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Äspö Hard Rock Laboratory

Prototype Repository

Instrumentation of buffer and backfill in Section II

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January 2003

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Äspö Hard Rock
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PROTOTYPE REPOSITORY

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Keywords: Instrumentation, total pressure, pore pressure, temperature, relative humidity, displacements, sampling, bentonite, backfill

Abstract

This report describes the instrumentation of the buffer and backfill for measurement of thermal, hydraulic, mechanical and chemical processes in section 2 of the Prototype Repository. Instrument type and exact position of each instrument is given and a description of the measuring technique and the motive for the installation is given where appropriate.

The table below yields a summary of the instruments in section 2

Instruments used in the buffer and backfill in section 2

Measure-ment	**Supplier**	**Principle**	**Number of sensors**			
			Tunnel	**Dep. holes**	**Rock surface**	**Sum**
Tempe-rature	Pentronic	Thermocouple	16	64		80
	BICC	FTR		8 cables		8
Total pressure	Geokon	Vibrating wire	8	29	3	40
	Kulite	Piezoresistive	8	22		30
Water pressure	Geokon	Vibrating wire	12	11	1	24
	Kulite	Piezoresistive	6	14	2	22
Relative humidity	Vaisala	Capacitive		38	2	40
	Rotronic	Capacitive		33	1	34
	Wescor	Psychrometer	32	35	9	76
Water content	GRS[1)]	Resistivity chains	1 chain	3	(3)[2)]	4
Water/gas .sampling	CT	Active sampling	4	4		8
	CT	Passive sampling		24		24
Copper corrosion				3		3
Canister displace-ments	AITEMIN/ Rocktest[1)]	Fibre optic		6		6[1)]
Buffer swelling	CT/Druck	Head measurement /strain gauges		2		2
Sum			**87**	**296**	**21**	**401**

[1)] described in a separate report

[2)] in the rock between holes 5 and 6

Sammanfattning

Denna rapport beskriver instrumentering av buffert och återfyllning för mätning av termiska, hydrauliska, mekaniska och kemiska processer i sektion 2 av Prototypförvaret. Instrumenttyper och exakt position av varje instrument anges och i förekommande fall ges en beskrivning av mättekniken och motiv för installationen.

Nedanstående tabell är en sammanfattning av instrumenteringen i sektion 2.

Instrumentering av buffert och återfyllning i section 2

Mätning	**Leverantör**	**Mätprincip**	**Antal sensorer**			
			Tunnel	**Dep. hål**	**Berg-ytan**	**Summa**
Tempe-ratur	Pentronic	Termoelement	16	64		80
	BICC	FTR		8 cables		8
Total-tryck	Geokon	Vibrerande sträng	8	29	3	40
	Kulite	Piezoresistiv	8	22		30
Vatten-tryck	Geokon	Vibrerande sträng	12	11	1	24
	Kulite	Piezoresistiv	6	14	2	22
Relativ fuktighet	Vaisala	Kapacitiv		38	2	40
	Rotronic	Kapacitiv		33	1	34
	Wescor	Psykrometer	32	35	9	76
Vatteninnehåll	GRS[1)]	Resistivitetskedja	1 kedja	3	(3)[2)]	4[1)]
Vatten/gas .provtagning	CT	Aktiv provtagning	4	4		8
	CT	Passiv provtagning		24		24
Koppar korrosion				3		3
Kapsel-förskjutning	AITEMIN/ Rocktest[1)]	Fiberoptik		6		6[1)]
Buffert-svällning	CT/Druck	Nivåmätning/Tråd-töjningsgivare		2		2
Summa			**87**	**296**	**21**	**401**

[1)] described in a separate report

[2)] in the rock between holes 5 and 6

Contents

1 Introduction

The Prototype Repository /1-1/ is located in the innermost part of the TBM-tunnel. Figure 1-1 shows the layout of the test. The test is divided into two sections, which are separated by a plug. This report deals with the instrumentation in section 2.

The Prototype Repository consists of six full-scale deposition holes, copper canisters equipped with electrical heaters, bentonite blocks (cylindrical and ring shaped) and a deposition tunnel backfilled with a mixture of bentonite and crushed rock and ends with a concrete plug. Temperature, water pressure, relative humidity, total pressure and displacements etc. are measured in numerous points in the test. The cables from the transducers are lead through the rock in watertight tubes to the data collection systems in the adjacent G-tunnel.

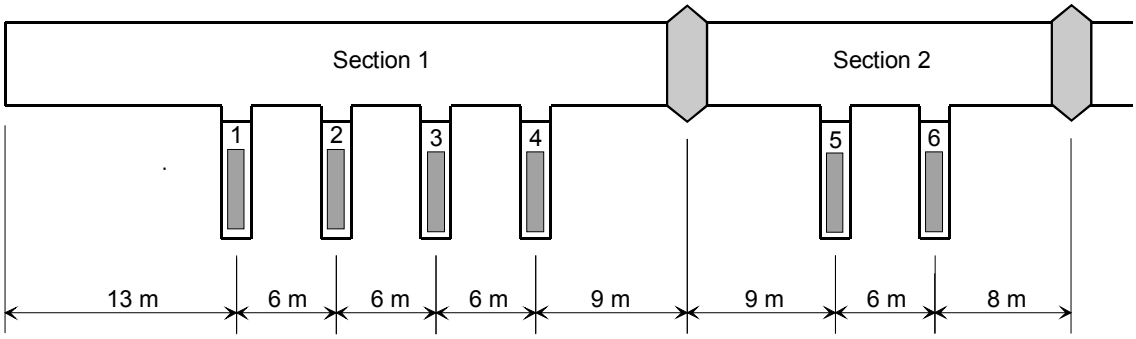

Figure 1-1. *Schematic view of the layout of the Prototype Repository.*

The basic instrumentation of the buffer and backfill in the Prototype Repository is described in a separate report /1-2/. Choice and measuring principles of transducers for measuring relative humidity, temperature, total pressure and pore pressure are described in that report as well as the location of the transducers. That report concerns mainly section 1.

The present report describes the instrumentation in section 2, with a description of the location of the instruments and measuring principles as well as the motivation of the choice. Since many instruments are the same as in section 1 the description of measuring principle and the motivation of the choice of instrument are not included for those instruments that are identical to the ones in section 1 and were reported in /1-2/.

Two instrument types are not included in either report. Measurement of canister displacement, which is done in deposition hole 6, and resisitivity measurements, which are done in deposition hole 6, is described in separate reports.

One type of rock instrumentation is included in this report as well since it actually concerns the hydraulic interaction between the buffer and the rock. For this instrumentation 6 sensors for measuring the relative humidity in the rock have been installed very close to the surface of deposition hole 6.

2 Instruments and measuring principles

2.1 General

The major part of the instruments in section 2 are measuring temperature, pressure and relative humidity and are identical to the instruments described in the report for section 1 /1-2/. Those instruments will not be further described in this report. The measurements are:

- Temperature measured with thermocouples
- Temperature on the canister surface measured with fibre optical cables
- Relative humidity of the buffer measured with capacitive sensors
- Relative humidity of the backfill measured with psychrometers
- Pore pressure and total pressure measured with piezoresistive sensors
- Pore pressure and total pressure measured with vibrating wire sensors

Several additional measurements with techniques that were either changed, used in another environment, not used or otherwise not described in /1-2/ will be used in section 2. Those techniques are described in this chapter.

2.2 Psychrometers

Psychrometers are used for measuring relative humidity above 95 %, which means that they are very well suited for measurements in the backfill where the relative humidity is higher than 97 % already from start. The reason is that the initial water ratio 12 % corresponds to a very high clay water ratio, yielding a high relative humidity. In the buffer material, however, the initial water ratio 17 % corresponds to a relative humidity of about 70 %, which is far from the measuring range of the instrument. This is the reason that these transducers were not installed in the buffer but only in the backfill in section 1. However, a number of psychrometers were installed in the buffer in the Canister Retrieval Test and seem to very accurately measure the end of the saturation process. Psychrometers will therefore be used as complement to the capacitive sensors from Rotronic and Vaisala. Altogether 38 psychrometers will be installed in the buffer in depositions 5 and 6.

In addition 6 psychrometers will be placed in the rock surface of hole 6 in dry parts of the rock close to the buffer in order to try to measure if there is any de-saturation of the rock by the strong suction of the bentonite. Preliminary measurements of the retention curve of the rock imply that the 95 %-100 % relative humidity of the rock correspond to 50%-100% degree of saturation, which means that psychrometers should be very well suited for measurements in the rock (see chapter 2.6).

Protection tubes of titanium will be used for the psychrometers. They will be furnished with titanium housing (including filter) which will be welded to the tubes.

2.3 Buffer displacement measurements

The surface between the buffer and the backfill will be displaced upwards when the buffer gets saturated. This depends partly on the swelling pressure of the buffer that will compress the backfill material and partly on the fact that the buffer during a limited time may be swelling before the backfill material is in position. A technique for measuring that displacement has been developed, and devices were installed in all 4 holes in section 1 and will be installed in deposition holes 5 and 6 in section 2.

The displacement is registered by measuring the height of an oil column between an oil volume placed in a vessel that is positioned on the buffer surface (Figure 2-1) and a pressure transducer placed outside the test site. Two tubes are led out from the vessel; one leading oil and the other one leading “atmospheric air pressure”. When the buffer swells, the vessel will follow and the height of the oil column will increase. By use of a pressure gauge with high accuracy the displacement can be calculated with an accuracy of 1mm. In section 1, water was used instead of oil, but problems originating from vaporization of the water in the vessel and corresponding condensation in the air tube, has lead to a decision to use oil instead of water.

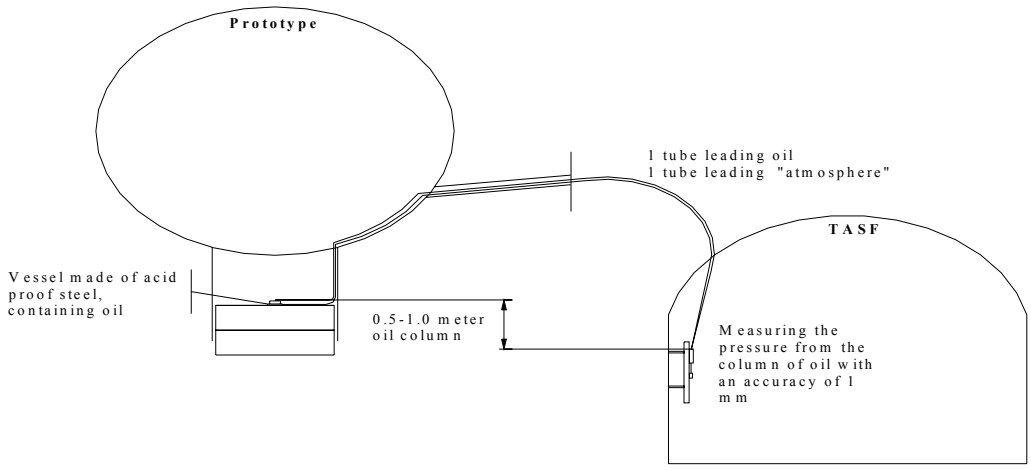

Figure 2-1. *Schematic view showing how the displacement of the surface between bentonite and backfill is measured.*

Equipment

The equipment needed for this measurement is the following:

- Specially designed vessels (see Figure 2-2) made of stainless steel
- Pressure gauges (Druck PTX 610; range 0-100 mbar)
- Polyamide tubes 6/3. The tubes will be led through the flange at one of the lead throughs.
- A panel with pressure gauges and valves placed in the TASF tunnel.

Installation

The installation will be done just before the backfilling takes place. It will be done as follows:

- The tubes through the rock will be installed in advance together with other cables and tubes passing through the lead through.
- The assembled vessel will be placed on the surface of the upper bentonite block. The tubes can then be connected to the vessel. The tube leading oil will be connected to the bottom of the vessel and the tube leading "atmospheric air pressure" will be connected to the top of the vessel.
- Paraffin oil will then slowly be pushed through the tube leading oil from the low point in the TASF. The tube connected to the top of the vessel will be loosened and an indicator rod will be used to measure the level in the vessel. The surface of the oil in the vessel will be set about 4 cm from the bottom.
- The tube, used at the filling of oil will then be connected to a pressure gauge by turning a three-way valve. The registration of the pressure will start immediately.
-

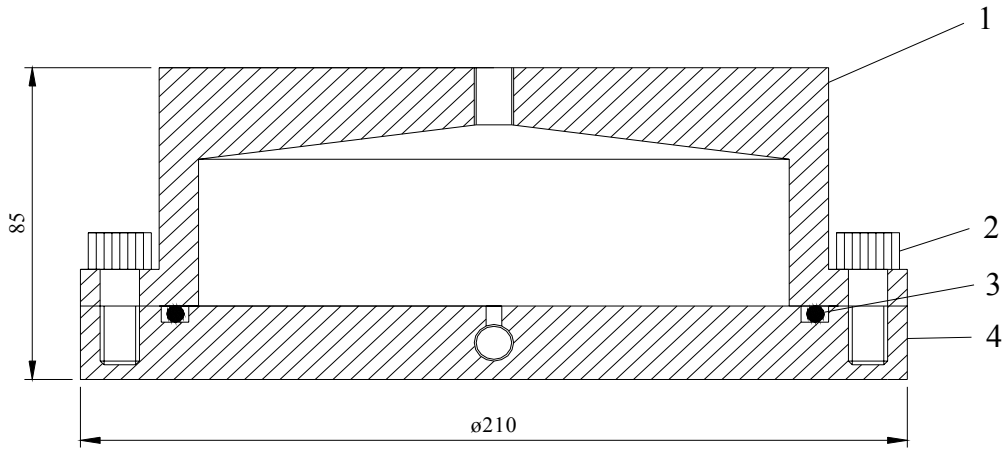

Figure 2-2. *Vessel used for displacement measurements.*
1: Steel cover. 2: Bolts. 3: O-ring. 4: Steel plate.

2.4 Sample collectors for water and gas sampling

Cups for collecting pore water and gas in the buffer and backfill will be installed. Two types of sample collectors will be used; one that allows sampling of water and gas during the test and one that collects water that will be analyzed after excavation.

1. 12 isolated sample collectors will be placed in the bentonite in each deposition hole. A sample collector consists of a titanium cup with a titanium filter placed on the top. Pore water from the bentonite will after saturation of the material, flow through the filter and into the cup. When the test is over and the excavating of the bentonite has started, the cups will be located and the water will be analyzed. The cups have an inner diameter of 15 mm and an inner height of 14 mm.
2. 8 additional sample collectors that are connected to tubes leading out of the site will be installed; 4 in the backfill, 2 in the interface rock/bentonite at the top of deposition hole 6 and 2 in the interface rock/bentonite at the top of deposition hole 5. The same equipment will be used as for the isolated cups, except for a tube made of PEEK that will be connected to the bottom of the cup. This makes it possible to take water and gas samples during the test period.

2.5 In situ measurements of corrosion

A method for measuring corrosion in situ is to measure the electric-chemical noise. The method has been tested in one of the parcels in the LOT-project and seems feasible. This equipment will be installed in the buffer in deposition hole 5, which yields possibility to at a later stage decide if measurements will be done or not.

2.5.1 Equipment

In the upper block (C4) in deposition hole 5, three copper electrodes with the diameter 60 mm and a length of 100 mm will be installed. From each electrode, two copper cables will be led in polyamide tubes. The copper cables will be soldered to the electrodes. In order to get a secure sealing when the copper cables are led into the polyamide tube, a Swagelok ferrule connection will be mounted on the top of the electrode. A distance casing, made of PEEK, will be placed on the top of the electrode in order to isolate the ferrule connection from the copper electrode.

2.5.2 Installation

The electric cables will be led in polyamide tubes (10mm/6mm) in advance. The tubes will be led through the flange at one lead through. The copper cables coming from the polyamide tubes will be connected to the electrodes by tin soldering. Each copper electrode will be connected to two copper cables. Holes with a diameter of 60 mm and with a depth of 250 mm will be drilled in the bentonite block. The electrodes will be placed in the holes and the remaining space will be filled with bentonite powder.

2.6 Desaturation of the rock close to the buffer

In dry parts of the rock close to the deposition hole, there is a risk of desaturation if the loss of water to the bentonite caused by the suction of the bentonite is faster than the supply of water from fractures around the hole. An attempt will be made to measure if desaturation occurs by placing psychrometers in boreholes in the rock close to the deposition hole surface.

32 mm boreholes have been drilled in the rock from the surface of the deposition hole at different angles in order to place the sensors at different distances from the rock surface (25, 50 and 100 mm) as shown in Figure 2-3. Each sensor will be sealed against the deposition hole by an O-ring mounted around the sensor body. The outer part of the hole will then be filled with cement. A small chamber (measuring volume), isolated from external disturbances by the O-ring and the cement, will be left, where the relative humidity in the chamber may be in equilibrium with the relative humidity in the rock.

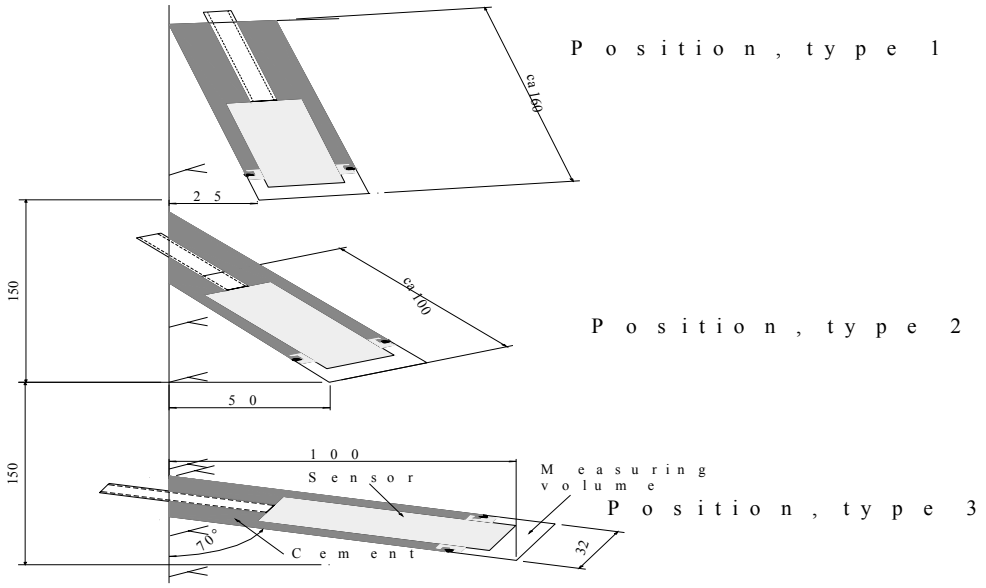

Figure 2-3. *Installation of relative humidity sensors in the rock surface.*

3 Location of instruments for standard measurement of THM processes in the bentonite

3.1 Introduction

Standard measurements of thermo-hydro-mechanical (THM) processes will be done in both hole 5 and 6. Standard refer to temperature, relative humidity, water pressure and total pressure. This chapter describes the location of the sensors and the type of instrument used for these measurements.

3.2 Overview

Standard measurement of THM-processes in the bentonite buffer in the deposition holes will be done by several instrument types. An overview of the instruments is given in this section. A more detailed description is given in the instrument report for section 1 /1-2/

3.2.1 Measurements of temperature

Thermocouples from Pentronic will be used to measure the temperature. Measurements will be done in 32 points in each deposition hole. In addition, temperature gauges are built in into the capacative relative humidity sensors (37 pcs) as well as in the pressure gauges of vibrating wire type (13 pcs). Temperature is also measured with the psychrometers. In addition temperature will be measured on the surface of the canister with optical fiber cables /1-2/.

3.2.2 Measurement of total pressure

Total pressure is the sum of the effective stress and the pore water pressure. It will be measured with the following instrument types:

- Geokon total pressure cells with vibrating wire transducers. 18 and 14 cells respectively of this type will be installed in each test hole.
- Kulite total pressure cells with piezo resistive transducers. 13 and 9 cells respectively of this type will be installed in each test hole.

Total pressure will be measured in totally 27 points in each test hole.

3.2.3 Measurement of pore water pressure

Pore water pressure will be measured with the following instrument types:

- Geokon pore pressure cells with vibrating wire transducers. 6 cells of this type will be installed in each test hole.
- Kulite pore pressure cells with piezo resistive transducers. 8 cells of this type will be installed in each test hole.

Pore pressure will be measured in totally 14 points in each test hole.

3.2.4 Measuring of the water saturation process

The water saturation process will be measured with the following techniques:

- Vaisala relative humidity sensors of capacitive type. 20 cells of this type will be installed in each test hole.
- Rotronic relative humidity sensors of capacitive type. 17 cells of this type will be installed in each test hole.
- Wescor psychrometers. 34 sensors of this type will be installed in deposition hole 6 and 10 sensors in deposition hole 5.

These devices measure the relative humidity in the pore system. The relative humidity will be measured in totally 47 points in deposition hole 5 and in 71 points in deposition hole 6.

3.3 Strategy for describing the position of each device

Every instrument is named with a unique name consisting of 1 letter describing the type of measurement, 1 letter describing where the measurement takes place (buffer, backfill, rock or canister), 1 figure denoting the deposition hole (1-6) or A for the main tunnel, and 2 figures specifying the position in the buffer according to a seperate list (see Table 3-1 to 3-8). Every instrument position is described with three coordinates according to Figure 3-1. The r-coordinate is the horizontal distance from the center of the hole and the z-coordinate is the height from the bottom of the hole (the block height is set to 500mm). The α–coordinate is the angle from the vertical direction A (headed against the end of the tunnel i.e. almost to the west).

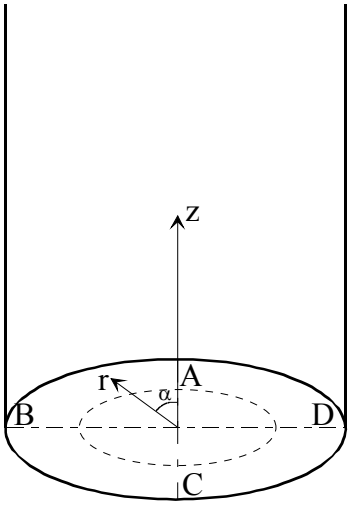

Figure 3-1. *Figure describing the coordinate system used when determining the instrument positions.*

3.4 Position of the instruments in the bentonite in hole 5 (DA3551G01)

The instrumented deposition holes in section 2 are termed DA3551G01 (hole 5) and DA3545G01 (hole 6) according to Figure 1-1. Deposition hole 5 will be instrumented in the same way as the two inner deposition holes, 1 and 3 i.e. measurements will be done in four vertical sections A, B, C and D according to Figure 3-2.

Direction A and C are placed in the tunnel axial direction with A headed against the end of the tunnel i.e. almost to the west, see Figure 3-1. The bentonite blocks are called cylinders and rings. The cylinders are numbered C1-C4 and the rings R1-R10 respectively (Figure 3-2).

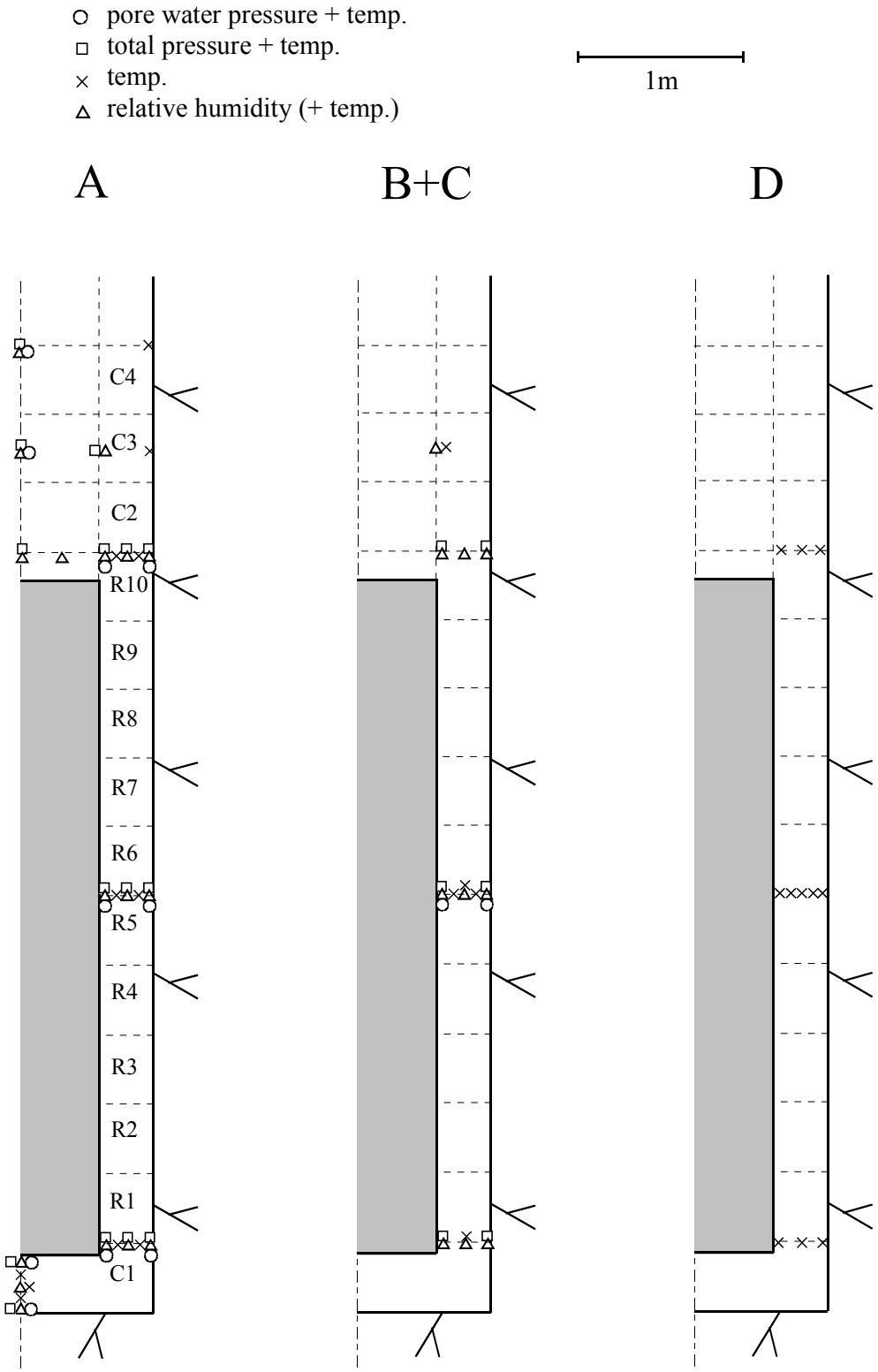

Figure 3-2. *Schematic view over the instruments positions in deposition hole 5. The instruments are placed in four vertical sections. The figure also shows the block designati*

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 50mm level and the other gauges in the 160 mm level except for the Rotronic humidity sensors and the Geocon pore pressure sensors, which are placed in the 250 mm level depending on the size of the sensor house.

The position of ten Wescor psychrometers has been based on the distribution of water inflow on the surface of the deposition hole. The water inflow has been determined by help of diapers and the positions of these sensors are based on the results from these measurements.

The positions of each instrument, the cable length and the corresponding lead through connections are described in Tables 3-1 to 3-5.

Table 3-1 Numbering and position of instruments for measuring temperature (T)

Prototype Repository, Instrumentation

Instrument type	**Thermocouple**
Deposition hole, No	**5**
Lead through, No	**LT52**
Length of lead through	**36,3**
Length in G-tunnel, m	**10,0**
Estimated length in backfill, m	**10,0**

		Instrument position in block				Cable dir.		Cable lengths			Remark
Mark	Block	Direction	α	r	z	α	Fabricate	Buffer	In test volume	Total	
			degree	mm	mm	degree		m	m	m	
TB501	Cyl. 1	Center	270	50	50	344	Pentronic	7,9	**18**	64	
TB502	Cyl. 1	Center	270	60	250	342	Pentronic	7,9	**18**	64	
TB503	Cyl. 1	Center	270	70	450	340	Pentronic	7,8	**18**	64	
TB504	Cyl. 1	A	355	525	450	358	Pentronic	7,4	**17**	64	On canister
TB505	Cyl. 1	A	355	685	450	356	Pentronic	7,2	**17**	64	
TB506	Cyl. 1	B	85	685	450	84	Pentronic	7,2	**17**	64	
TB507	Cyl. 1	C	175	685	450	176	Pentronic	7,2	**17**	64	
TB508	Cyl. 1	D	270	585	450	274	Pentronic	7,3	**17**	64	
TB509	Cyl. 1	D	270	685	450	272	Pentronic	7,2	**17**	64	
TB510	Cyl. 1	D	270	785	450	270	Pentronic	7,1	**17**	63	
TB511	Ring 5	A	0	525	2950	42	Pentronic	4,9	**15**	61	On canister
TB512	Ring 5	A	0	685	2950	38	Pentronic	4,7	**15**	61	
TB513	Ring 5	B	85	585	2950	88	Pentronic	4,8	**15**	61	
TB514	Ring 5	B	85	685	2950	90	Pentronic	4,7	**15**	61	
TB515	Ring 5	B	85	785	2950	92	Pentronic	4,6	**15**	61	
TB516	Ring 5	C	175	585	2950	152	Pentronic	4,8	**15**	61	
TB517	Ring 5	C	175	685	2950	154	Pentronic	4,7	**15**	61	
TB518	Ring 5	C	175	735	2950	156	Pentronic	4,6	**15**	61	
TB519	Ring 5	D	270	585	2950	290	Pentronic	4,8	**15**	61	
TB520	Ring 5	D	270	635	2950	288	Pentronic	4,7	**15**	61	
TB521	Ring 5	D	270	685	2950	286	Pentronic	4,7	**15**	61	
TB522	Ring 5	D	270	735	2950	284	Pentronic	4,6	**15**	61	
TB523	Ring 5	D	270	785	2950	282	Pentronic	4,6	**15**	61	
TB524	Ring 10	A	0	525	5250	18	Pentronic	2,3	**12**	59	On canister
TB525	Ring 10	A	0	685	5450	14	Pentronic	2,2	**12**	58	
TB526	Ring 10	D	270	585	5450	260	Pentronic	2,3	**12**	59	
TB527	Ring 10	D	270	685	5450	262	Pentronic	2,2	**12**	58	
TB528	Ring 10	D	270	785	5450	264	Pentronic	2,1	**12**	58	
TB529	Cyl. 3	A	0	785	6250	22	Pentronic	1,3	**11**	58	
TB530	Cyl. 3	B	95	585	6250	102	Pentronic	1,5	**12**	58	
TB531	Cyl. 3	C	185	585	6250	204	Pentronic	1,5	**12**	58	
TB532	Cyl. 4	A	0	785	6950	24	Pentronic	0,5	**11**	57	

Table 3-2 Numbering and position of instruments for measuring total pressure (P)

Prototype Repository, Instrumentation

Instrument type **Total Pressure**
Deposition hole, No **5**
Lead through, No **LT52**
Length of lead through **36,3**
Length in G-tunnel, m **10,0**
Estimated length in backfill, m **10,0**

Mark	Block	Instrument position in block				Cable dir.	Fabricate	Cable lengths				Remark
		Direction	α	r	Z	α		Buffer		In test volume	Total	
			degree	mm	mm	degree		m	m	m	m	
PB501	Cyl. 1	Center	0	0	0	4	Geokon	7,9	**8,0**	**18**	64	Bottom
PB502	Cyl. 1	Center	0	100	500	346	Geokon	7,8	**8,0**	**18**	64	
PB503	Cyl. 1	A	5	585	360	30	Kulite	7,3	**8,0**	**17**	64	Vertical
PB504	Cyl. 1	A	5	685	360	28	Kulite	7,2	**8,0**	**17**	64	Vertical
PB505	Cyl. 1	A	5	785	360	94	Kulite	7,1	**8,0**	**17**	63	Vertical
PB506	Cyl. 1	B	95	635	500	118	Geokon	7,3	**8,0**	**17**	64	
PB507	Cyl. 1	B	105	735	500	106	Geokon	7,2	**8,0**	**17**	63	
PB508	Cyl. 1	C	185	635	500	184	Geokon	7,3	**8,0**	**17**	64	
PB509	Cyl. 1	C	195	735	500	194	Geokon	7,2	**8,0**	**17**	63	
PB510	Ring 5	A	10	535	2840	44	Kulite	4,8	**6,0**	**15**	61	In the slot
PB511	Ring 5	A	5	685	3000	40	Geokon	4,7	**5,0**	**15**	61	Delivery1
PB512	Ring 5	A	5	825	2840	36	Kulite	4,6	**6,0**	**15**	61	In the slot
PB513	Ring 5	B	95	635	3000	98	Geokon	4,7	**5,0**	**15**	61	Delivery1
PB514	Ring 5	B	95	785	3000	96	Geokon	4,6	**5,0**	**15**	61	Delivery1
PB515	Ring 5	C	185	635	3000	198	Geokon	4,7	**5,0**	**15**	61	Delivery1
PB516	Ring 5	C	190	825	2840	186	Kulite	4,6	**6,0**	**15**	61	In the slot
PB517	Ring 10	Center	0	50	5500	8	Geokon	2,8	**4,0**	**13**	59	
PB518	Ring 10	A	10	585	5360	20	Kulite	2,3	**4,0**	**12**	59	Vertical
PB519	Ring 10	A	10	685	5360	16	Kulite	2,2	**4,0**	**12**	58	Vertical
PB520	Ring 10	A	10	785	5360	12	Kulite	2,1	**4,0**	**12**	58	Vertical
PB521	Ring 10	B	95	635	5500	124	Geokon	2,2	**4,0**	**12**	59	
PB522	Ring 10	B	105	735	5500	120	Geokon	2,1	**4,0**	**12**	58	
PB523	Ring 10	C	180	635	5500	210	Geokon	2,2	**4,0**	**12**	59	
PB524	Ring 10	C	190	735	5500	214	Geokon	2,1	**4,0**	**12**	58	
PB525	Cyl. 3	Center	0	100	6500	48	Geokon	2,0	**4,0**	**12**	58	
PB526	Cyl. 3	A	5	585	6500	34	Geokon	1,5	**4,0**	**12**	58	
PB527	Cyl. 4	Center	0	100	7000	56	Geokon	1,2	**4,0**	**11**	58	

Table 3-3 Numbering and position of instruments for measuring pore water pressure (U)

Prototype Repository, Instrumentation

Instrument type **Pore Pressure**
Deposition hole, No **5**
Lead through, No **LT52**
Length of lead through **36,3**
Length in G-tunnel, m **10,0**
Estimated length in backfill, m **10,0**

Mark	Block	Instrument position in block				Cable dir.		Cable lengths				Remark
		Direction	α	r	Z	α	Fabricate	Buffer		In test volume	Total	
			degree	mm	mm	degree		m		m	m	
UB501	Cyl. 1	Center	90	50	250	166	Kulite	7,9	**8,0**	**18**	64	
UB502	Cyl. 1	Center	90	100	50	168	Geokon	7,8	**8,0**	**18**	64	
UB503	Cyl. 1	A	355	585	250	0	Geokon	7,3	**8,0**	**17**	64	
UB504	Cyl. 1	A	355	785	340	354	Kulite	7,1	**8,0**	**17**	63	
UB505	Ring 5	A	355	585	2750	332	Geokon	4,8	**6,0**	**15**	61	
UB506	Ring 5	A	355	785	2840	338	Kulite	4,6	**6,0**	**15**	61	
UB507	Ring 5	B	85	535	2840	68	Kulite	4,8	**6,0**	**15**	61	In the slot
UB508	Ring 5	B	85	825	2840	74	Kulite	4,6	**6,0**	**15**	61	In the slot
UB509	Ring 5	C	175	535	2750	150	Geokon	4,8	**6,0**	**15**	61	In the slot
UB510	Ring 5	C	175	825	2750	158	Geokon	4,6	**6,0**	**15**	61	In the slot
UB511	Ring 10	A	355	585	5340	322	Kulite	2,3	**4,0**	**12**	59	
UB512	Ring 10	A	355	785	5340	328	Kulite	2,1	**4,0**	**12**	58	
UB513	Cyl. 3	Center	135	100	6250	52	Kulite	2,0	**4,0**	**12**	58	
UB514	Cyl. 4	Center	90	100	6750	58	Geokon	1,2	**4,0**	**11**	58	

Table 3-4 Numbering and position of instruments for measuring wetting (W)

Prototype Repository, Instrumentation

Instrument type **Relative Humidity**
Deposition hole, No **5**
Lead through, No(Rotronic) **LT53**
Lead through, No(Vaisala) **LT61**
Length of lead through LT53 **33,5**
Length of lead through LT61 **33,8**
Length in G-tunnel, m **10,0**
Length in backfill (LT53), m **8,2**
Length in backfill (LT61), m **10,5**

		Instrument position in block				Cable dir.		Cable lengths				Remark
Mark	Block	Direction	α	r	z	α	Fabricate	Titanium		In test volume	Total	
			degree	mm	mm	degree		m	**m**	m	m	
WB501	Cyl. 1	Center	180	50	250	160	Rotronic	7,6	**7,5**	16	59	
WB502	Cyl. 1	Center	180	100	50	2	Rotronic	7,6	**7,5**	16	59	
WB503	Cyl. 1	Center	0	400	250	164	Rotronic	7,3	**7,5**	15	59	Horizontal
WB504	Cyl. 1	A	350	585	340	352	Vaisala	7,1	**7,5**	18	61	
WB505	Cyl. 1	A	350	685	340	350	Vaisala	7,0	**7,5**	17	61	
WB506	Cyl. 1	A	350	785	340	348	Vaisala	6,9	**7,5**	17	61	
WB507	Cyl. 1	B	80	585	340	76	Vaisala	7,1	**7,5**	18	61	
WB508	Cyl. 1	B	80	685	250	78	Rotronic	7,0	**7,5**	15	59	
WB509	Cyl. 1	B	80	785	250	80	Rotronic	6,9	**7,5**	15	59	
WB510	Cyl. 1	C	170	585	250	174	Rotronic	7,1	**7,5**	15	59	
WB511	Cyl. 1	C	170	685	250	172	Rotronic	7,0	**7,5**	15	59	
WB512	Cyl. 1	C	170	785	250	170	Rotronic	6,9	**7,5**	15	59	
WB513	Ring 5	A	350	585	2840	330	Vaisala	4,5	**4,5**	15	59	
WB514	Ring 5	A	350	685	2840	334	Vaisala	4,4	**4,5**	15	59	
WB515	Ring 5	A	350	785	2840	336	Vaisala	4,3	**4,5**	15	59	
WB516	Ring 5	B	80	535	2750	66	Rotronic	4,6	**4,5**	13	56	In the slot
WB517	Ring 5	B	80	685	2750	70	Rotronic	4,4	**4,5**	13	56	
WB518	Ring 5	B	80	785	2750	72	Rotronic	4,3	**4,5**	13	56	
WB519	Ring 5	C	180	535	2840	196	Vaisala	4,6	**4,5**	15	59	In the slot
WB520	Ring 5	C	180	685	2840	192	Vaisala	4,4	**4,5**	15	59	
WB521	Ring 5	C	180	785	2750	188	Rotronic	4,3	**4,5**	13	56	
WB522	Ring 10	Center	180	50	5340	10	Vaisala	2,5	**2,5**	13	57	
WB523	Ring 10	A	0	262	5340	6	Vaisala	2,3	**2,5**	13	57	
WB524	Ring 10	A	350	585	5340	320	Vaisala	2,0	**2,0**	13	56	
WB525	Ring 10	A	350	685	5340	324	Vaisala	1,9	**2,0**	12	56	
WB526	Ring 10	A	350	785	5340	326	Vaisala	1,8	**2,0**	12	56	
WB527	Ring 10	B	80	585	5250	86	Rotronic	2,0	**2,0**	10	54	
WB528	Ring 10	B	80	685	5250	82	Rotronic	1,9	**2,0**	10	54	
WB529	Ring 10	B	80	785	5250	80	Rotronic	1,8	**2,0**	10	54	
WB530	Ring 10	C	170	585	5340	180	Vaisala	2,0	**2,0**	13	56	
WB531	Ring 10	C	170	785	5250	182	Rotronic	1,8	**2,0**	10	54	
WB532	Cyl. 3	Center	270	100	6250	50	Vaisala	1,5	**2,0**	12	56	
WB533	Cyl. 3	A	350	585	6250	32	Vaisala	1,0	**1,0**	11	55	
WB534	Cyl. 3	B	90	585	6250	100	Vaisala	1,0	**1,0**	11	55	
WB535	Cyl. 3	C	180	585	6250	202	Rotronic	1,0	**1,0**	9	53	
WB536	Cyl. 4	Center	180	100	6840	224	Vaisala	1,0	**1,0**	11	55	
WB537	Cyl. 4	Center	270	100	6680	228	Vaisala	1,0	**1,0**	11	55	

Table 3-5 Numbering of instruments for measuring wetting (positions were determined after inflow measurements) (W)

Prototype Repository, Instrumentation

Instrument type	**Relative Humidity**
Deposition hole, No	**5**
Lead through, No(Wescor)	**Plug**
Length of lead through Plug	**5.0**
Length outside Plug, m	**10.0**
Length in backfill (PLUG), m	**20.0**

		Instrument position in block				Cable dir.		Cable lengths				Remark
Mark	Block	Direction	α	r	z	α	Fabricate	Titanium		In test volume	Total	
			degree	mm	mm	degree		m	**m**	m	m	
WB538	Ring 3	C-D	225	775	1600	225	Wescor	5.4	**7.5**	**25**	40	
WB539	Ring 3	C-D	235	680	1600	235	Wescor	5.5	**7.5**	**25**	40	
WB540	Ring 3	C-D	245	585	1600	245	Wescor	5.6	**7.5**	**26**	41	
WB541	Ring 3	C-D	255	680	1600	255	Wescor	5.5	**6.0**	**25**	40	
WB542	Ring 3	C-D	265	775	1600	265	Wescor	5.4	**6.0**	**25**	40	
WB543	Ring 8	C-D	225	775	1600	225	Wescor	2.8	**6.0**	**23**	38	
WB544	Ring 8	C-D	235	680	1600	235	Wescor	2.9	**3.0**	**23**	38	
WB545	Ring 8	C-D	245	585	1600	245	Wescor	3.0	**3.0**	**23**	38	
WB546	Ring 8	C-D	255	680	1600	255	Wescor	2.9	**3.0**	**23**	38	
WB547	Ring 8	C-D	265	775	1600	265	Wescor	2.8	**3.0**	**23**	38	

3.5 Position of the instruments in the bentonite in hole 6 (DA3545G01)

Deposition hole 6 will be instrumented according to another strategy. The instruments will be placed in eight directions, where four directions are represented in each instrumented block, see Figures 3- and 3-4.

The motivation for changing the instrument positions in hole 6 is the following:

There is a risk that a high concentration of transducers may influence the thermal and moisture transport, especially when the transducers are placed in radial direction since the transport of both heat and moisture mainly takes place in that direction. If moisture has to pass other transducers on its way, it may be delayed or accelerated.

The new strategy is to install only one set of instruments in the same radial direction. The instruments are placed at 7 locations, all with different distance to the canister surface, in 3 levels (upper, centre and lower part of the canister). The sets of instruments are separated 45 degrees tangentially. A set of instruments consists of transducers for measuring relative humidity, pore pressure and total pressure and since all these transducers also include temperature measurements no thermocouples will be installed in these directions. They will instead be placed in a separate direction.

The instruments will be placed in the centre of the bentonite rings, i.e. 25 cm from the horizontal surfaces. In order to avoid interferences as much as possible two rings will be used, i.e. every second set of instruments will be placed in the upper ring and every second in the lower ring. Rings 1 and 2, 4 and 5, and 8 and 9 will be used.

Another advantage of this constellation is that the results can be plotted with the assumption that there is axial symmetry around the canister axis. The scatter in results will then be a measure of the deviation from the symmetry.

Figures 3-3 and 3-4 show the instrument positions in the bentonite rings and the bottom block. The upper blocks, C2, C3 and C4 are instrumented in the same way as those in deposition hole 5.

10 additional Wescor psychrometers and 5 additional Vaisala relative humidity sensors have been placed in order to try to detect differences in behavior of the buffer at dry and wet conditions of the rock surface. The position of these sensors has been based on the distribution of water inflow determined by help of diapers.

The positions of each instrument, the cable length and the corresponding lead through connections are described in Tables 3-6 to 3-10.

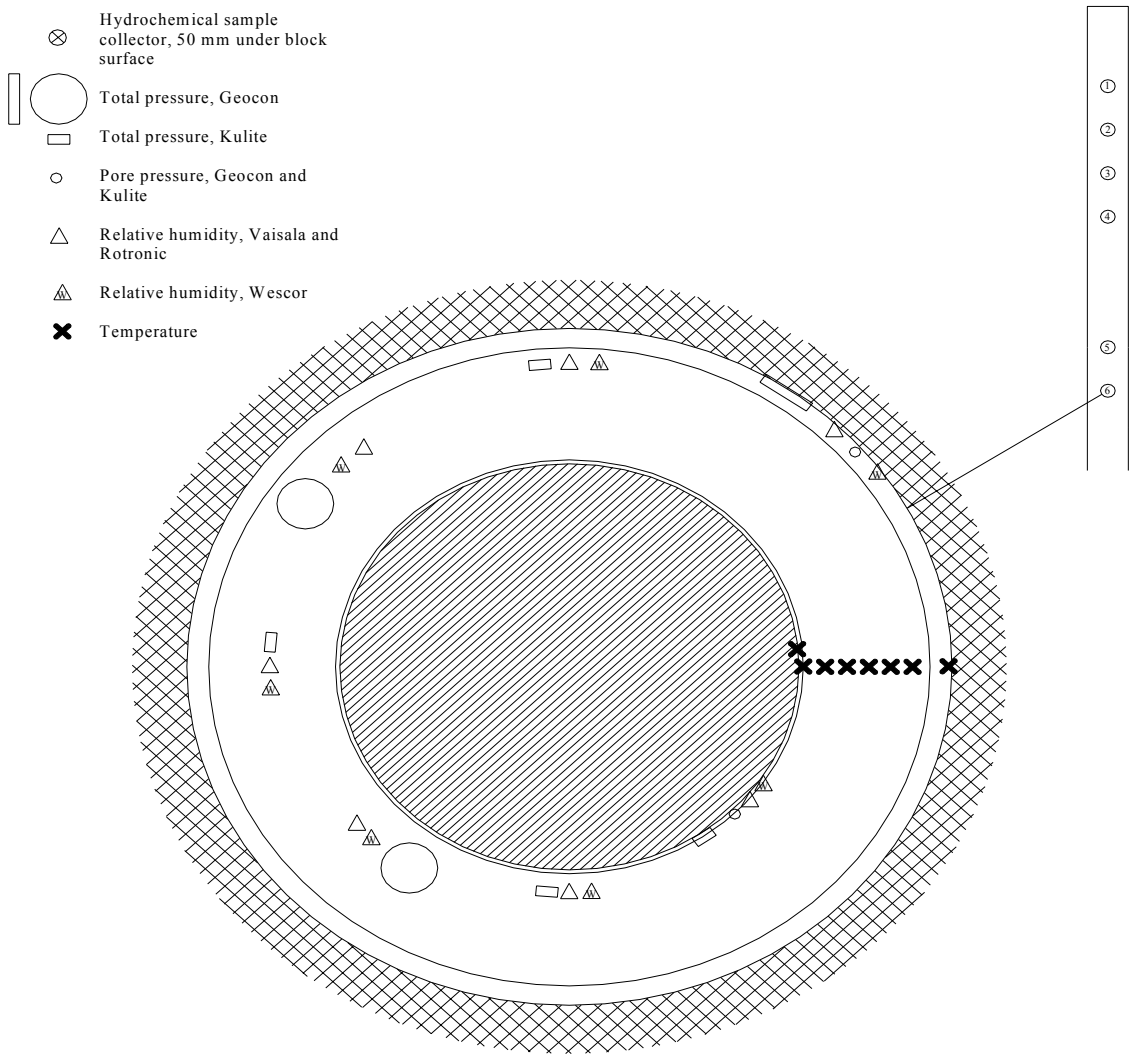

Figure 3-3. *Schematic view over the instruments positions in the bentonite rings in deposition hole 6. The instruments are placed in eight vertical sections, where four sections are represented in each instrumented block.*

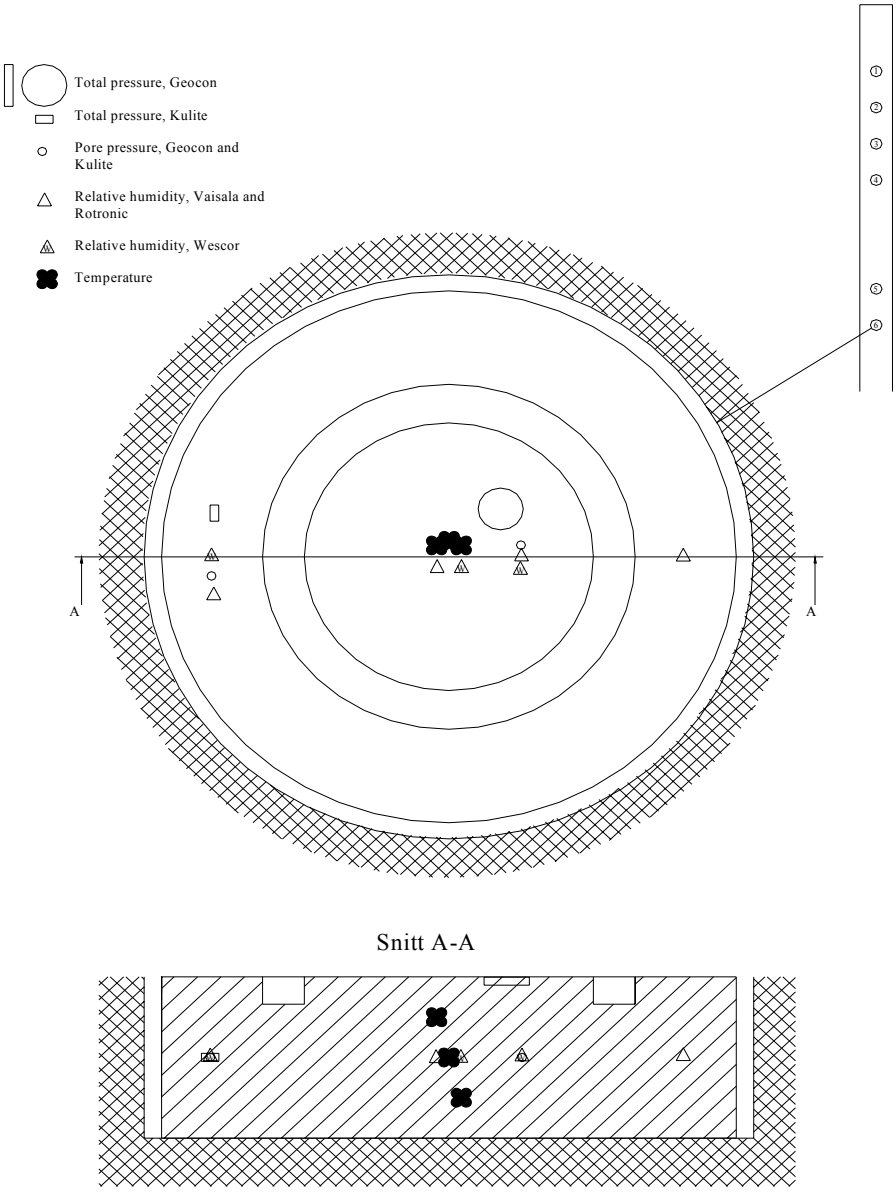

Figure 3-4. *Instrument positions in the bottom block of hole 6.*

Table 3-6 Numbering and position of instruments for measuring temperature (T)

Prototype Repository, Instrumentation

Instrument type **Thermocouple**
Deposition hole, No **6**
Lead through, No **LT62**
Length of lead through **33.7**
Length in G-tunnel, m **10.0**
Estimated length in backfill, m **9.0**

		Instrument position in block				Cable dir.		Cable lengths			Remark
Mark	Block	Direction	α	r	z	α	Fabricate	Buffer	In test volume	Total	
			degree	mm	mm	degree		m	m	m	
TB601	Cyl. 1	Center	45	50	375	4	Pentronic	7.9	**17**	61	
TB602	Cyl. 1	Center	315	50	250	2	Pentronic	7.9	**17**	61	
TB603	Cyl. 1	Center	0	50	125	0	Pentronic	7.9	**17**	61	
TB604	Ring 1	D	270	535	750	282	Pentronic	6.9	**16**	60	
TB605	Ring 1	D	270	585	750	280	Pentronic	6.8	**16**	60	
TB606	Ring 1	D	270	635	750	278	Pentronic	6.8	**16**	59	
TB607	Ring 1	D	270	685	750	276	Pentronic	6.7	**16**	59	
TB608	Ring 1	D	270	735	750	274	Pentronic	6.7	**16**	59	
TB609	Ring 1	D	270	785	750	272	Pentronic	6.6	**16**	59	
TB610	Ring 1	D	270	875	750	270	Pentronic	6.5	**16**	59	On rock
TB611	Ring 1	D	275	525	750	284	Pentronic	6.9	**16**	60	On canister
TB612	Ring 5	D	270	535	2750	294	Pentronic	4.8	**14**	58	
TB613	Ring 5	D	270	585	2750	292	Pentronic	4.8	**14**	57	
TB614	Ring 5	D	270	635	2750	290	Pentronic	4.7	**14**	57	
TB615	Ring 5	D	270	685	2750	288	Pentronic	4.7	**14**	57	
TB616	Ring 5	D	270	735	2750	286	Pentronic	4.6	**14**	57	
TB617	Ring 5	D	270	785	2750	284	Pentronic	4.6	**14**	57	
TB618	Ring 5	D	270	875	2750	270	Pentronic	4.5	**14**	57	On rock
TB619	Ring 5	D	275	525	2750	296	Pentronic	4.9	**14**	58	On canister
TB620	Ring 8	D	270	535	4250	306	Pentronic	3.3	**12**	56	
TB621	Ring 8	D	270	585	4250	304	Pentronic	3.3	**12**	56	
TB622	Ring 8	D	270	635	4250	302	Pentronic	3.2	**12**	56	
TB623	Ring 8	D	270	685	4250	300	Pentronic	3.2	**12**	56	
TB624	Ring 8	D	270	735	4250	298	Pentronic	3.1	**12**	56	
TB625	Ring 8	D	270	785	4250	296	Pentronic	3.1	**12**	56	
TB626	Ring 8	D	270	875	4250	270	Pentronic	3.0	**12**	56	On rock
TB627	Ring 8	D	275	525	4250	308	Pentronic	3.3	**12**	56	On canister
TB628	Cyl. 3	A	0	785	6250	0	Pentronic	1.0	**10**	54	
TB629	Cyl. 3	B	95	585	6250	94	Pentronic	1.2	**10**	54	
TB630	Cyl. 3	C	185	585	6250	184	Pentronic	1.2	**10**	54	
TB631	Cyl. 4	Center	225	100	6950	224	Pentronic	1.2	**10**	54	
TB632	Cyl. 4	A	0	785	6950	2	Pentronic	0.5	**10**	53	

Table 3-7 Numbering and position of instruments for measuring total pressure (P)

Prototype Repository, Instrumentation

Instrument type **Total Pressure**
Deposition hole, No **6**
Lead through, No **LT62**
Length of lead through **33.7**
Length in G-tunnel, m **10.0**
Estimated length in backfill, m **9.0**

		Instrument position in block				Cable dir.		Cable lengths				Remark
Mark	Block	Direction	α	r	z	α	Fabricate	Buffer		In test volume	Total	
			degree	mm	mm	degree		m	m	m	m	
PB601	Cyl. 1	Center	315	210	500	314	Geokon	7.7	**8.0**	**17**	60	
PB602	Cyl. 1	B	80	685	250	70	Kulite	7.2	**8.0**	**16**	60	Vertical
PB603	Ring 1	A	10	785	750	20	Kulite	6.6	**8.0**	**16**	59	Vertical
PB604	Ring 1	B	80	685	750	68	Kulite	6.7	**8.0**	**16**	59	Vertical
PB605	Ring 1	C	170	585	750	130	Kulite	6.8	**6.0**	**16**	60	Vertical
PB606	Ring 2	AB	55	735	1500	80	Geokon	6.2	**8.0**	**15**	59	
PB607	Ring 2	BC	145	635	1500	178	Geokon	6.3	**8.0**	**15**	59	
PB608	Ring 2	CD	215	535	1250	216	Kulite	6.4	**6.0**	**15**	59	In the slot
PB609	Ring 2	DA	325	875	1250	316	Geokon	6.0	**8.0**	**15**	59	At rock
PB610	Ring 5	A	10	785	2750	44	Kulite	4.6	**6.0**	**14**	57	Vertical
PB611	Ring 5	B	80	685	2750	66	Kulite	4.7	**4.0**	**14**	57	Vertical
PB612	Ring 5	C	170	585	2750	136	Kulite	4.8	**4.0**	**14**	57	Vertical
PB613	Ring 6	AB	55	785	3500	64	Geokon	4.1	**8.0**	**13**	57	
PB614	Ring 6	BC	145	635	3500	132	Geokon	4.2	**8.0**	**13**	57	
PB615	Ring 6	CD	215	535	3250	200	Kulite	4.3	**4.0**	**13**	57	In the slot
PB616	Ring 6	DA	325	875	3250	318	Geokon	4.0	**6.0**	**13**	57	At rock
PB617	Ring 8	A	10	785	4250	22	Kulite	3.1	**4.0**	**12**	56	Vertical
PB618	Ring 8	B	80	685	4250	70	Kulite	3.2	**4.0**	**12**	56	Vertical
PB619	Ring 8	C	170	585	4250	132	Kulite	3.3	**4.0**	**12**	56	Vertical
PB620	Ring 9	AB	55	735	5000	82	Geokon	2.6	**6.0**	**12**	55	
PB621	Ring 9	BC	145	635	5000	180	Geokon	2.7	**6.0**	**12**	55	
PB622	Ring 9	CD	215	535	4750	218	Kulite	2.8	**4.0**	**12**	56	In the slot
PB623	Ring 9	DA	325	875	4750	318	Geokon	2.5	**5.0**	**11**	55	At rock,Delivery 1
PB624	Ring 10	Center	270	50	5500	268	Geokon	2.8	**4.0**	**12**	55	
PB625	Cyl. 3	Center	0	100	6500	320	Geokon	2.0	**4.0**	**11**	55	
PB626	Cyl. 3	A	5	585	6500	324	Geokon	1.5	**4.0**	**11**	54	
PB627	Cyl. 4	Center	0	100	7000	326	Geokon	1.2	**4.0**	**10**	54	

Table 3-8 Numbering and position of instruments for measuring pore water pressure (U)

Prototype Repository, Instrumentation

Instrument type **Pore Pressure**
Deposition hole, No **6**
Lead through, No **LT62**
Length of lead through **33.7**
Length in G-tunnel, m **10.0**
Estimated length in backfill, m **9.0**

Mark	Block	Instrument position in block				Cable dir.	Fabricate	Cable lengths				Remark
		Direction	α	r	z	α		Buffer		In test volume	Total	
			degree	mm	mm	degree		m		m	m	
UB601	Cyl. 1	Center	280	210	250	268	Kulite	7.7	**8.0**	**19**	62	
UB602	Cyl. 1	B	95	685	250	96	Geokon	7.2	**8.0**	**18**	62	
UB603	Ring 2	CD	225	535	1250	226	Geokon	6.4	**8.0**	**17**	61	In the slot
UB604	Ring 2	DA	310	875	1250	310	Kulite	6.0	**8.0**	**17**	61	At the rock
UB605	Ring 5	C	190	585	2750	190	Geokon	4.8	**6.0**	**16**	59	
UB606	Ring 5	A	350	785	2750	350	Kulite	4.6	**6.0**	**16**	59	
UB607	Ring 6	AB	35	735	3250	40	Kulite	4.1	**6.0**	**15**	59	
UB608	Ring 6	BC	125	635	3250	126	Kulite	4.2	**6.0**	**15**	59	
UB609	Ring 6	CD	225	535	3250	226	Geokon	4.3	**6.0**	**15**	59	In the slot
UB610	Ring 6	DA	310	875	3250	312	Geokon	4.0	**6.0**	**15**	59	At the rock
UB611	Ring 9	CD	225	535	4750	222	Geokon	2.8	**4.0**	**14**	58	In the slot
UB612	Ring 9	DA	310	875	4750	308	Kulite	2.5	**4.0**	**13**	57	At the rock
UB613	Cyl. 3	Center	135	100	6250	134	Kulite	2.0	**4.0**	**13**	57	
UB614	Cyl. 4	Center	90	100	6750	90	Kulite	1.2	**4.0**	**12**	56	

Table 3-9 Numbering and position of instruments for measuring wetting (W)

Prototype Repository, Instrumentation

Instrument type	**Relative Humidity**
Deposition hole, No	**6**
Lead through, No(Rotronic)	**LT65**
Lead through, No(Wescor)	**Plug**
Lead through, No(Vaisala)	**LT61**
Length of lead through LT65	**32,2**
Length of lead through Plug	**5,0**
Length of lead through LT61	**33,8**
Length in G-tunnel, m	**10,0**
Length in backfill (LT65), m	**11,0**
Length in backfill (Plug), m	**15,0**
Length in backfill (LT61), m	**9,0**

		Instrument position in block				Cable dir.		Cable lengths				Remark
Mark	Block	Direction	α	r	z	α	Fabricate	Titanium		In test volume	Total	
			degree	mm	mm	degree		m	**m**	m	m	
WB601	Cyl. 1	Center	135	50	250	134	Rotronic	7,6	**7,5**	**19**	61	
WB602	Cyl. 1	Center	225	50	250	220	Wescor	7,6	**7,5**	**23**	38	
WB603	Cyl. 1	Center	260	210	250	266	Wescor	7,5	**7,5**	**22**	37	
WB604	Cyl. 1	Center	270	210	250	264	Rotronic	7,5	**7,5**	**18**	61	
WB605	Cyl. 1	B	85	685	250	92	Wescor	7,0	**7,5**	**22**	37	
WB606	Cyl. 1	B	100	685	250	100	Rotronic	7,0	**7,5**	**18**	60	
WB607	Ring 1	B	90	685	750	86	Vaisala	6,5	**6,5**	**15**	59	
WB608	Ring 1	B	95	685	750	88	Wescor	6,5	**6,5**	**21**	36	
WB609	Ring 1	C	180	585	750	182	Vaisala	6,6	**6,5**	**16**	59	
WB610	Ring 1	C	185	585	750	184	Wescor	6,6	**6,5**	**22**	37	
WB611	Ring 1	A	355	785	750	358	Wescor	6,4	**6,5**	**21**	36	
WB612	Ring 1	A	360	785	750	360	Vaisala	6,4	**6,5**	**15**	59	
WB613	Ring 2	AB	40	735	1250	42	Rotronic	5,9	**6,0**	**17**	59	
WB614	Ring 2	AB	45	735	1250	44	Wescor	5,9	**6,0**	**21**	36	
WB615	Ring 2	BC	130	635	1250	126	Rotronic	6,0	**6,0**	**17**	59	
WB616	Ring 2	BC	135	635	1250	128	Wescor	6,0	**6,0**	**21**	36	
WB617	Ring 2	CD	230	535	1250	216	Rotronic	6,1	**6,0**	**17**	59	In the slot
WB618	Ring 2	CD	235	535	1250	220	Wescor	6,1	**6,0**	**21**	36	In the slot
WB619	Ring 2	DA	305	875	1250	312	Wescor	5,8	**6,0**	**21**	36	At rock
WB620	Ring 2	DA	315	875	1250	316	Rotronic	5,8	**6,0**	**17**	59	At rock
WB621	Ring 5	B	90	685	2750	100	Rotronic	4,4	**4,5**	**15**	58	
WB622	Ring 5	B	95	685	2750	102	Wescor	4,4	**4,5**	**19**	34	
WB623	Ring 5	C	180	585	2750	186	Rotronic	4,5	**4,5**	**16**	58	
WB624	Ring 5	C	185	585	2750	188	Wescor	4,5	**4,5**	**20**	35	
WB625	Ring 5	A	355	785	2750	350	Wescor	4,3	**4,5**	**19**	34	
WB626	Ring 5	A	360	785	2750	352	Rotronic	4,3	**4,5**	**15**	58	
WB627	Ring 6	AB	40	735	3250	44	Vaisala	3,9	**4,5**	**13**	57	
WB628	Ring 6	AB	45	735	3250	46	Wescor	3,9	**4,5**	**19**	34	
WB629	Ring 6	BC	130	635	3250	128	Vaisala	4,0	**4,5**	**13**	57	
WB630	Ring 6	BC	135	635	3250	130	Wescor	4,0	**4,5**	**19**	34	
WB631	Ring 6	CD	230	535	3250	234	Vaisala	4,1	**4,5**	**13**	57	In the slot
WB632	Ring 6	CD	235	535	3250	238	Wescor	4,1	**4,5**	**19**	34	In the slot
WB633	Ring 6	DA	305	875	3250	310	Wescor	3,7	**4,5**	**19**	34	At rock
WB634	Ring 6	DA	315	875	3250	320	Vaisala	3,7	**4,5**	**13**	57	At rock
WB635	Ring 8	B	90	685	4250	110	Rotronic	2,9	**3,0**	**14**	56	
WB636	Ring 8	B	95	685	4250	112	Wescor	2,9	**3,0**	**18**	33	
WB637	Ring 8	C	180	585	4250	208	Rotronic	3,0	**3,0**	**14**	56	
WB638	Ring 8	C	185	585	4250	212	Wescor	3,0	**3,0**	**18**	33	
WB639	Ring 8	A	355	785	4250	350	Wescor	2,8	**3,0**	**18**	33	
WB640	Ring 8	A	360	785	4250	352	Rotronic	2,8	**3,0**	**14**	56	
WB641	Ring 9	AB	40	735	4750	36	Rotronic	2,4	**3,0**	**13**	56	
WB642	Ring 9	AB	45	735	4750	38	Wescor	2,4	**3,0**	**17**	32	
WB643	Ring 9	BC	130	635	4750	126	Vaisala	2,5	**3,0**	**11**	55	
WB644	Ring 9	BC	135	635	4750	128	Wescor	2,5	**3,0**	**17**	32	
WB645	Ring 9	CD	230	535	4750	250	Vaisala	2,6	**3,0**	**12**	55	In the slot
WB646	Ring 9	CD	235	535	4750	254	Wescor	2,6	**3,0**	**18**	33	In the slot
WB647	Ring 9	DA	305	875	4750	304	Wescor	2,2	**3,0**	**17**	32	At rock
WB648	Ring 9	DA	315	875	4750	314	Vaisala	2,2	**3,0**	**11**	55	At rock
WB649	Ring 10	Center	90	50	5340	90	Vaisala	2,5	**3,0**	**12**	55	
WB650	Ring 10	Center	270	210	5340	270	Vaisala	2,4	**3,0**	**11**	55	
WB651	Cyl. 3	Center	225	100	6250	224	Rotronic	1,5	**3,0**	**12**	55	
WB652	Cyl. 3	B	90	585	6250	88	Vaisala	1,0	**1,0**	**10**	54	
WB653	Cyl. 3	C	180	585	6250	178	Rotronic	1,0	**1,0**	**12**	54	
WB654	Cyl. 3	A	350	585	6250	350	Vaisala	1,0	**1,0**	**10**	54	
WB655	Cyl. 4	Center	180	100	6680	190	Rotronic	1,0	**1,0**	**12**	54	

Table 3-10 Numbering of instruments for measuring wetting (positions were determined after inflow measurements) (W)

Prototype Repository, Instrumentation

Instrument type	**Relative Humidity**
Deposition hole, No	**6**
Lead through, No(Wescor)	**Plug**
Lead through, No(Vaisala)	**LT61**
Length of lead through Plug	**5.0**
Length of lead through LT61	**33.8**
Length in G-tunnel, m	**10.0**
Length in backfill (Plug), m	**15.0**
Length in backfill (LT61), m	**9.0**

		Instrument position in block				Cable dir.		Cable lengths				Remark
Mark	Block	Direction	α	r	z	α	Fabricate	Titanium		In test volume	Total	
			degree	mm	mm	degree		m	**m**	m	m	
WB657	Ring 6	C	190	625	3250	190	Wescor	4.0	**7.5**	**19**	34	
WB658	Ring 6	C	190	725	3250	190	Wescor	3.9	**7.5**	**19**	34	
WB659	Rock	C	190	900	3100	190	Wescor	3.7	**7.5**	**19**	34	
WB660	Rock	C	190	925	3250	190	Wescor	3.7	**6.0**	**19**	34	
WB661	Rock	C	190	975	3400	190	Wescor	3.6	**6.0**	**19**	34	
WB662	Ring 8	D	280	625	4250	280	Wescor	3.0	**6.0**	**18**	33	
WB663	Ring 8	D	280	725	4250	280	Wescor	2.9	**3.0**	**18**	33	
WB664	Rock	D	280	900	4100	280	Wescor	2.7	**3.0**	**18**	33	
WB665	Rock	D	280	925	4250	280	Wescor	2.7	**3.0**	**18**	33	
WB666	Rock	D	280	975	4400	280	Wescor	2.6	**3.0**	**18**	33	
WB667	Cyl.1	D	280	685	250	280	Vaisala	7.0	**6.5**	**16**	60	
WB668	Ring 6	C	200	625	3250	200	Vaisala	4.0	**4.5**	**13**	57	
WB669	Ring 6	C	200	725	3250	200	Vaisala	3.9	**4.5**	**13**	57	
WB670	Ring 8	D	290	625	4250	290	Vaisala	3.0	**3.0**	**12**	56	
WB671	Ring 8	D	290	725	4250	290	Vaisala	2.9	**3.0**	**12**	56	

4 Location of instruments for standard measurements of THM-processes in the backfill

4.1 Brief description of instruments

All instruments will be of the same type as those in the bentonite (described in chapter 3 and /1-2/).

4.2 Strategy for describing the position of each device

The backfill will mainly be instrumented in vertical sections above and between the deposition holes (Figure 4-1 and 4-2). Every instrument will be named with a unique name according to the same system as described in chapter 3.2. Every instrument position is described with three coordinates. The x-coordinate is the horizontal distance from the center of the tunnel and the y-coordinate is the vertical distance from the center of the tunnel. The z-coordinate is the same as in the tunnel coordinate system, i.e. the coordinate 3599 corresponds to the end of the tunnel.

4.3 Position of each instrument in the backfill

Figure 4-1 shows the location of the vertical measuring sections and the position of the sensors between the deposition holes and the plugs. The instrumentation is very similar to the instrumentation in section 1. The instrumentation differs between section E located above the deposition holes and section F located between the deposition holes. Figure 4-2 shows the position of the sensors in these two sections. The exact positions of each instrument are described in Tables 4-1 to 4-4.

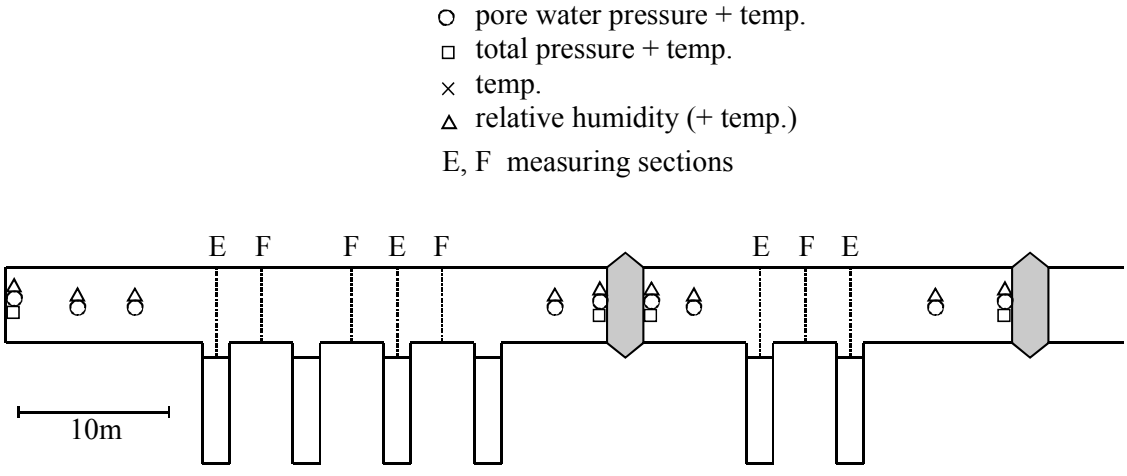

Figure 4-1. *Schematic view over the instrumentation of the backfill*

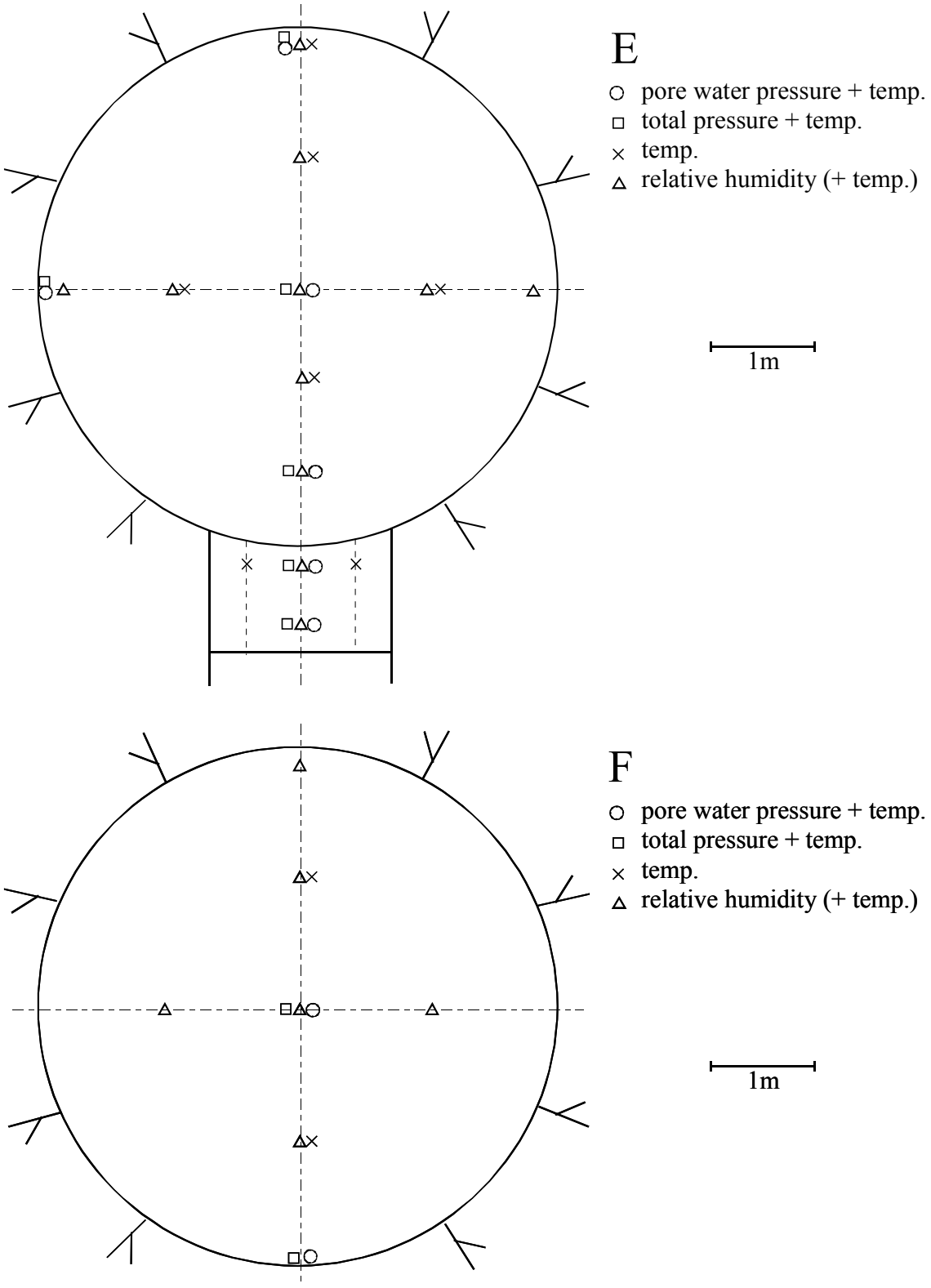

***Figure 4-2**. Schematic view over the sensors positions in the different sections.*

Table 4-1 Numbering and position of instruments for measuring temperature (T)

Prototype Repository, Instrumentation

Instrument type **Thermocouple**
Backfill
Lead through, No(TFA01-TFA07) **LT53**
Lead through, No(TFA08-TFA16) **LT62**
Length of lead through LT53 **33,5**
Length of lead throughLT62 **33,7**
Length in G-tunnel, m **10**

Mark	Instrument position Section	x	y	z	Fabricate	Cable lengths In test volume	Total	Remark
		m	m	m		m	m	
TFA01	E, over dep.hole 5	0	2,3	3551	Pentronic	15,0	58,5	
TFA02	E, over dep.hole 5	0	1,25	3551	Pentronic	15,0	58,5	
TFA03	E, over dep.hole 5	0	-0,8	3551	Pentronic	15,0	58,5	
TFA04	E, over dep.hole 5	-0,5	-2,6	3551	Pentronic	15,0	58,5	
TFA05	E, over dep.hole 5	0,5	-2,6	3551	Pentronic	15,0	58,5	
TFA06	E, over dep.hole 5	-1,25	0	3551	Pentronic	15,0	58,5	
TFA07	E, over dep.hole 5	1,25	0	3551	Pentronic	15,0	58,5	
TFA08	F, between dep.hole 5 and 6	0	1,25	3548	Pentronic	15,0	58,7	
TFA09	F, between dep.hole 5 and 6	0	-1,25	3548	Pentronic	15,0	58,7	
TFA10	E, over dep.hole 6	0	2,3	3545	Pentronic	15,0	58,7	
TFA11	E, over dep.hole 6	0	1,25	3545	Pentronic	15,0	58,7	
TFA12	E, over dep.hole 6	0	-0,8	3545	Pentronic	15,0	58,7	
TFA13	E, over dep.hole 6	-0,5	-2,6	3545	Pentronic	15,0	58,7	
TFA14	E, over dep.hole 6	0,5	-2,6	3545	Pentronic	15,0	58,7	
TFA15	E, over dep.hole 6	-1,25	0	3545	Pentronic	15,0	58,7	
TFA16	E, over dep.hole 6	1,25	0	3545	Pentronic	15,0	58,7	

Table 4-2 Numbering and position of instruments for measuring total pressure (P)

Prototype Repository, Instrumentation

Instrument type **Total Pressure**
Backfill
Lead through, No(PFA01-PFA07) **LT53**
Lead through, No(PFA08-PFA16) **LT55**
Length of lead through LT53 **33,5**
Length of lead throughLT55 **35,3**
Length in G-tunnel, m **10**

Mark	Instrument position Section	x	y	z	Fabricate	Cable lengths In test volume	Total	Remark
		m	m	m		m	m	
PFA01	Inner part	0	0	3556	Kulite	25,0	68,5	
PFA02	E, over dep.hole 5	0	0	3551	Geokon	15,0	58,5	
PFA03	E, over dep.hole 5	0	-1,75	3551	Geokon	15,0	58,5	
PFA04	E, over dep.hole 5	0	-2,6	3551	Geokon	15,0	58,5	
PFA05	E, over dep.hole 5	0	-3,15	3551	Kulite	15,0	58,5	
PFA06	E, over dep.hole 5	-2,3	0	3551	Kulite	15,0	58,5	
PFA07	E, over dep.hole 5	0	2,3	3551	Kulite	15,0	58,5	
PFA08	F, between dep.hole 5 and 6	0	0	3548	Geokon	15,0	58,5	
PFA09	F, between dep.hole 5 and 6	0	-2,3	3548	Geokon	15,0	58,5	
PFA10	E, over dep.hole 6	0	0	3545	Kulite	15,0	60,3	
PFA11	E, over dep.hole 6	0	-1,75	3545	Kulite	15,0	60,3	
PFA12	E, over dep.hole 6	0	-2,6	3545	Kulite	15,0	60,3	
PFA13	E, over dep.hole 6	0	-3,15	3545	Geokon	15,0	60,3	
PFA14	E, over dep.hole 6	-2,3	0	3545	Geokon	15,0	60,3	
PFA15	E, over dep.hole 6	0	2,3	3545	Geokon	15,0	60,3	
PFA16	In front of plug	0	0	3540	Kulite	25,0	70,3	

Table 4-3 Numbering and position of instruments for measuring pore water pressure (U)

Prototype Repository, Instrumentation

Instrument type **Pore Pressure**
Backfill
Lead through, No(UFA01-UFA08) **LT53**
Lead through, No(UFA09-UFA18) **LT62**
Length of lead through LT53 **33,5**
Length of lead throughLT62 **33,7**
Length in G-tunnel, m **10**

Mark	Instrument position				Fabricate	Cable lengths		Remark
	Section	x	y	z		In test volume	Total	
		m	m	m		m	m	
UFA01	Inner part	0	0	3556	Kulite	25,0	68,5	
UFA02	Inner part	0	0	3554	Geokon	20,0	63,5	
UFA03	E, over dep.hole 5	0	0	3551	Geokon	15,0	58,5	
UFA04	E, over dep.hole 5	0	-1,75	3551	Kulite	15,0	58,5	
UFA05	E, over dep.hole 5	0	-2,6	3551	Kulite	15,0	58,5	
UFA06	E, over dep.hole 5	0	-3,15	3551	Kulite	15,0	58,5	
UFA07	E, over dep.hole 5	-2,3	0	3551	Geokon	15,0	58,5	
UFA08	E, over dep.hole 5	0	2,3	3551	Geokon	15,0	58,5	
UFA09	F, between dep.hole 5 and 6	0	0	3548	Kulite	15,0	58,5	
UFA10	F, between dep.hole 5 and 6	0	-2,3	3548	Geokon	15,0	58,5	
UFA11	E, over dep.hole 6	0	0	3545	Geokon	15,0	58,7	
UFA12	E, over dep.hole 6	0	-1,75	3545	Geokon	15,0	58,7	
UFA13	E, over dep.hole 6	0	-2,6	3545	Geokon	15,0	58,7	
UFA14	E, over dep.hole 6	0	-3,15	3545	Geokon	15,0	58,7	
UFA15	E, over dep.hole 6	-2,3	0	3545	Geokon	15,0	58,7	
UFA16	E, over dep.hole 6	0	2,3	3545	Geokon	15,0	58,7	
UFA17	In front of plug	0	0	3542	Kulite	20,0	63,7	
UFA18	In front of plug	0	0	3540	Geokon	25,0	68,7	

Table 4-4 Numbering and position of instruments for measuring relative humidity (W)

Prototype Repository, Instrumentation

Instrument type **Relative Humidity**
Backfill
Lead through, No(WFA01-WFA13) **LT53**
Lead through, No(WFA14-WFA32) **LT62**
Length of lead through LT53 **33,5**
Length of lead throughLT62 **33,7**
Length in G-tunnel, m **10**

Mark	Instrument position Section	x	y	z	Fabricate	Cable lengths In test volume	Total	Remark
		m	m	m		m	m	
WFA01	Inner part	0	0	3556	Wescor	25,0	68,5	
WFA02	Inner part	0	0	3554	Wescor	20,0	63,5	
WFA03	E, over dep.hole 5	0	2,3	3551	Wescor	15,0	58,5	
WFA04	E, over dep.hole 5	0	1,25	3551	Wescor	15,0	58,5	
WFA05	E, over dep.hole 5	0	0	3551	Wescor	15,0	58,5	
WFA06	E, over dep.hole 5	0	-0,8	3551	Wescor	15,0	58,5	
WFA07	E, over dep.hole 5	0	-1,75	3551	Wescor	15,0	58,5	
WFA08	E, over dep.hole 5	0	-2,6	3551	Wescor	15,0	58,5	
WFA09	E, over dep.hole 5	0	-3,15	3551	Wescor	15,0	58,5	
WFA10	E, over dep.hole 5	-2,3	0	3551	Wescor	15,0	58,5	
WFA11	E, over dep.hole 5	-1,25	0	3551	Wescor	15,0	58,5	
WFA12	E, over dep.hole 5	1,25	0	3551	Wescor	15,0	58,5	
WFA13	E, over dep.hole 5	2,3	0	3551	Wescor	15,0	58,5	
WFA14	F, between dep.hole 5 and 6	0	2,3	3548	Wescor	15,0	58,5	
WFA15	F, between dep.hole 5 and 6	0	1,25	3548	Wescor	15,0	58,5	
WFA16	F, between dep.hole 5 and 6	0	0	3548	Wescor	15,0	58,5	
WFA17	F, between dep.hole 5 and 6	0	-0,8	3548	Wescor	15,0	58,5	
WFA18	F, between dep.hole 5 and 6	-1,25	0	3548	Wescor	15,0	58,5	
WFA19	F, between dep.hole 5 and 6	1,25	0	3548	Wescor	15,0	58,5	
WFA20	E, over dep.hole 6	0	2,3	3545	Wescor	15,0	58,7	
WFA21	E, over dep.hole 6	0	1,25	3545	Wescor	15,0	58,7	
WFA22	E, over dep.hole 6	0	0	3545	Wescor	15,0	58,7	
WFA23	E, over dep.hole 6	0	-0,8	3545	Wescor	15,0	58,7	
WFA24	E, over dep.hole 6	0	-1,75	3545	Wescor	15,0	58,7	
WFA25	E, over dep.hole 6	0	-2,6	3545	Wescor	15,0	58,7	
WFA26	E, over dep.hole 6	0	-3,15	3545	Wescor	15,0	58,7	
WFA27	E, over dep.hole 6	-2,3	0	3545	Wescor	15,0	58,7	
WFA28	E, over dep.hole 6	-1,25	0	3545	Wescor	15,0	58,7	
WFA29	E, over dep.hole 6	1,25	0	3545	Wescor	15,0	58,7	
WFA30	E, over dep.hole 6	2,3	0	3545	Wescor	15,0	58,7	
WFA31	In front of plug	0	0	3542	Wescor	20,0	63,7	
WFA32	In front of plug	0	0	3540	Wescor	25,0	68,7	

5 Location of instruments for special measurements

5.1 Buffer displacement measurement

The displacement of the interface between the buffer material and the backfill will be measured in both deposition holes. The technique and locations of the measuring vessels are described in chapter 2.3.

5.2 Water and gas sampling

24 isolated water sample collectors (titanium cups) and 4 connected water/gas collectors will be placed in the bentonite buffer and 4 connected water/gas collectors will be placed in the backfill. The position of each titanium cup is described according to the same system as the THM sensors in the bentonite and backfill (chapters 3-3 and 4-2).

The locations of the titanium cups in the bentonite buffer are the same in holes 5 and 6. Measurements will be done in four vertical sections A, B, C and D according to Figure 5-1. Direction A and C are placed in the axial direction of the tunnel with A headed against the end of the tunnel i.e. almost towards the west.

The exact positions of each titanium cup in the buffer are described in Tables 5-1 and to 5-2.

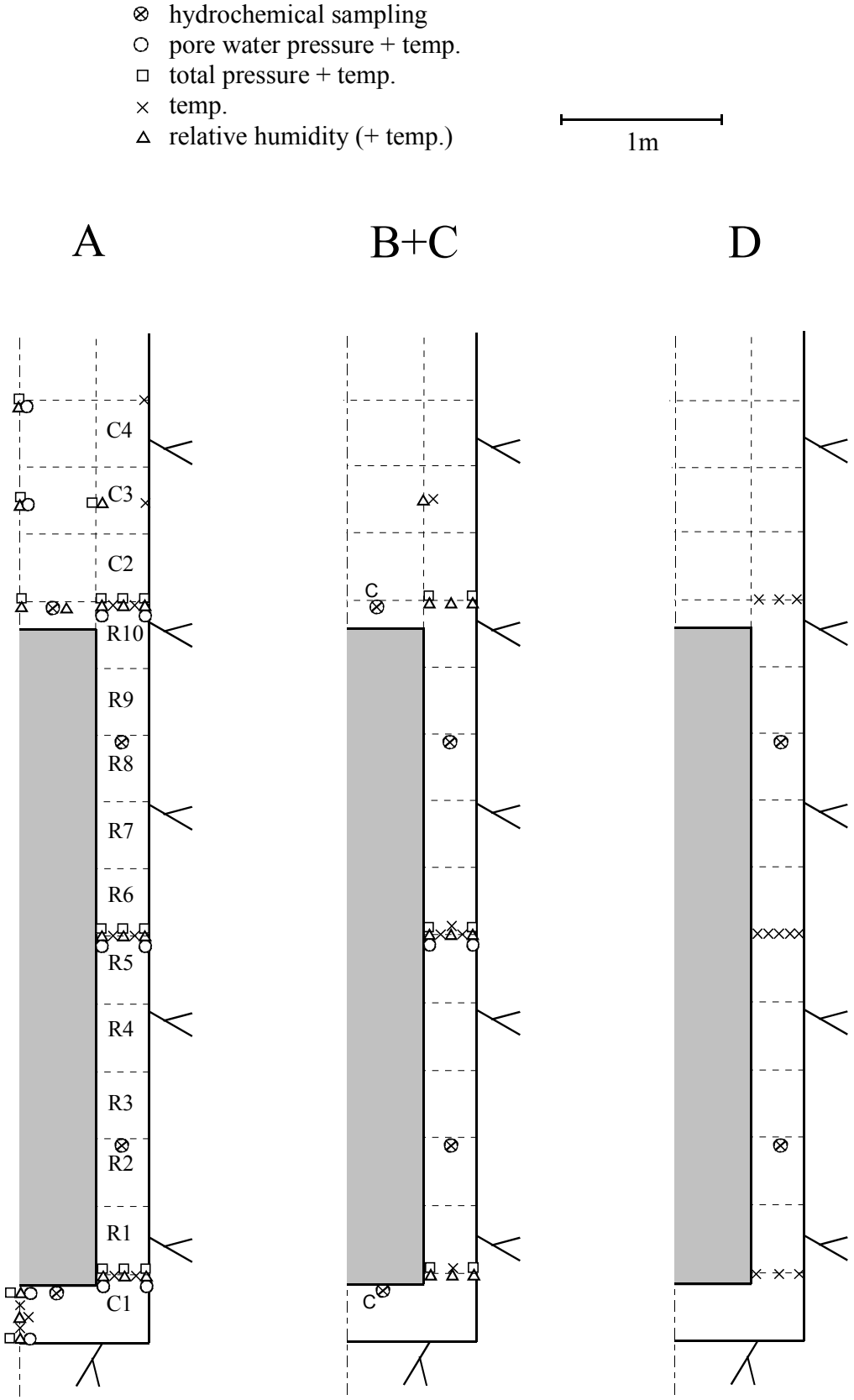

Figure 5-1. *Schematic view of the instruments in four vertical sections. The cups for water/gas sampling are denoted as a ring with a cross. The "C" beside two of the measuring points, indicates that the cups are only placed in measuring section C.*

Table 5-1 Table showing the positions of the titanium cups that will be placed in deposition hole 5

Instrument type **Hydrochemical sampling**
Deposition hole, No **5**
Lead through, No **Plug**
Length of lead through PlugA, m **2**
Length in G-tunnel, m **10**
Length in backfill, m **11**

Mark	Block	Instrument position in block				Cable dir.	Fabricate	Cable lengths			Remark	Installed
		Direction	α	r	z	α		Buffer	In test volume	Total		Signature /date
			degree	mm	mm	degree		m	m	m		
KB501	Cyl. 1	A	0	262	450		CT					
KB502	Cyl. 1	C	180	262	450		CT					
KB503	R2	A	0	685	1450		CT					
KB504	R2	B	90	685	1450		CT					
KB505	R2	C	180	685	1450		CT					
KB506	R2	D	270	685	1450		CT					
KB507	R8	A	0	685	4450		CT					
KB508	R8	B	90	685	4450		CT					
KB509	R8	C	180	685	4450		CT					
KB510	R8	D	270	685	4450		CT					
KB511	R10	A	0	262	5450		CT					
KB512	R10	C	180	262	5450		CT					
KB513	C4	A	0	875	6950	334	CT				with tube	
KB514	C4	A	0	875	6950	334	CT				with tube	

Table 5-2 Table showing the positions of the titanium cups that will be placed in deposition hole 6

Instrument type **Hydrochemical sampling**
Deposition hole, No **6**
Lead through, No **PlugA**
Length of lead through PlugA, m **2**
Length in G-tunnel, m **10**

Mark	Block	Instrument position in block				Cable dir.	Fabricate	Cable lengths			Remark	Installed
		Direction	α	r	z	α		Buffer	In test volume	Total		Signature /date
			degree	mm	mm	degree		m	m	m		
KB601	Cyl. 1	A	0	262	450		CT					
KB602	Cyl. 1	C	180	262	450		CT					
KB603	R2	A	0	685	1450		CT					
KB604	R2	B	90	685	1450		CT					
KB605	R2	C	180	685	1450		CT					
KB606	R2	D	270	685	1450		CT					
KB607	R9	A	0	685	4950		CT					
KB608	R9	B	90	685	4950		CT					
KB609	R9	C	180	685	4950		CT					
KB610	R9	D	270	685	4950		CT					
KB611	R10	A	0	262	5450		CT					
KB612	R10	C	180	262	5450		CT					
KB613	C4	A	0	875	6950	334	CT	0.5	25.0	37.0	with tube	
KB614	C4	A	0	875	6950	334	CT	0.5	25.0	37.0	with tube	

The locations of the titanium cups in the backfill in section 2 are similar to the locations in section 1. The locations are shown in Figure 5-2 and the exact position of each cup is described in Table 5-3.

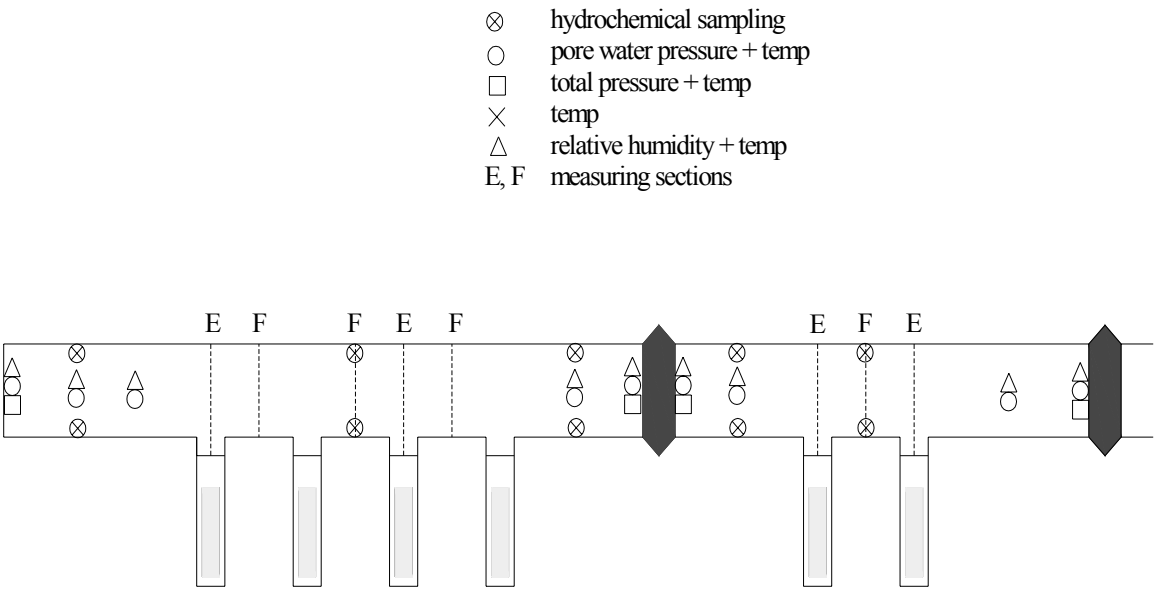

Figure 5-2. *Figure showing the positions of the titanium cups in the backfill (denoted as a ring with a cross).*

Table 5-3 Table showing the positions of the titanium cups that will be placed in the backfill

Prototype Repository, Instrumentation

Instrument type **Hydrochemical sampling**
Backfill
Lead through, No **PlugA**
Length of lead throughLT-Plug **2**

Mark	Instrument position Section	x	y	z	Fabricate	Cable lengths n test volume	Total	Remark	Installed Signature /date
		m	m	m		m	m		
KFA01	Inner part	0	2.4	3556	CT	25.0	27		
KFA02	Inner part	0	-2.4	3556	CT	25.0	27		
KFA03	Between dep.hole 5 and 6	0	2.4	3548	CT	25.0	27		
KFA04	Between dep.hole 5 and 6	0	-2.4	3548	CT	25.0	27		

5.3 In situ measurement of copper corrosion

Three copper electrodes will be placed in the top block (C4) of hole 5. The electrodes, with the diameter 60 mm and length 100 mm will be placed at the radius 625 mm in direction D at the depth 250 mm with the individual distance of 10 mm as shown in Figure 5-3.

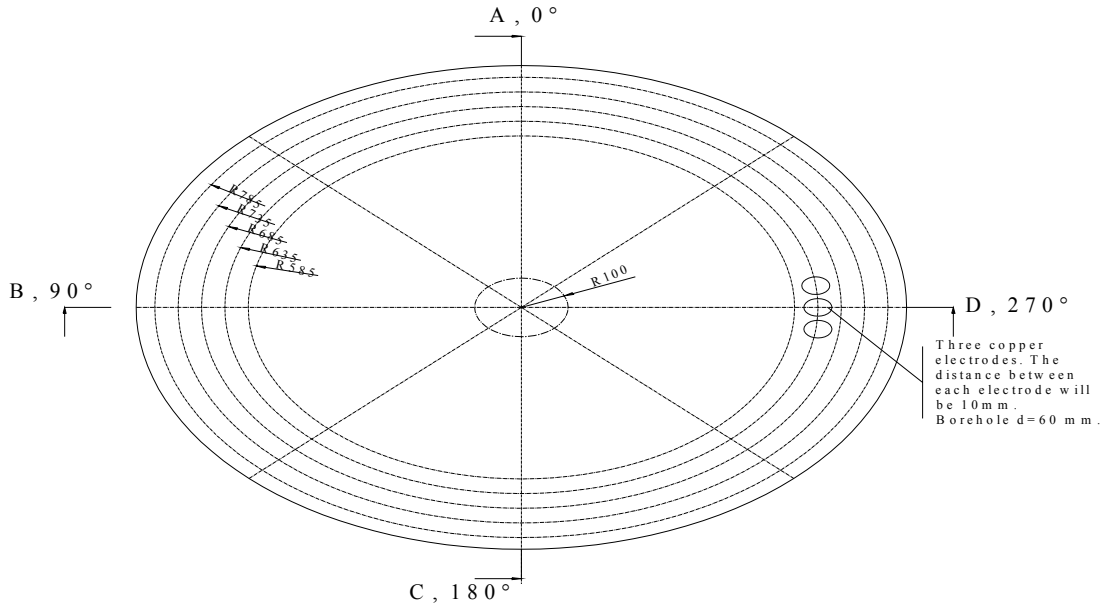

Figure 5-3. *Location of copper electrodes.*

5.4 Measurement of bentonite/rock interaction

5.4.1 Introduction

In order to measure the interaction between the rock and the buffer material a number of sensors will be placed on the surface of deposition hole 6. 12 sensors for measuring THM-processes at the rock surface will be placed and 6 sensors for measuring the desaturation in the rock will be installed.

5.4.2 THM-processes at the bentonite rock interface

3 sensors for measuring total pressure perpendicular to the rock surface, 3 sensors for measuring pore water pressure and 6 sensors for measuring relative humidity will be placed in the rock surface of deposition hole 6 according to Figure 5-4. The sensors will be inserted in prepared notches in the rock. All sensors are of the same type as placed in the buffer (see chapter 2.1 and /1-2/. The exact location is described in Table 5-4 in the same coordinate system as the other sensors (chapter 3.3).

Table 5-4 Table showing the instruments in the rock surface in deposition hole 6

Mark	Block	Instrument position in block				Cable dir.	Fabricate	Cable lengths				Remark
		Direction	α	r	Z	α		Buffer	Titanium	In test volume	Total	
PB609	Ring 2	DA	325	875	1250	316	Geokon	6,1	**8,0**	**15**	59	At rock
PB616	Ring 6	DA	325	875	3250	322	Geokon	4,0	**6,0**	**13**	57	At rock
PB623	Ring 9	DA	325	875	4750	318	Geokon	2,5	**5,0**	**12**	55	At rock
UB604	Ring 2	DA	310	875	1250	310	Kulite	6,1	**8,0**	**17**	61	At rock
UB610	Ring 6	DA	310	875	3250	312	Geokon	4,0	**6,0**	**15**	59	At rock
UB612	Ring 9	DA	310	875	4750	308	Kulite	2,5	**4,0**	**14**	57	At rock
WB619	Ring 2	DA	305	875	1250	324	Wescor	5,8	**6,0**	**21**	36	At rock
WB620	Ring 2	DA	315	875	1250	316	Rotronic	5,8	**6,0**	**17**	59	At rock
WB633	Ring 6	DA	305	875	3250	310	Wescor	3,7	**4,5**	**19**	34	At rock
WB634	Ring 6	DA	315	875	3250	320	Vaisala	3,7	**4,5**	**13**	57	At rock
WB647	Ring 9	DA	305	875	4750	304	Wescor	2,2	**3,0**	**17**	32	At rock
WB648	Ring 9	DA	315	875	4750	314	Vaisala	2,2	**3,0**	**11**	55	At rock

5.4.3 Desaturation of the rock

Six psychrometers will be placed in the rock surface of deposition hole 6 in positions shown in Figure 5-4. The measuring chambers will be placed 2.5-10 cm from the rock surface according to chapter 2.6. The exact location is described in Table 5-5 in the same coordinate system as the other sensors (chapter 3.3).

Table 5-5 Table showing the instruments that will be placed in the rock in deposition hole 6

Mark	Block	Instrument position in block				Cable dir.	Fabricate	Cable lengths				Remark
		Direction	α	r	Z	α		Titanium		In test volume	Total	
WB659	Rock	C	190	900	3100	190	Wescor	3,7	**7,5**	**19**	34	
WB660	Rock	C	190	925	3250	190	Wescor	3,7	**6,0**	**19**	34	
WB661	Rock	C	190	975	3400	190	Wescor	3,6	**6,0**	**19**	34	
WB664	Rock	D	280	900	4100	280	Wescor	2,7	**3,0**	**18**	33	
WB665	Rock	D	280	925	4250	280	Wescor	2,7	**3,0**	**18**	33	
WB666	Rock	D	280	975	4400	280	Wescor	2,6	**3,0**	**18**	33	

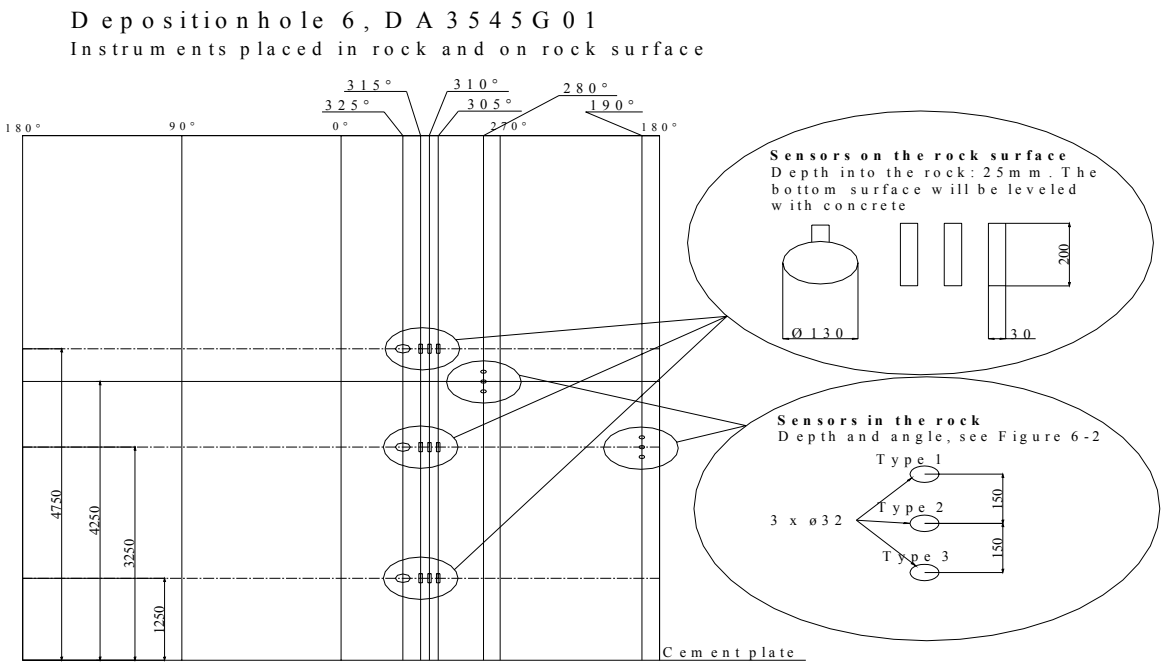

Figure 5-4. *Figure showing the positions of the instruments that will be placed in the rock and in the rock surface in deposition hole 6. The angle and depth of the six ø32mm holes for measuring desaturation of the rock are shown in Figure 2-3.*

6 Cable protection and position

All cables and tubes, coming from the instruments in the bentonite blocks, the cables from the rock surface, the four optic cables from the canister and the three (3 x Ø32 mm) power cables also from the canister will be led up along the bentonite block periphery surface.

Since a lot of cables and tubes will be led in the gap between rock and bentonite in the deposition holes (about 120 units/hole) they will be distributed on the block periphery in a prescribed order. Every cable or tube has a α–coordinate (Table 3-1 to 3-8), which is the angle from direction A (Figure 3-1). The cables will be led out to this position from the sensors position in pre-manufactured tracks on the blocks surface.

All instrument cables in the bentonite buffer are led in titanium tubes (Ø 8 mm or Ø 6 mm) except for the thermocouples (Ø 4 mm, which are made of cupro-nickel. Tracks will be made on the block surface from the instrument position in the bentonite block to the decided position on the bentonite block periphery (Table 3-1 to 3-8), where the tubes will be bend and led axial along the bentonite blocks. Expandable strings will be placed on about every third block in order to fix he cables.

All cables in the backfill are led in polyamide tubes, which pass through a lead through connection leading the tubes either through the rock or through the plug.

7 Summary of instruments

The total number of instruments in the buffer and backfill in section 2 are 401. Table 7-1 yields a summary of the measurements, suppliers, measuring principles and number of sensors that will be used.

Table 7-1 Instruments used in the buffer and backfill in section 2

Measure-ment	**Supplier**	**Principle**	**Number of sensors**			
			Tunnel	**Dep. holes**	**Rock surface**	**Sum**
Tempe-	Pentronic	Thermocouple	16	64		80
Rapture	BICC	FTR		8 cables		8
Total	Geokon	Vibrating wire	8	29	3	40
Pressure	Kulite	Piezoresistive	8	22		30
Water	Geokon	Vibrating wire	12	11	1	24
Pressure	Kulite	Piezoresistive	6	14	2	22
Relative	Vaisala	Capacitive		38	2	40
Humidity	Rotronic	Capacitive		33	1	34
	Wescor	Psychrometer	32	35	9	76
Water content	GRS[1)]	Resistivity	1 chain	3	(3)[2)]	4[1)]
Water/gas	CT	Active sampling	4	4		8
.sampling	CT	Passive sampling		24		24
Copper corrosion				3		3
Canister displace-ment	AITEMIN/ Rocktest[1)]	Fibre optic		6		6[1)]
Buffer swelling	CT/Druck	Head measurment /strain gauges		2		2
Sum			**87**	**296**	**21**	**401**

[1)] described in a separate report

[2)] in the rock between holes 5 and 6

References

/1-1/ **Svemar C. and Pusch R., 2000.** Prototype Repository, Project description. ÄHRL IPR-00-30.

/**1-2/** **Pusch R. and Börgesson L., 2001**. Prototype Repository. Instrumentation of buffer and backfill in Section 1. ÄHRL IPR-01-60.