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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

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February 2001

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Abstract

This report describes the instrumentation in the bentonite for the deposition holes in the Prototype Repository with identification numbering, exact location in each bentonite block and required preparations of each block for installation of instruments and cables. In each instrumented deposition hole the temperature will be measured in 32 points, total pressure in 27 points, pore water pressure in 14 points and relative humidity in 37 points. Additional temperature measurements can be done in some of the pressure gauges and in all relative humidity gauges.

The positions of the measuring points in the bentonite are related to co-ordinate systems in the deposition holes. Three coordinates are related to every measuring point.

Sammanfattning

Denna rapport beskriver instrumenteringen av bentoniten i deponeringshålen i Prototype Repository med identitetsnummer, exakt position i varje bentonitblock och erforderlig bearbetning av varje block för att kunna installera instrument och kablar. I varje instrumenterat deponeringshål kommer temperaturen att mätas i 32 punkter, total trycket i 27 punkter, porvattentrycket i 14 punkter och relativa fuktigheten i 37 punkter. Ytterligare temperaturmätningar kan göras i flera av tryckgivarna och i alla givare som mäter relativa fuktigheten.

Positionerna hos givarna i bentoniten är relaterade till koordinatsystem i deponeringshålen. Till varje mätpunkt finns kopplat tre koordinater.

Table of contents

List of Tables

List of Figures

List of Appendices

1 Introduction

The Äspö Hard Rock Laboratory is an important part of SKB`s work on design of the deep repository and is constructed with the aim of providing possibilities for research, development and demonstration in a realistic and undisturbed under ground environment at the depth which is considered for the deep repository. The Prototype Repository is one project that will be performed at Äspö HRL with the purpose to demonstrate a deep repository in crystalline rock under natural and realistic conditions.

An important part of the work is to measure the thermal, hydraulic and mechanical processes in the bentonite during saturation and afterwards. The Prototype Repository consists of two sections, Figure 1-1. Section 1 consists of four deposition holes and section 2 of two deposition holes. The sections are divided by a plug of concrete. Two deposition holes in section 1 are instrumented (number 1 and 3) and both deposition holes in section 2. In each instrumented deposition hole, measurements will be done in 110 points in the bentonite. Additional measurements will be done on the canister surface and in the surrounding rock.

This report deals with the measurements in the bentonite and in the backfill. The instruments exact positions and the technique for placing them in the bentonite blocks will be described. The transducers and the measuring system are not described (see /1-1/).

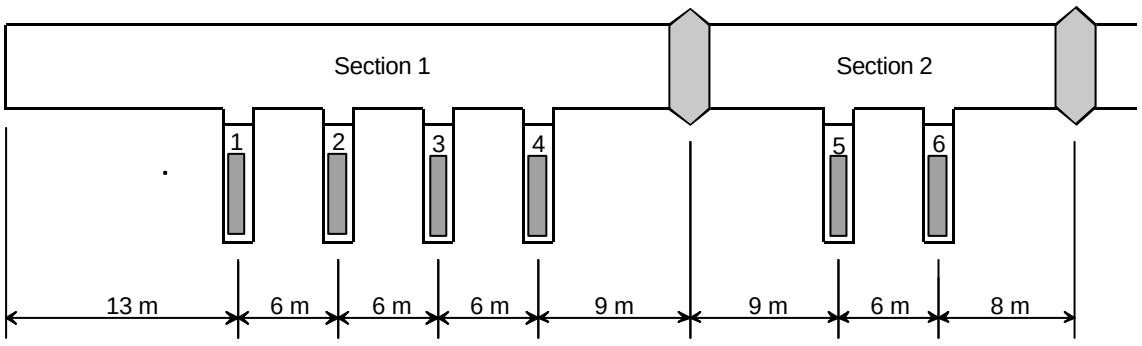


Figure 1-1. *Schematic view of the layout of the Prototype Repository.*

2 Prototype Repository

The Prototype Repository is described in the test plan /2-1/. The test is located in the inner part of the A-tunnel i.e. the TBM tunnel. The test consists of full scale deposition holes, copper/steel canisters equipped with electrical heaters for simulating the heating caused by the radioactive decay. The canisters will be embedded in dense buffer clay consisting of blocks (cylindrical and ring shaped) of compacted bentonite powder.

The four instrumented deposition holes equipped with pressure cells (total and water pressure), thermocouples and moisture gauges. Thermocouples will also be installed in the rock. Temperature and strain will be measured on the surface of all canisters.

The installation of the Prototype Repository will be done in two steps. When the canisters and bentonite with instrumentation have been installed in the four inner deposition holes this part of the drift will be backfilled with a mixture of crushed rock and bentonite. A concrete plug will then be built in order to support the backfill. The deposition holes in the outer section will be installed in a second step.

3 Location of instruments in the bentonite

3.1 Brief description of the instruments

The different instruments that will be used in the experiment are briefly described in this section. A more detailed description is given in /1-1/.

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 (29 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 /1-1/.

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. 16 cells of this type will be installed in each test hole.

- Kulite total pressure cells with piezo resistive transducers. 11 cells of this type will be installed in each test hole.

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

Measurement of pore water pressure

The pore water pressure will be measured with the following instrument types:

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

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

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.

These devices measure the relative humidity in the pore system. It can be converted into water ratio or total suction (negative water pressure).

The relative humidity will be measured in totally 37 points in each test hole.

3.2 Strategy for describing the position of each device

The instrumented deposition holes in section 1 are termed DA3587G01 and DA3575G01, hole number 1 and 3 respectively according to Figure 1-1. Measurements will be done in four vertical sections A, B, C and D according to Figure 3-1 and 3-2. Direction A and C are placed in the tunnels axial direction with A headed against the end of the tunnel i.e. almost at West.

The bentonite blocks are called cylinders and rings. The cylinders are numbered C1-C4 and the rings R1-R10 respectively (Figure 3-1).

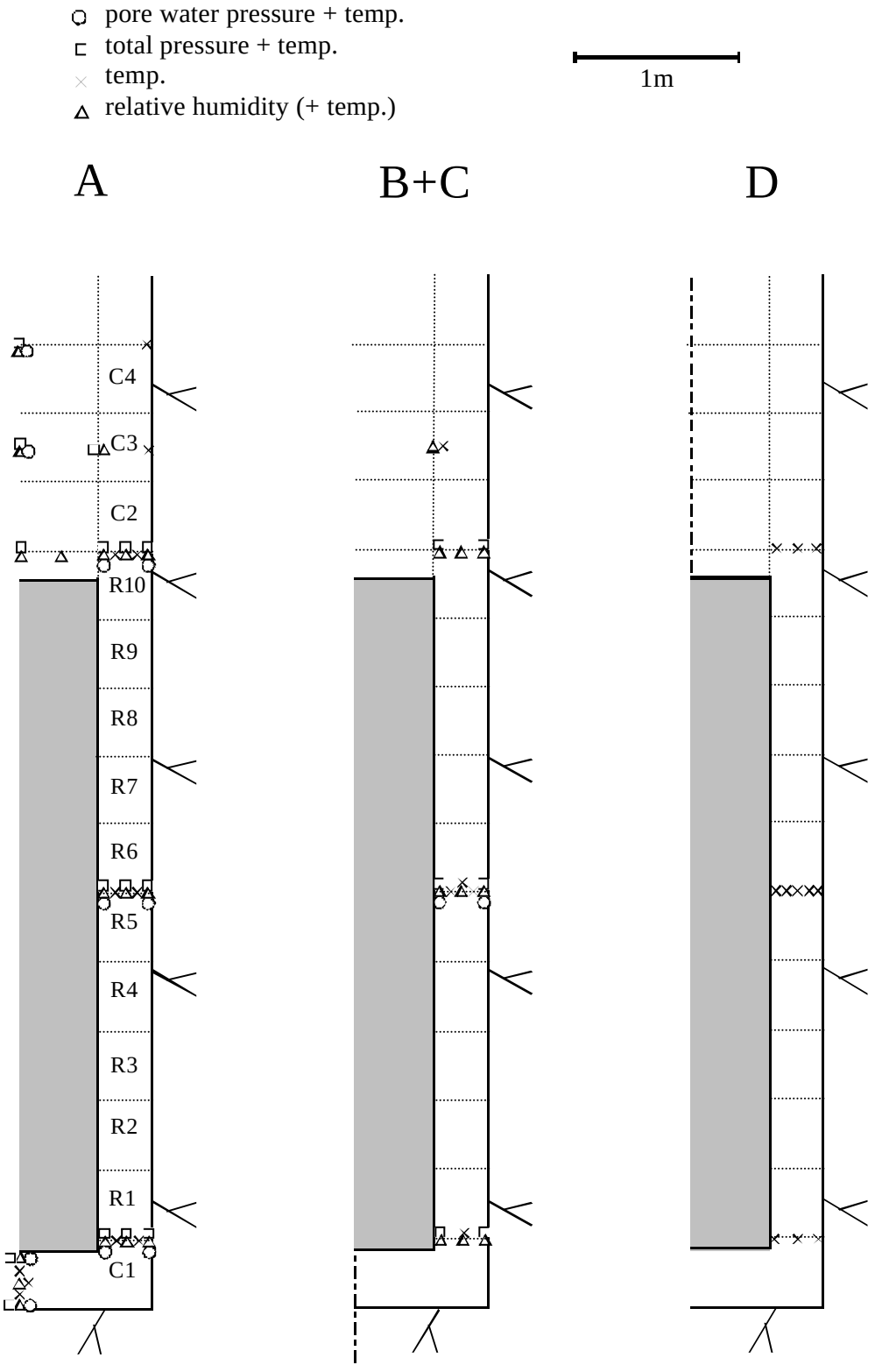


Figure 3-1 *Schematic view over the instruments in four vertical sections and the block designation.*

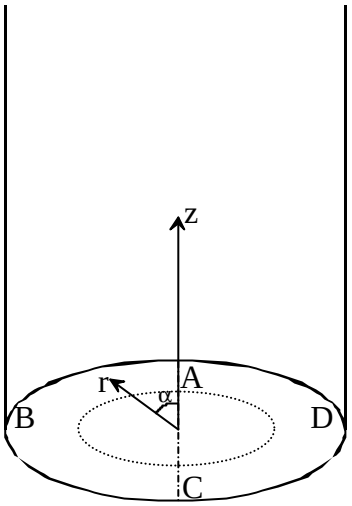


Figure 3-2 *Figure describing the coordinate system used when determining the instrument positions.*

Every instrument will be 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 digit denoting the deposition hole (1-6) and 4 digits specifying the position in the buffer according to a separate list (see Table 3-1 to 3-8). Every instrument position is described with three coordinates according to Figure 3-2. 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 500 mm). The α−coordinate is the angle from the vertical direction A (almost West).

3.3 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 on 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.

The positions of each instrument are described in Tables 3-1 to 3-4.

Each instrumented bentonite block is shown in the Appendicies with the position and numbering of the instruments.

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

Prototype Repository, Instrumentation

Instrument type **Thermocouple**
Deposition hole, No **1**
Lead through, No **LT12**
Length of lead through **56.9**
Length in G-tunnel, m **35.0**
Estimated length in backfill, m **6.0**

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	
TBU10001	Cyl. 1	Center	270	50	50	344	Pentronic	7.9	13.9	105.8	
TBU10002	Cyl. 1	Center	270	50	250	342	Pentronic	7.9	13.9	105.8	
TBU10003	Cyl. 1	Center	270	50	450	340	Pentronic	7.9	13.9	105.8	
TBU10004	Cyl. 1	A	355	635	450	358	Pentronic	7.3	13.3	105.2	
TBU10005	Cyl. 1	A	355	735	450	356	Pentronic	7.2	13.2	105.1	
TBU10006	Cyl. 1	B	85	685	450	84	Pentronic	7.2	13.2	105.1	
TBU10007	Cyl. 1	C	175	685	450	176	Pentronic	7.2	13.2	105.1	
TBU10008	Cyl. 1	D	270	585	450	274	Pentronic	7.3	13.3	105.2	
TBU10009	Cyl. 1	D	270	685	450	272	Pentronic	7.2	13.2	105.1	
TBU10010	Cyl. 1	D	270	785	450	270	Pentronic	7.1	13.1	105.0	
TBU10011	Ring 5	A	0	635	2950	42	Pentronic	4.7	10.7	102.6	
TBU10012	Ring 5	A	0	735	2950	38	Pentronic	4.6	10.6	102.5	
TBU10013	Ring 5	B	90	585	2950	88	Pentronic	4.8	10.8	102.7	
TBU10014	Ring 5	B	90	685	2950	90	Pentronic	4.7	10.7	102.6	
TBU10015	Ring 5	B	90	785	2950	92	Pentronic	4.6	10.6	102.5	
TBU10016	Ring 5	C	175	585	2950	152	Pentronic	4.8	10.8	102.7	
TBU10017	Ring 5	C	175	685	2950	154	Pentronic	4.7	10.7	102.6	
TBU10018	Ring 5	C	175	735	2950	156	Pentronic	4.6	10.6	102.5	
TBU10019	Ring 5	D	270	585	2950	290	Pentronic	4.8	10.8	102.7	
TBU10020	Ring 5	D	270	635	2950	288	Pentronic	4.7	10.7	102.6	
TBU10021	Ring 5	D	270	685	2950	286	Pentronic	4.7	10.7	102.6	
TBU10022	Ring 5	D	270	735	2950	284	Pentronic	4.6	10.6	102.5	
TBU10023	Ring 5	D	270	785	2950	282	Pentronic	4.6	10.6	102.5	
TBU10024	Ring 10	A	0	635	5450	18	Pentronic	2.2	8.2	100.1	
TBU10025	Ring 10	A	0	735	5450	14	Pentronic	2.1	8.1	100.0	
TBU10026	Ring 10	D	270	585	5450	260	Pentronic	2.3	8.3	100.2	
TBU10027	Ring 10	D	270	685	5450	262	Pentronic	2.2	8.2	100.1	
TBU10028	Ring 10	D	270	785	5450	264	Pentronic	2.1	8.1	100.0	
TBU10029	Cyl. 3	A	0	785	6250	22	Pentronic	1.3	7.3	99.2	
TBU10030	Cyl. 3	B	95	585	6250	102	Pentronic	1.5	7.5	99.4	
TBU10031	Cyl. 3	C	185	585	6250	204	Pentronic	1.5	7.5	99.4	
TBU10032	Cyl. 4	A	0	785	6950	24	Pentronic	0.5	6.5	98.4	

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

Prototype Repository, Instrumentation

Instrument type	**Total Pressure**
Deposition hole, No	**1**
Lead through, No	**LT13**
Length of lead through	**56.3**
Length in G-tunnel, m	**35.0**
Estimated length in backfill, m	**8.0**

		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	
PBU10001	Cyl. 1	Center	0	0	0	4	Geocon	7.9	**8.0**	16	107.2	In cement
PBU10002	Cyl. 1	Center	0	100	500	346	Geocon	7.8	**8.0**	16	107.1	
PBU10003	Cyl. 1	A	5	585	450	30	Kulite	7.3	**8.0**	15	106.6	Vertical
PBU10004	Cyl. 1	A	5	685	450	28	Kulite	7.2	**8.0**	15	106.5	Vertical
PBU10005	Cyl. 1	A	5	785	450	94	Kulite	7.1	**8.0**	15	106.4	Vertical
PBU10006	Cyl. 1	B	95	635	500	118	Geocon	7.3	**8.0**	15	106.6	
PBU10007	Cyl. 1	B	105	735	500	106	Geocon	7.2	**8.0**	15	106.5	
PBU10008	Cyl. 1	C	185	635	500	184	Geocon	7.3	**8.0**	15	106.6	
PBU10009	Cyl. 1	C	195	735	500	194	Geocon	7.2	**8.0**	15	106.5	
PBU10010	Ring 5	A	5	585	2950	44	Kulite	4.8	**5.0**	13	104.1	In the slot
PBU10011	Ring 5	A	5	685	2840	40	Geocon I	4.7	**5.0**	13	104.0	
PBU10012	Ring 5	A	5	785	2950	36	Kulite	4.6	**5.0**	13	103.9	In the slot
PBU10013	Ring 5	B	95	585	2750	98	Geocon I	4.8	**5.0**	13	104.1	
PBU10014	Ring 5	B	95	785	2750	96	Geocon I	4.6	**5.0**	13	103.9	
PBU10015	Ring 5	C	185	535	2840	198	Geocon I	4.8	**5.0**	13	104.1	In the slot
PBU10016	Ring 5	C	185	825	2950	186	Kulite	4.6	**5.0**	13	103.9	In the slot
PBU10017	Ring 10	Center	0	50	5340	8	Geocon	2.8	**3.0**	11	102.1	
PBU10018	Ring 10	A	5	585	5450	20	Kulite	2.3	**3.0**	10	101.6	Vertical
PBU10019	Ring 10	A	5	685	5450	16	Kulite	2.2	**3.0**	10	101.5	Vertical
PBU10020	Ring 10	A	5	785	5450	12	Kulite	2.1	**3.0**	10	101.4	Vertical
PBU10021	Ring 10	B	90	635	5500	124	Geocon	2.2	**3.0**	10	101.5	
PBU10022	Ring 10	B	100	735	5500	120	Geocon	2.1	**3.0**	10	101.4	
PBU10023	Ring 10	C	180	635	5500	210	Geocon	2.2	**3.0**	10	101.5	
PBU10024	Ring 10	C	190	735	5500	214	Geocon	2.1	**3.0**	10	101.4	
PBU10025	Cyl. 3	Center	0	50	6250	48	Kulite	2.0	**3.0**	10	101.3	Vertical
PBU10026	Cyl. 3	A	5	585	6500	34	Geocon	1.5	**3.0**	10	100.8	
PBU10027	Cyl. 4	Center	0	50	6950	56	Kulite	1.3	**3.0**	9	100.6	Vertical

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

Prototype Repository, Instrumentation

Instrument type	**Pore Pressure**
Deposition hole, No	**1**
Lead through, No	**LT12**
Length of lead through	**56.9**
Length in G-tunnel, m	**35.0**
Estimated length in backfill, m	**6.0**

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	
UBU10001	Cyl. 1	Center	90	50	50	166	Kulite	7.9	**8.0**	14	105.8	
UBU10002	Cyl. 1	Center	90	50	450	168	Geocon	7.9	**8.0**	14	105.8	Horizontal
UBU10003	Cyl. 1	A	355	585	340	0	Geocon	7.3	**8.0**	13	105.2	
UBU10004	Cyl. 1	A	355	785	340	354	Kulite	7.1	**8.0**	13	105.0	
UBU10005	Ring 5	A	355	585	2840	332	Geocon	4.8	**5.0**	11	102.7	
UBU10006	Ring 5	A	355	785	2840	338	Kulite	4.6	**5.0**	11	102.5	
UBU10007	Ring 5	B	85	535	2840	68	Kulite	4.8	**5.0**	11	102.7	In the slot
UBU10008	Ring 5	B	85	825	2840	74	Kulite	4.6	**5.0**	11	102.5	In the slot
UBU10009	Ring 5	C	175	535	2840	150	Geocon	4.8	**5.0**	11	102.7	In the slot
UBU10010	Ring 5	C	175	825	2840	158	Geocon	4.6	**5.0**	11	102.5	In the slot
UBU10011	Ring 10	A	355	585	5340	322	Kulite	2.3	**3.0**	8	100.2	
UBU10012	Ring 10	A	355	785	5340	328	Geocon	2.1	**3.0**	8	100.0	
UBU10013	Cyl. 3	Center	90	50	6250	52	Geocon	2.0	**3.0**	8	99.9	
UBU10014	Cyl. 4	Center	90	50	6940	58	Geocon	1.3	**3.0**	7	99.2	

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

Prototype Repository, Instrumentation

Instrument type	**Relative Humidity**
Deposition hole, No	**1**
Lead through, No(Rotronic)	**LT13**
Lead through, No(Vaisala)	**LT23**
Length of lead through LT13	**56.2**
Length of lead throughLT23	**52.2**
Length in G-tunnel, m	**35.0**
Length in backfill (LT13), m	**8.0**
Length in backfill (LT23), 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	
WBU10001	Cyl. 1	Center	180	50	50	160	Rotronic	7.9	15.9	107.1	
WBU10002	Cyl. 1	Center	0	400	250	2	Rotronic	7.5	15.5	106.7	
WBU10003	Cyl. 1	Center	180	50	340	164	Rotronic	7.9	15.9	107.1	Horizontal
WBU10004	Cyl. 1	A	350	585	340	352	Vaisala	7.3	17.3	104.5	
WBU10005	Cyl. 1	A	350	685	340	350	Vaisala	7.2	17.2	104.4	
WBU10006	Cyl. 1	A	350	785	340	348	Vaisala	7.1	17.1	104.3	
WBU10007	Cyl. 1	B	80	585	340	76	Vaisala	7.3	17.3	104.5	
WBU10008	Cyl. 1	B	80	685	250	78	Rotronic	7.2	15.2	106.4	
WBU10009	Cyl. 1	B	80	785	250	80	Rotronic	7.1	15.1	106.3	
WBU10010	Cyl. 1	C	170	585	250	174	Rotronic	7.3	15.3	106.5	
WBU10011	Cyl. 1	C	170	685	250	172	Rotronic	7.2	15.2	106.4	
WBU10012	Cyl. 1	C	170	785	250	170	Rotronic	7.1	15.1	106.3	
WBU10013	Ring 5	A	350	585	2840	330	Vaisala	4.8	14.8	102.0	
WBU10014	Ring 5	A	350	685	2840	334	Vaisala	4.7	14.7	101.9	
WBU10015	Ring 5	A	350	785	2840	336	Vaisala	4.6	14.6	101.8	
WBU10016	Ring 5	B	80	535	2750	66	Rotronic	4.8	12.8	104.0	In the slot
WBU10017	Ring 5	B	80	685	2750	70	Rotronic	4.7	12.7	103.9	
WBU10018	Ring 5	B	80	785	2750	72	Rotronic	4.6	12.6	103.8	
WBU10019	Ring 5	C	180	535	2840	196	Vaisala	4.8	14.8	102.0	In the slot
WBU10020	Ring 5	C	180	685	2840	192	Vaisala	4.7	14.7	101.9	
WBU10021	Ring 5	C	180	785	2750	188	Rotronic	4.6	12.6	103.8	
WBU10022	Ring 10	Center	180	50	5340	10	Vaisala	2.8	12.8	100.0	
WBU10023	Ring 10	A	180	262	5340	6	Vaisala	2.6	12.6	99.8	
WBU10024	Ring 10	A	350	585	5340	320	Vaisala	2.3	12.3	99.5	
WBU10025	Ring 10	A	350	685	5340	324	Vaisala	2.2	12.2	99.4	
WBU10026	Ring 10	A	350	785	5340	326	Vaisala	2.1	12.1	99.3	
WBU10027	Ring 10	B	80	585	5250	86	Rotronic	2.3	10.3	101.5	
WBU10028	Ring 10	B	80	685	5250	82	Rotronic	2.2	10.2	101.4	
WBU10029	Ring 10	B	80	785	5250	80	Rotronic	2.1	10.1	101.3	
WBU10030	Ring 10	C	170	585	5340	180	Vaisala	2.3	12.3	99.5	
WBU10031	Ring 10	C	170	785	5250	182	Rotronic	2.1	10.1	101.3	
WBU10032	Cyl. 3	Center	180	50	6250	50	Vaisala	2.0	12.0	99.2	
WBU10033	Cyl. 3	A	350	585	6250	32	Vaisala	1.5	11.5	98.7	
WBU10034	Cyl. 3	B	90	585	6250	100	Vaisala	1.5	11.5	98.7	
WBU10035	Cyl. 3	C	180	585	6250	202	Rotronic	1.5	9.5	100.7	
WBU10036	Cyl. 4	Center	270	50	6680	224	Vaisala	1.3	11.3	98.5	
WBU10037	Cyl. 4	Center	180	50	6840	228	Vaisala	1.3	11.3	98.5	

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

The instruments are located according to the same system as those in DA3587G01. The positions of each instrument are described in Tables 3-5 to 3-8.

Each instrumented bentonite block is shown in Appendix 1 with the position and numbering of the instruments. Note that the first digit in the instrument number is 1 for deposition hole DA3587G01 and 3 for deposition hole DA3575G01. In the drawings only the digit 1 is used, but the drawings are also valid for the instrument numbers beginning with digit 3.

Table 3-5 Numbering and position of instruments for measuring temperature (T)

Prototype Repository, Instrumentation

Instrument type **Thermocouple**
Deposition hole, No **3**
Lead through, No **LT31**
Length of lead through **50.3**
Length in G-tunnel, m **35.0**
Estimated length in backfill, m **6.0**

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	
TBU30001	Cyl. 1	Center	270	50	50	344	Pentronic	7.9	13.9	99.2	
TBU30002	Cyl. 1	Center	270	50	250	342	Pentronic	7.9	13.9	99.2	
TBU30003	Cyl. 1	Center	270	50	450	340	Pentronic	7.9	13.9	99.2	
TBU30004	Cyl. 1	A	355	635	450	358	Pentronic	7.3	13.3	98.6	
TBU30005	Cyl. 1	A	355	735	450	356	Pentronic	7.2	13.2	98.5	
TBU30006	Cyl. 1	B	85	685	450	84	Pentronic	7.2	13.2	98.5	
TBU30007	Cyl. 1	C	175	685	450	176	Pentronic	7.2	13.2	98.5	
TBU30008	Cyl. 1	D	270	585	450	274	Pentronic	7.3	13.3	98.6	
TBU30009	Cyl. 1	D	270	685	450	272	Pentronic	7.2	13.2	98.5	
TBU30010	Cyl. 1	D	270	785	450	270	Pentronic	7.1	13.1	98.4	
TBU30011	Ring 5	A	0	635	2950	42	Pentronic	4.7	10.7	96.0	
TBU30012	Ring 5	A	0	735	2950	38	Pentronic	4.6	10.6	95.9	
TBU30013	Ring 5	B	90	585	2950	88	Pentronic	4.8	10.8	96.1	
TBU30014	Ring 5	B	90	685	2950	90	Pentronic	4.7	10.7	96.0	
TBU30015	Ring 5	B	90	785	2950	92	Pentronic	4.6	10.6	95.9	
TBU30016	Ring 5	C	175	585	2950	152	Pentronic	4.8	10.8	96.1	
TBU30017	Ring 5	C	175	685	2950	154	Pentronic	4.7	10.7	96.0	
TBU30018	Ring 5	C	175	735	2950	156	Pentronic	4.6	10.6	95.9	
TBU30019	Ring 5	D	270	585	2950	290	Pentronic	4.8	10.8	96.1	
TBU30020	Ring 5	D	270	635	2950	288	Pentronic	4.7	10.7	96.0	
TBU30021	Ring 5	D	270	685	2950	286	Pentronic	4.7	10.7	96.0	
TBU30022	Ring 5	D	270	735	2950	284	Pentronic	4.6	10.6	95.9	
TBU30023	Ring 5	D	270	785	2950	282	Pentronic	4.6	10.6	95.9	
TBU30024	Ring 10	A	0	635	5450	18	Pentronic	2.2	8.2	93.5	
TBU30025	Ring 10	A	0	735	5450	14	Pentronic	2.1	8.1	93.4	
TBU30026	Ring 10	D	270	585	5450	260	Pentronic	2.3	8.3	93.6	
TBU30027	Ring 10	D	270	685	5450	262	Pentronic	2.2	8.2	93.5	
TBU30028	Ring 10	D	270	785	5450	264	Pentronic	2.1	8.1	93.4	
TBU30029	Cyl. 3	A	0	785	6250	22	Pentronic	1.3	7.3	92.6	
TBU30030	Cyl. 3	B	95	585	6250	102	Pentronic	1.5	7.5	92.8	
TBU30031	Cyl. 3	C	185	585	6250	204	Pentronic	1.5	7.5	92.8	
TBU30032	Cyl. 4	A	0	785	6950	24	Pentronic	0.5	6.5	91.8	

Table 3-6 Numbering and position of instruments for measuring total pressure (P)

Prototype Repository, Instrumentation

Instrument type	**Total Pressure**
Deposition hole, No	**3**
Lead through, No	**LT32**
Length of lead through	**49.9**
Length in G-tunnel, m	**35.0**
Estimated length in backfill, m	**6.0**

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	
PBU30001	Cyl. 1	Center	0	0	0	4	Geocon	7.9	**8.0**	14	98.8	In cement
PBU30002	Cyl. 1	Center	0	100	500	346	Geocon	7.8	**8.0**	14	98.7	
PBU30003	Cyl. 1	A	5	585	450	30	Kulite	7.3	**8.0**	13	98.2	Vertical
PBU30004	Cyl. 1	A	5	685	450	28	Kulite	7.2	**8.0**	13	98.1	Vertical
PBU30005	Cyl. 1	A	5	785	450	94	Kulite	7.1	**8.0**	13	98.0	Vertical
PBU30006	Cyl. 1	B	95	635	500	118	Geocon	7.3	**8.0**	13	98.2	
PBU30007	Cyl. 1	B	105	735	500	106	Geocon	7.2	**8.0**	13	98.1	
PBU30008	Cyl. 1	C	185	635	500	184	Geocon	7.3	**8.0**	13	98.2	
PBU30009	Cyl. 1	C	195	735	500	194	Geocon	7.2	**8.0**	13	98.1	
PBU30010	Ring 5	A	5	585	2950	44	Kulite	4.8	**5.0**	11	95.7	In the slot
PBU30011	Ring 5	A	5	685	2840	40	Geocon I	4.7	**5.0**	11	95.6	
PBU30012	Ring 5	A	5	785	2950	36	Kulite	4.6	**5.0**	11	95.5	In the slot
PBU30013	Ring 5	B	95	585	2750	98	Geocon I	4.8	**5.0**	11	95.7	
PBU30014	Ring 5	B	95	785	2750	96	Geocon I	4.6	**5.0**	11	95.5	
PBU30015	Ring 5	C	185	535	2840	198	Geocon I	4.8	**5.0**	11	95.7	In the slot
PBU30016	Ring 5	C	185	825	2950	186	Kulite	4.6	**5.0**	11	95.5	In the slot
PBU30017	Ring 10	Center	0	50	5340	8	Geocon	2.8	**3.0**	9	93.7	
PBU30018	Ring 10	A	5	585	5450	20	Kulite	2.3	**3.0**	8	93.2	Vertical
PBU30019	Ring 10	A	5	685	5450	16	Kulite	2.2	**3.0**	8	93.1	Vertical
PBU30020	Ring 10	A	5	785	5450	12	Kulite	2.1	**3.0**	8	93.0	Vertical
PBU30021	Ring 10	B	90	635	5500	124	Geocon	2.2	**3.0**	8	93.1	
PBU30022	Ring 10	B	100	735	5500	120	Geocon	2.1	**3.0**	8	93.0	
PBU30023	Ring 10	C	180	635	5500	210	Geocon	2.2	**3.0**	8	93.1	
PBU30024	Ring 10	C	190	735	5500	214	Geocon	2.1	**3.0**	8	93.0	
PBU30025	Cyl. 3	Center	0	50	6250	48	Kulite	2.0	**3.0**	8	92.9	Vertical
PBU30026	Cyl. 3	A	5	585	6500	34	Geocon	1.5	**3.0**	8	92.4	
PBU30027	Cyl. 4	Center	0	50	6950	56	Kulite	1.3	**3.0**	7	92.2	Vertical

Table 3-7 Numbering and position of instruments for measuring pore water pressure (U)

Prototype Repository, Instrumentation

Instrument type **Pore Pressure**
Deposition hole, No **3**
Lead through, No **LT32**
Length of lead through **49.9**
Length in G-tunnel, m **35.0**
Estimated length in backfill, m **6.0**

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	
UBU30001	Cyl. 1	Center	90	50	50	166	Kulite	7.9	**8.0**	14	98.8	
UBU30002	Cyl. 1	Center	90	50	450	168	Geocon	7.9	**8.0**	14	98.8	Horizontal
UBU30003	Cyl. 1	A	355	585	340	0	Geocon	7.3	**8.0**	13	98.2	
UBU30004	Cyl. 1	A	355	785	340	354	Kulite	7.1	**8.0**	13	98.0	
UBU30005	Ring 5	A	355	585	2840	332	Geocon	4.8	**5.0**	11	95.7	
UBU30006	Ring 5	A	355	785	2840	338	Kulite	4.6	**5.0**	11	95.5	
UBU30007	Ring 5	B	85	535	2840	68	Kulite	4.8	**5.0**	11	95.7	In the slot
UBU30008	Ring 5	B	85	825	2840	74	Kulite	4.6	**5.0**	11	95.5	In the slot
UBU30009	Ring 5	C	175	535	2840	150	Geocon	4.8	**5.0**	11	95.7	In the slot
UBU30010	Ring 5	C	175	825	2840	158	Geocon	4.6	**5.0**	11	95.5	In the slot
UBU30011	Ring 10	A	355	585	5340	322	Kulite	2.3	**3.0**	8	93.2	
UBU30012	Ring 10	A	355	785	5340	328	Geocon	2.1	**3.0**	8	93.0	
UBU30013	Cyl. 3	Center	90	50	6250	52	Geocon	2.0	**3.0**	8	92.9	
UBU30014	Cyl. 4	Center	90	50	6940	58	Geocon	1.3	**3.0**	7	92.2	

Table 3-8 Numbering and position of instruments for measuring water content (W)

Prototype Repository, Instrumentation

Instrument type	**Relative Humidity**
Deposition hole, No	**3**
Lead through, No(Rotronic)	**LT31**
Lead through, No(Vaisala)	**LT23**
Length of lead through LT31	**50.3**
Length of lead throughLT23	**52.2**
Length in G-tunnel, m	**35.0**
Length in backfill (LT31), m	**6.0**
Length in backfill (LT23), 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	
WBU30001	Cyl. 1	Center	180	50	50	160	Rotronic	7.9	13.9	99.2	
WBU30002	Cyl. 1	Center	0	400	250	2	Rotronic	7.5	13.5	98.8	
WBU30003	Cyl. 1	Center	180	50	340	164	Rotronic	7.9	13.9	99.2	Horizontal
WBU30004	Cyl. 1	A	350	585	340	352	Vaisala	7.3	16.3	103.5	
WBU30005	Cyl. 1	A	350	685	340	350	Vaisala	7.2	16.2	103.4	
WBU30006	Cyl. 1	A	350	785	340	348	Vaisala	7.1	16.1	103.3	
WBU30007	Cyl. 1	B	80	585	340	76	Vaisala	7.3	16.3	103.5	
WBU30008	Cyl. 1	B	80	685	250	78	Rotronic	7.2	13.2	98.5	
WBU30009	Cyl. 1	B	80	785	250	80	Rotronic	7.1	13.1	98.4	
WBU30010	Cyl. 1	C	170	585	250	174	Rotronic	7.3	13.3	98.6	
WBU30011	Cyl. 1	C	170	685	250	172	Rotronic	7.2	13.2	98.5	
WBU30012	Cyl. 1	C	170	785	250	170	Rotronic	7.1	13.1	98.4	
WBU30013	Ring 5	A	350	585	2840	330	Vaisala	4.8	13.8	101.0	
WBU30014	Ring 5	A	350	685	2840	334	Vaisala	4.7	13.7	100.9	
WBU30015	Ring 5	A	350	785	2840	336	Vaisala	4.6	13.6	100.8	
WBU30016	Ring 5	B	80	535	2750	66	Rotronic	4.8	10.8	96.1	In the slot
WBU30017	Ring 5	B	80	685	2750	70	Rotronic	4.7	10.7	96.0	
WBU30018	Ring 5	B	80	785	2750	72	Rotronic	4.6	10.6	95.9	
WBU30019	Ring 5	C	180	535	2840	196	Vaisala	4.8	13.8	101.0	In the slot
WBU30020	Ring 5	C	180	685	2840	192	Vaisala	4.7	13.7	100.9	
WBU30021	Ring 5	C	180	785	2750	188	Rotronic	4.6	10.6	95.9	
WBU30022	Ring 10	Center	180	50	5340	10	Vaisala	2.8	11.8	99.0	
WBU30023	Ring 10	A	180	262	5340	6	Vaisala	2.6	11.6	98.8	
WBU30024	Ring 10	A	350	585	5340	320	Vaisala	2.3	11.3	98.5	
WBU30025	Ring 10	A	350	685	5340	324	Vaisala	2.2	11.2	98.4	
WBU30026	Ring 10	A	350	785	5340	326	Vaisala	2.1	11.1	98.3	
WBU30027	Ring 10	B	80	585	5250	86	Rotronic	2.3	8.3	93.6	
WBU30028	Ring 10	B	80	685	5250	82	Rotronic	2.2	8.2	93.5	
WBU30029	Ring 10	B	80	785	5250	80	Rotronic	2.1	8.1	93.4	
WBU30030	Ring 10	C	170	585	5340	180	Vaisala	2.3	11.3	98.5	
WBU30031	Ring 10	C	170	785	5250	182	Rotronic	2.1	8.1	93.4	
WBU30032	Cyl. 3	Center	180	50	6250	50	Vaisala	2.0	11.0	98.2	
WBU30033	Cyl. 3	A	350	585	6250	32	Vaisala	1.5	10.5	97.7	
WBU30034	Cyl. 3	B	90	585	6250	100	Vaisala	1.5	10.5	97.7	
WBU30035	Cyl. 3	C	180	585	6250	202	Rotronic	1.5	7.5	92.8	
WBU30036	Cyl. 4	Center	270	50	6680	224	Vaisala	1.3	10.3	97.5	
WBU30037	Cyl. 4	Center	180	50	6840	228	Vaisala	1.3	10.3	97.5	

4 Position of each cable and tube on the block periphery

All cables and tubes, coming out from the instruments in the bentonite blocks, 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 blocks 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) it's important to distribute them on the block periphery in a prescribed order. Every cable or tube has an α–coordinate (Table 3-1 to 3-8), which is the angle from direction A (Figure 3-2). The cables will be led out to this position from the sensors position in pre-manufactured tracks on the blocks surface.

4.1 Cables and tubes from instruments in the bentonite

All instrument cables 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 they will be bent and led axial by along the bentonite blocks. Expandable strings will be placed on every block in order to fix he cables.

4.2 Cables from the canister

The following cables come from the canister:

- 3 x 32 mm power cables for the electrical heaters
- 4 x 2 mm fiber optic cables (two loops) from the temperature measurements on the canister surface

The direction of the cables are shown in Figure 4-1.

From the canister the cables are led through the bentonite where slots have been sawed in advance in block no. R10 (see Figure 4-1). The cables are then led up along the bentonite blocks.

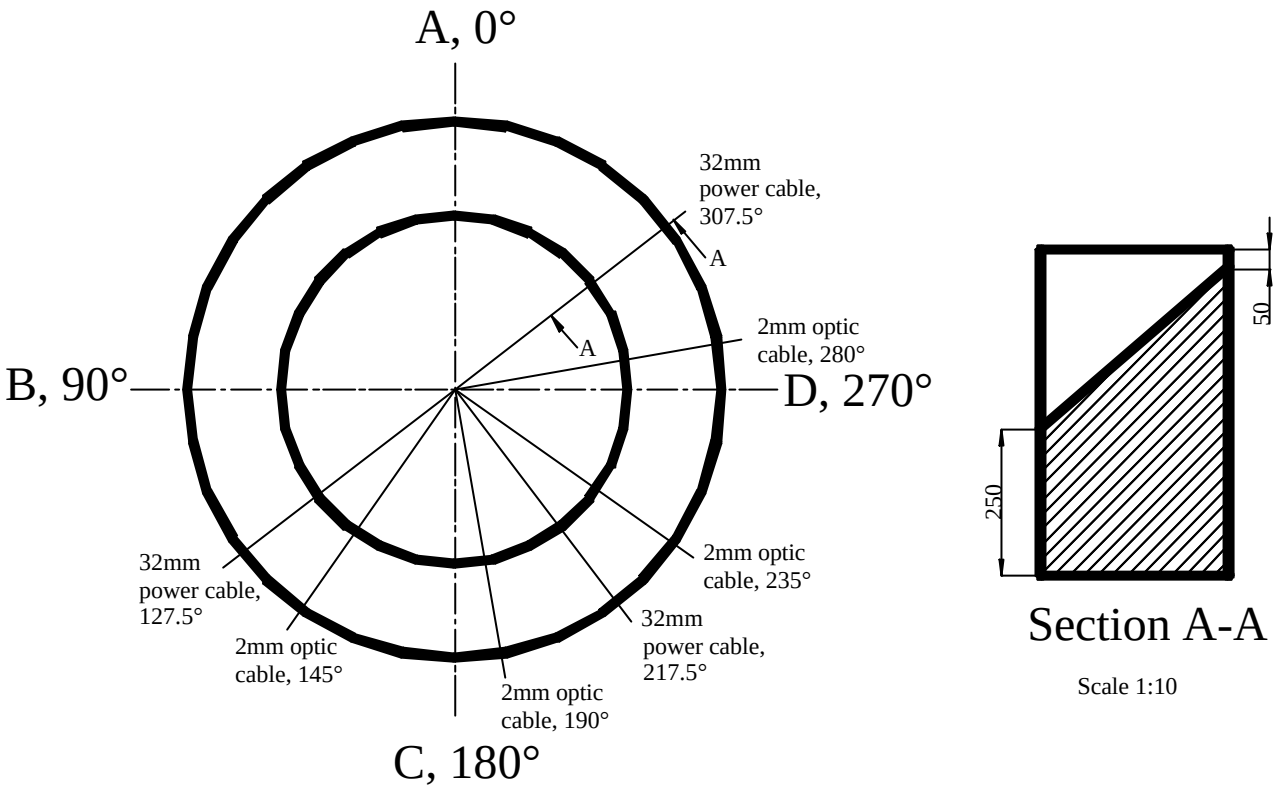


Figure 4-1 *Figure showing the directions of cables from the canister relative the instrument directions A, B, C and D in block R10. In this block slots will be sawed in order to let the cables from the canister pass through the bentonite and out to the rock. The width of the slots will be about 40 mm for the power cables and about 5 to 10 mm for the optic cables.*

5 Preparation of the bentonite blocks

5.1 Preparation for instruments

Every instrumented block (see Appendix 1) will be prepared in advance, i.e. most of the bentonite work will be done on ground in a laboratory. The preparation is somewhat different depending on instrument type.

Thermocouples

- The thermocouples have an outer diameter of 4.0 mm. A hand-hold boring-machine will be used at installation. **Working:** Bore-hole Ø 5 mm, depth 50 mm.

Total pressure

- **Geokon 1.** Shaped as a cylindrical tube with an outer diameter of 25 mm and a length of 117 mm. The holes for these gauges will be bored with a drilling machine of Hilti-type fastened with a vacuum plate. **Working:** Bore-hole Ø 27mm, depth 250mm

- **Geokon 2.** Shaped as an ice hockey puck with a diameter of 125 mm and a thickness of 22 mm. The instruments are countersunk in the bentonite block surface by use of a hand hold cutter. **Working:** Bore-hole Ø 126-130 mm, depth 25 mm.

- **Kulite.** Shaped as an ice hockey puck with a diameter of 55 mm and a thickness of 23 mm. These instruments will all be placed vertically, which means that an almost rectangular hole is needed. This can be done by drilling 2-3 holes with a diameter of 25 mm in a row and then form the hole with a chisel. **Working:** Bore-hole Ø 25mm, depth 60 mm. Forming the rectangular hole with a chisel.

Pore pressure

- **Geokon.** Shaped as a cylindrical tube with an outer diameter of 25 mm and a length of 127 mm. The holes for these gauges will be bored with a drilling machine of Hilti-type fastened with a vacuum plate. **Working:** Bore-hole Ø 27mm, depth 250mm.

- **Kulite.** Shaped as a cylindrical tube with an outer diameter of 19 mm and a length of 55 mm.. The holes for these gauges will be bored with a drilling machine of Hilti-type fastened with a vacuum plate. **Working:** Bore-hole Ø 20mm, depth 160mm.

Relative humidity

- **Vaisala.** Shaped as a cylindrical tube with an outer diameter of 22 mm and a length of 63 mm. The holes for these gauges will be bored with a drilling machine of Hilti-type fastened with a vacuum plate. **Working:** Bore-hole Ø 23 mm, depth 160mm.

- **Rotronic.** Shaped as a cylindrical tube with an outer diameter of 22 mm and a length of 35 mm.. The holes for these gauges will be bored with a drilling machine of Hilti-type fastened with a vacuum plate. **Working:** Bore-hole Ø 23mm, depth 250 mm.

5.2 Tracks for cables and tubes on the bentonite blocks surface

Tracks will be made on the blocks´ surface from each instrument position, leading the tubes out to the block periphery. The tracks will be made by a hand–hold cutter.

Working: All tubes from the instruments, except for the thermocouples will have a track with the dimension 10 x 10 mm. The thermocouples will have a track with the dimension 6 x 6 mm. When the tracks reaches the sensor hole, the track will get deeper in order to let the tube make a smooth bend (Figure 5-1).

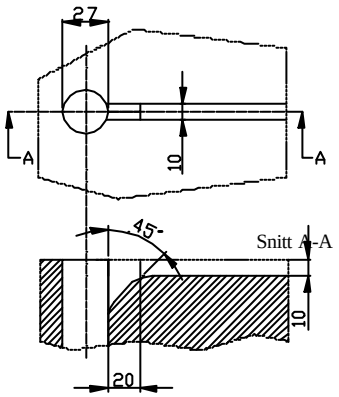


Figure 5-1 *Schematic view showing how the tracks on the bentonite block surface are connected to the sensor holes. The view shows a sensor hole for Geokon 1.*

5.3 Preparation for cables through block R10

The cables from the canisters must be led through the bentonite (block R10). This will be done by sawing slots in the bentonite block in advance (see Figure 4-1). Figure 4-1 also shows the directions of the cables from the canister. The slots will have different width depending on the cable type. They will be sawed with a special alligator-saw.

The slots will result in a weakening of the bentonite block since about 30% of the cross-section will be cut off. In order to minimize the strain, a special case will be manufactured which will be placed in the center of the block during all handling.

Working: The depth and shape of the slots are shown in Figure 4-1. The width of the slots will be about 40 mm for the power cables and 5 mm for the fiber optic cables

5.4 Preparation for the bottom of the canister in block C1

The canister will be standing on a cylindrical shaped bentonite block. The canisters are by design equipped with a skirt on the bottom (Figure 5-2). This means that a corresponding track must be done in this block. Holes will be seam-bored with a drilling machine of Hilti-type fastened with a vacuum plate.

Working: Holes with a diameter of 120 mm will be seam drilled to a depth of 85 mm. The track will then be formed with chisels in order to get a clean track.

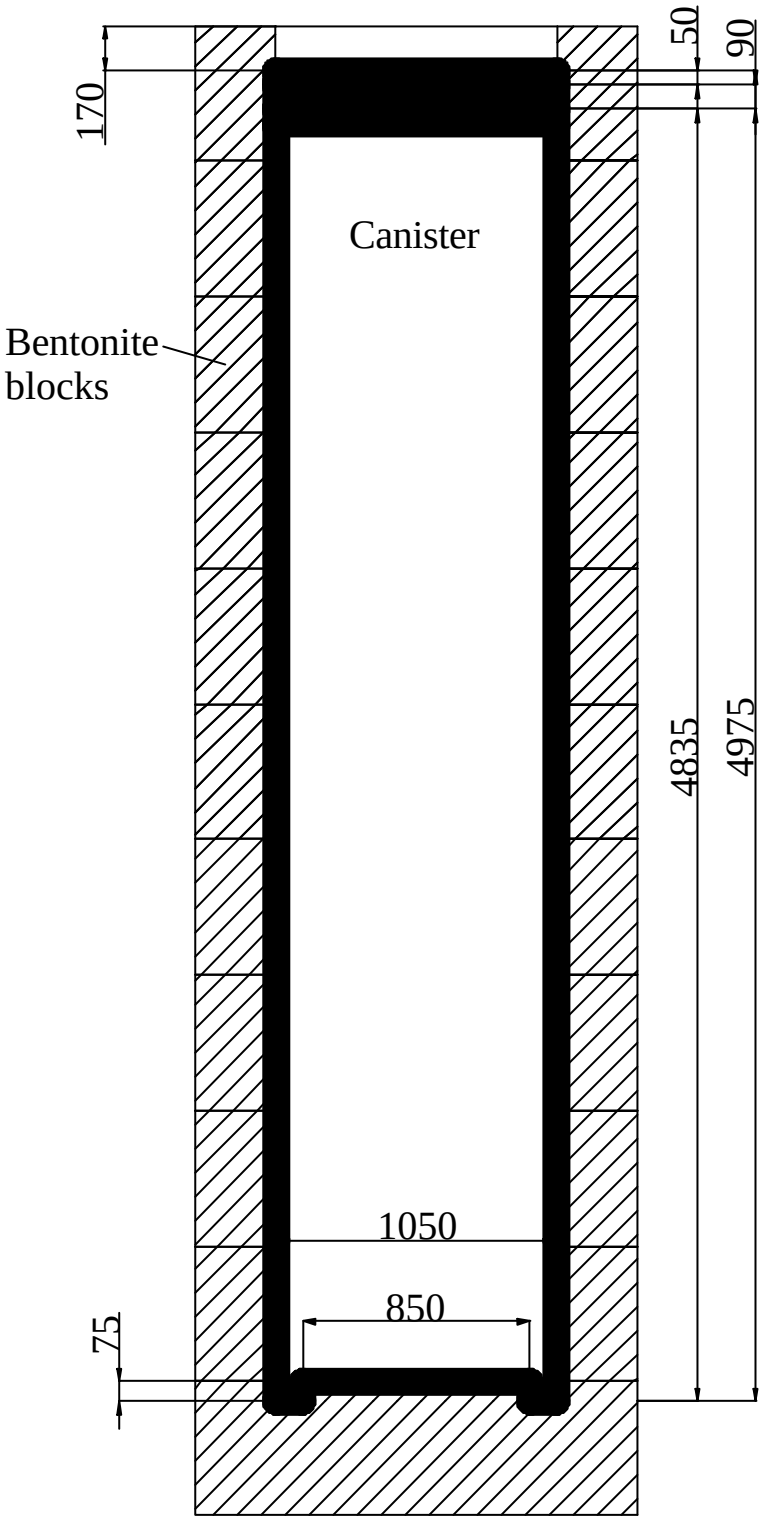


Figure 5-2 *Schematic view over the canisters position relative the bentonite blocks.*

6 Location of instruments in the backfill

6.1 Brief description of instruments

All instruments will be of the same type as those in the bentonite (described in chapter 3) except for the instruments measuring the water saturation process.

Measuring of the water saturation process

The relative humidity will be measured with the following technique:

- Wescor soil psychrometer. The sensor is measuring the dry and the wet temperature in the pore volume of the material.

6.2 Strategy for describing the position of each device

The backfill will mainly be instrumented in vertical sections straight above and between the deposition holes (Figure 6-1 and 6-2).

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. 3599 is the end of the tunnel.

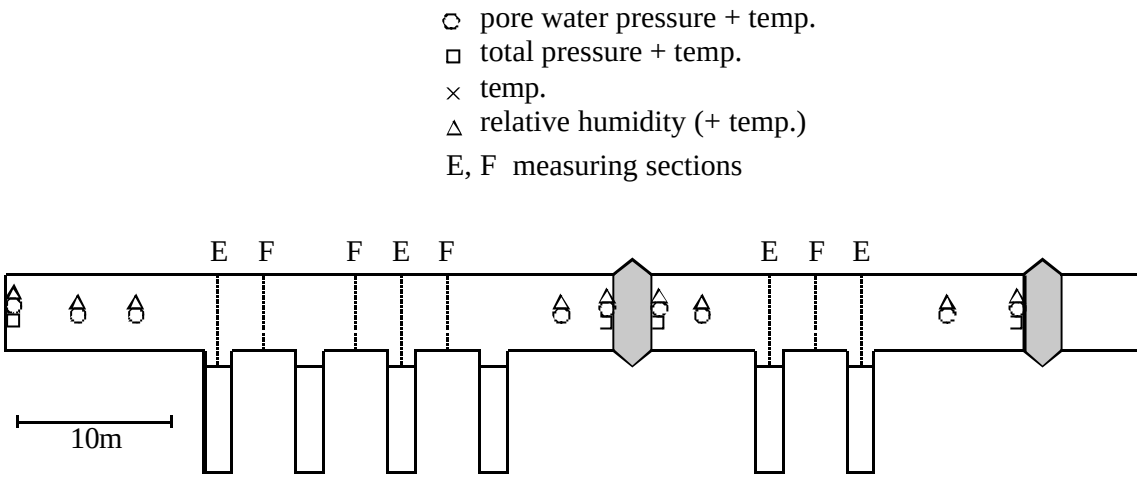


Figure 6-1 *Schematic view over the instrumentation of the backfill*

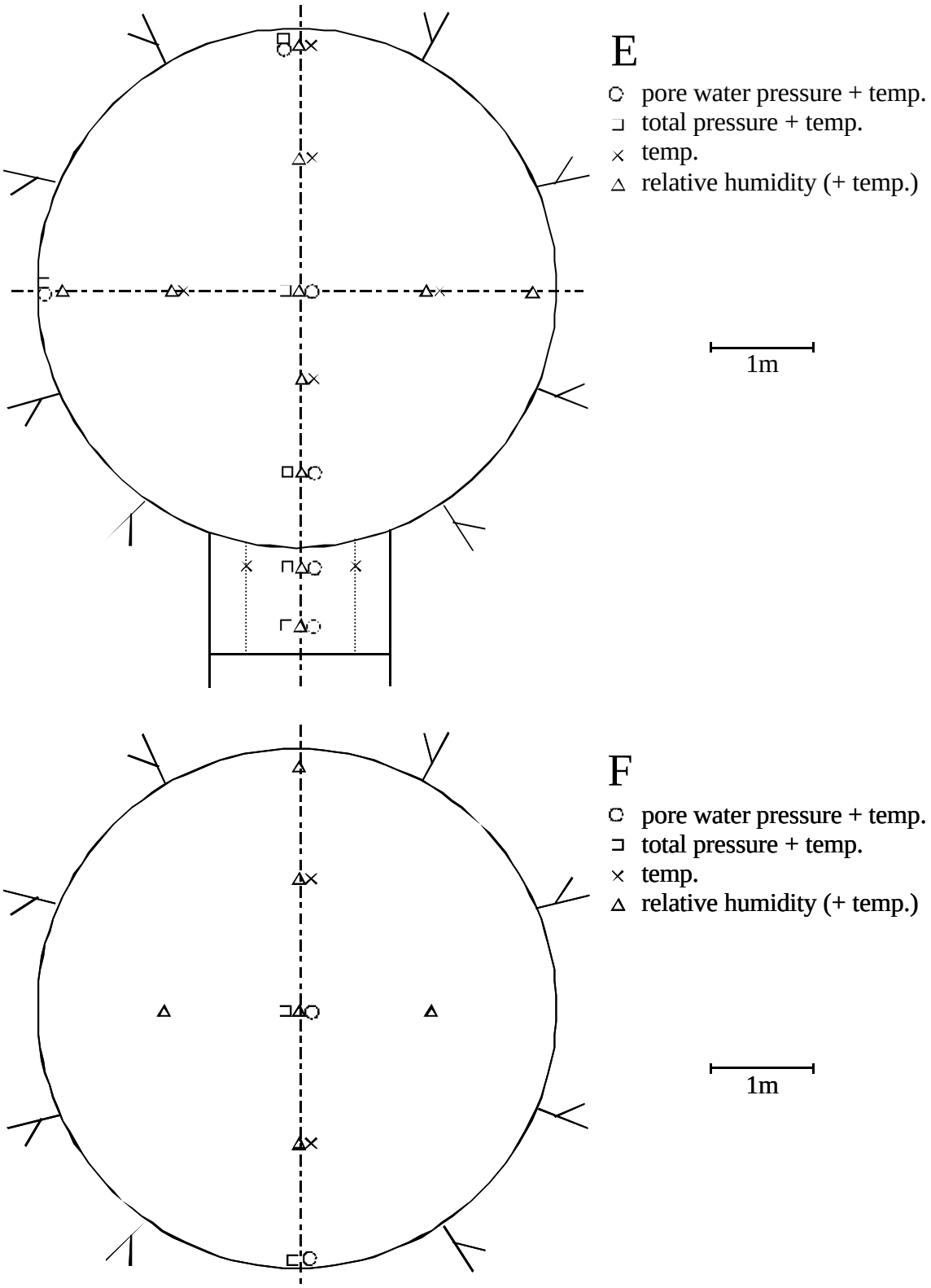


Figure 6-2 *Schematic view over the sensors positions in the different sections.*

6.3 Position of each instrument in the backfill

The positions of each instrument are described in Tables 6-1 to 6-4.

Table 6-1 Numbering and position of instruments for measuring temperature (T)

Prototype Repository, Instrumentation

Instrument type	**Thermocouple**
Backfill	
Lead through, No(TBA101-TBA109)	**LT22**
Lead through, No(TBA110-TBA120)	**LT43**
Length of lead through LT22	**53.5**
Length of lead throughLT43	**44.4**
Length in G-tunnel, m	**35**

Mark	Instrument position Section	x	y	z	Fabricate	Cable lengths In test volume	Total	Remark
		m	m	m		m	m	
TBA10001	E, over dep.hole 1	0	2.3	3587	Pentronic	12.0	100.5	
TBA10002	E, over dep.hole 1	0	1.25	3587	Pentronic	12.0	100.5	
TBA10003	E, over dep.hole 1	0	-0.8	3587	Pentronic	12.0	100.5	
TBA10004	E, over dep.hole 1	-0.5	-2.5	3587	Pentronic	12.0	100.5	
TBA10005	E, over dep.hole 1	0.5	-2.5	3587	Pentronic	12.0	100.5	
TBA10006	E, over dep.hole 1	-1.25	0	3587	Pentronic	12.0	100.5	
TBA10007	E, over dep.hole 1	1.25	0	3587	Pentronic	12.0	100.5	
TBA10008	F, between dep.hole 1 and 2	0	1.25	3584	Pentronic	9.0	97.5	
TBA10009	F, between dep.hole 1 and 2	0	0.8	3584	Pentronic	9.0	97.5	
TBA10010	F, between dep.hole 2 and 3	0	1.25	3578	Pentronic	15.0	94.4	
TBA10011	F, between dep.hole 2 and 3	0	0.8	3578	Pentronic	15.0	94.4	
TBA10012	E, over dep.hole 3	0	2.3	3575	Pentronic	12.0	91.4	
TBA10013	E, over dep.hole 3	0	1.25	3575	Pentronic	12.0	91.4	
TBA10014	E, over dep.hole 3	0	-0.8	3575	Pentronic	12.0	91.4	
TBA10015	E, over dep.hole 3	-0.5	-2.5	3575	Pentronic	12.0	91.4	
TBA10016	E, over dep.hole 3	0.5	-2.5	3575	Pentronic	12.0	91.4	
TBA10017	E, over dep.hole 3	-1.25	0	3575	Pentronic	12.0	91.4	
TBA10018	E, over dep.hole 3	1.25	0	3575	Pentronic	12.0	91.4	
TBA10019	F, between dep.hole 3 and 4	0	1.25	3572	Pentronic	9.0	88.4	
TBA10020	F, between dep.hole 3 and 4	0	0.8	3572	Pentronic	9.0	88.4	

Table 6-2 Numbering and position of instruments for measuring total pressure (P)

Prototype Repository, Instrumentation

Instrument type	**Total Pressure**
Backfill	
Lead through, No(PBA101-PBA109)	**LT22**
Lead through, No(PBA110-PBA121)	**LT43**
Length of lead through LT22	**53.5**
Length of lead throughLT43	**44.4**
Length in G-tunnel, m	**35**

Mark	Instrument position Section	x	y	z	Fabricate	Cable lengths In test volume	Total	Remark
		m	m	m		m	m	
PBA10001	Inner part	0	0	3599	Kulite	25.0	113.5	
PBA10002	E, over dep.hole 1	0	0	3587	Geocon	12.0	100.5	
PBA10003	E, over dep.hole 1	0	-1.75	3587	Geocon	12.0	100.5	
PBA10004	E, over dep.hole 1	-0.5	-3	3587	Geocon	12.0	100.5	
PBA10005	E, over dep.hole 1	0.5	-3	3587	Kulite	12.0	100.5	
PBA10006	E, over dep.hole 1	-2.3	0	3587	Kulite	12.0	100.5	
PBA10007	E, over dep.hole 1	0	2.3	3587	Kulite	12.0	100.5	
PBA10008	F, between dep.hole 1 and 2	0	0	3584	Geocon	9.0	97.5	
PBA10009	F, between dep.hole 1 and 2	0	-2.3	3584	Geocon	9.0	97.5	
PBA10010	F, between dep.hole 2 and 3	0	0	3578	Kulite	15.0	94.4	
PBA10011	F, between dep.hole 2 and 3	0	-2.3	3578	Kulite	15.0	94.4	
PBA10012	E, over dep.hole 3	0	0	3575	Kulite	12.0	91.4	
PBA10013	E, over dep.hole 3	0	-1.75	3575	Kulite	12.0	91.4	
PBA10014	E, over dep.hole 3	-0.5	-3	3575	Kulite	12.0	91.4	
PBA10015	E, over dep.hole 3	0.5	-3	3575	Geocon	12.0	91.4	
PBA10016	E, over dep.hole 3	-2.3	0	3575	Geocon	12.0	91.4	
PBA10017	E, over dep.hole 3	0	2.3	3575	Geocon	12.0	91.4	
PBA10018	F, between dep.hole 3 and 4	0	0	3572	Geocon	9.0	88.4	
PBA10019	F, between dep.hole 3 and 4	0	-2.3	3572	Geocon	9.0	88.4	
PBA10020	In front of plug	0	0	3561	Kulite	17.0	96.4	

Table 6-3 Numbering and position of instruments for measuring pore water pressure (U)

Prototype Repository, Instrumentation

Instrument type **Pore Pressure**
Backfill
Lead through, No(UBA101-UBA111) **LT22**
Lead through, No(UBA112-UBA123) **LT43**
Length of lead through LT22 **53.5**
Length of lead throughLT43 **44.4**
Length in G-tunnel, m **35**

Mark	Instrument position Section	X	Y	Z	Fabricate	Cable lengths In test volume	Total	Remark
		m	m	m		m	m	
UBA10001	Inner part	0	0	3599	Kulite	25.0	113.5	
UBA10002	Inner part	0	0	3594.5	Geocon	20.0	108.5	
UBA10003	Inner part	0	0	3590	Geocon	16.0	104.5	
UBA10004	E, over dep.hole 1	0	0	3587	Geocon	12.0	100.5	
UBA10005	E, over dep.hole 1	0	-1.75	3587	Kulite	12.0	100.5	
UBA10006	E, over dep.hole 1	-0.5	-3	3587	Kulite	12.0	100.5	
UBA10007	E, over dep.hole 1	0.5	-3	3587	Kulite	12.0	100.5	
UBA10008	E, over dep.hole 1	-2.3	0	3587	Geocon	12.0	100.5	
UBA10009	E, over dep.hole 1	0	2.3	3587	Geocon	12.0	100.5	
UBA10010	F, between dep.hole 1 and 2	0	0	3584	Kulite	9.0	97.5	
UBA10011	F, between dep.hole 1 and 2	0	-2.3	3584	Kulite	9.0	97.5	
UBA10012	F, between dep.hole 2 and 3	0	0	3578	Kulite	15.0	94.4	
UBA10013	F, between dep.hole 2 and 3	0	-2.3	3578	Kulite	15.0	94.4	
UBA10014	E, over dep.hole 3	0	0	3575	Kulite	12.0	91.4	
UBA10015	E, over dep.hole 3	0	-1.75	3575	Geocon	12.0	91.4	
UBA10016	E, over dep.hole 3	-0.5	-3	3575	Geocon	12.0	91.4	
UBA10017	E, over dep.hole 3	0.5	-3	3575	Geocon	12.0	91.4	
UBA10018	E, over dep.hole 3	-2.3	0	3575	Geocon	12.0	91.4	
UBA10019	E, over dep.hole 3	0	2.3	3575	Geocon	12.0	91.4	
UBA10020	F, between dep.hole 3 and 4	0	0	3572	Kulite	9.0	88.4	
UBA10021	F, between dep.hole 3 and 4	0	-2.3	3572	Kulite	9.0	88.4	
UBA10022	In front of plug	0	0	3565	Kulite	13.0	92.4	
UBA10023	In front of plug	0	0	3561	Kulite	17.0	96.4	

Table 6-4 Numbering and position of instruments for measuring relative humidity (W)

Prototype Repository, Instrumentation

Instrument type **Relative Humidity**
Backfill
Lead through, No(WBA101-WBA120) **LT22**
Lead through, No(WBA121-WBA145) **LT42**
Length of lead through LT22 **53.5**
Length of lead throughLT42 **45.7**
Length in G-tunnel, m **35**

Mark	Instrument position Section	x	y	z	Fabricate	Cable lengths In test volume	Total	Remark
		m	m	m		m	m	
WBA10001	Inner part	0	0	3599	Wescor	25.0	113.5	
WBA10002	Inner part	0	0	3594.5	Wescor	20.0	108.5	
WBA10003	Inner part	0	0	3590	Wescor	16.0	104.5	
WBA10004	E, over dep.hole 1	0	2.3	3587	Wescor	12.0	100.5	
WBA10005	E, over dep.hole 1	0	1.25	3587	Wescor	12.0	100.5	
WBA10006	E, over dep.hole 1	0	0	3587	Wescor	12.0	100.5	
WBA10007	E, over dep.hole 1	0	-0.8	3587	Wescor	12.0	100.5	
WBA10008	E, over dep.hole 1	0	-1.75	3587	Wescor	12.0	100.5	
WBA10009	E, over dep.hole 1	-0.5	-3	3587	Wescor	12.0	100.5	
WBA10010	E, over dep.hole 1	0.5	-3	3587	Wescor	12.0	100.5	
WBA10011	E, over dep.hole 1	-2.3	0	3587	Wescor	12.0	100.5	
WBA10012	E, over dep.hole 1	-1.25	0	3587	Wescor	12.0	100.5	
WBA10013	E, over dep.hole 1	1.25	0	3587	Wescor	12.0	100.5	
WBA10014	E, over dep.hole 1	2.3	0	3587	Wescor	12.0	100.5	
WBA10015	F, between dep.hole 1 and 2	0	2.3	3584	Wescor	9.0	97.5	
WBA10016	F, between dep.hole 1 and 2	0	1.25	3584	Wescor	9.0	97.5	
WBA10017	F, between dep.hole 1 and 2	0	0	3584	Wescor	9.0	97.5	
WBA10018	F, between dep.hole 1 and 2	0	-0.8	3584	Wescor	9.0	97.5	
WBA10019	F, between dep.hole 1 and 2	-1.25	0	3584	Wescor	9.0	97.5	
WBA10020	F, between dep.hole 1 and 2	1.25	0	3584	Wescor	9.0	97.5	
WBA10021	F, between dep.hole 2 and 3	0	2.3	3578	Wescor	15.0	95.7	
WBA10022	F, between dep.hole 2 and 3	0	1.25	3578	Wescor	15.0	95.7	
WBA10023	F, between dep.hole 2 and 3	0	0	3578	Wescor	15.0	95.7	
WBA10024	F, between dep.hole 2 and 3	0	-0.8	3578	Wescor	15.0	95.7	
WBA10025	F, between dep.hole 2 and 3	-1.25	0	3578	Wescor	15.0	95.7	
WBA10026	F, between dep.hole 2 and 3	1.25	0	3578	Wescor	15.0	95.7	
WBA10027	E, over dep.hole 3	0	2.3	3575	Wescor	12.0	92.7	
WBA10028	E, over dep.hole 3	0	1.25	3575	Wescor	12.0	92.7	
WBA10029	E, over dep.hole 3	0	0	3575	Wescor	12.0	92.7	
WBA10030	E, over dep.hole 3	0	-0.8	3575	Wescor	12.0	92.7	
WBA10031	E, over dep.hole 3	0	-1.75	3575	Wescor	12.0	92.7	
WBA10032	E, over dep.hole 3	-0.5	-3	3575	Wescor	12.0	92.7	
WBA10033	E, over dep.hole 3	0.5	-3	3575	Wescor	12.0	92.7	
WBA10034	E, over dep.hole 3	-2.3	0	3575	Wescor	12.0	92.7	
WBA10035	E, over dep.hole 3	-1.25	0	3575	Wescor	12.0	92.7	
WBA10036	E, over dep.hole 3	1.25	0	3575	Wescor	12.0	92.7	
WBA10037	E, over dep.hole 3	2.3	0	3575	Wescor	12.0	92.7	
WBA10038	F, between dep.hole 3 and 4	0	2.3	3572	Wescor	9.0	89.7	
WBA10039	F, between dep.hole 3 and 4	0	1.25	3572	Wescor	9.0	89.7	
WBA10040	F, between dep.hole 3 and 4	0	0	3572	Wescor	9.0	89.7	
WBA10041	F, between dep.hole 3 and 4	0	-0.8	3572	Wescor	9.0	89.7	
WBA10042	F, between dep.hole 3 and 4	-1.25	0	3572	Wescor	9.0	89.7	
WBA10043	F, between dep.hole 3 and 4	1.25	0	3572	Wescor	9.0	89.7	
WBA10044	In front of plug	0	0	3565	Wescor	13.0	93.7	
WBA10045	In front of plug	0	0	3561	Wescor	17.0	97.7	

References

/1-1/ **Collin M and Börgesson L.** Prototype Repository. Instrumentation of buffer and backfill for measuring THM processes, IPR-xx

/2-1/ **Svemar C**. Test plan for the Prototype

Appendix

1 Bentonite block, Cylinder 1, Instrument direction A and Center

2 Bentonite block, Cylinder 1, Instrument direction B

3 Bentonite block, Cylinder 1, Instrument direction C

4 Bentonite block, Cylinder 1, Instrument direction D

5 Bentonite block, Ring 5, Instrument direction A

6 Bentonite block, Ring 5, Instrument direction B

7 Bentonite block, Ring 5, Instrument direction C

8 Bentonite block, Ring 5, Instrument direction D

9 Bentonite block, Ring 10, Instrument direction A

10 Bentonite block, Ring 10, Instrument direction A and Center

11 Bentonite block, Ring 10, Instrument direction B

12 Bentonite block, Ring 10, Instrument direction C

13 Bentonite block, Ring 10, Instrument direction D

14 Bentonite block, Cylinder 3, Instrument direction A and Center

15 Bentonite block, Cylinder 3, Instrument direction B

16 Bentonite block, Cylinder 3, Instrument direction C

17 Bentonite block, Cylinder 4, Instrument direction A and Center

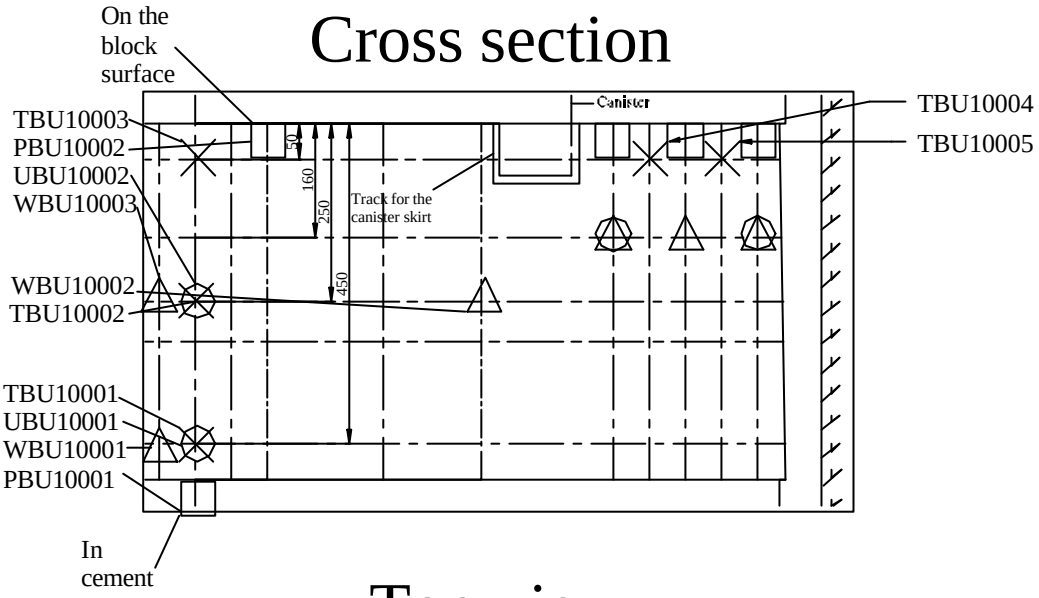
Instrument locations

DA3575G01 and DA3587G01

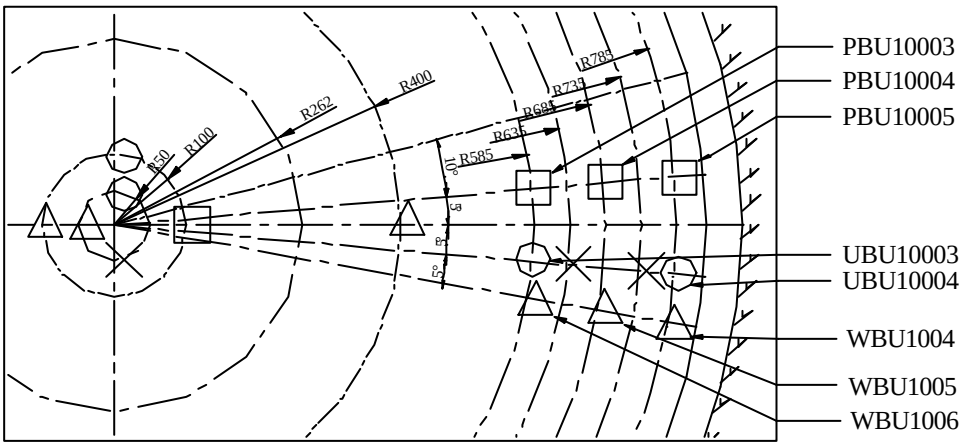
Cylinder 1

Instrument direction A (0°) and Center

Cross section



Top view



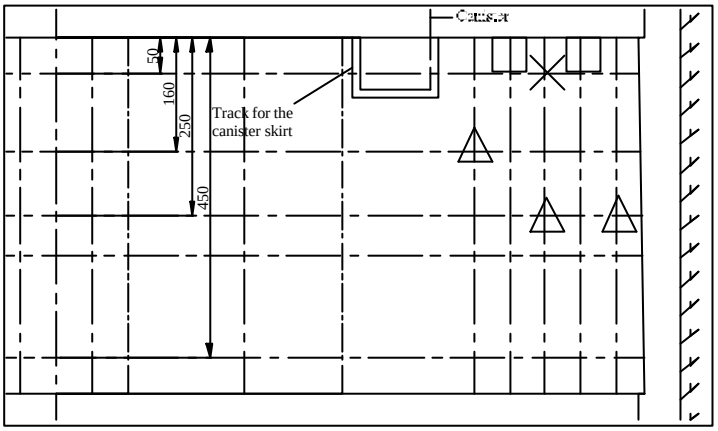
Instrument locations

DA3575G01 and DA3587G01

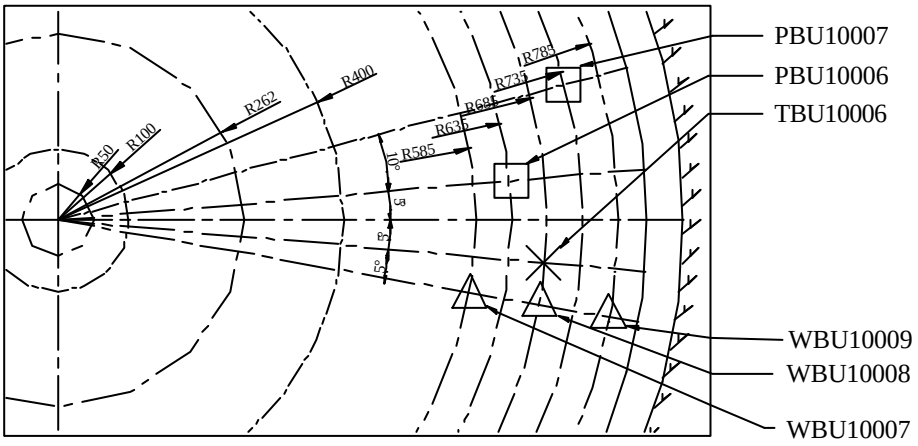
Cylinder 1

Instrument direction B (90°)

Cross section



Top view



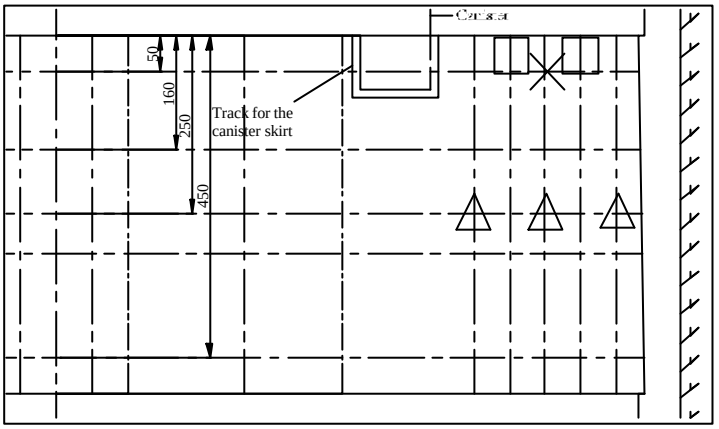
Instrument locations

DA3575G01 and DA3587G01

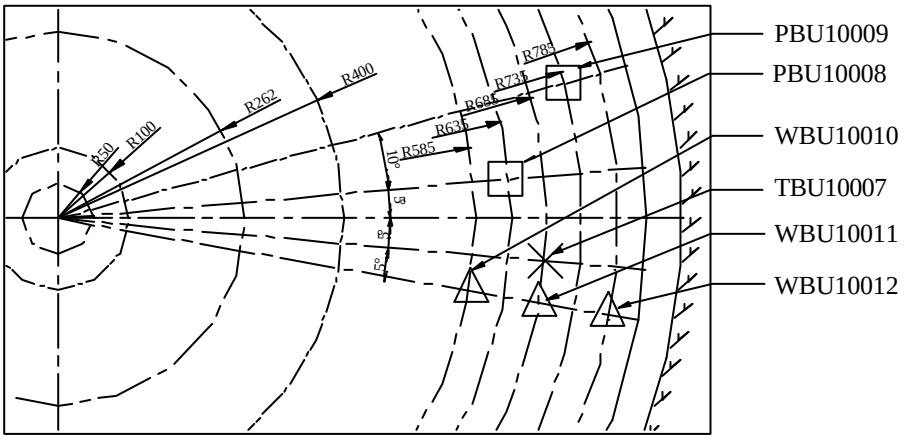
Cylinder 1

Instrument direction C (180°)

Cross section



Top view



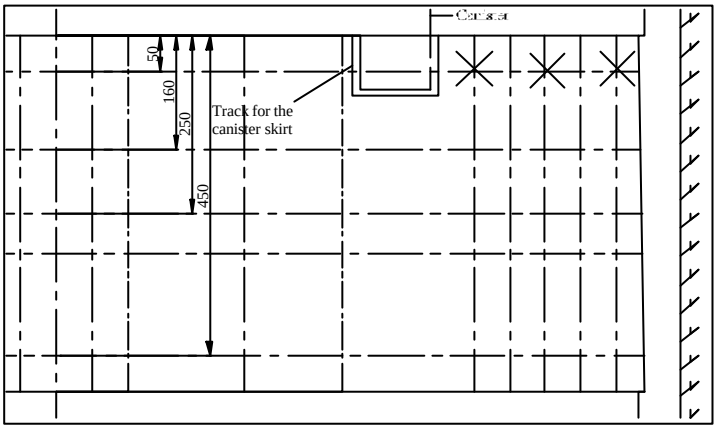
Instrument locations

DA3575G01 and DA3587G01

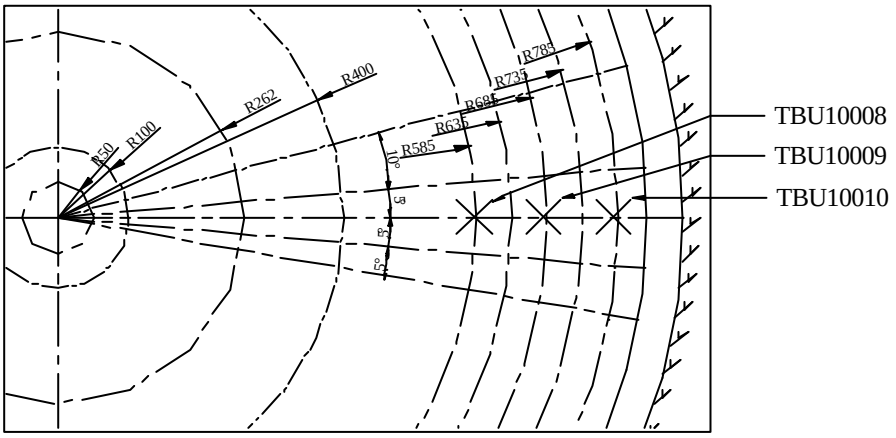
Cylinder 1

Instrument direction D (270°)

Cross section



Top view



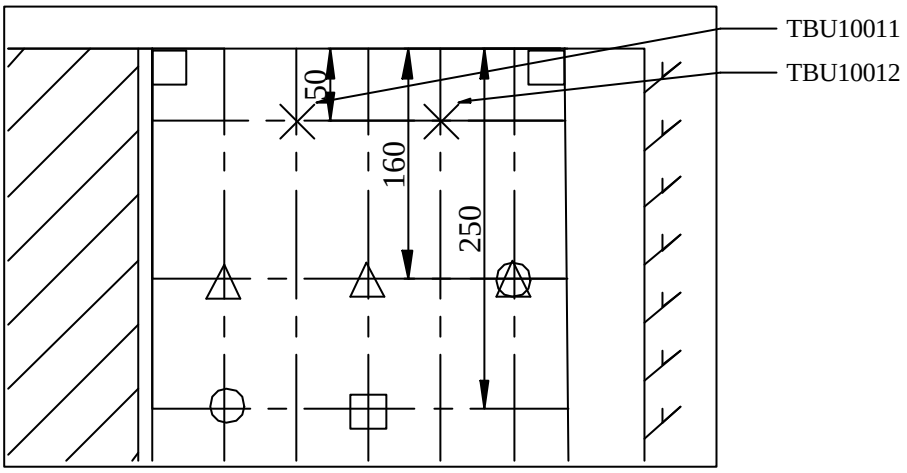
Instrument locations

DA3575G01 and DA3587G01

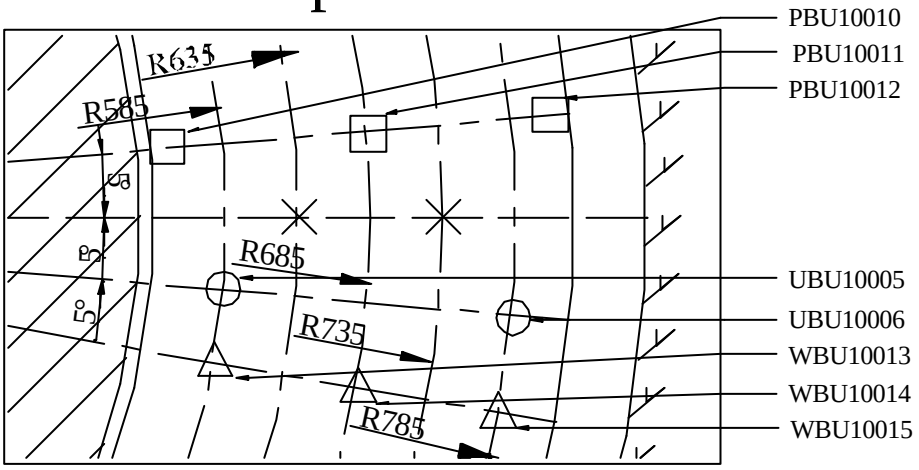
Ring 5

Instrument direction A (0°)

Cross section



Top view



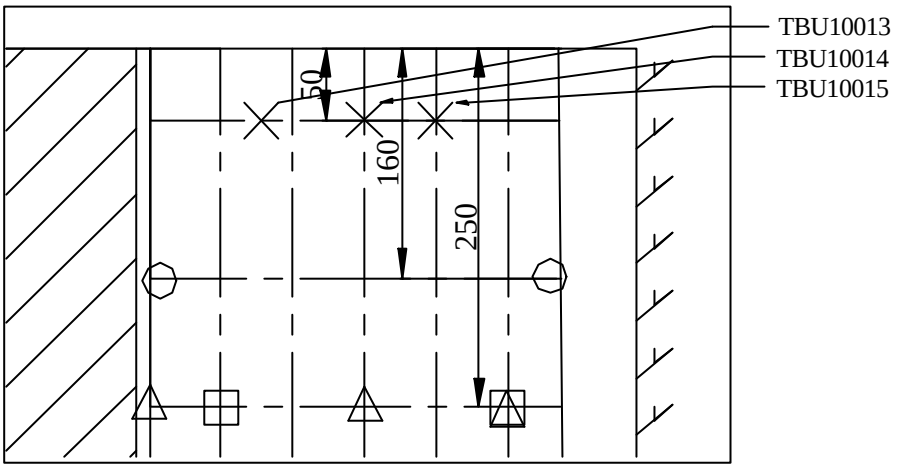
Instrument locations

DA3575G01 and DA3587G01

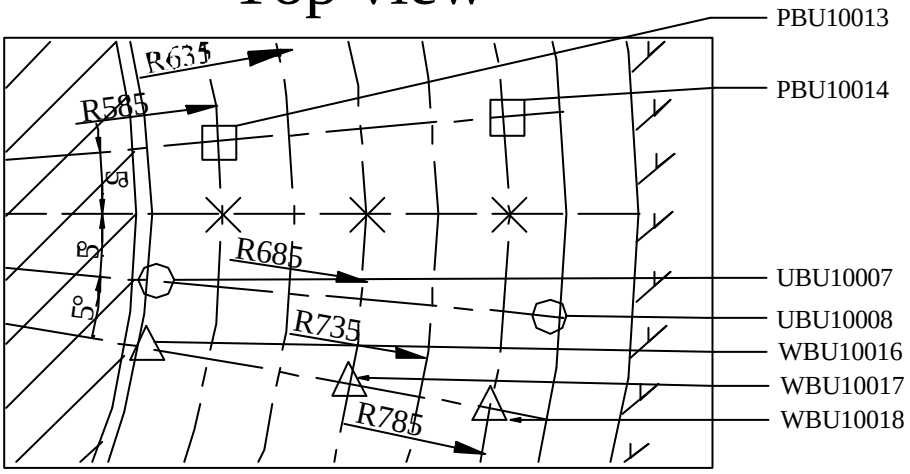
Ring 5

Instrument direction B (90°)

Cross section



Top view



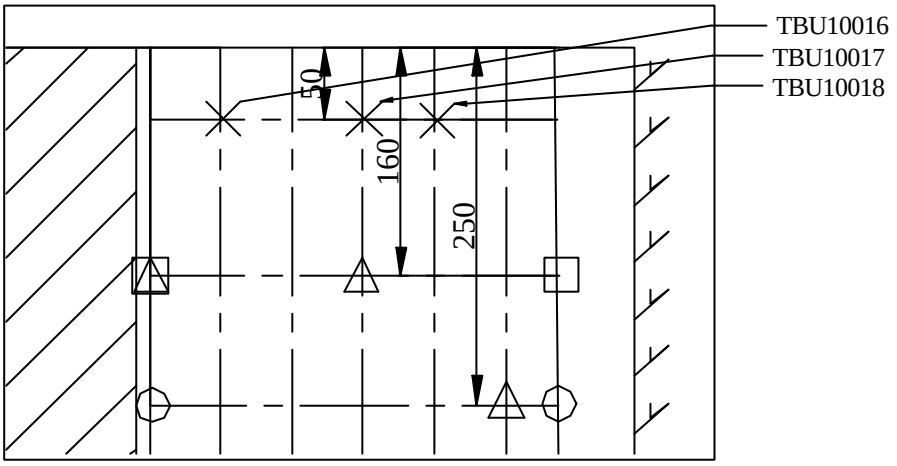
Instrument locations

DA3575G01 and DA3587G01

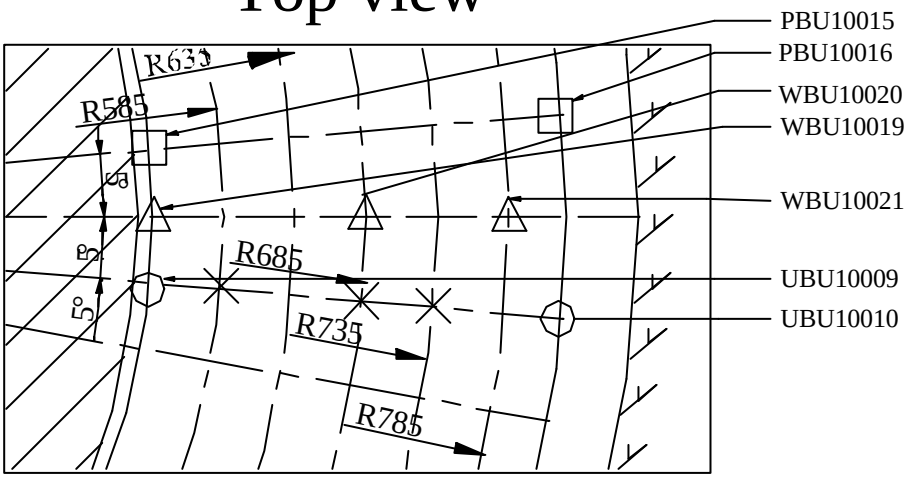
Ring 5

Instrument direction C (180°)

Cross section



Top view



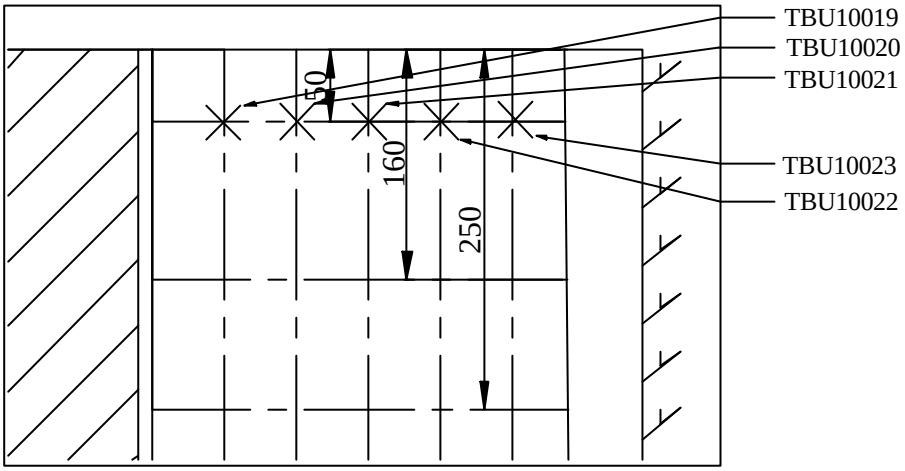
Instrument locations

DA3575G01 and DA3587G01

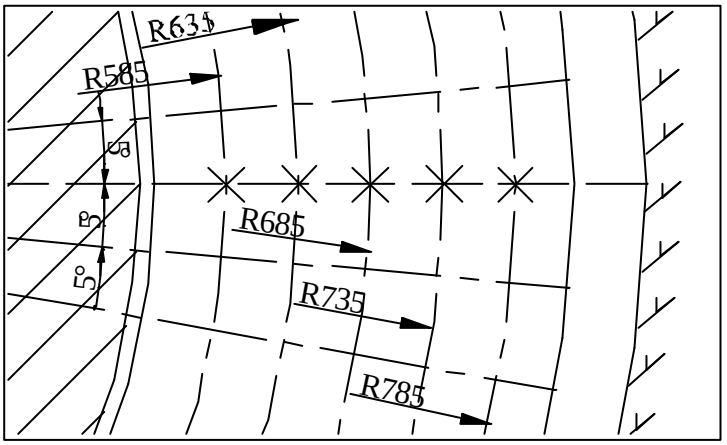
Ring 5

Instrument direction D (270°)

Cross section



Top view



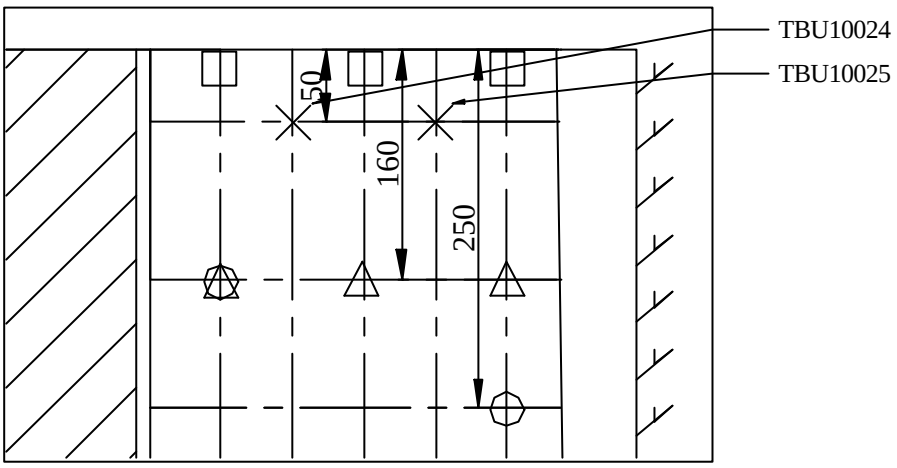
Instrument locations

DA3575G01 and DA3587G01

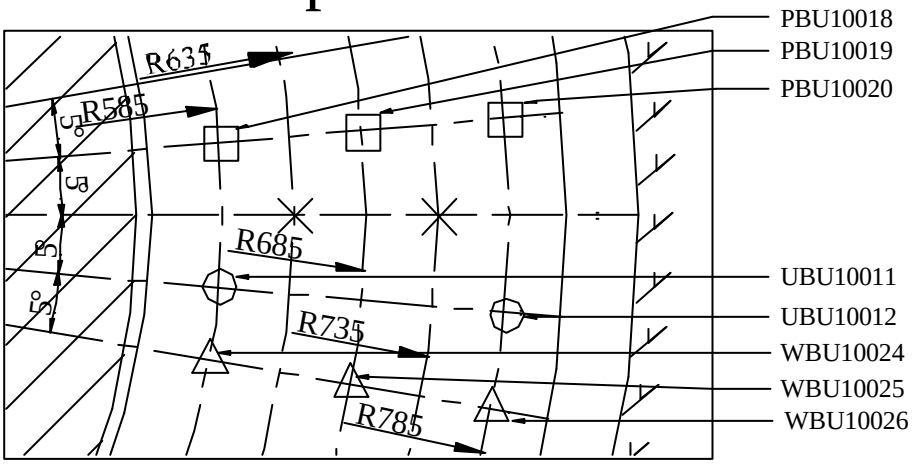
Ring 10

Instrument direction A (0°)

Cross section



Top view



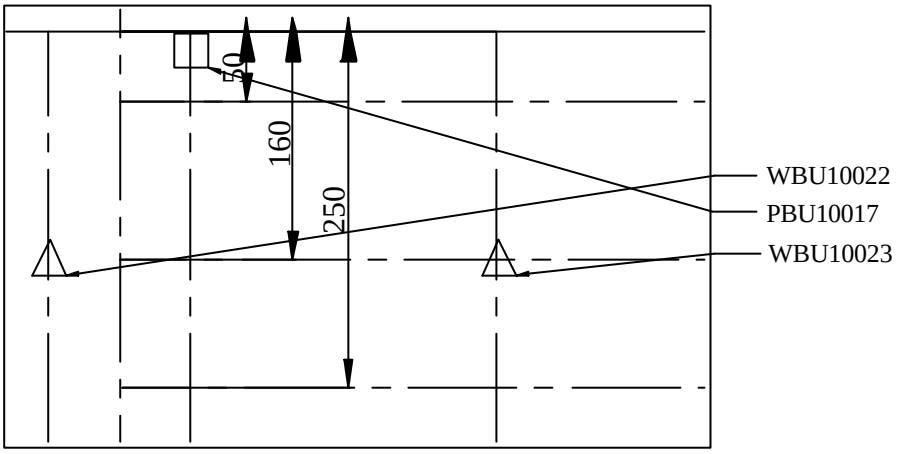
Instrument locations

DA3575G01 and DA3587G01

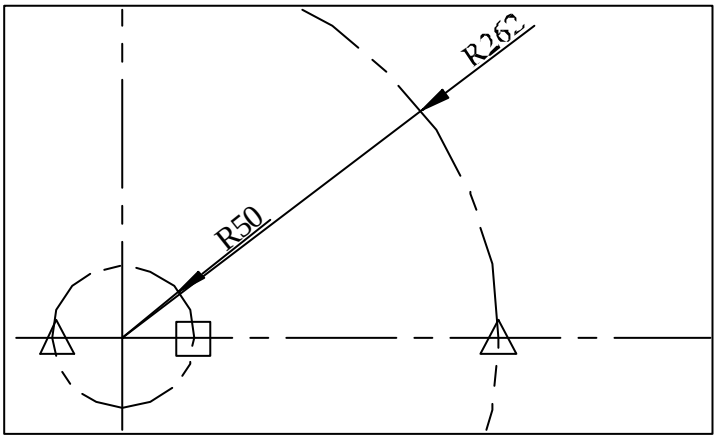
Ring 10

Instrument direction A (0°) and Center

Cross section



Top view



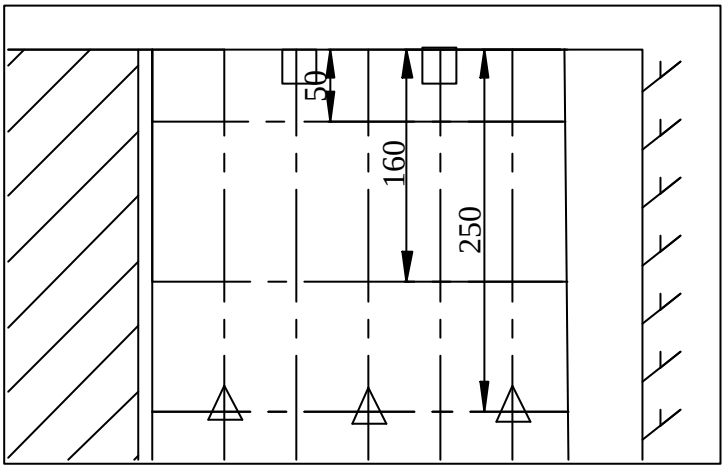
Instrument locations

DA3575G01 and DA3587G01

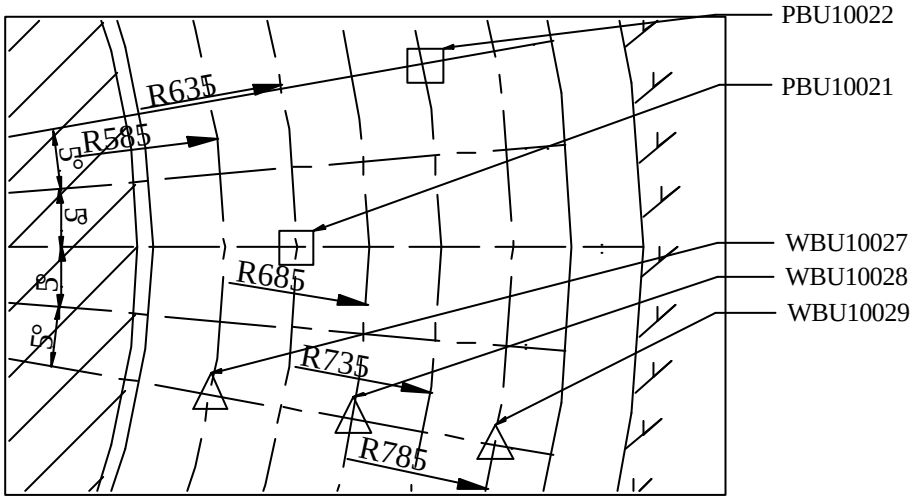
Ring 10

Instrument direction B (90°)

Cross section



Top view



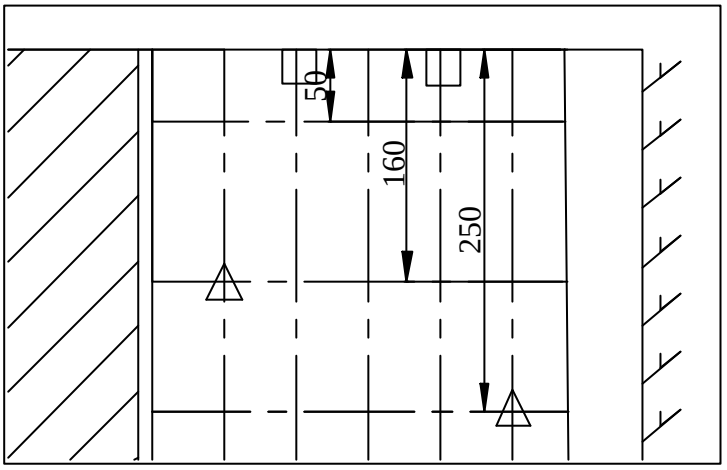
Instrument locations

DA3575G01 and DA3587G01

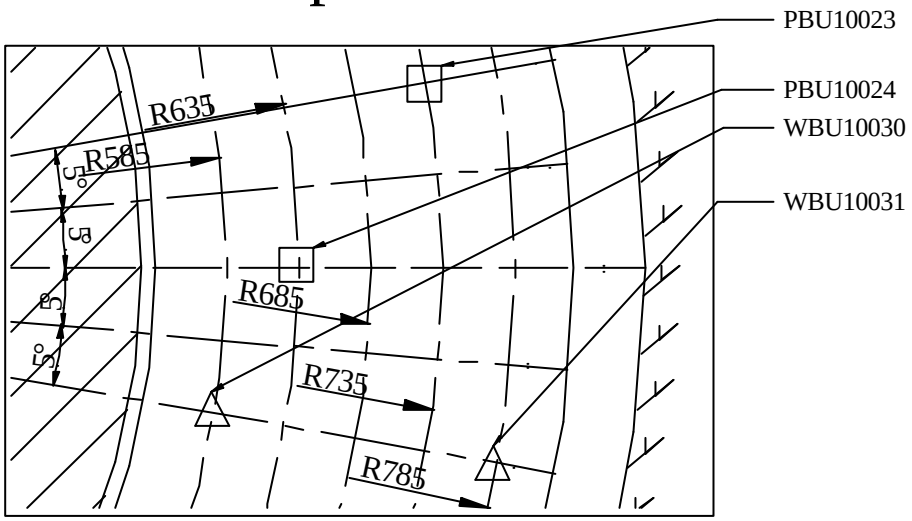
Ring 10

Instrument direction C (180°)

Cross section



Top view



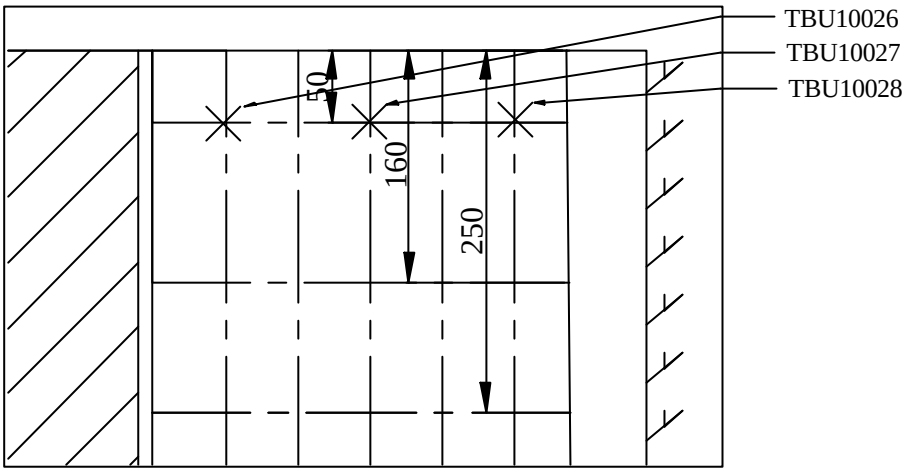
Instrument locations

DA3575G01 and DA3587G01

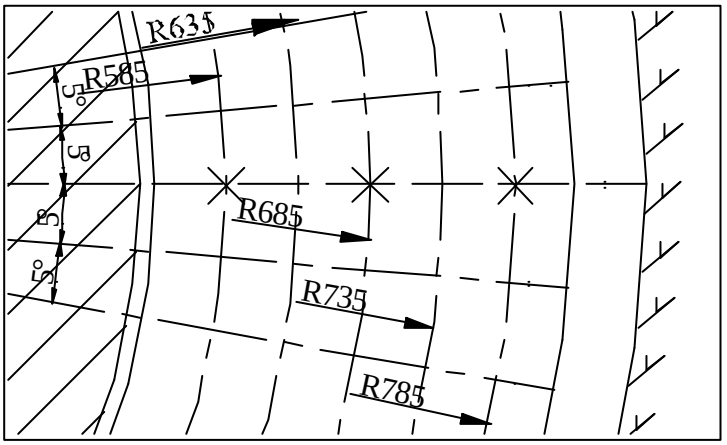
Ring 10

Instrument direction D (270°)

Cross section



Top view



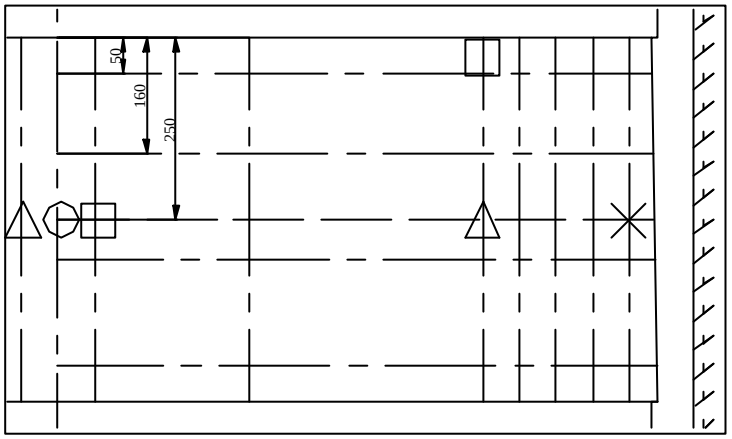
Instrument locations

DA3575G01 and DA3587G01

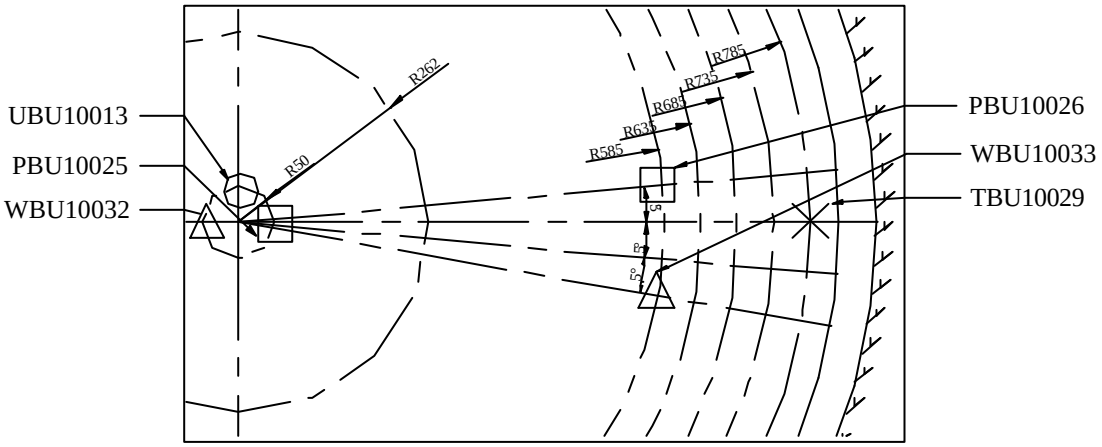
Cylinder 3

Instrument direction A (0°) and Center

Cross section



Top view



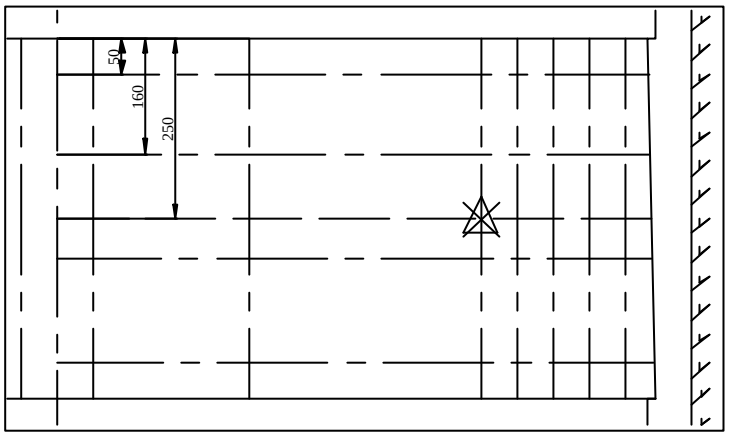
Instrument locations

DA3575G01 and DA3587G01

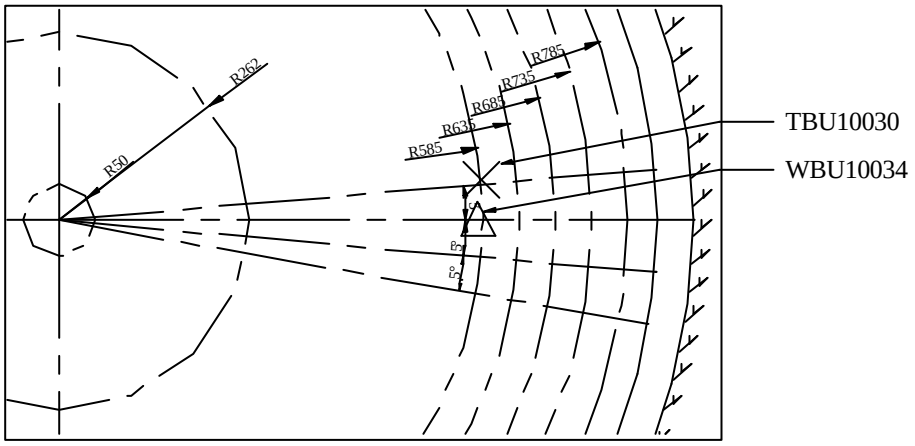
Cylinder 3

Instrument direction B (90°)

Cross section



Top view



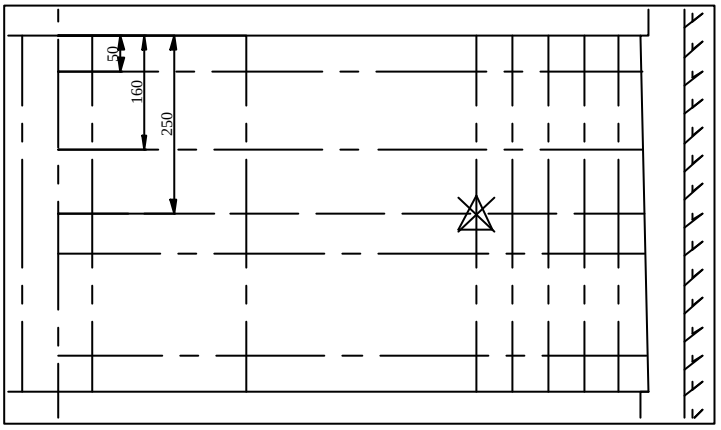
Instrument locations

DA3575G01 and DA3587G01

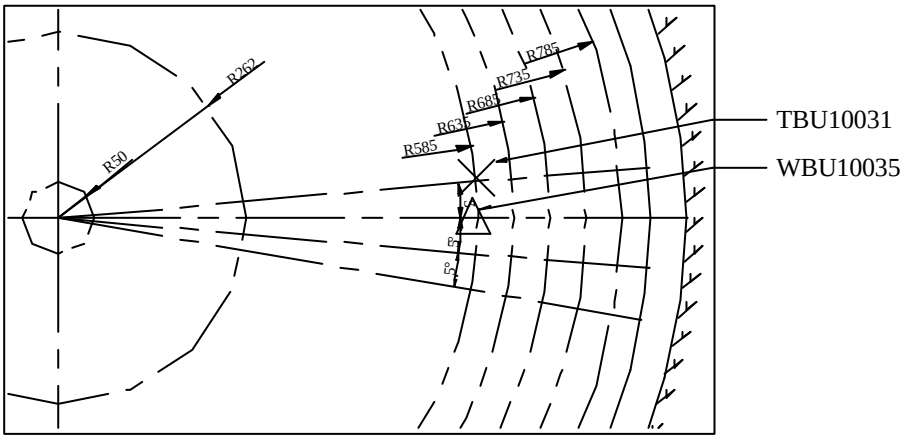
Cylinder 3

Instrument direction C (180°)

Cross section



Top view



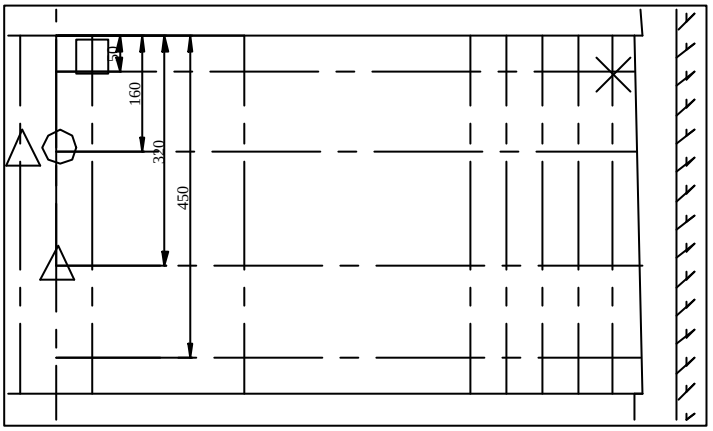
Instrument locations

DA3575G01 and DA3587G01

Cylinder 4

Instrument direction A (0°) and Center

Cross section



Top view