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Äspö Hard Rock Laboratory

Temperature Buffer Test

Sensors data report
(Period 030326-040401)
Report No:3

Reza Goudarzi

Lennart Börgesson

Harald Hökmark

Clay Technology AB

April 2004

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co
Box 5864
SE-102 40 Stockholm Sweden
Tel 08-459 84 00
+46 8 459 84 00
Fax 08-661 57 19
+46 8 661 57 19

Äspö Hard Rock
Laboratory

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Author
Reza Goudarzi
Lennart Börgesson
Harald Hökmark

Date
April 2004

Checked by

Date

Approved
Christer Svemar
Bertrand Vignal

Date
2004-09-24

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Résumé

TBT (Test de Barrière ouvragée en Température) est une expérience menée par SKB et l'ANDRA, soutenue par ENRESA et DBE, qui vise à comprendre et modéliser le comportement thermo-hydro-mécanique de barrières ouvragées à base d'argile gonflante soumises à des températures élevées (>100°C) pendant leur hydratation.

Le test est mené au HRL d'Äspö dans une alvéole de 8 m de profondeur et 1,75 m de diamètre. Deux sondes chauffantes (chacune de 3 m de long et 0,6 m de diamètre) sont entourées d'argile gonflante, de bentonite, et confinées par un bouchon ancré sur 9 câbles. L'essai a été mis en place début 2003. Les sondes sont chauffées chacune par une puissance de 1500 W et un dispositif d'alimentation artificiel fournit de l'eau au contact de l'argile et du granite sous une pression de 800 kPa.

Le présent rapport fournit les données de TBT enregistrées depuis son début le 26 mars 2003 jusqu'au premier avril 2004.

Dans la bentonite, la pression totale est mesurée en 29 points, la pression interstitielle en 8 points et l'humidité relative en 35 points. La température est mesurée en 89 points et l'est aussi à l'emplacement de chaque capteur dont la mesure nécessite d'être compensée en température.

Des mesures additionnelles sont faites : température en 40 points dans la roche environnante, en 11 points de la surface et 6 points à l'intérieur de chaque sonde chauffante. La force exercée sur le bouchon est mesurée sur trois des neuf câbles d'ancrage. Le débit et la pression d'eau fournie au système sont également mesurés.

Globalement, le système de mesure et de transmission des données fonctionne bien et presque tous les capteurs fournissent des données fiables. La seule exception concerne les capteurs d'humidité relative dont plusieurs ne fonctionnent plus, notamment ceux placés dans les zones les plus chaudes.

Environ 40 % de la quantité d'eau requise pour saturer la bentonite a été injectée, sans compter l'eau de remplissage du filtre en sable placé entre la bentonite et la roche. La pression d'eau nécessaire pour injecter dans ce filtre indique que des modifications de sa résistance hydraulique sont intervenues. La cause n'en est pas claire, colmatage des embouts du filtre ou intrusion de particules de bentonite dans le sable.

Une baisse de la pression totale et quelques remontées des succions sont enregistrées autour de la sonde supérieure, ce qui pourrait avoir pour cause un déficit d'alimentation en eau de la partie supérieure du filtre en sable.

La forte densité de thermocouples placée dans la bentonite à mi-hauteur de chaque sonde se révèle utile pour apprécier qualitativement l'état d'hydratation. Autour de la sonde inférieure, des signes clairs indiquent une déshydratation précoce survenue dans la bentonite sur une zone annulaire de 0,15 m d'épaisseur. La resaturation de cette zone progresse désormais lentement.

Abstract

TBT (Temperature Buffer Test) is a joint project between SKB/ANDRA and supported by ENRESA (modelling) and DBE (optical sensors), which aims at understanding and modelling the thermo-hydro-mechanical behaviour of buffers made of swelling clay submitted to high temperatures (over 100°C) during the water saturation process.

The test is carried out in Äspö HRL in a 8 meters deep and 1.75 m diameter deposition hole, with two canisters (3 m long, 0.6 m diameter), surrounded by a bentonite buffer and a confining plug on top anchored with 9 rods. It was installed during spring 2003. The canisters are heated with 1500 W power and an artificial wetting with a water pressure of 800 kPa is in progress.

This report presents data from measurements in the Temperature Buffer Test from 030326 to 040401 (26 March 2003 to 01 April 2004).

The following measurements are made in the bentonite: Temperature is measured in 89 points, total pressure in 29 points, pore water pressure in 8 points and relative humidity in 35 points. Temperature is also measured by all gauges as an auxiliary measurement used for compensation.

The following additional measurements are done: Temperature is measured in 40 points in the rock in 11 points on the surface of each canister and in 6 points inside each canister. The force on the confining plug is measured in 3 of the 9 rods and its vertical displacement is measured in three points. The water inflow and water pressure in the outer sand filter is also measured.

A general conclusion is that measuring systems and transducers work well and almost all sensors deliver reliable values. The only exception is Relative Humidity sensors in the high temperature area around the lower canister, where several sensors have failed.

The highest temperature measured on the canister surfaces is 142 °C on the lower canister and 156 °C on the upper. Strong wetting with measured high RH (>90%) and high swelling pressure (3-8 MPa) has reached about 20 cm into the buffer everywhere with exception of the top blocks between the plug and heater 2.

About 40% of the water needed to saturate the bentonite has been injected, in addition to the water needed to fill up the outer sand slot. The sand slot injection pressure required to maintain the inflow indicates that some change in the flow resistance of the filter/sand system has taken place. It is not clear if this is a result of clogging of the filter tips or a successive intrusion of bentonite particles in the sand slot.

A decrease in total pressure and some increase in suction are recorded around the upper canister, which may be caused by lack of water supply in the upper part of the sand filter.

The dense arrays of thermocouples at the mid-height of the two heaters appear to be useful for examining the dehydration/hydration process qualitatively. In the lower 6 section there are clear signs of early dehydration in a 0.15 m annular zone around the heater. Resaturation of this part is now slowly in progress.

Sammanfattning

TBT (Temperature Buffer Test) är ett gemensamt SKB/ANDRA projekt med deltagande av ENRESA (modellering) och DBE (optiska mätinstrument), syftet är att öka förståelsen för de termiska, hydrauliska och mekaniska processerna i en buffert gjord av svällande lera som utsätts för höga temperaturer (över 100 ˚C) under vattenmättnadsfasen och kunna modellera dessa processer.

Försöket görs i Äspö HRL i ett 8 m djupt deponeringshål med diametern 1,75 m, där två kapslar (3 m lång, 0,6 m diameter), omgivande bentonitbuffert och en ovanpåliggande plugg, som förankrats med 9 stag, installerades våren 2003. Uppvärmning av kapslarna med effekten 1500 W och konstgjord bevätning med vattentrycket 800 kPa i sandfiltret pågår.

I denna rapport presenteras data från mätningar i TBT under perioden 030326-040401.

Följande mätningar görs i bentoniten: Temperaturen mäts i 89 punkter, totaltryck i 29 punkter, porvattentryck i 8 punkter och relativa fuktigheten i 35 punkter. Temperaturen mäts även i alla relativa fuktighetsmätare, för att kompensera för temperaturens inverkan på mätresultaten.

Följande övriga mätningar görs: Temperatur mäts i 40 punkter i berget, i 11 punkter på ytan av varje kapsel och i 6 punkter inne varje kapsel. Kraften på den ovanpåliggande pluggen mäts i 3 av de 9 stagen och vertikala förskjutningen av pluggen mäts i tre punkter. Vatteninflödet och vattentrycket i den yttre sandfyllda spalten mäts också.

En generell slutsats är att mätsystemen och givarna fungera bra och i stort sett alla givare levererar pålitliga mätvärden. Enda undantaget är mätningarna av relativa fuktigheten i högtemperaturområdet runt den undre kapseln, där ett flertal givare inte fungerar.

Högsta temperaturen som mäts på kapselytorna är 142 ˚C på nedre kapseln respektive 156 ˚C på övre. Stark bevätning med mätta höga RH (>90%) och höga svälltryck (3-8 MPa) har nått cirka 20 cm in i bufferten överallt utom i de översta blocken mellan pluggen och kapsel 2.

Omkring 40% av den vattenmängd som behövs för att vattenmätta bentoniten har nu tillförts, förutom den mängd vatten som har behövts för att fylla upp den yttre sandspalten. Det injekteringstryck i sandspalten som fordras för att upprätthålla inflödet tyder på att en förändring av flödesmotståndet i systemet filter/sandspalt har ägt rum. Det är oklart om detta beror på långsam igensättning av filterspetsarna eller en successiv inträngning av bentonitpartiklar i spalten.

En sänkning av totaltrycket och en viss höjning av buffertens inre undertryck noteras runt den översta kapseln, vilket kan bero på brist på vattentillgång i övre delen av sandfiltret.

De täta linjerna av termoelement vid de två värmarnas höjdcentrum visar sig vara användbara för att undersöka torkning/mättnadsprocessen kvalitativt. I den under sektionen finns det tydliga tecken på uttorkning inom ett avstånd av 0,15 m från värmarytan. En långsam återmättnad av denna zon pågår nu.

Contents

1 Introduction

The installation of the Temperature Buffer Test was made during spring 2003 in Äspö Hard Rock Laboratory, Sweden.

The Temperature Buffer Test, TBT, is a full-scale experiment that ANDRA and SKB carry out at the SKB Äspö Hard Rock Laboratory. In addition ENRESA supports TBT with THM modelling and DBE has installed a number of optical pressure sensors.

The test aims at understanding and modelling the thermo-hydro-mechanical behaviour of buffers made of swelling clay submitted to high temperatures (over 100°C) during the water saturation process. No other full scales tests have been carried out with buffer temperatures exceeding 100°C so far.

The test consists of a full-scale KBS3 deposition hole, 2 steel canisters equipped with electrical heaters simulating the power of radioactive decay and a mechanical plug at the top. Figure 1-1 shows the layout and denomination of blocks and canisters. The canisters are embedded in dense clay buffer consisting of blocks (cylindrical and ring shaped) of compacted bentonite powder.

An artificial water pressure is applied in the outer slot between the buffer and the rock, which is filled with compacted sand and functions as a filter.

The upper canister is surrounded by sand in order to reduce the temperature in the bentonite.

The buffer material is instrumented with pressure cells (total and water pressure), thermocouples and moisture gauges. Thermocouples are also installed in the rock.

A retaining plug is built in order to confine the buffer swelling.

Measured results and general comments concerning the collected data are given in chapter 2. A test overview with the positions of the measuring points and a brief description of the instruments are presented in chapters 3 and 4. **The instrument positions in the buffer have been updated since the second report and the exact positions measured during installation have been inserted.** Finally analyses and discussions of the results are given in chapter 5.

In general the data in this report are presented in diagrams covering the time period 030326 to 040401[1]. The time axis in the diagrams represents days from 030326. The diagrams are attached in Appendix A.

Results regarding DBE's sensors will be included in the next TBT sensor data report.

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[1] YYMMDD (Swedish way of expressing dates implying that the first two numbers are the year, the next two numbers are the month and the final two numbers are the date)

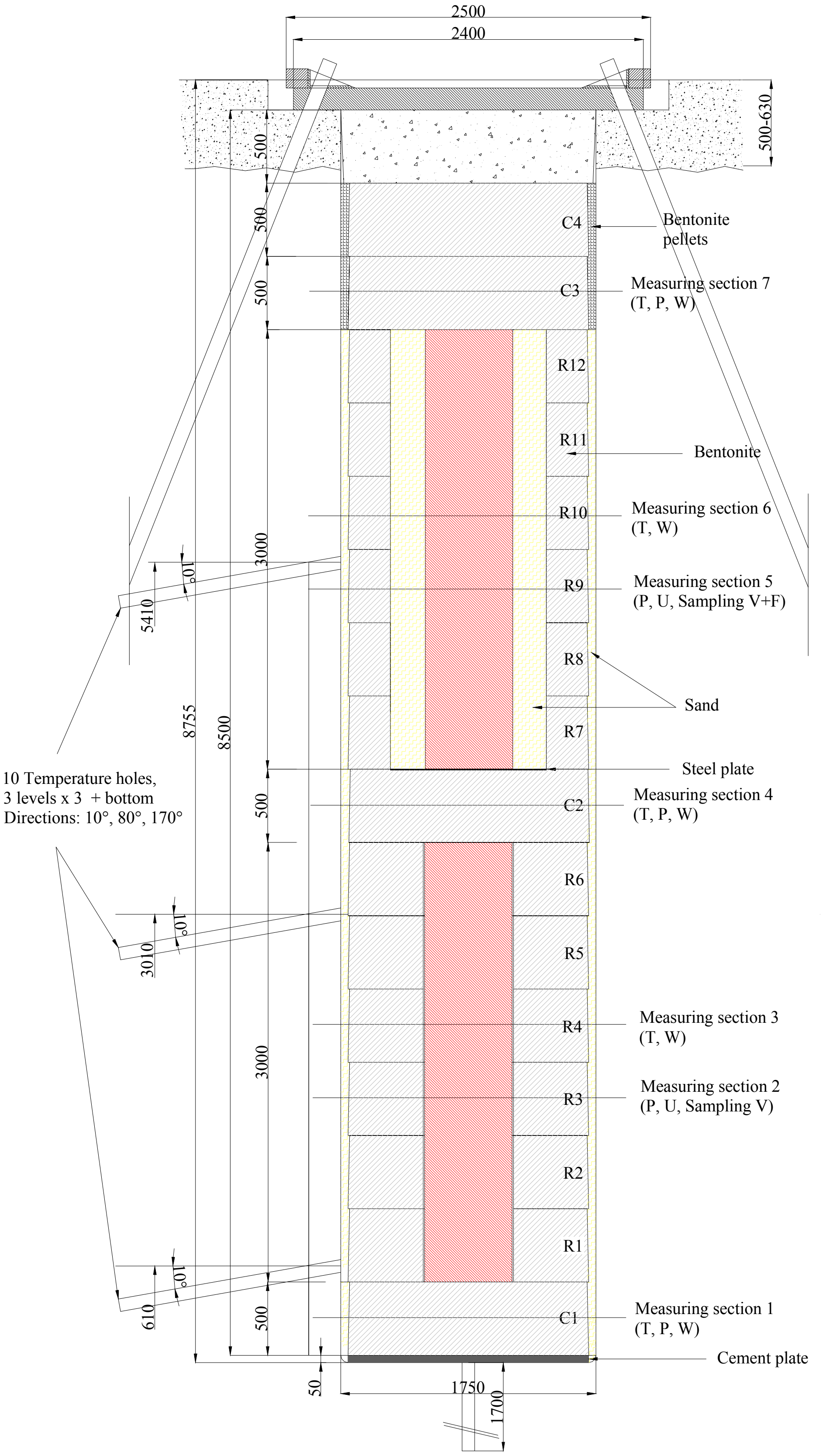


Figure 1-1. *Schematic view showing the layout of the experiment and the numbering of bentonite blocks. The lower heater is denominated No. 1 and the upper heater is No. 2.*

2 Comments

2.1 General

In this chapter short comments on general trends in the measurements are given. Sensors that are not delivering reliable data or no data at all are noted and comments on the data in general are given but no evaluation or comparison with predictions will been given here.

The heating of both canisters started with an initially applied constant power of 900 W on 030326. This date is also marked as start date. The power was raised to 1200 W on 030403. The power was further raised to 1500 W on 030410. Several power failures have occurred. Important events and dates are shown in Table 2-1.

Table 2-1. Key dates for TBT

Activity	Date (time)	Day No.
900 W power applied	030326	0
Start water filling of filter	030327	1
1200 W power applied	030403	8
1500 W power applied	030410	15
Finished water filling	~030604	~70
Power failure heater 1	030423 (~20.00)-030424 (~10.00)	27-28
Power failure heater 1	030527 (~01.00)-030527 (~12.00)	62
Power failure heater 1	030603 (~12.00)-030603 (~14.00)	69
Power failure heater 1	030606 (~19.00)-030609 (~10.00)	72-75
Power failure heater 1	030612 (~12.00)-030612 (~14.00)	78
Power failure heaters 1 and 2	030923 (~12.00[1)])-030923 (~18.00[1)])	181
Power failure heaters 1 and 2	031028 (~18.00[1)])-031029 (~11.00[1)])	216
Power failure heater 1	040120 (~16.00)-040120 (~19.00)	300
Power failure heater 2	040120 (~18.00)-040120 (~20.00)	300

1) The duration of the power loss is not known since no data was recorded between the times noted.

The water filling was done through four tubes leading to the bottom of the sand filter. The filling was slow due to flow resistance in the sand and the rate was increased by pressurizing the water (see chapter 2.6). The filling was completed after 60-80 days. The water pressure in the bottom of the sand filter has been kept with periodical interruptions (see chapter 2.6) but the valves to the 4 upper tubes leading out water from the top of the sand filter have been open at all times.

This report is the third one and covers the results up to 040401.

2.2 Total pressure, Geokon (App. A, pages 45-53)

The measured pressure ranges from 0 to 8.0MPa. The start of the pressure increase takes place shortly after the water filling has reached the level of the different transducer. Only one transducer measures very low pressure (~500 kPa). This transducer measures radial pressure above the upper canister (PB228).

Notable is that one transducer around heater 1 and eight transducers around heater 2 are recording decreasing total pressure. The reason for and other observations are discussed in chapter 5.

One transducer (PB207) has failed.

2.3 Suction, Wescore Psychrometers (App. A, pages 54-58)

Wescor psychrometers are only working at suction below ~5000 kPa, which correspond to high relative humidity (higher than 96%).

Ten transducers have started yielding interpretable values, which means that they are close to water saturation. Two of them have ceased functioning. Notable is that two transducers around heater 2 are yielding increasing suction (drying) during a period of about 80 days, which is consistent with the measured decrease in total pressure. On the other hand the suction of those transducers are again dropping in suction during the last 2 months

2.4 Relative humidity, Vaisala and Rotronic (App. A, pages 59-64)

Relative humidity and temperature measured with Vaisala and Rotronic transducers are shown on pages 63-68. For most transducers RH starts to increase just after the filling of water has reached the sensor level. Only one sensor in the buffer shows an obvious reduction in RH, namely WB206, which is located in the high temperature zone close to the lower heater. Sensors WB221 and WB222 are located in the sand in contact with the bentonite rings 9 and 10. The high initial RH measured by WB221 may be caused by the free water in the sand that had the water content of about 1% from start.

6 of 23 sensors are presently out of order for other reasons than high degree of saturation. Five of those are sensors in ring 4.

2.5 Pore water pressure, Geokon (App. A, pages 65-66)

All water pressure sensors yield pressure close to zero.

2.6 Water flow and water pressure in the sand (App. A, pages 67-68)

Water filling and measurement of water inflow into the sand started on 030327. The total inflow to the sand has since that date been 1430 litre. The total volume of voids in the sand filter was initially about 790 litres. The inflow rate has been in average about 0.3 l/day since day 110. The inflow rate has increased during the latest reporting period and has been in average about 1.2 l/day in the last three month.

There is also an outflow that started after completed filling since the valves from the top of the sand filter was kept open. The total outflow of water has since that date been 44 litre. Today there is no water outflow in spite of the high water pressure in the bottom.

The water pressure in the bottom of the sand filter is shown on page 72. The water pressure was increased to 800 – 900 kPa during the first 50 days and then kept "constant". However, problems with the water pump have lead to many interruptions in the applied pressure. During the last 140 days a rather constant pressure without interruptions has been kept.

2.7 Forces on the plug (App. A, page 69)

The forces on the plug have been measured since 030404.The total force is about 5655 kN at 040401.

During the first about 15 days the plug was only fixed with 3 rods. When the total force exceeded 1100 kN the rest of the 9 rods were fixed in a prescribed manner. This procedure took place 10-11 April 2003 that is 15-16 days after test start. From that time only every third anchor is measured and the results should thus be multiplied with 3. The diagram shows both the actual measurements and after multiplication with 3.

2.8 Displacement of the plug (App. A, page 70)

The three displacement gauges were placed and started to measure displacements from 030409 (day 14) (except for zero reading that was done day 0). One of them (DP201) did not work well and was replaced on 030923 with a new transducer.

2.9 Canister power (App A, page 71-72)

The heating of both canisters started with an initially applied constant power of 900 W on 030326 and was raised to 1500 W according to Table 2-1. Only one out of three heaters in each canister is presently used (RAH1 and RAH2).

2.10 Temperature in the buffer (App. A, pages 73-81)

Temperature is measured in a large number of points. The plotting of results is done so that the effect of wetting and cracking can be traced, since sensors placed close to each other are collected in the same diagrams.

The highest measured temperature in the bentonite is 137 °C by sensor TB215 located in the midplane of canister 1 at the distance 15 mm from the canister surface. The corresponding temperature on the canister surface is 142 °C, which shows that the temperature drop at the slot between the canister and the bentonite ring is very small.

Temperature is also measured in the sand around canister 2 (page 82), where the temperature drop is rather large (~3.1 °C/cm)

One transducer (TB281) is out of order.

2.11 Temperature in the rock (App. A, pages 82-85)

The maximum temperature measured in the rock (72 degrees) is measured in the central section on the surface of the deposition hole. The deviation from axial symmetry of the temperature measured in the rock is caused by the influence from the heating of the neighbouring Canister Retrieval Test.

2.12 Temperature on the canister surface (App. A, pages 86-87)

The maximum temperature measured on the surface of canister 1 is about 142 °C and on the surface of canister 2 about 156 °C on 040401. There are strong temperature differences in the canisters, both radial and axial. The highest measured difference on the surface is 27 °C on canister 1 and 37 °C on canister 2.

The steady increase in temperature of heater 1 has turned into a slow decrease. The temperature of heater 2 has decreased since day 50.

2.13 Temperature inside the canister (App. A, pages 88-89)

The maximum temperature measured inside canister 1 is about 164 °C and about 210 °C in canister 2 on 040401. However, the very high value 210 °C may be questioned since it deviates from all other values measured in canister 2. The other sensor at the same level (upper part of the canister) measures only about 179 °C, which is consistent with the other measurements in canister 2.

3 Coordinate system

Measurements will be done in 7measuring sections placed on different levels (see Figure 1-1). On each level, sensors are placed in eight main directions A, AB, B, BC, C, CD, D and DA according to Figure 3-1. Direction A and C are placed in the tunnels axial direction with A headed against the end of the tunnel i.e. almost to the South (see Figure 1-1, 3-1 and 4-1). The angle α is counted anti-clockwise from direction A. The z-coordinate is counted from the bottom of the deposition hole (the cement base).

The bentonite blocks are called cylinders and rings. The cylinders are numbered C1-C4 and the rings R1-R12 respectively (see Figure 1-1).

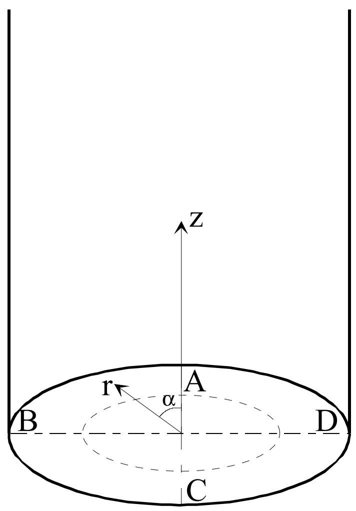


Figure 3-1 *Figure describing the coordinate system used when determining the instrument positions.*

4 Location of instruments

4.1 Brief description of the instruments

The different instruments that are used in the experiment are briefly described in this chapter.

Measurements of temperature

Buffer

Thermocouples from Pentronic have been installed for measuring temperature in the buffer. Measurements are done in 89 points in the test hole. In addition, temperature gauges are built in into the capacitive relative humidity sensors (23 sensors) as well as in the pressure gauges of vibrating wire type (37 gauges). Temperature is also measured in the psychrometers.

Canister

Temperature is measured in 11 points on the surface of the each canister. Temperature is also measured in each canister insert in 6 points.

Rock

Temperature in the rock and on the rock surface of the hole is measured in 40 points with thermocouples from Pentronic.

Measurement of total pressure in the buffer

Total pressure is the sum of the swelling pressure and the pore water pressure. It is measured with Geokon total pressure cells with vibrating wire transducers. 29 cells of this type have been installed.

Measurement of pore water pressure in the buffer

Pore water pressure is measured with Geokon pore pressure cells with vibrating wire transducer. 8 cells of this type have been installed.

Measurement of the water saturation process

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

- Vaisala relative humidity sensor of capacitive type. 29 cells of this type have been installed. The measuring range is 0-100 % RH.

- Wescor psychrometers measure the dry and the wet temperature in the pore system. The measuring range is 95.5-99.6 % RH corresponding to the pore water pressure -0.5 to -6MPa. 12 cells of this type have been installed.

Measurements of forces on the plug

The force on the plug caused by the swelling pressure of the bentonite is measured in 3 of the 9 anchors. The force transducers are of the type GLÖTZL.

Measurements of plug displacement

Due to straining of the anchors the swelling pressure of the bentonite will cause not only a force on the plug but also displacement of the plug. The displacement is measured in three points with transducers of the type LVDT with the range 0 – 50 mm.

Measurement of water flow into the sand

An artificial water pressure is applied in the outer slot, which is filled with sand. Titanium tubes equipped with filter tips are placed in the sand on two levels, 250 mm and 6750 mm from bottom (four at each level).

4.2 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, (T-Temperature, P-Total Pressure, U-Pore Pressure, W-Relative Humidity, C-Chemical sampling, D-Displacement and A-Artificial water), 1 letter describing where the measurement takes place (B-Buffer, H-Heater, S-Sand, R-Rock and P-plug), 1 figure denoting the deposition hole (1 is used for the CRT test and 2 is used for this experiment), and 2 figures specifying the position in the buffer according to a separate list (see Table 4-1 to 4-7). 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 coordinate is the angle from the vertical direction A (almost South).

The position of each instrument is described in the legend in the diagrams according to the following strategy:

Buffer: Three positions according to Figure 3-1: (z \ α \ r) meaning (z-coordinate in m. from the bottom \ the angle α \ the radius in m.)

The cells measuring total pressure have been installed in three different directions in order to measure the radial stress (R), the axial stress (A) and the tangential stress (T). The direction of the pressure measurement is added in Table 4-2 and in the legend for each cell.

Rock: Three positions with the following meaning: (distance in meters from the bottom \ α according to Fig 3-1 \ distance in meters from the rock surface)

The bentonite blocks are called cylinders and rings. The cylinders are numbered C1-C4 and the rings R1-R12 respectively (Figure 1-1).

Canister: The denomination of the instruments in the canister differs a little from the other instruments. At first there are two letters and one figure describing the type of measurement and the place (TH for temperature and heater) and which heater (1 for lower heater and 2 for upper). Then there are again two letters describing if it is an external or internal sensor (SE or SI) and one figure describing the position on the canister (0-4 according to Figure 4-2). Finally the angle clockwise from direction A is written.

4.3 Position of each instrument in the bentonite

Measurements are done in 7 measuring sections placed on different levels (see Figure 1-1). On each level, sensors are placed in eight main directions A, AB, B, BC, C, CD, D and DA according to Figure 4-1. The bentonite blocks are called cylinders and rings. The cylinders are numbered C1-C4 and the rings R1-R12 respectively (see Figure 1-1).

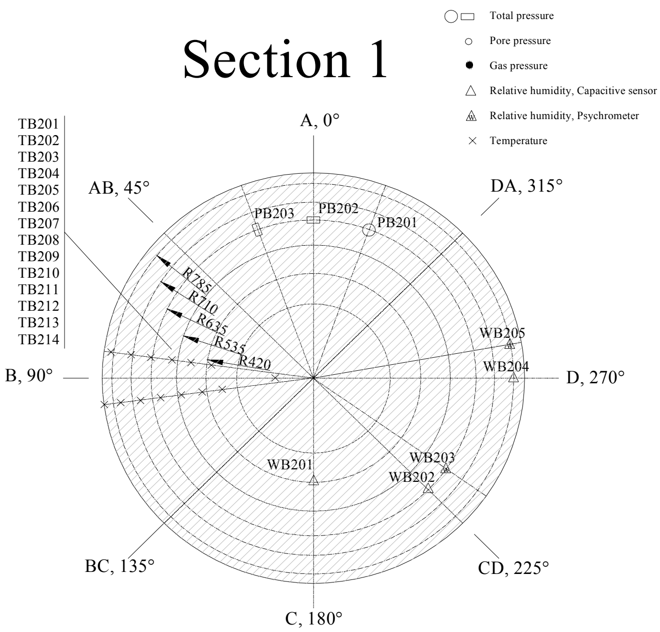


Figure 4-1 *Schematic view, showing the main directions of the instrument positioning. The drawing shows the instrumentation in measuring section 1.*

An overview of the positions of the instruments is shown in Fig 1-1 and 4-1. Exact positions are described in Tables 4-1 to 4-6. These tables have been updated since the last report and the measured exact position of the transducers have been inserted.

The instruments are located in three main levels in each instrumented block, the surface of the block (only total pressure cells measuring the horizontal pressure) and 50 mm and 250 mm from the upper block surface. The thermocouples and the total pressure cells are placed in the 50 mm level by practical reasons and the other sensors in the 250 mm level.

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

Type and number	Measuring section	Block	Instrument position in block				Instrument Fabricate
			Direction	α	r	Z	
				degree	m	m	
TB201	1	Cyl. 1	B	90	0,150	0,452	Pentronic
TB202	1	Cyl. 1	B	95	0,360	0,452	Pentronic
TB203	1	Cyl. 1	B	85	0,400	0,452	Pentronic
TB204	1	Cyl. 1	B	95	0,440	0,452	Pentronic
TB205	1	Cyl. 1	B	85	0,480	0,452	Pentronic
TB206	1	Cyl. 1	B	95	0,520	0,452	Pentronic
TB207	1	Cyl. 1	B	85	0,560	0,452	Pentronic
TB208	1	Cyl. 1	B	95	0,600	0,452	Pentronic
TB209	1	Cyl. 1	B	85	0,640	0,452	Pentronic
TB210	1	Cyl. 1	B	95	0,680	0,452	Pentronic
TB211	1	Cyl. 1	B	85	0,720	0,452	Pentronic
TB212	1	Cyl. 1	B	95	0,760	0,452	Pentronic
TB213	1	Cyl. 1	B	85	0,800	0,452	Pentronic
TB214	1	Cyl. 1	B	95	0,840	0,452	Pentronic
TB215	3	Ring 4	B	97,5	0,320	2,469	Pentronic
TB216	3	Ring 4	B	82,5	0,360	2,469	Pentronic
TB217	3	Ring 4	B	97,5	0,390	2,469	Pentronic
TB218	3	Ring 4	B	92,5	0,420	2,469	Pentronic
TB219	3	Ring 4	B	87,5	0,435	2,469	Pentronic
TB220	3	Ring 4	B	82,5	0,450	2,469	Pentronic
TB221	3	Ring 4	B	97,5	0,465	2,469	Pentronic
TB222	3	Ring 4	B	92,5	0,480	2,469	Pentronic
TB223	3	Ring 4	B	87,5	0,495	2,469	Pentronic
TB224	3	Ring 4	B	82,5	0,510	2,469	Pentronic
TB225	3	Ring 4	B	97,5	0,525	2,469	Pentronic
TB226	3	Ring 4	B	92,5	0,540	2,469	Pentronic
TB227	3	Ring 4	B	87,5	0,555	2,469	Pentronic
TB228	3	Ring 4	B	82,5	0,570	2,469	Pentronic
TB229	3	Ring 4	B	97,5	0,585	2,469	Pentronic
TB230	3	Ring 4	B	92,5	0,600	2,469	Pentronic
TB231	3	Ring 4	B	87,5	0,615	2,469	Pentronic
TB232	3	Ring 4	B	82,5	0,630	2,469	Pentronic
TB233	3	Ring 4	B	97,5	0,645	2,469	Pentronic
TB234	3	Ring 4	B	92,5	0,660	2,469	Pentronic
TB235	3	Ring 4	B	87,5	0,690	2,469	Pentronic
TB236	3	Ring 4	B	92,5	0,720	2,469	Pentronic
TB237	3	Ring 4	B	87,5	0,750	2,469	Pentronic
TB238	3	Ring 4	B	92,5	0,780	2,469	Pentronic
TB239	3	Ring 4	B	87,5	0,810	2,469	Pentronic
TB240	4	Cyl. 2	B	90	0,150	3,983	Pentronic
TB241	4	Cyl. 2	B	95	0,360	3,983	Pentronic
TB242	4	Cyl. 2	B	85	0,400	3,983	Pentronic
TB243	4	Cyl. 2	B	95	0,440	3,983	Pentronic
TB244	4	Cyl. 2	B	85	0,480	3,983	Pentronic
TB245	4	Cyl. 2	B	95	0,520	3,983	Pentronic

Type and number	Measuring section	Block	Instrument position in block				Instrument Fabricate
			Direction	α	r	Z	
				degree	m	m	
TB246	4	Cyl. 2	B	85	0,560	3,983	Pentronic
TB247	4	Cyl. 2	B	95	0,600	3,983	Pentronic
TB248	4	Cyl. 2	B	85	0,640	3,983	Pentronic
TB249	4	Cyl. 2	B	95	0,680	3,983	Pentronic
TB250	4	Cyl. 2	B	85	0,720	3,983	Pentronic
TB251	4	Cyl. 2	B	95	0,760	3,983	Pentronic
TB252	4	Cyl. 2	B	85	0,800	3,983	Pentronic
TB253	4	Cyl. 2	B	95	0,825	3,983	Pentronic
TB254	6	Ring 10	B	90	0,343	6,056	Pentronic
TB255	6	Ring 10	B	90	0,400	6,056	Pentronic
TB256	6	Ring 10	B	90	0,463	6,056	Pentronic
TB257	6	Ring 10	B	97,5	0,540	6,006	Pentronic
TB258	6	Ring 10	B	92,5	0,555	6,006	Pentronic
TB259	6	Ring 10	B	87,5	0,570	6,006	Pentronic
TB260	6	Ring 10	B	82,5	0,585	6,006	Pentronic
TB261	6	Ring 10	B	97,5	0,600	6,006	Pentronic
TB262	6	Ring 10	B	92,5	0,615	6,006	Pentronic
TB263	6	Ring 10	B	87,5	0,630	6,006	Pentronic
TB264	6	Ring 10	B	82,5	0,645	6,006	Pentronic
TB265	6	Ring 10	B	97,5	0,660	6,006	Pentronic
TB266	6	Ring 10	B	92,5	0,675	6,006	Pentronic
TB267	6	Ring 10	B	87,5	0,690	6,006	Pentronic
TB268	6	Ring 10	B	82,5	0,705	6,006	Pentronic
TB269	6	Ring 10	B	97,5	0,720	6,006	Pentronic
TB270	6	Ring 10	B	92,5	0,735	6,006	Pentronic
TB271	6	Ring 10	B	87,5	0,750	6,006	Pentronic
TB272	6	Ring 10	B	82,5	0,765	6,006	Pentronic
TB273	6	Ring 10	B	97,5	0,780	6,006	Pentronic
TB274	6	Ring 10	B	92,5	0,795	6,006	Pentronic
TB275	6	Ring 10	B	87,5	0,810	6,006	Pentronic
TB276	7	Cyl. 3	B	90	0,150	7,524	Pentronic
TB277	7	Cyl. 3	B	95	0,360	7,524	Pentronic
TB278	7	Cyl. 3	B	85	0,400	7,524	Pentronic
TB279	7	Cyl. 3	B	95	0,440	7,524	Pentronic
TB280	7	Cyl. 3	B	85	0,480	7,524	Pentronic
TB281	7	Cyl. 3	B	95	0,520	7,524	Pentronic
TB282	7	Cyl. 3	B	85	0,560	7,524	Pentronic
TB283	7	Cyl. 3	B	95	0,600	7,524	Pentronic
TB284	7	Cyl. 3	B	85	0,640	7,524	Pentronic
TB285	7	Cyl. 3	B	95	0,680	7,524	Pentronic
TB286	7	Cyl. 3	B	85	0,720	7,524	Pentronic
TB287	7	Cyl. 3	B	95	0,760	7,524	Pentronic
TB288	7	Cyl. 3	B	85	0,800	7,524	Pentronic
TB289	7	Cyl. 3	B	95	0,825	7,524	Pentronic
B290		Ring 12	B	90	0,360	7,389	Pentronic
B291		Ring 12	B	90	0,420	7,389	Pentronic
B292		Ring 12	B	90	0,480	7,389	Pentronic

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

Type and number	Measuring section	Block	Instrument position in block Direction	α	r	Z	Instrument Fabricate	Direction of pressure measurement
				degree	m	m		
PB201	1	Cyl. 1	A	340	0,635	0,502	Geokon	Axial
PB202	1	Cyl. 1	A	0	0,635	0,452	Geokon	Radial
PB203	1	Cyl. 1	A	20	0,635	0,452	Geokon	Tangential
PB204	2	R3	D	250	0,420	1,968	Geokon	Radial
PB205	2	R3	D	290	0,420	2,018	Geokon	Axial
PB206	2	R3	A	8	0,535	1,968	Geokon	Radial
PB207	2	R3	A	20	0,535	1,968	Geokon	Tangential
PB208	2	R3	AB	45	0,585	2,018	Geokon	Axial
PB209	2	R3	B	100	0,635	1,968	Geokon	Tangential
PB210	2	R3	C	170	0,710	1,968	Geokon	Tangential
PB211	2	R3	C	180	0,710	1,968	Geokon	Radial
PB212	2	R3	D	260	0,748	2,018	Geokon	Axial
PB213	2	R3	D	270	0,875	1,950	Geokon	Radial on rock
PB214	4	Cyl. 2	A	340	0,635	4,033	Geokon	Axial
PB215	4	Cyl. 2	A	0	0,635	3,983	Geokon	Radial
PB216	4	Cyl. 2	A	20	0,635	3,983	Geokon	Tangential
PB217	5	Ring 9	D	270	0,535	5,319	Geokon	Radial,against sand
PB218	5	Ring 9	A	340	0,635	5,554	Geokon	Axial
PB219	5	Ring 9	A	0	0,635	5,504	Geokon	Radial
PB220	5	Ring 9	A	20	0,635	5,504	Geokon	Tangential
PB221	5	Ring 9	B	70	0,710	5,554	Geokon	Axial
PB222	5	Ring 9	B	110	0,710	5,504	Geokon	Radial
PB223	5	Ring 9	C	160	0,745	5,554	Geokon	Axial
PB224	5	Ring 9	C	180	0,770	5,504	Geokon	Radial
PB225	5	Ring 9	C	200	0,740	5,504	Geokon	Tangential
PB226	5	Ring 9	D	270	0,875	5,450	Geokon	Radial on rock
PB227	7	Cyl. 3	A	340	0,635	7,574	Geokon	Axial
PB228	7	Cyl. 3	A	0	0,635	7,524	Geokon	Radial
PB229	7	Cyl. 3	A	20	0,635	7,524	Geokon	Tangential
PB230	2	R3	C	180	0,315	1,968	DBE	Radial
PB231	5	R9	C	180	0,535	5,504	DBE	Radial

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

Type and number	Measuring section	Block	Instrument position in block Direction	α	r	Z	Instrument Fabricate	Remark
				degree	m	m		
UB201	2	Ring 3	D	270	0,420	1,768	Geokon	
UB202	2	Ring 3	A	350	0,535	1,768	Geokon	
UB203	2	Ring 3	B	90	0,635	1,768	Geokon	
UB204	2	Ring 3	D	280	0,785	1,768	Geokon	
US205	5	Ring 9	D	270	0,510	5,304	Geokon	In sand
UB206	5	Ring 9	DA	315	0,635	5,304	Geokon	
UB207	5	Ring 9	B	90	0,710	5,304	Geokon	
UB208	5	Ring 9	CD	225	0,785	5,304	Geokon	
UB209	2	Ring 3	C	200	0,315	1,968	DBE	
UB210	5	Ring 9	C	150	0,510	5,304	DBE	

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

Type and number	Measuring section	Block	Instrument position in block				Instrument Fabricate	Remark
			Direction	α	r	Z		
				degree	m	m		
WB201	1	Cyl.1	C	180	0,420	0,252	Rotronic	
WB202	1	Cyl.1	CD	225	0,635	0,252	Vaisala	
WB203	1	Cyl.1	CD	235	0,635	0,252	Wescor	
WB204	1	Cyl.1	D	270	0,785	0,252	Rotronic	
WB205	1	Cyl.1	D	280	0,785	0,252	Wescor	
WB206	3	Ring 4	BC	135	0,360	2,269	Vaisala	
WB207	3	Ring 4	C	180	0,420	2,269	Rotronic	
WB208	3	Ring 4	CD	225	0,485	2,269	Vaisala	
WB209	3	Ring 4	D	270	0,560	2,269	Rotronic	
WB210	3	Ring 4	DA	315	0,635	2,269	Vaisala	
WB211	3	Ring 4	DA	325	0,635	2,269	Wescor	
WB212	3	Ring 4	A	0	0,710	2,269	Rotronic	
WB213	3	Ring 4	A	10	0,710	2,269	Wescor	
WB214	3	Ring 4	AB	45	0,785	2,269	Vaisala	
WB215	3	Ring 4	AB	55	0,785	2,269	Wescor	
WB216	4	Cyl.2	C	180	0,420	3,783	Rotronic	
WB217	4	Cyl.2	CD	225	0,635	3,783	Vaisala	
WB218	4	Cyl.2	CD	235	0,635	3,783	Wescor	
WB219	4	Cyl.2	D	270	0,785	3,783	Rotronic	
WB220	4	Cyl.2	D	280	0,785	3,783	Wescor	
WS221	5	Ring 9	BC	135	0,525	5,304	Vaisala	In sand
WS222	6	Ring 10	BC	135	0,525	5,806	Vaisala	In sand
WB223	6	Ring 10	C	180	0,585	5,806	Rotronic	
WB224	6	Ring 10	CD	225	0,635	5,806	Vaisala	
WB225	6	Ring 10	D	270	0,685	5,806	Rotronic	
WB226	6	Ring 10	D	280	0,685	5,806	Wescor	
WB227	6	Ring 10	DA	315	0,735	5,806	Vaisala	
WB228	6	Ring 10	DA	325	0,735	5,806	Wescor	
WB229	6	Ring 10	A	0	0,785	5,806	Rotronic	
WB230	6	Ring 10	A	10	0,785	5,806	Wescor	
WB231	7	Cyl.3	C	180	0,420	7,374	Rotronic	
WB232	7	Cyl.3	CD	225	0,635	7,374	Vaisala	
WB233	7	Cyl.3	CD	235	0,635	7,374	Wescor	
WB234	7	Cyl.3	D	270	0,785	7,374	Rotronic	
WB235	7	Cyl.3	D	280	0,785	7,374	Wescor	

4.4 Instruments in the rock

Temperature measurements

40 thermocouples are located in ten boreholes in the rock (see Figure 1-1). The depth of each borehole is 1.5 m. In each borehole 4 thermocouples are placed at different distances from the rock surface. Observe that the coordinate system does not count the radius but the radial distance from the rock surface of the deposition hole. The position of each instrument is described in Table 4-5.

Table 4-5 Numbering and positions of thermocouples in the rock

Mark	Level	Direction	Distance from rock surface	Instrument Fabricate
	m	degree	m	
TR201	0	Center	0,000	Pentronic
TR202	0	Center	0,375	Pentronic
TR203	0	Center	0,750	Pentronic
TR204	0	Center	1,500	Pentronic
TR205	0,61	10°	0,000	Pentronic
TR206	0,61	10°	0,375	Pentronic
TR207	0,61	10°	0,750	Pentronic
TR208	0,61	10°	1,500	Pentronic
TR209	0,61	80°	0,000	Pentronic
TR210	0,61	80°	0,375	Pentronic
TR211	0,61	80°	0,750	Pentronic
TR212	0,61	80°	1,500	Pentronic
TR213	0,61	170°	0,000	Pentronic
TR214	0,61	170°	0,375	Pentronic
TR215	0,61	170°	0,750	Pentronic
TR216	0,61	170°	1,500	Pentronic
TR217	3,01	10°	0,000	Pentronic
TR218	3,01	10°	0,375	Pentronic
TR219	3,01	10°	0,750	Pentronic
TR220	3,01	10°	1,500	Pentronic
TR221	3,01	80°	0,000	Pentronic
TR222	3,01	80°	0,375	Pentronic
TR223	3,01	80°	0,750	Pentronic
TR224	3,01	80°	1,500	Pentronic
TR225	3,01	170°	0,000	Pentronic
TR226	3,01	170°	0,375	Pentronic
TR227	3,01	170°	0,750	Pentronic
TR228	3,01	170°	1,500	Pentronic
TR229	5,41	10°	0,000	Pentronic
TR230	5,41	10°	0,375	Pentronic
TR231	5,41	10°	0,750	Pentronic
TR232	5,41	10°	1,500	Pentronic
TR233	5,41	80°	0,000	Pentronic
TR234	5,41	80°	0,375	Pentronic
TR235	5,41	80°	0,750	Pentronic
TR236	5,41	80°	1,500	Pentronic
TR237	5,41	170°	0,000	Pentronic
TR238	5,41	170°	0,375	Pentronic
TR239	5,41	170°	0,750	Pentronic
TR240	5,41	170°	1,500	Pentronic

4.5 Instruments in the canister

Temperature is measured both on the canister surface and inside the canister. Eleven thermocouples are installed on each canisters surface. Three groups of three thermocouples are installed 100 mm from each heater end, and in the middle of the heater, with a distribution of 120°. Two additional thermocouples are installed in the centre of the bottom lid and the top cover. Temperature inside the canister insert is measured at 6 points with thermocouples.

Figure 4-2 shows how these thermocouples are placed (see also chapter 4.2). Table 4-6 and 4-7 show the positions.

Table 4-6 Numbering and position of instruments for measuring the temperature on the heaters surface (T)

Type and number	Heater	Instruments coordinates				Instrument	Remark
		Position	α	r	z	Fabricate	
			degree	m	m		
TH1 SE0	1	Bottom	0	0,000	0,500		
TH1 SE1 0º	1	Lower sec.	0	0,305	0,600		
TH1 SE1 240º	1	Lower sec.	240	0,305	0,600		
TH1 SE1 120º	1	Lower sec.	120	0,305	0,600		
TH1 SE2 0º	1	Middle sec.	0	0,305	2,000		
TH1 SE2 240º	1	Middle sec.	240	0,305	2,000		
TH1 SE2 120º	1	Middle sec.	120	0,305	2,000		
TH1 SE3 0º	1	Upper sec.	0	0,305	3,400		
TH1 SE3 240º	1	Upper sec.	240	0,305	3,400		
TH1 SE3 120º	1	Upper sec.	120	0,305	3,400		
TH1 SE4	1	Top	0	0,000	3,500		
TH2 SE0	2	Bottom	0	0,000	4,000		
TH2 SE1 0º	2	Lower sec.	0	0,305	4,100		
TH2 SE1 240º	2	Lower sec.	240	0,305	4,100		
TH2 SE1 120º	2	Lower sec.	120	0,305	4,100		
TH2 SE2 0º	2	Middle sec.	0	0,305	5,500		
TH2 SE2 240º	2	Middle sec.	240	0,305	5,500		
TH2 SE2 120º	2	Middle sec.	120	0,305	5,500		
TH2 SE3 0º	2	Upper sec.	0	0,305	6,900		
TH2 SE3 240º	2	Upper sec.	240	0,305	6,900		
TH2 SE3 120º	2	Upper sec.	120	0,305	6,900		
TH2 SE4	2	Top	0	0,000	7,000		

Table 4-7 Numbering and position of instruments for measuring the temperature inside the heaters (T)

Type and number	Heater	Instruments coordinates			Instrument Fabricate	Remark
		Position	α	Z		
			degree	m		
TH1 SI1 0º	1	Lower sec.	0	0,60		
TH1 SI1 180º	1	Lower sec.	180	0,60		
TH1 SI2 0º	1	Middle sec.	0	2,00		
TH1 SI2 180º	1	Middle sec.	180	2,00		
TH1 SI3 0º	1	Upper sec.	0	3,40		
TH1 SI3 180º	1	Upper sec.	180	3,40		
TH2 SI1 0º	2	Lower sec.	0	0,60		
TH2 SI1 180º	2	Lower sec.	180	0,60		
TH2 SI2 0º	2	Middle sec.	0	2,00		
TH2 SI2 180º	2	Middle sec.	180	2,00		
TH2 SI3 0º	2	Upper sec.	0	3,40		
TH2 SI3 180º	2	Upper sec.	180	3,40		

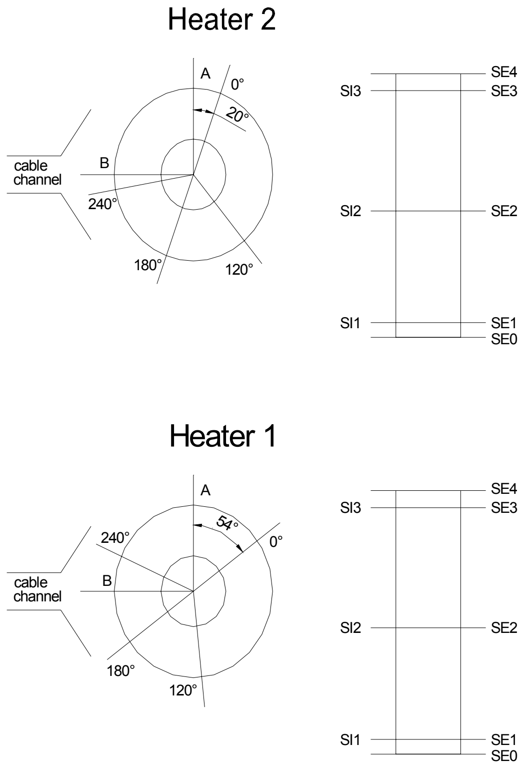


Figure 4-2. *Location of thermocouples inside (SI) and on (SE) the canisters*

4.6 Instruments on the plug

Three force transducers and three displacement transducers have been placed on the plug to measure the force of the anchors and the displacement of the plug. The location of these transducers can be described in relation to Fig 4-3, which shows a schematic view of the plug with the slots, rods and cables.

The rods are numbered 1-9 anti-clockwise and number 1 is the northern rod 18 degrees from direction A. The force transducers are placed on rods 3, 6, and 9. The displacement transducers are placed between the rods on the steel ring in the periphery of the plug. They are fixed on the rock surface and measure thus the displacement relative to the rock.

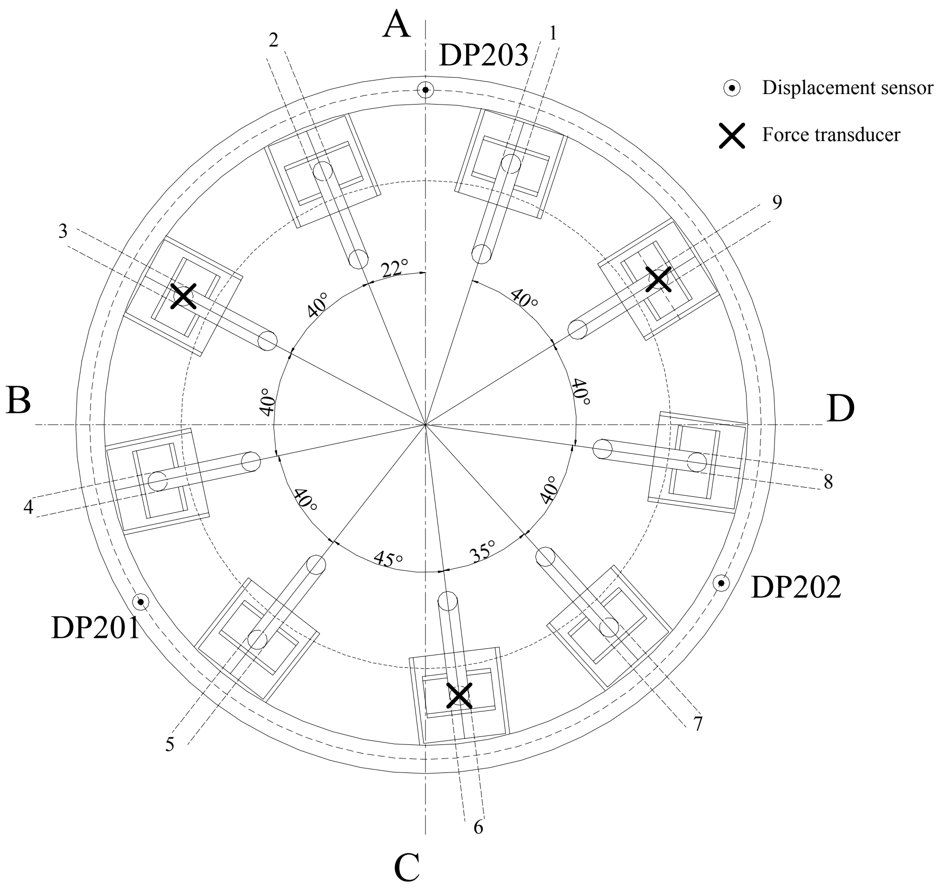


Figure 4-3. *Schematic view showing the positions of the rods and the displacement and force transducers on the retaining plug.*

5 Discussion of results

5.1 General

Below some of the results commented in previous chapters are highlighted and discussed.

5.2 Total inflow of water

The sand filter was filled through four tubes ending at the bottom of the sand filter. The accumulated water inflow up to day 82 was measured to 1.165 m^3 and from day 50 and onwards, the pressure in these tubes was measured to 0.8 MPa (App. A, page.72). However, that pressure was not effective continuously, but dropped to zero in periods. At day 82, water began to flow through tubes connecting the uppermost parts of the sand filter with the atmosphere, indicating that the sand filter was filled after about 80 days. At present (March 2004) approximately 1.3 m^3 has been injected into the system. During the first 75 days the inflow was about $1.7 \cdot 10^{-7}$ m^3/s. After 100 days the inflow had dropped to about $9.5 \cdot 10^{-9}$ m^3/s. Table 5-1 shows the inflow data and the average hydraulic conductivity of the sand filter, calculated assuming the pressure drop to be uniformly distributed over the height of the column. Table 5-2 shows the pore space available at the beginning of the test and the space remaining now (March 2004).

Table 5-1: Total inflow rate and estimated average sand filter conductivity

Time period	Total inflow [m^3/s]		Apparent sand filter conductivity [m/s]
Day 0- 75	$1.7 \cdot 10^{-7}$	(average)	$1 \cdot 10^{-7}$ (at the end of the period)
Day 100 and onwards	$9.5 \cdot 10^{-9}$	(when pressure was effective)	$5 \cdot 10^{-9}$
	0	(when pressure was zero)	
Lab data, compressed filter sand			$5 \cdot 10^{-7}$

The apparent sand filter conductivity at test start was only 20 % percent of the lab value, probably because of flow restrictions around the filter tips. In the period between 75 and 100 days, the apparent hydraulic conductivity decreased by a factor of about 20. The reason may be sand filter compression combined with bentonite intrusion and/or clogging of the filter tips.

Table 5-2: TBT Pore space

	Available at test start [m³]		Injected water [m³]	Remaining [m³]
Sand filter	0.77		0.77	0.00
Pellets filling	0.24	1.38	0.53	0.85
Bentonite	1.08			
Heater/bentonite clearance	0.06			
Sand shield	0.55		0.00	0.55
Total	2.70		1.30	1.40

5.3 Temperatures

Temperatures are monitored by use of thermocouples in three cylinders (Cyl 1, 2 and 3) and two rings (Ring 4 and 10). In addition, temperature readings are provided by the capacity RH sensors (App. A, pages 63-68). In general, the temperature results exhibit regular trends up to maximum values after about 200 days (App. A, pages 77 -85). A few exceptions have occurred for inner parts in Cyl 2 and the inner sand shield at Ring 10, where the maximum temperatures were reached after only about 40 and 60 days, respectively (App. A, pages A81-82).

A minor temperature decrease has also been recorded at the innermost points in these sections. Similar trends are found on the heater surfaces and in the interior of the heaters. For the upper heater the trend is very clear (App. A, page 91; page 93) and can be explained by the delayed wetting of the upper parts of the sand filter (not completed until after 80 days). The gentle decrease in heater temperature after completion of the sand filter saturation may be due to compression of the sand shield and following increase in sand shield thermal conductivity. Details in these trends may be due to successive and slow changes in the heat flow organization around the heaters.

The temperature readings are compiled in Table 5-3 below. It can be noted that the highest temperatures in the bentonite blocks are found in Ring 4, whereas the lowest can be found in Cyl 3. It should also be noted that the 120° isotherm appears to narrow in between the heaters in Cyl 2.

Table 5-3: Temperature distribution (°C) at day 295.

Radius (mm):

	150	200	250	300	350	400	450	500	550	600	650	700
Cyl 3	52				49	48	47	46	45	44	43	42
Ring10					137	120	110	98	89	83	78	74
Cyl 2	120				109	104	98	90	88	82	79	75
Ring 4					125	119	108	103	95	92	86	81
Cyl 1	113				92	87	82	76	72	68	65	62

Legend: < 80° | 80 - 100° | 100-120° | >120°

The TBT experiment is located 6 m from the CRT experiment. The latter was initiated approximately 850 days before the start of the TBT experiment and has therefore affected the surrounding rock temperature. In general, recorded temperatures in the rock follow the same trend as in the bentonite blocks, but on a lower level (App A., pages 86-89). A compilation of the initial and the recently measured temperatures at different levels, depths and azimuths is presented in table 5-4 below. It can be noted that the current rock surface temperatures towards the CRT (Az 10°) are 5°C higher than the corresponding temperatures on the opposite side (Az 170°). The initial difference was not more than 3°C.

Table 5-4: Rock temperatures at the walls of the experiment hole

Time	Level	Temp.(°C) - rock surface		Temp.(°C) - 1,5 m in rock	
(d)	(m)	Az:10°	Az:170°	Az:10°	Az:170°
0	5,41	21	19	24	17
	3,01	22	19	26	18
	0,61	22	19	25	18
295	5,41	64	63	44	38
	3,01	71	66	47	40
	0,61	61	57	41	35

Azimuth 0° is towards the CRT experiment.

Sporadic irregularities in the temperature trends, especially around the lower heater, can be attributed to a number of power failures (App A., pages 75-76).

Figure 5-1 shows Azimuth 90° temperatures measured in Ring 4 and 10. The effect of the wetting of the sand filter outside Ring 10 is obvious: After 60 days the temperature drop across the filter disappeared.

Figure 5-2 and 5-3 below illustrate changes in apparent thermal conductivity. The results are based on the slopes of temperature-distance curves derived from thermocouple readings in rings 10 and 4 (Fig. 5-1), and on the assumption of a constant radial heat output at heater mid-height. There are systematic increases that indicate that saturation may be proceeding at a reasonably high rate (as opposed to the findings from the preliminary evaluation). This is consistent with Table 5-2, i.e. that the bentonite (blocks, canister/block clearance and pellet filling) has taken up about 40% of the amount required for full saturation. There is also an apparent increase in the sand shield conductivity, in particular in the period between 60 and 145 days.

Figs 5-2 and 5-3 should be interpreted with some caution: some of the changes may be due to variation of the mid-height heat flux, and some may be due to dislocation of individual sensors.

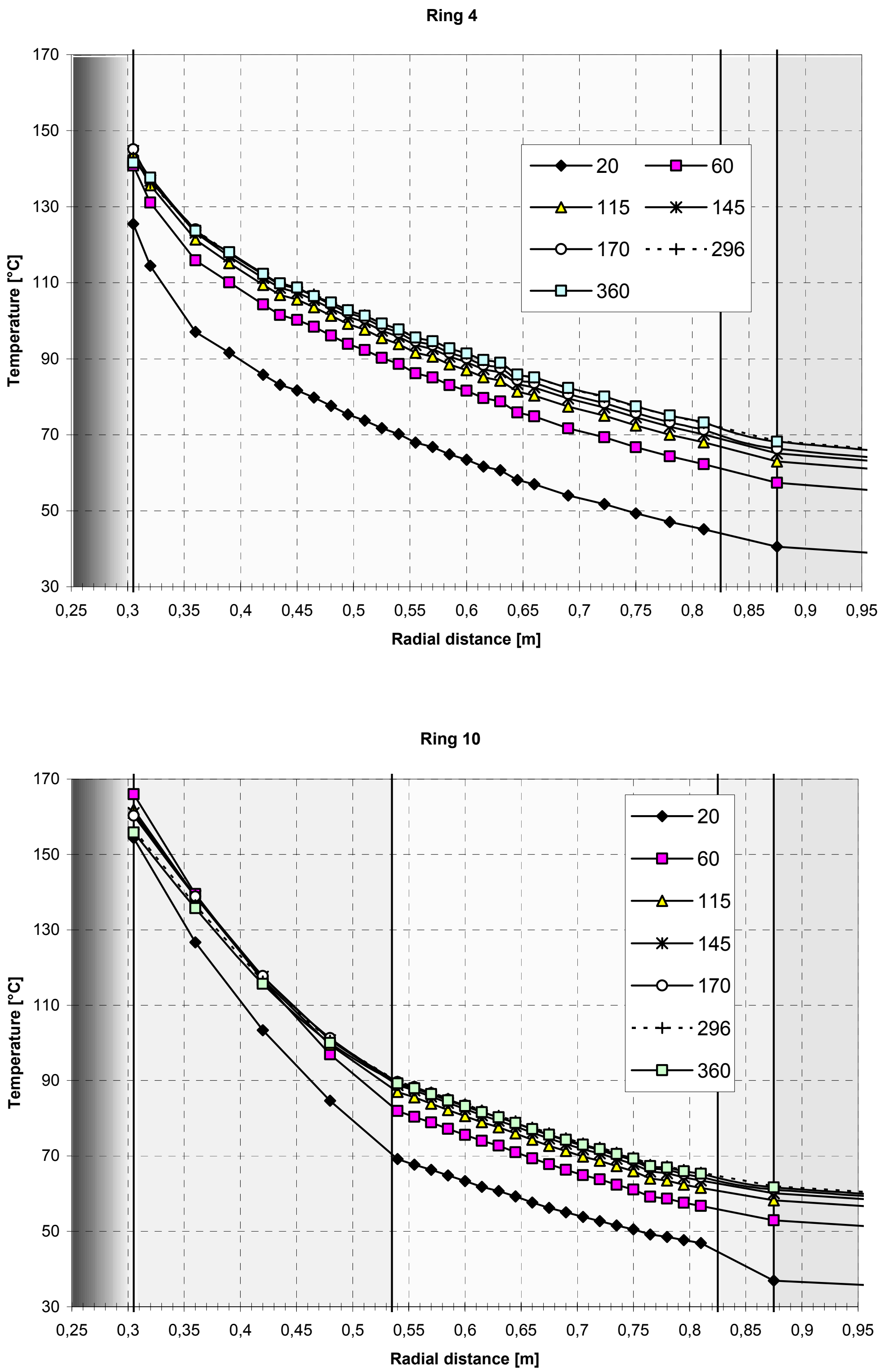
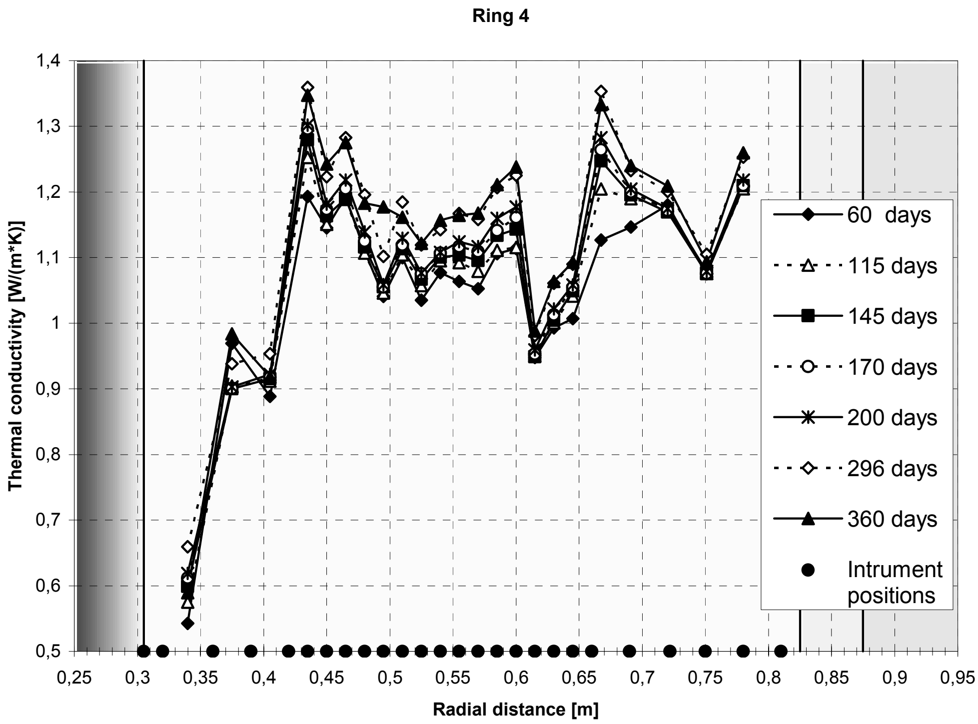


Figure 5-1. *Temperatures measured at mid-height of heater 1 (Ring 4) and heater 2 (Ring 10).*



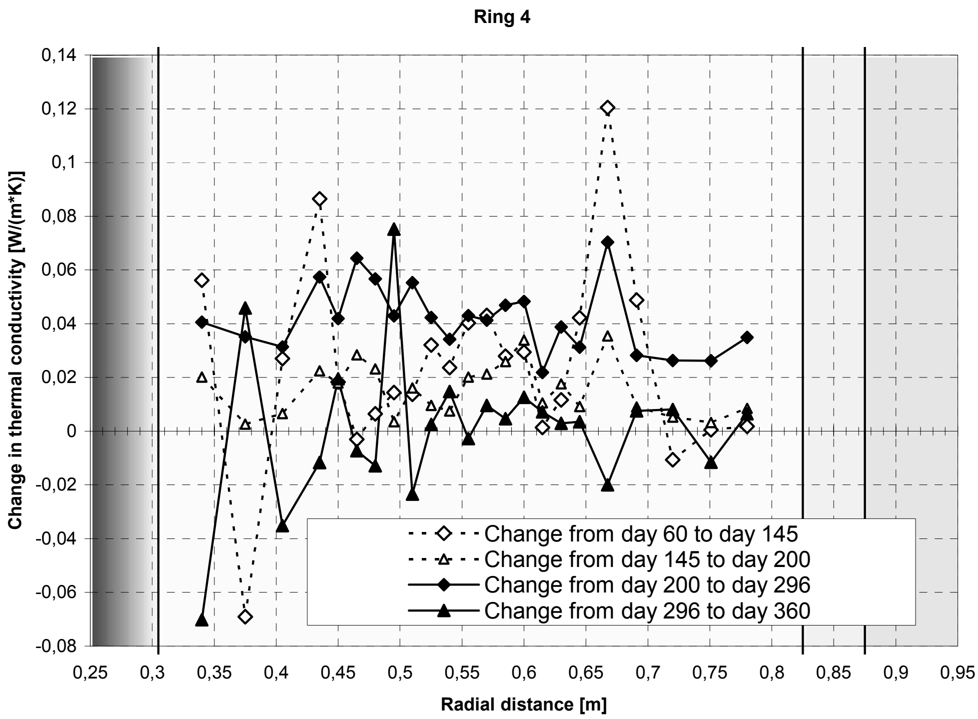
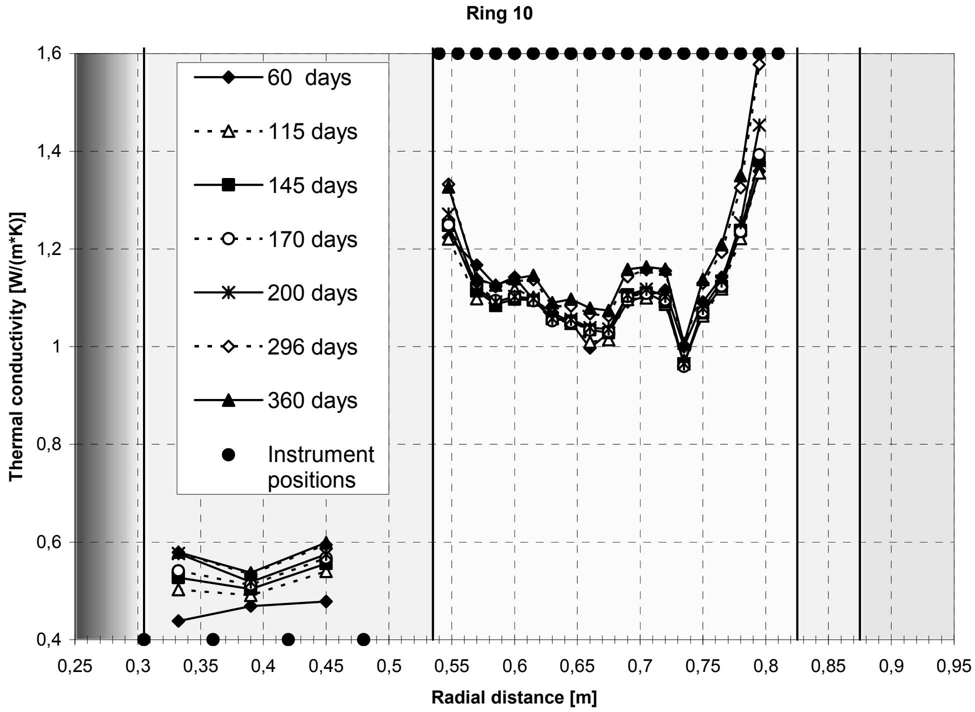


Figure 5-2. *Upper: Thermal conductivity in ring 4 as computed from slopes of distance-temperature relation. Lower: Change in thermal conductivity during four time intervals. Day 60 data are slightly affected by the transient heating effect.*



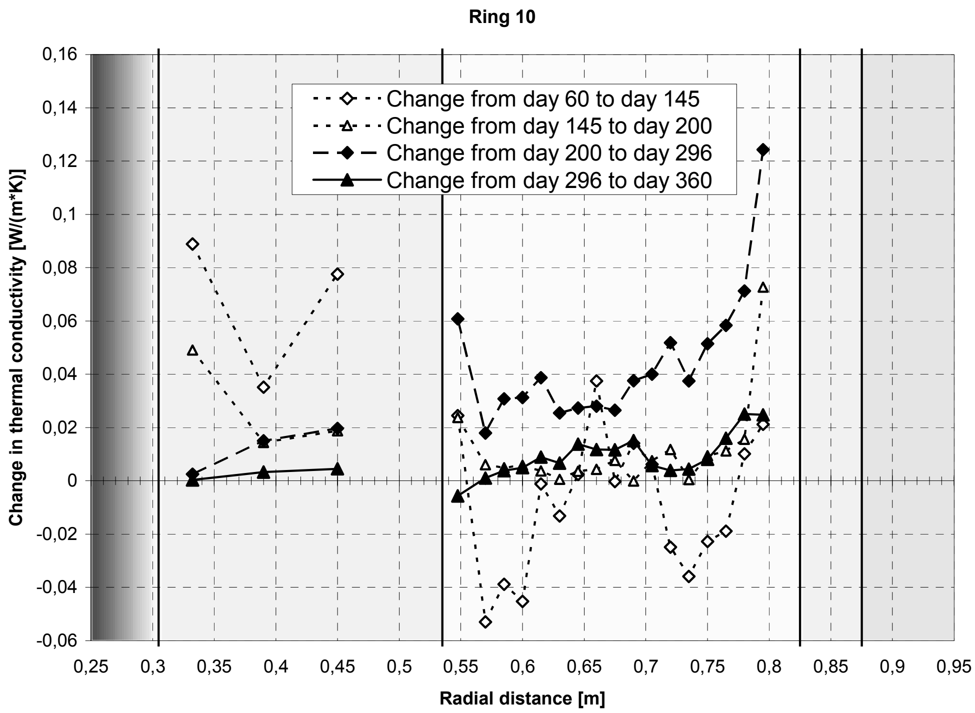


Figure 5-3. *Upper: Thermal conductivity in ring 10 and in sand shield as computed from slopes of distance- temperature relation. Lower: Change in thermal conductivity during four time intervals.*

5.4 Relative humidity/suction

Recorded RH values and suctions indicate that moisture contents generally increase: RH from 72 to maximum 100 % (App A., pages 63-68); suction between 6 and 2 MPa (App. A, pages 58-62). A significant exception is the suction increase in Ring 10 at radius 785 and 735 mm after day 225 (App. A. page 61).

An indication of drying within 150 mm from the lower heater (Ring 4), measured by a RH sensor at radius 360 which failed around day 140 (App. A, page 64), has previously been derived through calculation of thermal conductivities (Figure 5-2, upper).

A compilation of sensors indicating saturated conditions is presented in Table 3-5 below. They are arranged in time intervals. As can be noted, the minimum radius that has reached saturation so far is 635 mm (cf. the thermal conductivity plot in Figure 5-2, which shows a maximum just outside r = 0.65 m).

An observation that can be made is that Cyl 2, closely followed by Ring 4, seems to have gone through a rapid saturation of the outermost parts. The relatively fast saturation here may be an effect of vapor diffusing outwards from the hot, desaturated, parts close to the heater.

Table 5-5: Occurrence of saturation* in different sections.

	Time interval from start (days):													
	0 - 19	20 - 39	40 - 59	60 - 79	80 - 99	100 - 119	120 - 139	140 - 159	160 - 179	180 - 199	200 - 219	220 - 239	240 - 259	260 - 279
Cyl 3											W785			V785
Ring 10				W785 V785			W735			V685				W685
Ring 9														
Cyl 2		V785	W785						W635					
Ring 4		W785			W710 V710						W635			
Cyl 1				W785	V785									

* W = Wescor sensor generating data, indicating saturation > approx. 95%

V = Vaisala/Rotronic sensor indicating saturation (RH ≈ 100 %)

Number = Radius (mm)

5.5 Total pressure

Results from pressure monitoring are shown in App. A, pages 49-57.

Figure 5-4 below shows the axial stress in different sections. Figure 5-5 shows the vertical buffer force transfer calculated by use of the measured axial stresses, assuming that the forces are transferred within a 0.275 m annular region just inside the sand filter. The total cable force is shown for comparison. The assumed annular force transfer area and the positions of the axial pressure transducers are shown in the right part.

The following can be observed:

- Although the annular transfer cross section area is probably underestimated rather than overestimated, the force transfer in the lower parts is significantly larger than the force taken up by the cables after 330 days. This indicates that the force balance is maintained by considerable shear stresses in the bentonite /sand filter interface.

- The increase in the cable forces was much more rapid than the pressure build-up in the bentonite. This is an effect of thermal volume expansion, in particular that of the two heaters: A 100°C temperature increase will result in about 7 mm increase in total heater length. Some of the axial heater expansion was probably absorbed by low-stiffness interfaces between cylinders and heaters, but some may have contributed to the straining of the cables, see App. A, page 74. (The heater temperatures have increased by much more than 100°C, but the increase relative to the rock is of that magnitude).

- Some 100 or 120 days after test start, the axial stress in Ring 9 did not increase any further. This seems to coincide with the appearance of radial stresses in the sand shield (App A. page 54). A possible explanation is that the buffer was successively plasticized as result of the change in properties following the wetting and that the plastication front reached the vicinity of the sand/buffer interface at this time. The failure of the bentonite block brought about an inward movement and established a supporting lateral pressure on the sand shield. The process may have transferred some of the axial forces from the buffer to the sand.

- After about 225 days, most stresses in Ring 9 began to decrease very significantly. A possible explanation is that there was an additional period of changes in the axial load transfer, perhaps triggered by further plastication. Alternatively, there may be a disturbance in the supply of water from the sand filter. The change in axial stress found in Cylinder 3 after about 225 days may be correlated to this.

- There was a sudden (local) loss of axial stress in Cylinder 3 after about 80 days. This is probably an effect of brittle block failure. It could also be caused by a temporary malfunctioning of the total pressure sensor, as none of the two other sensors in Cylinder 3 indicated anything at that time.

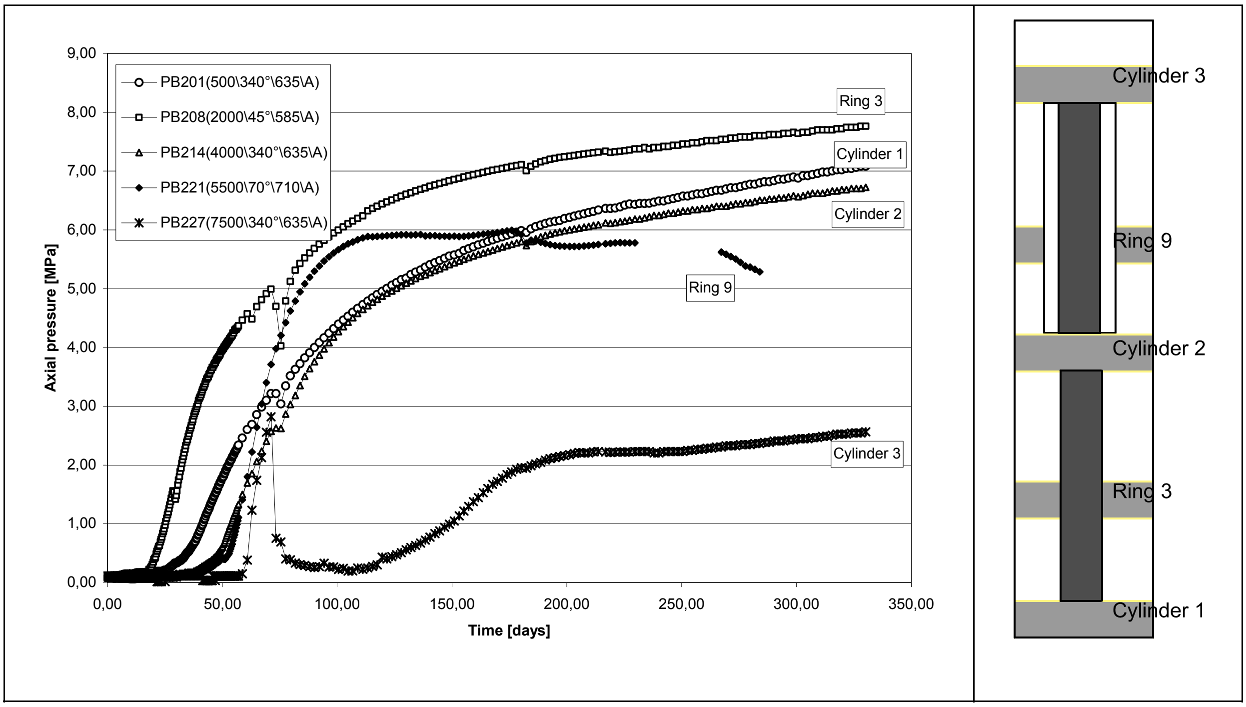


Figure 5-4. *Axial pressure measured in different sections*

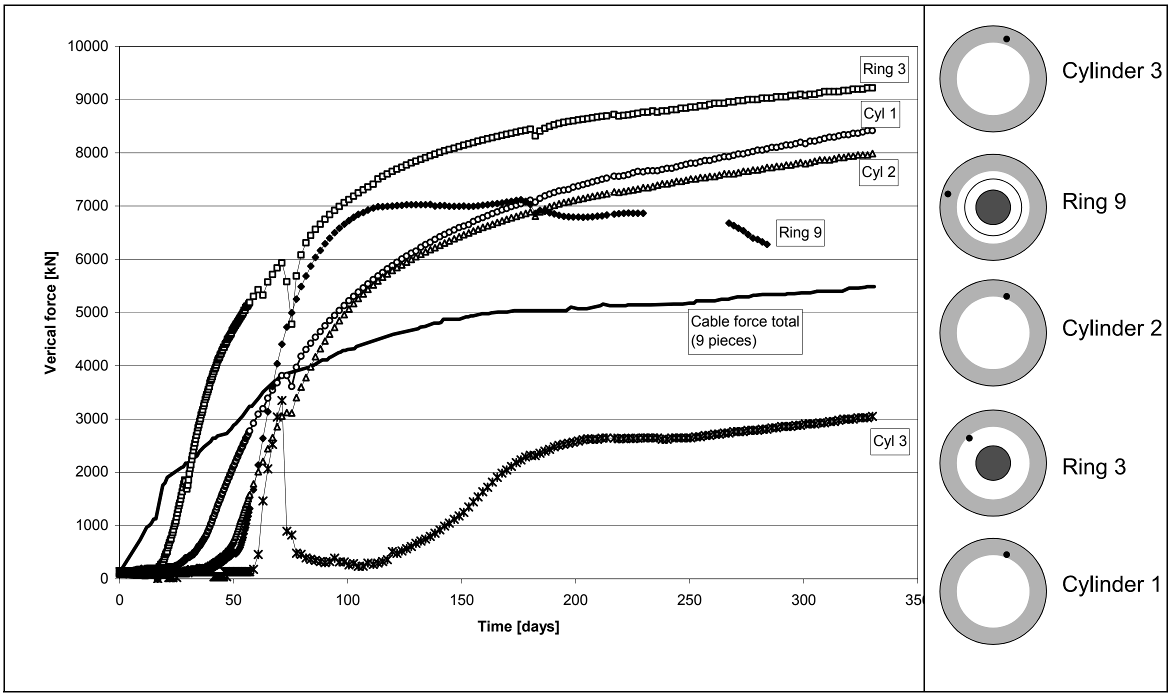
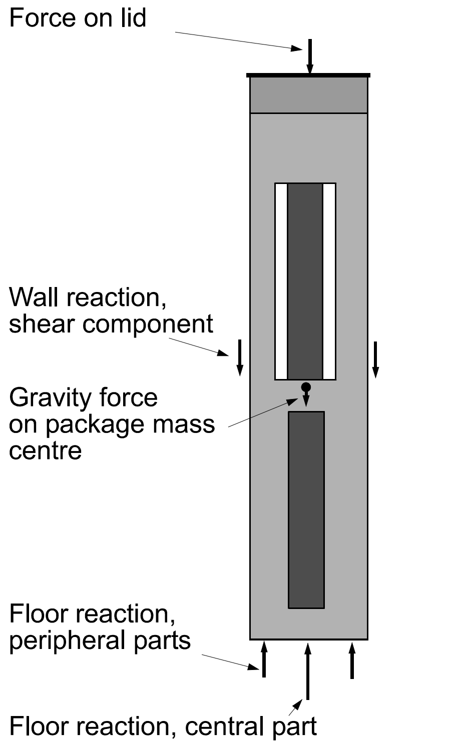


Figure 5-5. *Axial pressure measurement translated into vertical forces, assuming annular region shown to the right (grey-shaded) to be involved in force transfer. The black dots show the stress measurement positions.*

Figure 5-6 shows a schematic of the vertical forces acting on the package. The force balance seems to require that shear stresses in the periphery are significant. The pattern of the internal vertical force transfer is complicated and will vary over time as a result of creep movements in the peripheral parts (leading to reduced shear reactions), swelling, failure of individual blocks and temperature changes. Probably part of the variations in stress and suction readings are due to such changes in the axial force transfer, and not only to differences in wetting rate.



Up		Force [kN]
↑	Floor reaction, peripheral parts (estimated from cylinder 1 axial stress measurement, cf. Fig. 3-5)	8500
	Floor reaction, central part (should be high because of thermal heater expansion)	?
	Total	>>8500
Down		**Force [kN]**
↓	Force on lid (measured cable forces, cf. Fig. 3-5)	5500
	Gravity force (heaters, bentonite, sand, concrete plug, lid)	500
	Shear reaction	>>2500
	Total	>>8500

Figure 5-6. *Schematic of vertical forces acting on the package*

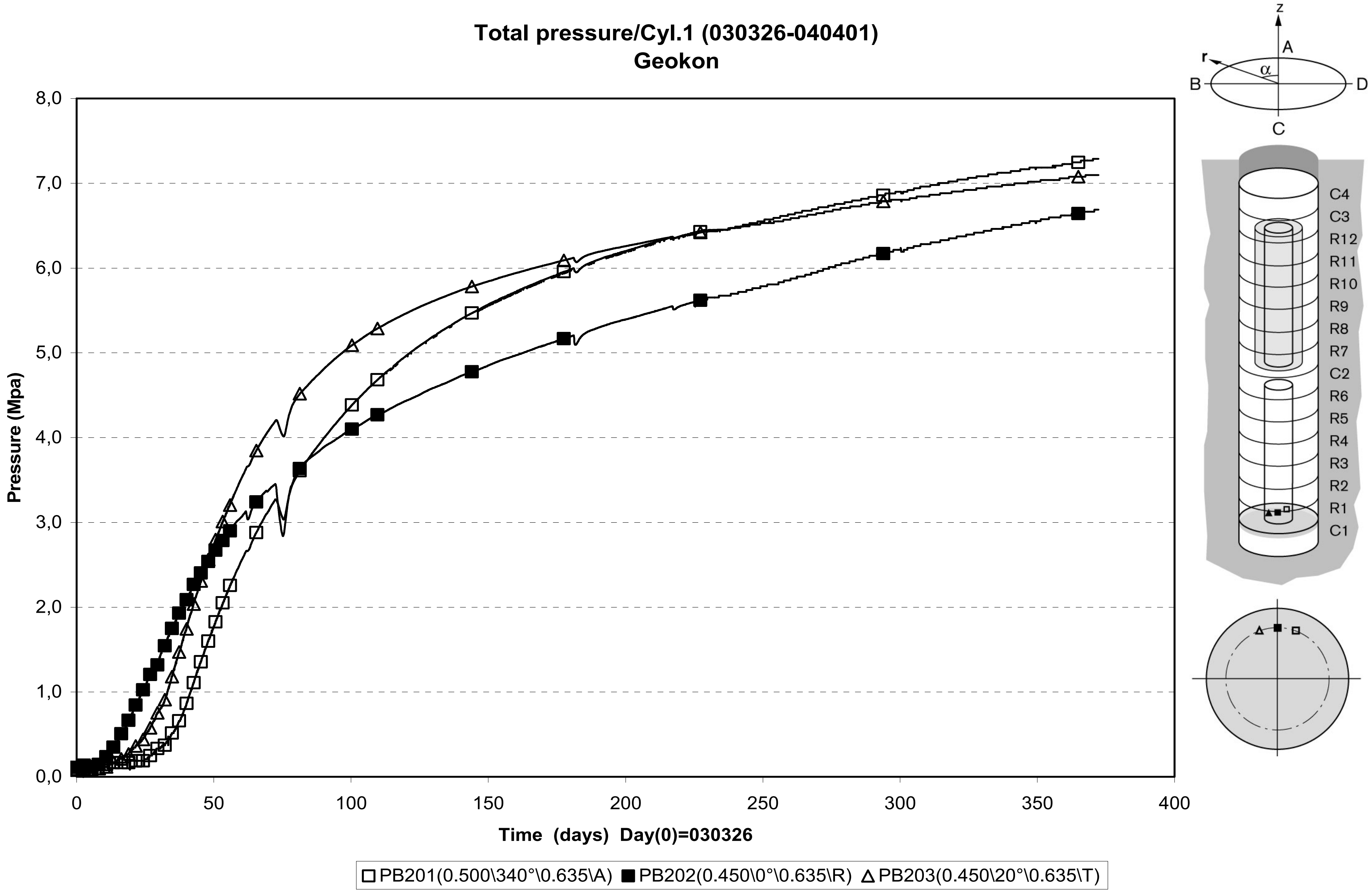
6 References

/1-1/ Sandén T and Börgesson L. Report on instruments and their positions for THM measurements in buffer and rock and preparation of bentonite blocks for instruments and cables. Temperature Buffer Test, Report R5 , 2002. SKB ITD-02-05

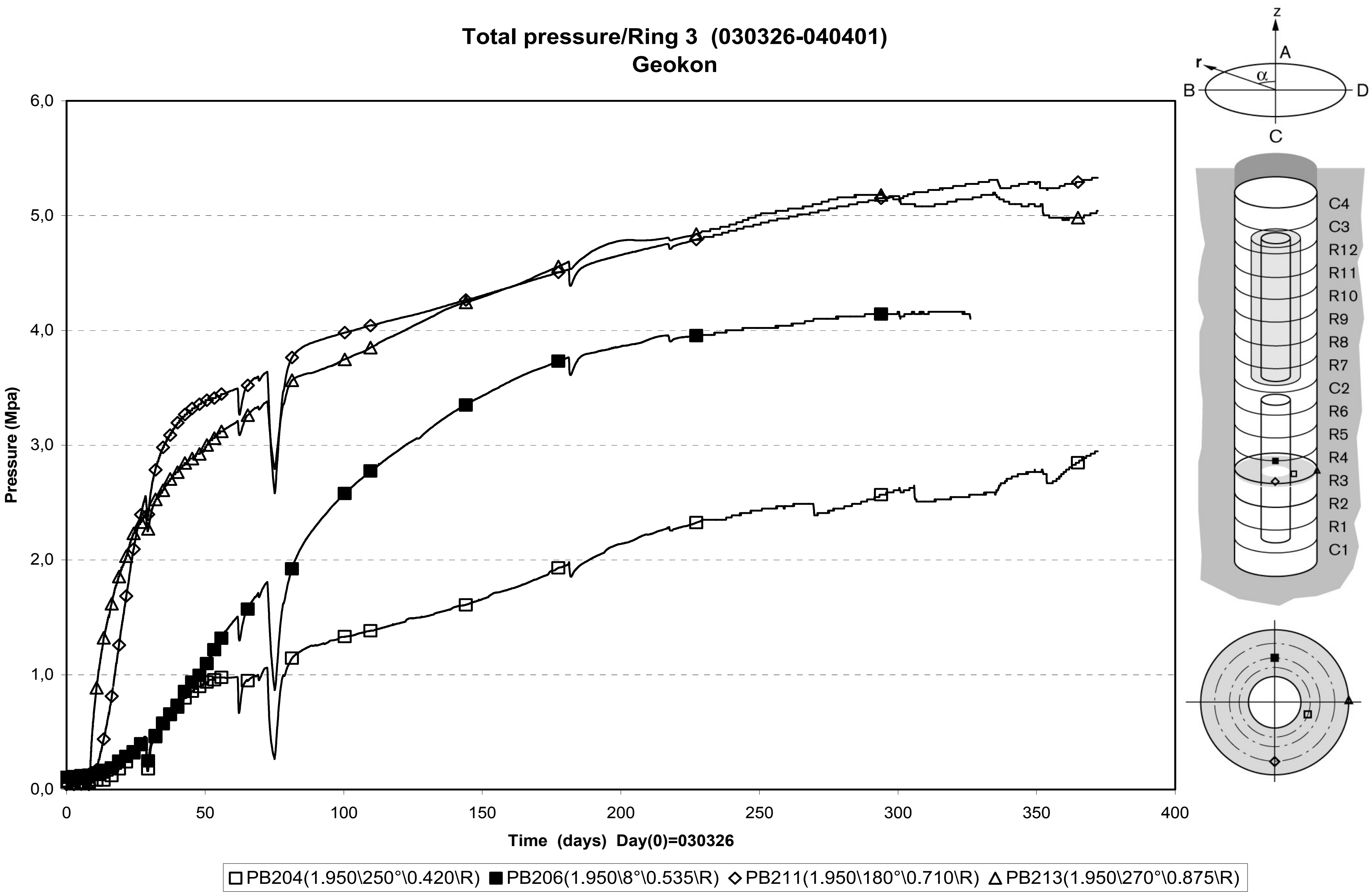
/2-1/ Garcia-Sineriz, J.L and Fuentes- Cantillana. Feasibility study for the heating system at the TBT test carried out at the Äspö HRL in Sweden. Temperature Buffer Test , October 2002. SKB IPR-03-18

7 Appendix A

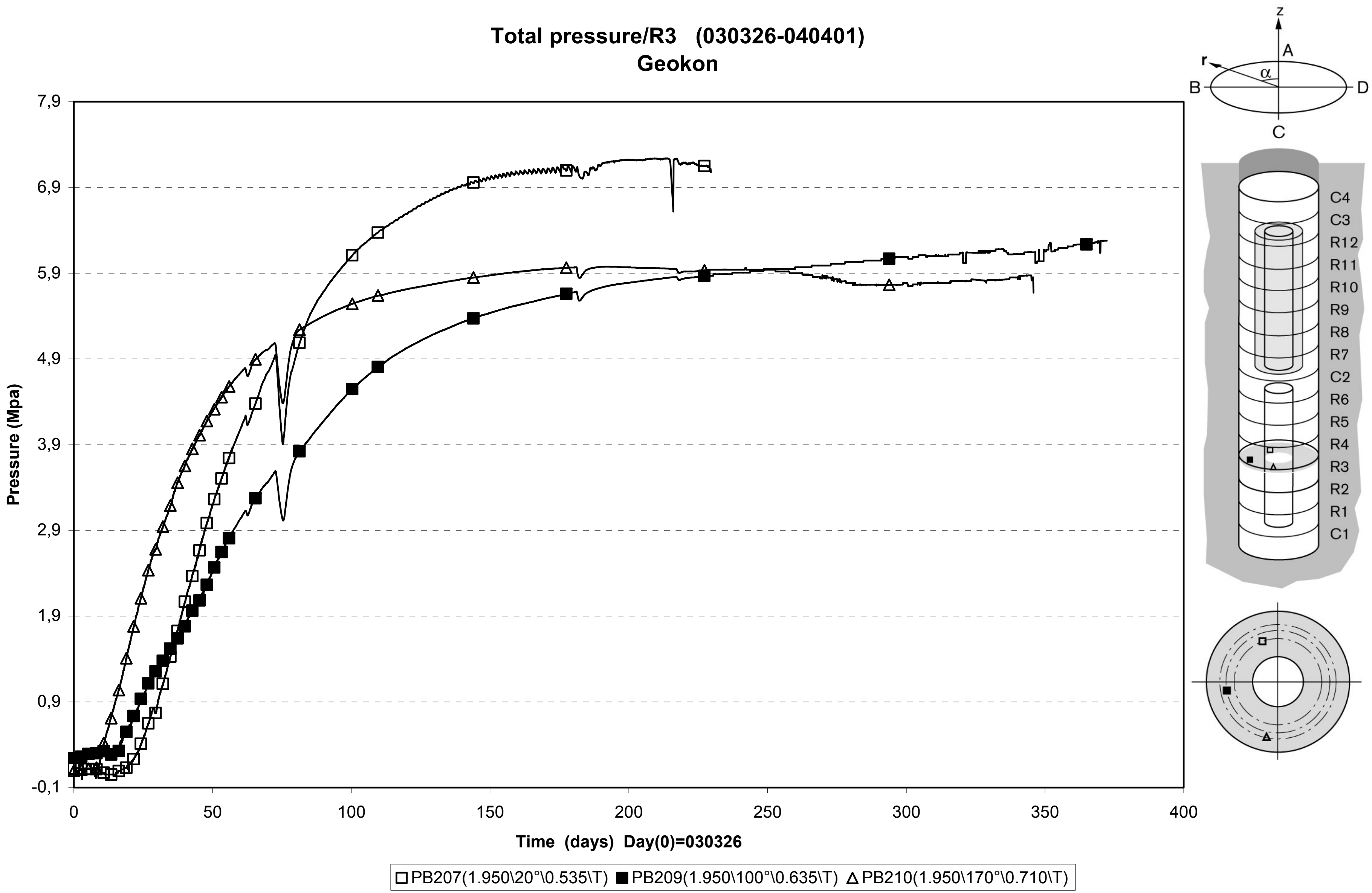
Measured data

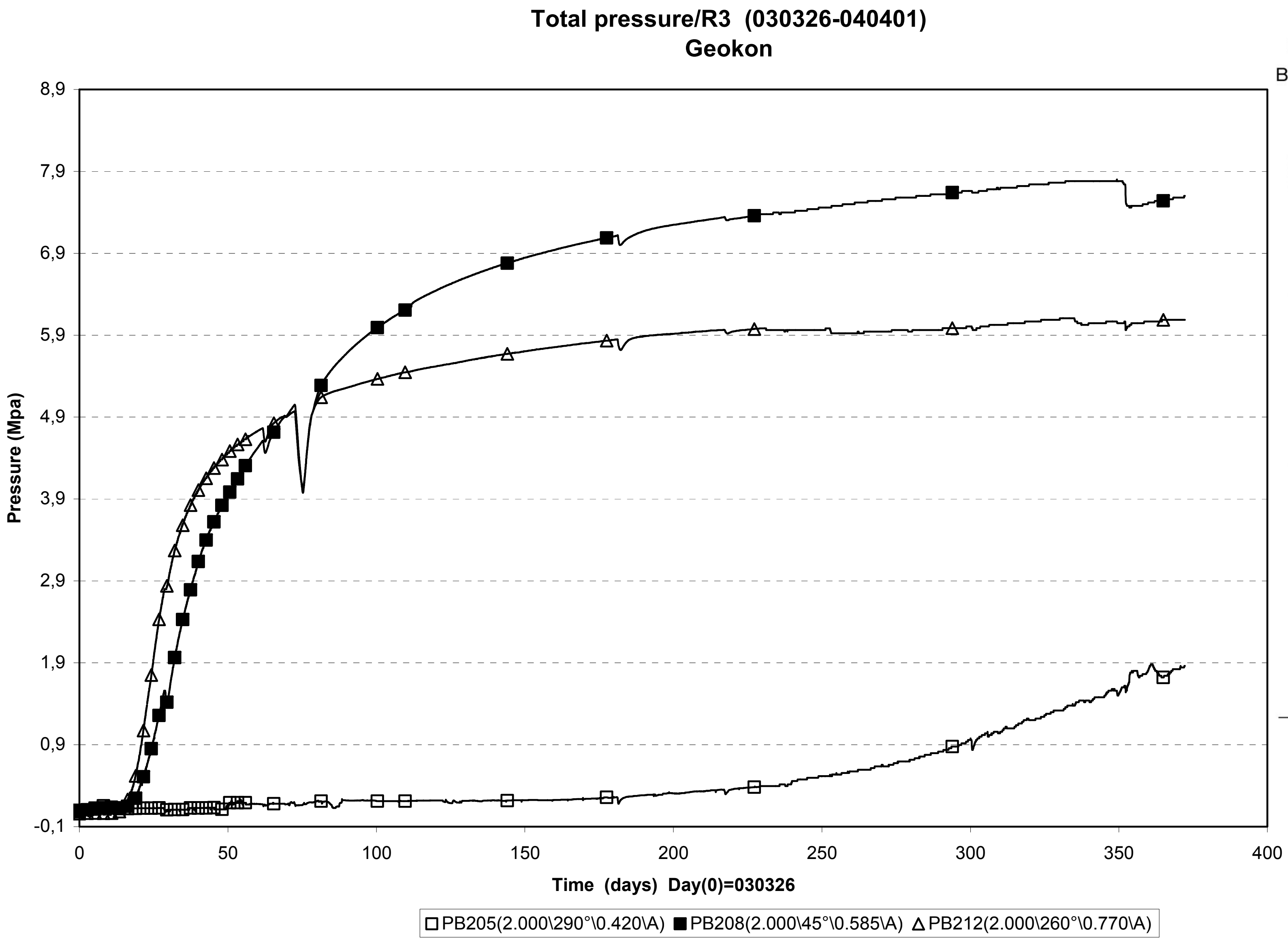


Total pressure/Cyl.1 (030326-040401)
Geokon
Pressure (Mpa)
Time (days) Day(0)=030326
PB201(0.500\340°\0.635\A) PB202(0.450\0°\0.635\R) PB203(0.450\20°\0.635\T)
z
A
r
α
B
D
C
C4
C3
R12
R11
R10
R9
R8
R7
C2
R6
R5
R4
R3
R2
R1
C1

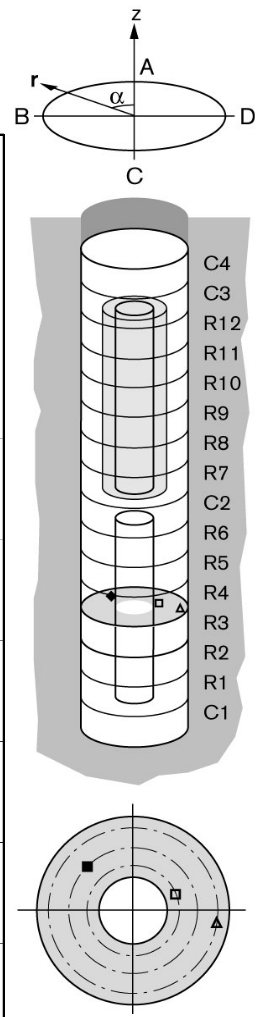


Total pressure/Ring 3 (030326-040401)
Geokon
Pressure (Mpa)
6,0
5,0
4,0
3,0
2,0
1,0
0,0
0
50
100
150
200
250
300
350
400
Time (days) Day(0)=030326
PB204(1.950\250°\0.420\R) PB206(1.950\8°\0.535\R) PB211(1.950\180°\0.710\R) PB213(1.950\270°\0.875\R)
z
A
r
α
B
D
C
C4
C3
R12
R11
R10
R9
R8
R7
C2
R6
R5
R4
R3
R2
R1
C1

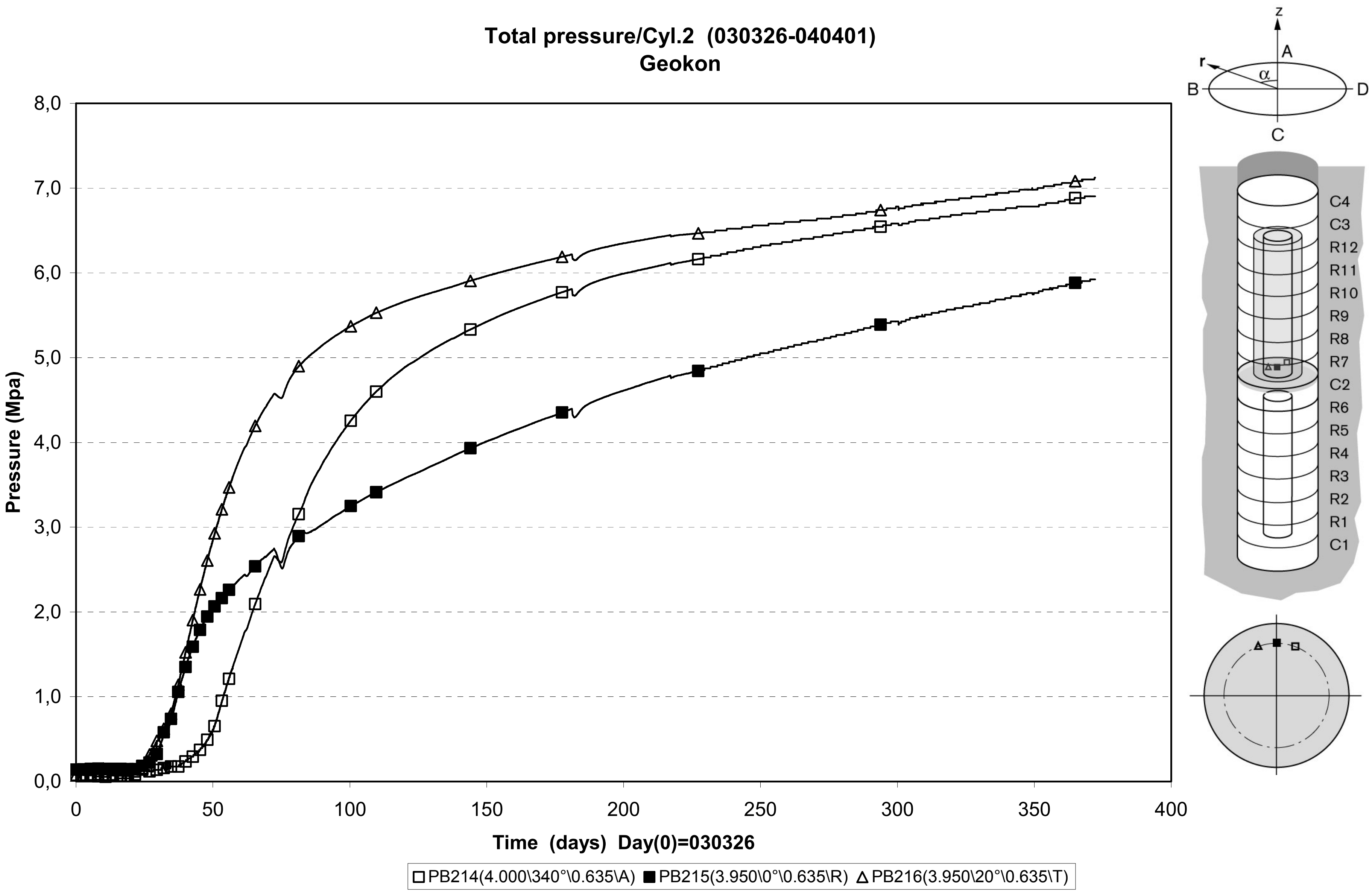

Total pressure/R3 (030326-040401)
Geokon
Pressure (Mpa)
7,9
6,9
5,9
4,9
3,9
2,9
1,9
0,9
-0,1
0
50
100
150
200
250
300
350
400
Time (days) Day(0)=030326
PB207(1.950\20°\0.535\T)
PB209(1.950\100°\0.635\T)
PB210(1.950\170°\0.710\T)
z
A
r
α
B
D
C
C4
C3
R12
R11
R10
R9
R8
R7
C2
R6
R5
R4
R3
R2
R1
C1

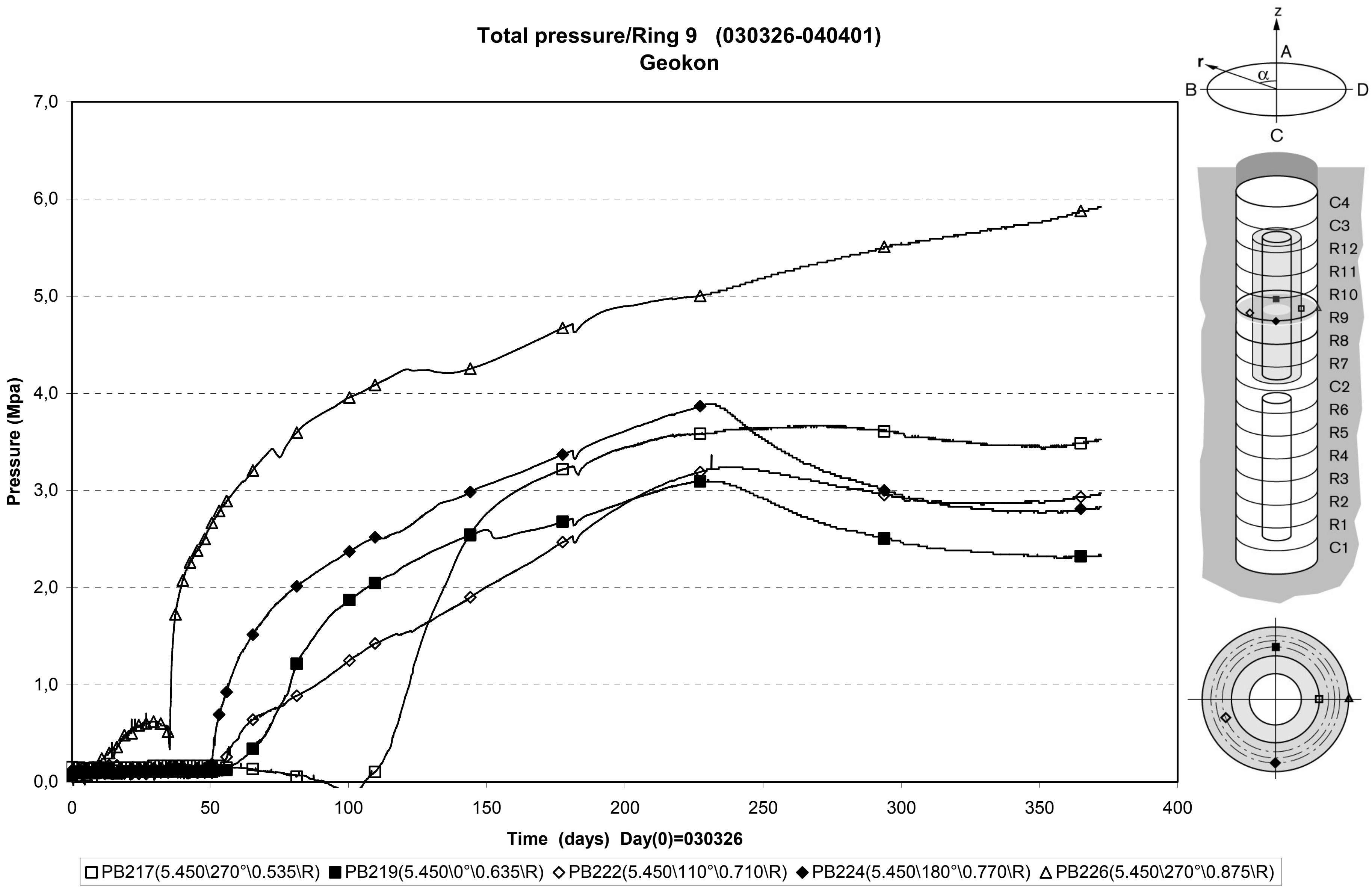


Total pressure/R3 (030326-040401)
Geokon
Pressure (Mpa)
8,9
7,9
6,9
5,9
4,9
3,9
2,9
1,9
0,9
-0,1
0
50
100
150
200
250
300
350
400
Time (days) Day(0)=030326
PB205(2.000\290°\0.420\A)
PB208(2.000\45°\0.585\A)
PB212(2.000\260°\0.770\A)

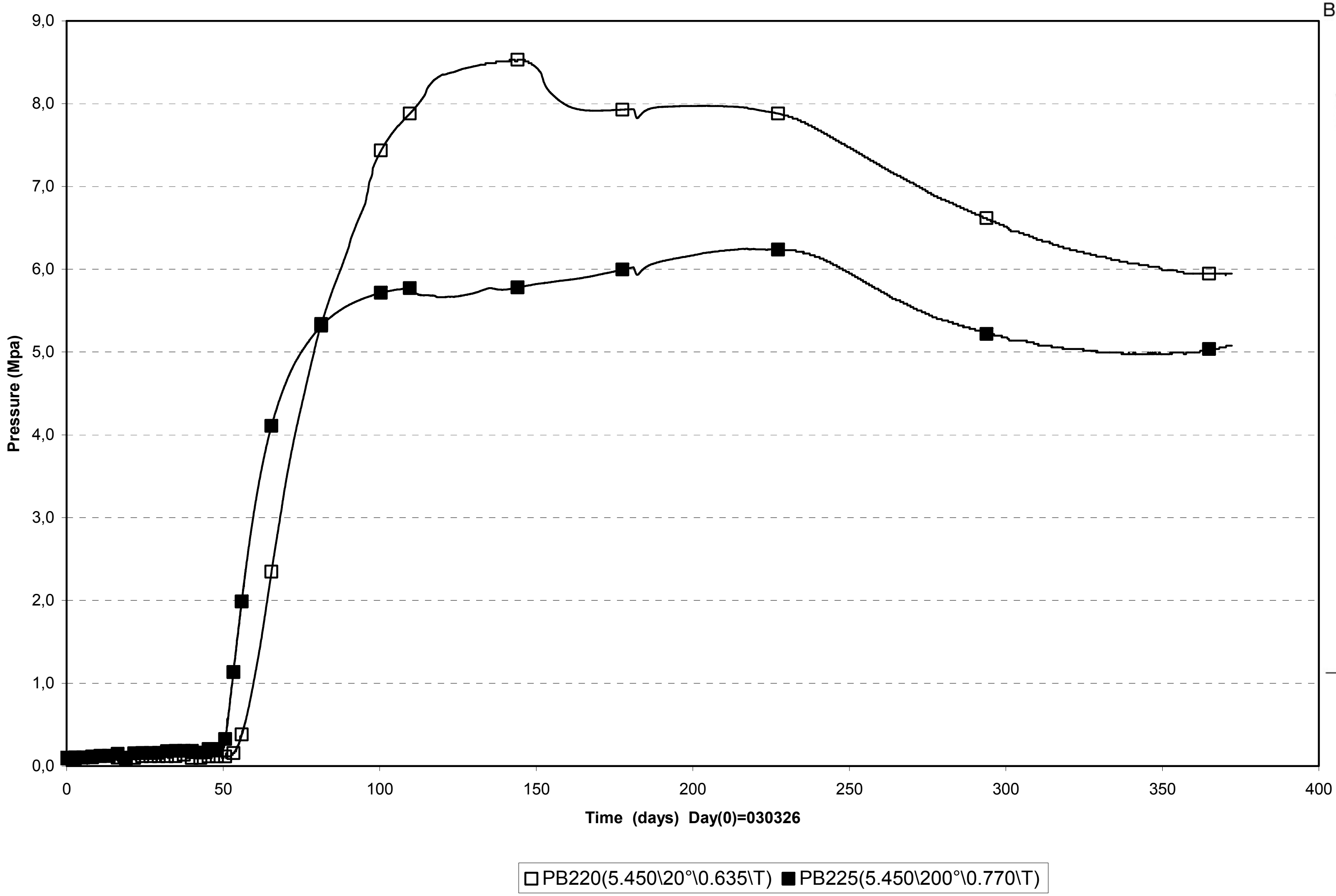


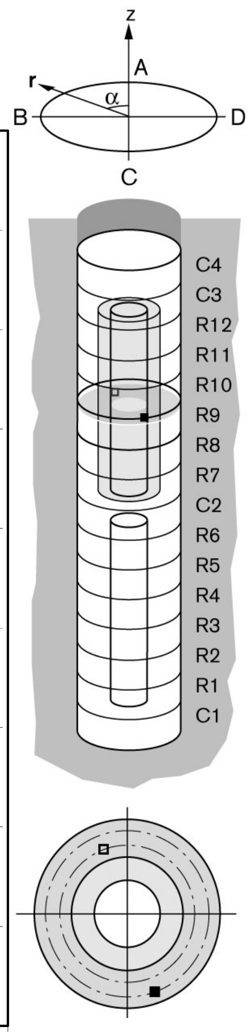
z
A
r
α
B
D
C
C4
C3
R12
R11
R10
R9
R8
R7
C2
R6
R5
R4
R3
R2
R1
C1

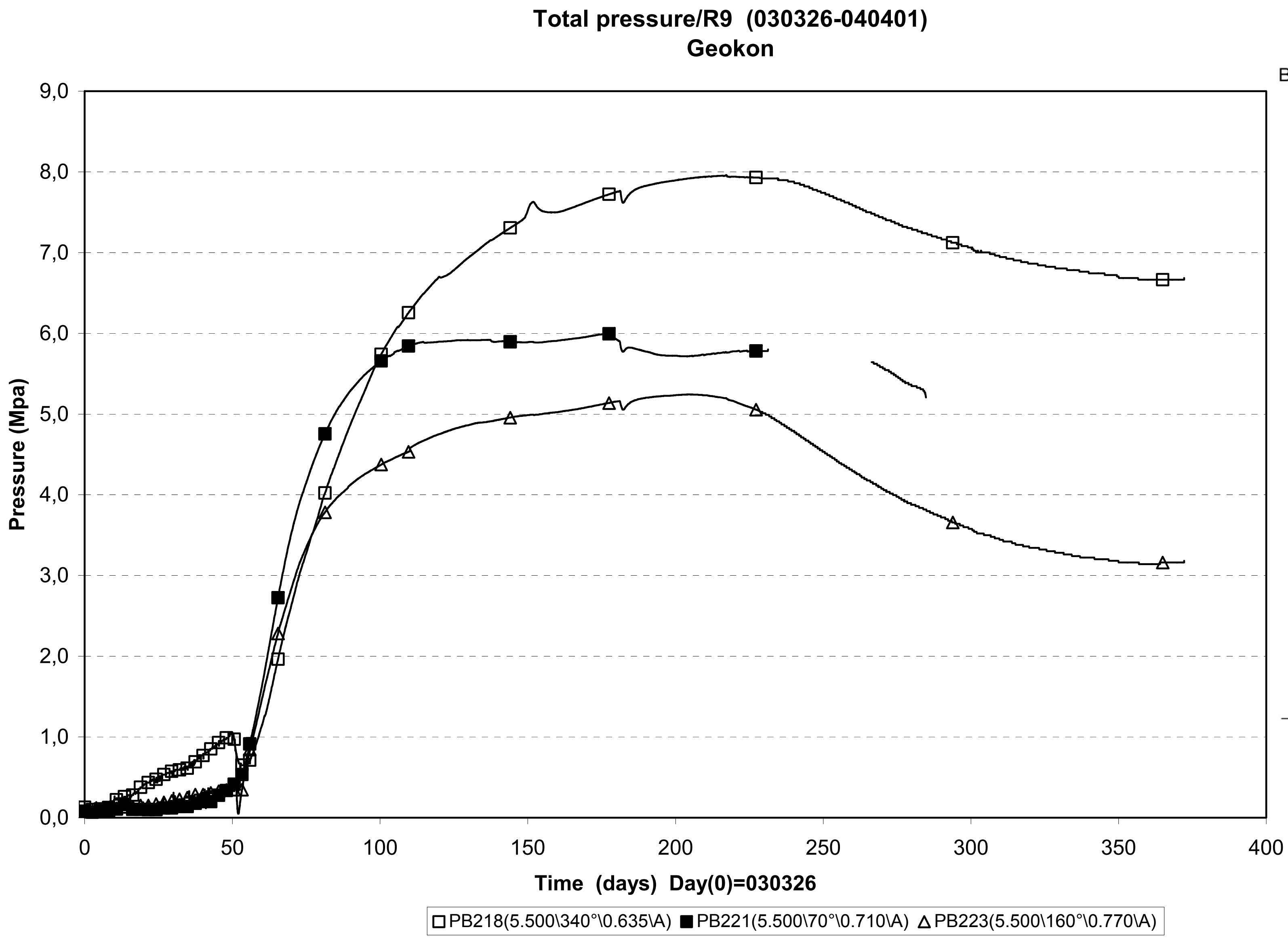

Total pressure/Cyl.2 (030326-040401)
Geokon
Pressure (Mpa)
8,0
7,0
6,0
5,0
4,0
3,0
2,0
1,0
0,0
0
50
100
150
200
250
300
350
400
Time (days) Day(0)=030326
□PB214(4.000\340°\0.635\A) ■PB215(3.950\0°\0.635\R) △PB216(3.950\20°\0.635\T)
z
A
r
α
B
D
C
C4
C3
R12
R11
R10
R9
R8
R7
C2
R6
R5
R4
R3
R2
R1
C1

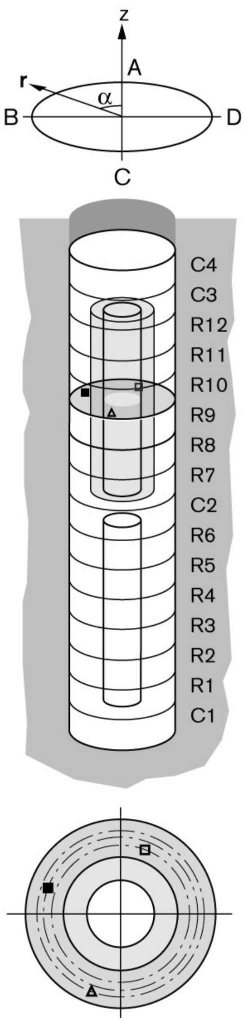

Total pressure/Ring 9 (030326-040401)
Geokon
Pressure (Mpa)
7,0
6,0
5,0
4,0
3,0
2,0
1,0
0,0
0
50
100
150
200
250
300
350
400
Time (days) Day(0)=030326
PB217(5.450\270°\0.535\R)
PB219(5.450\0°\0.635\R)
PB222(5.450\110°\0.710\R)
PB224(5.450\180°\0.770\R)
PB226(5.450\270°\0.875\R)
z
A
r
α
B
D
C
C4
C3
R12
R11
R10
R9
R8
R7
C2
R6
R5
R4
R3
R2
R1
C1

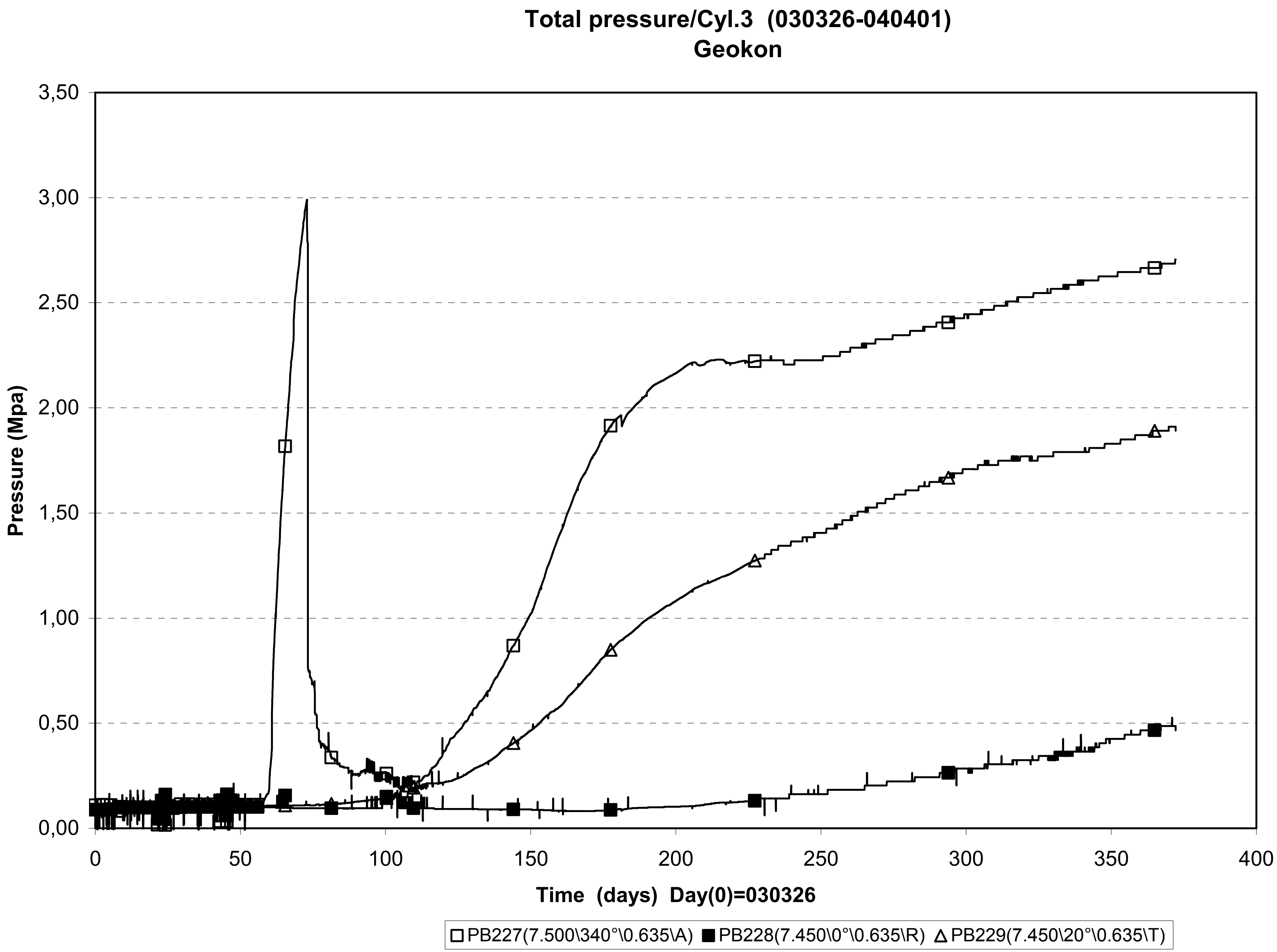
Total pressure/Ring 9 (030326-040401)
Geokon

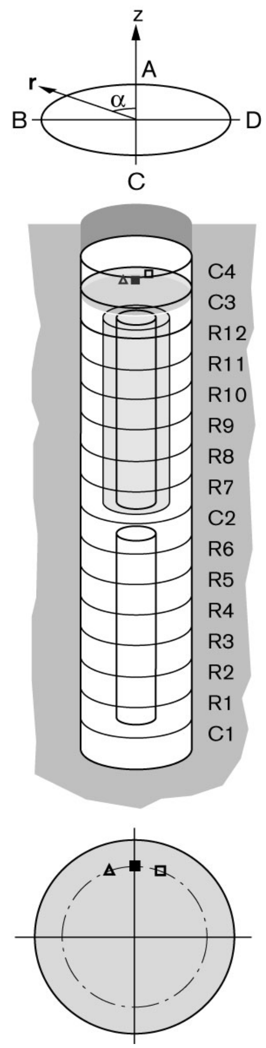


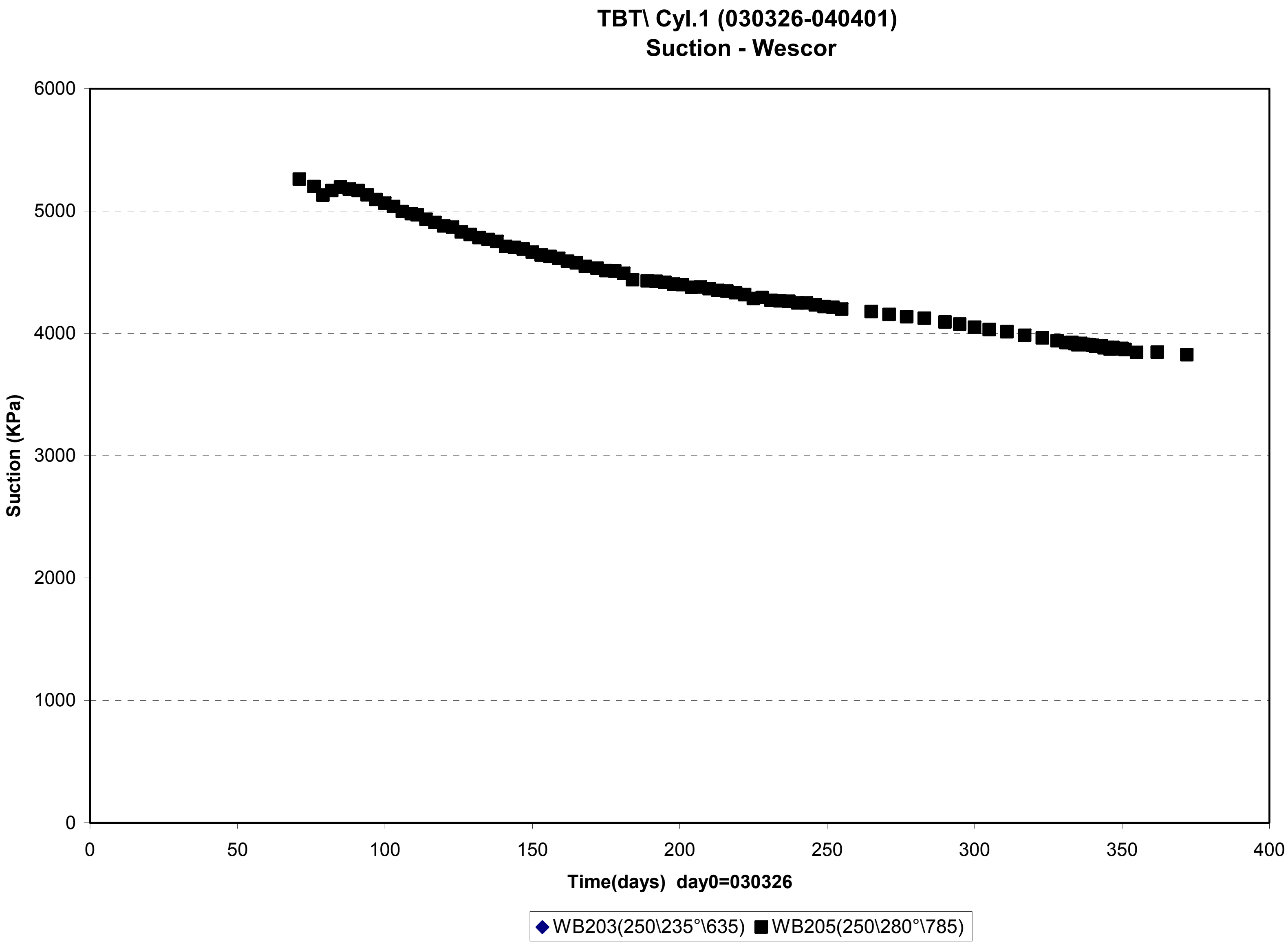



Total pressure/R9 (030326-040401)
Geokon
Pressure (Mpa)
9,0
8,0
7,0
6,0
5,0
4,0
3,0
2,0
1,0
0,0
0
50
100
150
200
250
300
350
400
Time (days) Day(0)=030326
PB218(5.500\340°\0.635\A)
PB221(5.500\70°\0.710\A)
PB223(5.500\160°\0.770\A)

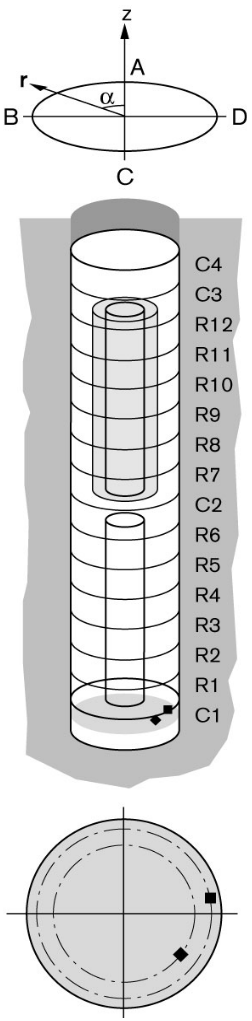

z
A
r
α
B
D
C
C4
C3
R12
R11
R10
R9
R8
R7
C2
R6
R5
R4
R3
R2
R1
C1


Total pressure/Cyl.3 (030326-040401)
Geokon
Pressure (Mpa)
3,50
3,00
2,50
2,00
1,50
1,00
0,50
0,00
0
50
100
150
200
250
300
350
400
Time (days) Day(0)=030326
□ PB227(7.500\340°\0.635\A) ■ PB228(7.450\0°\0.635\R) △ PB229(7.450\20°\0.635\T)

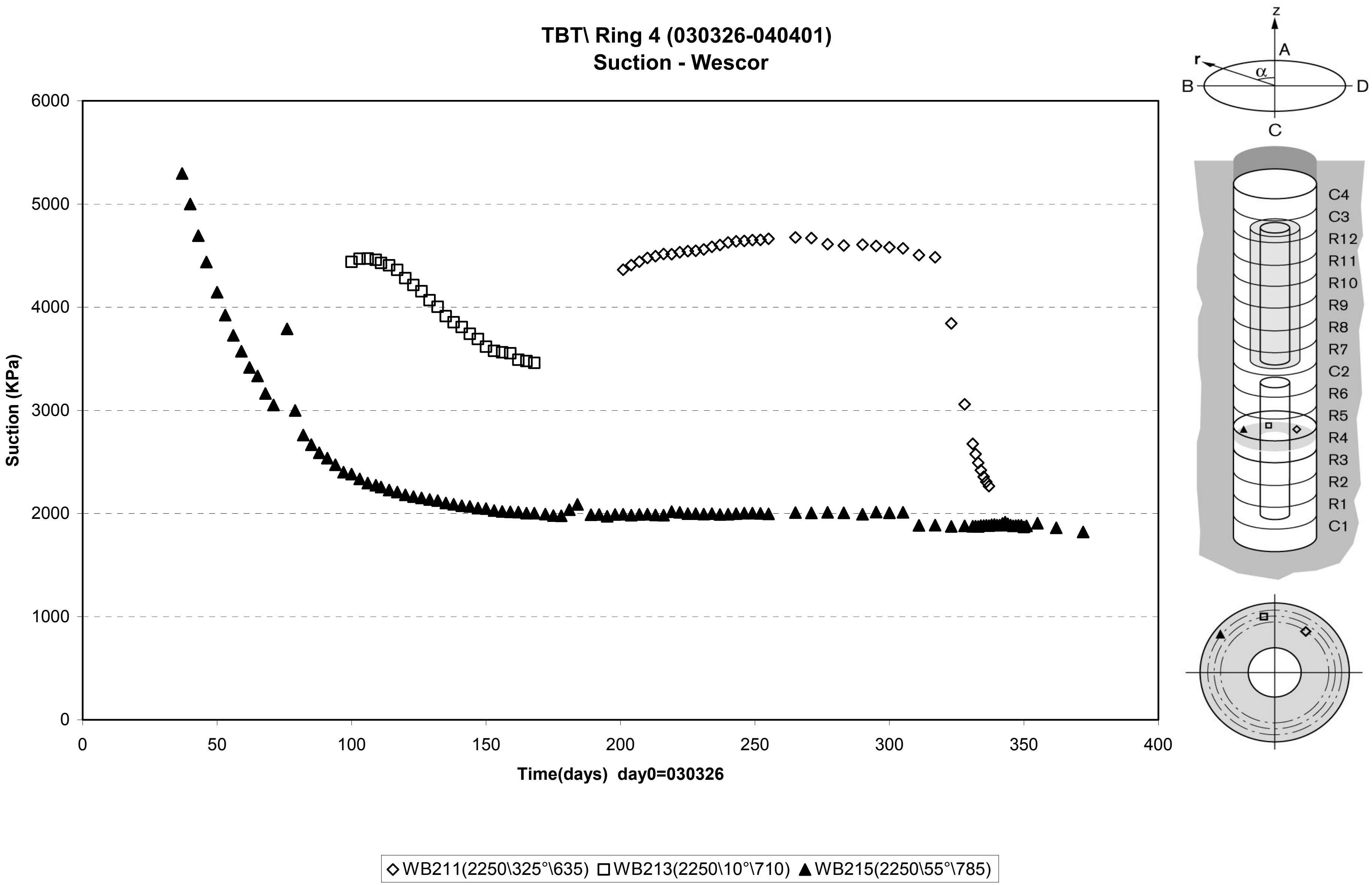

z
A
r
α
B
D
C
C4
C3
R12
R11
R10
R9
R8
R7
C2
R6
R5
R4
R3
R2
R1
C1

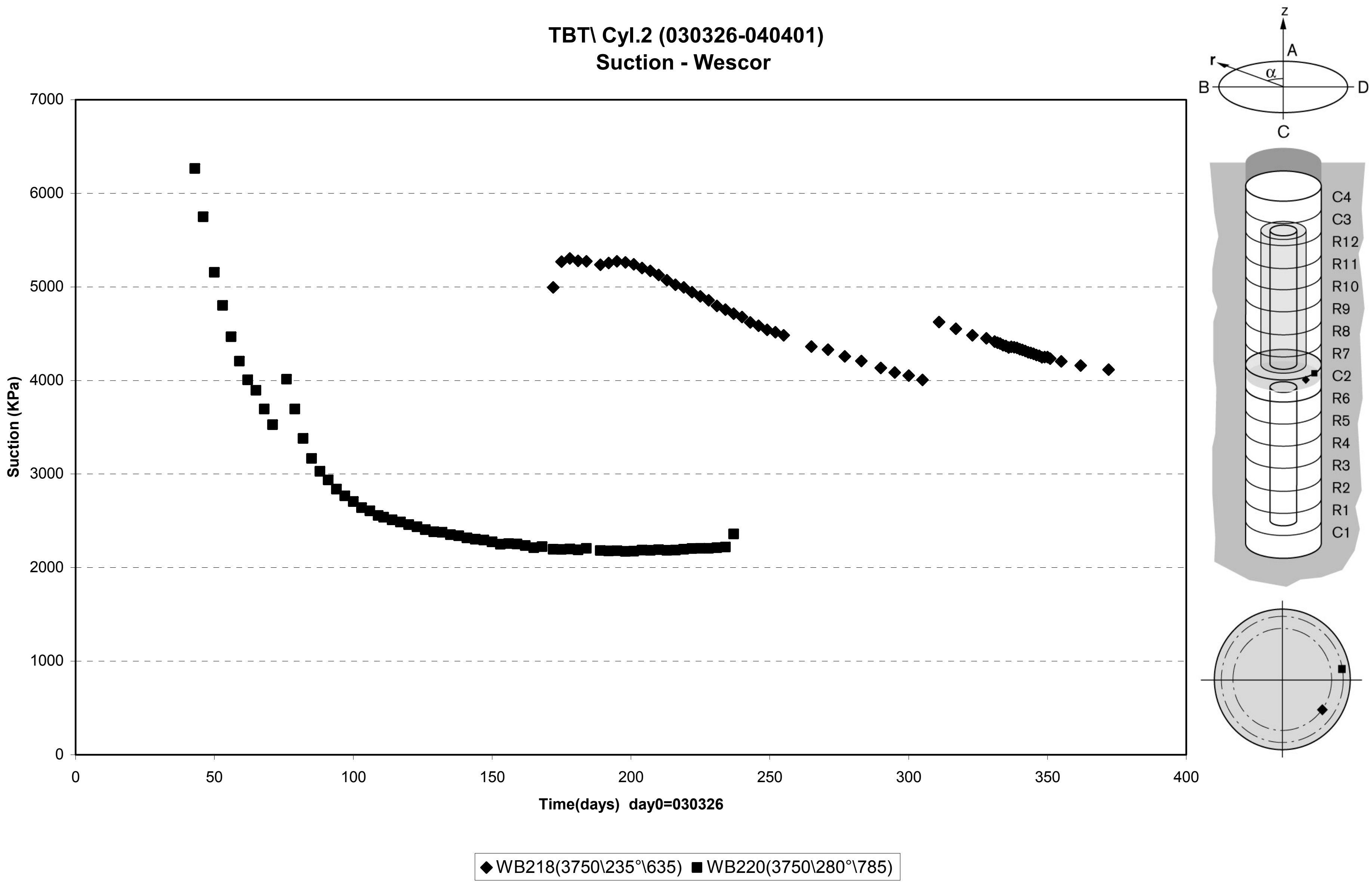


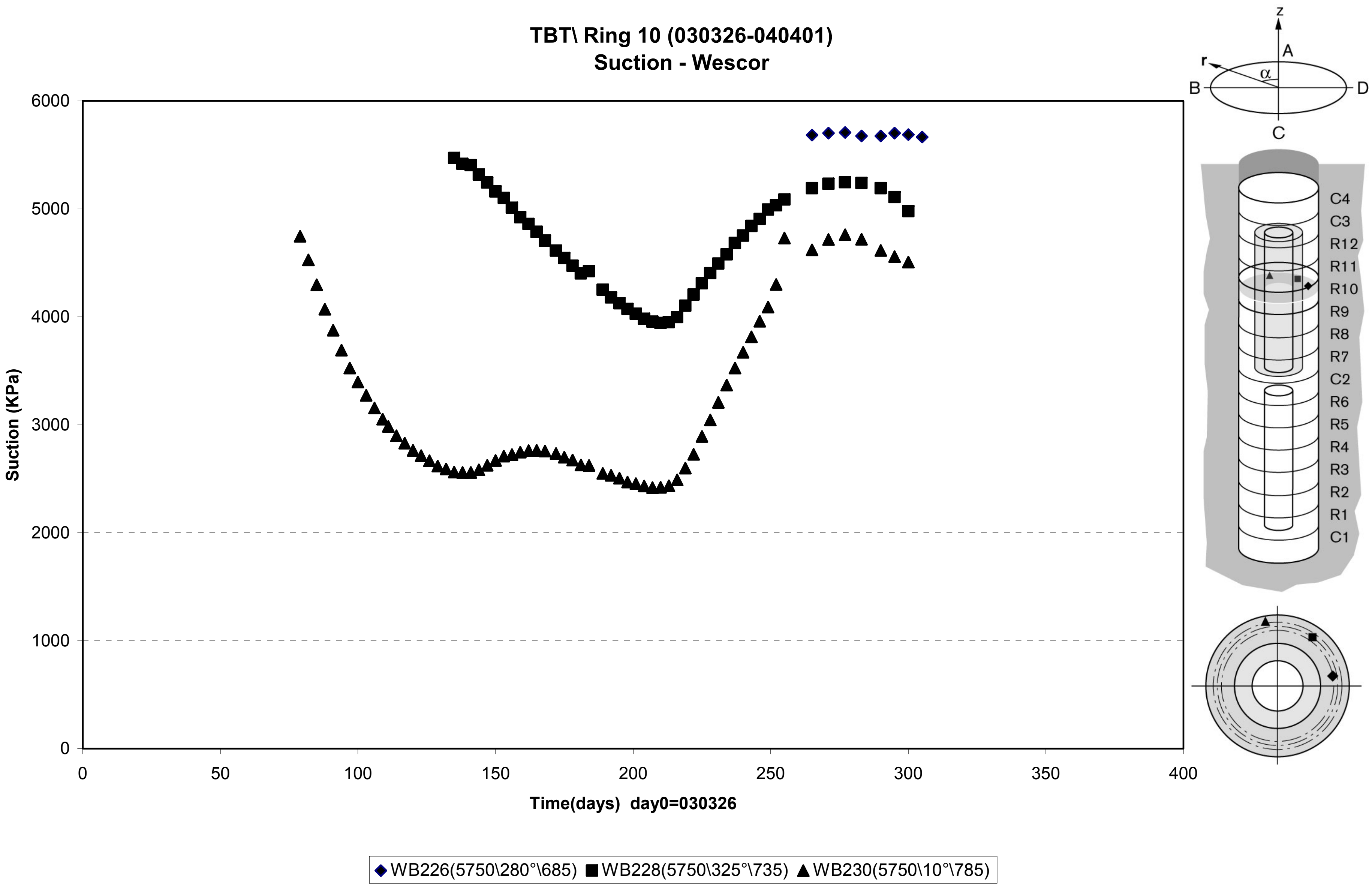
TBT\ Cyl.1 (030326-040401)
Suction - Wescor
6000
5000
4000
3000
2000
1000
0
Suction (KPa)
0
50
100
150
200
250
300
350
400
Time(days) day0=030326
WB203(250\235°\635)
WB205(250\280°\785)

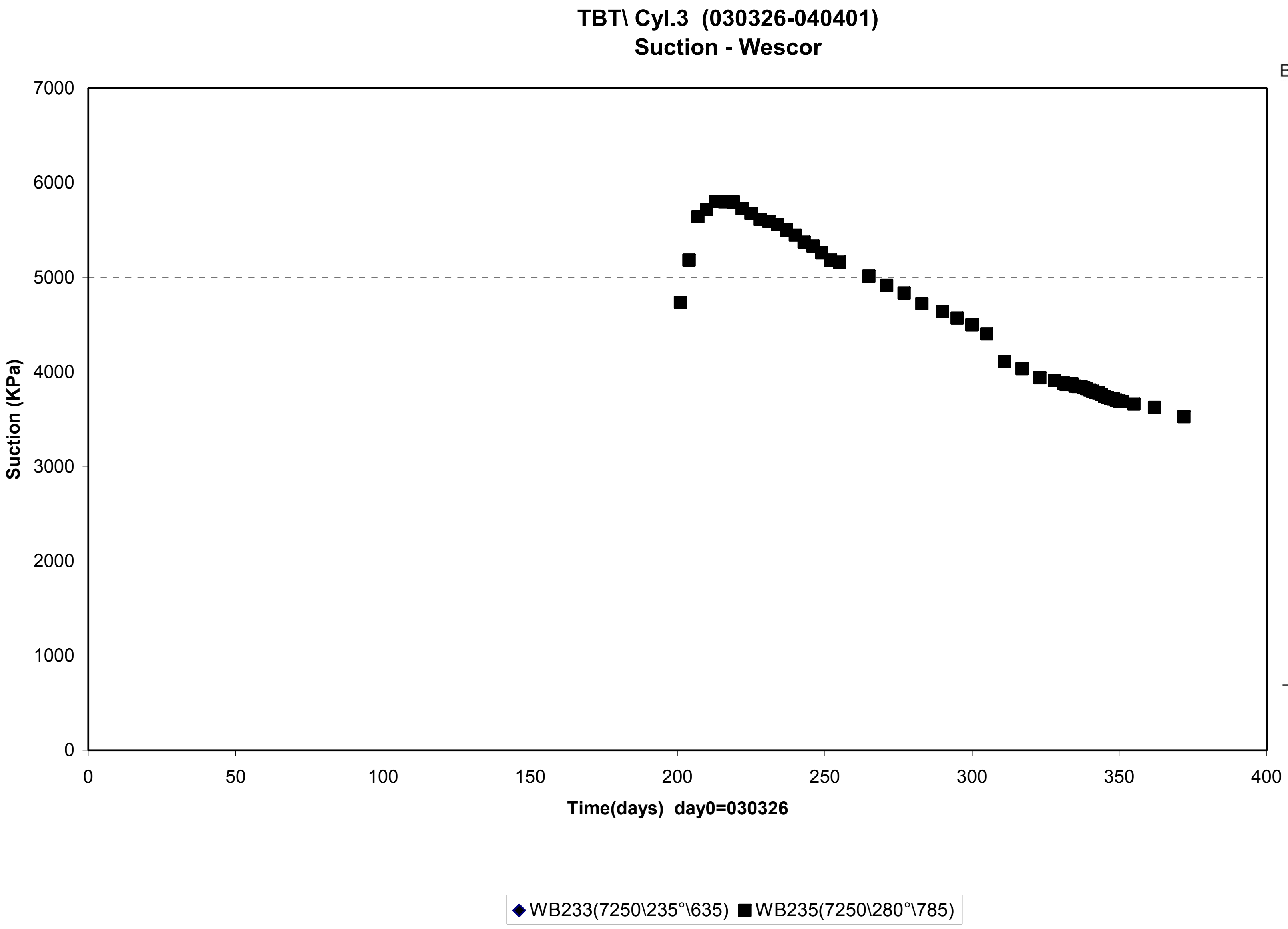


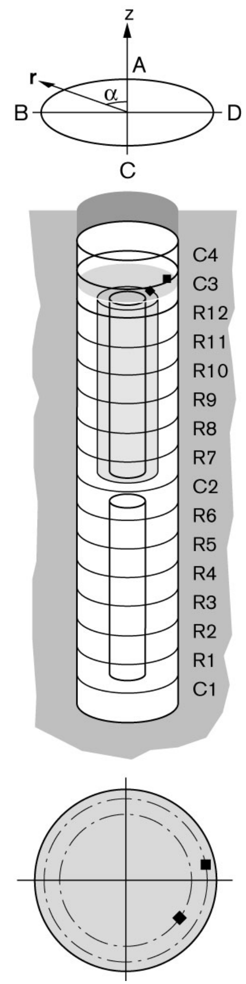
z
A
r
α
B
D
C
C4
C3
R12
R11
R10
R9
R8
R7
C2
R6
R5
R4
R3
R2
R1
C1

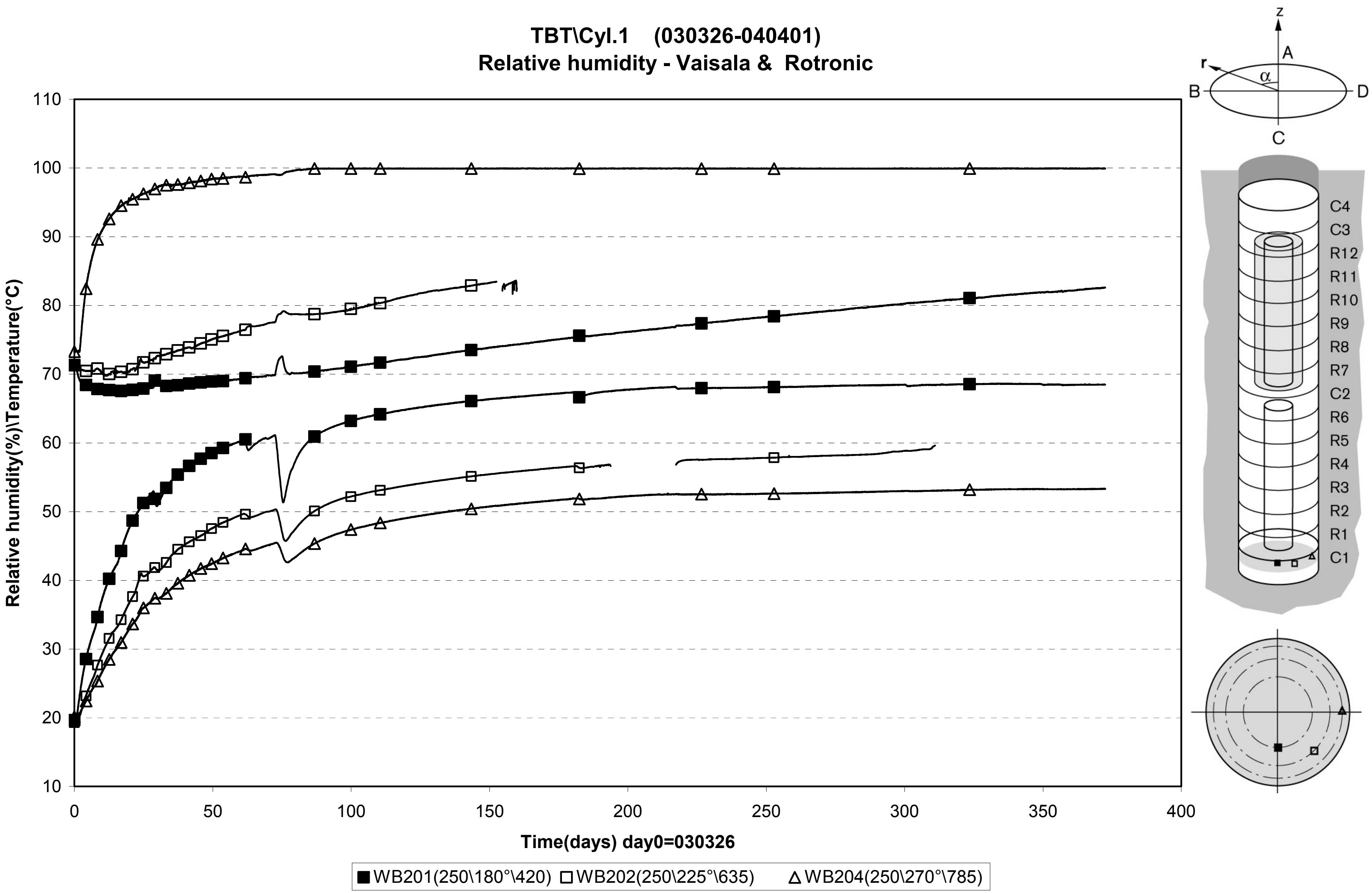

TBT\ Ring 4 (030326-040401)
Suction - Wescor
Suction (KPa)
6000
5000
4000
3000
2000
1000
0
0
50
100
150
200
250
300
350
400
Time(days) day0=030326
◇WB211(2250\325°\635) □WB213(2250\10°\710) ▲WB215(2250\55°\785)
z
A
r
α
B
D
C
C4
C3
R12
R11
R10
R9
R8
R7
C2
R6
R5
R4
R3
R2
R1
C1


TBT\ Cyl.2 (030326-040401)
Suction - Wescor
Suction (KPa)
7000
6000
5000
4000
3000
2000
1000
0
0
50
100
150
200
250
300
350
400
Time(days) day0=030326
◆ WB218(3750\235°\635) ■ WB220(3750\280°\785)
z
A
r
α
B
D
C
C4
C3
R12
R11
R10
R9
R8
R7
C2
R6
R5
R4
R3
R2
R1
C1

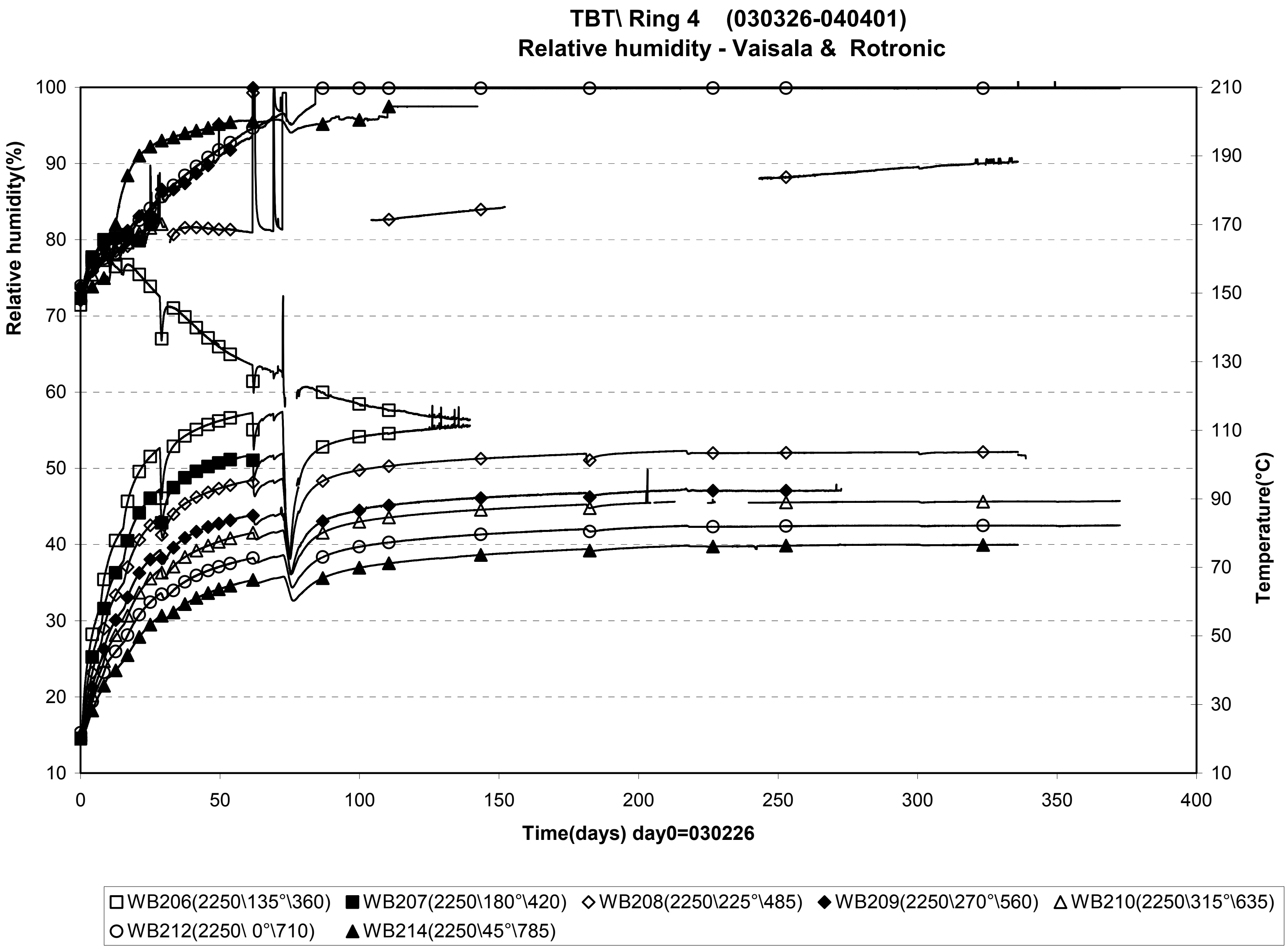

TBT\ Ring 10 (030326-040401)
Suction - Wescor
Suction (KPa)
6000
5000
4000
3000
2000
1000
0
0
50
100
150
200
250
300
350
400
Time(days) day0=030326
WB226(5750\280°\685)
WB228(5750\325°\735)
WB230(5750\10°\785)
z
A
r
α
B
D
C
C4
C3
R12
R11
R10
R9
R8
R7
C2
R6
R5
R4
R3
R2
R1
C1


TBT\ Cyl.3 (030326-040401)
Suction - Wescor
7000
6000
5000
4000
3000
2000
1000
0
Suction (KPa)
0
50
100
150
200
250
300
350
400
Time(days) day0=030326
◆WB233(7250\235°\635) ■WB235(7250\280°\785)

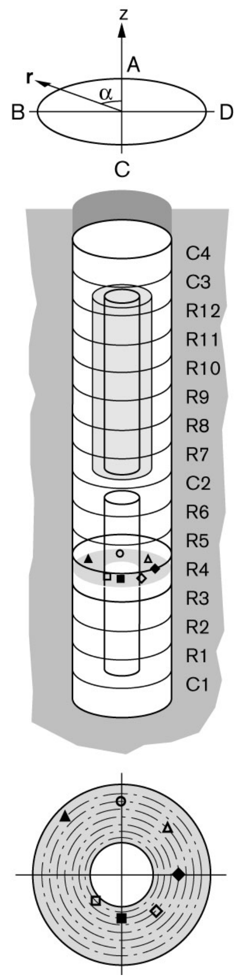

z
A
r
α
B
D
C
C4
C3
R12
R11
R10
R9
R8
R7
C2
R6
R5
R4
R3
R2
R1
C1



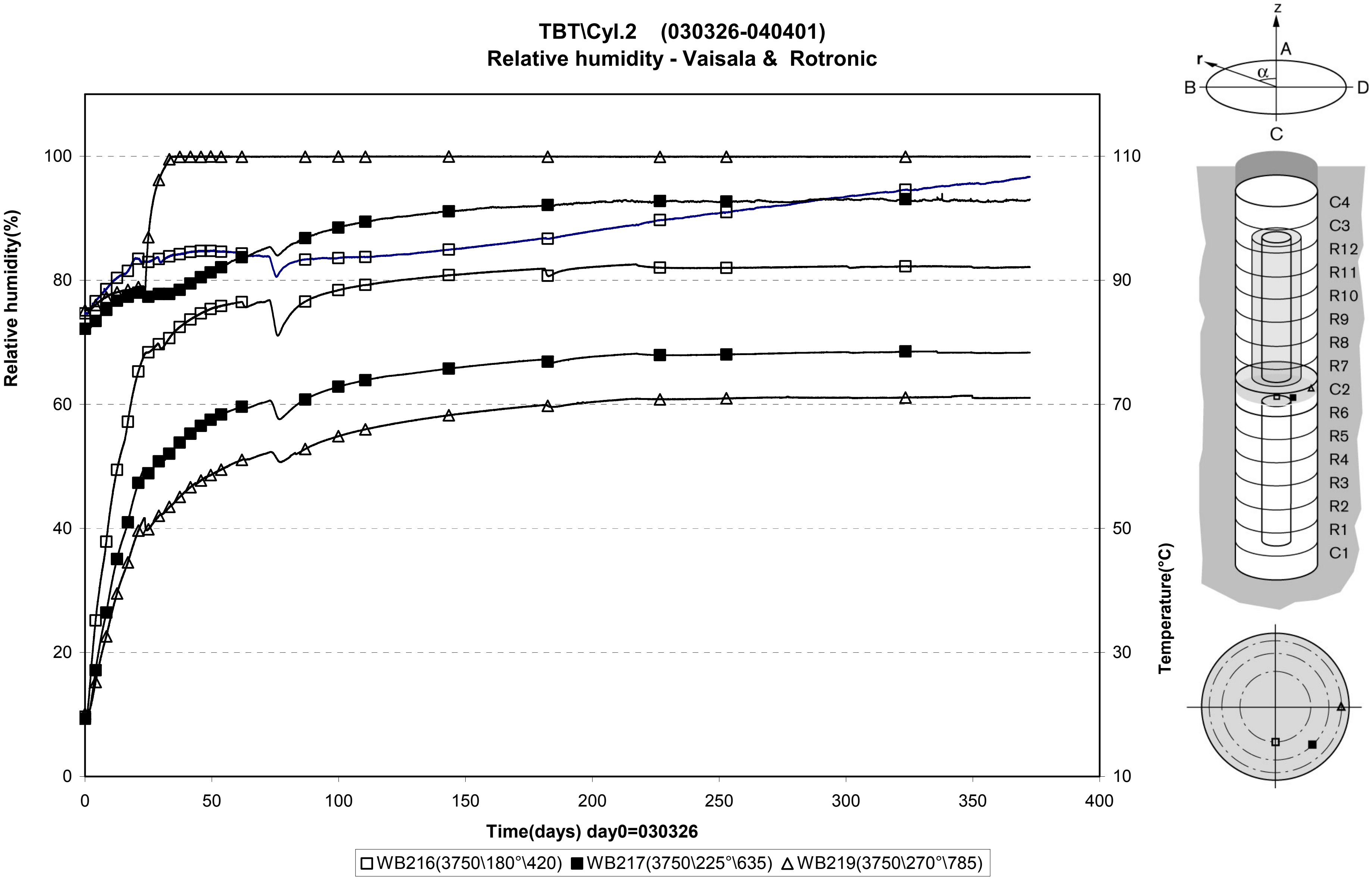
TBT\Cyl.1 (030326-040401)
Relative humidity - Vaisala & Rotronic
Relative humidity(%)\Temperature(°C)
Time(days) day0=030326
WB201(250\180°\420)
WB202(250\225°\635)
WB204(250\270°\785)
z
A
r
α
B
D
C
C4
C3
R12
R11
R10
R9
R8
R7
C2
R6
R5
R4
R3
R2
R1
C1

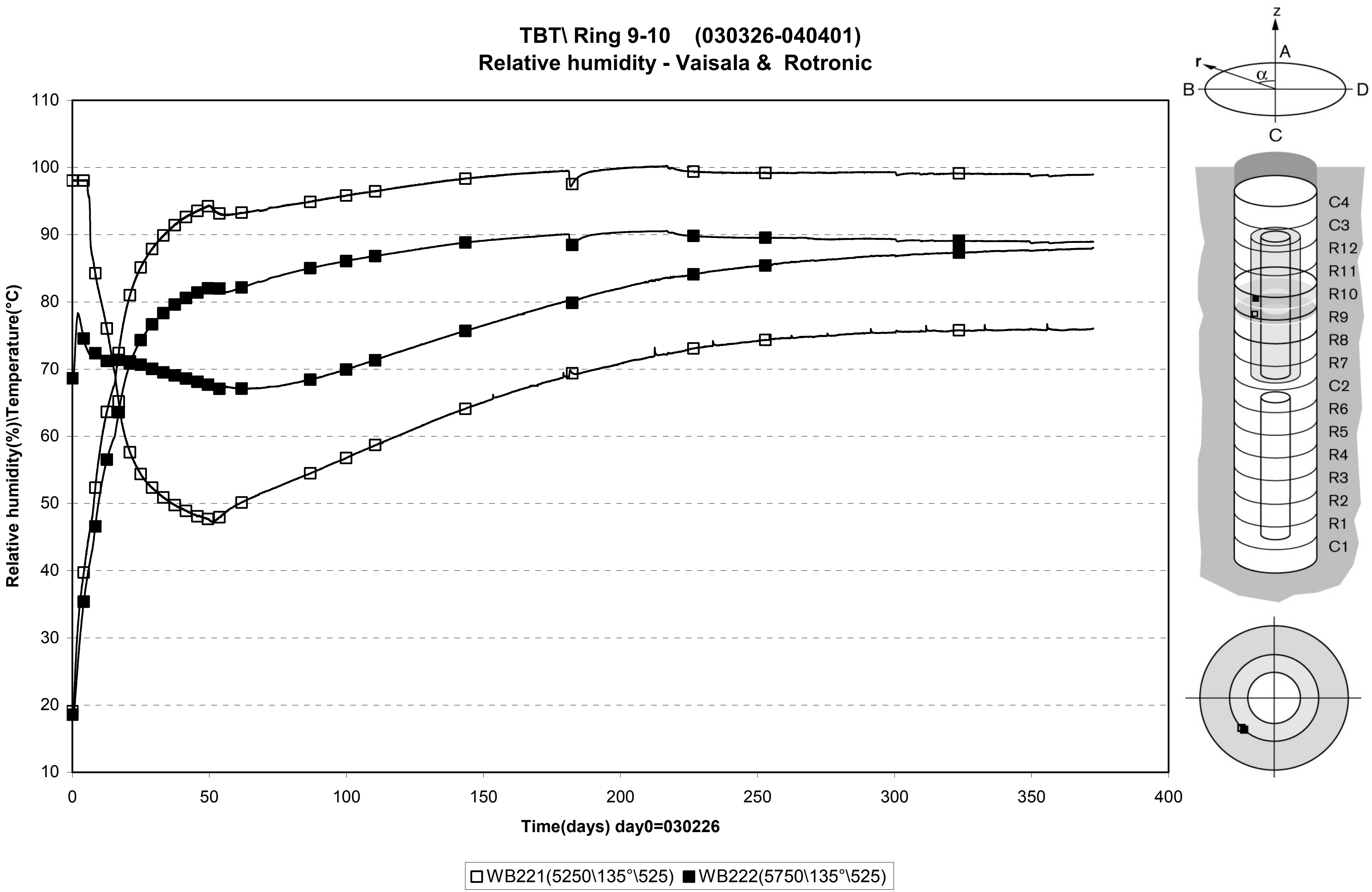


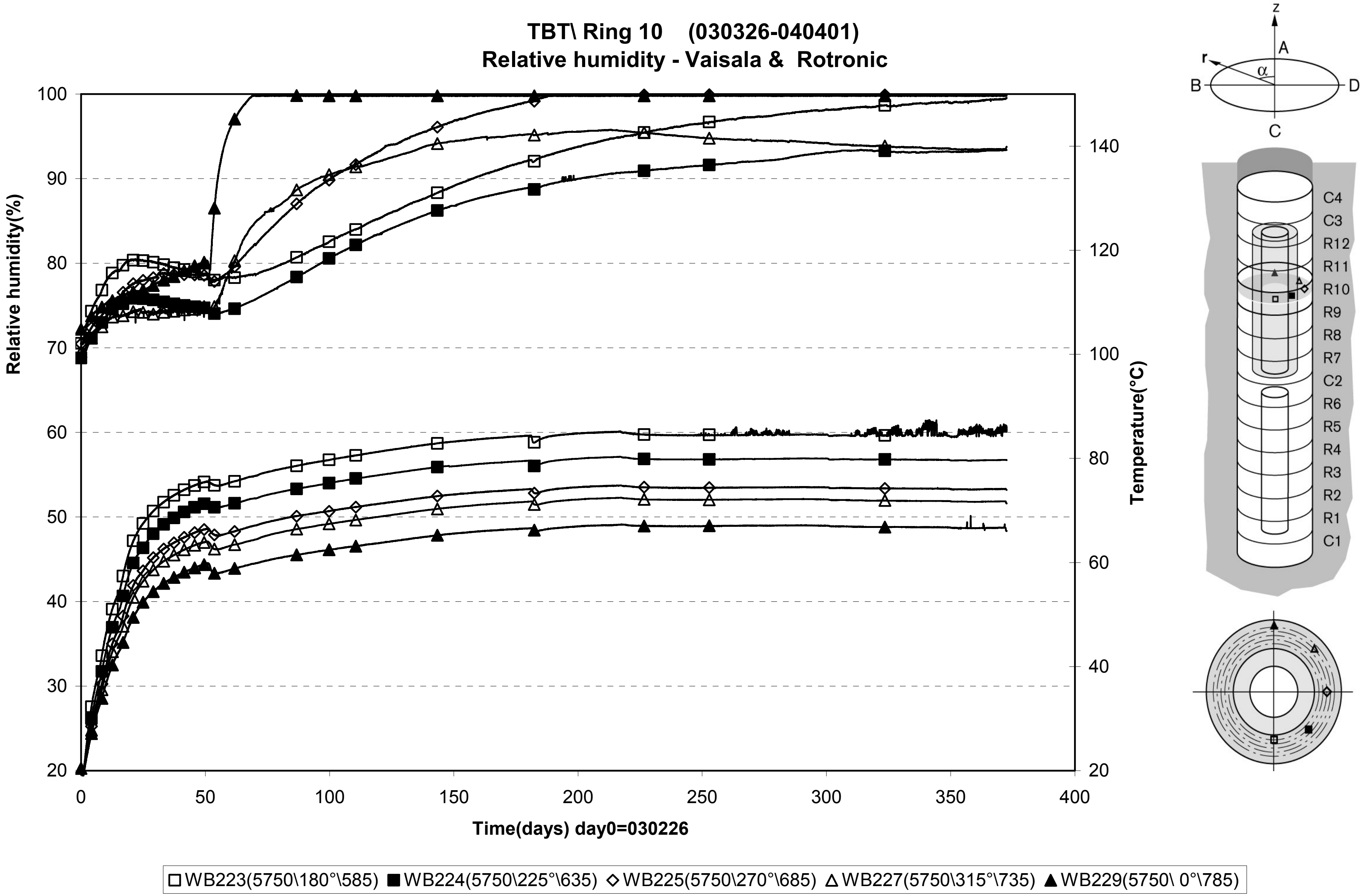
TBT\ Ring 4 (030326-040401)
Relative humidity - Vaisala & Rotronic
Relative humidity(%)
Temperature(°C)
Time(days) day0=030226
100
90
80
70
60
50
40
30
20
10
210
190
170
150
130
110
90
70
50
30
10
0
50
100
150
200
250
300
350
400
WB206(2250\135°\360)
WB207(2250\180°\420)
WB208(2250\225°\485)
WB209(2250\270°\560)
WB210(2250\315°\635)
WB212(2250\ 0°\710)
WB214(2250\45°\785)

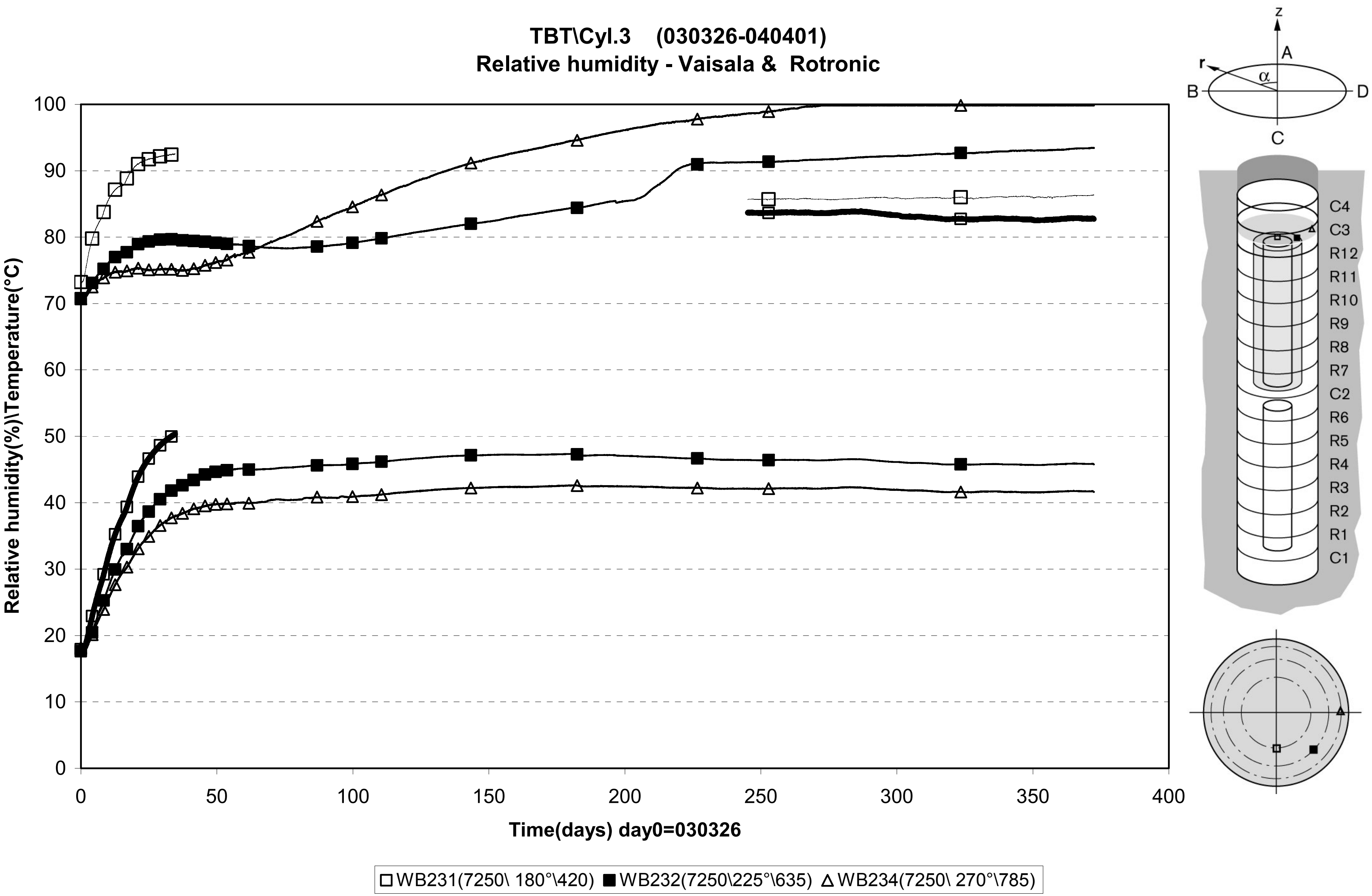


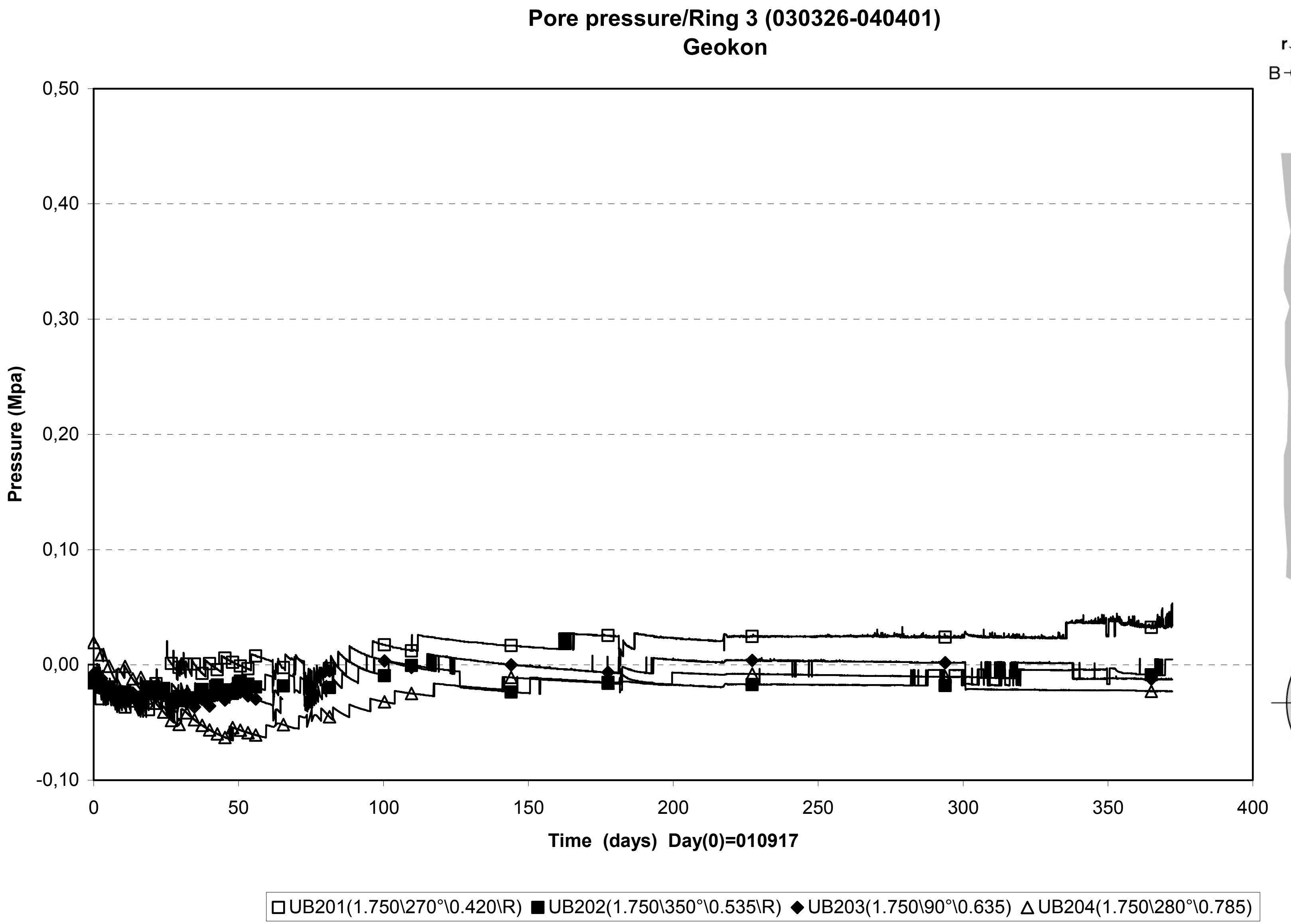
z
A
r
α
B
D
C
C4
C3
R12
R11
R10
R9
R8
R7
C2
R6
R5
R4
R3
R2
R1
C1


TBT\Cyl.2 (030326-040401)
Relative humidity - Vaisala & Rotronic
Relative humidity(%)
Temperature(°C)
Time(days) day0=030326
WB216(3750\180°\420)
WB217(3750\225°\635)
WB219(3750\270°\785)
0
20
40
60
80
100
10
30
50
70
90
110
0
50
100
150
200
250
300
350
400
z
A
r
α
B
D
C
C4
C3
R12
R11
R10
R9
R8
R7
C2
R6
R5
R4
R3
R2
R1
C1

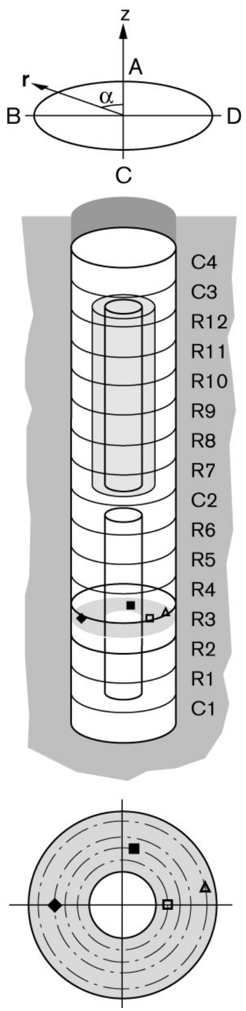

TBT\ Ring 9-10 (030326-040401)
Relative humidity - Vaisala & Rotronic
Relative humidity(%)\Temperature(°C)
Time(days) day0=030226
WB221(5250\135°\525)
WB222(5750\135°\525)
z
A
r
α
B
D
C
C4
C3
R12
R11
R10
R9
R8
R7
C2
R6
R5
R4
R3
R2
R1
C1


TBT\ Ring 10 (030326-040401)
Relative humidity - Vaisala & Rotronic
Relative humidity(%)
Temperature(°C)
Time(days) day0=030226
□WB223(5750\180°\585) ■WB224(5750\225°\635) ◇WB225(5750\270°\685) △WB227(5750\315°\735) ▲WB229(5750\ 0°\785)
z
A
B
C
D
r
α
C4
C3
R12
R11
R10
R9
R8
R7
C2
R6
R5
R4
R3
R2
R1
C1

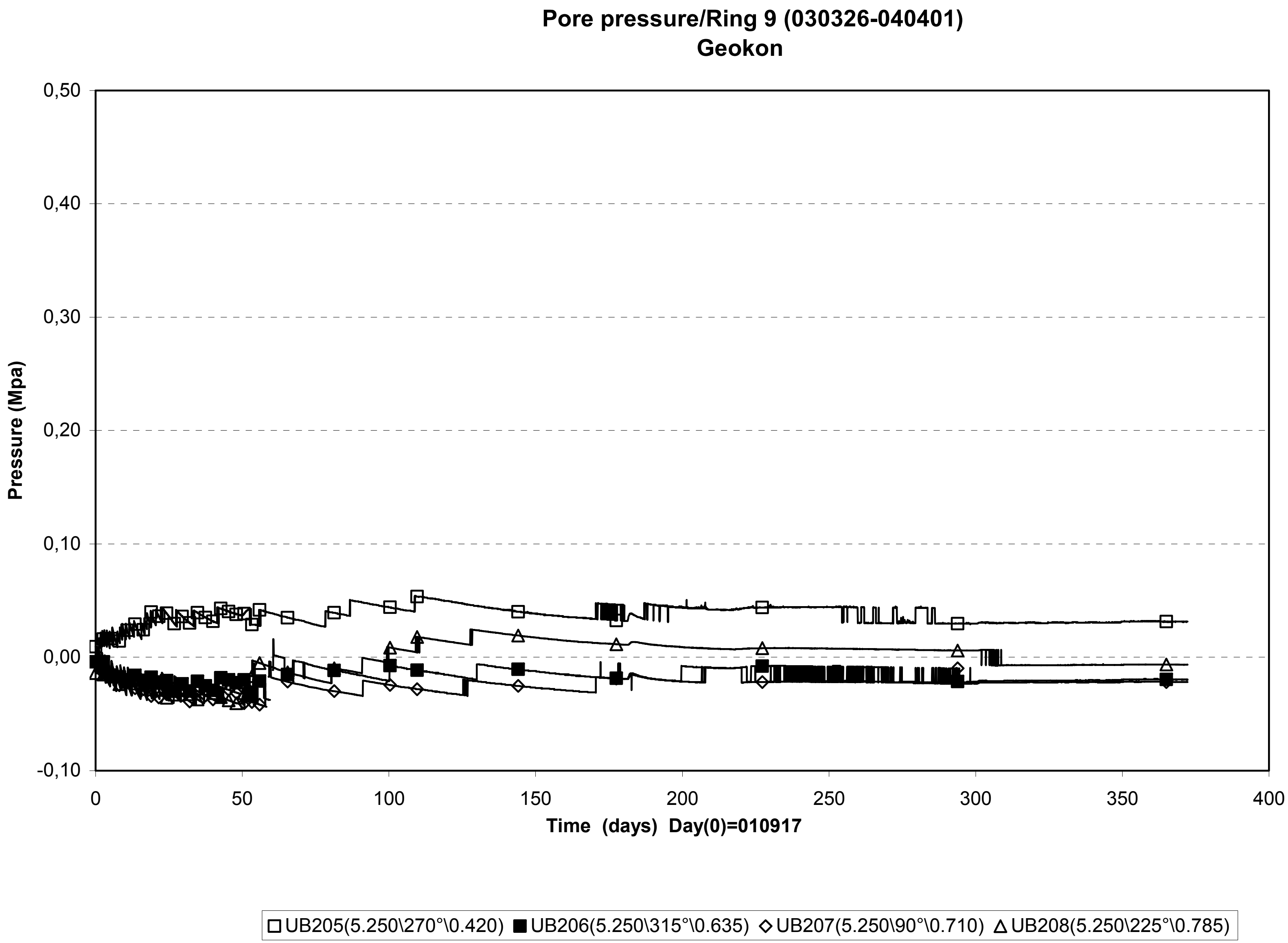

TBT\Cyl.3 (030326-040401)
Relative humidity - Vaisala & Rotronic
Relative humidity(%)\Temperature(°C)
100
90
80
70
60
50
40
30
20
10
0
0
50
100
150
200
250
300
350
400
Time(days) day0=030326
WB231(7250\ 180°\420)
WB232(7250\225°\635)
WB234(7250\ 270°\785)
z
A
r
α
B
D
C
C4
C3
R12
R11
R10
R9
R8
R7
C2
R6
R5
R4
R3
R2
R1
C1



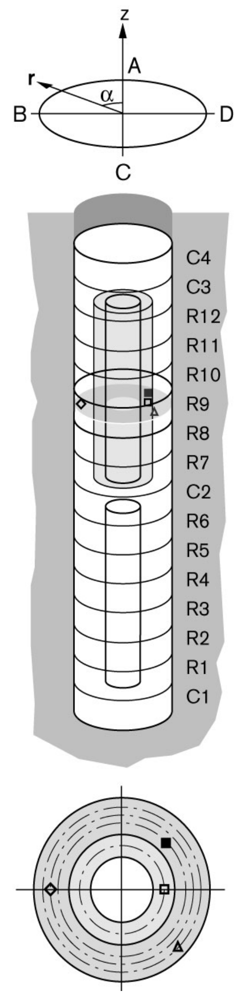
Pore pressure/Ring 3 (030326-040401)
Geokon
Pressure (Mpa)
0,50
0,40
0,30
0,20
0,10
0,00
-0,10
0
50
100
150
200
250
300
350
400
Time (days) Day(0)=010917
UB201(1.750\270°\0.420\R) UB202(1.750\350°\0.535\R) UB203(1.750\90°\0.635) UB204(1.750\280°\0.785)



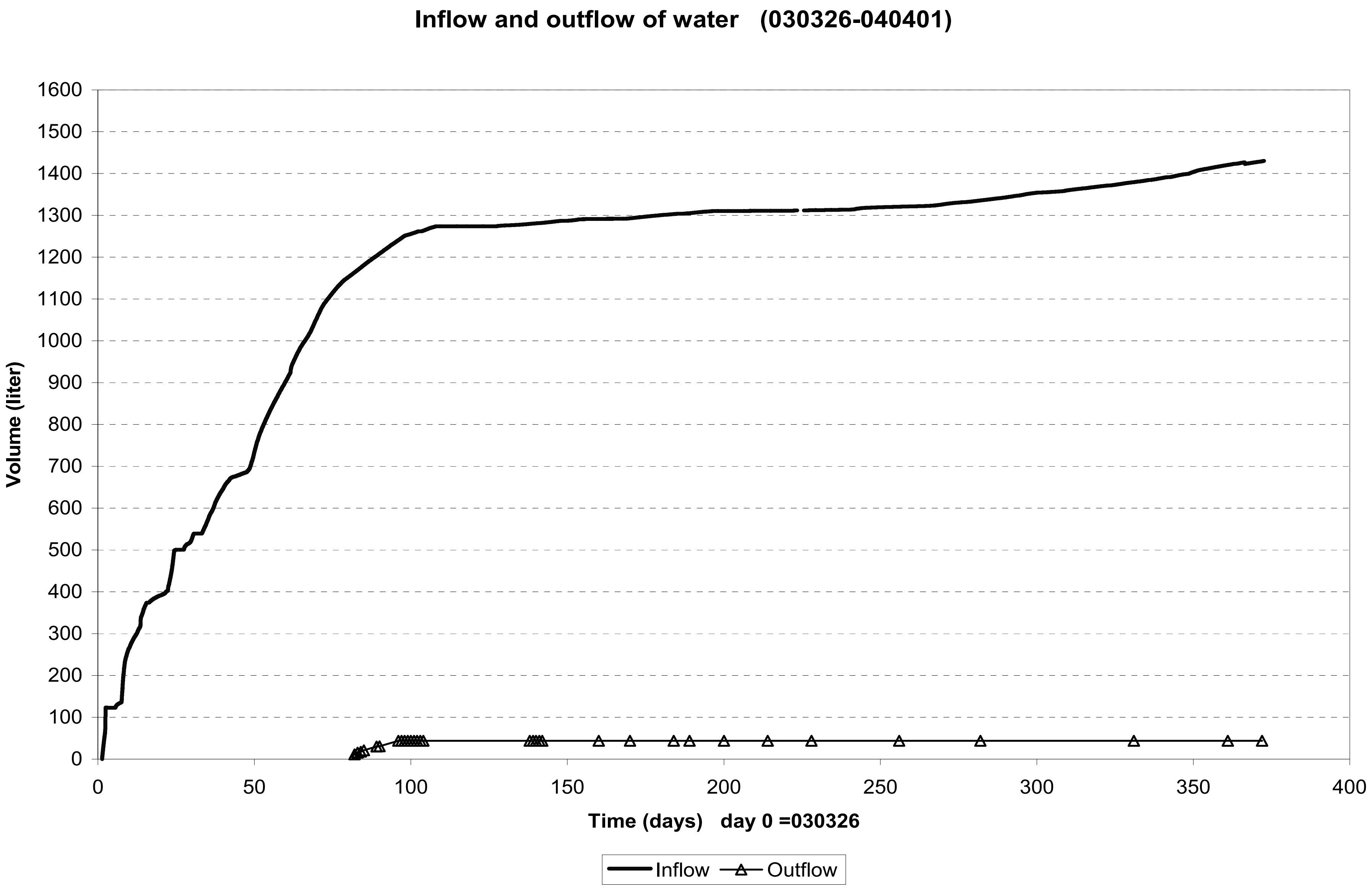
z
A
r
α
B
D
C
C4
C3
R12
R11
R10
R9
R8
R7
C2
R6
R5
R4
R3
R2
R1
C1

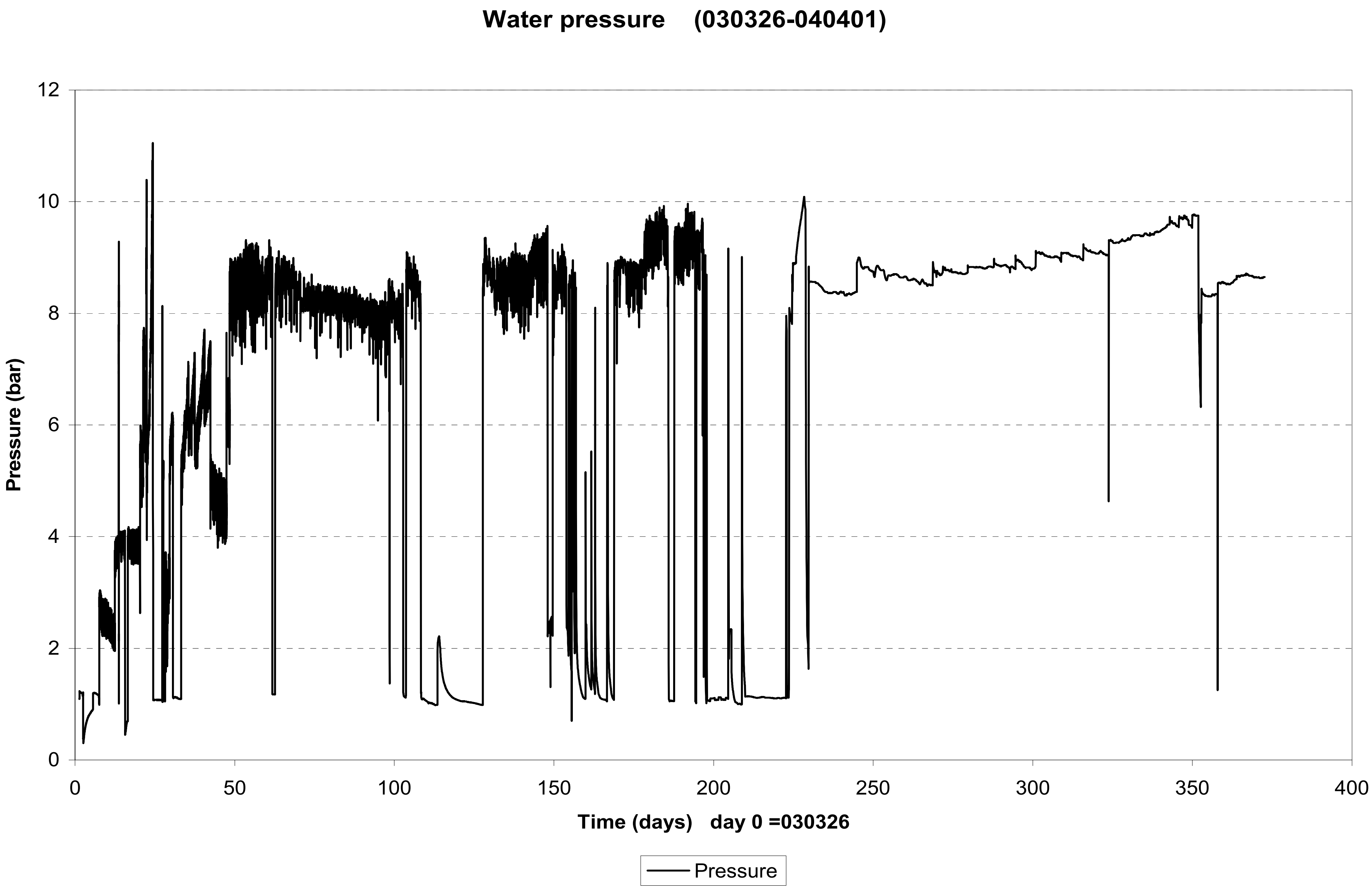


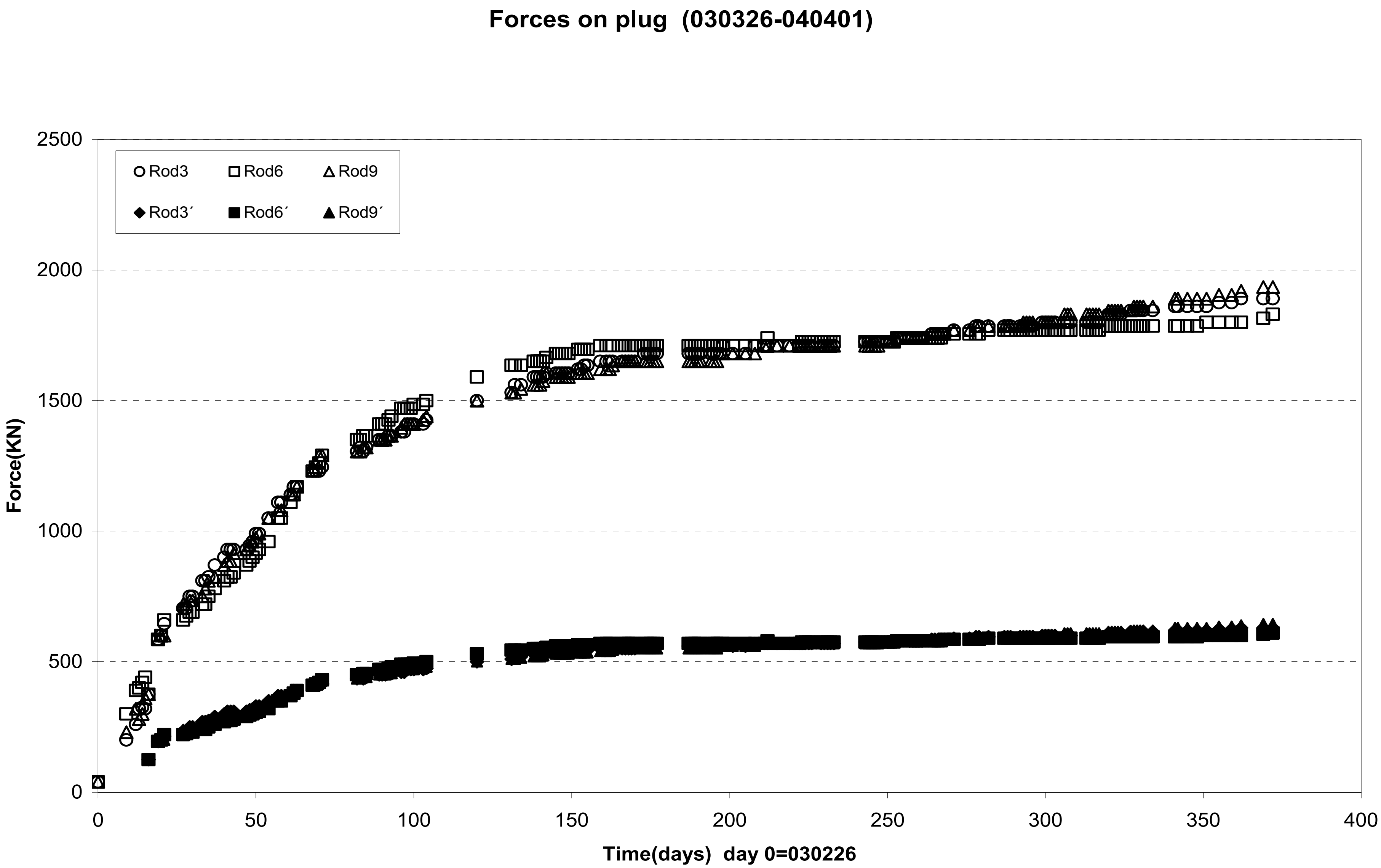
Pore pressure/Ring 9 (030326-040401)
Geokon
0,50
0,40
0,30
0,20
0,10
0,00
-0,10
Pressure (Mpa)
0
50
100
150
200
250
300
350
400
Time (days) Day(0)=010917
□ UB205(5.250\270°\0.420) ■ UB206(5.250\315°\0.635) ◇ UB207(5.250\90°\0.710) △ UB208(5.250\225°\0.785)

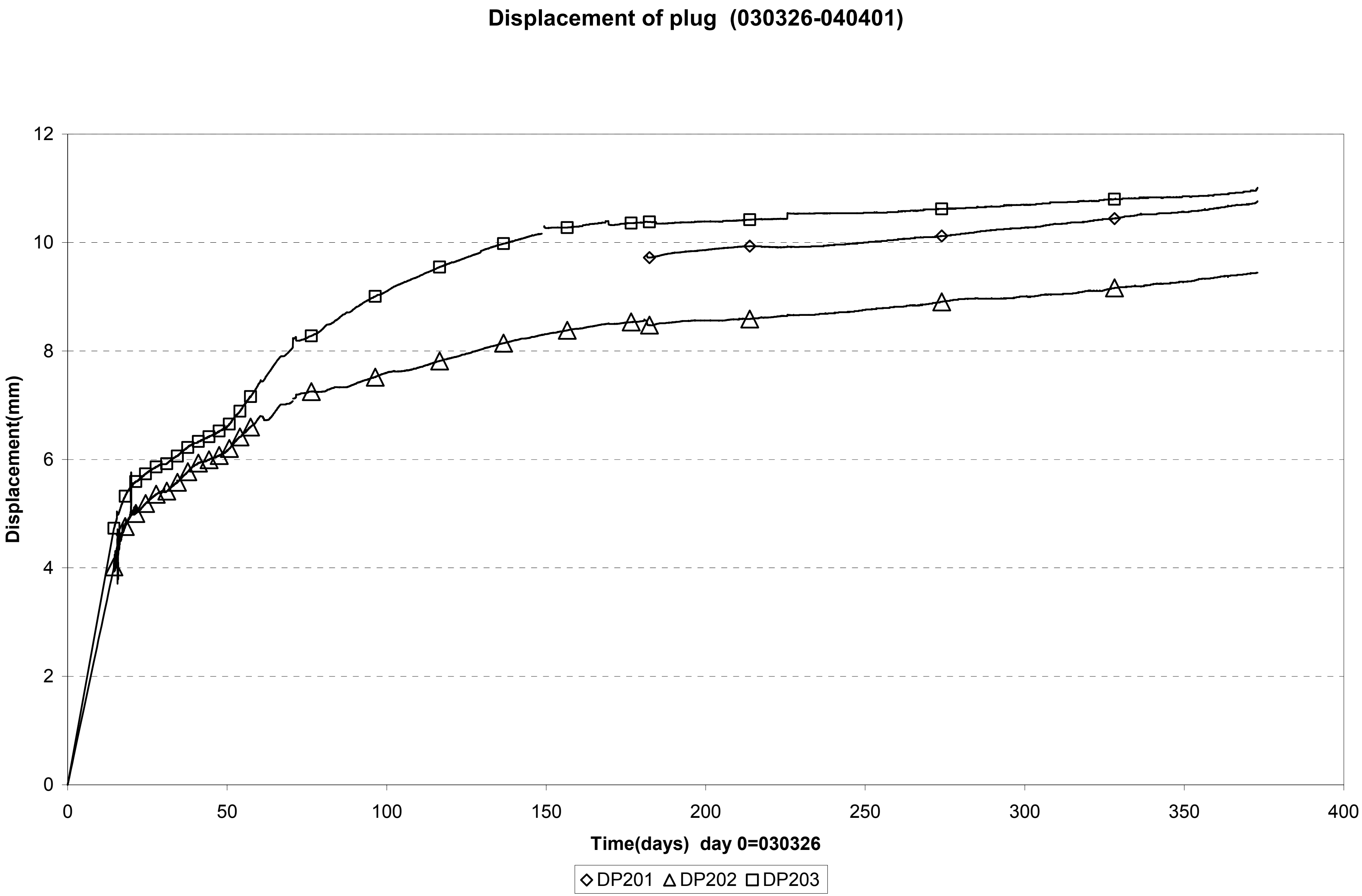


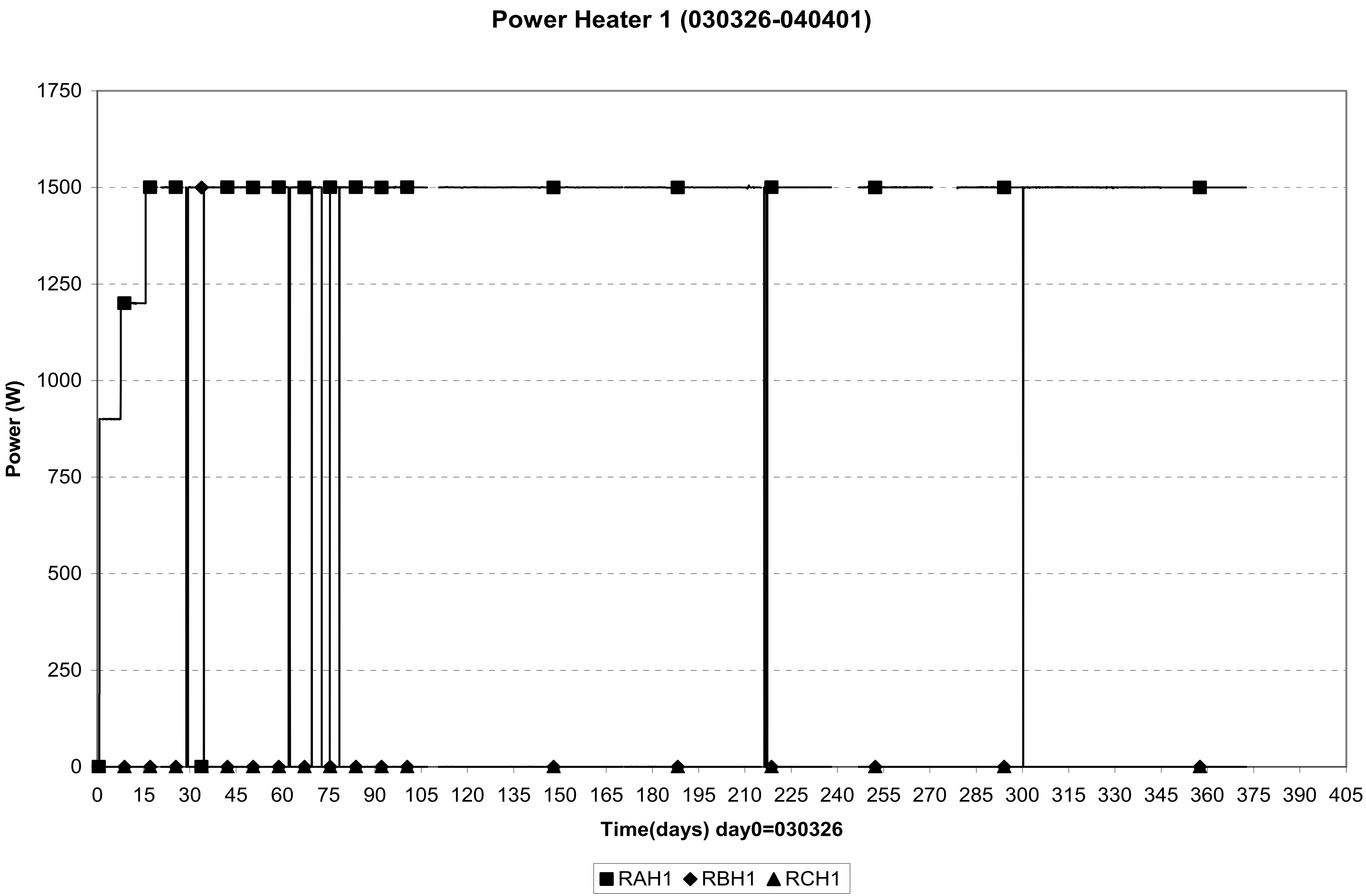
z
A
r
α
B
D
C
C4
C3
R12
R11
R10
R9
R8
R7
C2
R6
R5
R4
R3
R2
R1
C1


Inflow and outflow of water (030326-040401)
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
Volume (liter)
0
50
100
150
200
250
300
350
400
Time (days) day 0 =030326
Inflow
Outflow

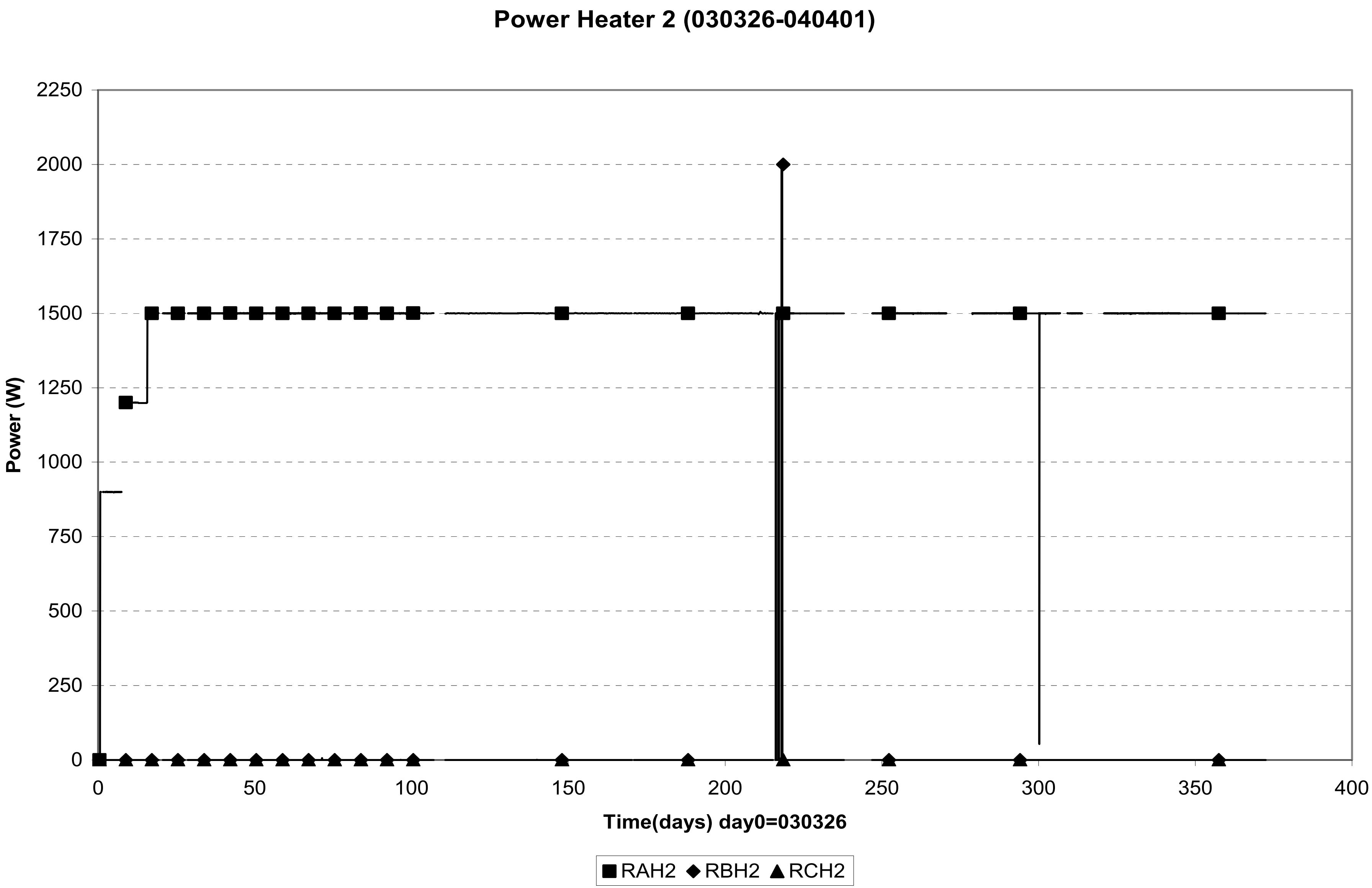

Water pressure (030326-040401)
12
10
8
6
4
2
0
Pressure (bar)
0
50
100
150
200
250
300
350
400
Time (days) day 0 =030326
Pressure

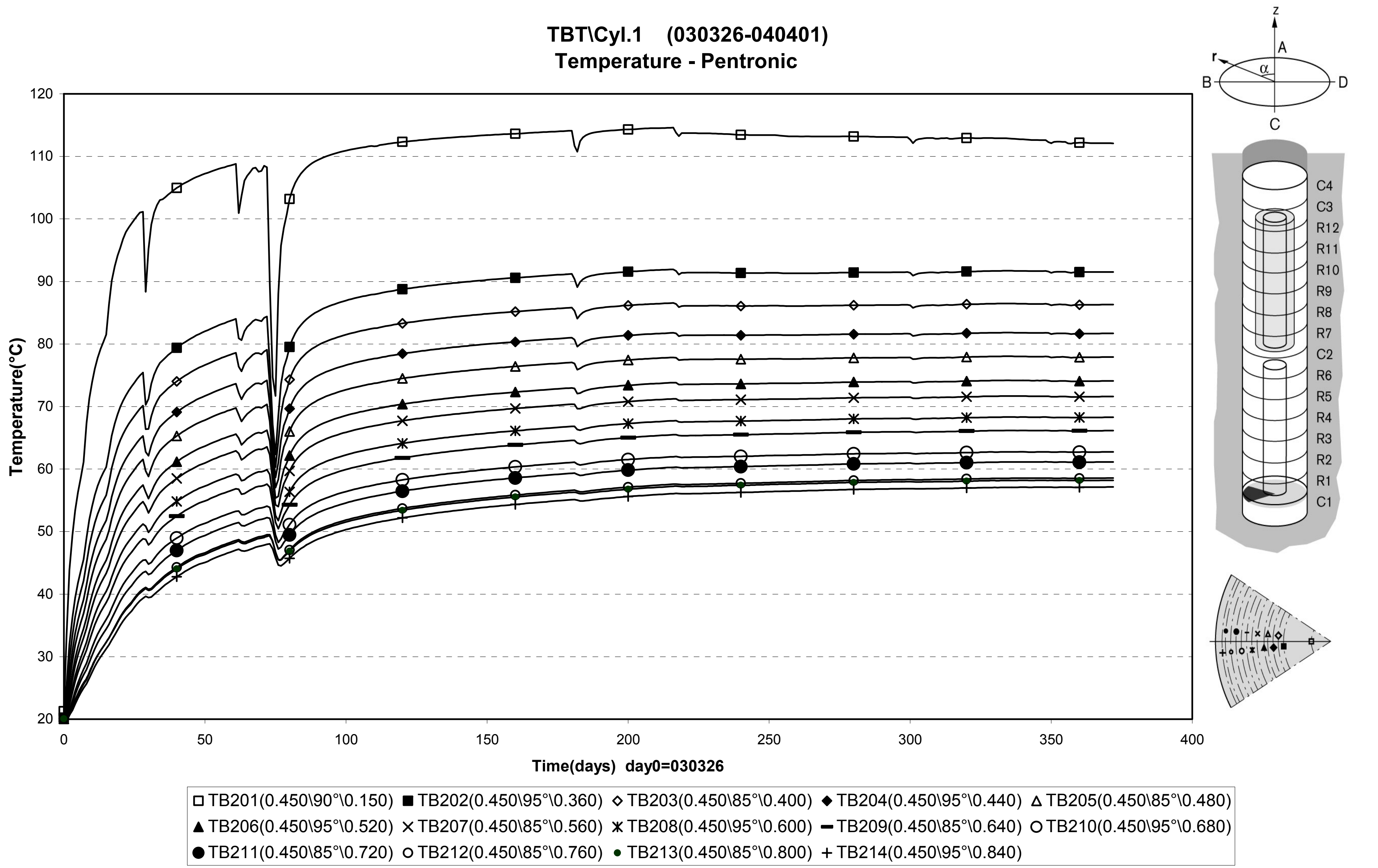

Forces on plug (030326-040401)
2500
2000
1500
1000
500
0
0
50
100
150
200
250
300
350
400
Rod3
Rod6
Rod9
Rod3´
Rod6´
Rod9´
Force(KN)
Time(days) day 0=030226

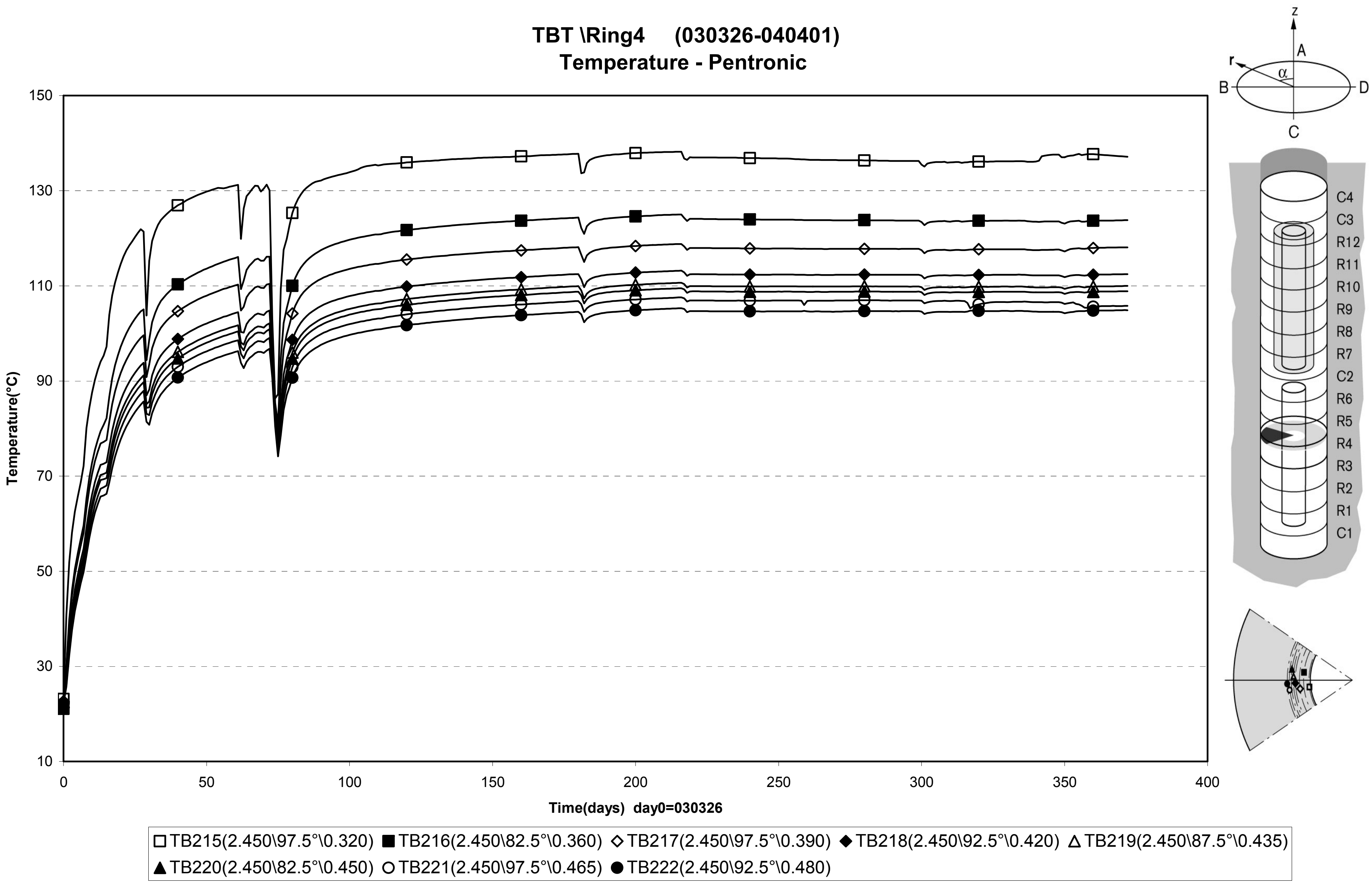

Displacement of plug (030326-040401)
Displacement(mm)
0
2
4
6
8
10
12
0
50
100
150
200
250
300
350
400
Time(days) day 0=030326
DP201 DP202 DP203

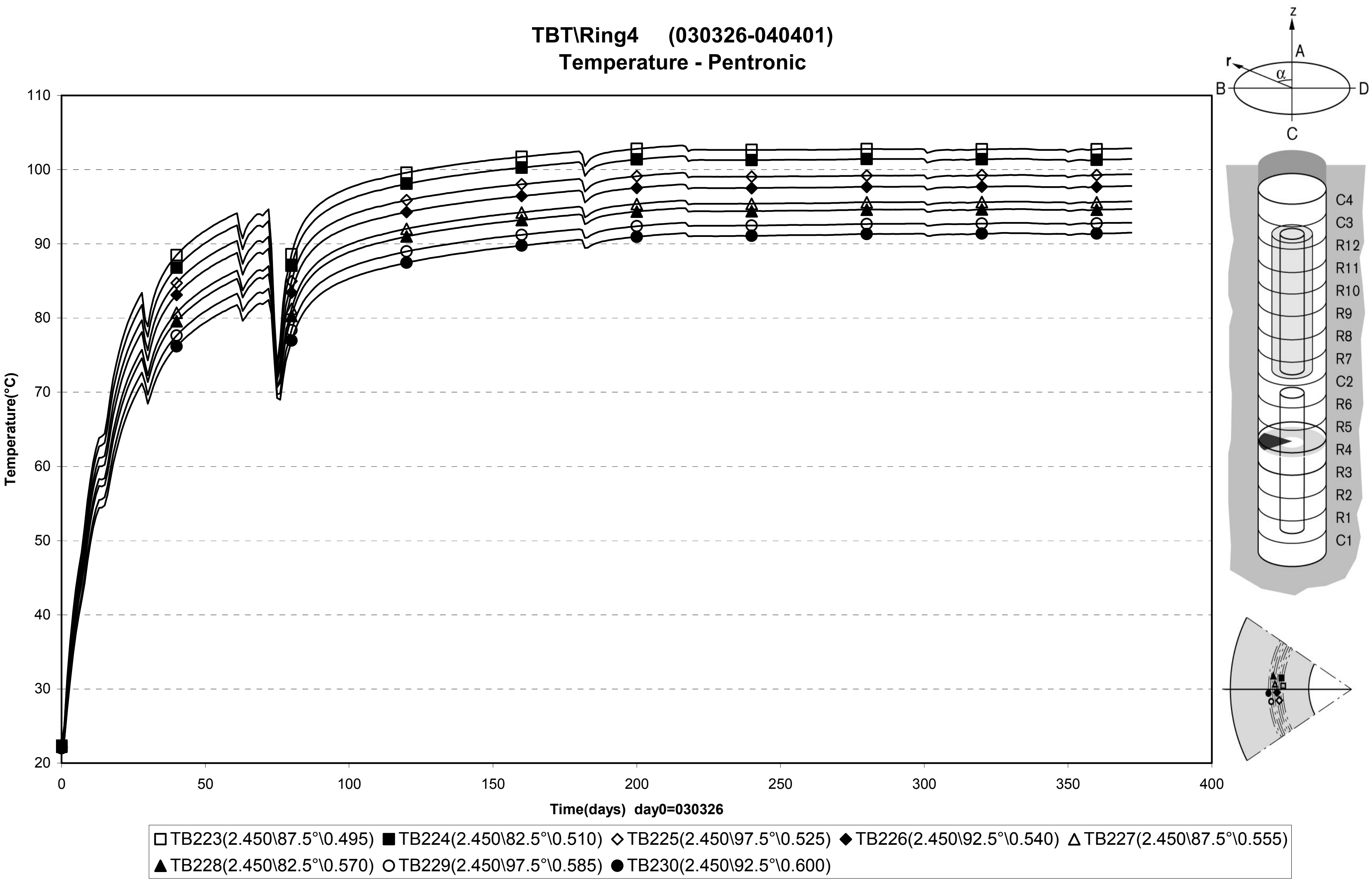


Power Heater 1 (030326-040401)
1750
1500
1250
1000
750
500
250
0
Power (W)
0 15 30 45 60 75 90 105 120 135 150 165 180 195 210 225 240 255 270 285 300 315 330 345 360 375 390 405
Time(days) day0=030326
RAH1 RBH1 RCH1

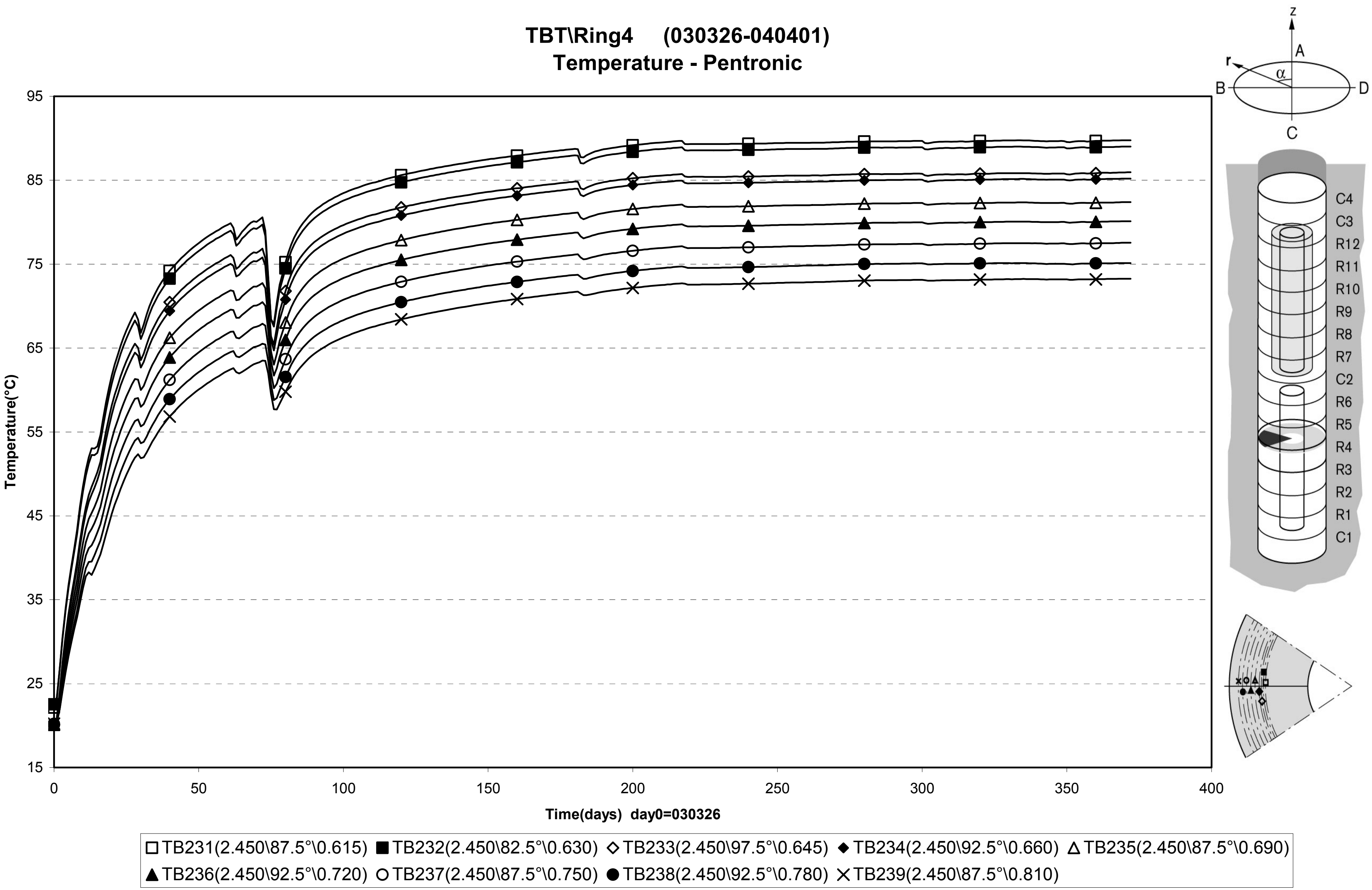

Power Heater 2 (030326-040401)
2250
2000
1750
1500
1250
1000
750
500
250
0
Power (W)
0
50
100
150
200
250
300
350
400
Time(days) day0=030326
RAH2
RBH2
RCH2

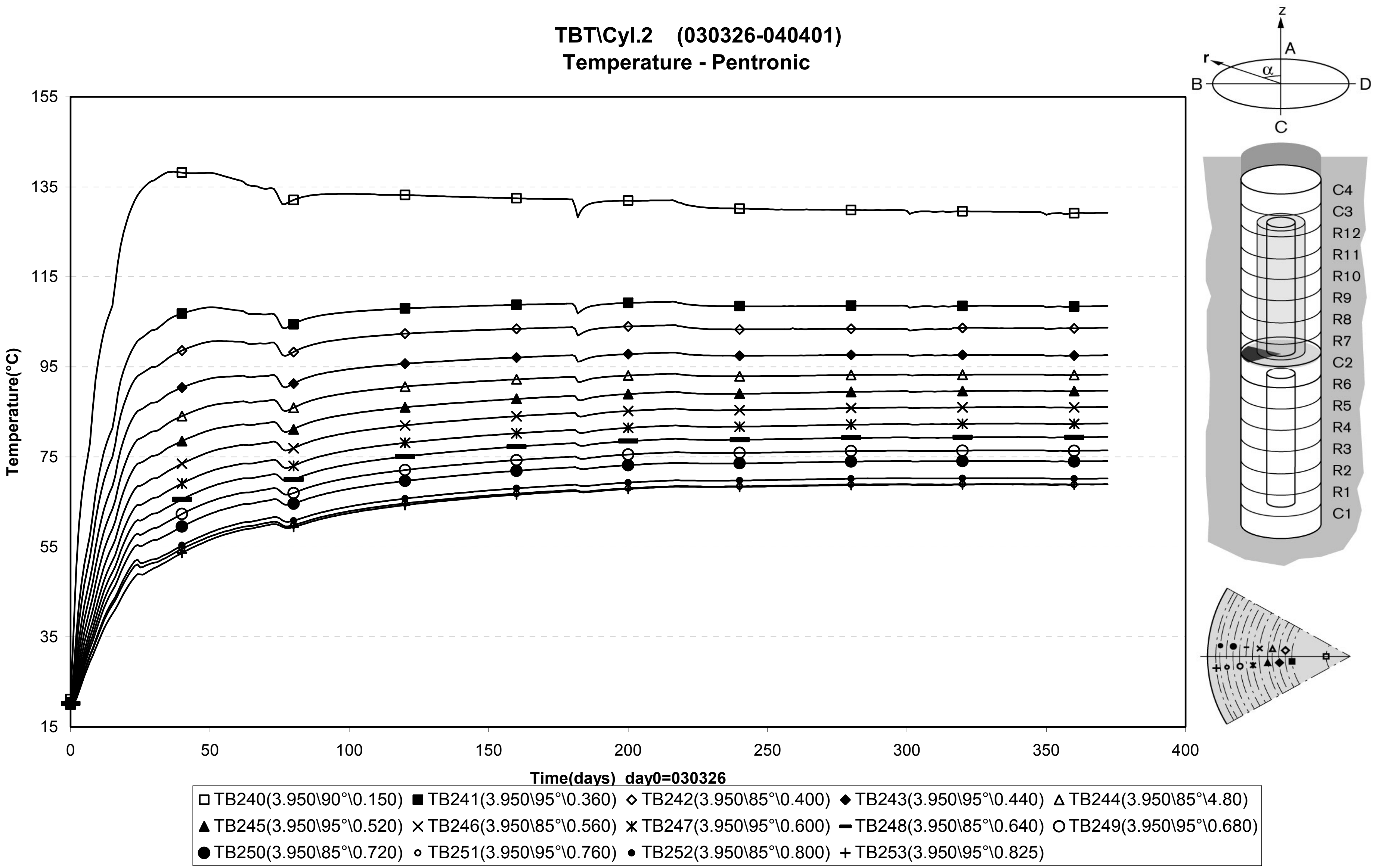

TBT\Cyl.1 (030326-040401)
Temperature - Pentronic
Temperature(°C)
Time(days) day0=030326
TB201(0.450\90°\0.150)
TB202(0.450\95°\0.360)
TB203(0.450\85°\0.400)
TB204(0.450\95°\0.440)
TB205(0.450\85°\0.480)
TB206(0.450\95°\0.520)
TB207(0.450\85°\0.560)
TB208(0.450\95°\0.600)
TB209(0.450\85°\0.640)
TB210(0.450\95°\0.680)
TB211(0.450\85°\0.720)
TB212(0.450\85°\0.760)
TB213(0.450\85°\0.800)
TB214(0.450\95°\0.840)
z
A
B
C
D
r
α
C4
C3
R12
R11
R10
R9
R8
R7
C2
R6
R5
R4
R3
R2
R1
C1


TBT \Ring4 (030326-040401)
Temperature - Pentronic
Temperature(°C)
Time(days) day0=030326
TB215(2.450\97.5°\0.320)
TB216(2.450\82.5°\0.360)
TB217(2.450\97.5°\0.390)
TB218(2.450\92.5°\0.420)
TB219(2.450\87.5°\0.435)
TB220(2.450\82.5°\0.450)
TB221(2.450\97.5°\0.465)
TB222(2.450\92.5°\0.480)
z
A
r
α
B
D
C
C4
C3
R12
R11
R10
R9
R8
R7
C2
R6
R5
R4
R3
R2
R1
C1

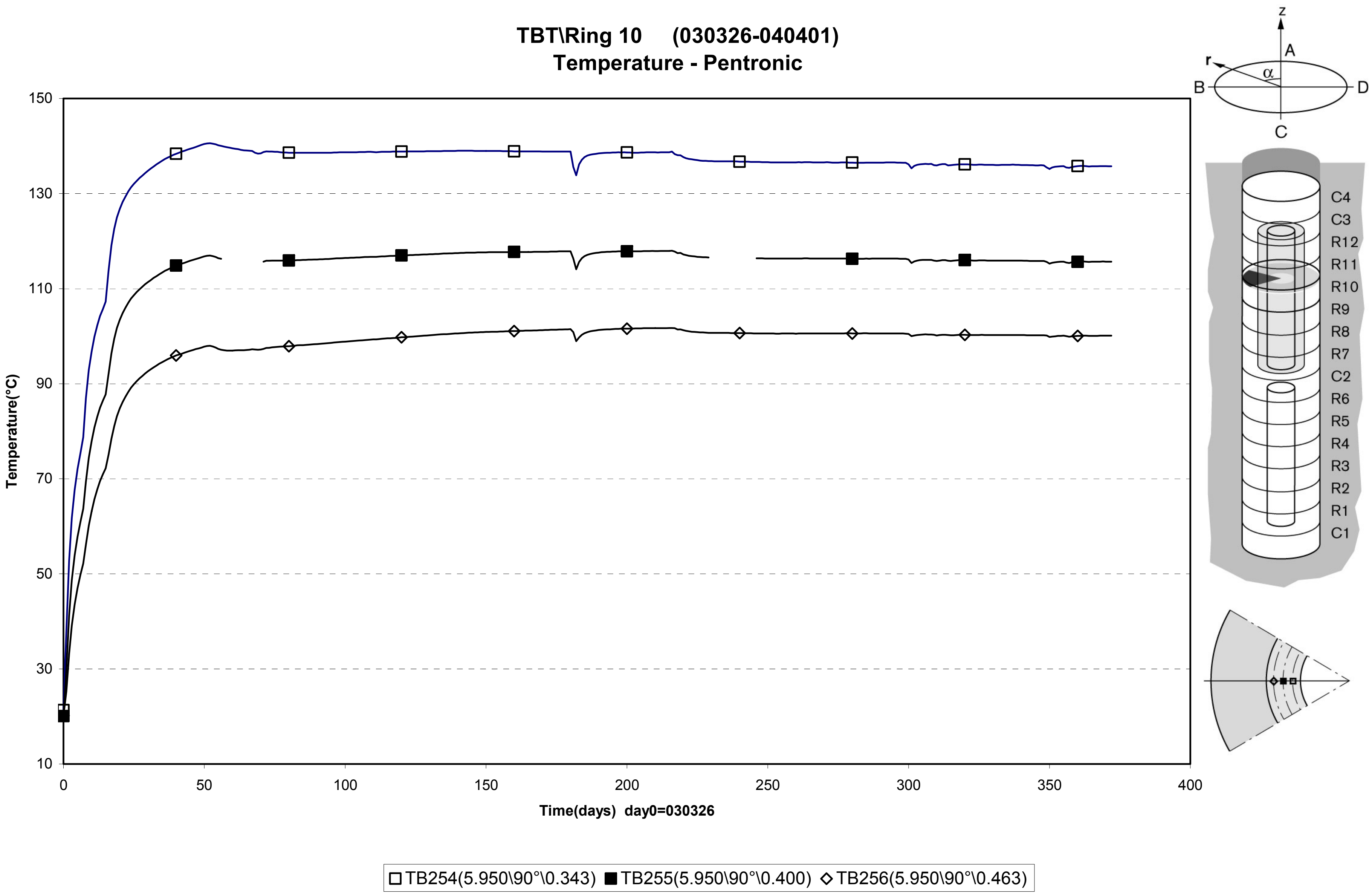


TBT\Ring4 (030326-040401)
Temperature - Pentronic
Temperature(°C)
Time(days) day0=030326
TB223(2.450\87.5°\0.495) TB224(2.450\82.5°\0.510) TB225(2.450\97.5°\0.525) TB226(2.450\92.5°\0.540) TB227(2.450\87.5°\0.555)
TB228(2.450\82.5°\0.570) TB229(2.450\97.5°\0.585) TB230(2.450\92.5°\0.600)
z
A
B
C
D
r
α
C4
C3
R12
R11
R10
R9
R8
R7
C2
R6
R5
R4
R3
R2
R1
C1

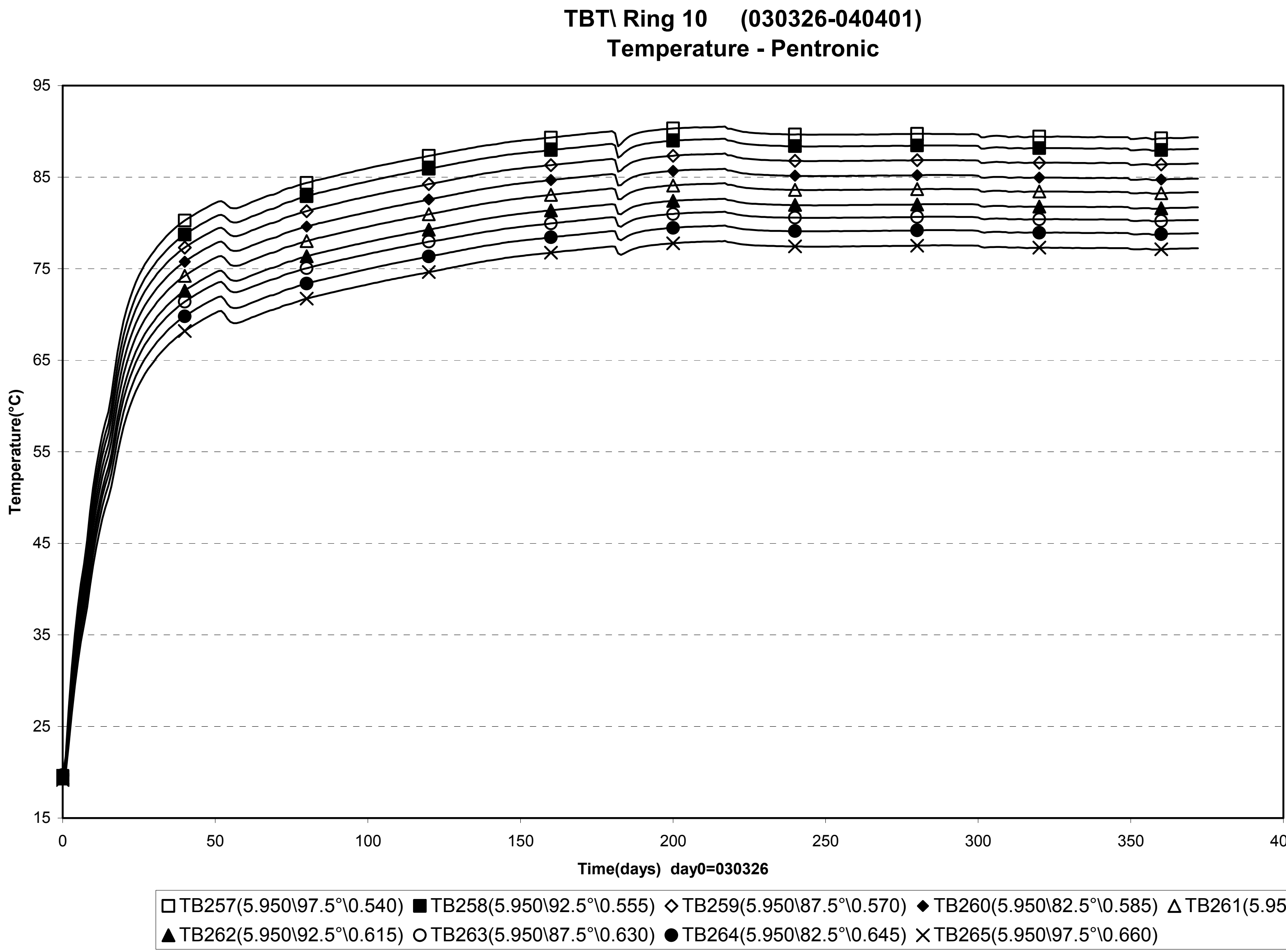

TBT\Ring4 (030326-040401)
Temperature - Pentronic
Temperature(°C)
95
85
75
65
55
45
35
25
15
0
50
100
150
200
250
300
350
400
Time(days) day0=030326
TB231(2.450\87.5°\0.615)
TB232(2.450\82.5°\0.630)
TB233(2.450\97.5°\0.645)
TB234(2.450\92.5°\0.660)
TB235(2.450\87.5°\0.690)
TB236(2.450\92.5°\0.720)
TB237(2.450\87.5°\0.750)
TB238(2.450\92.5°\0.780)
TB239(2.450\87.5°\0.810)
z
A
r
α
B
D
C
C4
C3
R12
R11
R10
R9
R8
R7
C2
R6
R5
R4
R3
R2
R1
C1

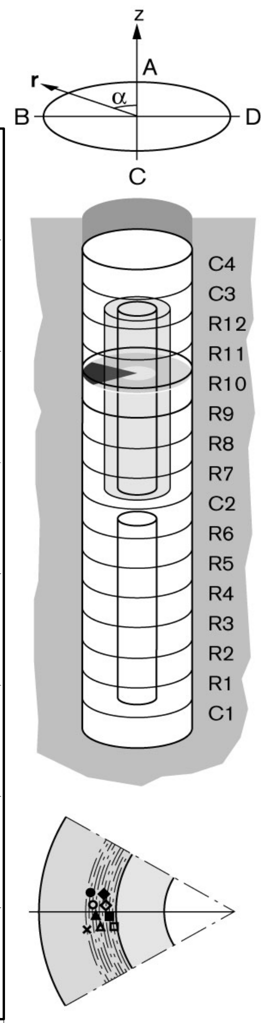


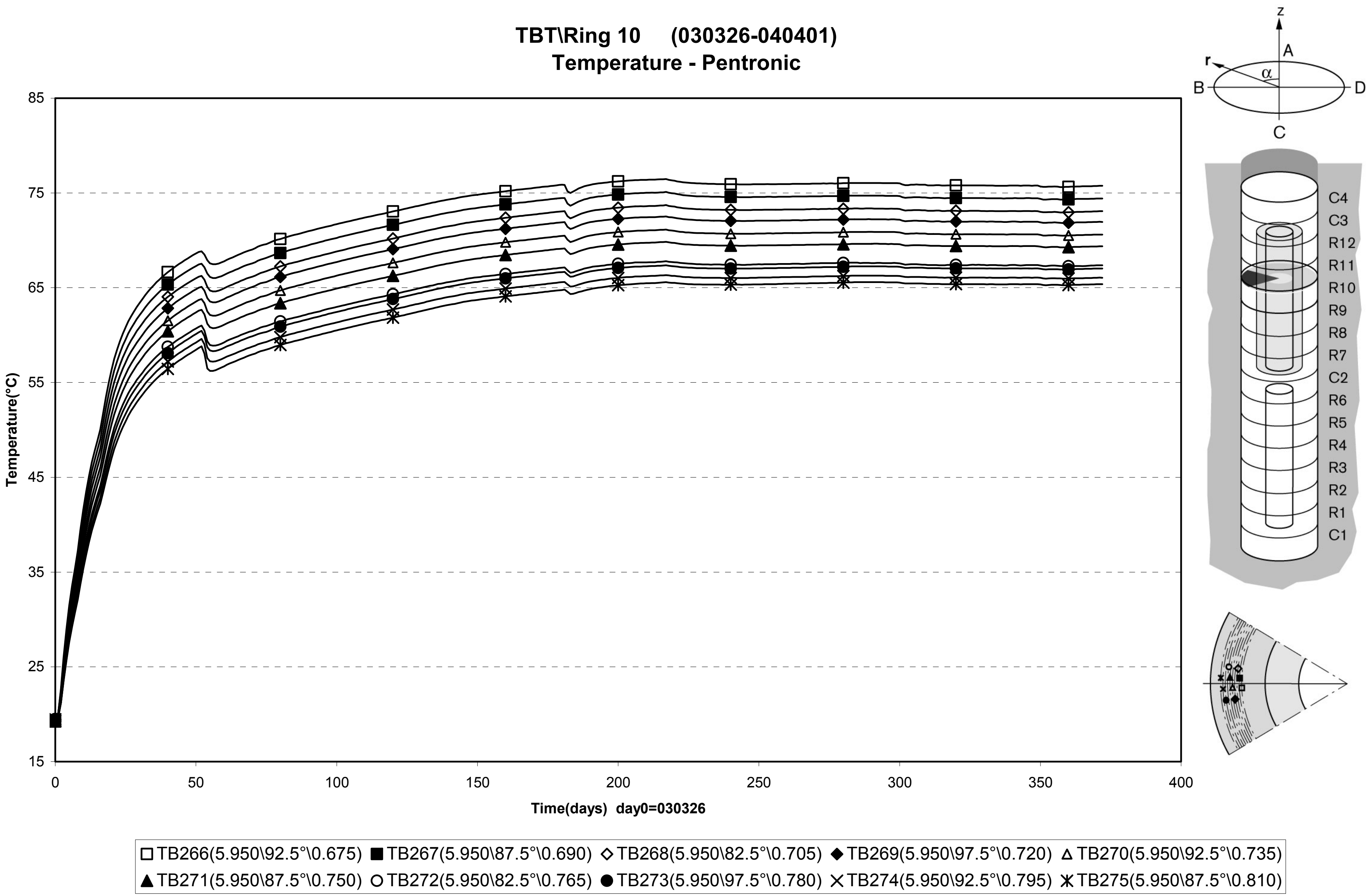
TBT\Cyl.2 (030326-040401)
Temperature - Pentronic
Temperature(°C)
155
135
115
95
75
55
35
15
0
50
100
150
200
250
300
350
400
Time(days) day0=030326
TB240(3.950\90°\0.150)
TB241(3.950\95°\0.360)
TB242(3.950\85°\0.400)
TB243(3.950\95°\0.440)
TB244(3.950\85°\4.80)
TB245(3.950\95°\0.520)
TB246(3.950\85°\0.560)
TB247(3.950\95°\0.600)
TB248(3.950\85°\0.640)
TB249(3.950\95°\0.680)
TB250(3.950\85°\0.720)
TB251(3.950\95°\0.760)
TB252(3.950\85°\0.800)
TB253(3.950\95°\0.825)
z
A
r
α
B
D
C
C4
C3
R12
R11
R10
R9
R8
R7
C2
R6
R5
R4
R3
R2
R1
C1

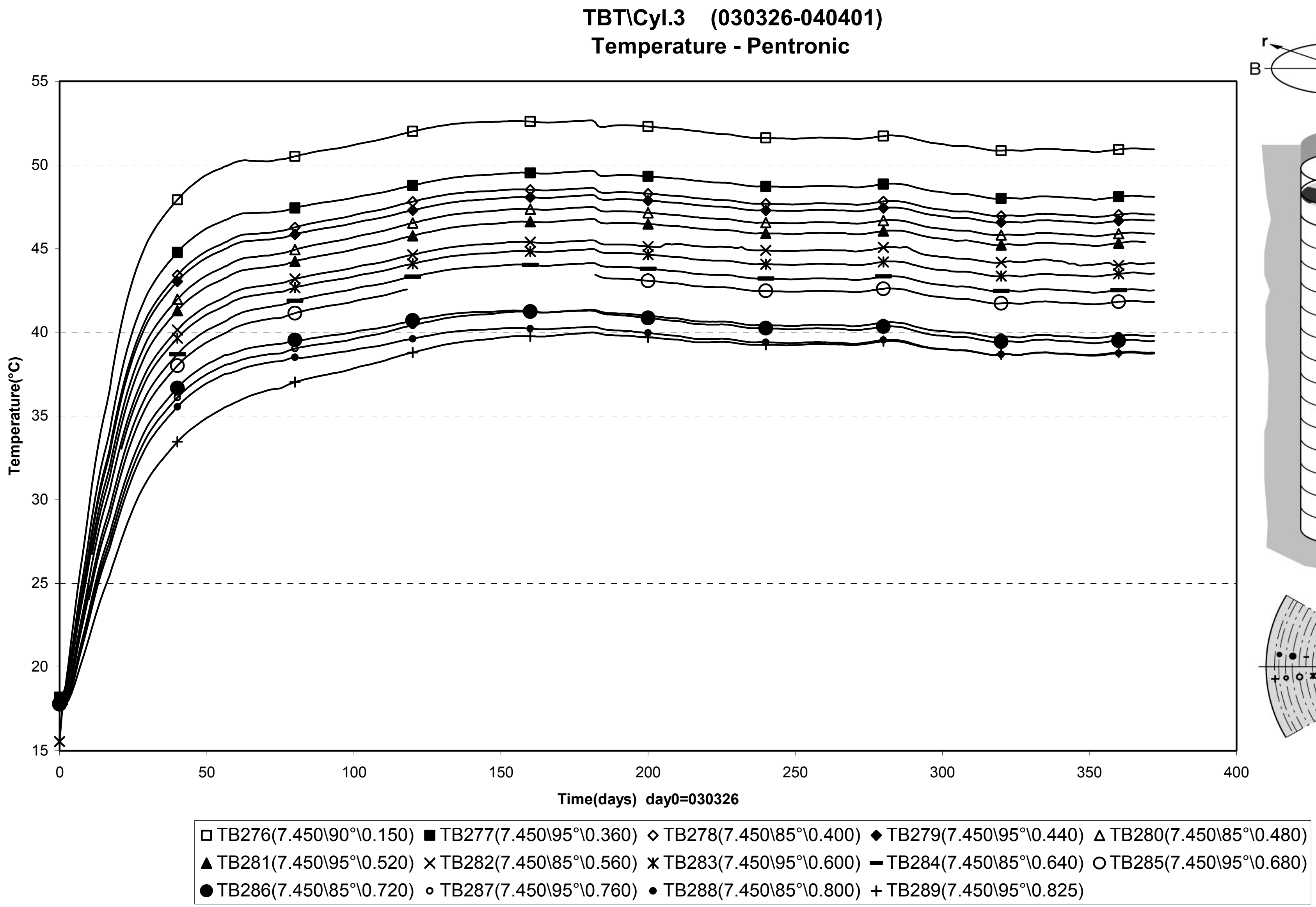


TBT\Ring 10 (030326-040401)
Temperature - Pentronic
Temperature(°C)
Time(days) day0=030326
150
130
110
90
70
50
30
10
0
50
100
150
200
250
300
350
400
z
A
B
C
D
r
α
C4
C3
R12
R11
R10
R9
R8
R7
C2
R6
R5
R4
R3
R2
R1
C1
□TB254(5.950\90°\0.343) ■TB255(5.950\90°\0.400) ◇TB256(5.950\90°\0.463)

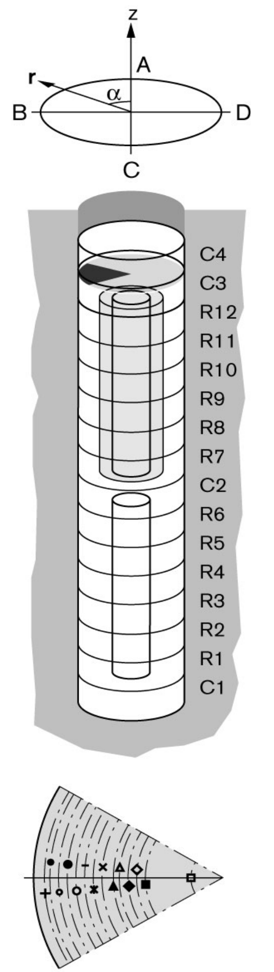

TBT\ Ring 10 (030326-040401)
Temperature - Pentronic
Temperature(°C)
Time(days) day0=030326
95
85
75
65
55
45
35
25
15
0
50
100
150
200
250
300
350
400
TB257(5.950\97.5°\0.540)
TB258(5.950\92.5°\0.555)
TB259(5.950\87.5°\0.570)
TB260(5.950\82.5°\0.585)
TB261(5.950\97.5°\0.600)
TB262(5.950\92.5°\0.615)
TB263(5.950\87.5°\0.630)
TB264(5.950\82.5°\0.645)
TB265(5.950\97.5°\0.660)


z
A
r
α
B
D
C
C4
C3
R12
R11
R10
R9
R8
R7
C2
R6
R5
R4
R3
R2
R1
C1

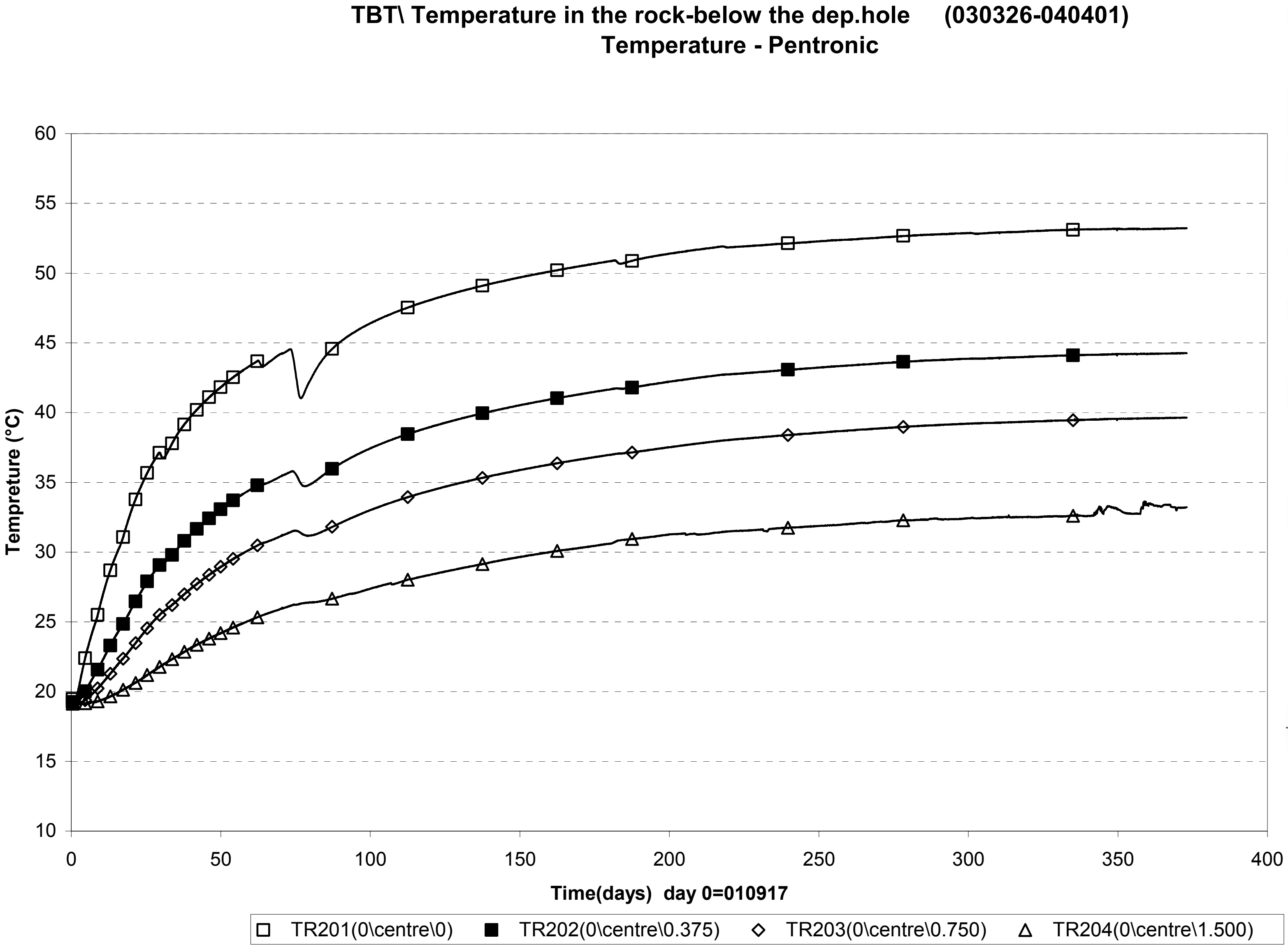

TBT\Ring 10 (030326-040401)
Temperature - Pentronic
Temperature(°C)
Time(days) day0=030326
85
75
65
55
45
35
25
15
0
50
100
150
200
250
300
350
400
□TB266(5.950\92.5°\0.675) ■TB267(5.950\87.5°\0.690) ◇TB268(5.950\82.5°\0.705) ◆TB269(5.950\97.5°\0.720) △TB270(5.950\92.5°\0.735)
▲TB271(5.950\87.5°\0.750) ○TB272(5.950\82.5°\0.765) ●TB273(5.950\97.5°\0.780) ×TB274(5.950\92.5°\0.795) ✳TB275(5.950\87.5°\0.810)
z
A
r
α
B
D
C
C4
C3
R12
R11
R10
R9
R8
R7
C2
R6
R5
R4
R3
R2
R1
C1

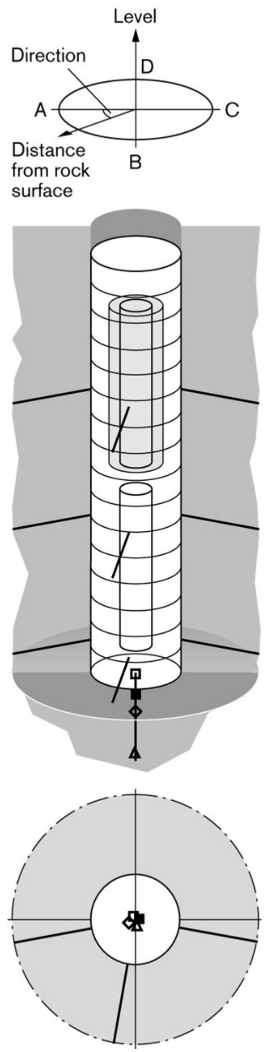


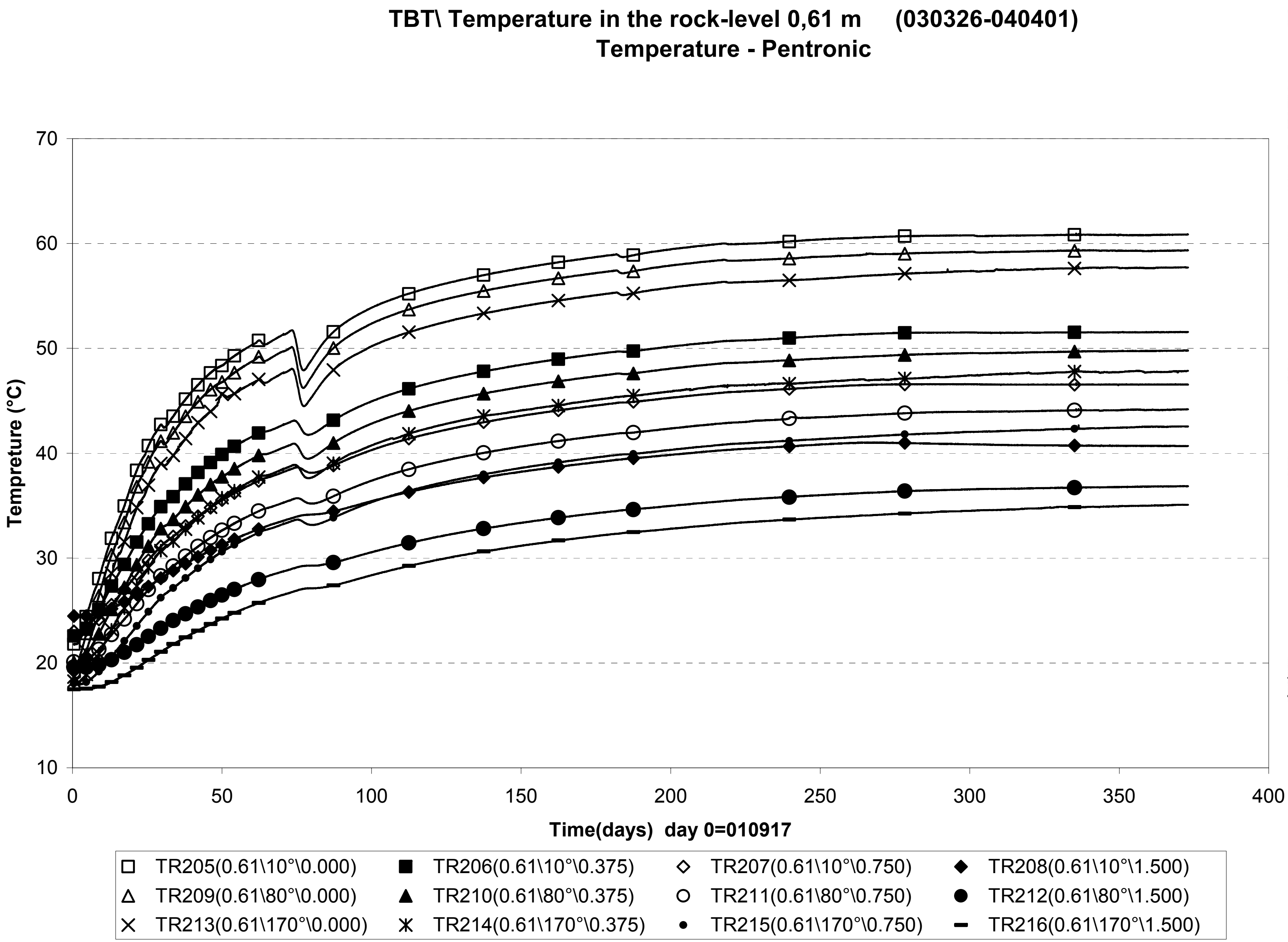
TBT\Cyl.3 (030326-040401)
Temperature - Pentronic
Temperature(°C)
55
50
45
40
35
30
25
20
15
0
50
100
150
200
250
300
350
400
Time(days) day0=030326
TB276(7.450\90°\0.150)
TB277(7.450\95°\0.360)
TB278(7.450\85°\0.400)
TB279(7.450\95°\0.440)
TB280(7.450\85°\0.480)
TB281(7.450\95°\0.520)
TB282(7.450\85°\0.560)
TB283(7.450\95°\0.600)
TB284(7.450\85°\0.640)
TB285(7.450\95°\0.680)
TB286(7.450\85°\0.720)
TB287(7.450\95°\0.760)
TB288(7.450\85°\0.800)
TB289(7.450\95°\0.825)



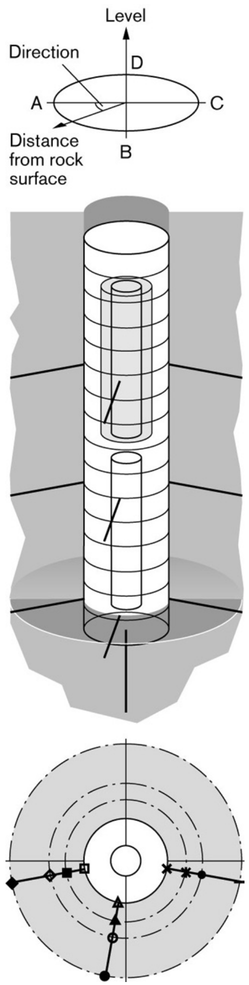
z
A
r
α
B
D
C
C4
C3
R12
R11
R10
R9
R8
R7
C2
R6
R5
R4
R3
R2
R1
C1


TBT\ Temperature in the rock-below the dep.hole (030326-040401)
Temperature - Pentronic
Tempreture (°C)
60
55
50
45
40
35
30
25
20
15
10
0
50
100
150
200
250
300
350
400
Time(days) day 0=010917
TR201(0\centre\0)
TR202(0\centre\0.375)
TR203(0\centre\0.750)
TR204(0\centre\1.500)


Level
Direction
D
A
C
Distance from rock surface
B

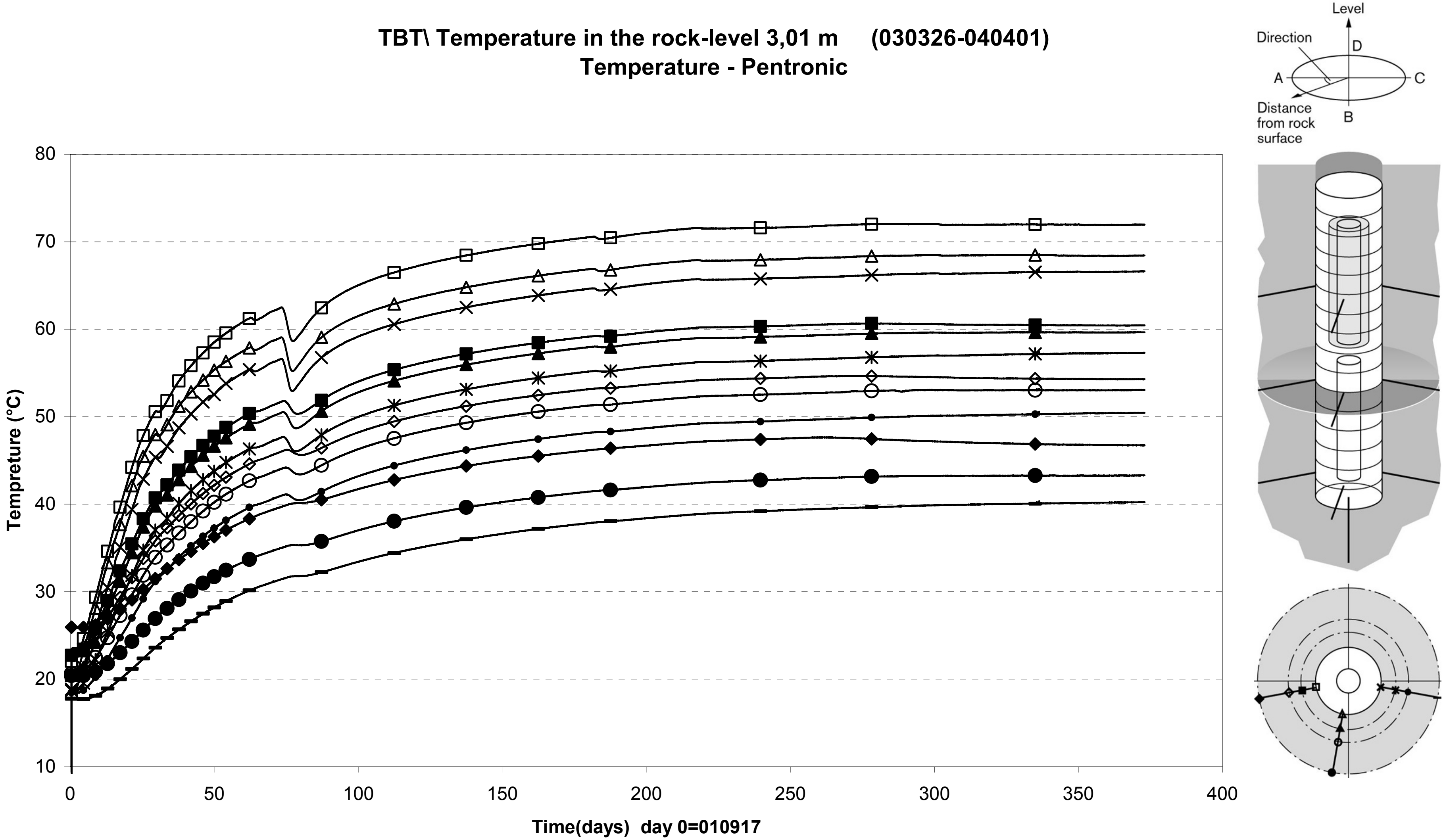


TBT\ Temperature in the rock-level 0,61 m (030326-040401)
Temperature - Pentronic
Tempreture (°C)
70
60
50
40
30
20
10
0
50
100
150
200
250
300
350
400
Time(days) day 0=010917
TR205(0.61\10°\0.000)
TR206(0.61\10°\0.375)
TR207(0.61\10°\0.750)
TR208(0.61\10°\1.500)
TR209(0.61\80°\0.000)
TR210(0.61\80°\0.375)
TR211(0.61\80°\0.750)
TR212(0.61\80°\1.500)
TR213(0.61\170°\0.000)
TR214(0.61\170°\0.375)
TR215(0.61\170°\0.750)
TR216(0.61\170°\1.500)

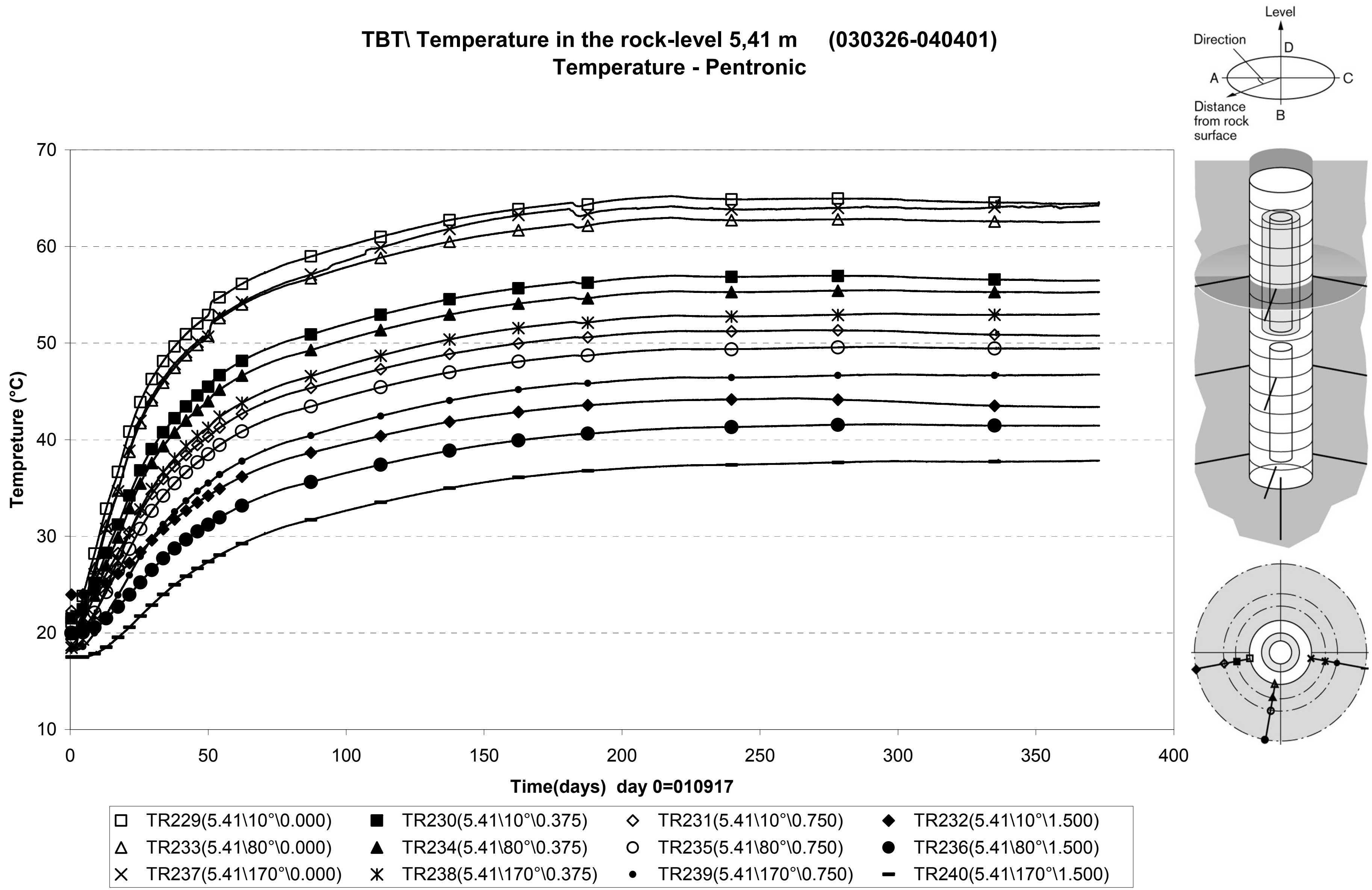


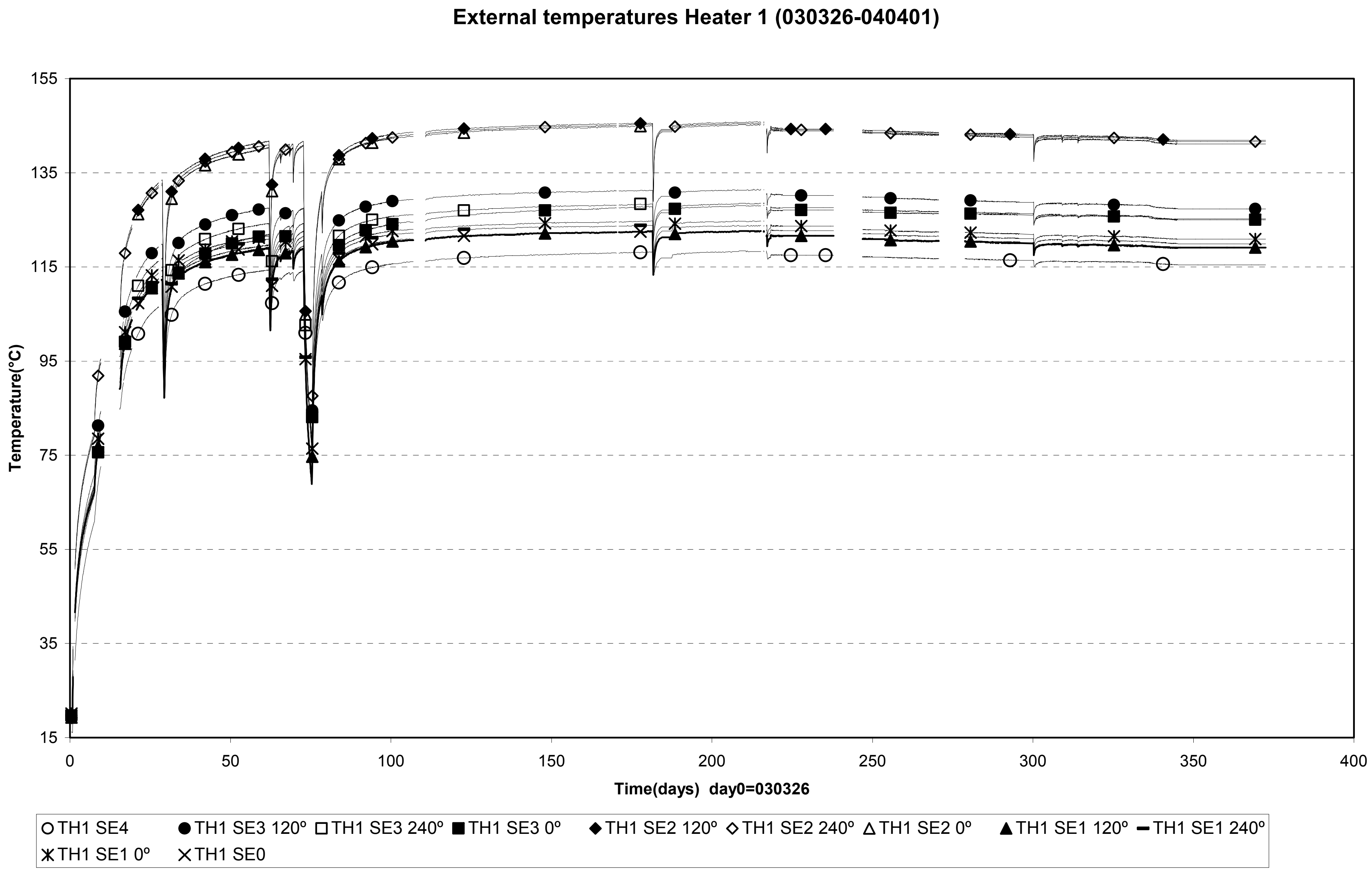
Level
Direction
D
A
C
B
Distance
from rock
surface

TBT\ Temperature in the rock-level 3,01 m (030326-040401)
Temperature - Pentronic

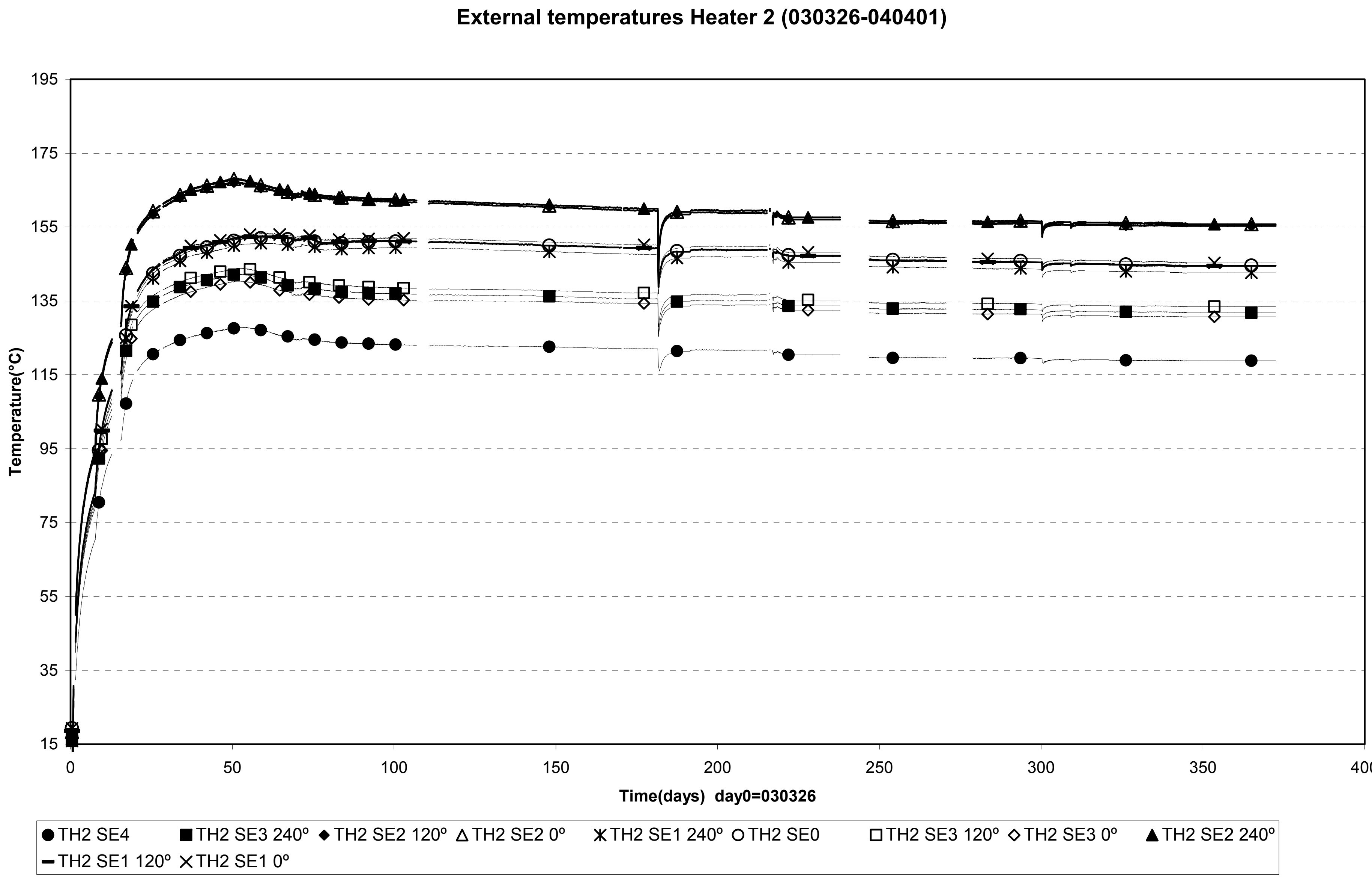


□ TR217(3.01\10°\0.000)	■ TR218(3.01\10°\0.375)	◇ TR219(3.01\10°\0.750)	◆ TR220(3.01\10°\1.500)
△ TR221(3.01\80°\0.000)	▲ TR222(3.01\80°\0.375)	○ TR223(3.01\80°\0.750)	● TR224(3.01\80°\1.500)
× TR225(3.01\170°\0.000)	✳ TR226(3.01\170°\0.375)	• TR227(3.01\170°\0.750)	▬ TR228(3.01\170°\1.500)

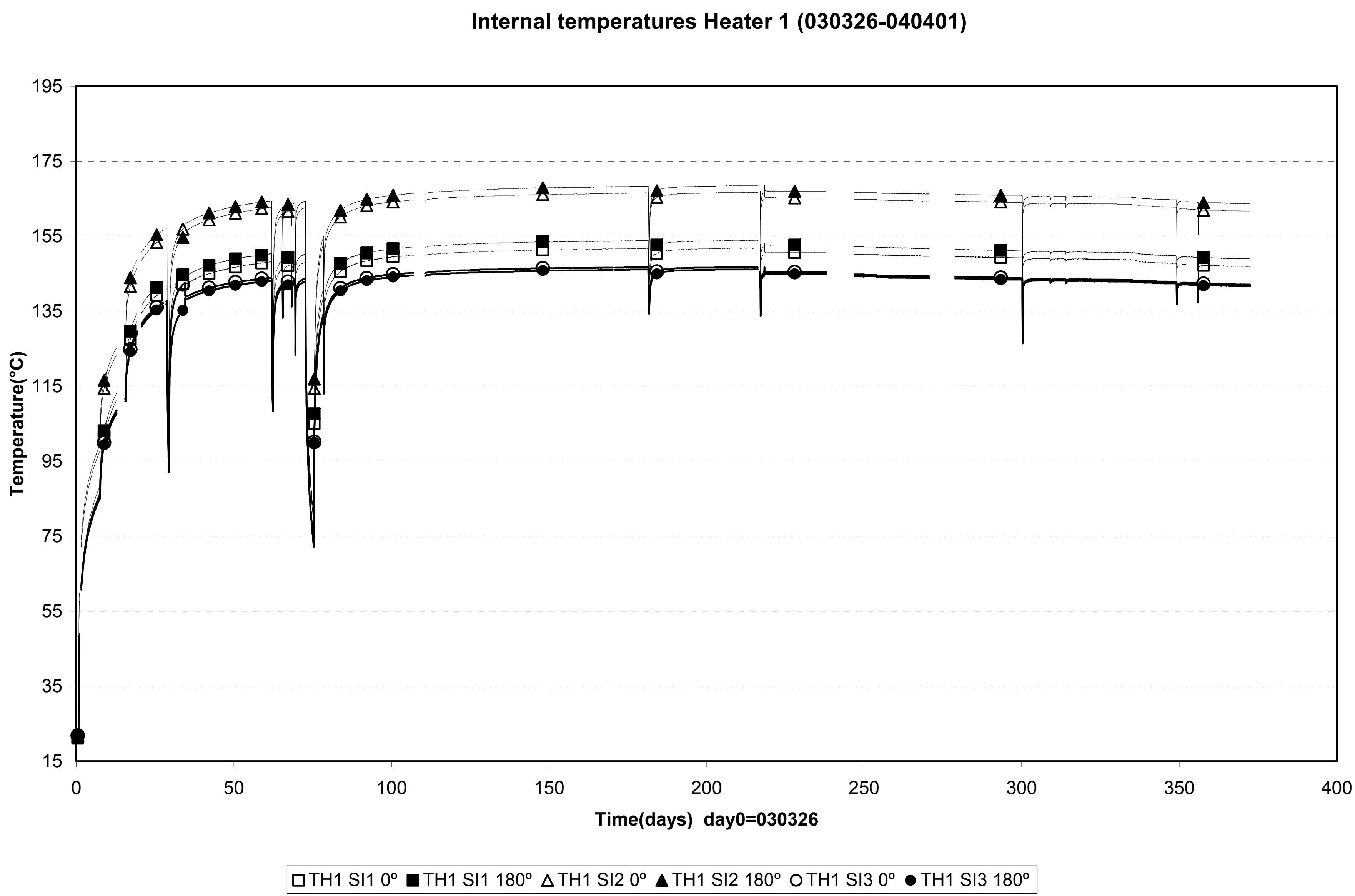

TBT\ Temperature in the rock-level 5,41 m (030326-040401)
Temperature - Pentronic
Level
Direction
D
A
C
B
Distance from rock surface
70
60
50
40
30
20
10
Tempreture (°C)
0
50
100
150
200
250
300
350
400
Time(days) day 0=010917
TR229(5.41\10°\0.000)
TR230(5.41\10°\0.375)
TR231(5.41\10°\0.750)
TR232(5.41\10°\1.500)
TR233(5.41\80°\0.000)
TR234(5.41\80°\0.375)
TR235(5.41\80°\0.750)
TR236(5.41\80°\1.500)
TR237(5.41\170°\0.000)
TR238(5.41\170°\0.375)
TR239(5.41\170°\0.750)
TR240(5.41\170°\1.500)

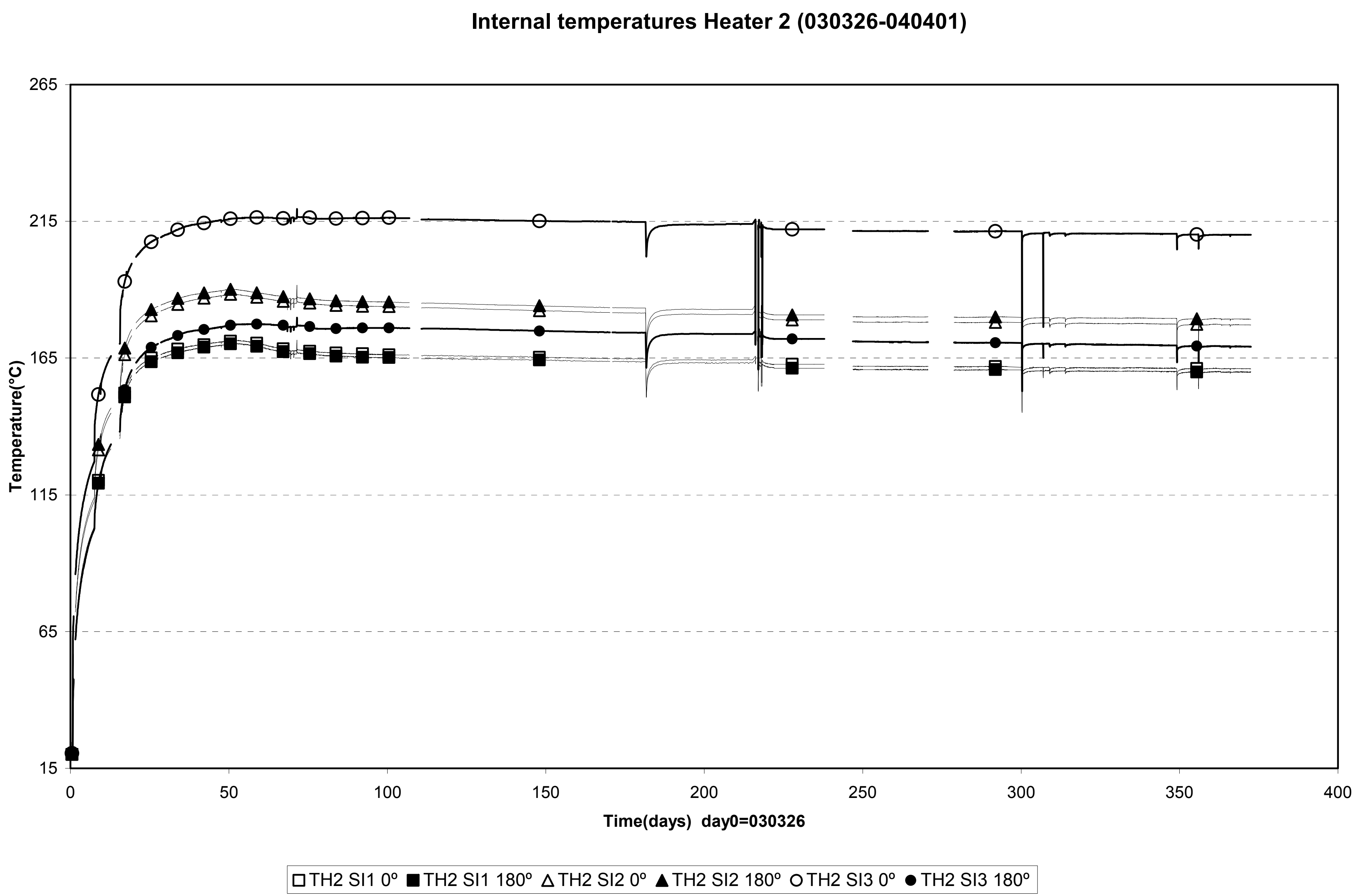


External temperatures Heater 1 (030326-040401)
Temperature(°C)
155
135
115
95
75
55
35
15
0
50
100
150
200
250
300
350
400
Time(days) day0=030326
TH1 SE4
TH1 SE3 120º
TH1 SE3 240º
TH1 SE3 0º
TH1 SE2 120º
TH1 SE2 240º
TH1 SE2 0º
TH1 SE1 120º
TH1 SE1 240º
TH1 SE1 0º
TH1 SE0



External temperatures Heater 2 (030326-040401)
Temperature(°C)
195
175
155
135
115
95
75
55
35
15
0
50
100
150
200
250
300
350
400
Time(days) day0=030326
TH2 SE4
TH2 SE3 240º
TH2 SE2 120º
TH2 SE2 0º
TH2 SE1 240º
TH2 SE0
TH2 SE3 120º
TH2 SE3 0º
TH2 SE2 240º
TH2 SE1 120º
TH2 SE1 0º


Internal temperatures Heater 1 (030326-040401)
195
175
155
135
115
95
75
55
35
15
Temperature(°C)
0
50
100
150
200
250
300
350
400
Time(days) day0=030326
TH1 SI1 0º
TH1 SI1 180º
TH1 SI2 0º
TH1 SI2 180º
TH1 SI3 0º
TH1 SI3 180º



Internal temperatures Heater 2 (030326-040401)
265
215
165
115
65
15
0
50
100
150
200
250
300
350
400
Temperature(°C)
Time(days) day0=030326
TH2 SI1 0º
TH2 SI1 180º
TH2 SI2 0º
TH2 SI2 180º
TH2 SI3 0º
TH2 SI3 180º