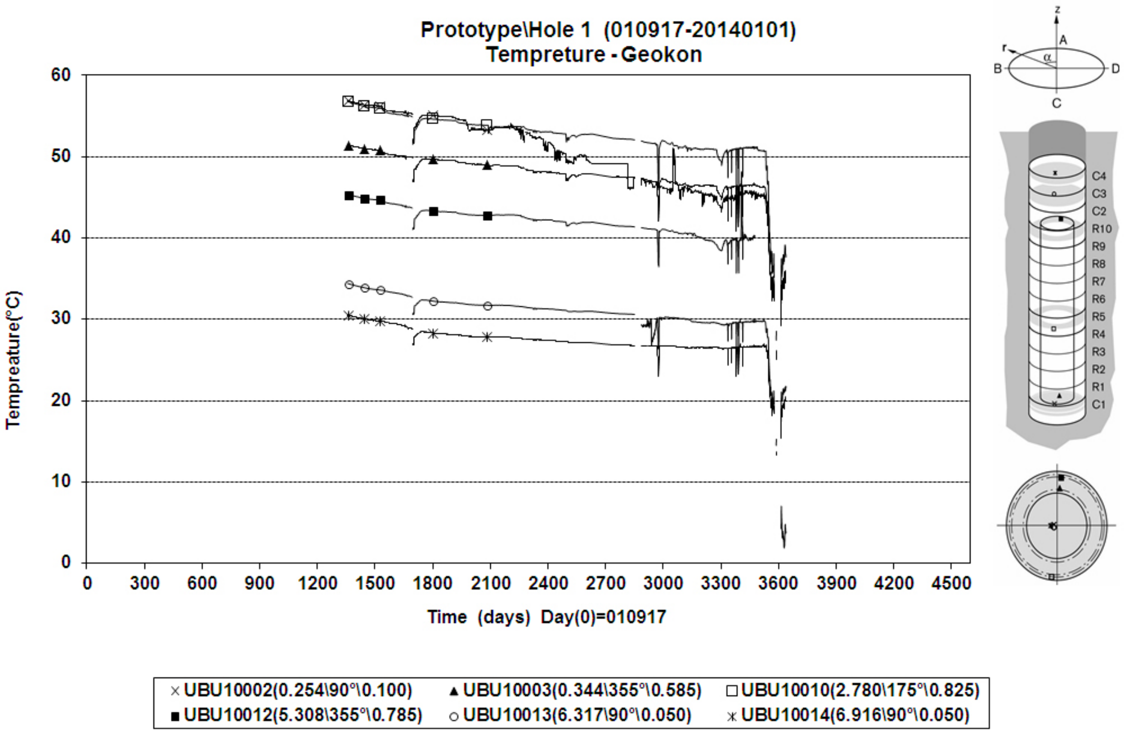


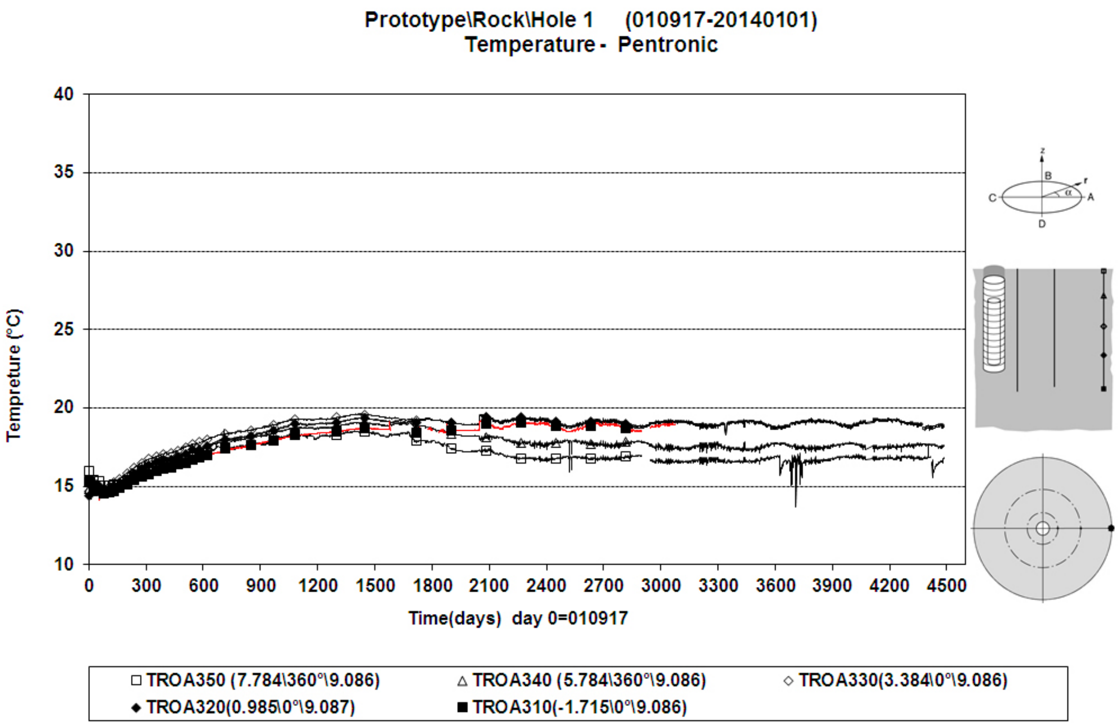
Prototype\Hole 1 \Ring5 (010917-20140101)
Temperature - Pentronic
Temperature(°C)
Time(days) day0=010917
TBU10017(2.980\175°\0.685)
TBU10018(2.980\175°\0.735)
TBU10019(2.980\270°\0.585)
TBU10020(2.980\270°\0.635)
TBU10021(2.980\270°\0.685)
TBU10022(2.980\270°\0.735)

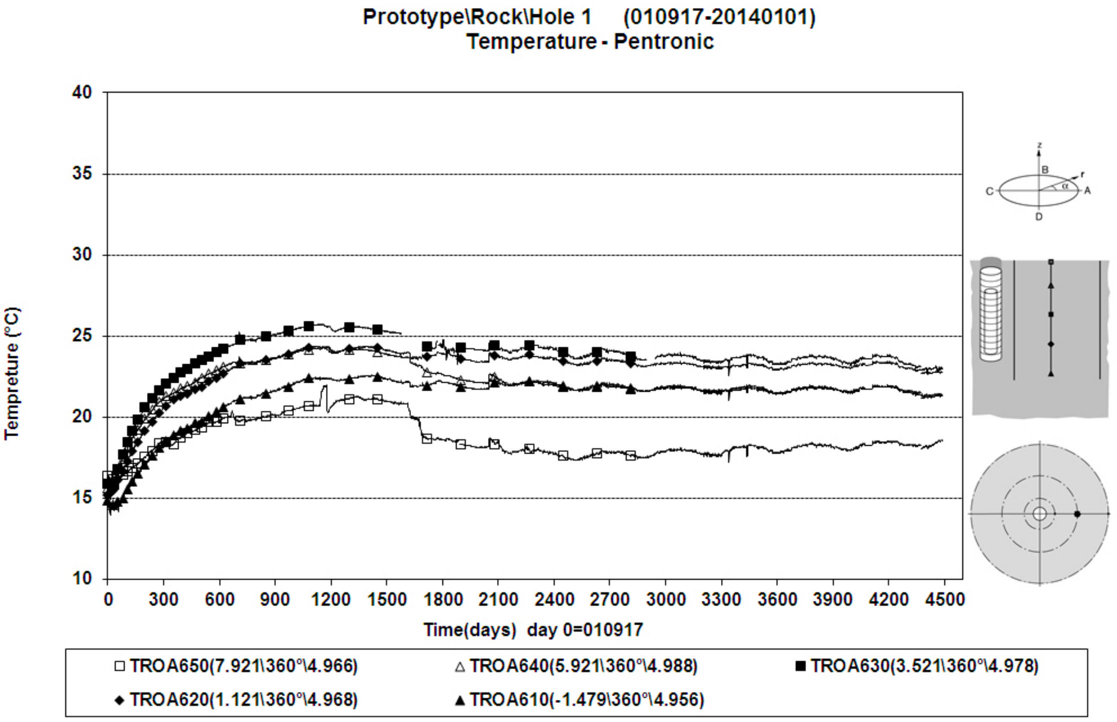

Prototype\Hole 1 \Ring10 (010917-20140101)
Temperature - Pentronic
Temperature(°C)
Time(days) day0=010917
○ TBU10024(5.508\0°\0.635)
■ TBU10025(5508\0°\735)
◆ TBU10026(5508\270°\585)
▲ TBU10027(5.508\270°\0.685)
□ TBU10028(5.508\270°\0.785)
C4
C3
C2
R10
R9
R8
R7
R6
R5
R4
R3
R2
R1
C1

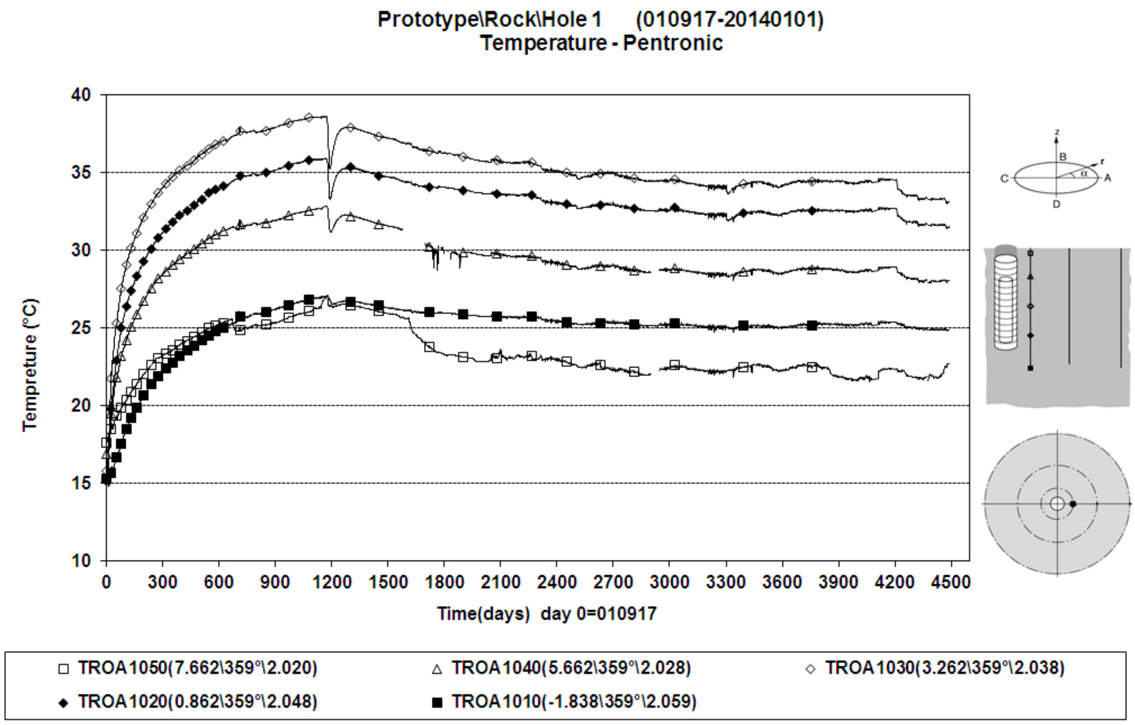

Prototype\Hole 1 \Cyl.3 and Cyl.4 (010917-20140101)
Temperature - Pentronic
Temperature(°C)
Time(days) day0=010917
□ TBU10029(6.317\0°\0.785)
△ TBU10030(6.317\95°\0.585)
■ TBU10031(6.317\185°\0.585)
▲ TBU10032(7.026\0°\0.785)
C4
C3
C2
R10
R9
R8
R7
R6
R5
R4
R3
R2
R1
C1

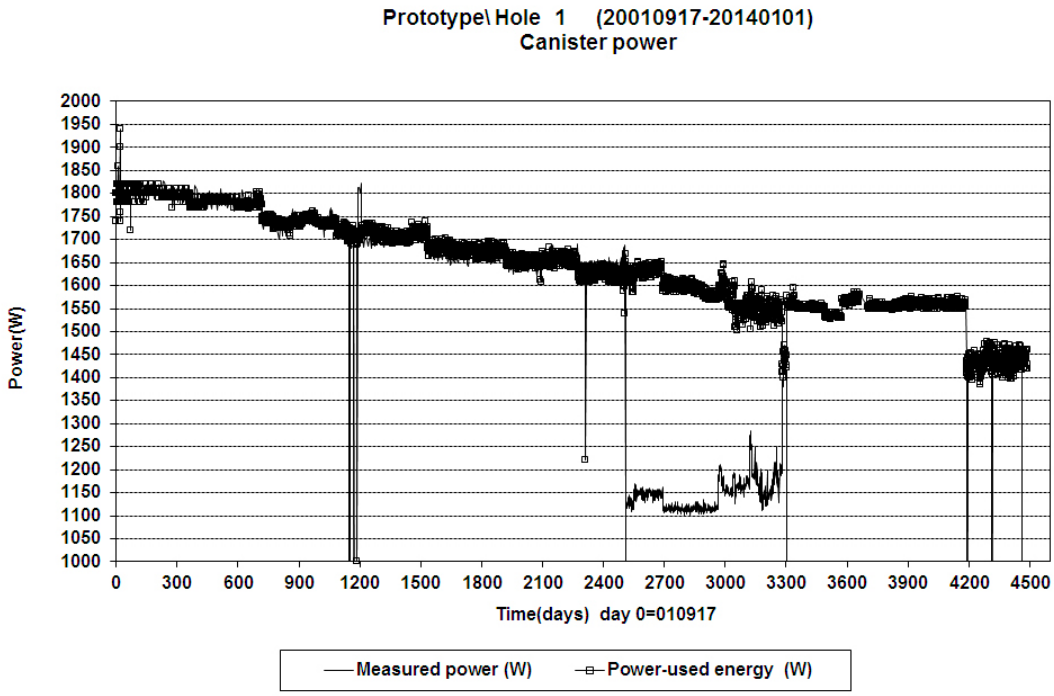

Prototype\Hole 1\Cyl.1 (010917-20140101)
Temprature - Geokon
Tempreature(°C)
Time (days) Day(0)=010917
PBU10002(0.504\0°\0.100)
PBU10011(2.780\5°\0.685)
PBU10026(6.567\5°\0.585)
C4
C3
C2
R10
R9
R8
R7
R6
R5
R4
R3
R2
R1
C1

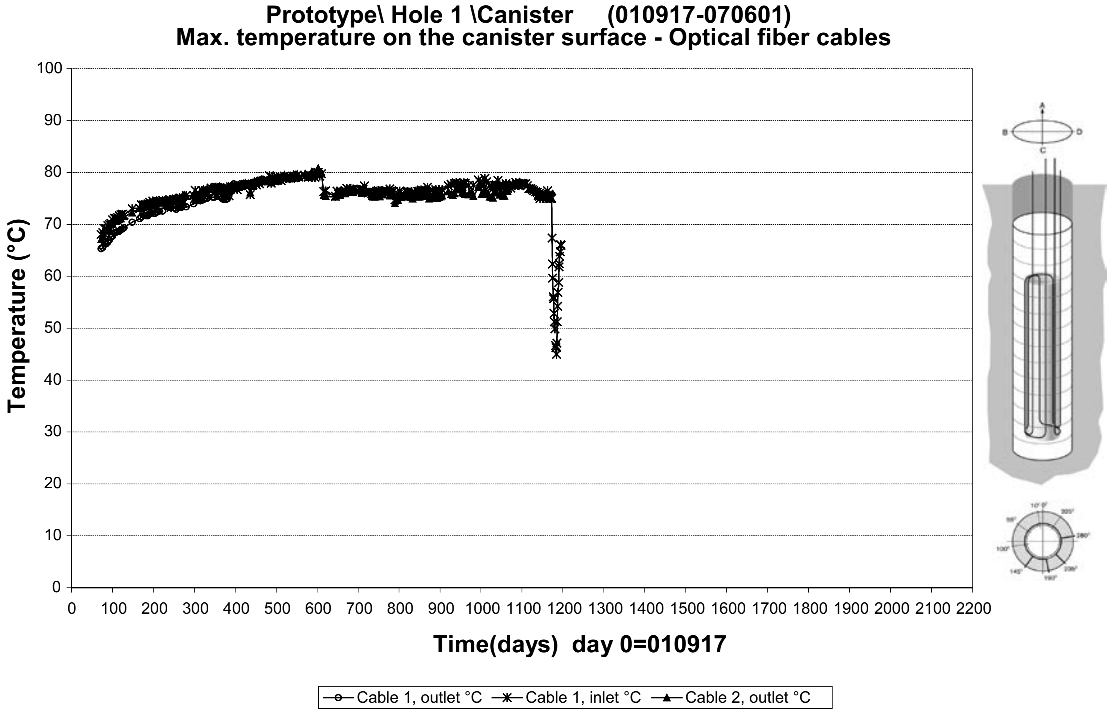

Prototype\Hole 1 (010917-20140101)
Tempreture - Geokon
Tempreature(°C)
Time (days) Day(0)=010917
UBU10002(0.254\90°\0.100)
UBU10003(0.344\355°\0.585)
UBU10010(2.780\175°\0.825)
UBU10012(5.308\355°\0.785)
UBU10013(6.317\90°\0.050)
UBU10014(6.916\90°\0.050)
C4
C3
C2
R10
R9
R8
R7
R6
R5
R4
R3
R2
R1
C1

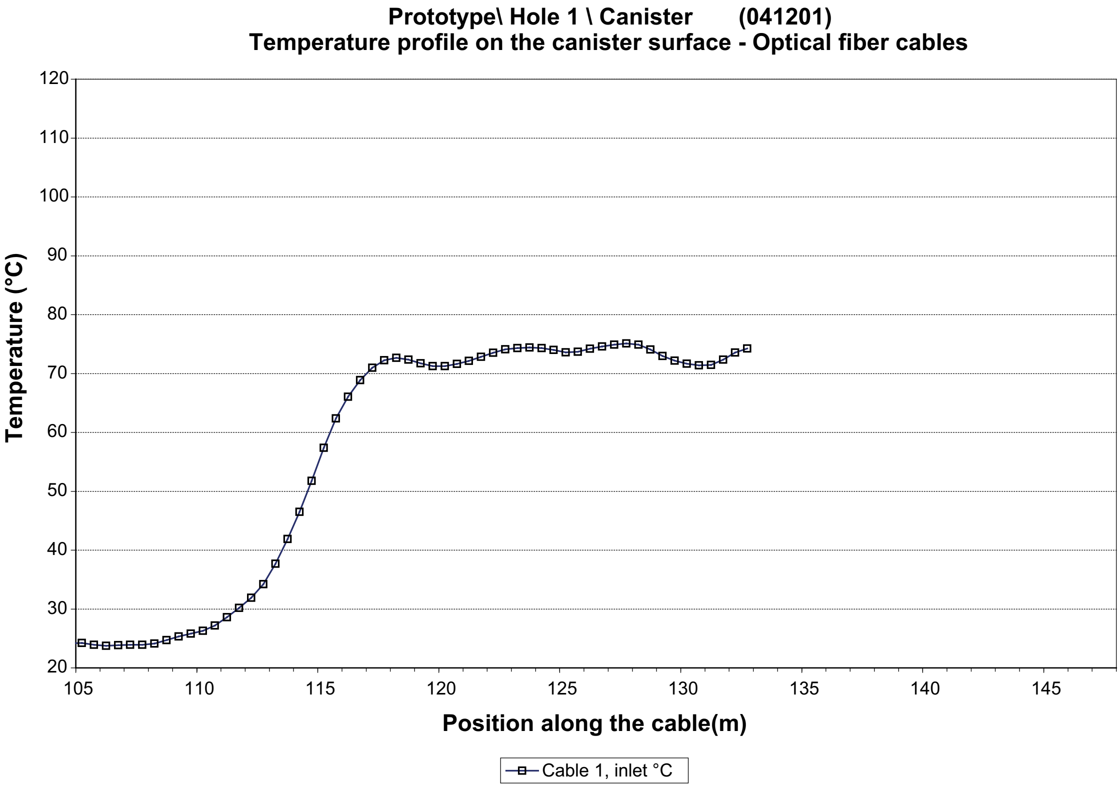

Prototype\Rock\Hole 1 (010917-20140101)
Temperature - Pentronic
Tempreture (°C)
40
35
30
25
20
15
10
0
300
600
900
1200
1500
1800
2100
2400
2700
3000
3300
3600
3900
4200
4500
Time(days) day 0=010917
□ TROA350 (7.784\360°\9.086)
△ TROA340 (5.784\360°\9.086)
◇ TROA330(3.384\0°\9.086)
◆ TROA320(0.985\0°\9.087)
■ TROA310(-1.715\0°\9.086)


Prototype\Rock\Hole 1 (010917-20140101)
Temperature - Pentronic
Tempreture (°C)
40
35
30
25
20
15
10
0
300
600
900
1200
1500
1800
2100
2400
2700
3000
3300
3600
3900
4200
4500
Time(days) day 0=010917
□ TROA650(7.921\360°\4.966)
△ TROA640(5.921\360°\4.988)
■ TROA630(3.521\360°\4.978)
◆ TROA620(1.121\360°\4.968)
▲ TROA610(-1.479\360°\4.956)

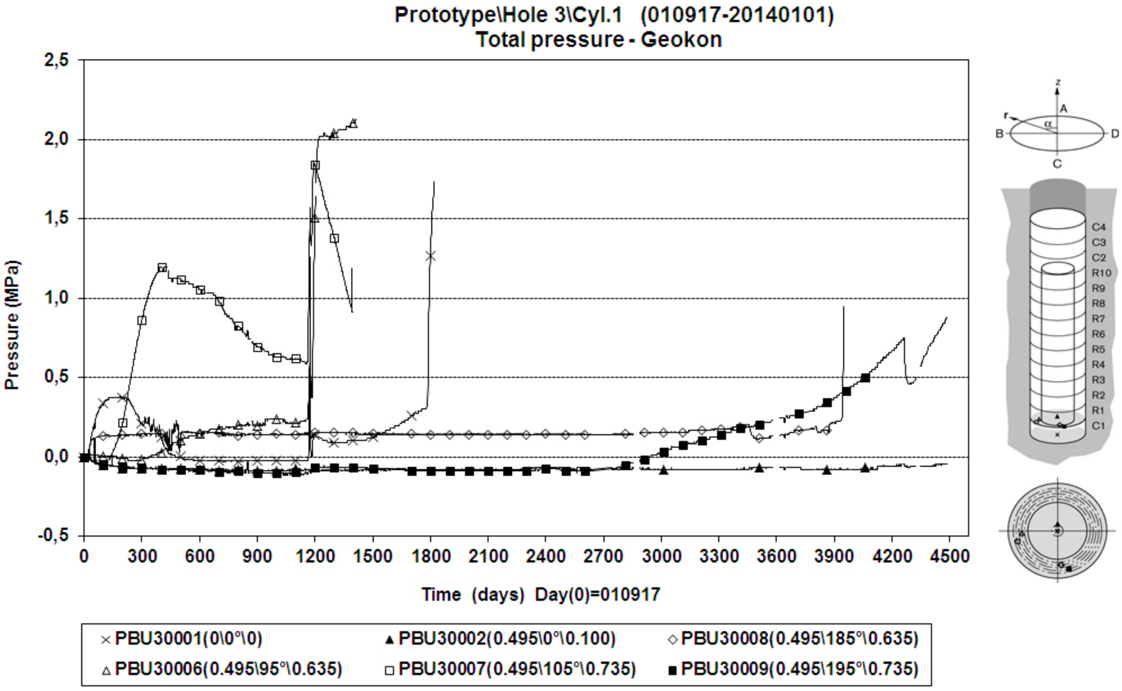

Prototype\Rock\Hole 1 (010917-20140101)
Temperature - Pentronic
Tempreture (°C)
Time(days) day 0=010917
TROA1050(7.662\359°\2.020)
TROA1040(5.662\359°\2.028)
TROA1030(3.262\359°\2.038)
TROA1020(0.862\359°\2.048)
TROA1010(-1.838\359°\2.059)

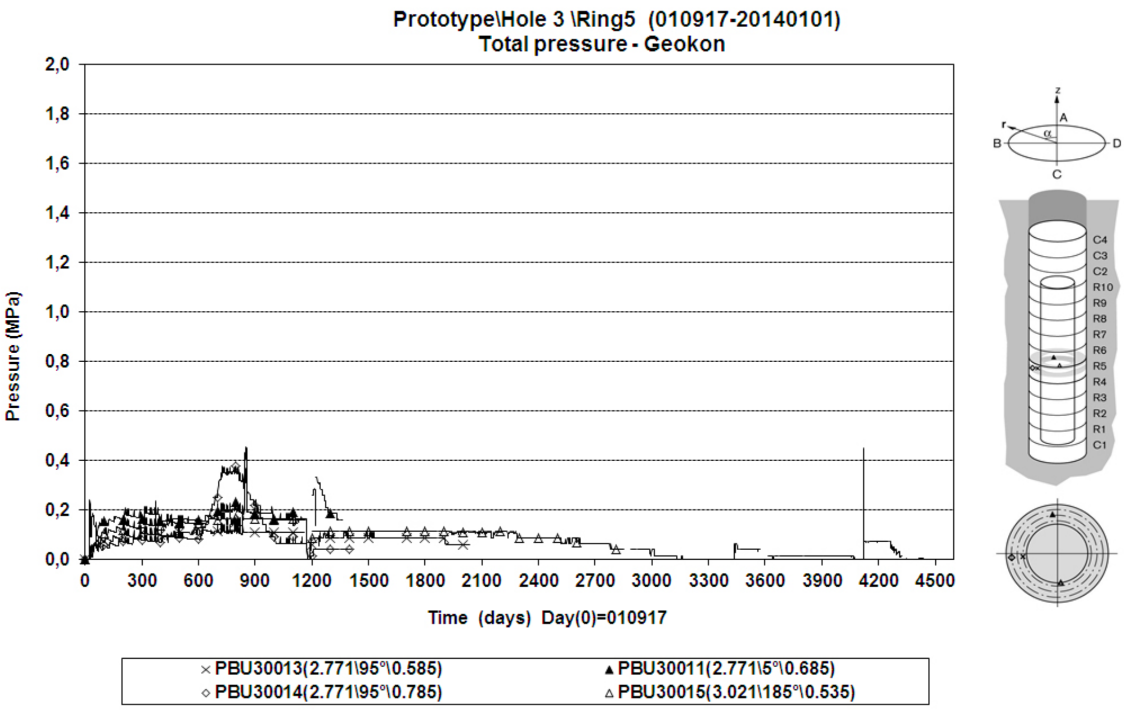

Prototype\ Hole 1 (20010917-20140101)
Canister power
Power(W)
Time(days) day 0=010917
Measured power (W)
Power-used energy (W)

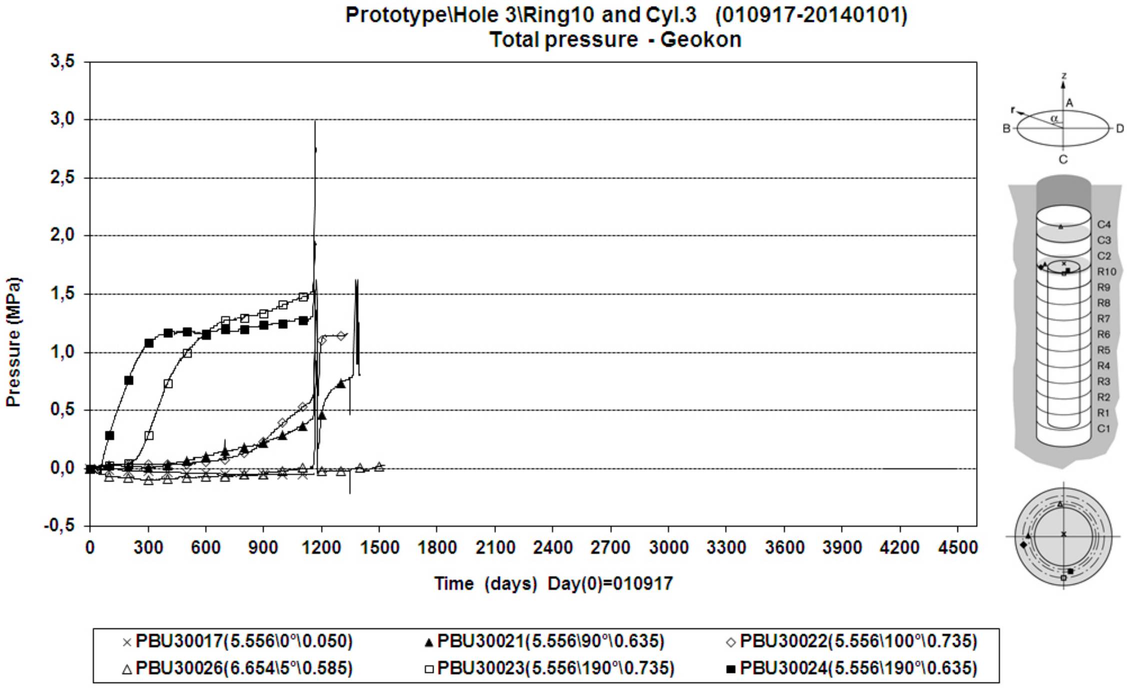

Prototype\ Hole 1 \Canister (010917-070601)
Max. temperature on the canister surface - Optical fiber cables
Temperature (°C)
Time(days) day 0=010917
Cable 1, outlet °C
Cable 1, inlet °C
Cable 2, outlet °C

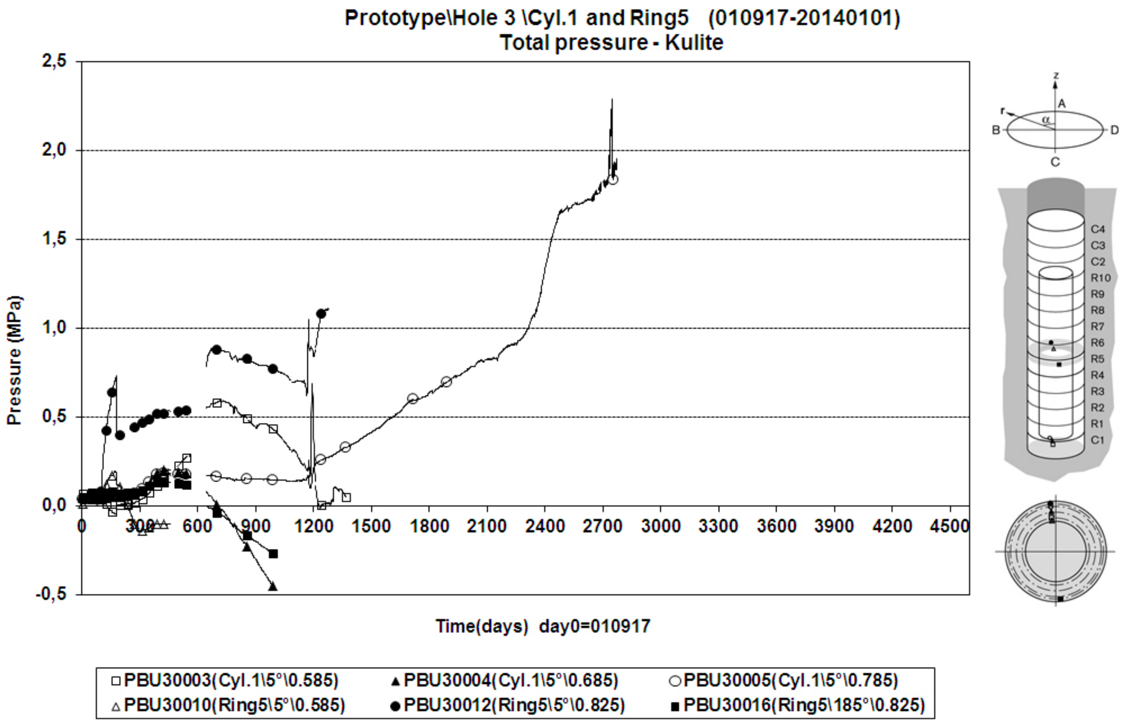

Prototype\ Hole 1 \ Canister (041201)
Temperature profile on the canister surface - Optical fiber cables
Temperature (°C)
Position along the cable(m)
Cable 1, inlet °C

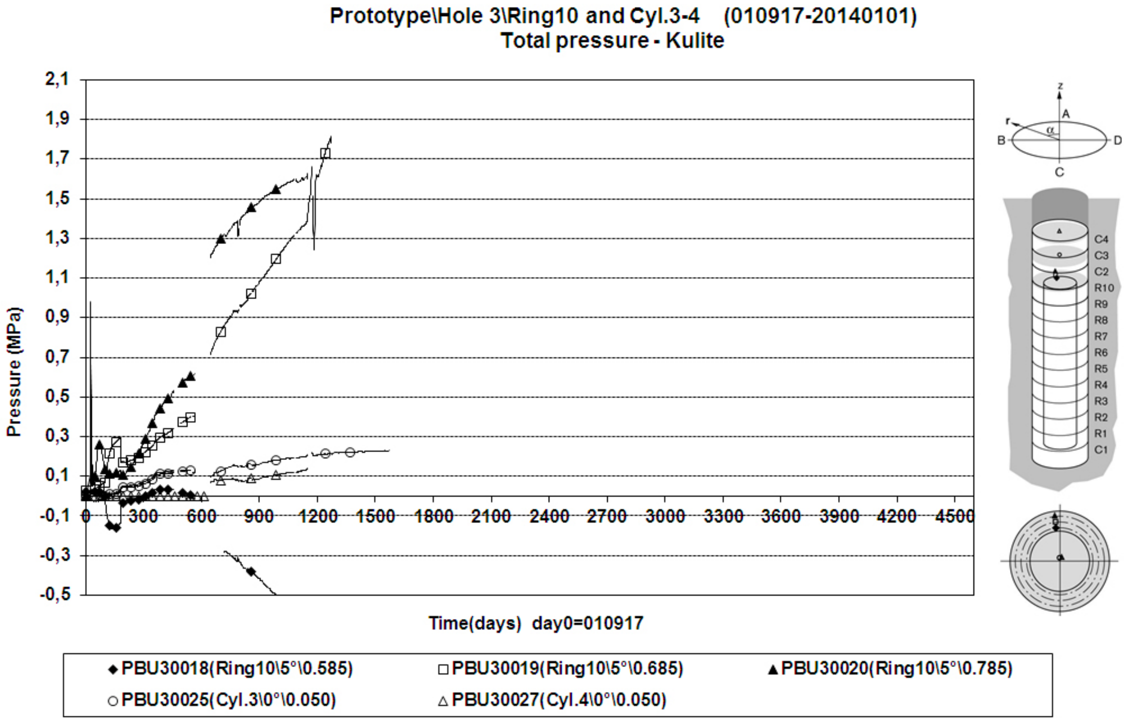
Dep. hole 3

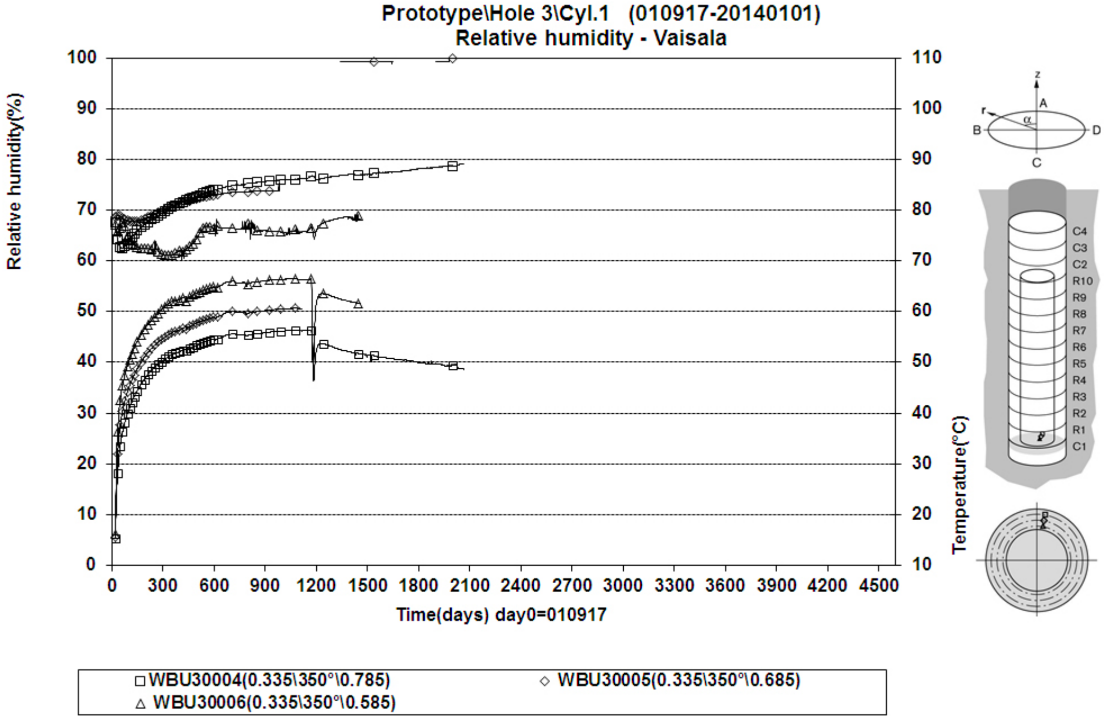

Prototype\Hole 3\Cyl.1 (010917-20140101)
Total pressure - Geokon
Pressure (MPa)
Time (days) Day(0)=010917
PBU30001(0\0°\0)
PBU30002(0.495\0°\0.100)
PBU30008(0.495\185°\0.635)
PBU30006(0.495\95°\0.635)
PBU30007(0.495\105°\0.735)
PBU30009(0.495\195°\0.735)

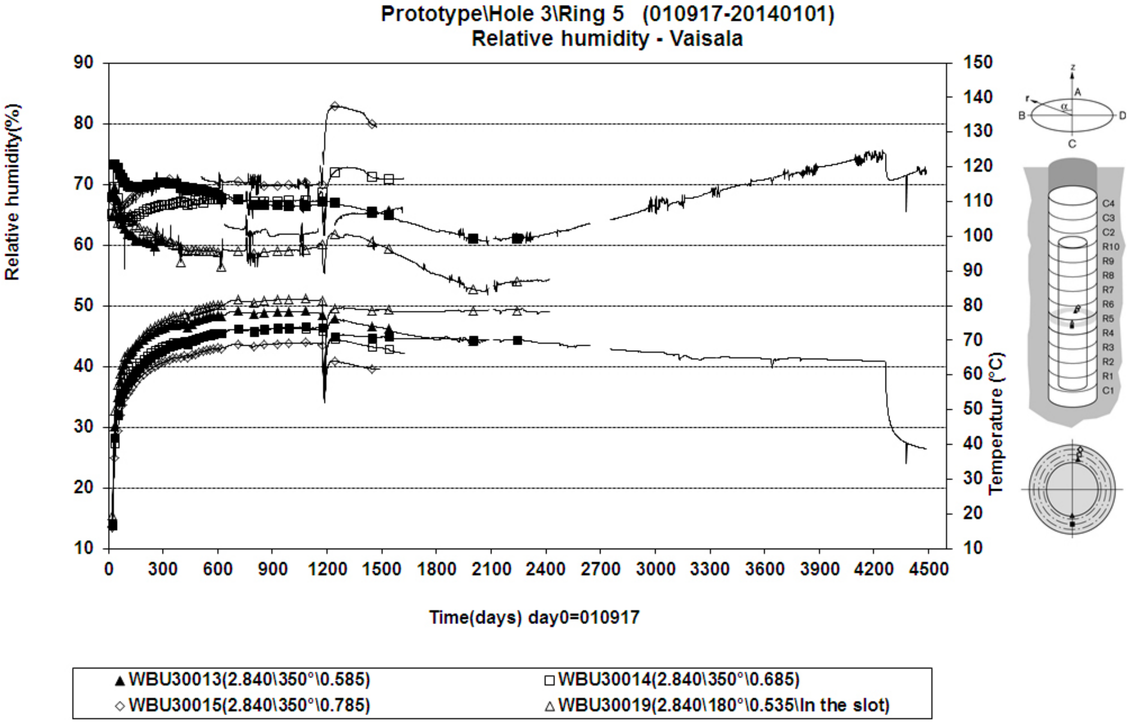

Prototype\Hole 3 \Ring5 (010917-20140101)
Total pressure - Geokon
Pressure (MPa)
Time (days) Day(0)=010917
PBU30013(2.771\95°\0.585)
PBU30011(2.771\5°\0.685)
PBU30014(2.771\95°\0.785)
PBU30015(3.021\185°\0.535)

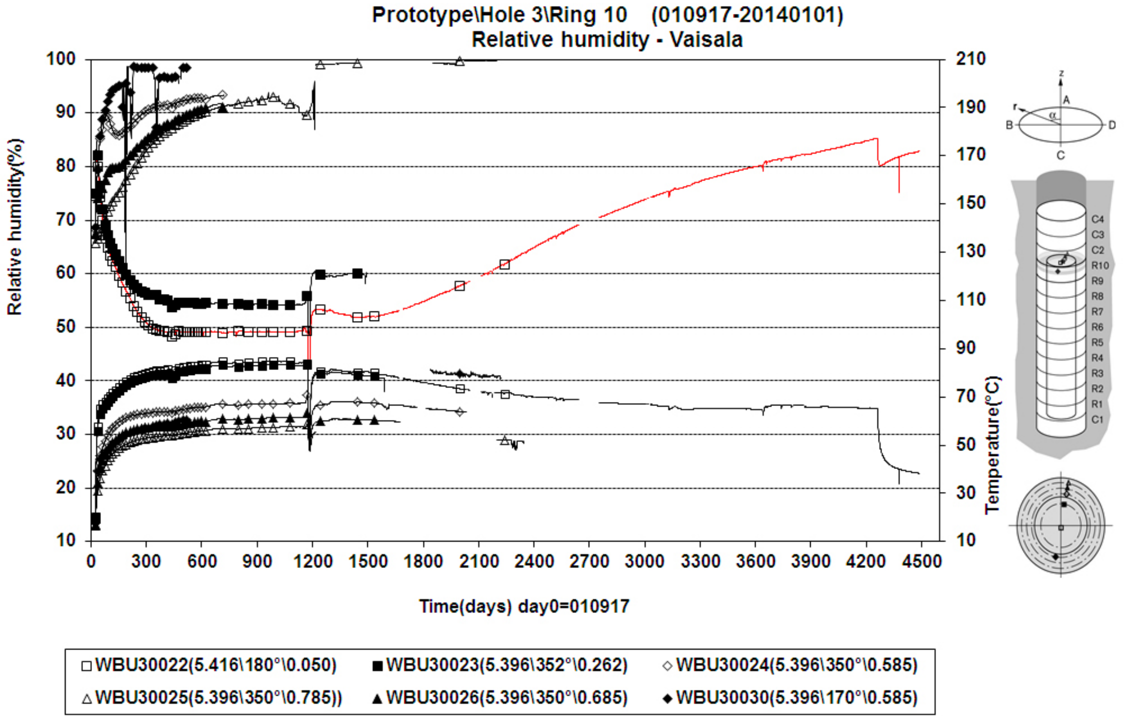

Prototype\Hole 3\Ring10 and Cyl.3 (010917-20140101)
Total pressure - Geokon
Pressure (MPa)
Time (days) Day(0)=010917
PBU30017(5.556\0°\0.050)
PBU30021(5.556\90°\0.635)
PBU30022(5.556\100°\0.735)
PBU30026(6.654\5°\0.585)
PBU30023(5.556\190°\0.735)
PBU30024(5.556\190°\0.635)

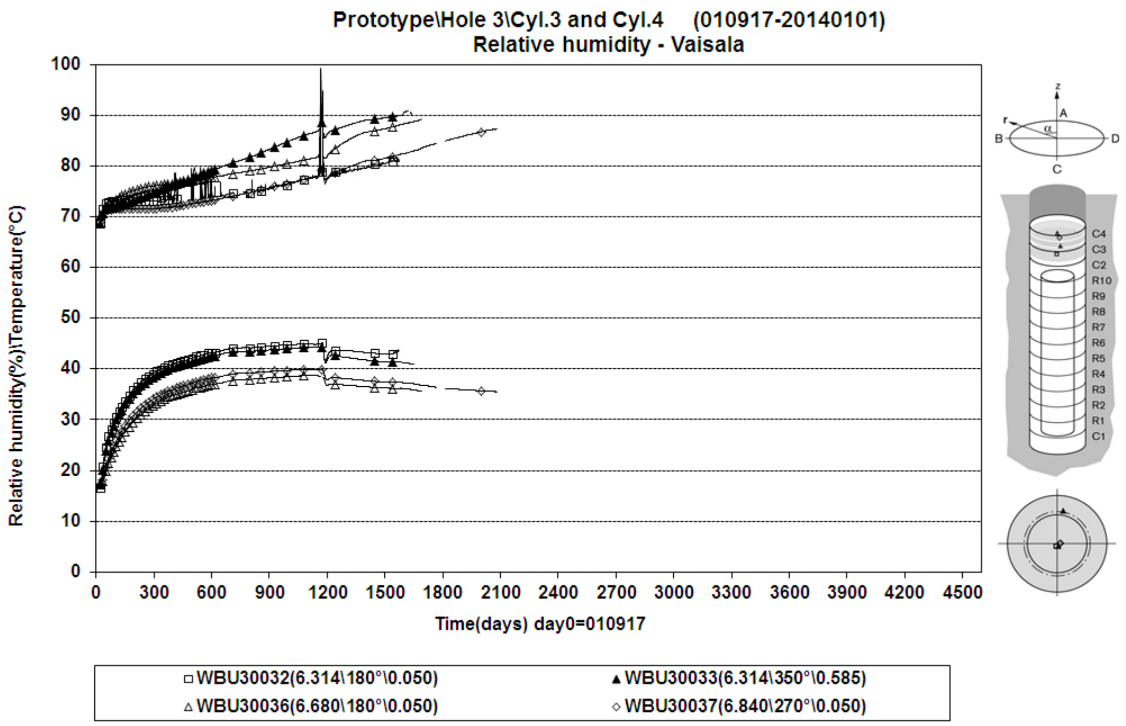

Prototype\Hole 3 \Cyl.1 and Ring5 (010917-20140101)
Total pressure - Kulite
Pressure (MPa)
Time(days) day0=010917
PBU30003(Cyl.1\5°\0.585)
PBU30004(Cyl.1\5°\0.685)
PBU30005(Cyl.1\5°\0.785)
PBU30010(Ring5\5°\0.585)
PBU30012(Ring5\5°\0.825)
PBU30016(Ring5\185°\0.825)

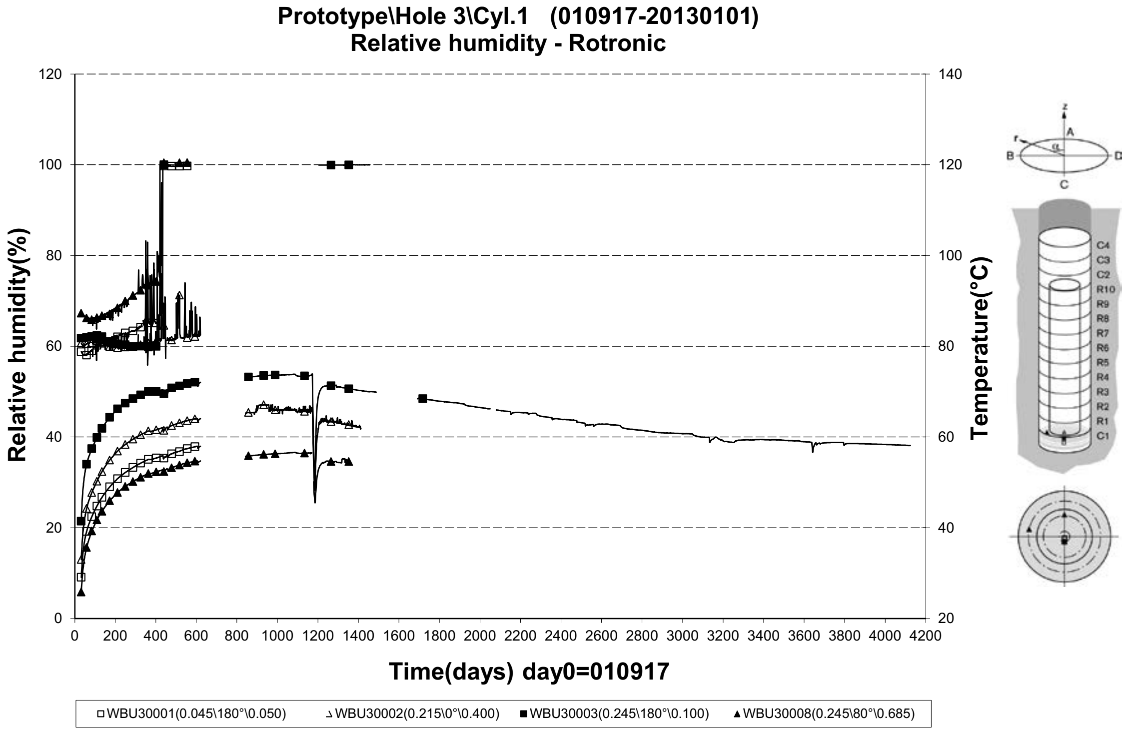

Prototype\Hole 3\Ring10 and Cyl.3-4 (010917-20140101)
Total pressure - Kulite
Pressure (MPa)
Time(days) day0=010917
PBU30018(Ring10\5°\0.585)
PBU30019(Ring10\5°\0.685)
PBU30020(Ring10\5°\0.785)
PBU30025(Cyl.3\0°\0.050)
PBU30027(Cyl.4\0°\0.050)

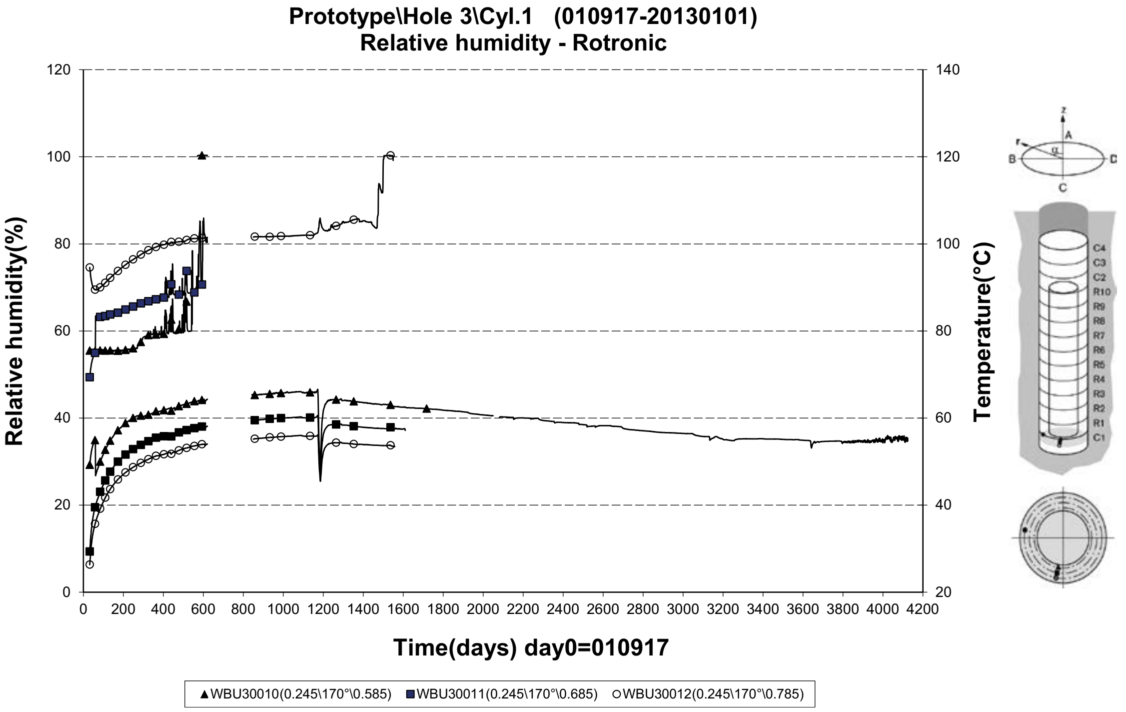

Prototype\Hole 3\Cyl.1 (010917-20140101)
Relative humidity - Vaisala
Relative humidity(%)
Temperature(°C)
Time(days) day0=010917
WBU30004(0.335\350°\0.785)
WBU30005(0.335\350°\0.685)
WBU30006(0.335\350°\0.585)

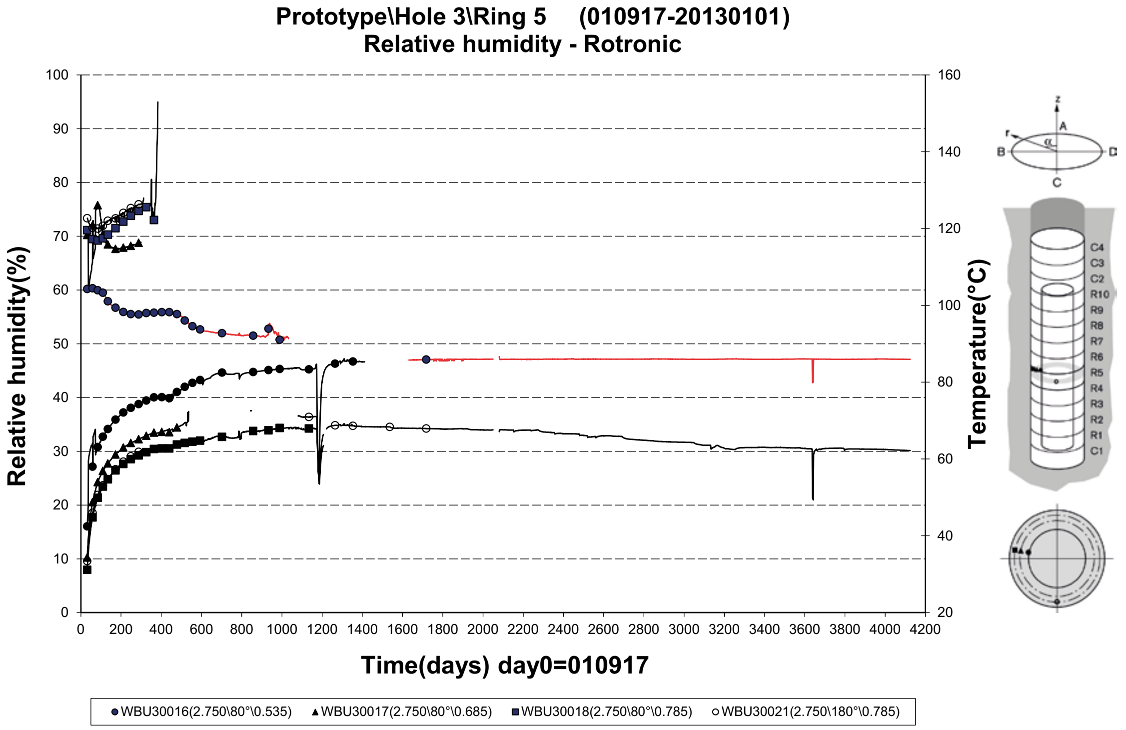

Prototype\Hole 3\Ring 5 (010917-20140101)
Relative humidity - Vaisala
Relative humidity(%)
Temperature (°C)
Time(days) day0=010917
▲WBU30013(2.840\350°\0.585)
□WBU30014(2.840\350°\0.685)
◇WBU30015(2.840\350°\0.785)
△WBU30019(2.840\180°\0.535\In the slot)

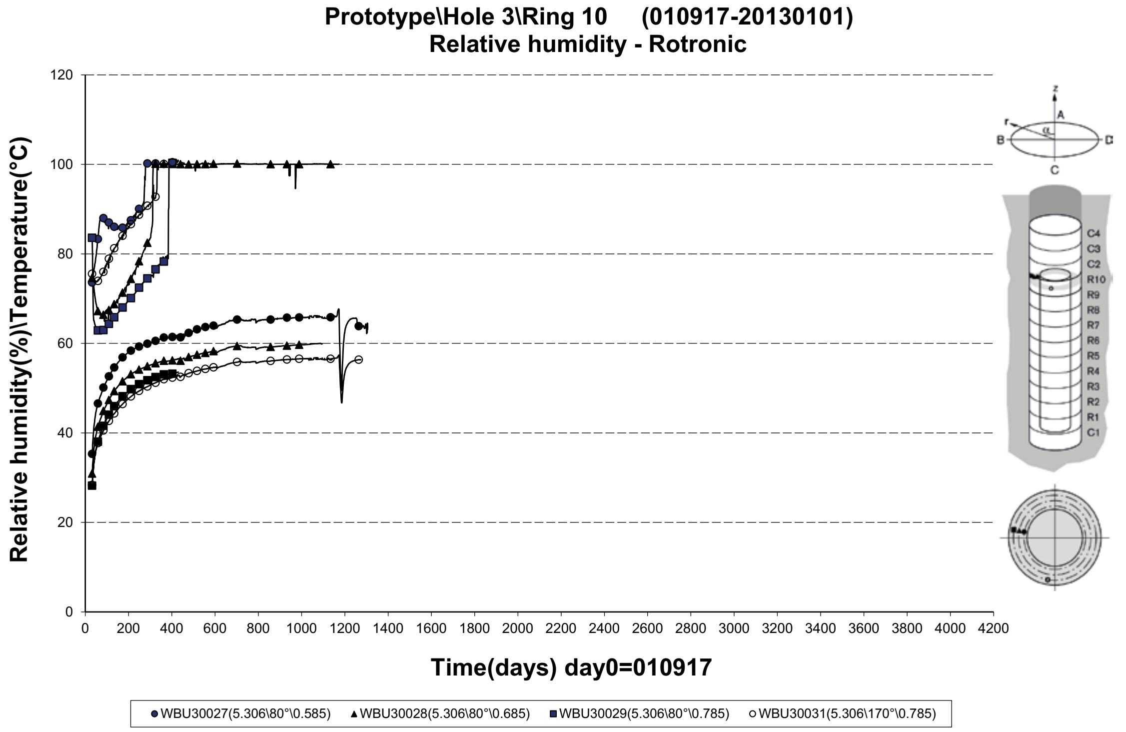

Prototype\Hole 3\Ring 10 (010917-20140101)
Relative humidity - Vaisala
Relative humidity(%)
Temperature(°C)
Time(days) day0=010917
□WBU30022(5.416\180°\0.050)
■WBU30023(5.396\352°\0.262)
◇WBU30024(5.396\350°\0.585)
△WBU30025(5.396\350°\0.785))
▲WBU30026(5.396\350°\0.685)
◆WBU30030(5.396\170°\0.585)

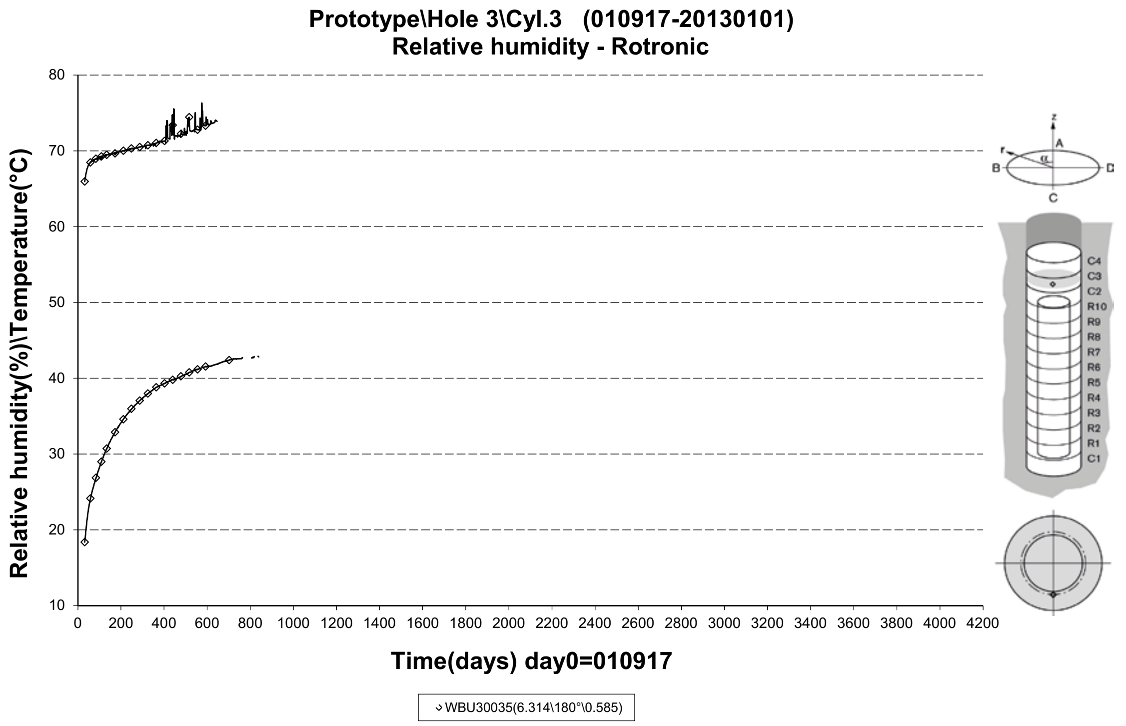

Prototype\Hole 3\Cyl.3 and Cyl.4 (010917-20140101)
Relative humidity - Vaisala
Relative humidity(%)\Temperature(°C)
Time(days) day0=010917
WBU30032(6.314\180°\0.050)
WBU30033(6.314\350°\0.585)
WBU30036(6.680\180°\0.050)
WBU30037(6.840\270°\0.050)
C4
C3
C2
R10
R9
R8
R7
R6
R5
R4
R3
R2
R1
C1

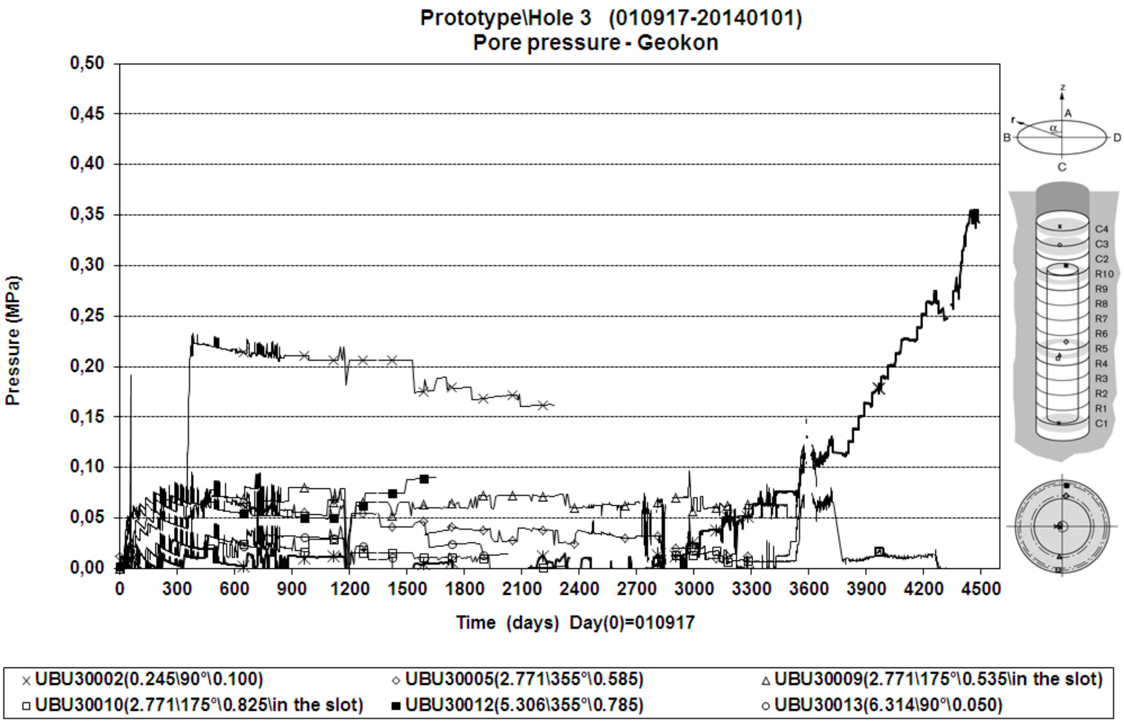

Prototype\Hole 3\Cyl.1 (010917-20130101)
Relative humidity - Rotronic
Relative humidity(%)
Temperature(°C)
Time(days) day0=010917
WBU30001(0.045\180°\0.050)
WBU30002(0.215\0°\0.400)
WBU30003(0.245\180°\0.100)
WBU30008(0.245\80°\0.685)
C4
C3
C2
R10
R9
R8
R7
R6
R5
R4
R3
R2
R1
C1

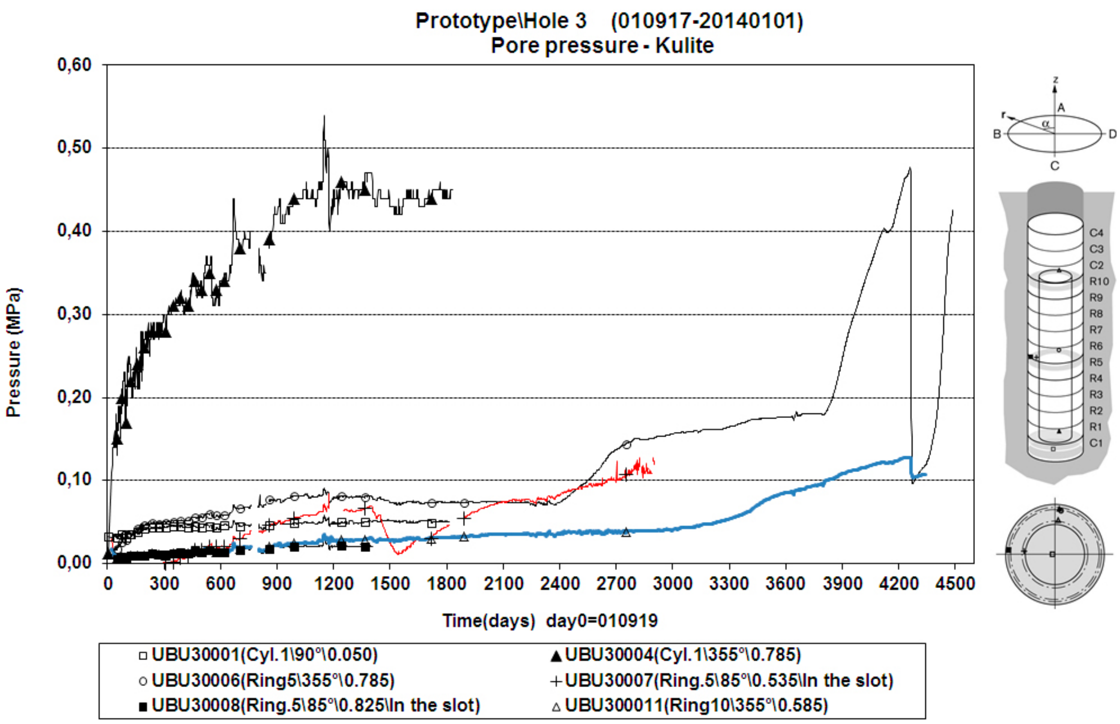

Prototype\Hole 3\Cyl.1 (010917-20130101)
Relative humidity - Rotronic
Relative humidity(%)
Temperature(°C)
Time(days) day0=010917
WBU30010(0.245\170°\0.585)
WBU30011(0.245\170°\0.685)
WBU30012(0.245\170°\0.785)
A
B
C
D
z
r
α
C4
C3
C2
R10
R9
R8
R7
R6
R5
R4
R3
R2
R1
C1

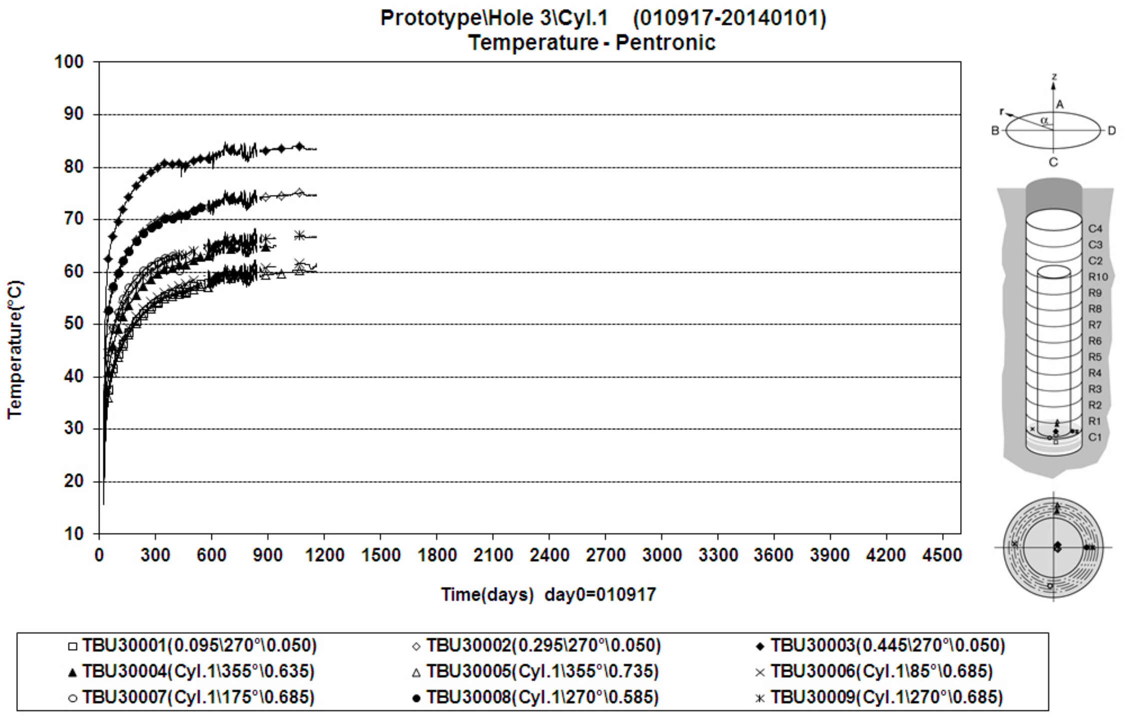

Prototype\Hole 3\Ring 5 (010917-20130101)
Relative humidity - Rotronic
Relative humidity(%)
Temperature(°C)
Time(days) day0=010917
WBU30016(2.750\80°\0.535)
WBU30017(2.750\80°\0.685)
WBU30018(2.750\80°\0.785)
WBU30021(2.750\180°\0.785)
A
B
C
D
z
r
α
C4
C3
C2
R10
R9
R8
R7
R6
R5
R4
R3
R2
R1
C1


Prototype\Hole 3\Ring 10 (010917-20130101)
Relative humidity - Rotronic
Relative humidity(%)\Temperature(°C)
Time(days) day0=010917
WBU30027(5.306\80°\0.585)
WBU30028(5.306\80°\0.685)
WBU30029(5.306\80°\0.785)
WBU30031(5.306\170°\0.785)

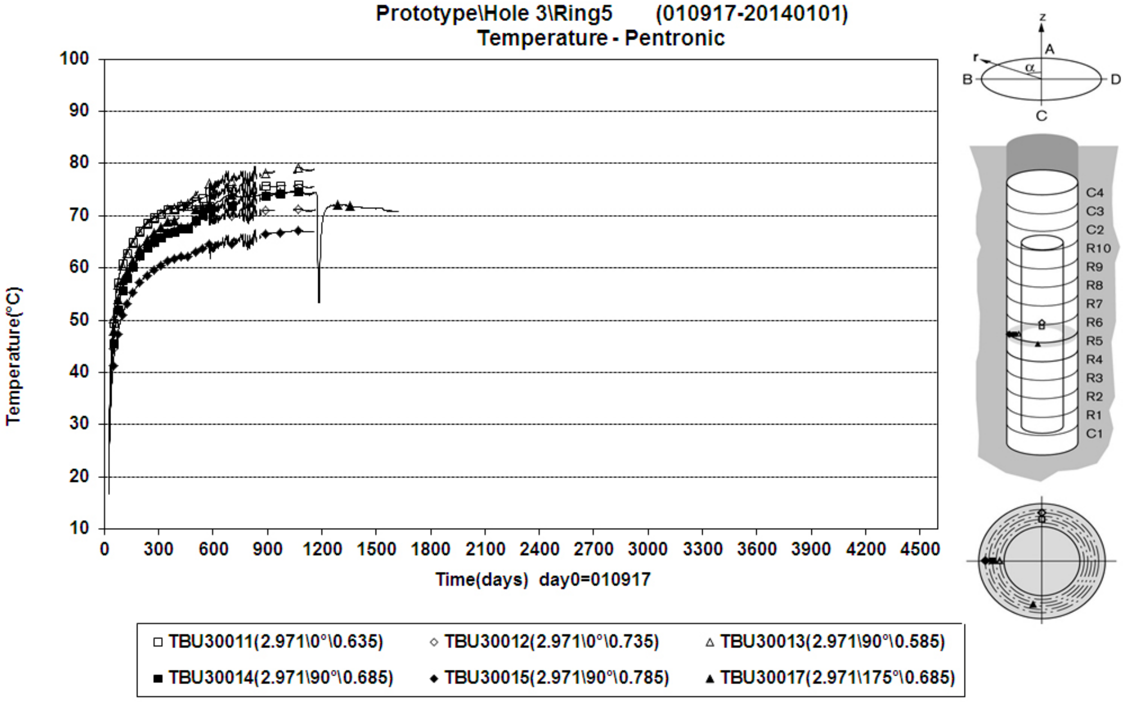

Prototype\Hole 3\Cyl.3 (010917-20130101)
Relative humidity - Rotronic
Relative humidity(%)\Temperature(°C)
Time(days) day0=010917
WBU30035(6.314\180°\0.585)


Prototype\Hole 3 (010917-20140101)
Pore pressure - Geokon
Pressure (MPa)
Time (days) Day(0)=010917
× UBU30002(0.245\90°\0.100)
◇ UBU30005(2.771\355°\0.585)
△ UBU30009(2.771\175°\0.535\in the slot)
□ UBU30010(2.771\175°\0.825\in the slot)
■ UBU30012(5.306\355°\0.785)
○ UBU30013(6.314\90°\0.050)

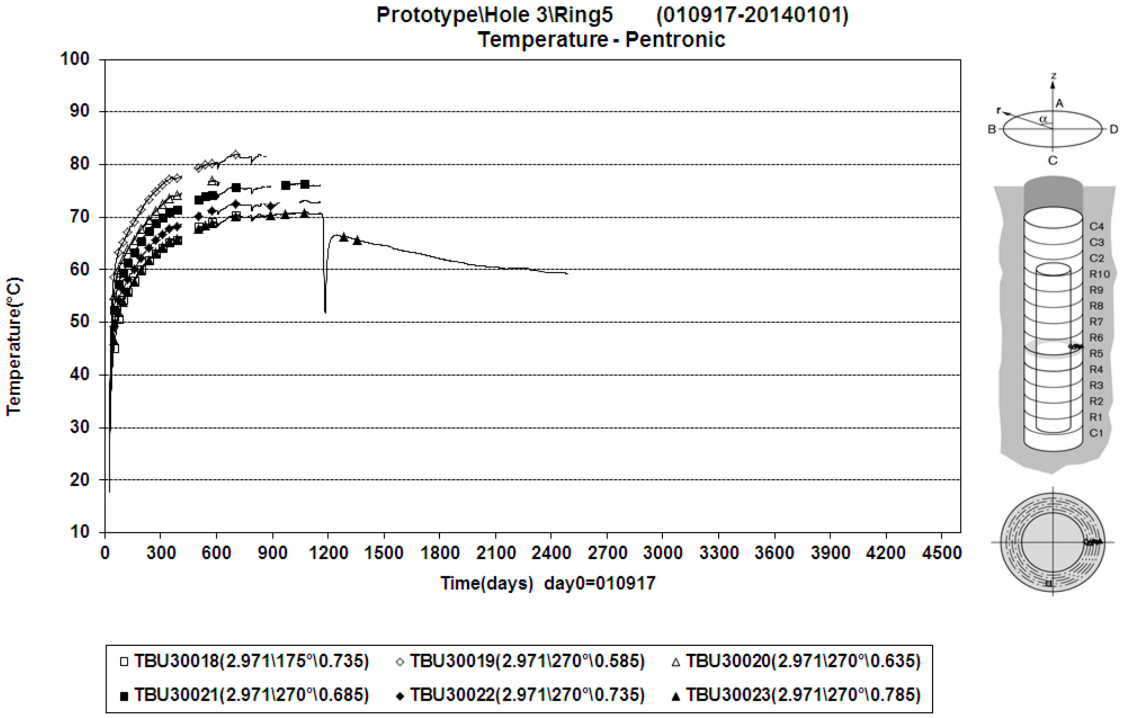

Prototype\Hole 3 (010917-20140101)
Pore pressure - Kulite
Pressure (MPa)
Time(days) day0=010919
□ UBU30001(Cyl.1\90°\0.050)
▲ UBU30004(Cyl.1\355°\0.785)
○ UBU30006(Ring5\355°\0.785)
+ UBU30007(Ring.5\85°\0.535\In the slot)
■ UBU30008(Ring.5\85°\0.825\In the slot)
△ UBU300011(Ring10\355°\0.585)

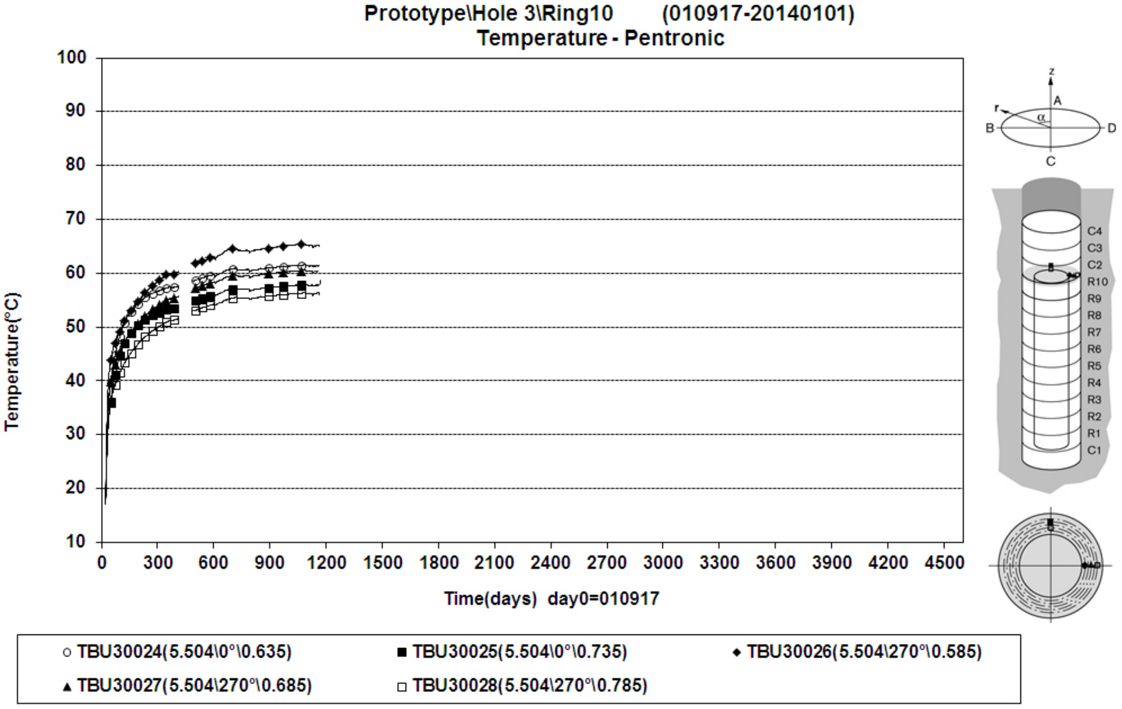


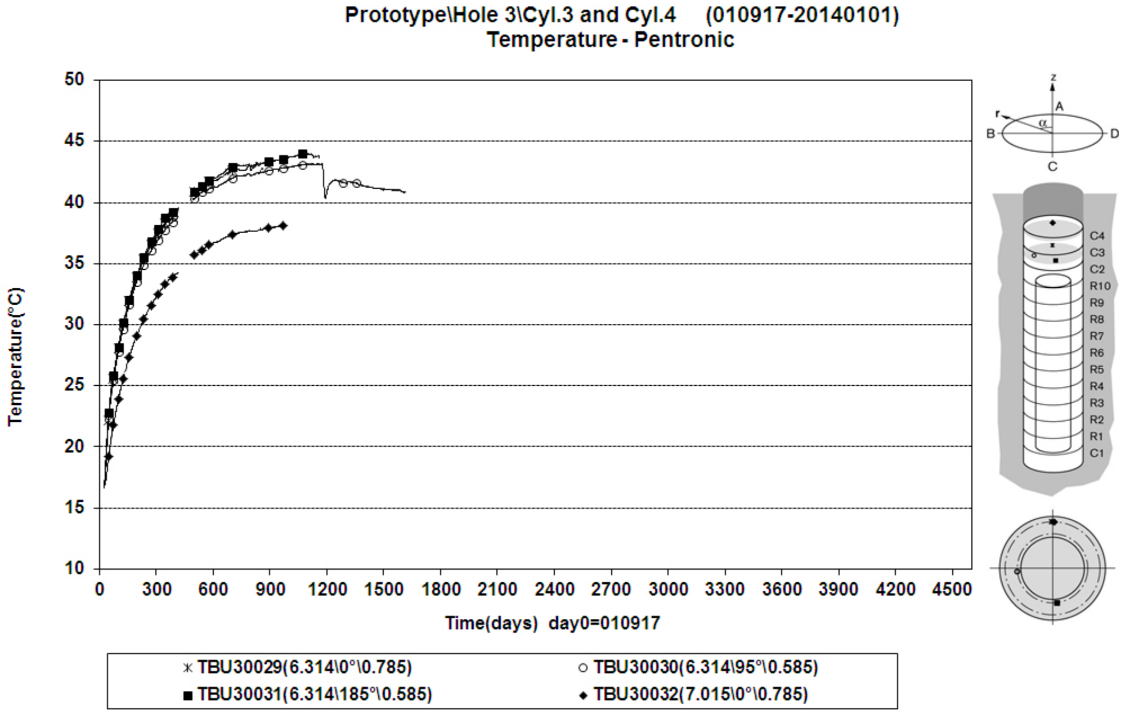
Prototype\Hole 3\Cyl.1 (010917-20140101)
Temperature - Pentronic
Temperature(°C)
Time(days) day0=010917
TBU30001(0.095\270°\0.050)
TBU30002(0.295\270°\0.050)
TBU30003(0.445\270°\0.050)
TBU30004(Cyl.1\355°\0.635)
TBU30005(Cyl.1\355°\0.735)
TBU30006(Cyl.1\85°\0.685)
TBU30007(Cyl.1\175°\0.685)
TBU30008(Cyl.1\270°\0.585)
TBU30009(Cyl.1\270°\0.685)

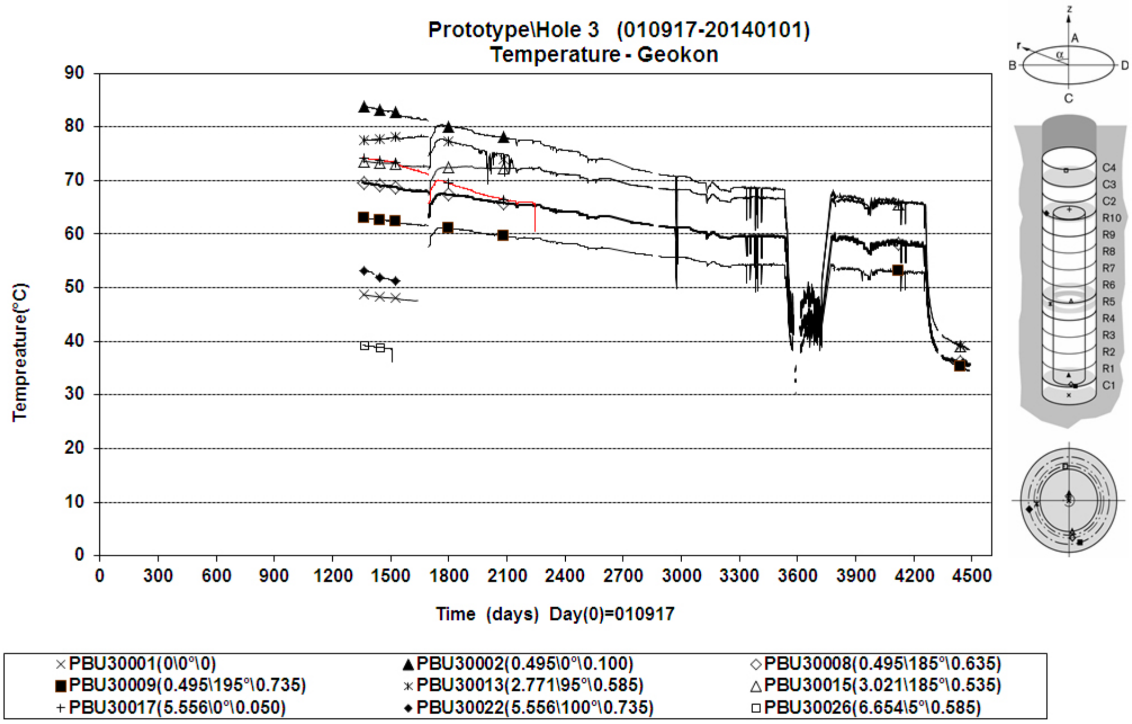


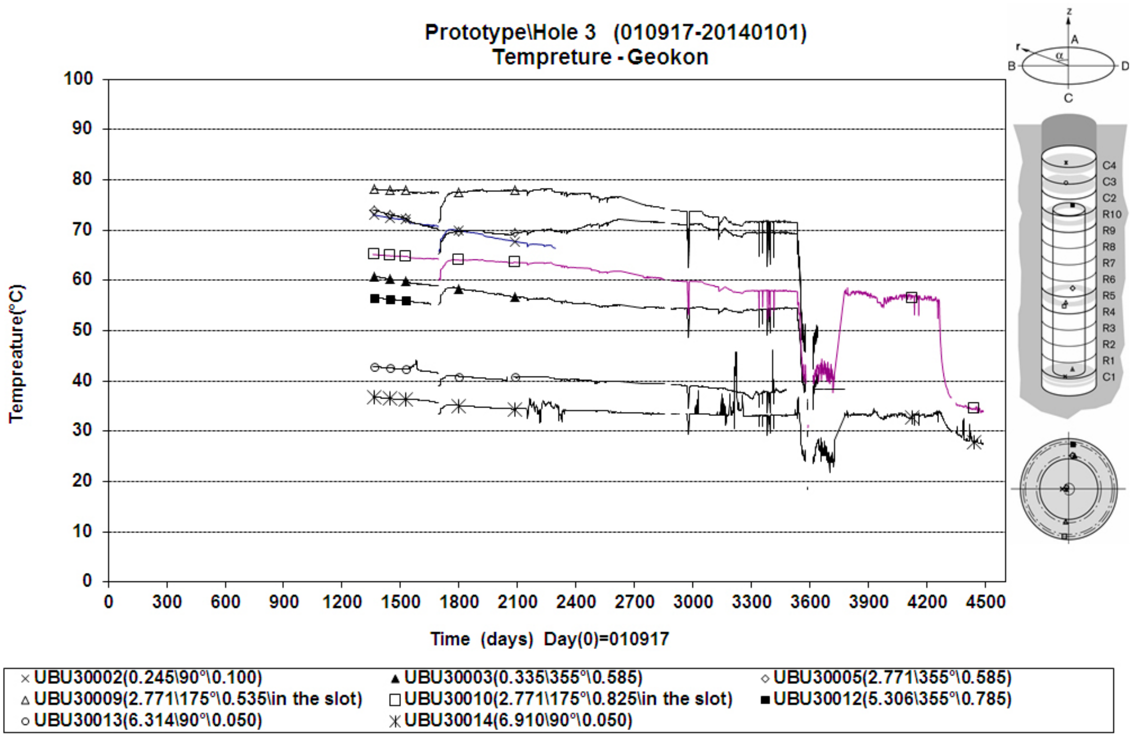
Prototype\Hole 3\Ring5 (010917-20140101)
Temperature - Pentronic
Temperature(°C)
Time(days) day0=010917
TBU30011(2.971\0°\0.635)
TBU30012(2.971\0°\0.735)
TBU30013(2.971\90°\0.585)
TBU30014(2.971\90°\0.685)
TBU30015(2.971\90°\0.785)
TBU30017(2.971\175°\0.685)

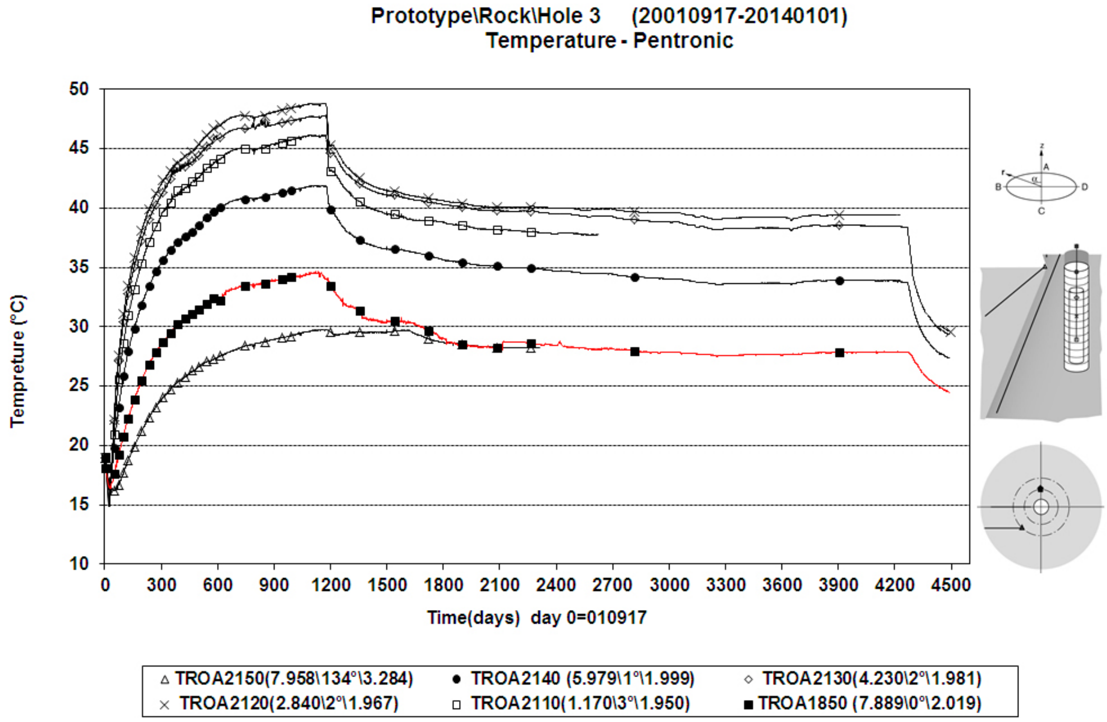

Prototype\Hole 3\Ring5 (010917-20140101)
Temperature - Pentronic
Temperature(°C)
Time(days) day0=010917
TBU30018(2.971\175°\0.735)
TBU30019(2.971\270°\0.585)
TBU30020(2.971\270°\0.635)
TBU30021(2.971\270°\0.685)
TBU30022(2.971\270°\0.735)
TBU30023(2.971\270°\0.785)

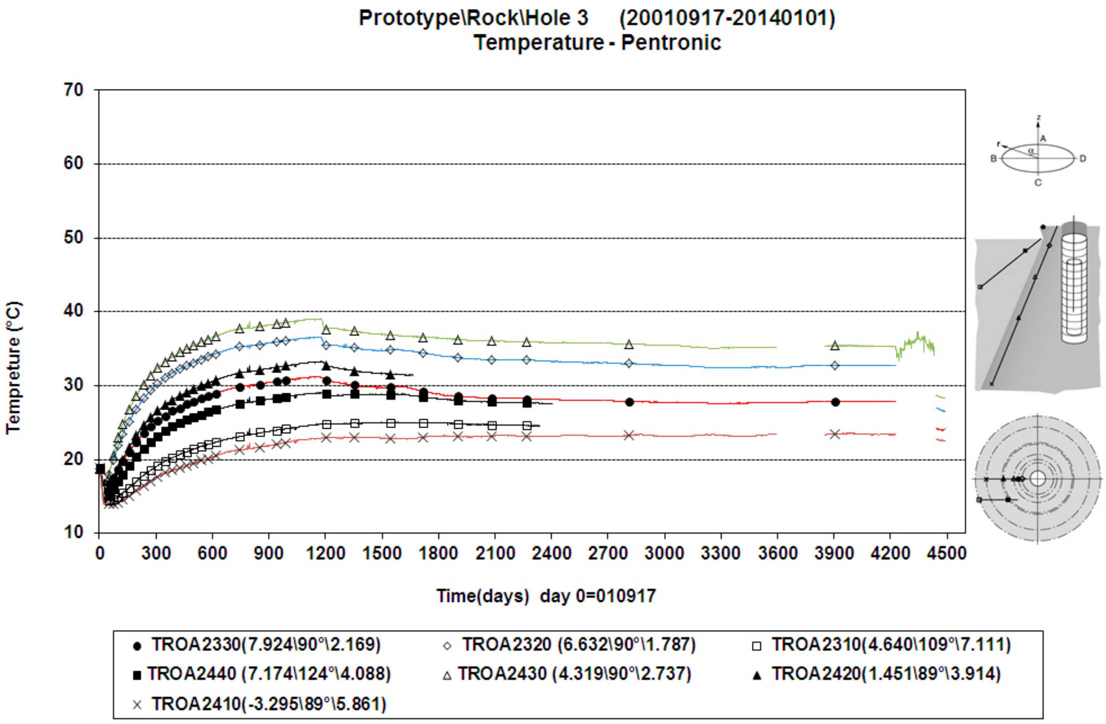

Prototype\Hole 3\Ring10 (010917-20140101)
Temperature - Pentronic
Temperature(°C)
Time(days) day0=010917
TBU30024(5.504\0°\0.635)
TBU30025(5.504\0°\0.735)
TBU30026(5.504\270°\0.585)
TBU30027(5.504\270°\0.685)
TBU30028(5.504\270°\0.785)


Prototype\Hole 3\Cyl.3 and Cyl.4 (010917-20140101)
Temperature - Pentronic
Temperature(°C)
Time(days) day0=010917
TBU30029(6.314\0°\0.785)
TBU30030(6.314\95°\0.585)
TBU30031(6.314\185°\0.585)
TBU30032(7.015\0°\0.785)
C4
C3
C2
R10
R9
R8
R7
R6
R5
R4
R3
R2
R1
C1

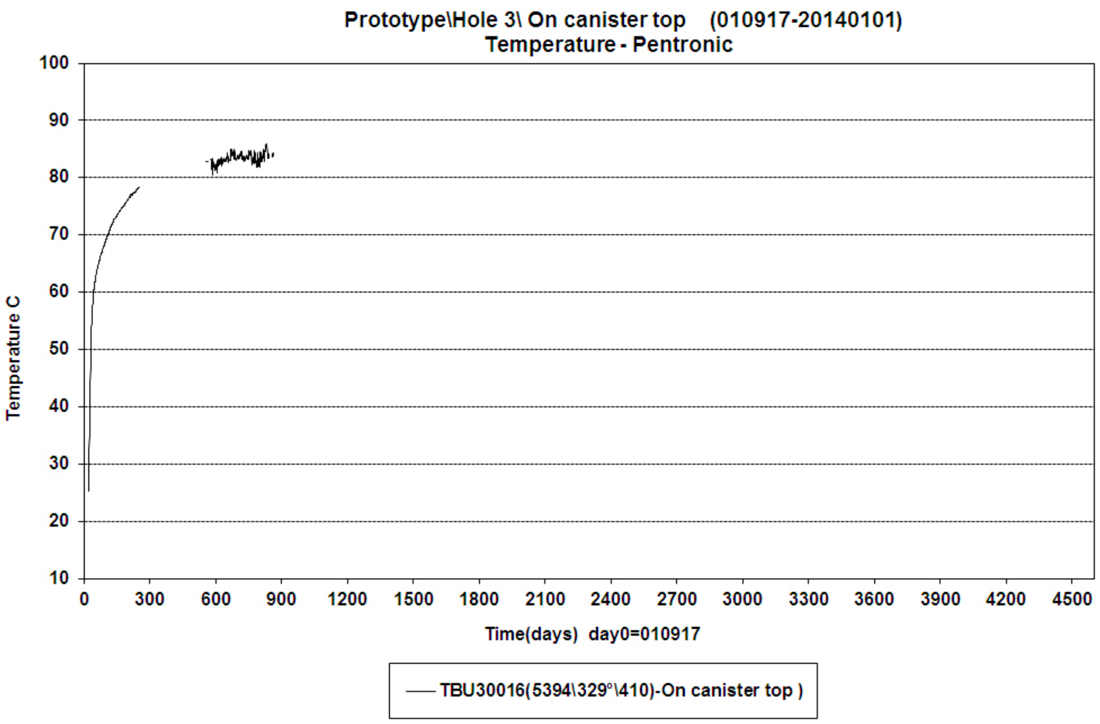

Prototype\Hole 3 (010917-20140101)
Temperature - Geokon
Tempreature(°C)
Time (days) Day(0)=010917
PBU30001(0\0°\0)
PBU30002(0.495\0°\0.100)
PBU30008(0.495\185°\0.635)
PBU30009(0.495\195°\0.735)
PBU30013(2.771\95°\0.585)
PBU30015(3.021\185°\0.535)
PBU30017(5.556\0°\0.050)
PBU30022(5.556\100°\0.735)
PBU30026(6.654\5°\0.585)
C4
C3
C2
R10
R9
R8
R7
R6
R5
R4
R3
R2
R1
C1


Prototype\Hole 3 (010917-20140101)
Tempreture - Geokon
Tempreature(°C)
Time (days) Day(0)=010917
UBU30002(0.245\90°\0.100)
UBU30003(0.335\355°\0.585)
UBU30005(2.771\355°\0.585)
UBU30009(2.771\175°\0.535\in the slot)
UBU30010(2.771\175°\0.825\in the slot)
UBU30012(5.306\355°\0.785)
UBU30013(6.314\90°\0.050)
UBU30014(6.910\90°\0.050)
C4
C3
C2
R10
R9
R8
R7
R6
R5
R4
R3
R2
R1
C1

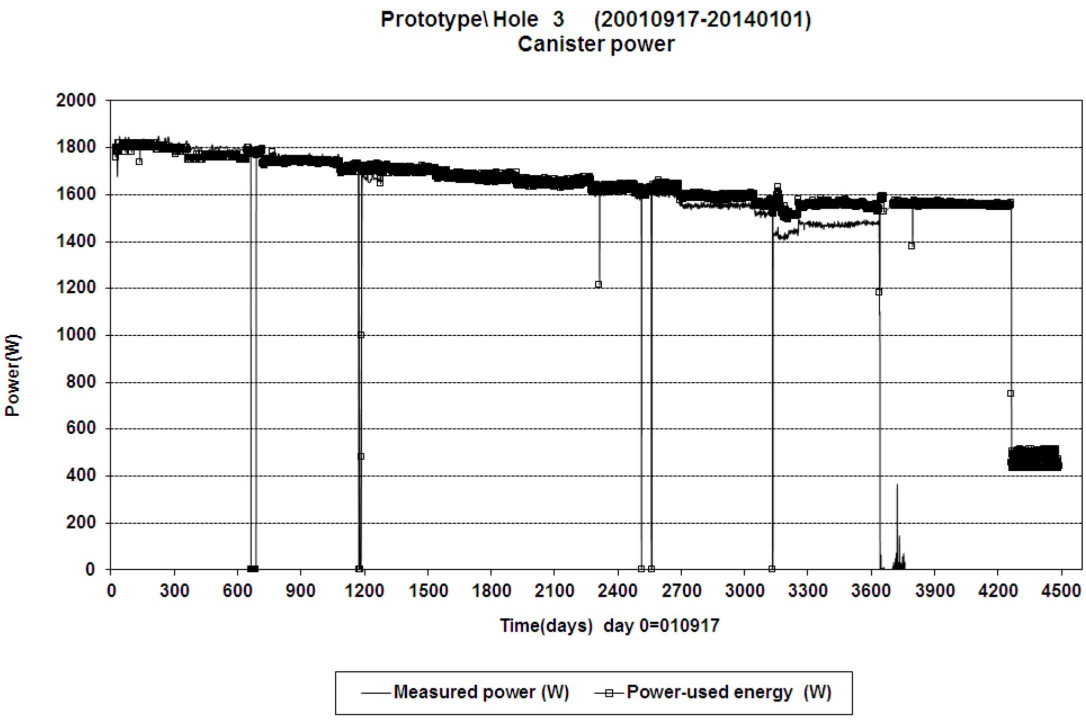

Prototype\Rock\Hole 3 (20010917-20140101)
Temperature - Pentronic
Tempreture (°C)
Time(days) day 0=010917
TROA2150(7.958\134°\3.284)
TROA2140 (5.979\1°\1.999)
TROA2130(4.230\2°\1.981)
TROA2120(2.840\2°\1.967)
TROA2110(1.170\3°\1.950)
TROA1850 (7.889\0°\2.019)

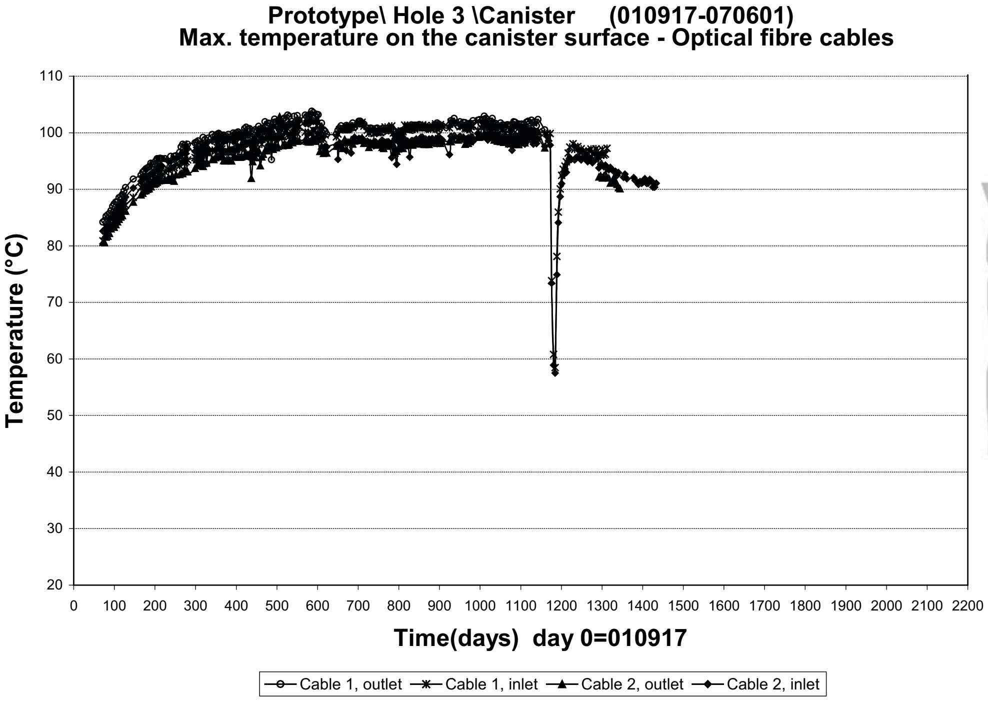


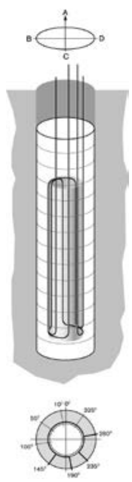
Prototype\Rock\Hole 3 (20010917-20140101)
Temperature - Pentronic
Tempreture (°C)
Time(days) day 0=010917
● TROA2330(7.924\90°\2.169)
◇ TROA2320 (6.632\90°\1.787)
□ TROA2310(4.640\109°\7.111)
■ TROA2440 (7.174\124°\4.088)
△ TROA2430 (4.319\90°\2.737)
▲ TROA2420(1.451\89°\3.914)
× TROA2410(-3.295\89°\5.861)

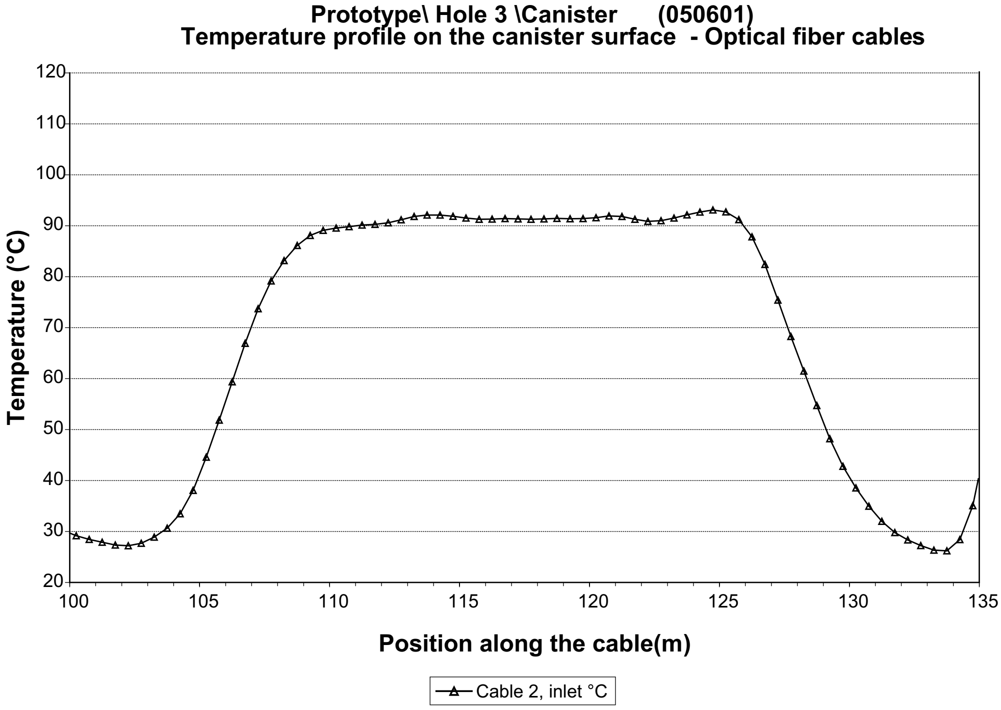


Prototype\Hole 3\ On canister top (010917-20140101)
Temperature - Pentronic
Temperature C
Time(days) day0=010917
TBU30016(5394\329°\410)-On canister top)

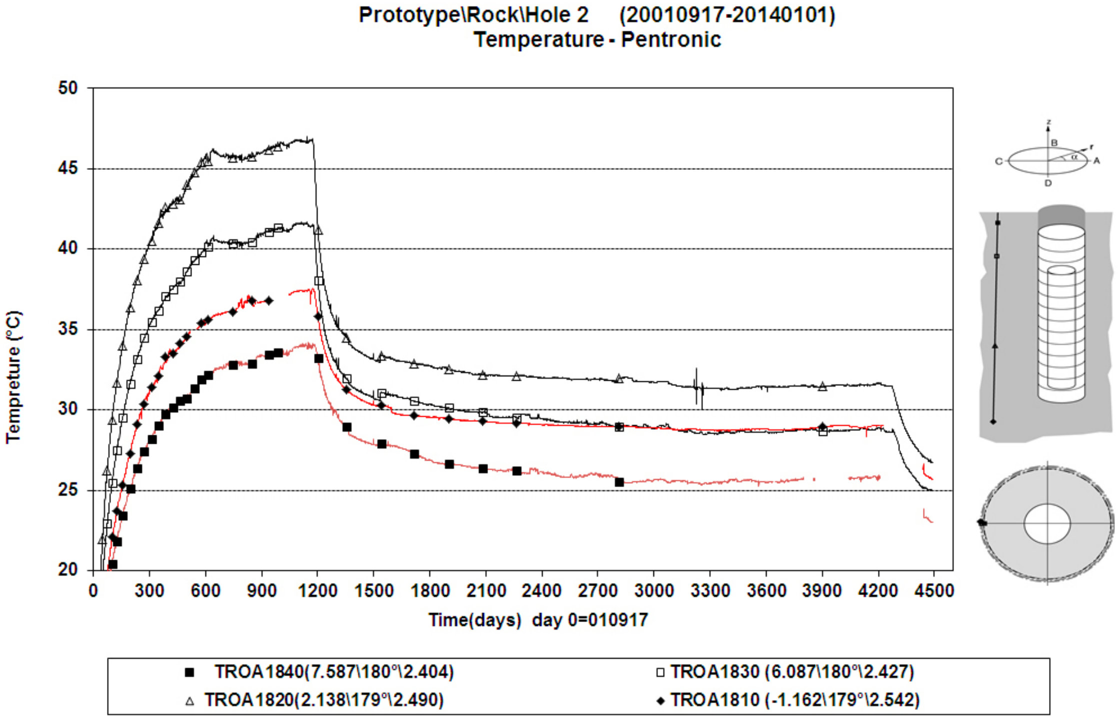

Prototype\ Hole 3 (20010917-20140101)
Canister power
Power(W)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0 300 600 900 1200 1500 1800 2100 2400 2700 3000 3300 3600 3900 4200 4500
Time(days) day 0=010917
Measured power (W)
Power-used energy (W)

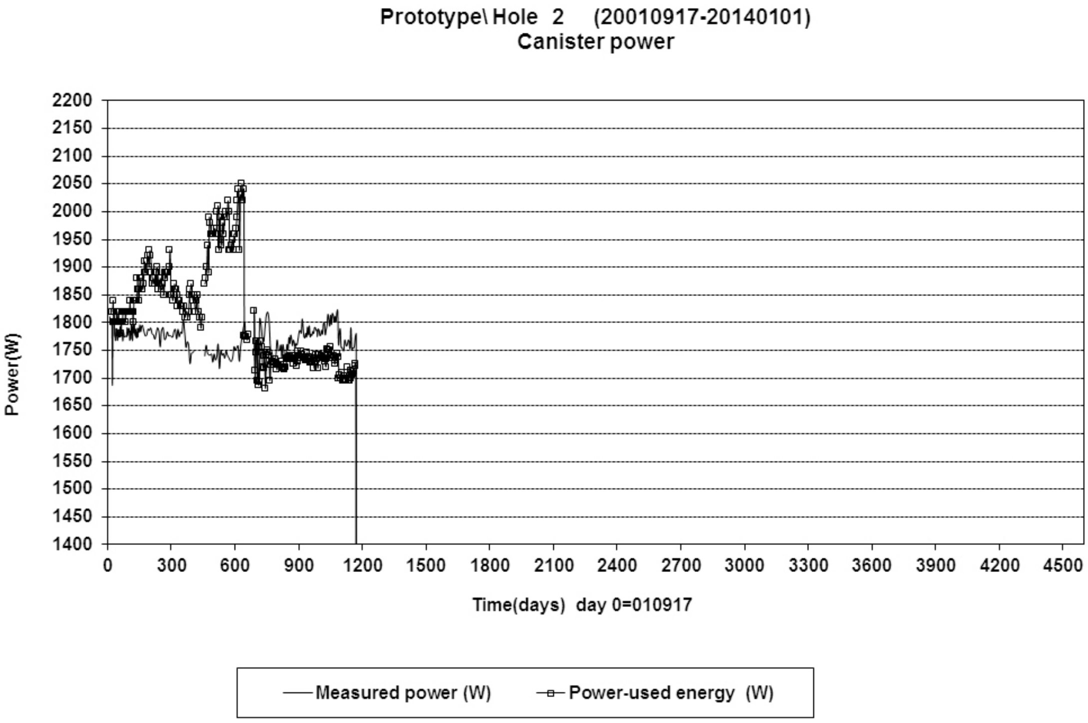

Prototype\ Hole 3 \Canister (010917-070601)
Max. temperature on the canister surface - Optical fibre cables
Temperature (°C)
110
100
90
80
70
60
50
40
30
20
0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200
Time(days) day 0=010917
Cable 1, outlet
Cable 1, inlet
Cable 2, outlet
Cable 2, inlet

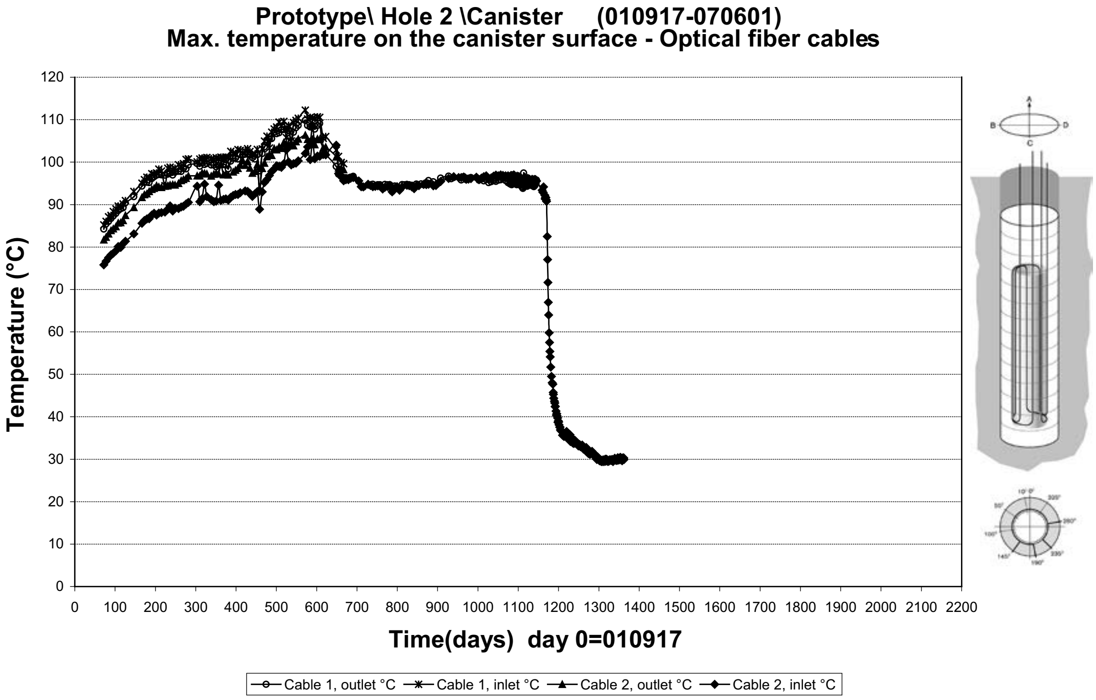


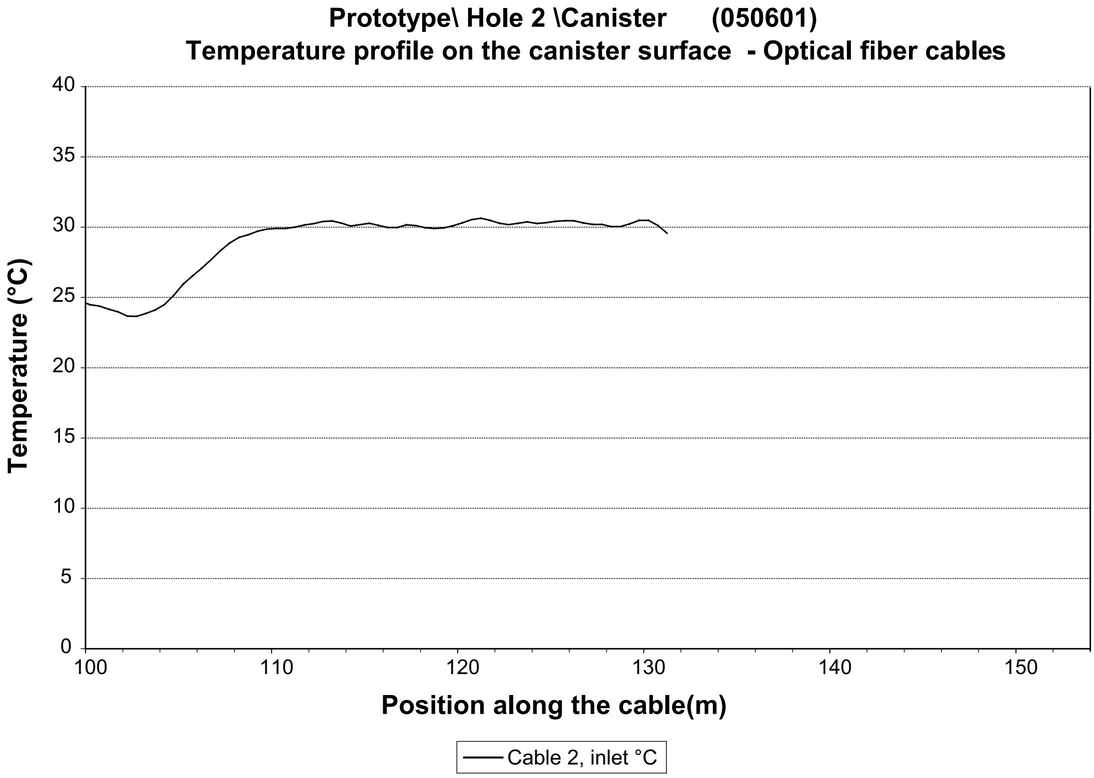

Prototype\ Hole 3 \Canister (050601)
Temperature profile on the canister surface - Optical fiber cables
Temperature (°C)
120
110
100
90
80
70
60
50
40
30
20
100
105
110
115
120
125
130
135
Position along the cable(m)
Cable 2, inlet °C

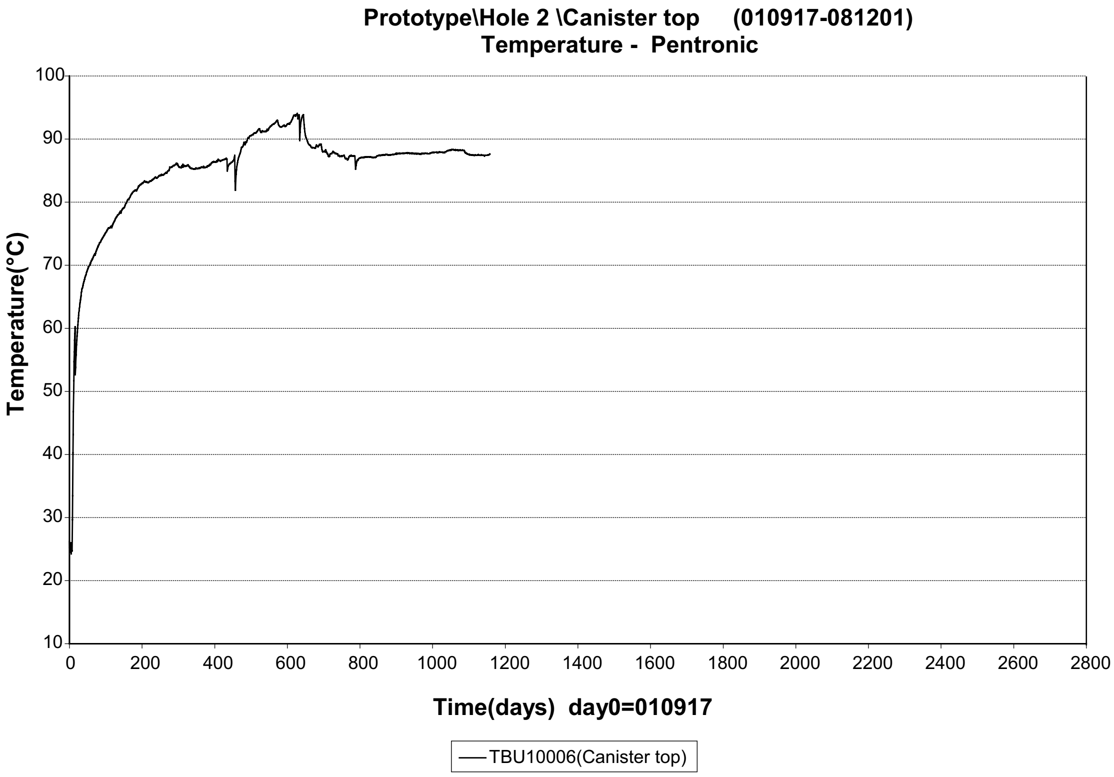
Dep. holes 2 and 4

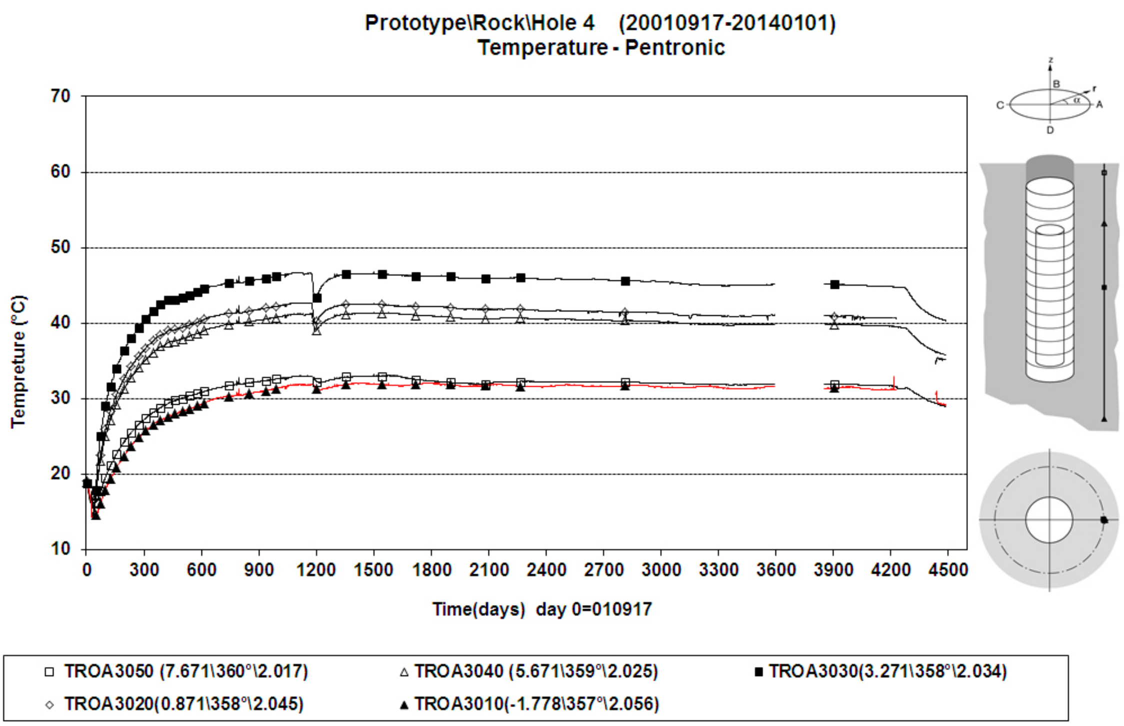




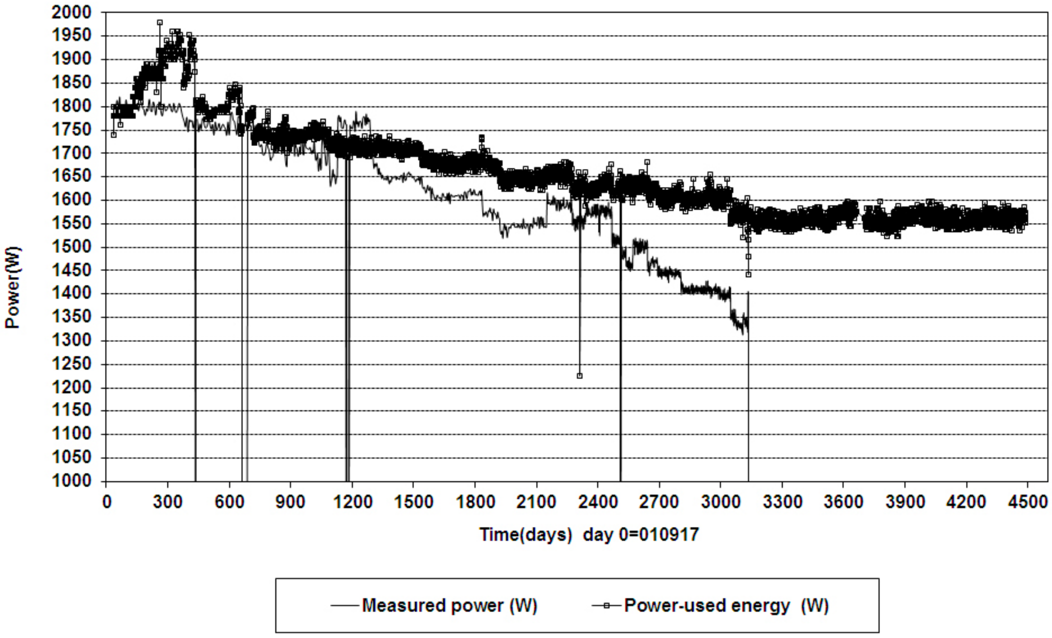

Prototype\ Hole 2 \Canister (010917-070601)
Max. temperature on the canister surface - Optical fiber cables
Temperature (°C)
Time(days) day 0=010917
Cable 1, outlet °C
Cable 1, inlet °C
Cable 2, outlet °C
Cable 2, inlet °C


Prototype\ Hole 2 \Canister (050601)
Temperature profile on the canister surface - Optical fiber cables
Temperature (°C)
Position along the cable(m)
Cable 2, inlet °C

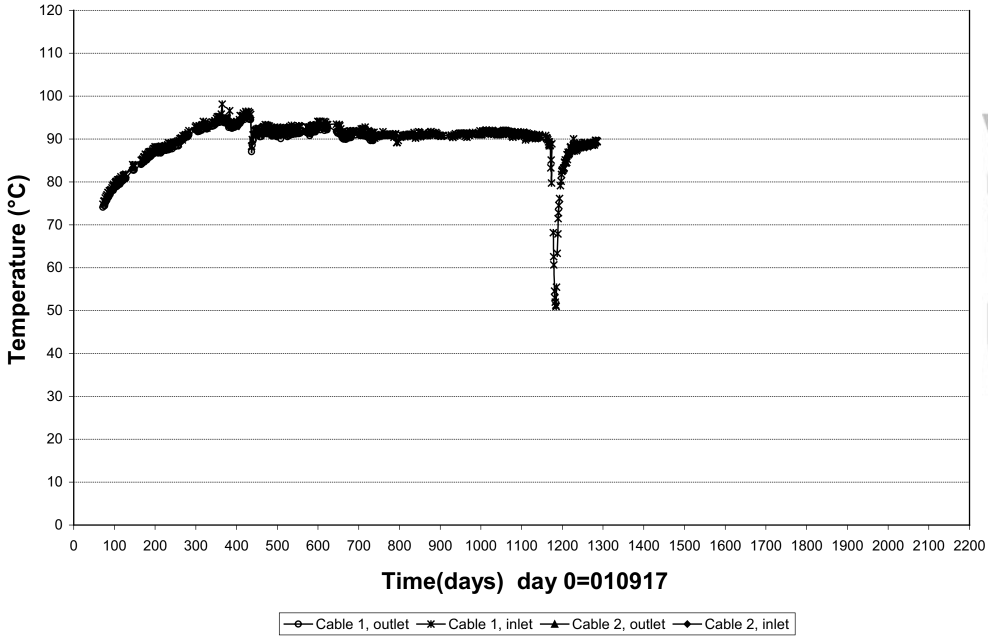

Prototype\Hole 2 \Canister top (010917-081201)
Temperature - Pentronic
Temperature(°C)
Time(days) day0=010917
TBU10006(Canister top)

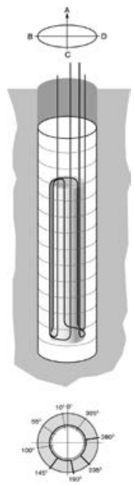

Prototype\Rock\Hole 4 (20010917-20140101)
Temperature - Pentronic
Tempreture (°C)
Time(days) day 0=010917
TROA3050 (7.671\360°\2.017)
TROA3040 (5.671\359°\2.025)
TROA3030(3.271\358°\2.034)
TROA3020(0.871\358°\2.045)
TROA3010(-1.778\357°\2.056)

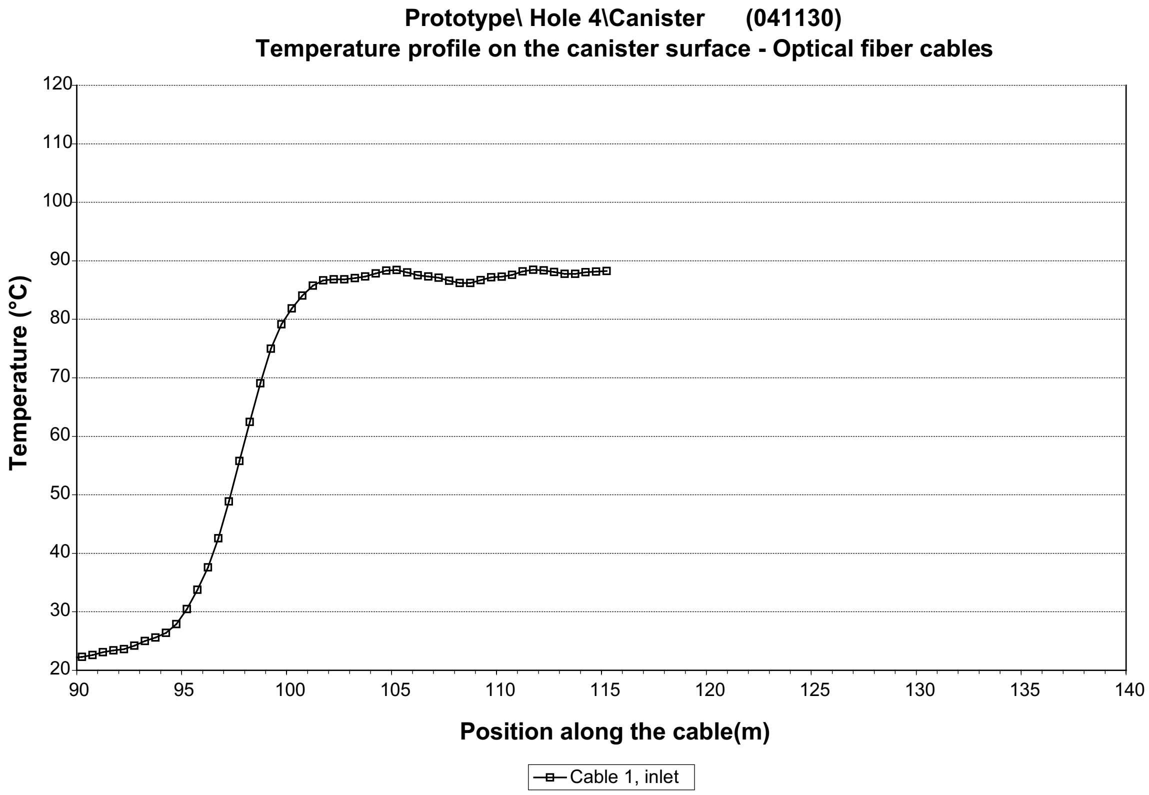
Prototype\Hole 4 (20010917-20140101)
Canister power



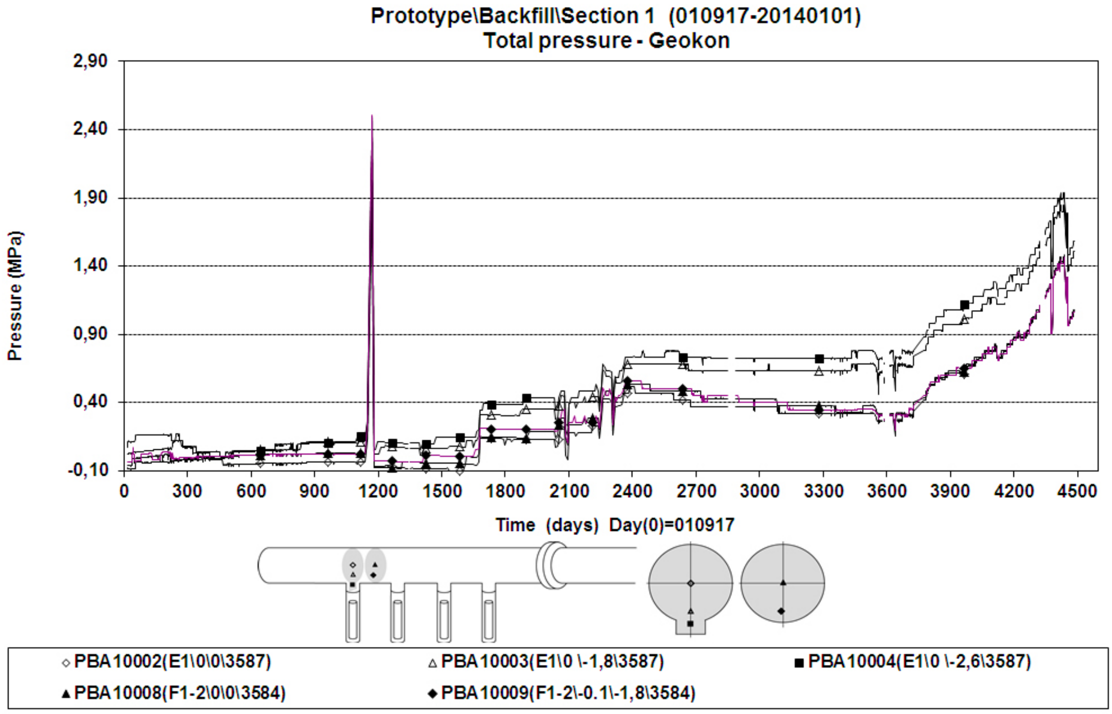
Prototype\ Hole 4 \Canister (010917-070601)
Max. temperature on the canister surface - Optical fiber cables

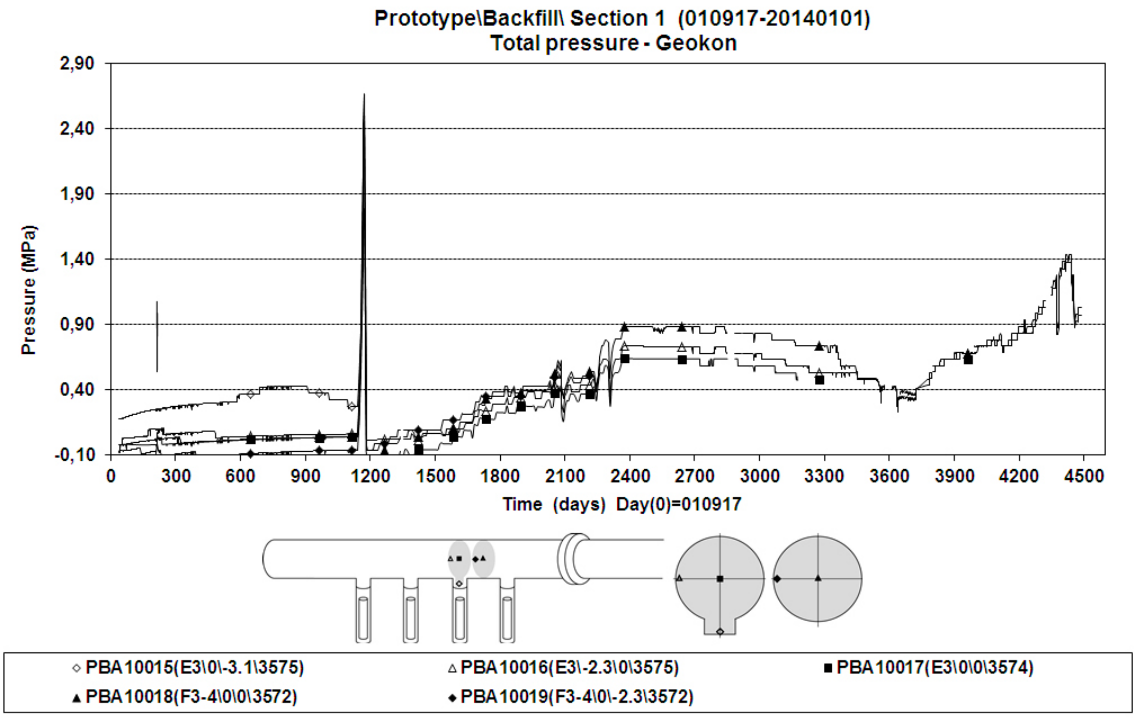


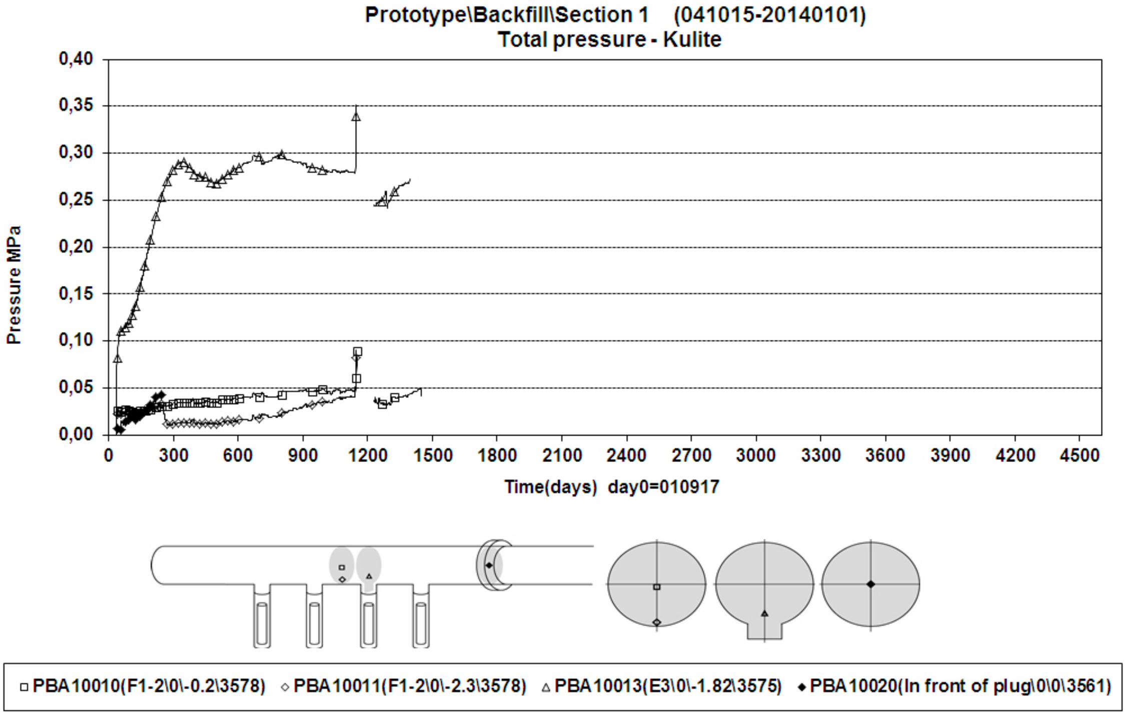



Prototype\ Hole 4\Canister (041130)
Temperature profile on the canister surface - Optical fiber cables
Temperature (°C)
120
110
100
90
80
70
60
50
40
30
20
90
95
100
105
110
115
120
125
130
135
140
Position along the cable(m)
Cable 1, inlet

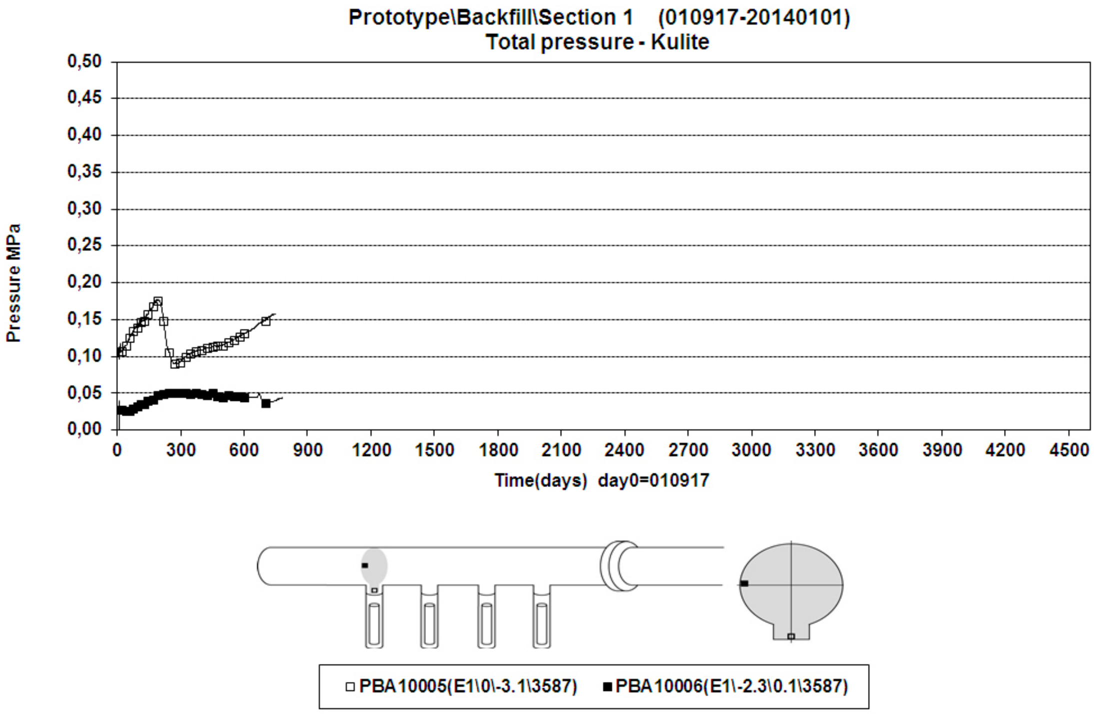
Backfill in Section 1



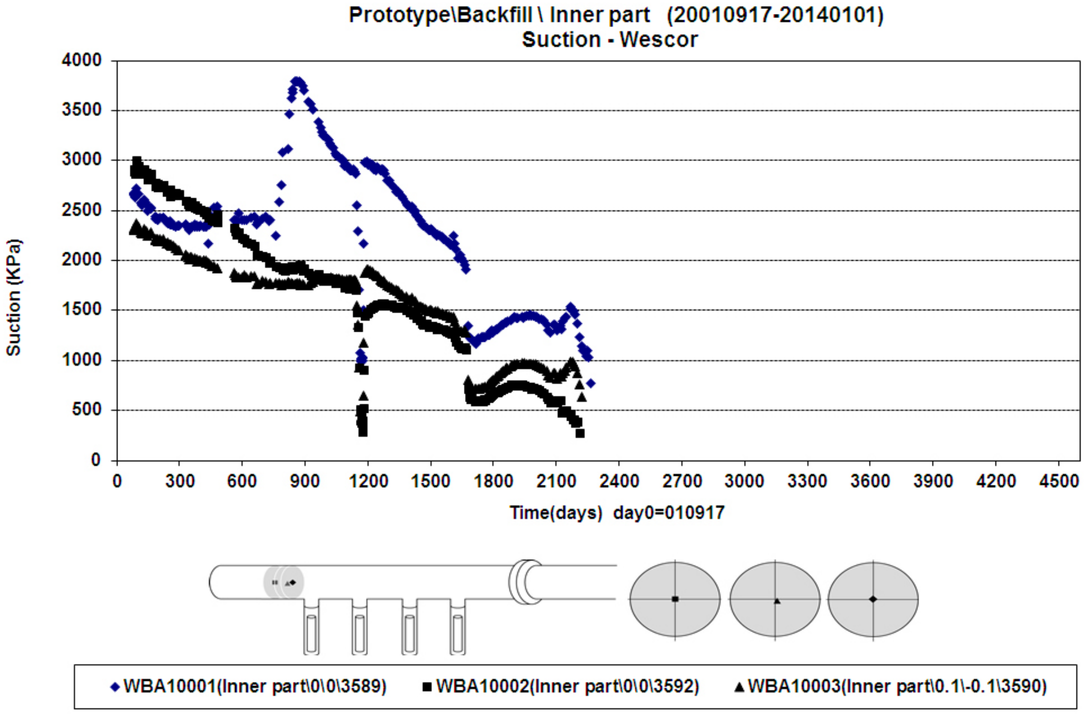


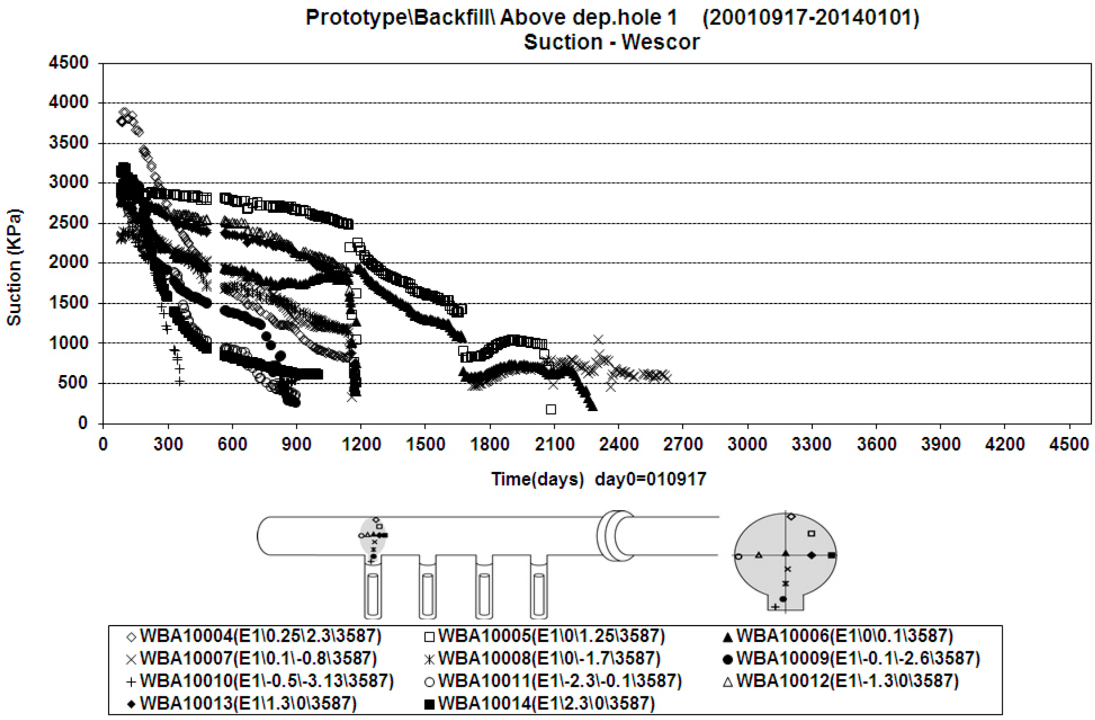


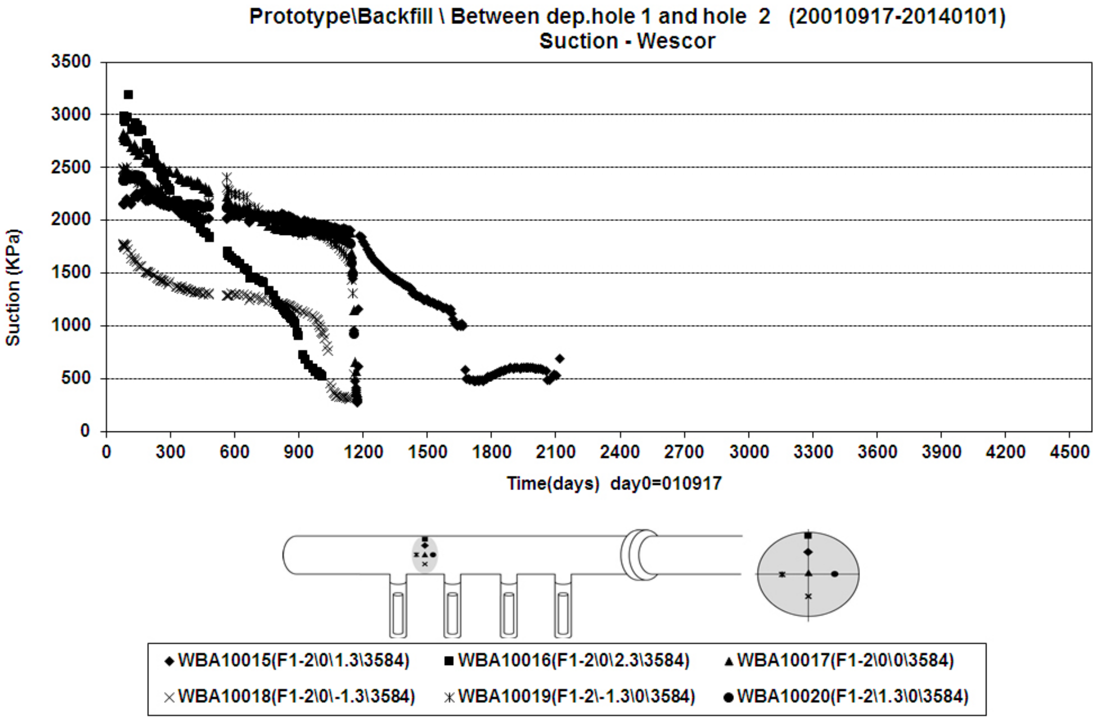
Prototype\Backfill\Section 1 (041015-20140101)
Total pressure - Kulite
Pressure MPa
0,40
0,35
0,30
0,25
0,20
0,15
0,10
0,05
0,00
0
300
600
900
1200
1500
1800
2100
2400
2700
3000
3300
3600
3900
4200
4500
Time(days) day0=010917
PBA10010(F1-2\0\-0.2\3578)
PBA10011(F1-2\0\-2.3\3578)
PBA10013(E3\0\-1.82\3575)
PBA10020(In front of plug\0\0\3561)

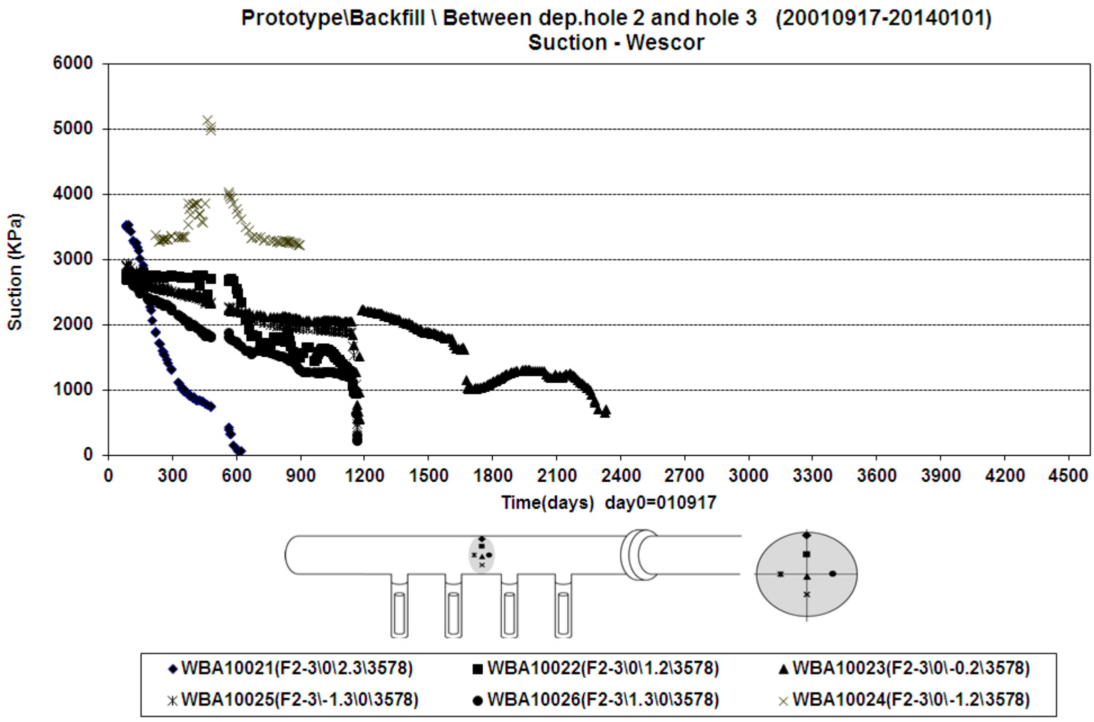


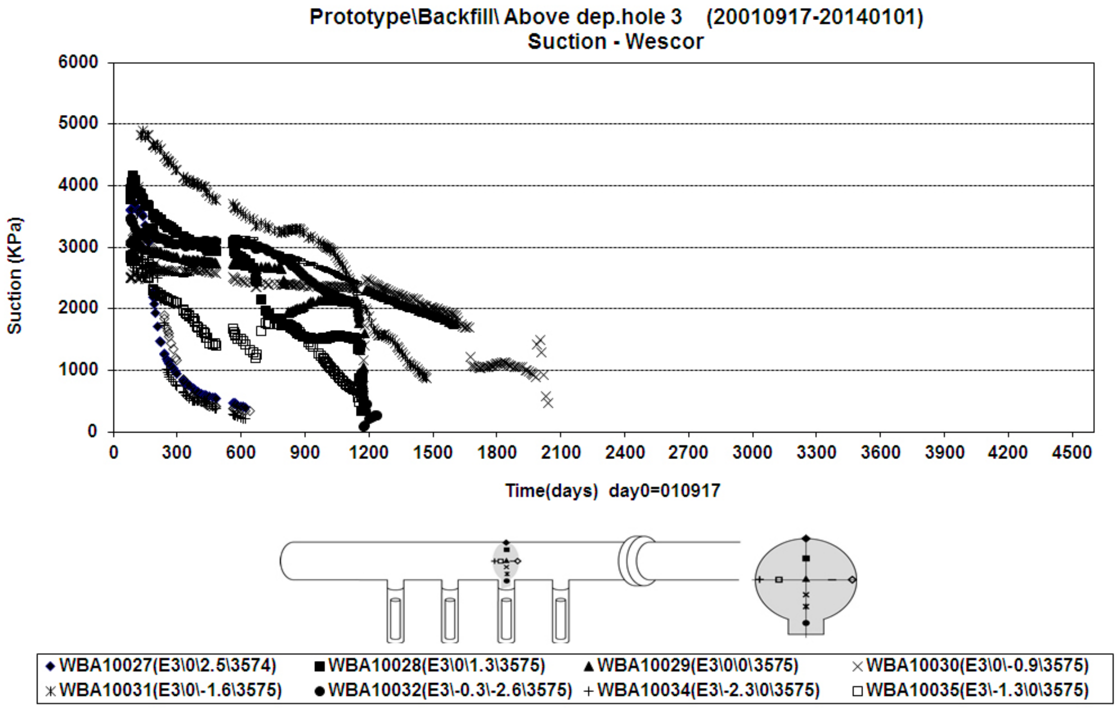
Prototype\Backfill\Section 1 (010917-20140101)
Total pressure - Kulite
Pressure MPa
0,50
0,45
0,40
0,35
0,30
0,25
0,20
0,15
0,10
0,05
0,00
0
300
600
900
1200
1500
1800
2100
2400
2700
3000
3300
3600
3900
4200
4500
Time(days) day0=010917
PBA10005(E1\0\-3.1\3587)
PBA10006(E1\-2.3\0.1\3587)


Prototype\Backfill \ Inner part (20010917-20140101)
Suction - Wescor
Suction (KPa)
Time(days) day0=010917
WBA10001(Inner part\0\0\3589)
WBA10002(Inner part\0\0\3592)
WBA10003(Inner part\0.1\-0.1\3590)

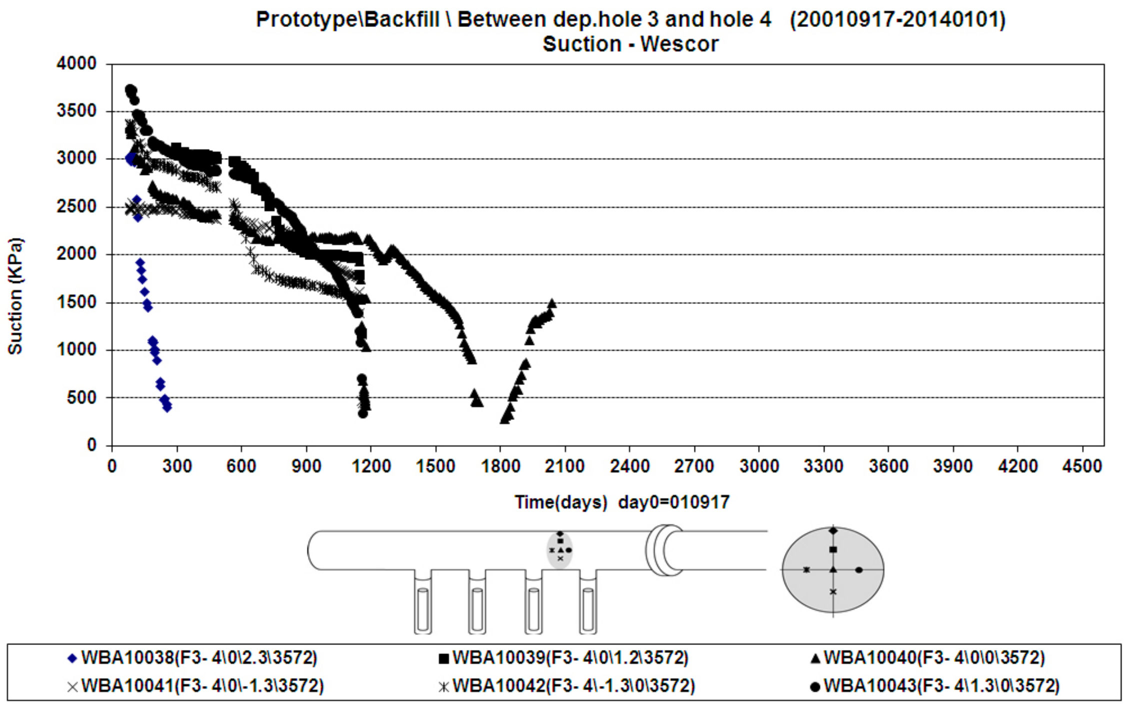

Prototype\Backfill\ Above dep.hole 1 (20010917-20140101)
Suction - Wescor
Suction (KPa)
Time(days) day0=010917
WBA10004(E1\0.25\2.3\3587)
WBA10005(E1\0\1.25\3587)
WBA10006(E1\0\0.1\3587)
WBA10007(E1\0.1\-0.8\3587)
WBA10008(E1\0\-1.7\3587)
WBA10009(E1\-0.1\-2.6\3587)
WBA10010(E1\-0.5\-3.13\3587)
WBA10011(E1\-2.3\-0.1\3587)
WBA10012(E1\-1.3\0\3587)
WBA10013(E1\1.3\0\3587)
WBA10014(E1\2.3\0\3587)


Prototype\Backfill \ Between dep.hole 1 and hole 2 (20010917-20140101)
Suction - Wescor
Suction (KPa)
Time(days) day0=010917
WBA10015(F1-2\0\1.3\3584)
WBA10016(F1-2\0\2.3\3584)
WBA10017(F1-2\0\0\3584)
WBA10018(F1-2\0\-1.3\3584)
WBA10019(F1-2\-1.3\0\3584)
WBA10020(F1-2\1.3\0\3584)

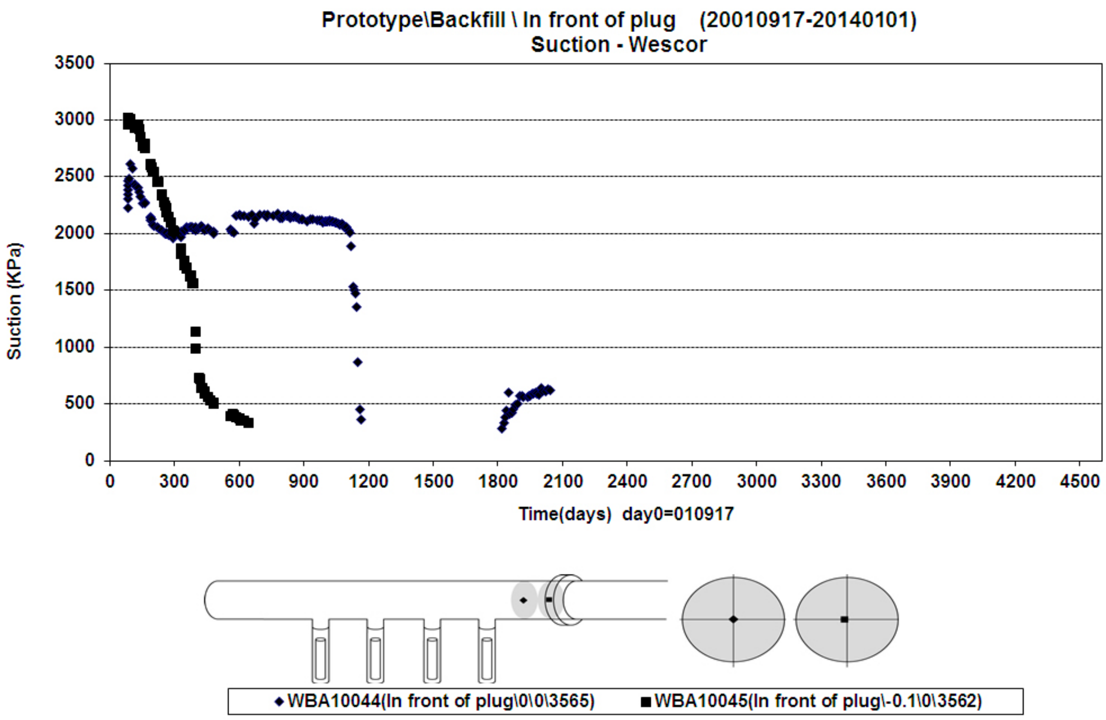

Prototype\Backfill \ Between dep.hole 2 and hole 3 (20010917-20140101)
Suction - Wescor
Suction (KPa)
Time(days) day0=010917
WBA10021(F2-3\0\2.3\3578)
WBA10022(F2-3\0\1.2\3578)
WBA10023(F2-3\0\-0.2\3578)
WBA10025(F2-3\-1.3\0\3578)
WBA10026(F2-3\1.3\0\3578)
WBA10024(F2-3\0\-1.2\3578)

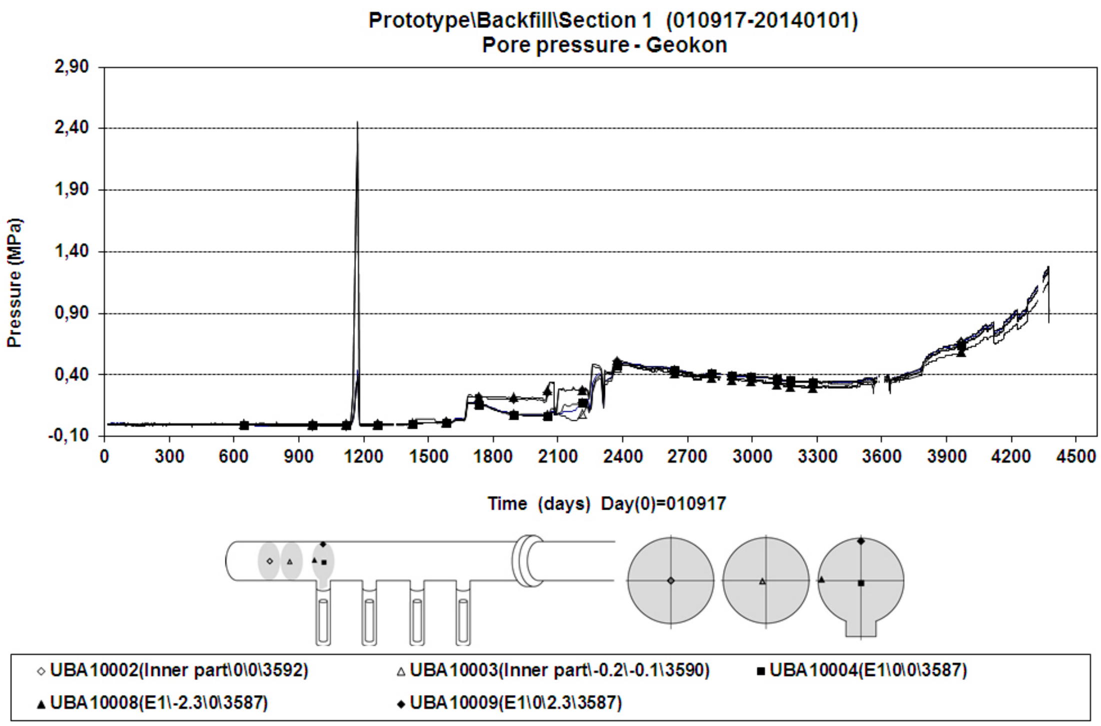


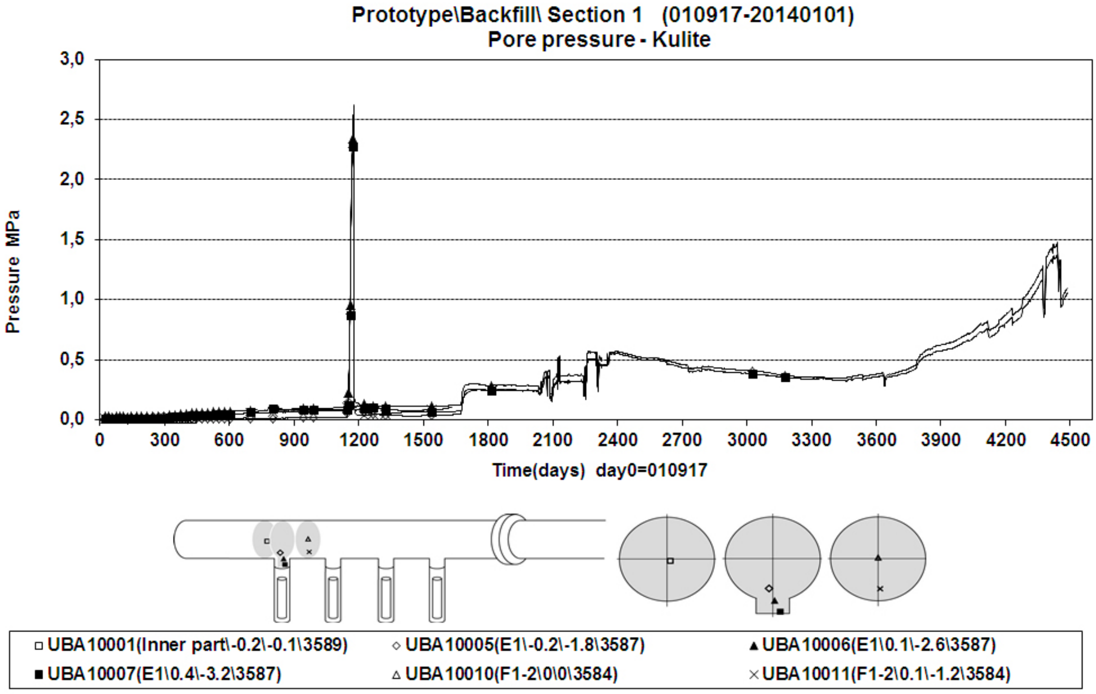
Prototype\Backfill\ Above dep.hole 3 (20010917-20140101)
Suction - Wescor
Suction (KPa)
Time(days) day0=010917
WBA10027(E3\0\2.5\3574)
WBA10028(E3\0\1.3\3575)
WBA10029(E3\0\0\3575)
WBA10030(E3\0\-0.9\3575)
WBA10031(E3\0\-1.6\3575)
WBA10032(E3\-0.3\-2.6\3575)
WBA10034(E3\-2.3\0\3575)
WBA10035(E3\-1.3\0\3575)

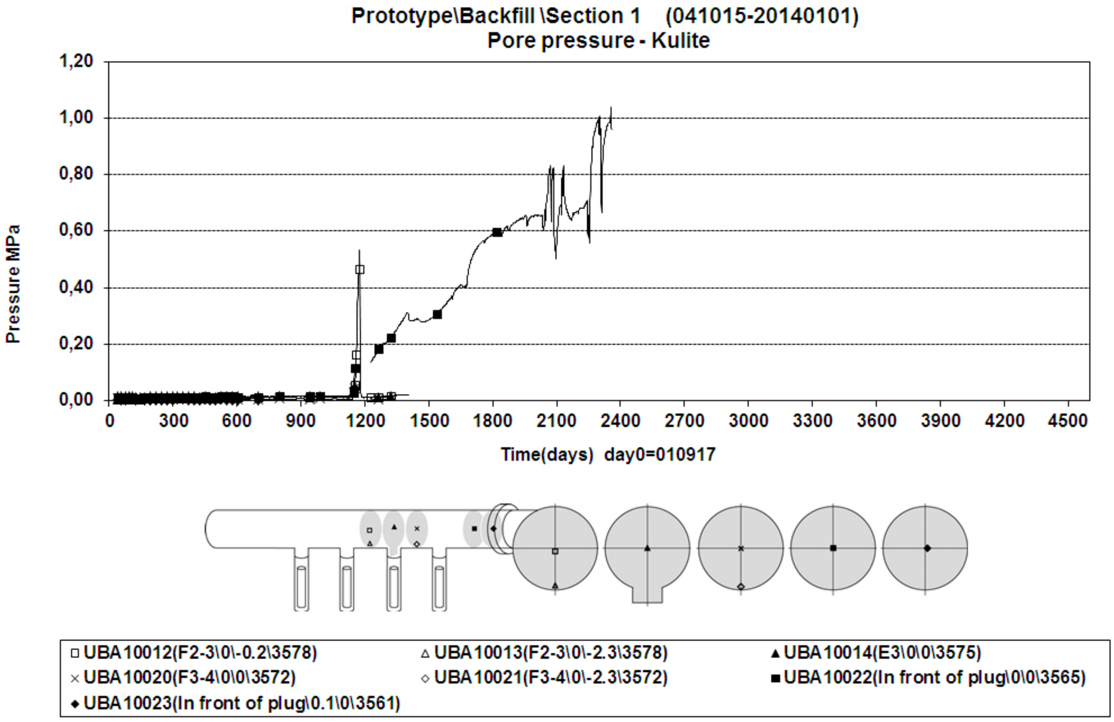


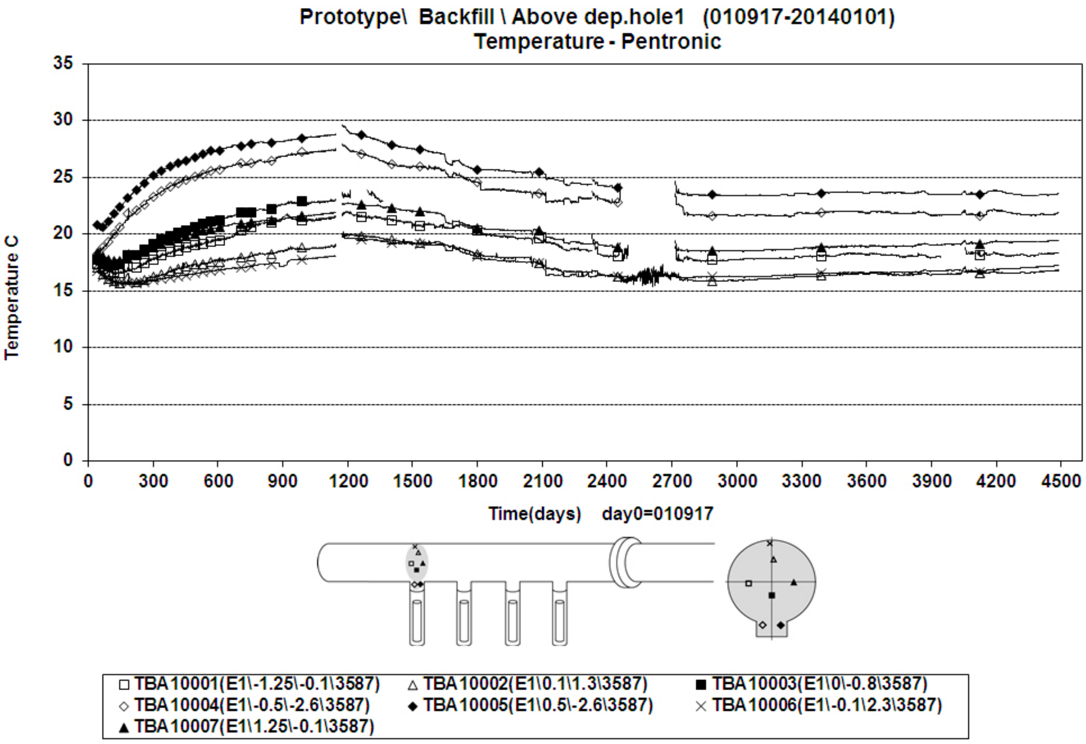
Prototype\Backfill \ Between dep.hole 3 and hole 4 (20010917-20140101)
Suction - Wescor
Suction (KPa)
Time(days) day0=010917
WBA10038(F3- 4\0\2.3\3572)
WBA10039(F3- 4\0\1.2\3572)
WBA10040(F3- 4\0\0\3572)
WBA10041(F3- 4\0\-1.3\3572)
WBA10042(F3- 4\-1.3\0\3572)
WBA10043(F3- 4\1.3\0\3572)


Prototype\Backfill \ In front of plug (20010917-20140101)
Suction - Wescor
Suction (KPa)
Time(days) day0=010917
WBA10044(In front of plug\0\0\3565)
WBA10045(In front of plug\-0.1\0\3562)

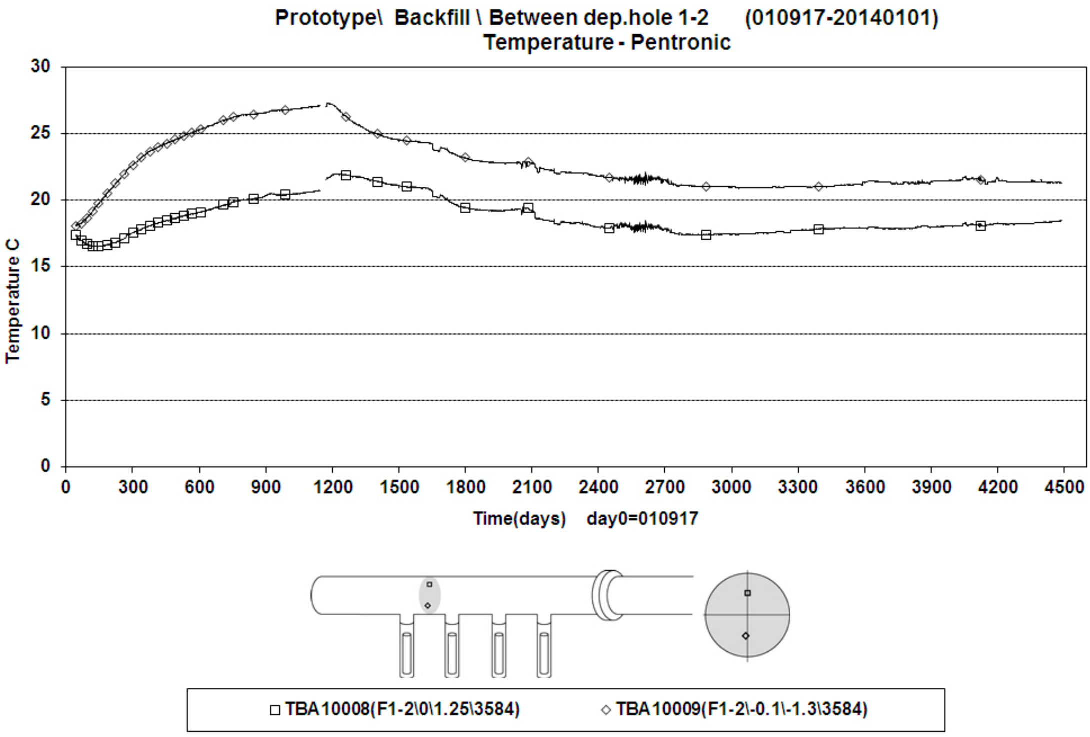

Prototype\Backfill\Section 1 (010917-20140101)
Pore pressure - Geokon
Pressure (MPa)
Time (days) Day(0)=010917
UBA10002(Inner part\0\0\3592)
UBA10003(Inner part\-0.2\-0.1\3590)
UBA10004(E1\0\0\3587)
UBA10008(E1\-2.3\0\3587)
UBA10009(E1\0\2.3\3587)


Prototype\Backfill\ Section 1 (010917-20140101)
Pore pressure - Kulite
Pressure MPa
Time(days) day0=010917
UBA10001(Inner part\-0.2\-0.1\3589)
UBA10005(E1\-0.2\-1.8\3587)
UBA10006(E1\0.1\-2.6\3587)
UBA10007(E1\0.4\-3.2\3587)
UBA10010(F1-2\0\0\3584)
UBA10011(F1-2\0.1\-1.2\3584)

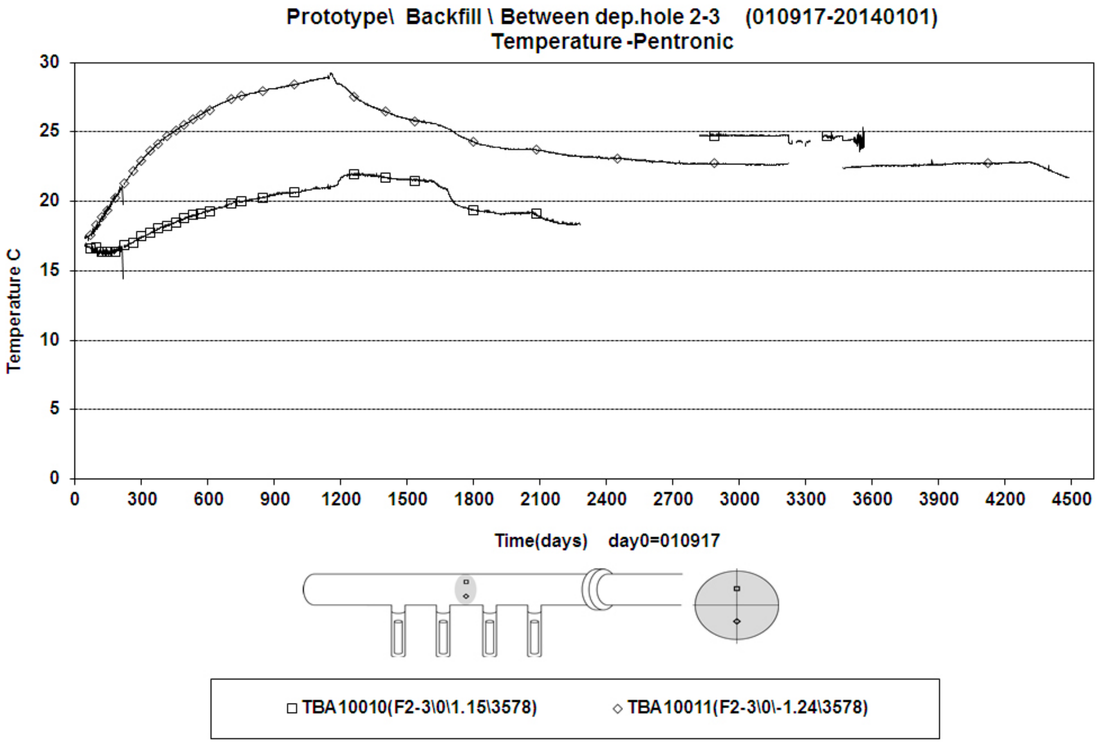

Prototype\Backfill \Section 1 (041015-20140101)
Pore pressure - Kulite
Pressure MPa
Time(days) day0=010917
UBA10012(F2-3\0\-0.2\3578)
UBA10013(F2-3\0\-2.3\3578)
UBA10014(E3\0\0\3575)
UBA10020(F3-4\0\0\3572)
UBA10021(F3-4\0\-2.3\3572)
UBA10022(In front of plug\0\0\3565)
UBA10023(In front of plug\0.1\0\3561)



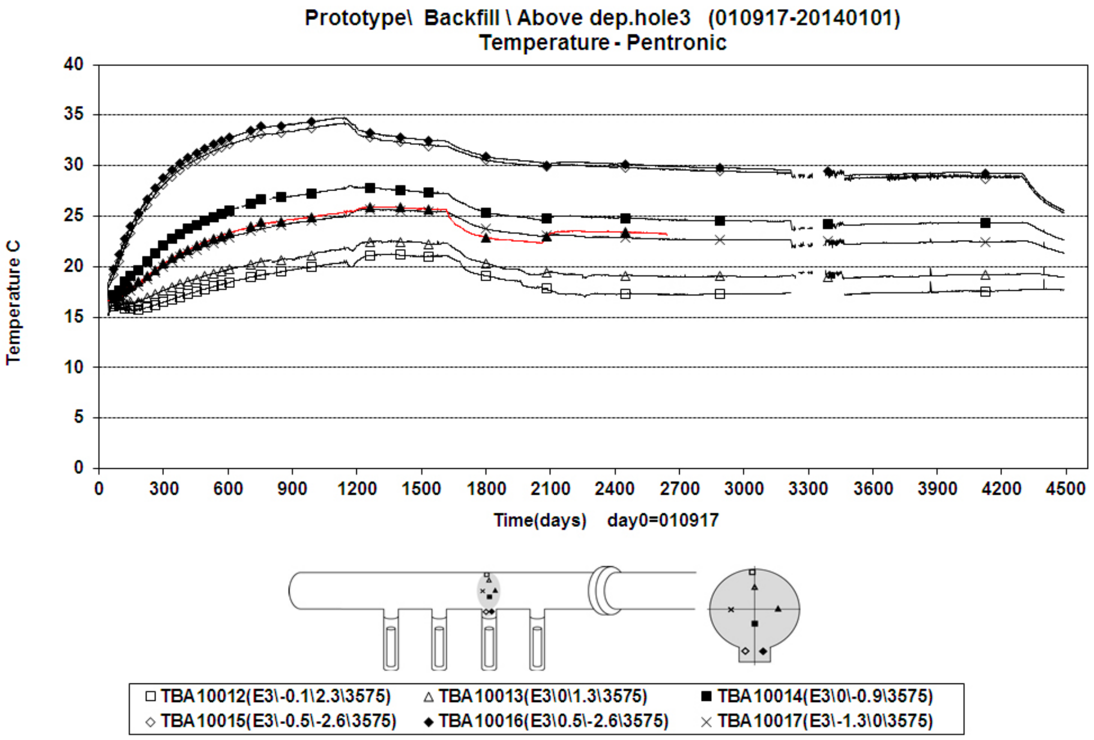
Prototype\ Backfill \ Above dep.hole1 (010917-20140101)
Temperature - Pentronic
Temperature C
Time(days) day0=010917
TBA10001(E1\-1.25\-0.1\3587)
TBA10002(E1\0.1\1.3\3587)
TBA10003(E1\0\-0.8\3587)
TBA10004(E1\-0.5\-2.6\3587)
TBA10005(E1\0.5\-2.6\3587)
TBA10006(E1\-0.1\2.3\3587)
TBA10007(E1\1.25\-0.1\3587)



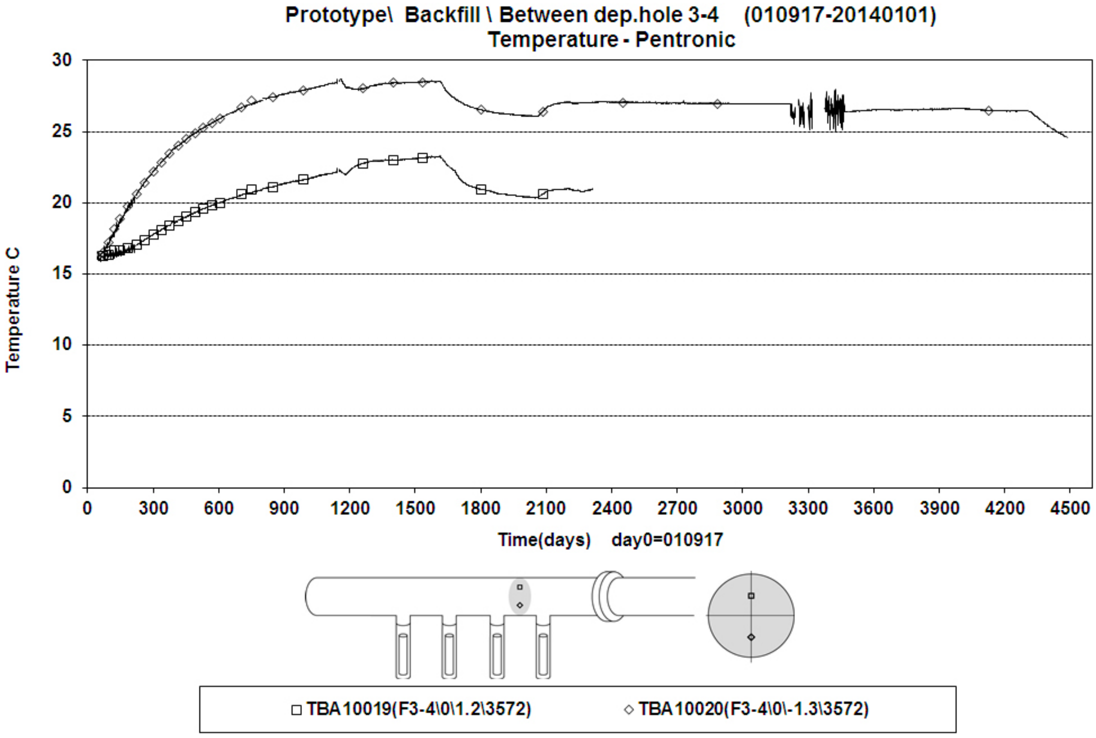
Prototype\ Backfill \ Between dep.hole 1-2 (010917-20140101)
Temperature - Pentronic
Temperature C
Time(days) day0=010917
TBA10008(F1-2\0\1.25\3584)
TBA10009(F1-2\-0.1\-1.3\3584)



Prototype\ Backfill \ Between dep.hole 2-3 (010917-20140101)
Temperature -Pentronic
Temperature C
Time(days) day0=010917
TBA10010(F2-3\0\1.15\3578)
TBA10011(F2-3\0\-1.24\3578)



Prototype\ Backfill \ Above dep.hole3 (010917-20140101)
Temperature - Pentronic
Temperature C
Time(days) day0=010917
TBA10012(E3\-0.1\2.3\3575)
TBA10013(E3\0\1.3\3575)
TBA10014(E3\0\-0.9\3575)
TBA10015(E3\-0.5\-2.6\3575)
TBA10016(E3\0.5\-2.6\3575)
TBA10017(E3\-1.3\0\3575)


Prototype\ Backfill \ Between dep.hole 3-4 (010917-20140101)
Temperature - Pentronic
Temperature C
30
25
20
15
10
5
0
0
300
600
900
1200
1500
1800
2100
2400
2700
3000
3300
3600
3900
4200
4500
Time(days) day0=010917
TBA10019(F3-4\0\1.2\3572)
TBA10020(F3-4\0\-1.3\3572)

Appendix 5

Canister displacement tracking

A5.1 Layout

Section 2 of the experiment was dismantled in February 2011, including the removal and decommissioning of sensors MCA60001 to MCA60006 in deposition hole 6. Therefore, those sensors are not considered any more in the data reports.

The measurement of displacements is carried out in Section 1 on the canister in deposition hole 3. Sensors are grouped into one measuring section at the bottom of the canister, as shown in Figure A5-1.

Three sensors, named MCA30001 to MCA30003, have been placed in vertical position into holes drilled into the bottom bentonite block. These three sensors determine the vertical displacement of the canister, as well as any possible tilt. The points where the sensors are attached to the canister are the same as for the horizontal sensors.

The other three displacement sensors, named MCA30004 to MCA30006, are placed horizontally at the top of the lower bentonite block, close to the lower lid of the canister and attached to it, in a 120° radial disposition. Thus, the sensors will be always in a horizontal position, so that the horizontal displacement of the canister can be measured. The sensors have been placed so as to avoid interfering with other sensors installed in the block. Figure A5-2 illustrates the position of the six sensors.

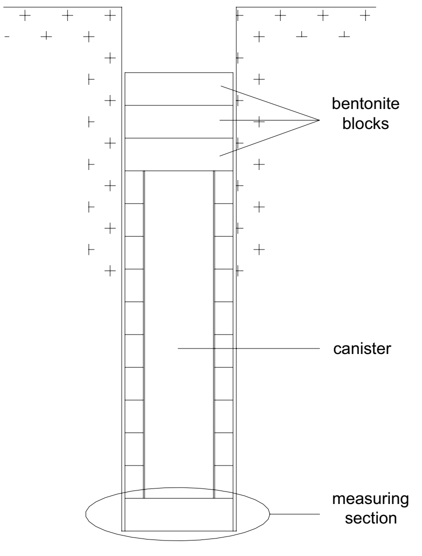


Figure A5-1. *Location of measuring section for deposition hole 3.*

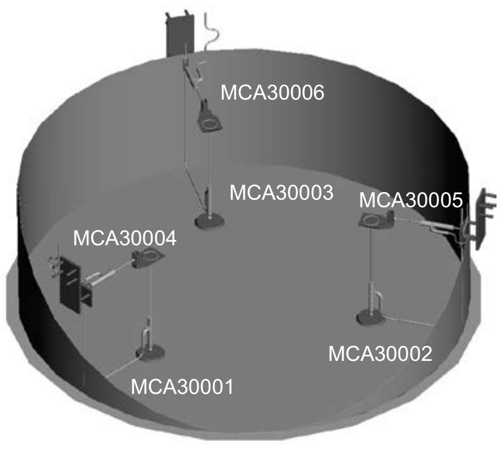


Figure A5-2. *General view of sensors in deposition hole 3.*

A5.2 General comments

This is the seventeenth “Prototype Repository in Operation” report issued for SKB, and the second annual one, and contains data up to 131231 (day 4,488 for dep. hole 3).

Monitoring is carried out since 010623 in deposition hole 3, and day 0 corresponds to 010917. Negative values correspond to a retraction of the transducer, which means vertical sinking or horizontal approaching to the rock surface, depending on the transducer position.

During the installation, it can be clearly noticed the moment when the protection plastic sheet was removed, right before the backfilling of the tunnel. At that point, the sensors started registering displacements due to the bentonite swelling.

The tunnel drainage was closed on 041101 (day 1,141) and re-opened on day 041206 (day 1,176). There was a power cut in all the canisters from 041202 (day 1,172) to 041215 (day 1,185).

The closure and subsequent re-opening of the tunnel drainage seemed to have a high influence. In comparison, the power cut had little effect in general in this hole.

A major problem was detected in the computer of the Data Acquisition System in September 2005. As a consequence, no data could be registered from 050925 (day 1,469) to 060207 (day 1,604), when the computer was checked “in situ” and put again in operation. On 060408 (day 1,664) the computer failed again, so no data was registered from that date until the problem was fixed on 060616 (day 1,733) by replacing the computer’s full hard drive. Other fails in the computer resulted in data loss from 070813 (day 2,156) to 070930 (day 2,204) and from 080425 (day 2,412) to 080513 (day 2,430).

The computer failed again in September 2008, so no data could be registered from 080930 (day 2,570) until 090225 (day 2,718), when the computer was replaced by a new one.

The data acquisition unit failed on 110225 (day 3,448). After some in situ checking to determine the problem, the unit came back to normal operation on 110419 (day 3,501).

One sensor out of the 6 installed in deposition hole 3 failed permanently on 020112 (day 117) during the monitoring phase until the end of this period: vertical sensor MCA30002.

The data acquisition unit failed again on 120108 (day 3,785). This time, in situ actions were not sufficient and the unit had to be sent to reparation. The unit was installed back on 120917 (day 4,018).

The data acquisition unit experienced a new failing period from 130926 (day 4,392) to 131008 (day 4,404). In situ actions did not succeed but after several remote testing proceedings the unit came back to normal performance.

The results obtained are described hereafter. Monitoring screens correspond to data of 131231 (day 4,488).

A5.3 Deposition hole 3

A5.3.1 Vertical sensors

Two vertical sensors are still in operation in this deposition hole. After an initial small rise of about 0.5 mm, the sensors showed a fast canister sinking that reached about 2 mm below the initial level, when, most likely due to the re-equilibration of pressures below and above the canister, the decrease ceased and the canister started to rise again.

From day 1,163 (041123), a fast sink of the canister could be noticed, in both vertical sensors at the same time. This could be due to the increase of pressure on top of the canister caused by the closure of the tunnel drainage, which was done 23 days before, on day 1,141 (041101). The canister sank 3 mm in two weeks, until day 1,176 (041206) when the drainage was opened again. On that point the canister experienced a fast rise, of one mm in one day.

Afterwards one of the vertical sensors (MCA30003) kept showing an elongation at a similar slow rate as before the events, while in the other vertical sensor still operative (MCA30001) the trend changed to a slight retraction. This could indicate that a small canister tilting had taken place, although the third value for defining the plane of the canister base is unavailable, and no clear signs of tilting were noticed in the corresponding horizontal sensors during that period.

The retraction trend of sensor MCA30001 stopped more than two years ago, being this sensor in a nearly constant value since. The elongation of sensor MCA30003 seemed to have stopped too, but in the last three years it can be noticed that the elongation continues in both sensors at a very slow rate, which again could indicate a very slight tilting, that cannot be confirmed without the third vertical sensor.

During the last year, a small rise (tenths of millimetres) occurred on both vertical sensors at the same time from day 130520 (4,263) to day 130606 (4,280) approx. Again, it is not possible to assert a canister tilting due to the lack of the third sensor, and in addition no correlation for this rise can be appreciated in the horizontal sensors in those dates.

A5.3.2 Horizontal sensors

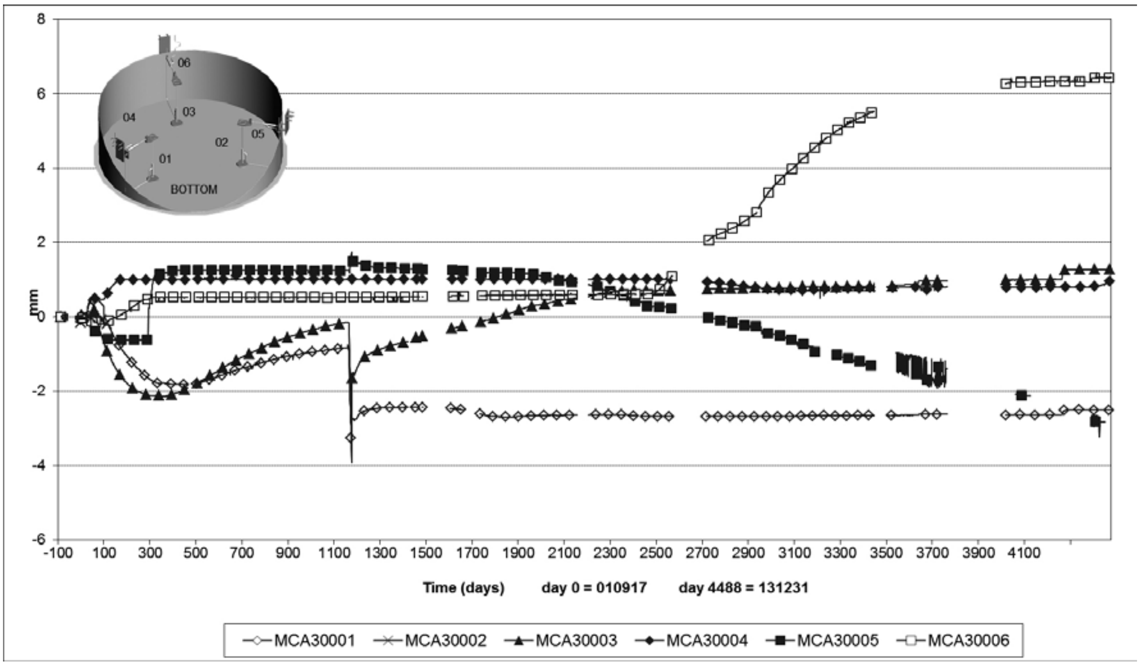
At the start of the monitoring phase, two of the horizontal sensors registered an initial small retraction, while the third one registered a similar elongation, all in the order of half of millimetre. This could indicate a horizontal displacement of the canister. Afterwards, the two sensors showing retraction changed to elongations of about 0.5 mm and 1.5 mm. One of the changes was very fast. No changes were registered in the third sensor, so it is not clear that this is due to a horizontal displacement of the canister. A possible explanation for this behaviour is that it is due to the vertical movement of the canister, although in principle the anchoring points of the horizontal sensors were conceived not to be affected by vertical displacements of the canister.

No changes were registered afterwards until 041127 (day 1,167 for dep. hole 3), when one of the horizontal sensors showed a fast elongation, followed by a retraction. This behaviour could reflect again the vertical displacement of the canister detected in the same dates, given that the shape of the plot matched exactly the vertical movement and that the other two horizontal sensors showed no displacement.

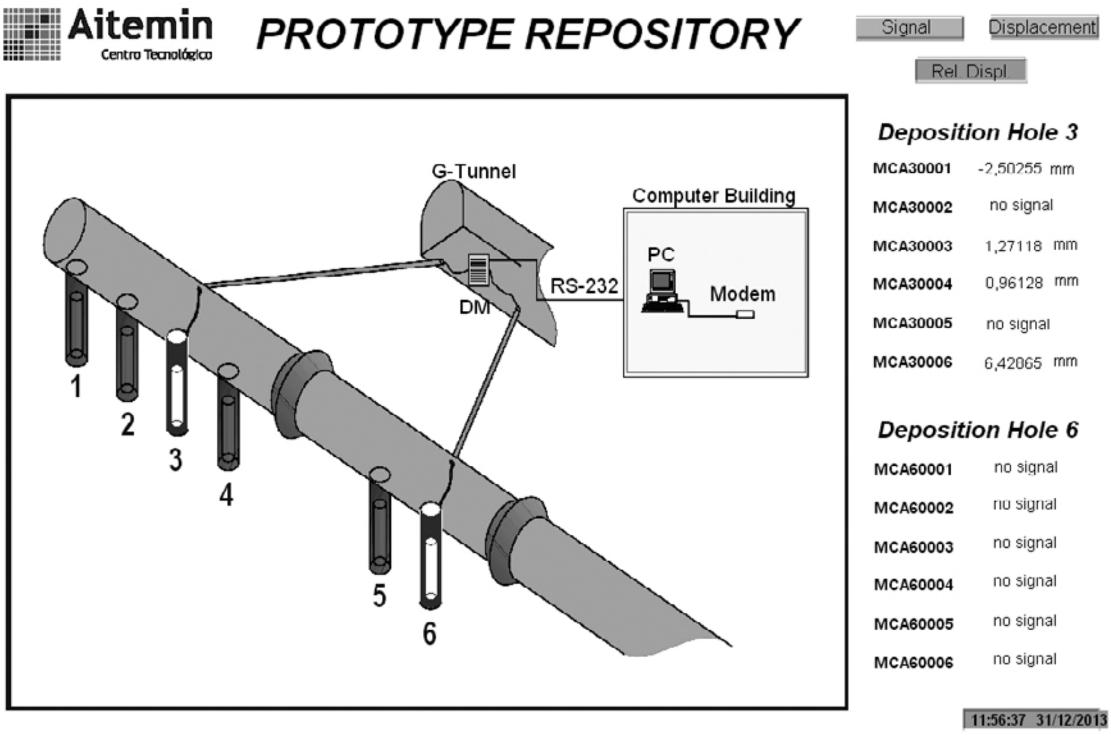
The retraction trend maintained during the last years by sensor MCA30005 is very clear, although values are fluctuating or lacking lately so its reliability might be compromised. Sensor MCA30004 seems to have more or less constant readings, and MCA30006 had an increasing trend before the DMI incident in February, which could be interpreted as a slow horizontal displacement of the canister towards a point located between sensors MCA30004 and MCA30005, and quite closer to the latter, given its higher retraction rate. As pointed out in the previous section, this displacement could be combined with a tiny tilting of the canister.

After the repair of the unit in 2012, trends seem to be maintained for MC30004 and MC30005, while MCA30006 have stopped elongating and shows fairly constant readings instead. Thus it seems the canister tilting is decreasing or even stopped. According to data available in this reported period, trends are maintained except for a small rise in sensor MCA30006, similar to those registered in the horizontal sensors but not exactly coincident in time, and a small increasing slope in sensor MCA30004 by the end of the reported period (starting approx. on day 4,419 corresponding to 23/10/2013).

A5.4 Data plot deposition hole 3



A5.5 Monitoring screens



Appendix 6

Geoelectric monitoring

Introduction

Within the frame of research activities in the prototype repository at Äspö GRS employs measurements of electrical resistivity to monitor water uptake in the drift backfill, the borehole buffer, and desaturation effects around one of the deposition boreholes.

The electrical resistivities in the buffer, the backfill, and around the boreholes are determined by use of multi-electrode arrays. The arrays consist of electrode chains. The resistivity distribution in the areas between the chains is determined by means of tomographic dipole-dipole measurements. The recording unit for these arrays is controlled remotely from Braunschweig / Germany via a telephone connection, which allows daily measurements of the in-situ resistivity distribution. From the measured apparent resistivity values the "true" resistivity distributions in the different parts are computed applying the latest inversion software.

In the geoelectric measurements advantage is taken of the dependence of the electrical resistivity in materials on the water (solution) content. In order to interpret the resistivity values in terms of water content the data are to be compared with laboratory calibration results which are available for the different materials.

In the following, the calculated inversion data for the different arrays are provided in the form of tomograms. Additional data for smaller time periods can be made available on demand.

All geoelectric measurements in Section I of the Prototype Repository were stopped in the course of the dismantling of the Section in 2011. Measurements in the backfill of Section I were continued until June 2013 when all geoelectric measurements at the Prototype Repository were finished.

A6.1 Backfill Section I

A6.1.1 Layout of electrode array in the backfill of Section I

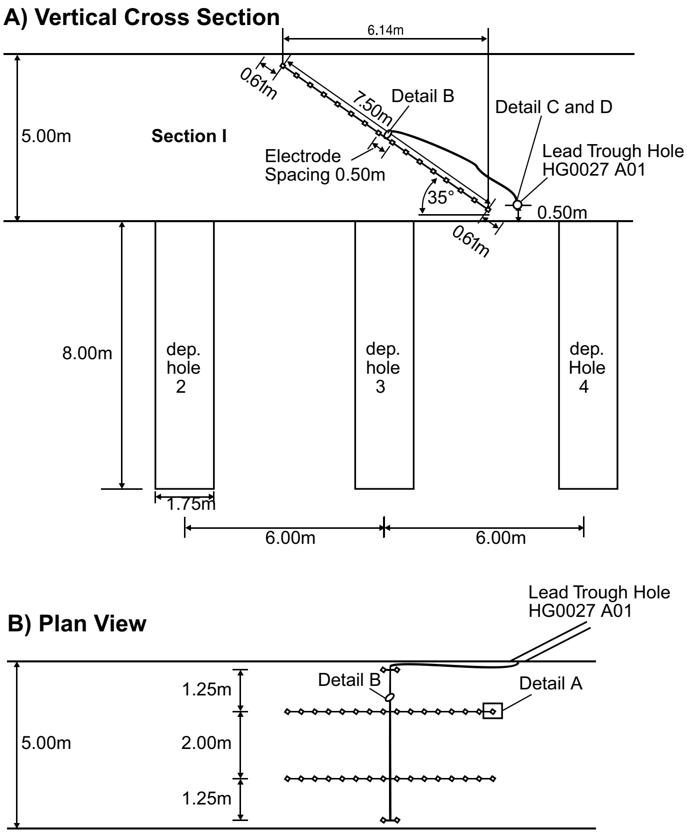
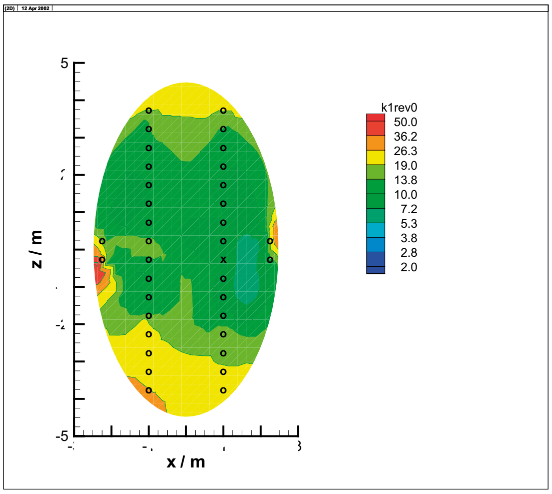
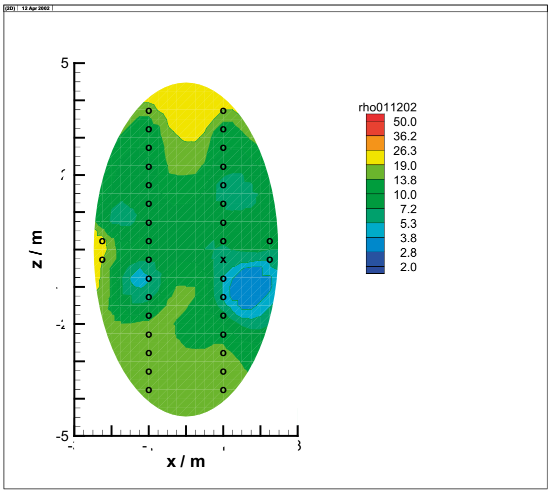


Figure A6-1. *Electrode array in the backfill in Section I.*

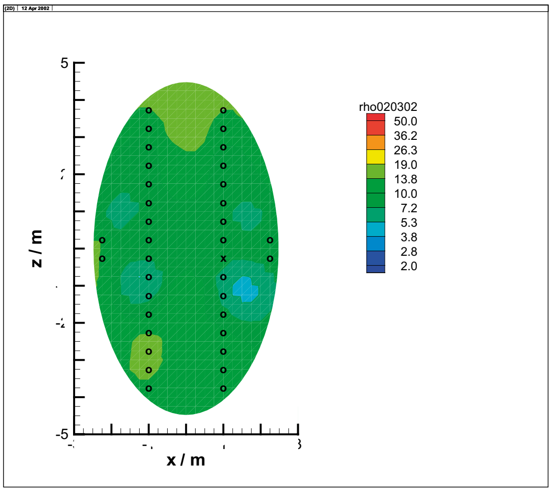
A6.1.2 Tomograms of the backfill array in Section I



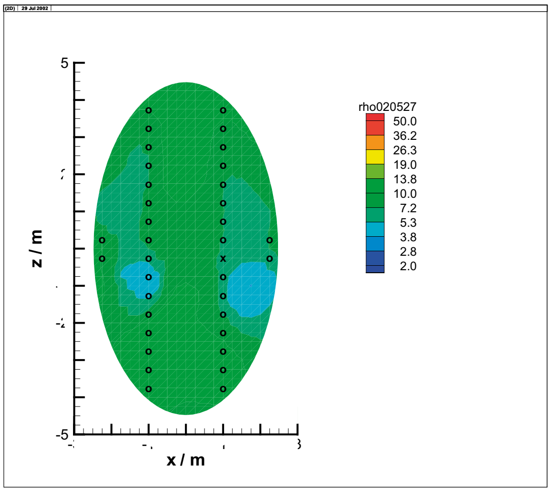
2001-10-27



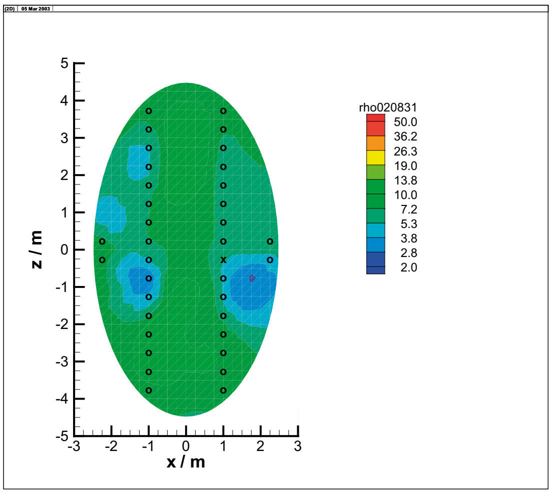
2001-12-02



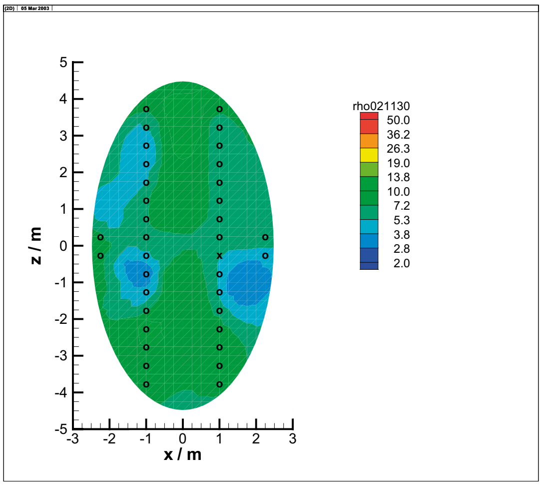
2002-03-02



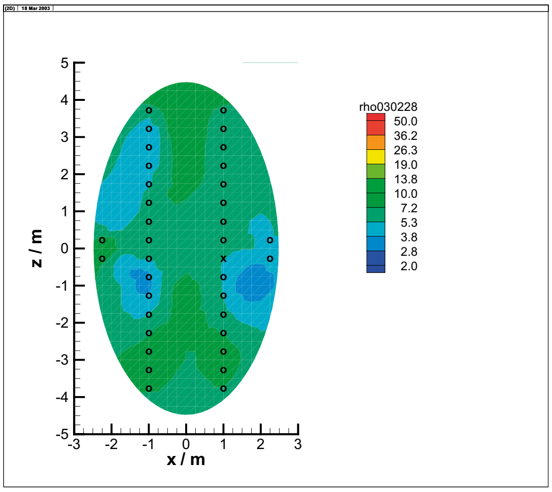
2002-05-27



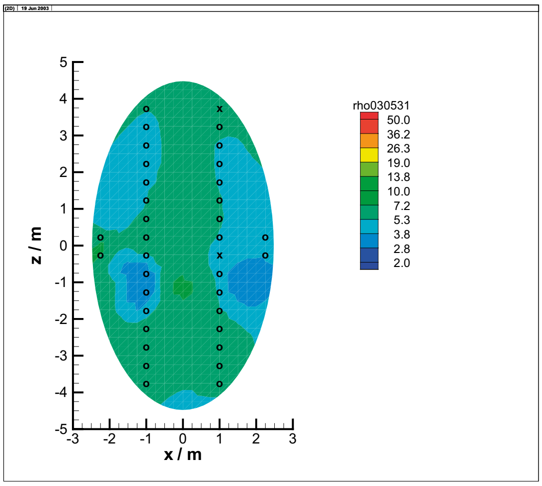
2002-08-31



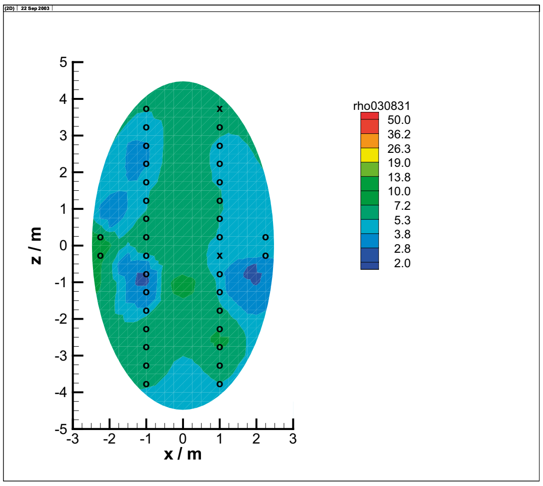
2002-11-30



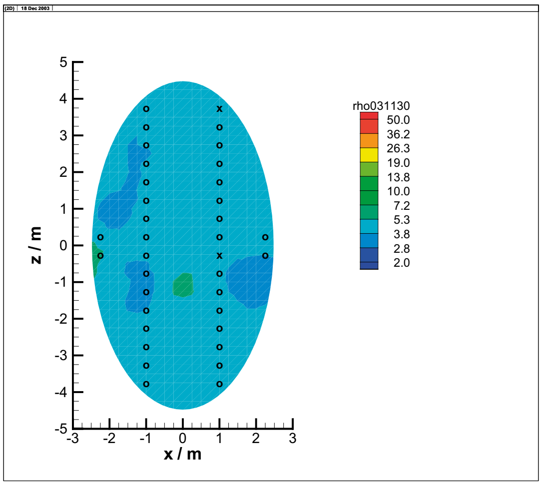
2003-02-28



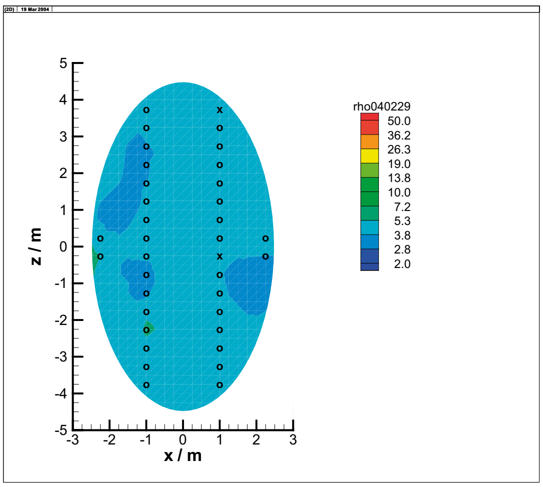
2003-05-31



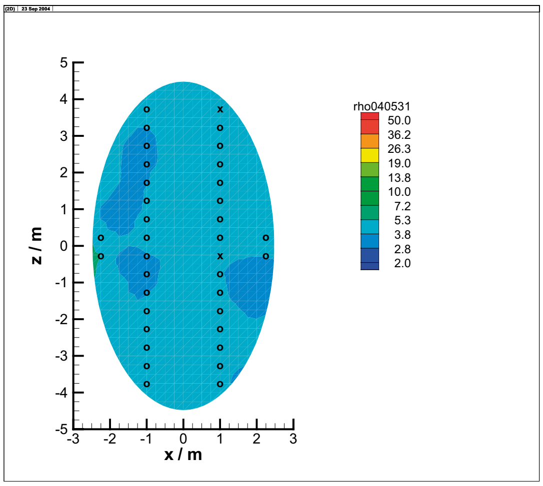
2003-08-31



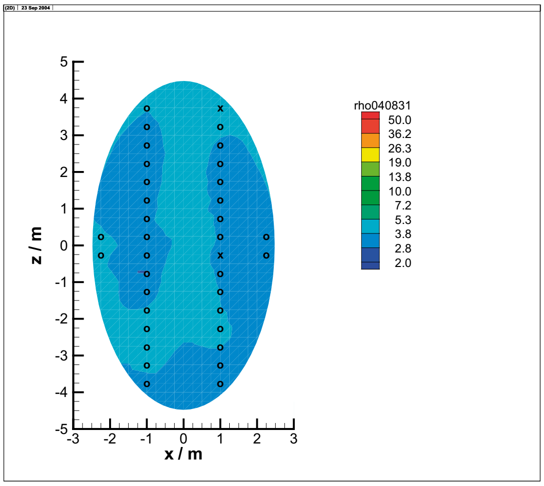
2003-11-30



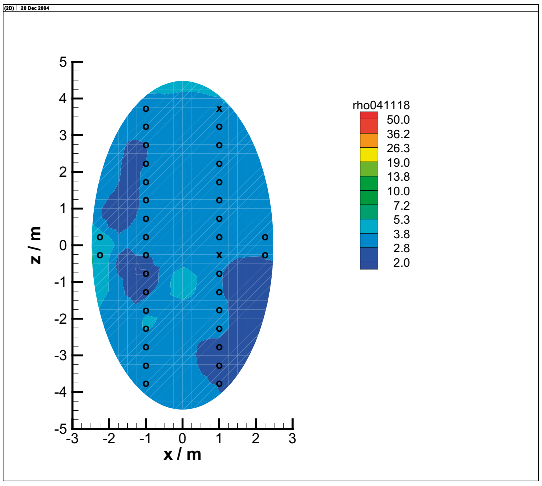
2004-02-29



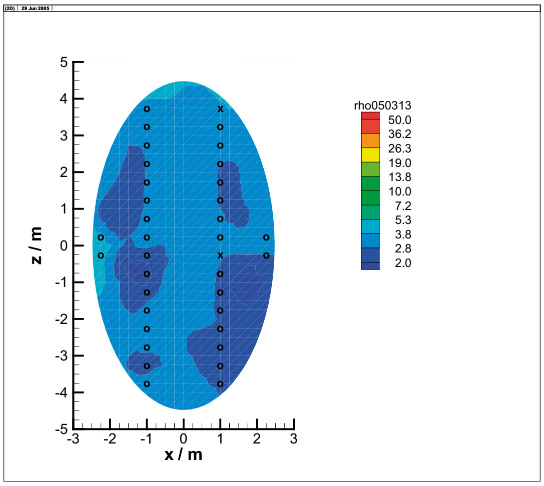
2004-05-31



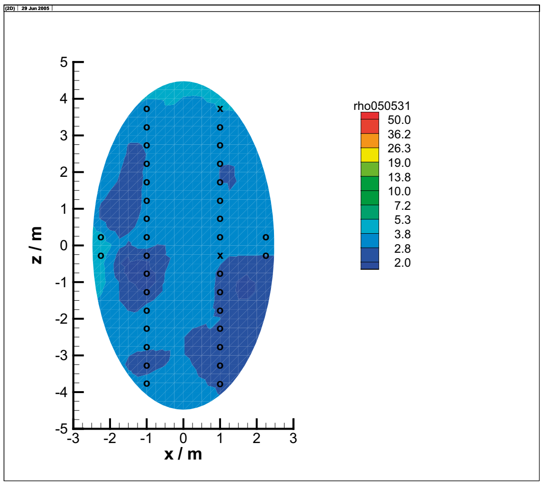
2004-08-31



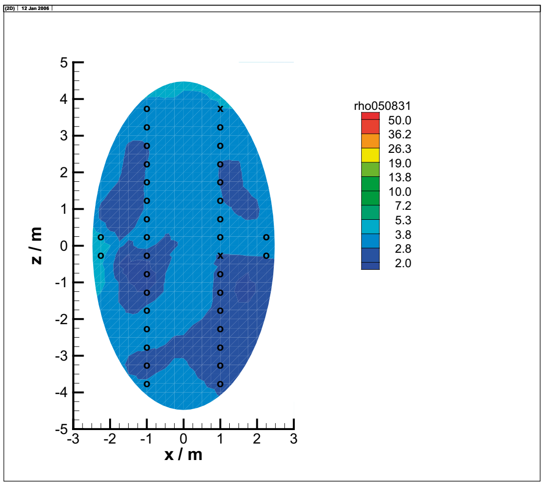
2004-11-18



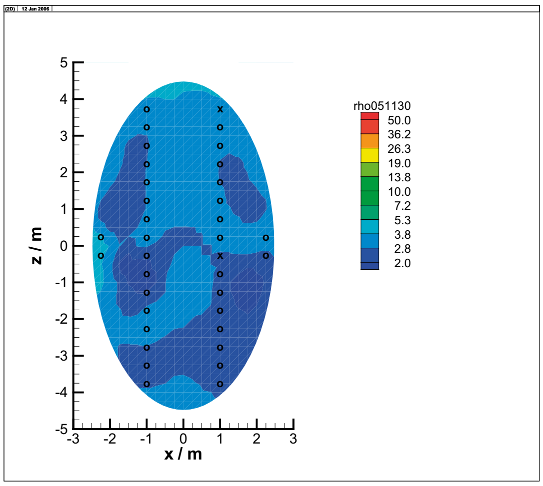
2005-03-13



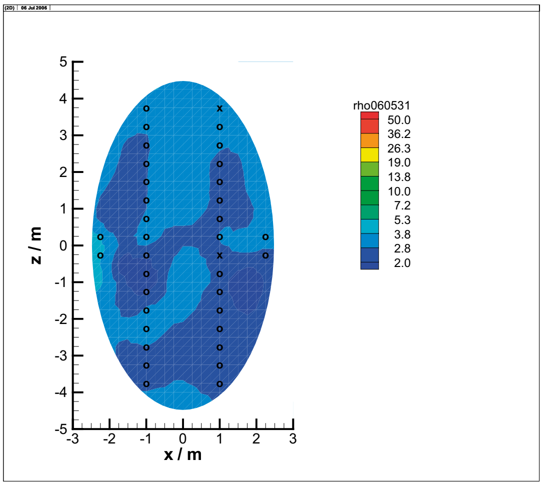
2005-05-31



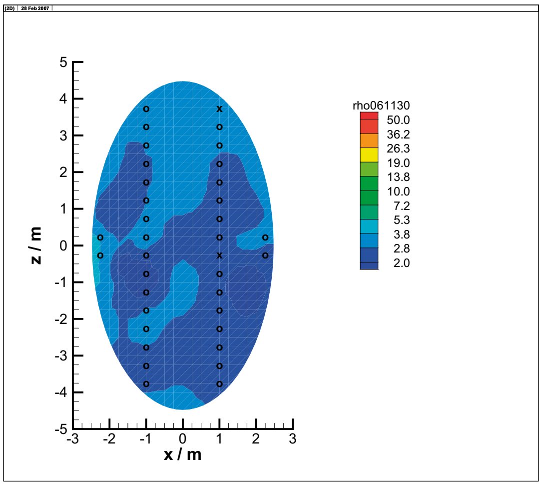
2005-08-31



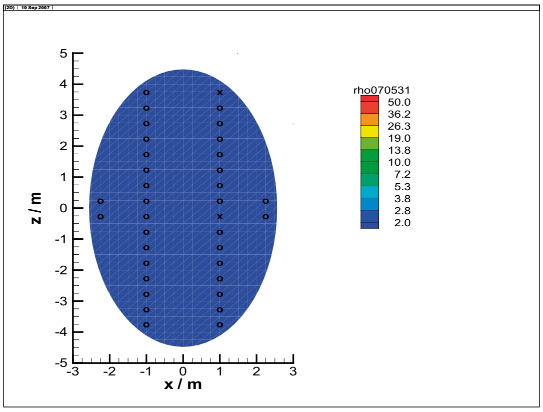
2005-11-30



2006-05-31



2006-11-30



2007-05-31

A6.1.3 Actual Interpretation

The initial resistivity value of the backfill in October 2001 is about 10 to 14 Ωm corresponding to a water content of 13 to 14%. In the following month the resistivity reduces to about 7 to 10 Ωm which corresponds to a water content of about 14 to 16%. However, this reduction in resistivity is most likely generated by the wet (light blue) areas close to the electrode chains. These wet areas are the consequence of moistened backfill used during installation of the electrodes for better covering of the electrode chains. From then on, the resistivity decreases continuously, starting near the drift walls and progressing into the drift centre. From November 2004 on, a very homogeneous resistivity distribution was reached; with a value around 3 Ωm corresponding to a water content of 21–22%.

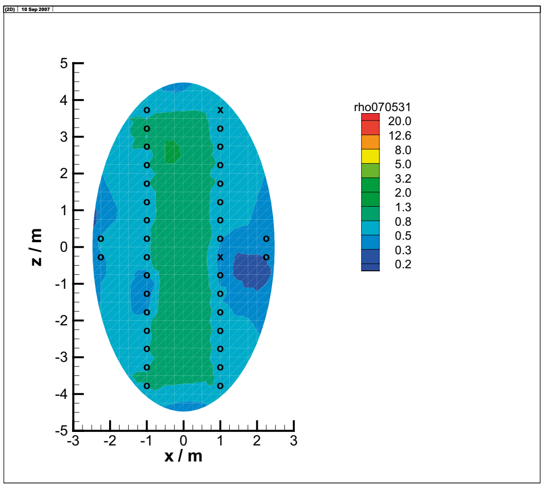
Besides the overall trend, minor changes in the tomograms from month to month are visible near the edges of the gallery, especially a light blue area on the right side of the tomograms is more or less pronounced. These are no real anomalies, but are caused by the fact that inaccuracies in the measurements can lead to the accumulation of "ghost" anomalies in areas of lower sensitivity. The areas of lower sensitivity are typically the edges of the model. In case of the blue area on the right side of the tomograms, the sensitivity is more reduced because one of the electrodes (marked with an "x" in the tomograms) is not active, as its cable broke after installation during backfilling.

The resistivity is also slightly decreased by the temperature increase in the backfill. The temperature increase can result in a resistivity reduction by not more than 1 Ωm.

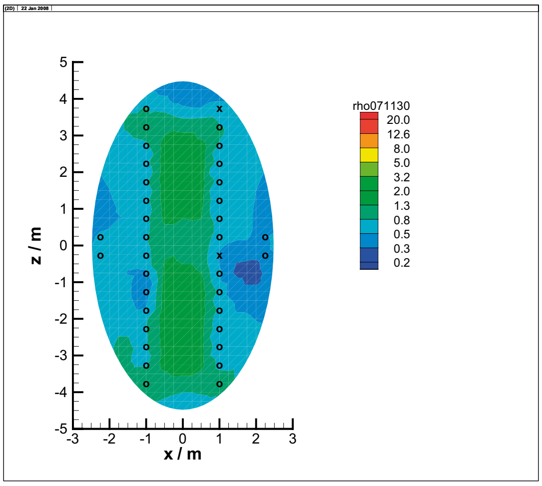
On May 2, 2003, the upper right electrode (also marked with an "x" in the tomogram from May 31, 2003) was lost. The reason is probably a cable failure. It is not clear whether this is already a corrosion effect.

The tomogram of May 2007 shows that the resistivity was below 2.8 Ωm everywhere in the backfill then. To get more detailed information, the tomograms below show the resistivity distributions since May 2007 in a higher resolution. Resistivity was in fact below 2 Ωm in all of the backfill during 2007, with the values near the walls being slightly lower than in the center. From 2008, however, resisitivity seems to have increased again. The respective tomograms show a slight increase in the entire cross section and a center of elevated resistivity above 5 Ωm near the tunnel roof. A possible reason for this may be the continuous pumping of water out of Section I, which may have led to a slight desaturation or a settling of the backfill, which resulted in a degradation of the electrode coupling.

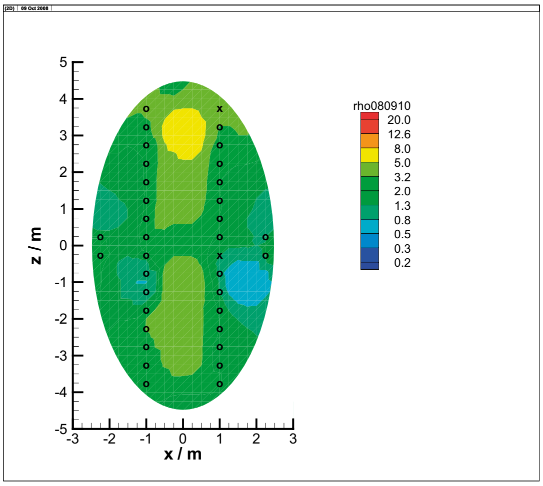
The measurements were finished in 2013, the tomogram from June 24, 2013 shows the results of the last data.



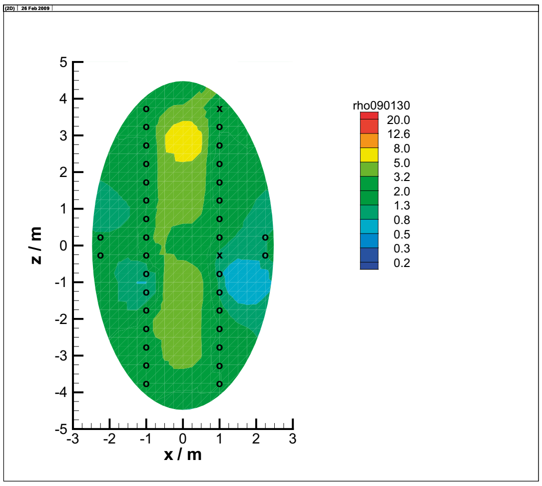
2007-05-31 (higher resolution)



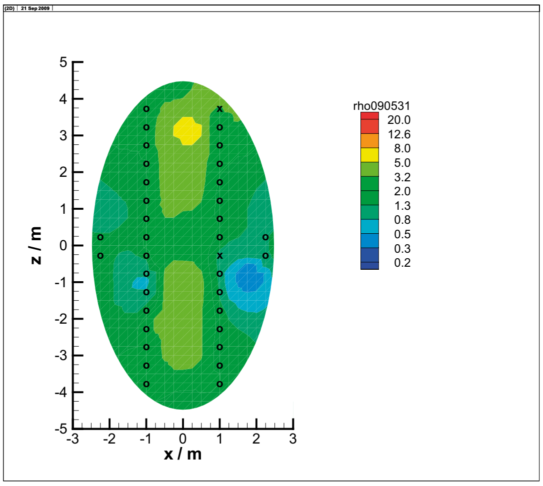
2007-11-30 (higher resolution)



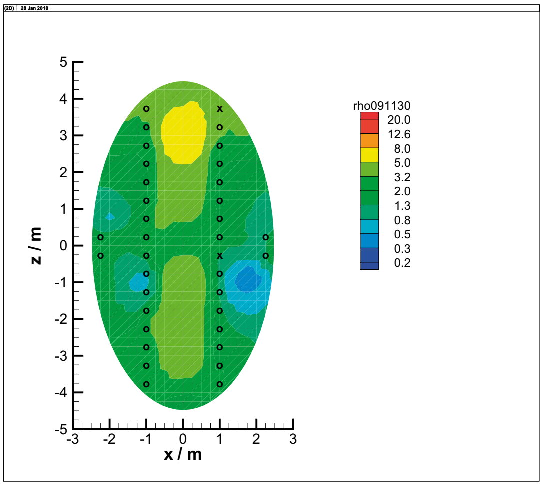
2008-09-10 (higher resolution)



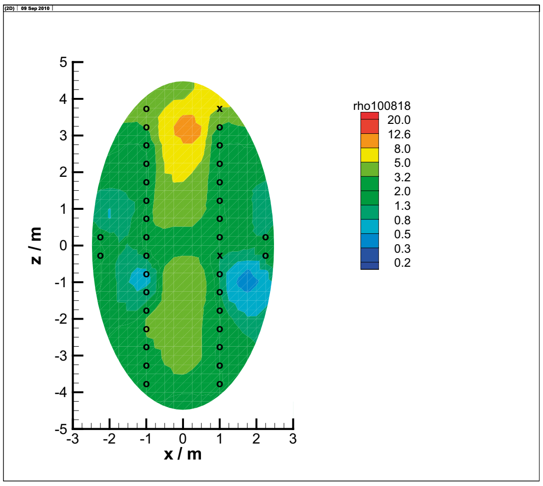
2009-01-30 (higher resolution)



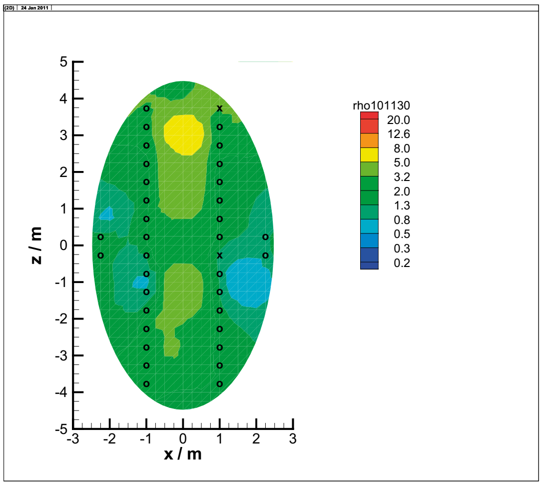
2009-05-31 (higher resolution)



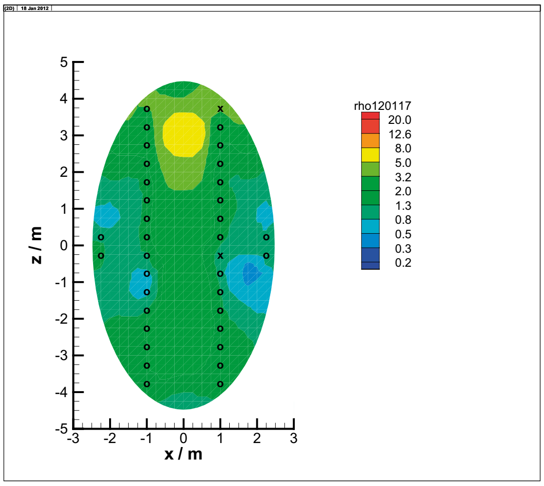
2009-11-30 (higher resolution)



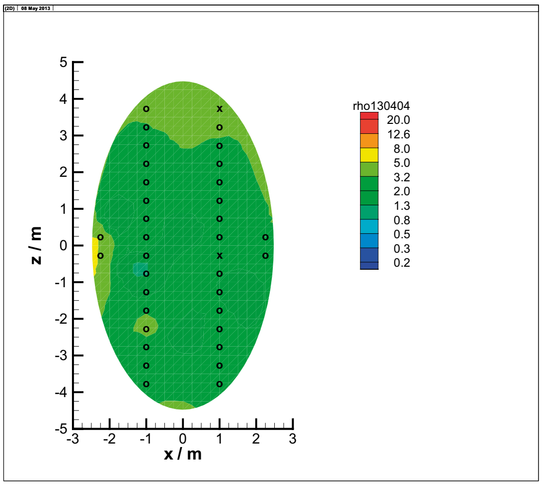
2010-08-18 (higher resolution)



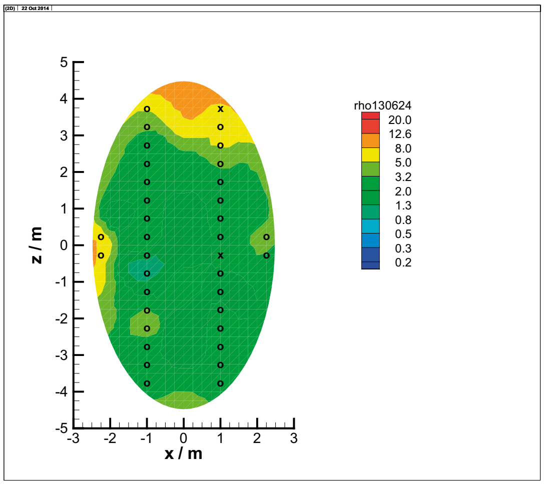
2010-11-30 (higher resolution)



2012-01-17 (higher resolution)



2013-04-04 (higher resolution)



2013-06-24 (higher resolution)