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Äspö Hard Rock Laboratory

Cleaning and sealing of Borehole

Report of Sub-project 2 on plugging of 5 m boreholes at Äspö

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November 2006

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Äspö Hard Rock Laboratory

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Abstract

The major aim of Sub-project 2 was to prepare and test plugs of four types, to predict their maturation rates under prevailing rock conditions, and to determine these rates by performing "extrusion" experiments. One concludes that the tested plug types can be used in practice according to the principles outlined in Sub-project 1, implying that "Basic"-type plugs can be used for plugging short and very deep holes oriented in any direction, that "Container"-type plugs are expected to be useful in the same types of holes with better protection against erosion in the placement phase, and that the "Couronne" and "Pellet"-type plugs are well suited for plugging shorter holes.

The similar conditions for maturation for the other plugs made it possible to compare the maturation rates. The "Basic" plug had the lowest maturation rate because of the retarding impact of the perforated tube, while the "Container" and "Couronne" plugs matured similarly but faster. The discrepancy between the predicted and recorded maturation rates was explained by the microstructural processes in the earliest maturation phase and possibly by insufficient water pressure to provide the plugs with water. The fact that the theoretical model gave too quick maturation suggests that it is not conservative in cases with low water pressure, while it is expected to be accurate where the water pressure is high, as in OL-KR24.

Summary

The major aim of Sub-project 2 was to prepare and test plugs of four types, to predict their maturation rates under prevailing rock conditions, and to determine these rates by performing "extrusion" experiments in which an axial force was exerted on one end of the plugs for displacing them sufficiently to make it possible to evaluate the shear strength of the "clay skin", i.e. the clay in contact with the rock. This work was successful but showed that the maturation of the plugs was somewhat slower than predicted according a simplified theoretical model. The 3 m long unsupported plugs could resist an axial force of 1.7-6 t (17kN till 60 kN) after 2 days, which corresponds to a water pressure of 3 to 12 MPa at one end. This makes it possible to use them in boreholes where such gradients can be built up. After a few months the sustainable pressure difference can be 20 MPa over 3 m length except for simple plugs made of pellet fills, with possible restriction with respect to piping (Sub-project 1). One concludes from the recorded maturation rates that the tested plug types can be used in practice according to the principles outlined in Sub-project 1, implying that "Basic"-type plugs already with today's techniques can be used for plugging short and very deep holes oriented in any direction, that "Container"-type plugs are expected to be useful in the same types of holes with better protection against erosion in the placement phase, and that the "Couronne" and "Pellet"-type plugs are well suited for plugging shorter holes.

The testing conditions were similar for all the plugs with respect to the rock structure and average inflow of water except for the pellet-plugged hole, to which less water flowed. The similar conditions for maturation for the other plugs made it possible to compare the maturation rates. The "Basic" plug had the lowest maturation rate because of the retarding impact of the perforated tube, while the "Container" and "Couronne" plugs matured similarly but faster. The discrepancy between the predicted and recorded maturation rates, which was obvious but not dramatic, could be explained by considering the complex microstructural processes in the earliest maturation phase and possibly insufficient water pressure to provide the plugs with water. The fact that the theoretical model gave too quick maturation suggests that it is not conservative in cases with low water pressure, while it is expected to be accurate where the water pressure is high, as in OL-KR24 [Sub-project 3].

Sammanfattning

Huvudsyftet med Sub-project 2 var att bygga och testa pluggar av fyra typer, att prediktera deras mognadshastighet under rådande bergförhållanden, samt att bestämma mognadshastigheten genom axiell belastning av pluggarnas ena ände för att åstadkomma sådan förskjutning att skjuvhållfastheten hos leran närmast hålväggen kunde utvärderas. Detta arbete var framgångsrikt men visade att mognaden hos pluggarna var långsammare än som förutsagts enligt den förenklade modell som redovisats i Sub-project 1. De 3 m långa pluggarna, som var fria att förskjutas i hålen, kunde motstå en axiell kraft av 1.7-6 t (17kN till 60 kN) efter 2 dygn, vilket motsvarar ett vattentryck av 3 till 12 MPa vid ena änden. Det gör det möjligt att använda dem i borrhål där sådana gradienter kan uppkomma. Efter några månader kan en tryckskillnad av 20 MPa över 3 m längd motstås utom för enkla pluggar åstadkomna genom pelletfyllning, möjligen med reservation för piping (Sub-Project 1). Slutsatsen från de bestämda mognadshastigheterna är att de undersökta pluggtyperna kan användas praktiskt enligt de principer som beskrivs i Sub-project 1, och som innebär att "Basic"-pluggar kan användas redan med dagens teknik för tät försegling av korta och långa hål med vilken riktning som helst, att "Container"-pluggar också förväntas vara användbara i samma slags hål med bättre skydd mot erosion, samt att "Couronne"- och "Pellet"-pluggar är väl lämpliga i kortare hål.

Testförhållandena var likartade för alla pluggar när det gäller bergstrukturen och medelinflödet av vatten i hålen utom för det pellet-fyllda hålet till vilket inflödet var litet. De likartade förutsättningarna gjorde det möjligt att jämföra mognadshastigheterna. "Basic"-pluggen hade den långsammaste mognadstakten på grund av den bromsande inverkan av det perforerade röret, medan "Container"- och "Couronne"-pluggarna hade samma mognadshastighet. Skillnaden mellan den förutsagda och bestämda mognadshastigheten, som var tydlig men inte dramatiskt stor, kan förklaras av att de mikrostrukturella processerna som skapar lerzonen närmast hålväggen är mycket komplexa i den inledande mognadsfasen. Det faktum att den teoretiska modellen förutspådde snabbare mognad än vad verkligheten visade innebär att den inte är konservativ för fall med lågt vattentryck medan den förväntas vara tillämplig där vattentrycket är högt, såsom i OL-KR24 [Sub-project 3].

Contents

1 Introduction

Sub-project 2 covers four items [1]:

- Hydraulic and structural characterization of the rock with clay plugs in bored holes
- Prediction of the maturation rate of the plugs
- Construction of plugs
- Testing for determining the maturation rate of the plugs by "extrusion"

While the conditions for maturation of clay-based plugs placed in tubes in the laboratory, as documented by Sub-project 1, have to be well defined and identical for comparing the performance of the four plugs, i.e. the "Basic", "Container", "Couronne", and "Pellet" types (Figure 1-1), they are artificial and may not yield the true physical state of the plugs in rock environment because of varying access to water along the larger part of their length. Maturation of such plugs under realistic conditions in rock is illustrated by the tests performed at Äspö as described in the present report. Focus is on the maturation rate of the four plug types as evaluated from "extrusion" tests.

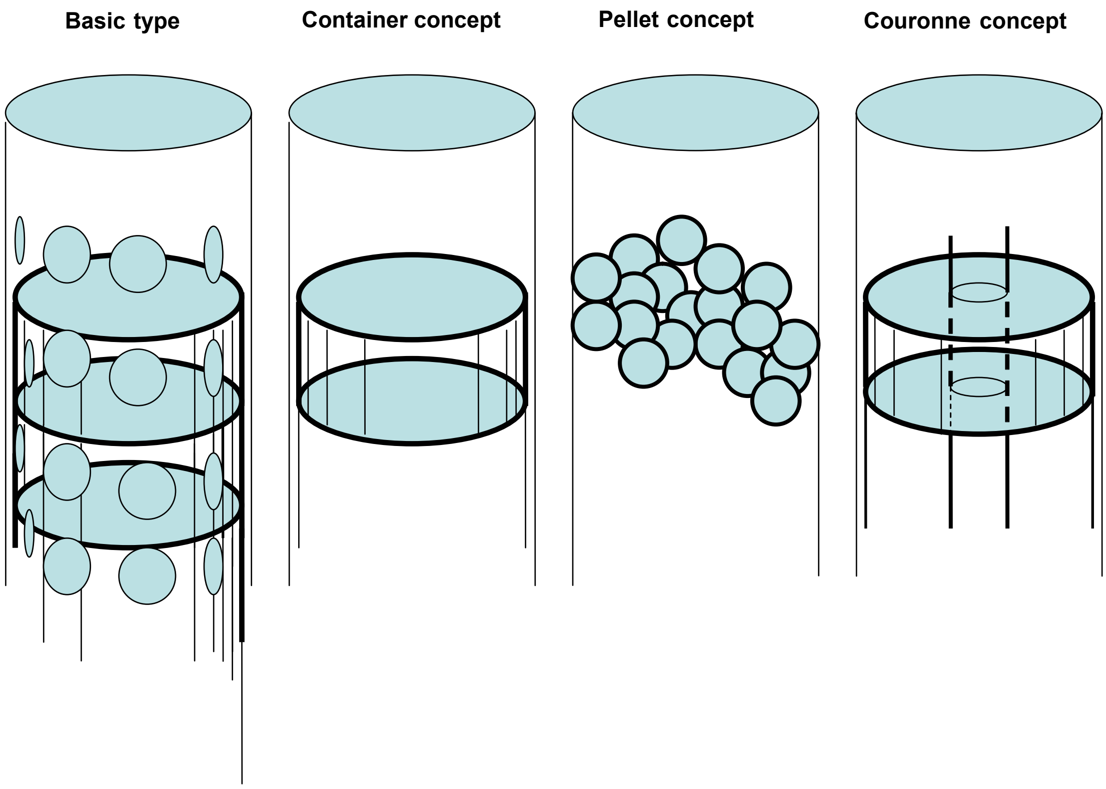

Figure 1-1. *The four alternative clay plug concepts. Left: The "Basic" plug with highly compacted MX-80 clay columns confined in perforated copper tubes. Second left: The "Container" plug with highly compacted MX-80 clay blocks contained in a cylinder attached to drilling rods and released when the tip of the cylinder is in the desired position. Third left: MX-80 pellets poured into the hole with slight compaction. Right: The "Couronne" plug with annuli of highly compacted MX-80 clay stacked around jointed copper rods that are pushed into the hole.*

2 Purpose and principles of testing of clay plugs

2.1 Principles of testing

2.1.1 Performance of the four plug types

The aim of the investigation was to determine the rate of maturation of the four plug types under real conditions in crystalline rock. It can be determined by performing piping tests, like those made in Sub-project 1, but it turned out to be difficult to accurately determine the critical pressure gradients in the type of rock where the holes had been bored since water pressurized at one end of the plugged holes could flow through intersecting fractures at this end and not through the plugs. This could not happen with the test arrangement in Sub-project 1, i.e. by using a steel tube for simulating the borehole, but it did not simulate uptake of water from the rock and illustrated only the formation of the clay "skin" around the dense clay, the maturation rate of which was determined by performing piping tests. The tests at Äspö involved maturation by water uptake both from fractures and from the rock matrix and determination of its rate by determining the axial force required for large displacement ("extrusion") of the plugs at suitable time intervals. The intermittent axial displacements gave data on the growth of the average shear strength of the contact between the rock and the plug, hence being a good measure of the maturation rate under true field conditions.

The holes were bored at 450 m depth in 2005 and considerable efforts made to characterize them with respect to the hydraulic conditions for selecting suitable holes for the experiment, implying that the holes for plugging should be as similar as possible while the intersecting "twin" holes hosting cables could be of different character (Appendix I). The test arrangement is shown in Figure 2-1.

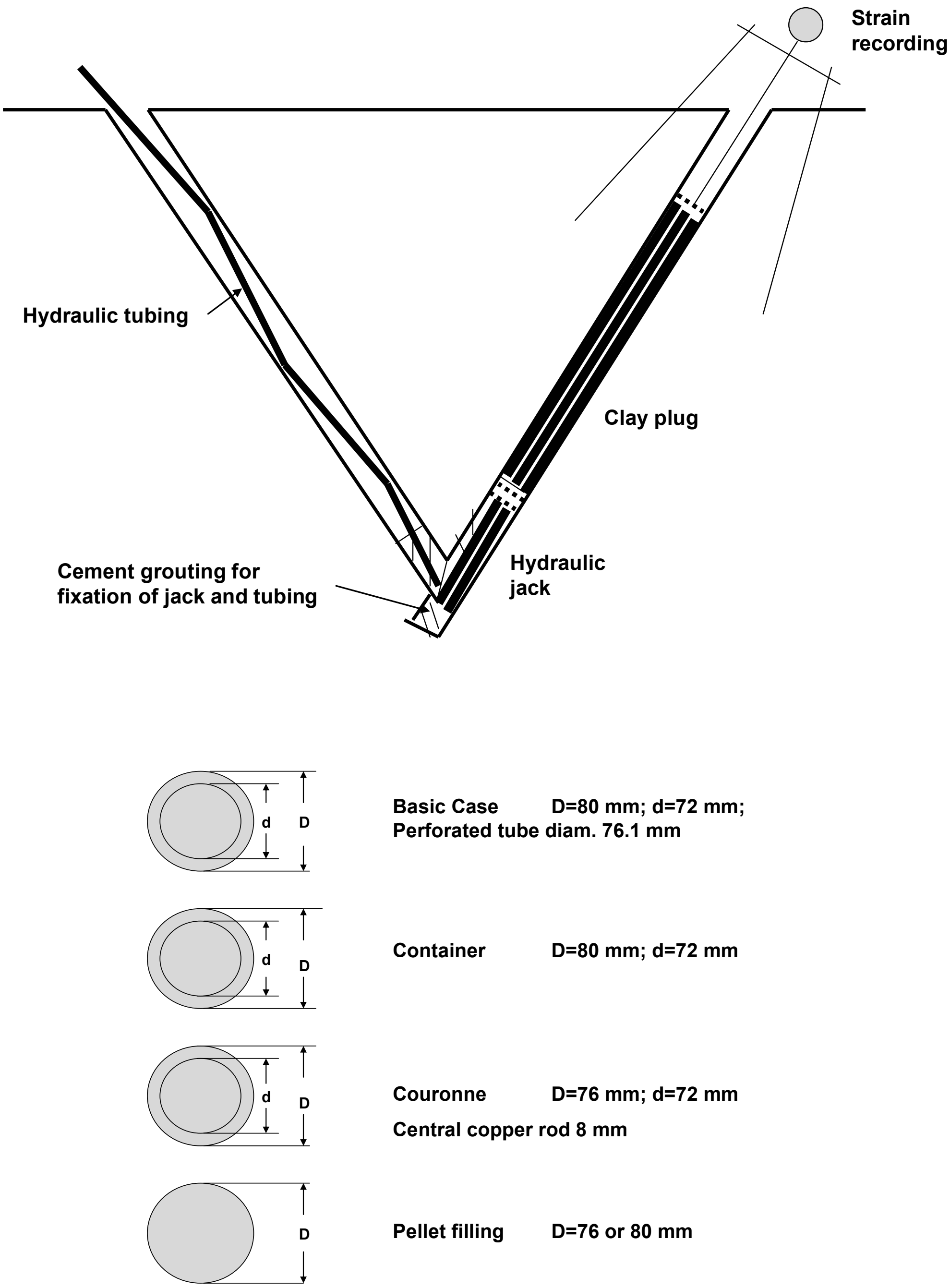

Figure 2-1. *Arrangement for measuring clay/rock adhesion by extruding the plugs in the 5 m long holes and measuring the displacement. The lower picture shows the selection of boreholes and clay core diameters for yielding approximately the same ultimate density.*

2.2 Testing conditions for the clay plugs

2.2.1 Rock structure

Figure 2-2 shows overall perspective views of the 5 m long holes and assumed major rock structural features representing water-bearing fractures. The holes are termed **A** to **H** with the complete number descriptions in Table 1 (**A**=KA3375A01 etc).

The model implies that all the boreholes interact hydraulically through the red discontinuity; holes **B** and **C** interact through the blue fracture, while holes **E**, **F**, **G** and **H** interact through three steep fracture zones (blue).

In the present context the purpose is not to go into structural details but to compare the rock conditions of the four holes to be plugged for finding out if they are sufficiently similar to allow for fair comparison of the plug performances.

Figures 2-2 to 2-6 show generalized structural models for the plugged holes based on BIPS and photos of the cores.

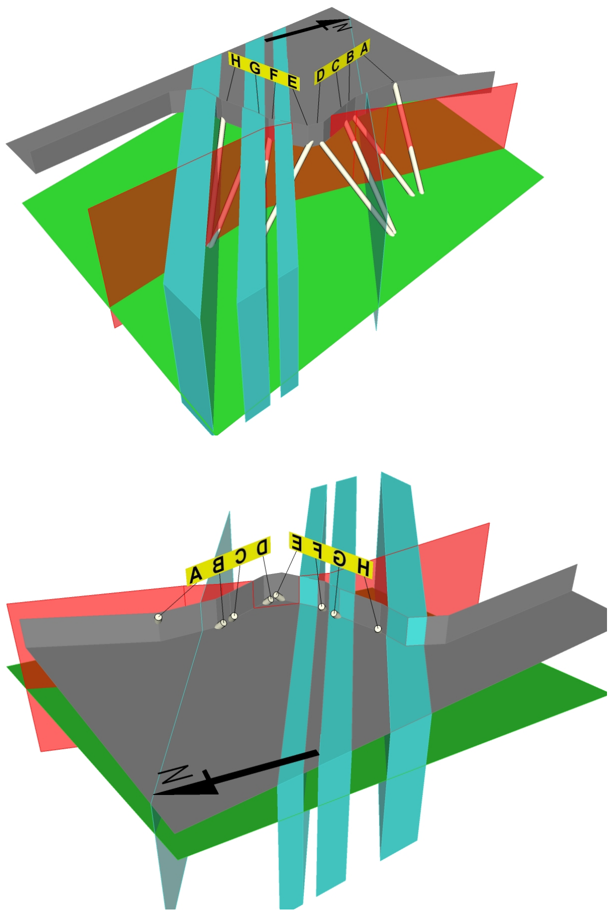

Figure 2-2. *Boreholes in the rock structure model. Light-blue colour indicates presumable hydraulically very active fractures and fracture zones, red is a moderately active steep fracture or fracture zone and green a moderately active subhorizontal fracture or thin zone. The lower part of the wall and the floor are shown grey.*

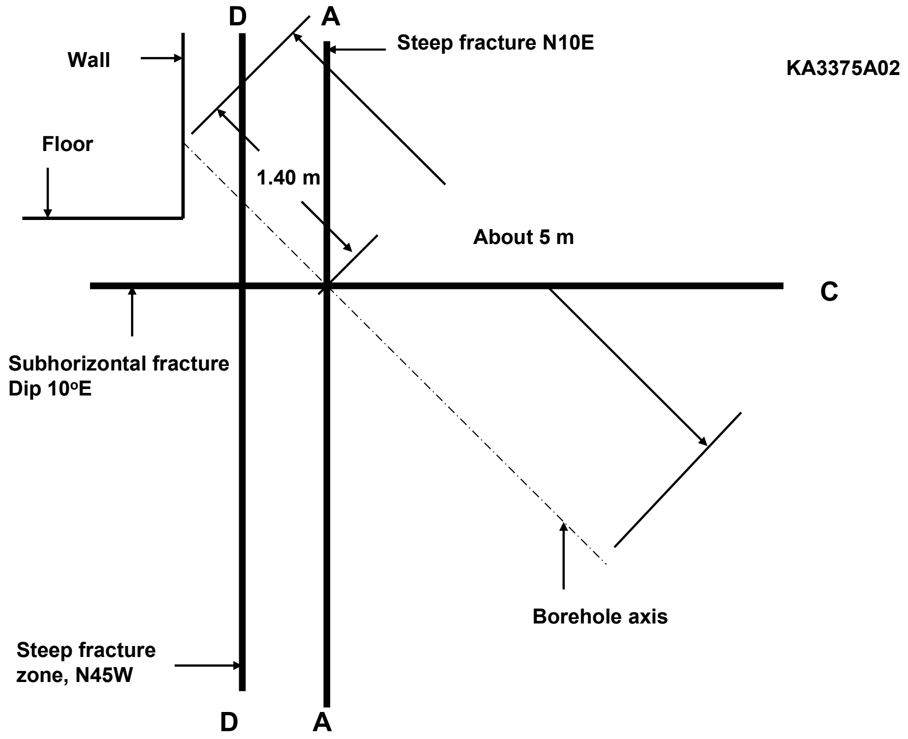

Figure 2-3. *Borehole **B** (KA3375A02). Upper: Axial section of the borehole that intersects borehole **A** at the lower end. Lower: The core photo, with the upper part of the core at the upper left, shows that the rock has rather few fractures but that core loss took place where the A- and C-fractures (A is a small zone) were intersected. The hole has an average spacing of presumably water-bearing fractures of 0.75 m. A plug of "Basic" type was inserted in the hole.*

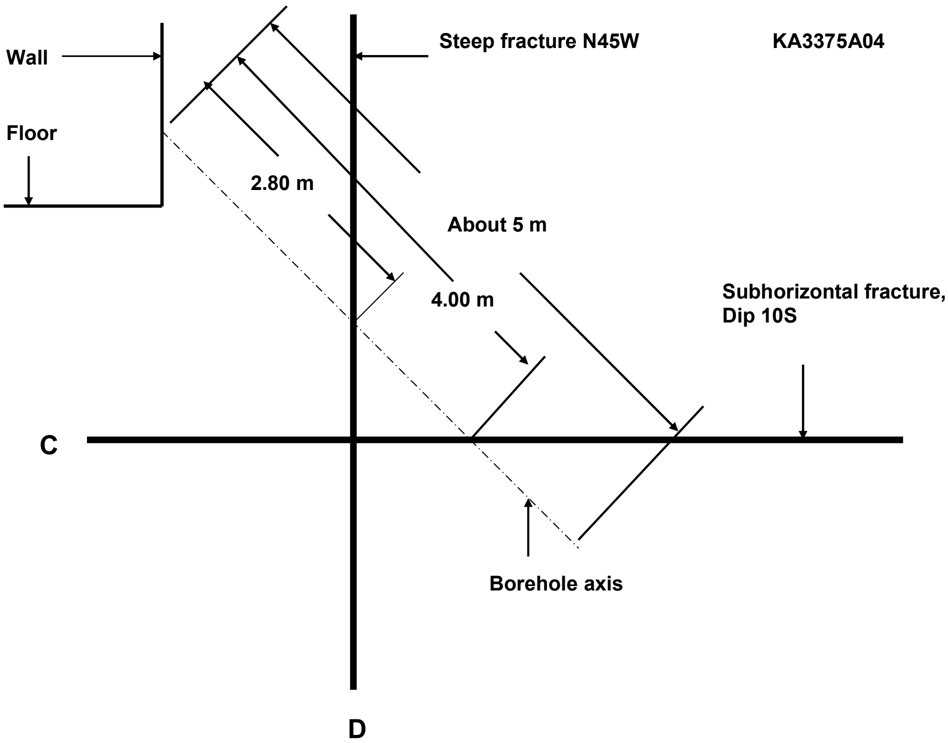

Figure 2-4. *Borehole* ***D*** *(KA3375A04). Upper: Axial section of the borehole that intersects borehole* ***C*** *at the lower end. Lower: The core photo, with the upper part of the core at the upper left, shows that the rock is intersected by two major fractures interpreted as* *<u>C</u>* *and* *<u>D</u>. The hole has an average spacing of presumably water-bearing fractures of 0.5 m. A plug of "Pellet" type was inserted in the hole.*

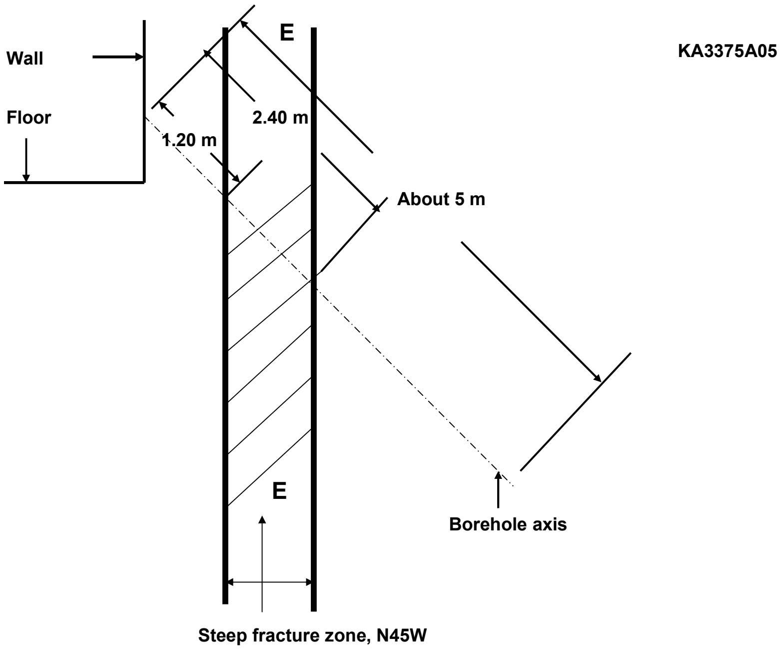

Figure 2-5. *Borehole **E** (KA3375A05). Upper: Axial section of the hole which intersects borehole **F** at the lower end. Lower: The core photo, with the upper part of the core at the upper left, shows that the hole is intersected by a fracture zone at about 2.5 m distance from the top. Above the zone the rock is poor in fractures. The hole has an average spacing of presumably water-bearing fractures of 0.75 m. A plug of "Couronne" type was inserted in the hole.*

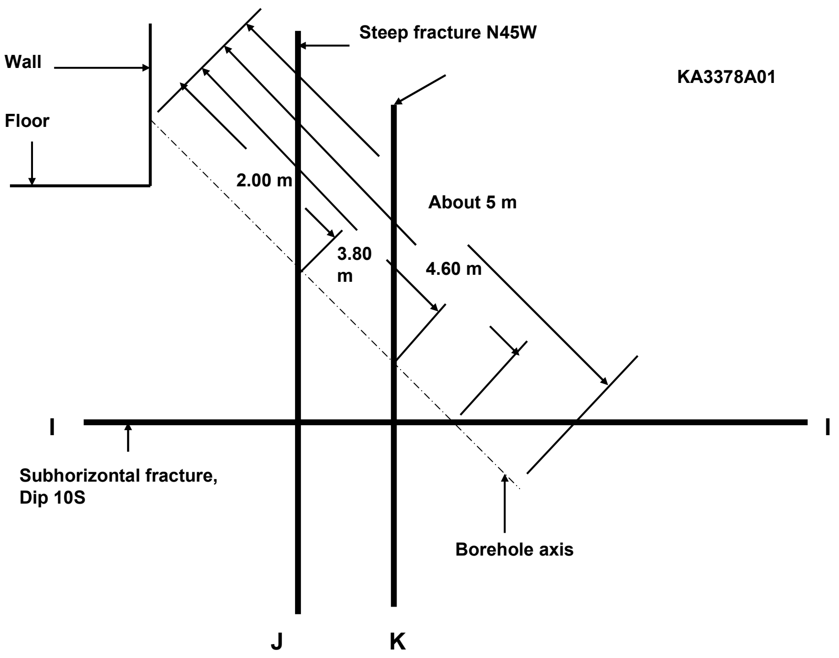

Figure 2-6. *Borehole* ***H*** *(KA3378A01). Upper: Axial section of the borehole that intersects borehole* ***G*** *at the lower end. Lower: The core photo, with the upper part of the core at the upper left, shows that the rock around the upper end of the hole is strongly fractured but that the rest is intersected by only a few presumably water-bearing fractures. The hole has an average spacing of presumably water-bearing fractures of 0.5 m. A plug of "Container" type was inserted in the hole.*

2.2.2 Selection of holes for plugging

Structural conditions

While the major criterion for locating clay plugs in deep boreholes is to insert them in fracture-poor parts for avoiding migration and loss of clay into fractures the present project aimed at selecting holes with similar hydraulic conditions for fair comparison of the performance of the plugs. Since the holes did not have the same diameter the selection of suitable holes had to be based both on the possibility to get the plugs down and on the hydraulic conditions. Table 2-1 is a compilation of major rock structural features of the holes based on BIPS and on core examination; it also shows the finally decided choice of holes to be plugged by different techniques. From structural points of view the holes for plugging are estimated to be similar and characterized by spacings of water-bearing fractures of 0.5 to 1 m.

Table 2-1. Rock structure data.

Borehole	Most important discontinuities as interpreted from BIPS	Fracture number in the holes as interpreted from core examination	Concept, borehole diameter	Hole for pressurizing ("twin" holes)
Holes to be plugged				
B = KA3375A02	Two steep + one subhorizontal	8	Basic, 80 mm	**A**
D = KA3375A04	One steep + one subhorizontal	7	Pellets, 80 mm	**C**
E= KA3375A05	One steep + one subhorizontal	6	Couronne, 76 mm	**F**
H= KA3378A01	One subhorizontal "BIPS" unclear	>6	Container, 76 mm	**G**
Holes for pressurizing connected with plugged holes				
A= KA3375A01	Steep fracture zone	18	-	Conn. with **B**
C= KA3375A03	One steep + one subhorizontal	11	-	Conn. with **D**
F= KA3376A01	Steep fracture zone	11	-	Conn. with **E**
G= KA3377A01	Three steep	13	-	Conn. with **H**

Groundwater conditions

For fair assessment of the performance of the different clay plug concepts the access to water and the water pressure in fractures intersecting the boreholes are important. The pressures and inflows in the empty holes have been recorded and the data compiled in Table 2-2 (cf. also APPENDIX I). It shows that the inflow into the holes selected for plugging was similar except for Hole **D,** which appeared to be "drier" than the others. The water pressure was logically high here.

Table 2-2. Hydraulic data.

Borehole	Pressure, kPa	Inflow, l/h (approximate)	Concept, borehole diameter	Hole for pipe connections etc
Holes to be plugged				
B = KA3375A02	417-1065	4.8	Basic, 80 mm	**A**
D = KA3375A04	187-1419	0.2	Pellets, 80 mm	**C**
E= KA3375A05	166- 1760	6	Couronne, 76 mm	**F**
H= KA3378A01	119-463	16	Container, 80 mm	**G**
Holes connected with plugged holes for hosting tubings etc				
A= KA3375A01	214-905	16	-	Conn. with **B**
C= KA3375A03	900	11	-	Conn. with **D**
F= KA3376A01	183-540	0.6	-	Conn. with **E**
G= KA3377A01	359-525	>5 (not confirmed)	-	Conn. with **H**

Groundwater composition

The chemical composition of the groundwater varies at a the depth of a few hundred meters but the average total salt content (TDS) can be taken as 1 % with Na as major cation and Cl as dominant anion. As shown in Sub-project 1, clay plugs should be inserted in fresh water and all the holes were therefore drained and filled with tap water before placing the plugs.

3 Prediction of the maturation of clay plugs

3.1 Controlling factors

The factors affecting the rate of plug maturation are:

- The hydraulic conductivity of the rock.
- The location of water-supplying fractures.
- The water pressure in the rock.
- The type, density and initial degree of water saturation of the clay plug.
- The rate of homogenization, i.e. redistribution of the density.

3.2 Conceptual model of maturation

3.2.1 General

The conditions for maturation of the alternative plugs are somewhat different as outlined in Sub-project 1. Thus, for the "Container" and "Couronne*"* concepts the dense clay column is instantly exposed to the water in the hole over its entire surface, which makes its outer part expand even quicker than for the *"Basic"* concept, hence forming a uniform, shallow, fully water saturated "clay skin" from which the rest of the clay sucks water for hydration. The same conditions for further hydration prevail for all the concepts, i.e. water flows from intersected water-bearing pressurized fractures through the skin for further transport into the dense core by suction. The earliest maturation and hence resistance to percolation of the skin occurs close to the fractures but its hydraulic conductivity will continue to be higher than that of the clay core for a long time and it will therefore serve as major water path until complete saturation and maturation of the entire plug is approached. For all the concepts the joints between the compact clay blocks will let water in quickly but self-sealing is assumed to close them soon. The impact of the water pressure is important in the early maturation phase.

For the "Pellet" plug the maturation is different in the sense that even the central part of the plug will hydrate quickly by water entering the voids all the way to the centre of the plug. However, further water uptake will be retarded by the early matured shallow part of the plug, adjacent to the borehole wall like for the other concepts. In the initially more or less wetted central part redistribution of water and solids will take place but it will remain heterogeneous until complete water saturation has taken place and sufficient time has passed for redistribution of clay particles to reach equilibrium positions.

3.2.2 Pressure conditions

In Sub-project 1 distinction was made between the impact of high and low pressure conditions in the groundwater on the saturation and maturation rates of the four plug types, particularly with respect to the spacing of intersecting water-bearing fractures.

For high water pressure in the fractures it was assumed that almost complete saturation and homogeneity of any of the alternative plug concepts will take place in a few months [2][1]. The spacing of major fractures, represented by 4^{th} order discontinuities, is commonly in the interval 1-3 m and plays a minor role except for larger spacings.

For low water pressures it was concluded that the maturation rate can be relatively accurately estimated by using a simple diffusion model with empirically derived constants [2,3].

Using the figure 3E-10 m^2/s for the coefficient and assuming that the clay fills up the hole from the start and initially has a uniform dry density of about 2000 kg/m^3, it was found that practically complete saturation will be reached in about 4 months.

In principle, the saturation of the clay plug of "Basic" type can be approximated in the same way as for the "Container" and "Couronne" concepts but the retarding influence on water migration and clay migration by the perforated tube makes both water saturation and homogenization of the "Basic" plug type slower by roughly 50 %. The internal friction will retard homogenization of the clay and probably lead to permanent differences in density in outer and central parts of the clay core.

3.2.3 Prediction of the maturation rate of the four plug types tested at Äspö

Pressure conditions

The average water pressure in the rock surrounding the clay plugs is of the same order of magnitude, i.e. at least 500 kPa, for all the holes, which suggests that the pressure *per se* does not have any important impact on the water saturation rate but that it can be assumed that intersecting fractures are currently supplied with water.

Fracture spacing

The average spacing of water-bearing fractures that intersect the holes, i.e. 0.5-1 m is similar in the four holes, indicating that the simple principle of water saturation of the "clay skin" and "dense clay core" outlined in Sub-project 1 apply.

Water saturation and maturation

Considering first the plug of "Basic" type, Figure 3-1 illustrates the first phase of maturation. It is characterized by formation of clay columns ("plugs") growing from the dense clay core through the perforation of the tube into the water-filled space between the rock and the tube and forming, in the first phase, a "clay skin" of varying density. After about 24 hours the clay components in the space between the tube and the rock wall have become relatively homogeneous but it takes weeks and months for it to reach a high degree of homogeneity and a density that approaches that of the successively softening central clay core.

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[1] The span is from a few weeks to about 4 months depending on the calculation method

Following the conceptual modelling described in Sub-project 1, the growth of the clay columns and the homogeneity and density of the "clay skin" can be predicted if the surrounding rock is able to supply it with water without limitation. Assuming that the water that occupies the space between the rock and the tube is instantly absorbed by the clay (Figure 3-1) and that it has to be replaced by water entering from the rock for formation of a "clay skin", the conditions are as shown in Figure 3-2.

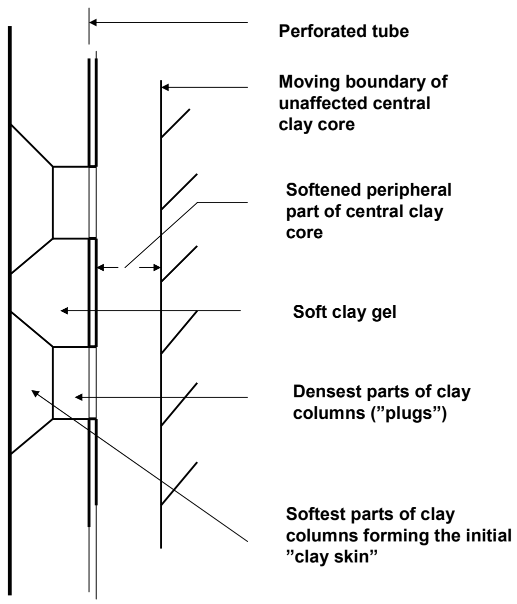


Figure 3-1. *Schematic picture of the earliest stage in the maturation of a clay plug of "Basic" type.*

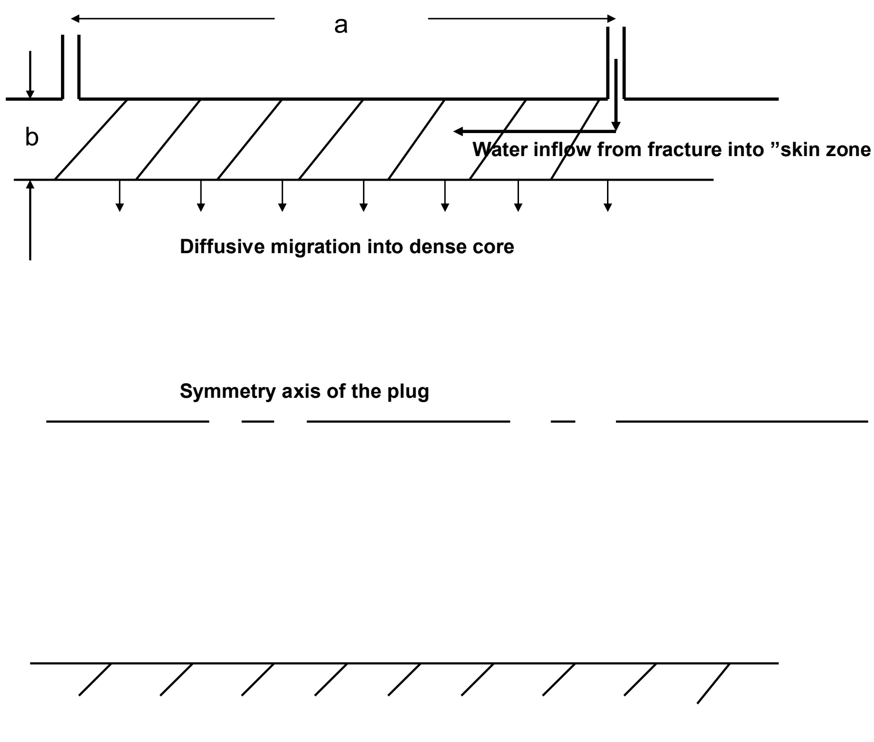


Figure 3-2. *Conditions for saturation of the clay core by absorbing water from the skin zone that is supplied with water from intersecting fractures.*

For the present case with a conservatively taken fracture spacing a=1 m in all the plugged holes one can consider the 0.5 m long element consisting of clay "skin and core" in Figure 3-2 for estimating the saturation[2] and maturation processes. For fulfilling the criterion that the flow must be sufficient to feed the densifying "clay skin", even at the opposite end of the element, the flux must be about 1/12 litres per hour, i.e. 0.2 litres per hour for the 2.5 m long plug. The cross section area of the "clay skin" is on the order of 10 cm^2, meaning that the minimum flow rate must be at least 0.6 m per day. Assuming zero water pressure at the inner end of the element and only the fracture pressure as driving force[3], this will, for the pressure of 500 kPa in the four holes, require a hydraulic conductivity *K* of the skin of *K*>3E-10 m/s, which is lower than that of MX-80 with a density of about 1100 kg/m^3, for percolation with low-electrolyte water. For brackish water of Äspö type it would be much more than required. The fact that the inflow of water is 4.8 to 16 litres per hour for all the holes, except **D** with pellets, means that the supply of water should be sufficient to make the clay plugs mature without delay.

Neglecting, to begin with, the retarding influence of the perforation of the tube in the "Basic" plug, the maturation rate can be predicted by assuming saturation to take place by diffusion from the interface of "skin" and "core". Following the reasoning in Sub-project 1 one finds that complete hydration of the dense core will take place to 0.3 cm radial distance from the wet boundary in 12 hours, hence requiring about 5 litres of water for the 2.5 m long clay core. The results are compiled in Table 3-1.

Table 3-1. Estimated amount of tap water for unlimited hydration of a freely expanding 2.5 m long clay core with an initial dry density of 1700 kg/m^3as a function of time. The shear strength for saturation with fresh water is given in the last column.

Time, hours	Density of saturated, expanded part, kg/m^3	Amount of absorbed water, litres (2.5 m plug length)	Hydraulic conductivity of "skin zone", m/s	Shear strength of "clay skin", kPa [1]
6	1100	10	E-9	50
12	1150	15	5E-10	200
24	1325	33	5E-11	400
48	1400	40	2E-11	550
96	1700	70	E-12	700

Taking the flow-retarding tube perforation of the "Basic" plug into consideration one can estimate that the time for maturation is twice that of a freely expanding plug in radial direction. This means that the shear strength of the "clay skin" can be about 25 kPa after 6 hours, 100 kPa after 12 hours, 200 kPa after 24 hours, 275 kPa after 48 hours and 350 kPa after 96 hours. For all the plug types the expansion is limited because of the confinement provided by the small-diameter boreholes, meaning that the "clay skin" starts to consolidate rather early under the compressive force exerted by the dense clay columns that move out from the dense core. This means that, in practice, only the amounts of water required for maturation in the first 12-48 hours are relevant since

[2] Saturation is equivalent to water uptake and hence part of the maturation process that includes also redistribution of solid matter.
[3] The incompletely saturated core generates a suction of hundreds to thousands of kPa that contributes to the hydraulic gradient, meaning that the estimated minimum conductivity is very conservative.

consolidation will then be the dominant process. For the other plugs, except the pellet plug, Table 3-1 is applicable, implying that the "clay skin" of the "Container" and "Couronne" plugs can be estimated to have a shear strength of 50 kPa after 6 hours, 200 kPa after 12 hours, and more than 400 kPa after 24 hours.

Prediction of the saturation and homogenization rates of the pellet plug in Hole **D** is as difficult as for the other plug types. However, taking into consideration the fact that the hole will be filled with water immediately after putting in the pellets it is estimated that the large majority of the voids between the pellets are instantly filled with water and that the additional amount of water required to fill the limited void space within the pellets is very small, the condition of unlimited access to water for maturation is largely fulfilled by the inflow of 0.2 litres per hour. It is hence concluded that the pellet plug should reach a high degree of saturation and maturation already after a few days. Subsequent uptake of water from the surrounding rock will be very slow even at very high water pressures.

The fact that the water entering from the Äspö rock is more saline than tap water means that the shear strength is somewhat lower than predicted. This will be taken into consideration in predicting the force required to displace ("extrude") the plugs.

3.3 Determination of the force required for displacing the plugs as a measure of their time-dependent maturati

3.3.1 Prediction of the force required for displacing the plugs

The rate of maturation of the clay plugs is mirrored by the time-dependent growth of the shear resistance when displacing them by applying an axial force. The resistance to displacement is determined by the shear strength of the clay contacting the borehole walls (i.e. the "clay skin"), which is predicted as a function of time in Table 3-2. The axial force that displaces the respective plug is equivalent to the product of the area of the clay/rock contact and the shear strength, which means that the force yielding displacement can be defined if the borehole diameter and the length of the plug, and the shear strength of the "clay skin" are known.

The force F_c required for displacing the plugs by overcoming the shear strength of the "clay skin" is:

$$F_c = \pi L D \tau_f \qquad (3\text{-}1)$$

where:

L= plug length (nearly 3 m)

D=borehole diameter (0.076 and 0.080 m)

τ_f=shear strength of "clay skin"

The shear strength of the early formed "clay skin" is determined by the low-electrolyte water with which the borehole is filled before inserting the plugs. However, already after a few hours sodium and calcium begin to enter the soft clay by which the shear strength drops. This is taken into consideration by defining one value that refers to saturation with tap water and one that is valid for Äspö groundwater (1 % TDS). Table 3-2 gives the expected force in tons for extruding the plugs. Multiplication of the figures by ten gives the force in kN.

Table 3-2. Predicted degrees of saturation and maturation (homogeneity) under natural pressure conditions. (Expected force to displace the plug=Expected shear strength multiplied by rock/plug contact area, which is about 0.8 m^2 for 3 m length and 0.08 m diameter. Multiplication of the figures by ten gives the force in kN.

Borehole	**Concept**	**Expected density of saturated "clay skin", kg/m^3**	**Expected shear strength of the "clay skin", kPa acc. to lab tests (fresh/salt)**	**Expected force in tons to displace the plug, tons (fresh/salt)**
B=KA3375A02	Basic			
After 6 hours	Basic	1100	50/0	4/0 (Average 2 t)
After 12 hours	Basic	1150	200/0	16/0 (Average 8 t)
After 24 hours	Basic	1325	325/0	26/0 (Average 13 t)
After 48 hours	Basic	1400	600/0	48/0 (Average 24 t)
After 96 hours	Basic	1600	800/300	64/24 (Average 44 t)
D=KA3375A04	Pellets			
After 6 hours	Pellets	1200	100/0	10/0 (Average 5 t)
After 12 hours	Pellets	1300	250/0	20/0 (Average 10 t)
After 24 hours	Pellets	1400	325/0	26/0 (Average 13 t)
After 48 hours	Pellets	1500	650/0	52/0 (Average 26 t)
After 96 hours	Pellets	1600	700/100	56/10 (Average 33 t)
E=KA3375A05	Couronne			
After 6 hours	Couronne	1100	50/0	4/0 (Average 2 t)
After 12 hours	Couronne	1150	200/0	16/0 (Average 8 t)
After 24 hours	Couronne	1325	325/0	26/0 (Average 13 t)
After 48 hours	Couronne	1500	650/0	52/0 (Average 26 t)
After 96 hours	Couronne	1800	850/350	68/28 (Average 48 t)
H=KA3378A01	Container			
After 6 hours	Container	1100	50/0	4/0 (Average 2 t)
After 12 hours	Container	1150	200/0	16/0 (Average 8 t)
After 24 hours	Container	1325	325/0	26/0 (Average 13 t)
After 48 hours	Container	1500	650/0	52/0 (Average 26 t)
After 96 hours	Container	1800	850/350	68/28 (Average 48 t)

It should be noted that if the shear strength of the "skin zone" is determined by tap water salinity the plugs would require at least 20 t (200kN) axial force to be extruded after 24 hours, while they would not resist any force at all even after 48 hours if Äspö water is a determinant. This illustrates the sensitivity of any theoretical modeling and prediction of the extrusion force, which are hence very uncertain. The important thing is, however, to be able to predict the force required to extrude the plugs after 3-4 days, i.e. when temporary supports in the form of mechanical packers may have to be removed or concrete be cast in the holes.

4 Tests

4.1 General

The tests involved exertion of an axial force for displacing the respective plugs at different times in order to determine the time-dependent increase in shear strength of the clay contacting the borehole walls, i.e. the “clay skin”.

4.2 Description of the test arrangements

4.2.1 Preparation on the test site

The principle of testing, which is shown in Figure 2-1, was as follows:

- Casting a concrete foundation for a hydraulic jack in the hole to be plugged.
- Placing and anchoring the jack by embedding it in concrete. The tubings connected to the jack for pressurizing and expansion are located in the “twin” hole intersecting the hole to be plugged.
- Filling the hole to be plugged with tap water.
- Placing the clay plug in the hole immediately after filling it with tap water.
- Placing and activation of a mechanical packer on top of the clay plug for confining the maturing plug. The plug serves to let the water pressure rise and to prevent clay from migrating from it. When testing the plug, the jack is activated for measuring the displacement after loosening the packer.

4.2.2 Preparation of the clay plugs

The four clay types were those shown in Figure 1-1. The one of “Basic” type had been constructed and tested in earlier tests, like in the Stripa Project where a 100 m long plug of this type was inserted in a horizontal hole, and in OL-KR24 where such a plug was inserted to about 500 m depth (Sub-project 3).

“Basic”-type

The detailed design and manufacturing of plugs of this type is described in the report on Sub-project 1 [3]. In the present tests the clay blocks had a water content of 6 % and a density of 2150 kg/m^3, corresponding to a dry density of 2028 kg/m^3. The void ratio and initial degree of saturation were e=0.37 (porosity 0.27) and 45 %, respectively. The diameter of the hole was 80 mm and the outer and inner diameters of the perforated tube 76.1 and 72.1 mm, and the calculated ultimate density of the plugs after complete water saturation 2078 kg/m^3.

"Container"-type

The detailed design and manufacturing of plugs of this type is described in the report on Sub-project 1 [3]. In the present tests the clay blocks had a water content of 6 % and a density of 2150 kg/m^3, corresponding to a dry density of 2028 kg/m^3. The void ratio and initial degree of saturation were *e*=0.37 (porosity 0.27) and 45 %, respectively. The diameter of the borehole was 80 mm and the calculated ultimate density of the plugs after complete water saturation was 2025 kg/m^3.

"Couronne"-type

The detailed design and manufacturing of plugs of this type is described in the report on Sub-project 1 [3]. In the present tests the clay blocks had a water content of 6 % and a density of 2150 kg/m^3, corresponding to a dry density of 2028 kg/m^3. The void ratio and initial degree of saturation were *e*=0.37 (porosity 0.27) and 45 %, respectively. The diameter of the borehole was 76 mm and the calculated ultimate density of the plugs after complete water saturation 2015 kg/m^3. The central rod had a diameter of 8 mm. The inner diameter of the blocks was 10 mm.

"Pellet"- type

The detailed design and manufacturing of plugs of this type is described in the report on Sub-project 1 [3]. Pellets with 10 % water content were poured in the hole with 80 mm diameter giving the air-dry fill a density of 1150 kg/m^3 corresponding to a dry density of 1035 kg/m^3 and a density at complete water saturation of 1650 kg/m^3.

4.2.3 Placement of clay plugs

Following the plans, four clay plugs representing the "Basic", "Pellet", "Couronne" and "Container" types (Figure 1-1) were placed in 5 m long holes at about 450 m depth on July 17, 2006. The length of the plugs was planned to be 2.5 m but had to be adjusted to 2.8 to 3.0 m for making room for the packers in the boreholes.

The placement of plugs started at about 9 o'clock in the morning of July 17, 2006, beginning with Hole **D**, i.e. the pellet hole, and continuing with Holes **B**, **E**, and **H**. The operations are described here in this order.

The "Pellet"-type Plug (Hole D)

The following steps were taken:

- Water was pumped out to yield dry conditions.
- Pellets were poured in the hole with slight compaction at every 0.5 m level (Figures 4-1 and 4-2). The total volume, which was initially planned to be 12.5 litres, was about 13 litres yielding a length and dry density of the pellet plug of 2.8 m and 990 kg/m^3.
- Immediately after filling the pellets, tap water with low electrolyte content was poured into the hole and a mechanical packer was then fixed in the hole (Figure 4-3). The packer was anchored to the rock by shallow bolts in the rock and activated for confining the maturing plug.
- Mechanical strain gauges were installed for measuring the displacement of the released packer resting on the upper end of the clay plug at the loadings.

Figure 4-1. *Pouring pellets in cylinder with known volume for subsequent filling of Hole **D**.*

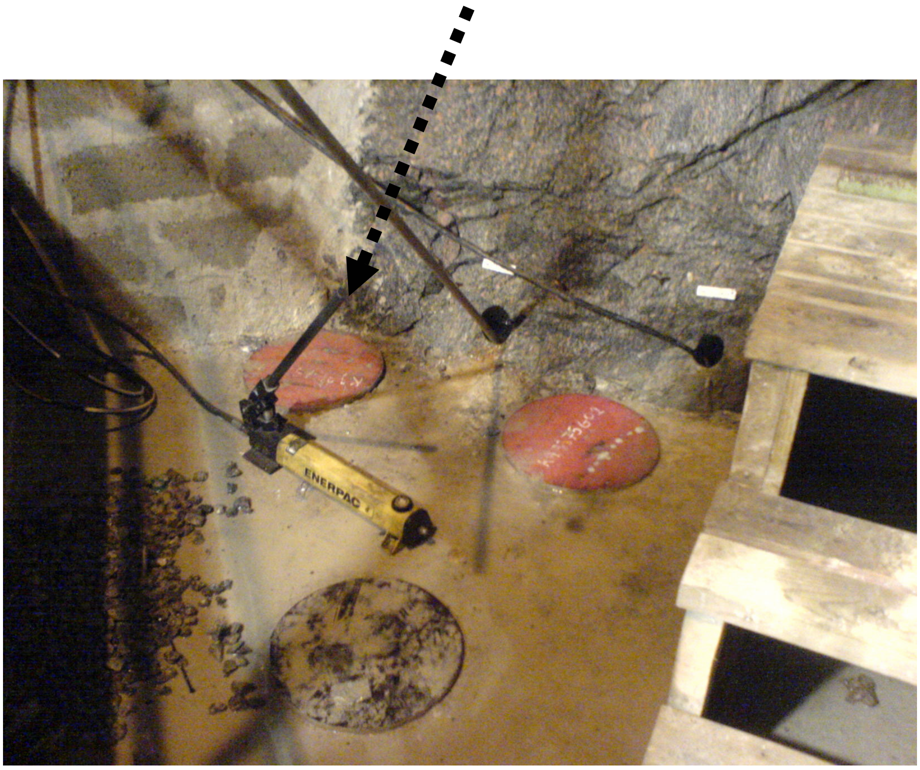


Figure 4-2. *Rod with plate (dotted arrow pointing at it) for light compaction of the pellet fill.*

Figure4-3. *Mechanical packers for sealing the plugged holes.*

The "Basic"-type Plug (Hole B)

The following steps were taken:

- Tap water was pumped into the hole for replacing initially present Äspö water.
- The perforated copper plug containing tightly fitting compacted bentonite blocks was lowered into the water-filled hole. (Figure 4-4). The initially planned length of the plug 2.5 m was increased to 3.0 m.
- A mechanical packer was fixed in the hole by anchoring it to the rock by shallow bolts.
- Mechanical strain gauges were installed for measuring the displacement of the released packer resting on the upper end of the clay plug at the loadings.

Figure 4-4. *Placement of the plug of "Basic Type" in Hole* ***B****.*

The plug of "Couronne"-type (Hole E)

The following steps were taken:

- Tap water was pumped into the hole for replacing initially contained Äspö water.
- The compacted clay blocks were stacked on the central rod of stainless steel (Figure 4-5) and they were lowered into the water-filled hole. The initially planned length of the plug 2.5 m was increased to 3.0 m.
- A mechanical packer was fixed in the hole by anchoring it to the rock by shallow bolts for confining the plug in the maturation phases.
- Mechanical strain gauges were installed for measuring the displacement of the released packer resting on the upper end of the clay plug at the loadings.

Figure 4-5. *Preparation of the plug of Couronne Type in Hole **E**. The blocks are being stacked around the central rod.*

The plug of "Container"-type (Hole H)

The following steps were taken:

- Tap water was pumped into the hole for replacing initially contained Äspö water.
- The placement of the clay blocks was made manually because the mechanical tools for the placement required high-pressure utilities that could not be used at the testing site (Figure 4-6). The initially planned length of the plug 2.5 m was increased to 3.0 m.
- A mechanical packer was fixed in the hole and anchored to the rock by shallow bolts.
- Mechanical strain gauges were installed for measuring the displacement of the released packer resting on the upper end of the clay plug at the loadings.

Figure 4-6. *Manual placement of the clay components of the Container Plug.*

4.2.4 Measurements

Definitions

The aim was to determine the force that had to be exerted on the lower end of the plugs for displacing them and this required definition of the "critical" displacement to represent overcoming the shear strength of the "clay skin" at different times after placement of the plugs, and of the magnitude and duration of the loading steps. The decisions were that the load (force) steps should correspond to an increase in shear stress of the "clay skin" of 50 kPa and hold them constant for 5 minutes until the upper end of the loaded plug had been displaced by 30 mm. This plan was slightly adjusted in the course of the tests, implying for instance that the rate of displacement and not only the absolute strain were used for determining when additional load steps should be applied. Another change was that the displacement of the plugs was measured not only at the top end but also at the lower one, the latter displacement being evaluated from the expansion of the hydraulic jack (cf. Appendix II).

For determining the maturation rate in terms of the time-dependent increase in critical load an appropriate period of time had to be selected for letting the clay plugs mature before the next loading should be made. Based on the laboratory studies and practical issues including selection of suitable times for getting access to the test site the time schedule was the following:

- Placement of all the plugs and initiation of the maturation process on July 18.
- First loading of all the plugs on July 19, about 24 hours after placement of the plugs.

- Second loading of all the plugs on July 20, about 48 hours after placement of the plugs.
- Third loading of the “Pellet” plug on July 22, about 96 hours after placement of the plugs.
- Fourth loading of the “Pellet” plug on August 23 about 720 hours after placement of the plug.

The results from the testing are summarized below; the complete protocols are collected in Appendix II.

“Pellet”-type plug

The total volume of the pellet mass poured in the hole and slightly compacted at each 0.5 m level, was planned to be 12.5 litres but the actual volume was 13 litres, yielding a length and dry density of the plug of 2.8 m and 990 kg/m^3, respectively. Table 4-1 gives the data for the ultimate “sheared” conditions.

Table 4-1. Force required for displacing the “Pellet” plug and the mobilized shear resistance of the “clay skin”.

Time after placement, h	Force required for displacement, t	Maximum displacement, mm Upper/lower	Average shear stress exerted on the “clay skin”, kPa
24	1.66	6.6/-	66
48	1.66	4.8/-	66
96	1.92	9.6/-	77
720	3.50	>10/-	140

The loadings gave evidence of compression of the plug rather than displacement as indicated by the unchanged position of the upper end of the plug and movement of the lower end. The shear strength of the “clay skin” was evaluated by assuming that the strength was mobilized where the strain exceeded 2 %, which is estimated to represent about 1/3 of the plug length, assuming the strain to be linearly distributed along the total plug length. The actual strength was in the predicted interval 0-100 kPa indicating that saline water had some impact on the strength which would have been about 100 kPa for tap water (Table 3-2).

“Basic”-type plug

The originally planned plug length 2.5 m was extended to 3 m by putting in a short plug element for practical reasons. The loading of this plug gave the data in Table 4-2 data for the ultimate “sheared” conditions at the respective testing events.

Table 4-2. Force required for displacing the "Basic" plug and the mobilized shear resistance of the "clay skin".

Time after placement, h	Force required for displacement, t	Maximum displacement, mm Upper/lower	Average shear stress exerted on the "clay skin", kPa
24	1.16	0.45/1.2	15
48	2.66	0.52/5	35
96	9.96	0.05/-	132
720	3.50	0/>10	>133

The very low shear strength, i.e. less than 50 % of the value for saline Äspö water after 96 hours, indicates that coagulation and microstructural heterogeneity prevailed in the first few days, but that the density and shear strength of the "clay skin" subsequently increased very much. The plug matured significantly slower than the pellet plug, which is primarily ascribed to the retarding impact of the perforated tube. This clearly shows that the perforated tube serves well as erosion protection in the placement phase by retarding migration of erosion-sensitive soft material to the space between the rock and the perforated tube.

"Container"-type plug

The originally planned plug length 2.5 m was extended to 3 m for practical reasons. The loading of this plug gave the data in Table 4-3 for the ultimate "sheared" conditions at the testing events.

Table 4-3. Force required for displacing the "Container" plug and the mobilized shear resistance of the "clay skin".

Time after placement, h	Force required for displacement, t	Maximum displacement, mm Upper/lower	Average shear stress exerted on the "clay skin", kPa
24	2.32	3.6/-	31
48	5.98	13.2/-	80
96	11.95	12/-	159
720	>12	>10/-	>160

The low shear strength, i.e. about 50 % of the value corresponding to saline Äspö water after 96 hours (cf. Table 3-2), indicates that coagulation and microstructural heterogeneity prevailed in the first few days, while the density and shear strength of the "clay skin" subsequently increased very much. In this context it is worth mentioning that flow rates on the order of 0.6 m/day, which may be reached in the early maturation phase (Section 3.2.3), can cause erosion and particle transport leading to considerable microstructural disturbance [4].

The shear strength grew twice as fast as for the "Basic" plug in the first two days but not much quicker after that. Measurement of the displacement of the upper end of the plug could not be made with acceptable accuracy.

"Couronne"-type plug

The originally planned plug length 2.5 m was extended to 3 m for practical reasons. The loading of this plug gave the data in Table 4-4 for the ultimate "sheared" conditions at the testing events.

Table 4-4. Force required for displacing the "Couronne" plug and the mobilized shear resistance of the "clay skin".

Time after placement, h	Force required for displacement, t	Maximum displacement, mm Upper/lower	Average shear stress exerted on the "clay skin", kPa
24	3.49	-/4.2	46
48	5.48	-/13.2	73
96	9.96	-/12.0	133
720	>10	0/>10	>133

As for the other plugs the very low shear strength, i.e. about 1/3 of the predicted value for saline Äspö water after 96 hours (Table 3-2), indicates that coagulation and microstructural heterogeneity prevailed in the first few days. Like for the other plugs the density and shear strength of the "clay skin" subsequently increased very much. As expected, this plug matured at about the same rate as the "Container" plug.

5 Discussion and conclusions

General conclusions

The major aim of Sub-project 1 was to prepare plugs of defined types, to predict their maturation rates under prevailing rock conditions, and to determine these rates by performing "extrusion" experiments in which an axial force was exerted on one end of the plugs for displacing them sufficiently much to estimate the shear strength of the "clay skin", i.e. the clay in contact with the rock. This work was successful and led to the conclusion that all the tested plug types can be used in practice according to the principles outlined in Sub-project 1, implying that "Basic"-type plugs already with today's techniques can be used for plugging short and very deep holes oriented in any direction, that "Container"-type plugs are expected to be useful in the same types of holes with better protection against erosion in the placement phase, and that the "Couronne" and "Pellet"-type plugs are well suited for plugging shorter holes.

Resistance to axial pressure

The 3 m long unsupported plugs could resist an axial force of 1.7-6 t (17 -60 kN) after 2 days, which corresponds to a water pressure of 3 to 12 MPa at one end. This makes it possible to use them in boreholes where such gradients can be built up. After a few months the sustainable pressure difference will be 20 MPa over 3 m length except for simple plugs made of pellet fills. Such absolute pressures and pressure differences may, however, induce piping [1].

Comparison of predicted and actual clay maturation rates

The testing of the four clay types in Sub-project 2 showed that the rate of maturation was significantly slower in the first few days after placement than what was predicted using the simple diffusion model. The main reason for this can be any of the following:

1. The model does not take into consideration that clay exfoliates from the dense core parallel to water migration from the space between the dense plug and the borehole walls into the dense clay core. The actual combined mechanisms, which can probably be best described as two coupled diffusion processes, are believed to be delayed by interdependence.

2. The inflow of water from fractures for maintaining complete water saturation of the gel-filled space can have been slower than predicted because of clogging of this space by displacement and consolidation of the gels close to the fracture aperture. This may have reduced the hydraulic conductivity of the gel and delayed inflow from the fractures.

3. The distribution of the water inflow may have been different than assumed, i.e. that only one or two fractures were actually water-bearing. This can have made the spacing larger than assumed and hence caused a delay in inflow of water in the gel-filled space. At higher water pressure this would hardly have had any influence.

It is believed that the rock structure and flow capacity of water-bearing fractures is a major parameter that are not known well enough for predicting the maturation of the clay plugs with accuracy. However, the evolution of the clay plugs predicted in this document is believed to be reasonably correct considering the actual physical state of "Basic"-type plugs reached in tests at Stripa [1], which showed that the water pressure in the fractures is of great significance, not for bringing water quickly into the dense parts of the plugs but for supplying fractures that intersect the boreholes with water. Hence, one expects that the 5 m deep plugged holes at Äspö will not mature as quickly as the OL-KR24 [5] hole but still be largely water saturated in 4 months.

6 References

1. Pusch R, Ramqvist G, 2004. Borehole sealing, preparative steps, design and function of plugs – basic concept. SKB Int. Progr. Rep. IPR-04-57.

2. Pusch R, Yong R N, 2006. "Microstructure of Smectite Clays and Engineering Performance". Taylor & Francis, London and New York.

3. Pusch R, Ramqvist G, 2006. Borehole plugging, Final Report of Sub-project 1. SKB IPR-06-28

4. Pusch R, Erlström M, Börgesson L, 1987. Piping and erosion phenomena in soft clay gels. SKB technical Report TR-87-09, SKB, Stockholm.

5. Pusch R, Ramqvist G, 2006. Borehole plugging, Final Report of Sub-project 3. SKB IPR-06-30

Appendices

Appendix 1. Protocols from hydraulic testing of boreholes for plug

Version 1.0.0

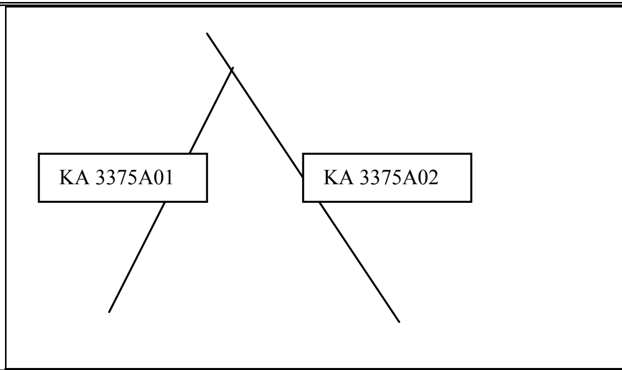
SKB

Protokoll flödes och tryck mätning

Protokoll ______av______

Område Äspö tunneln -450	Projekt Pluggning av borrhål
Grupp ID Borrhåls grupp ett Mätning nr 1	Aktivitetsplansnummer
Uppdragsansvarig på plats Hans Wimelius	Besättning (fullständiga namn) Anders Wikman, Anders Holm

IDCODE (borrhål)	**Längd Från-till**	**Dimension**
KA 3375A01	0-5,1m	76 mm
KA 3375A02	0-4,8 m	80 mm
KA 3375A02	4,8-5,1m	76 mm



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KA 3375A02	3,1-5,1	060221/10:22	5.65			Innan trycksättning
KA 3375A01	1,1-3,8	060221/10:43	5.87			Efter 20 min trycksättning
KA 3375A02	1,1-2,1	060221/10:43	8.48	6.5 bar		Efter 20 min trycksättning (Trycksatt sektion)
KA 3375A02	3,1-5,1	060221/10:43	6.05			Efter 20 min trycksättning
KA 3375A01	1,1-3,8	060221/10:52	5.90			Efter 10 min innestängt tryck
KA 3375A02	1,1-2,1	060221/10:52	4.68			Efter 10 min innestängt tryck
KA 3375A02	3,1-5,1	060221/10:52	6.08			Efter 10 min innestängt tryck

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KA3375A05	Enligt ritning	060221/10:22		0		Innan trycksättning
KA3377A01	Enligt ritning	060221/10:43		0		Efter 20 min trycksättning
KA3375A03	Enligt ritning	060221/10:43		9		Efter 20 min trycksättning
KA3375A05	Enligt ritning	060221/10:43		0		Efter 20 min trycksättning

Uppdragstagares signaturer samt datum		SKB:s signaturer samt datum	
Upprättad av	Kvalitetsgodkänd för leverans	Leverans godkänd	Införd i SICADA

Version 1.0.0

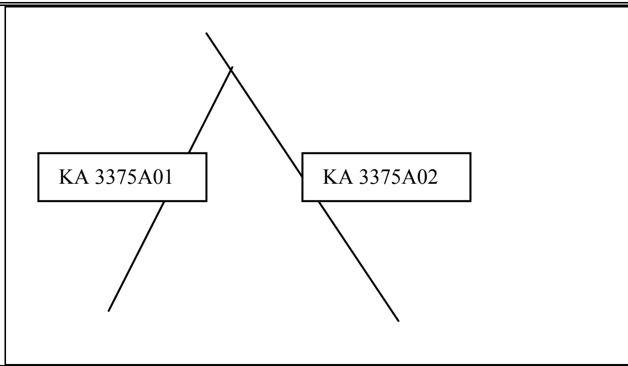
SKB

Protokoll flödes och tryck mätning

Protokoll ______av______

Område Äspö tunneln -450	Projekt Pluggning av borrhål
Grupp ID Borrhåls grupp ett Mätning nr två	Aktivitetsplansnummer
Uppdragsansvarig på plats Hans Wimelius	Besättning (fullständiga namn) Anders Wikman, Anders Holm

IDCODE (borrhål)	Längd Från-till	Dimension
KA 3375A01	0-5,1m	76 mm
KA 3375A02	0-4,8 m	80 mm
KA 3375A02	4,8-5,1m	76 mm



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KA 3375A02	3.1-5,1	060221/11:11	4.43			Innan trycksättning
KA 3375A01	1,1-3,8	060221/11:32	10.38			Efter 20 min trycksättning
KA 3375A02	1,1-2,1	060221/11:32	4.25			Efter 20 min trycksättning
KA 3375A02	3,1-5,1	060221/11:32	10.46	6.5 bar		Efter 20 min trycksättning (Trycksatt sektion)
KA 3375A01	1,1-3,8	060221/11:42	9.46			Efter 10 min innestängt tryck
KA 3375A02	1,1-2,1	060221/11:42	4.26			Efter 10 min innestängt tryck
KA 3375A02	3,1-5,1	060221/11:42	9.57			Efter 10 min innestängt tryck
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KA3375A05	Enligt ritning	060221/11:10		0		Innan trycksättning
KA3377A01	Enligt ritning	060221/11:37		0		Efter 20 min trycksättning
KA3375A03	Enligt ritning	060221/11:37		9		Efter 20 min trycksättning
KA3375A05	Enligt ritning	060221/11:37		0		Efter 20 min trycksättning

Uppdragstagares signaturer samt datum		SKB:s signaturer samt datum	
Upprättad av	Kvalitetsgodkänd för leverans	Leverans godkänd	Införd i SICADA

Version 1.0.0

Protokoll flödes och tryck mätning

Protokoll ______av______

Område Äspö tunneln -450	Projekt Pluggning av borrhål
Grupp ID Borrhåls grupp ett Mätning nr 3	Aktivitetsplansnummer
Uppdragsansvarig på plats Hans Wimelius	Besättning (fullständiga namn) Anders Wikman, Anders Holm

IDCODE (borrhål)	**Längd Från-till**	**Dimension**
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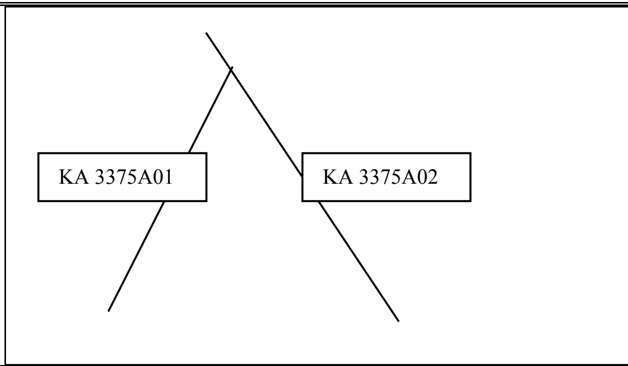
KA 3375A02	0-4,8 m	80 mm
KA 3375A02	4,8-5,1m	76 mm



IDCODE (borrhål)	**Section**	**Datum/Tid**	Grundvatten tryck (bar)	**Injekterat övertryck**		**Kommentar**
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KA 3375A02	2,1-3,1	060221/13:17	5.28			Innan trycksättning
KA 3375A02	4,1-5,1	060221/13:17	4.92			Innan trycksättning
KA 3375A01	1,1-3,8	060221/13:39	5.23			Efter 20 min trycksättning
KA 3375A02	2,1-3,1	060221/13:39	10.70	6 bar		Efter 20 min trycksättning (Trycksatt sektion)
KA 3375A02	4,1-5,1	060221/13:39	5.44			Efter 20 min trycksättning
KA 3375A01	1,1-3,8	060221/13:50	5.24			Efter 10 min innestängt tryck
KA 3375A02	2,1-3,1	060221/13:50	9.66			Efter 10 min innestängt tryck
KA 3375A02	4,1-5,1	060221/13:50	5.46			Efter 10 min innestängt tryck

IDCODE (borrhål)	**Section**	**Datum/Tid**	**Flödestid (min,sek)**	**20 min [ml]**	**10 min [ml]**	**Kommentar**
KA 3375A02	3,1-5,1	060221	20:00	60	22	

IDCODE (borrhål)	**Sektion**	**Datum/Tid**	**(min,sek)**	**Tryck (bar)**		**Kommentar**
KA3377A01	Enligt ritning	060221/13:17		0		Innan trycksättning
KA3375A03	Enligt ritning	060221/13:17		9		Innan trycksättning
KA3375A05	Enligt ritning	060221/13:17		0		Innan trycksättning
KA3377A01	Enligt ritning	060221/13:39		0		Efter 20 min trycksättning
KA3375A03	Enligt ritning	060221/13:39		9		Efter 20 min trycksättning
KA3375A05	Enligt ritning	060221/13:39		0		Efter 20 min trycksättning

Uppdragstagares signaturer samt datum		SKB:s signaturer samt datum	
Upprättad av	Kvalitetsgodkänd för leverans	Leverans godkänd	Införd i SICADA

Version 1.0.0

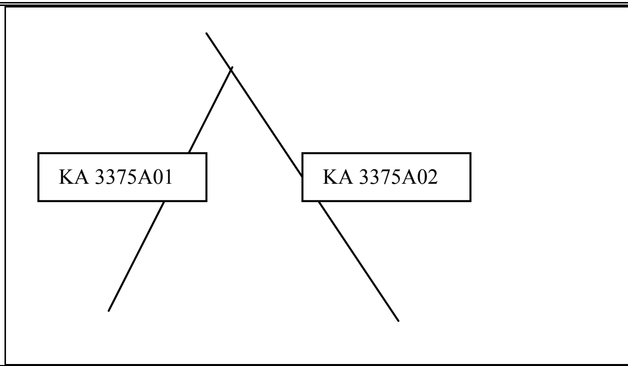
SKB

Protokoll flödes och tryck mätning

Protokoll ______av______

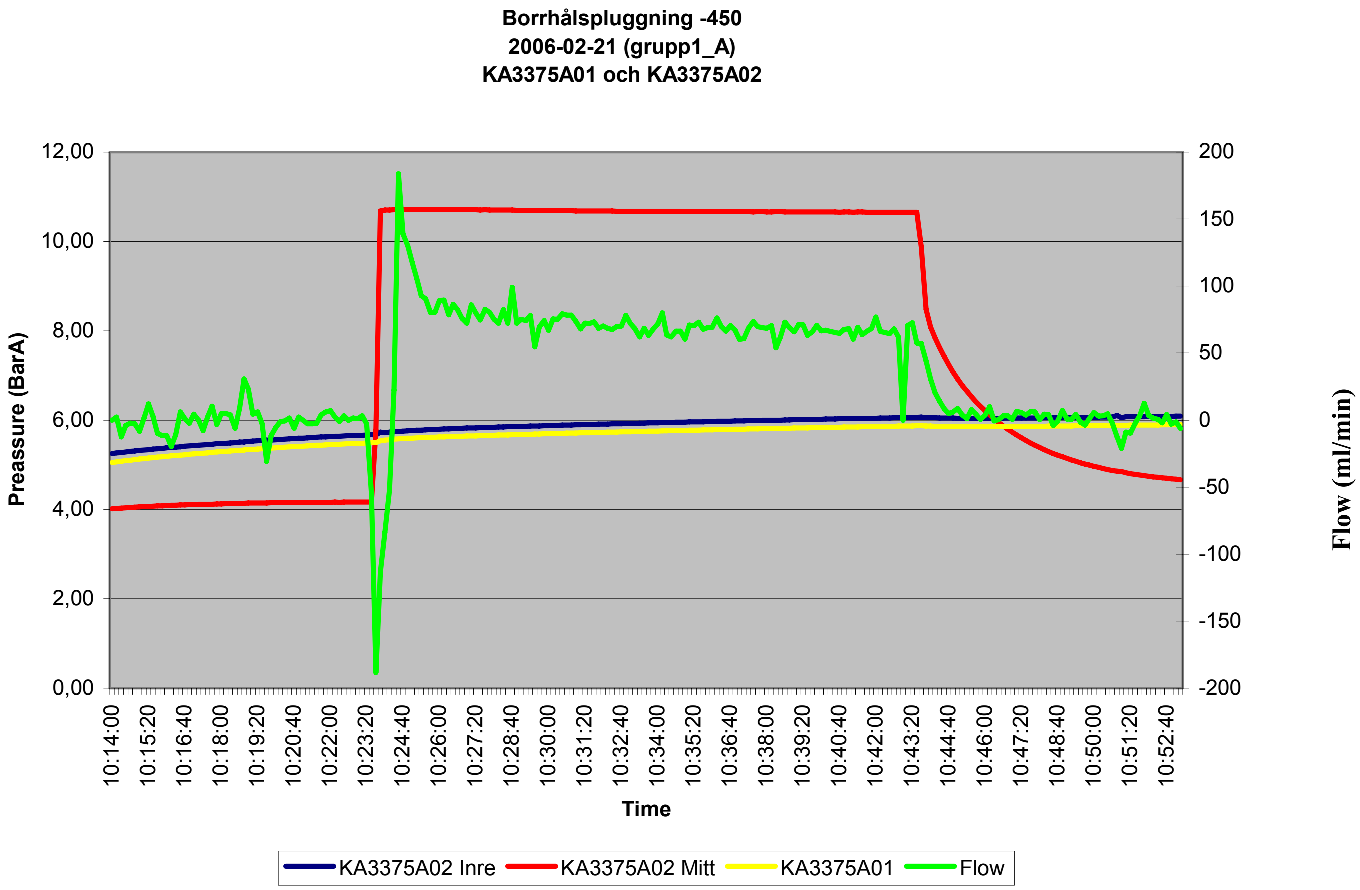
Område Äspö tunneln -450	Projekt Pluggning av borrhål
Grupp ID Borrhåls grupp ett Mätning nr 4	Aktivitetsplansnummer
Uppdragsansvarig på plats Hans Wimelius	Besättning (fullständiga namn) Anders Wikman, Anders Holm

IDCODE (borrhål)	**Längd Från-till**	**Dimension**
KA 3375A01	0-5,1m	76 mm
KA 3375A02	0-4,8 m	80 mm
KA 3375A02	4,8-5,1m	76 mm

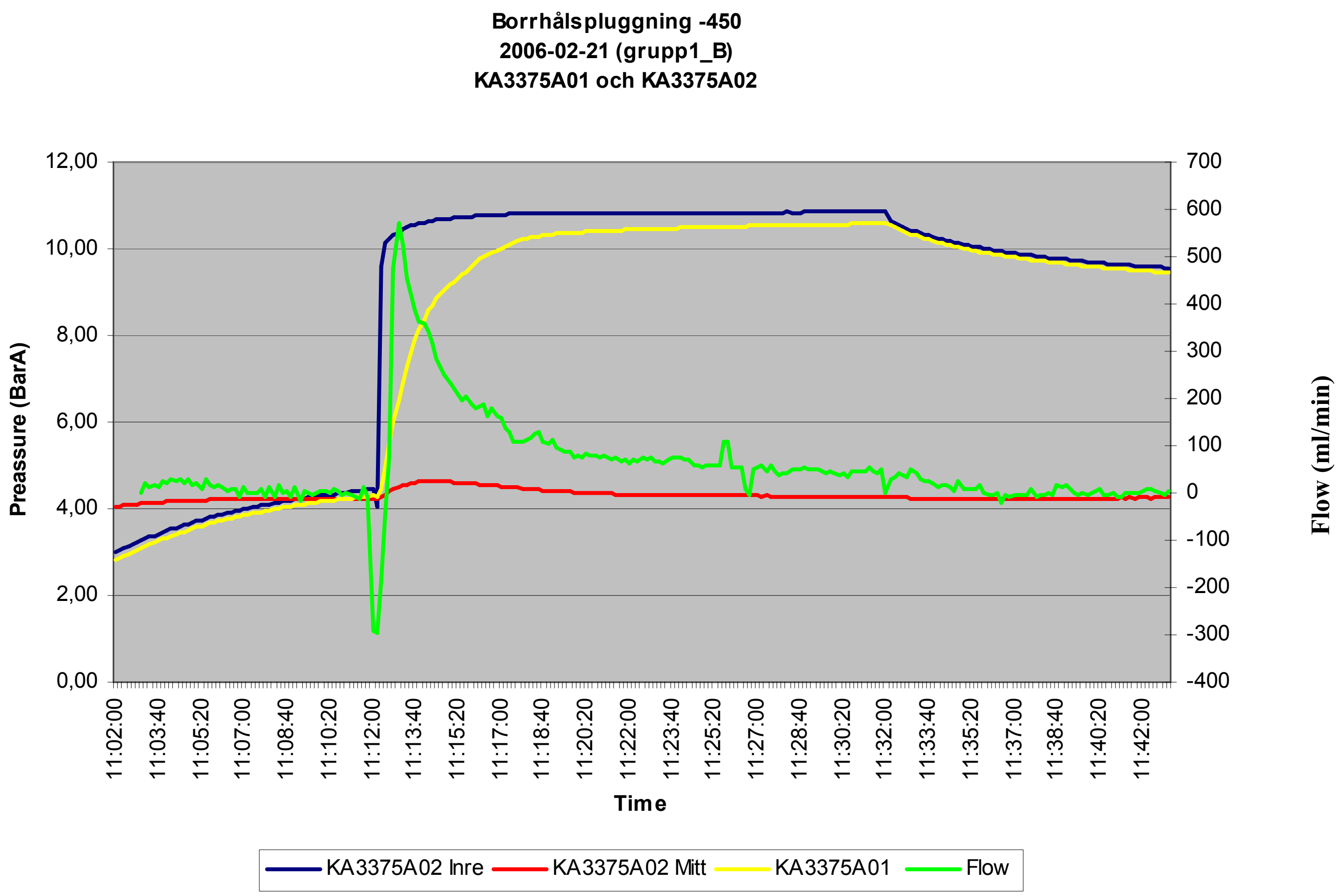


IDCODE (borrhål)	**Section**	**Datum/Tid**	Grundvatten tryck (bar)	**Injekterat övertryck**		**Kommentar**
KA 3375A01	1,1-3,8	060221/14:05	4.28			Innan trycksättning
KA 3375A02	4,1-4,8	060221/14:05	4.54			Innan trycksättning
KA 3375A02	2,1-3,1	060221/14:05	5.99			Innan trycksättning
KA 3375A01	1,1-3,8	060221/14:26	10.48			Efter 20 min trycksättning
KA 3375A02	4,1-4,8	060221/14:26	10.85	6.5 bar		Efter 20 min trycksättning (Trycksatt sektion)
KA 3375A02	2,1-3,1	060221/14:26	9.3			Efter 20 min trycksättning
KA 3375A01	1,1-3,8	060221/14:36	9.46			Efter 10 min innestängt tryck
KA 3375A02	4,1-4,8	060221/14:36	9.64			Efter 10 min innestängt tryck
KA 3375A02	2,1-3,1	060221/14:36	8.99			Efter 10 min innestängt tryck
IDCODE (borrhål)	**Section**	**Datum/Tid**	**Flödestid (min,sec)**	**20 min [ml]**	**10 min [ml]**	**Kommentar**
KA 3375A02	4,1-4,8	060221/14:26	20:00	2849	120	
IDCODE (borrhål)	**Section**	**Datum/Tid**	**(min,sec)**	**Tryck (bar)**		**Kommentar**
KA3377A01	Enligt ritning	060221/14:05		0		Innan trycksättning
KA3375A03	Enligt ritning	060221/14:05		9		Innan trycksättning
KA3375A05	Enligt ritning	060221/14:05		0		Innan trycksättning
KA3377A01	Enligt ritning	060221/14:26		0		Efter 20 min trycksättning
KA3375A03	Enligt ritning	060221/14:26		9		Efter 20 min trycksättning
KA3375A05	Enligt ritning	060221/14:26		0		Efter 20 min trycksättning

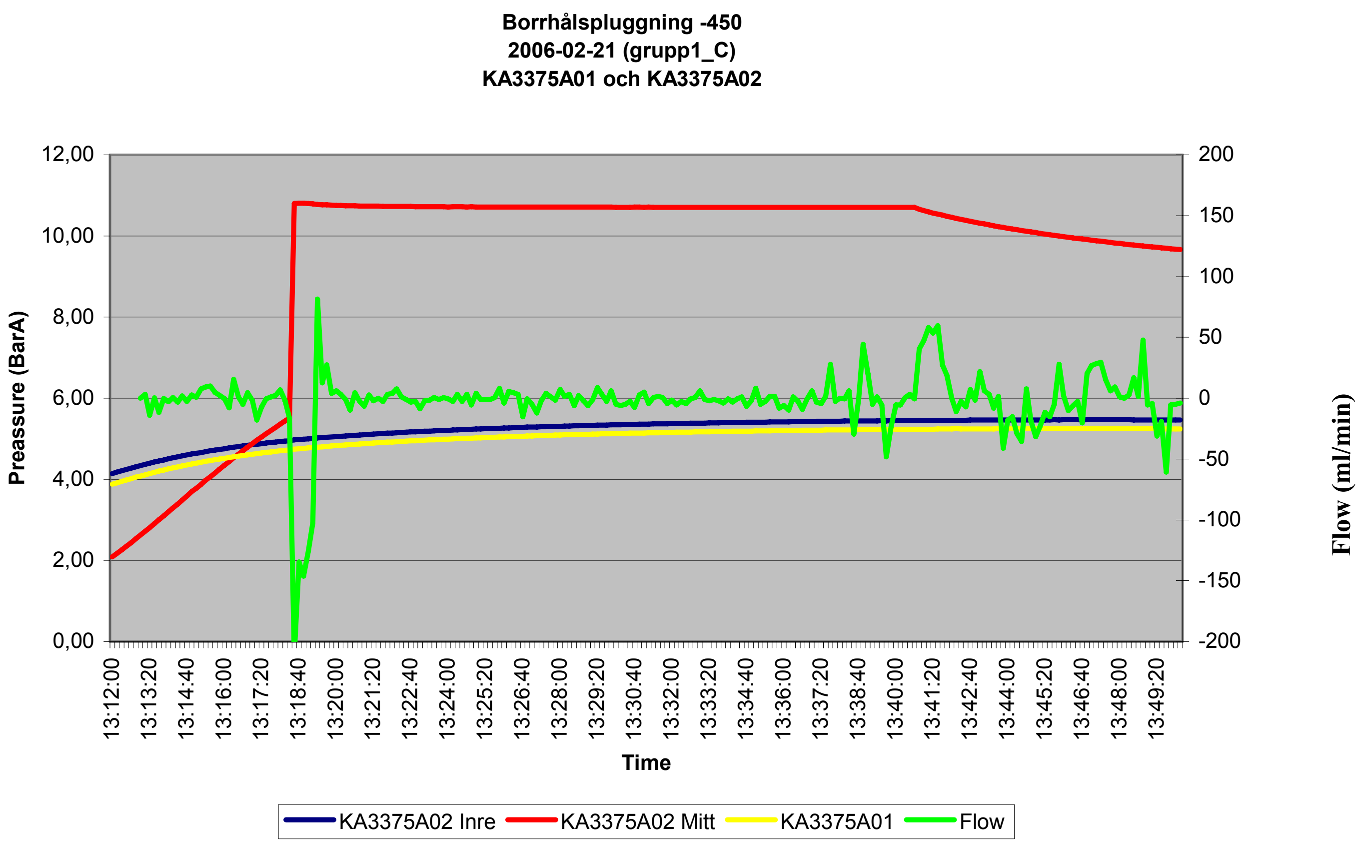
Uppdragstagares signaturer samt datum		SKB:s signaturer samt datum	
Upprättad av	Kvalitetsgodkänd för leverans	Leverans godkänd	Införd i SICADA

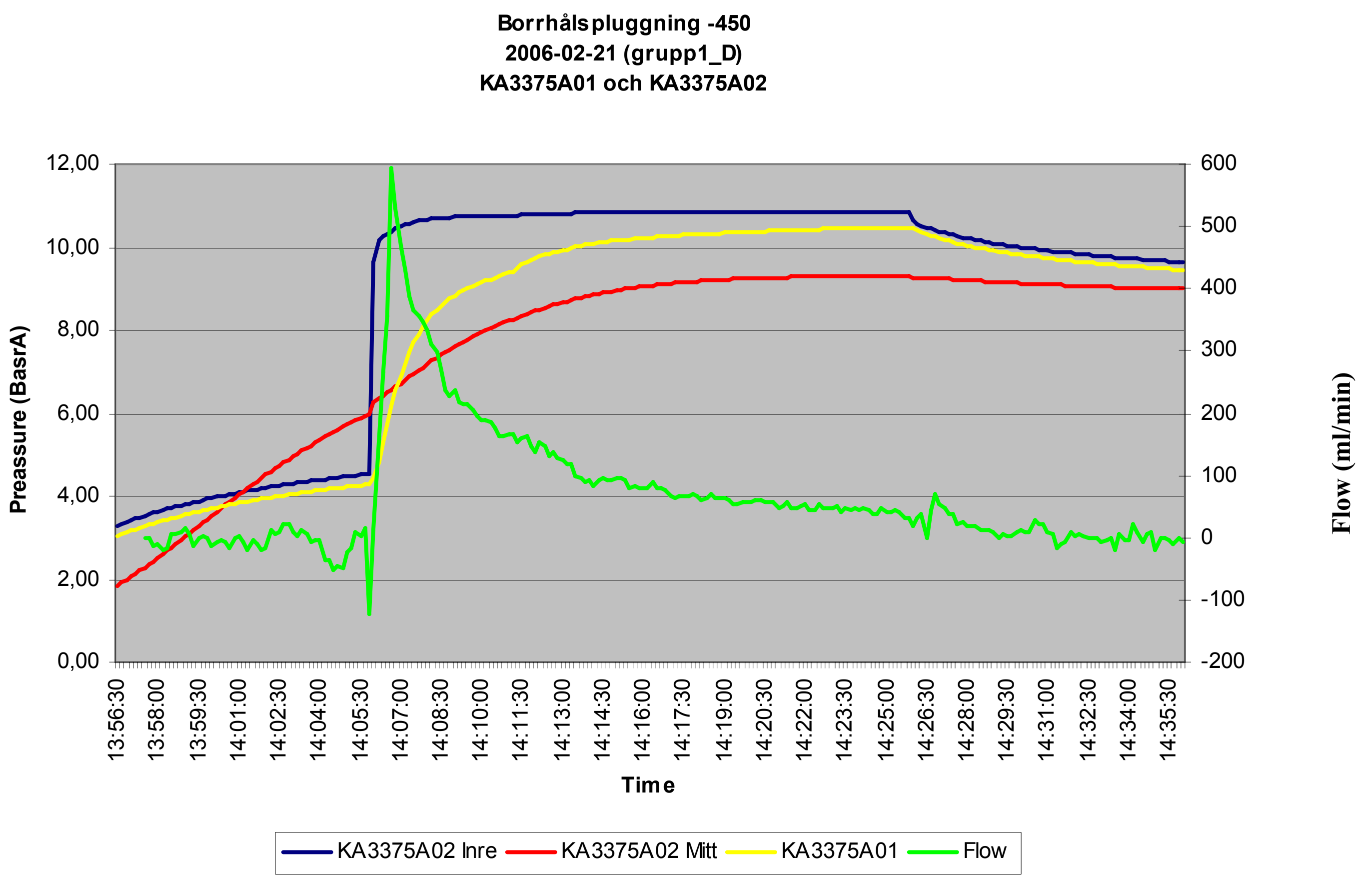


Borrhålspluggning -450
2006-02-21 (grupp1_A)
KA3375A01 och KA3375A02
Preassure (BarA)
Flow (ml/min)
Time
KA3375A02 Inre
KA3375A02 Mitt
KA3375A01
Flow



Borrhålspluggning -450
2006-02-21 (grupp1_B)
KA3375A01 och KA3375A02
Preassure (BarA)
Flow (ml/min)
Time
KA3375A02 Inre
KA3375A02 Mitt
KA3375A01
Flow


Borrhålspluggning -450
2006-02-21 (grupp1_C)
KA3375A01 och KA3375A02
Preassure (BarA)
Flow (ml/min)
Time
KA3375A02 Inre
KA3375A02 Mitt
KA3375A01
Flow


Borrhålspluggning -450
2006-02-21 (grupp1_D)
KA3375A01 och KA3375A02
Preassure (BasrA)
Flow (ml/min)
Time
KA3375A02 Inre
KA3375A02 Mitt
KA3375A01
Flow

Version 1.0.0

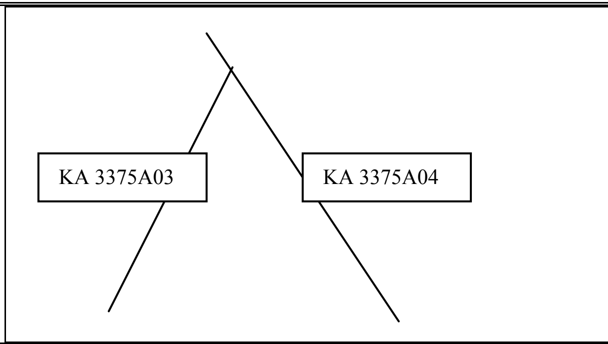
SKB

Protokoll flödes och tryck mätning

Protokoll ______av______

Område Äspö tunneln -450	Projekt Pluggning av borrhål
Grupp ID Borrhålsgrupp två mätning 1	Aktivitetsplansnummer
Uppdragsansvarig på plats Hans Wimelius	Besättning (fullständiga namn) Anders Wikman, Anders Holm, Hans Wimelius

IDCODE (borrhål)	Längd Från-till	Dimension
KA 3375A03	0-5,2m	76 mm
KA 3375A04	0-5,0 m	80 mm
KA 3375A04	5,0-5,5m	76 mm



IDCODE (borrhål)	Section	Datum/Tid	Grundvatten tryck (bar)	Injekterat övertryck		Kommentar
KA 3375A03	1,1-3,6	060224 10:19:40	6,62			Innan trycksättning
KA 3375A04	1,1-2,1	060224 10:19:40	1,87			Innan trycksättning
KA 3375A04	3,1-5,5	060224 10:19:40	6,62			Innan trycksättning
KA 3375A03	1,1-3,6	060224 10:39:40	7,18			Efter 20 min trycksättning
KA 3375A04	1,1-2,1	060224 10:39:40	14,27	12,73		Efter 20 min trycksättning (trycksatt sektion)
KA 3375A04	3,1-5,5	060224 10:39:40	7,15			Efter 20 min trycksättning
KA 3375A03	1,1-3,6	060224 10:48:40	7,39			Efter 9 min innestängt tryck
KA 3375A04	1,1-2,1	060224 10:48:40	14,19			Efter 9 min innestängt tryck
KA 3375A04	3,1-5,5	060224 10:48:40	7,36			Efter 9 min innestängt tryck
IDCODE (borrhål)	**Sektion**	**Datum/Tid**	**Flödestid (min,sek)**	**20 min ml**	**9 min ml**	**Kommentar**
KA 3375A04	1,1-2,1	060224 10:19:50	20:00	62,36	7,11	
IDCODE (borrhål)	**Sektion**	**Datum/Tid**	**(min,sek)**	**Tryck (bar)**		**Kommentar**
KA3375A01	Se ritning	060224 10:19:40		1,0		Innan trycksättning
KA3375A05	Se ritning	060224 10:19:40		0		Innan trycksättning
KA3377A01	Se ritning	060224 10:19:40		0		Innan trycksättning
KA3375A01	Se ritning	060224 10:39:40		1,8		Efter 20 min trycksättning
KA3375A05	Se ritning	060224 10:39:40		0		Efter 20 min trycksättning
KA3377A01	Se ritning	060224 10:39:40		0		Efter 20 min trycksättning

Uppdragstagares signaturer samt datum		SKB:s signaturer samt datum	
Upprättad av	Kvalitetsgodkänd för leverans	Leverans godkänd	Införd i SICADA

Version 1.0.0

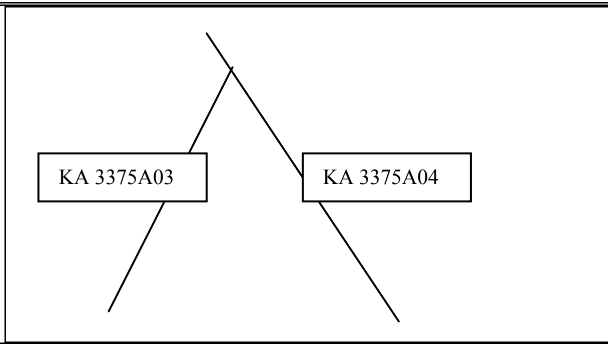
SKB

Protokoll flödes och tryck mätning

Protokoll ______av______

Område Äspö tunneln -450	Projekt Pluggning av borrhål
Grupp ID Borrhålsgrupp två mätning 2	Aktivitetsplansnummer
Uppdragsansvarig på plats Hans Wimelius	Besättning (fullständiga namn) Anders Wikman, Anders Holm, Hans Wimelius

IDCODE (borrhål)	Längd Från-till	Dimension
KA 3375A03	0-5,2m	76 mm
KA 3375A04	0-5,0 m	80 mm
KA 3375A04	5,0-5,5m	76 mm



IDCODE (borrhål)	Section	Datum/Tid	Grundvatten tryck (bar)	Injekterat övertryck		Kommentar
KA 3375A03	1,1-3,6	060224 11:04:20	7,62			Innan trycksättning
KA 3375A04	1,1-2,1	060224 11:04:20	1,32			Innan trycksättning
KA 3375A04	3,1-5,5	060224 11:04:20	7,66			Innan trycksättning
KA 3375A03	1,1-3,6	060224 11:24:20	10,11			Efter 20 min trycksättning
KA 3375A04	1,1-2,1	060224 11:24:20	1,53			Efter 20 min trycksättning
KA 3375A04	3,1-5,5	060224 11:24:20	14,44	6,65		Efter 20 min trycksättning (Trycksatt sektion)
KA 3375A03	1,1-3,6	060224 11:34:20	9,39			Efter 10 min innestängt tryck
KA 3375A04	1,1-2,1	060224 11:34:20	1,5			Efter 10 min innestängt tryck
KA 3375A04	3,1-5,5	060224 11:34:20	9,76			Efter 10 min innestängt tryck
IDCODE (borrhål)	**Section**	**Datum/Tid**	**Flödestid (min,sec)**	**20 min ml**	**10 min ml**	**Kommentar**
KA 3375A04	3,1-5,5	060224	20	2304,57	37,25	
IDCODE (borrhål)	**Section**	**Datum/Tid**	**(min,sec)**	**Tryck (bar)**		**Kommentar**
KA3375A01	Se ritning	060224 11:04:20		2		Innan trycksättning
KA3375A05	Se ritning	060224 11:04:20		0		Innan trycksättning
KA3377A01	Se ritning	060224 11:04:20		0		Innan trycksättning
KA3375A01	Se ritning	060224 11:24:20		2,4		Efter 20 min trycksättning
KA3375A05	Se ritning	060224 11:24:20		0		Efter 20 min trycksättning
KA3377A01	Se ritning	060224 11:24:20		0		Efter 20 min trycksättning

Uppdragstagares signaturer samt datum		SKB:s signaturer samt datum	
Upprättad av	Kvalitetsgodkänd för leverans	Leverans godkänd	Införd i SICADA

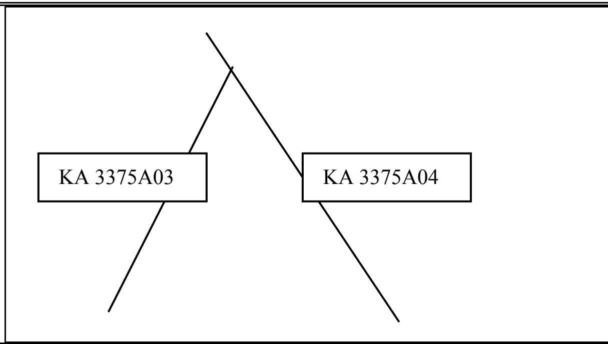
Version 1.0.0

Protokoll flödes och tryck mätning

Protokoll ______av______

Område Äspö tunneln -450	Projekt Pluggning av borrhål
Grupp ID Borrhålsgrupp två mätning 3	Aktivitetsplansnummer
Uppdragsansvarig på plats Hans Wimelius	Besättning (fullständiga namn) Anders Wikman, Anders Holm, Hans Wimelius

IDCODE (borrhål)	Längd Från-till	Dimension
KA 3375A03	0-5,2m	76 mm
KA 3375A04	0-5,0 m	80 mm
KA 3375A04	5,0-5,5m	76 mm



IDCODE (borrhål)	Section	Datum/Tid	Grundvatten tryck (bar)	Injekterat övertryck		Kommentar
KA 3375A03	1,1-3,6	060224 13:23:30	8,82			Innan trycksättning
KA 3375A04	2,1-3,1	060224 13:23:30	9,04			Innan trycksättning
KA 3375A04	4,1-5,5	060224 13:23:30	8,75			Innan trycksättning
KA 3375A03	1,1-3,6	060224 13:37:00	14,02			Efter 13:30 min trycksättning
KA 3375A04	2,1-3,1	060224 13:37:00	14,22			Efter 13:30 min trycksättning (trycksatt sektion)
KA 3375A04	4,1-5,5	060224 13:37:00	11,05			Efter 13:30 min trycksättning
KA 3375A03	1,1-3,6	060224 13:47:00	12,10			Efter 10 min innestängt tryck
KA 3375A04	2,1-3,1	060224 13:47:00	12,30			Efter10 min innestängt tryck
KA 3375A04	4,1-5,5	060224 13:47:00	10,81			Efter 10 min innestängt tryck

IDCODE (borrhål)	Section	Datum/Tid	Flödestid (min,sec)	13 min 30s ml	10 min ml	Kommentar
KA 3375A04	2,1-3,1	060224	13:30	5106,25	50,98	

IDCODE (borrhål)	Section	Datum/Tid	(min,sec)	Tryck (bar)		Kommentar
KA3375A01	Se ritning	060224 13:23:30		3		Innan trycksättning
KA3375A05	Se ritning	060224 13:23:30		0		Innan trycksättning
KA3377A01	Se ritning	060224 13:23:30		0		Innan trycksättning
KA3375A01	Se ritning	060224 13:37:00		3,5		Efter 13:30 min trycksättning
KA3375A05	Se ritning	060224 13:37:00		0		Efter 13:30 min trycksättning
KA3377A01	Se ritning	060224 13:37:00		0		Efter 13:30 min trycksättning

Uppdragstagares signaturer samt datum		SKB:s signaturer samt datum	
Upprättad av	Kvalitetsgodkänd för leverans	Leverans godkänd	Införd i SICADA

Version 1.0.0

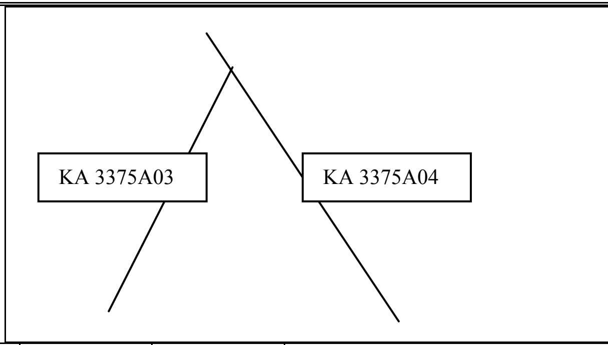
SKB

Protokoll flödes och tryck mätning

Protokoll ______av______

Område Äspö tunneln -450	Projekt Pluggning av borrhål
Grupp ID Borrhålsgrupp två mätning 4	Aktivitetsplansnummer
Uppdragsansvarig på plats Hans Wimelius	Besättning (fullständiga namn) Anders Wikman, Anders Holm, Hans Wimelius

IDCODE (borrhål)	Längd Från-till	Dimension
KA 3375A03	0-5,2m	76 mm
KA 3375A04	0-5,0 m	80 mm
KA 3375A04	5,0-5,5m	76 mm

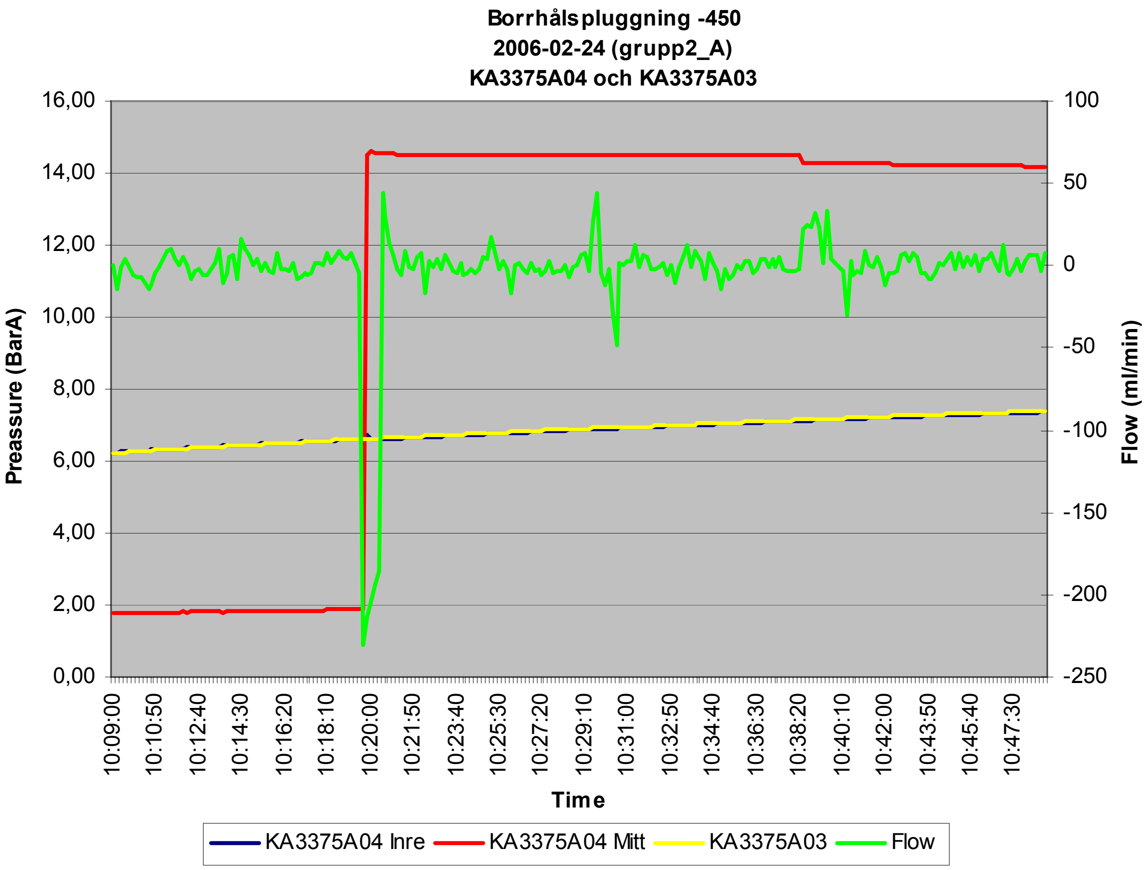


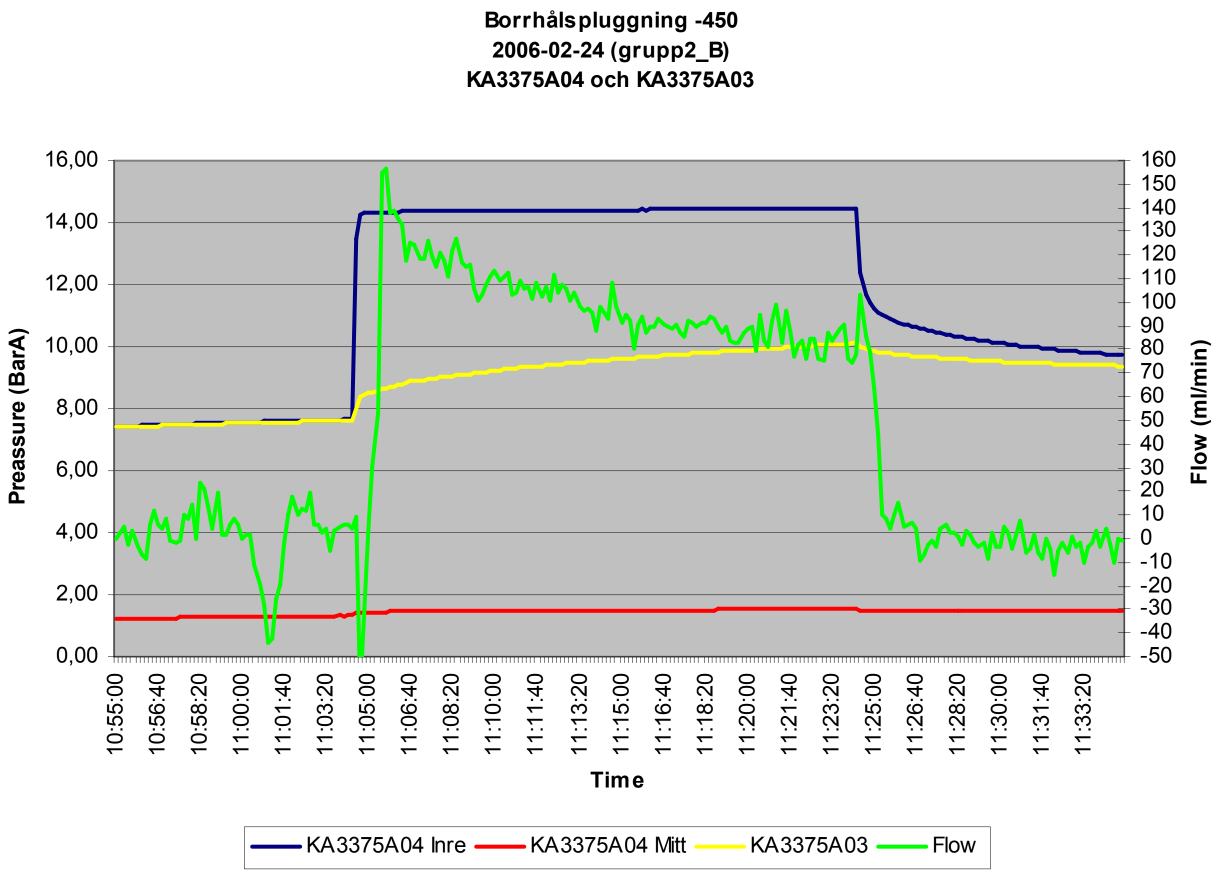
IDCODE (borrhål)	Section	Datum/Tid	Grundvatten tryck (bar)	Injekterat övertryck		Kommentar
KA 3375A03	1,1-3,6	060224 14:10:40	10,53			Innan trycksättning
KA 3375A04	2,1-3,1	060224 14:10:40	10,82			Innan trycksättning
KA 3375A04	4,1-5,5	060224 14:10:40	10,11			Innan trycksättning
KA 3375A03	1,1-3,6	060224 14:31:20	10,83			Efter 20:40 min trycksättning
KA 3375A04	2,1-3,1	060224 14:31:20	11,23			Efter 20:40 min trycksättning
KA 3375A04	4,1-5,5	060224 14:31:20	14,72	4,63 bar		Efter 20:40 min trycksättning (Trycksatt sektion)
KA 3375A03	1,1-3,6	060224 14:41:20	10,67			Efter 10 min innestängt tryck
KA 3375A04	2,1-3,1	060224 14:41:20	11,06			Efter 10 min innestängt tryck
KA 3375A04	4,1-5,5	060224 14:41:20	11,20			Efter 10 min innestängt tryck

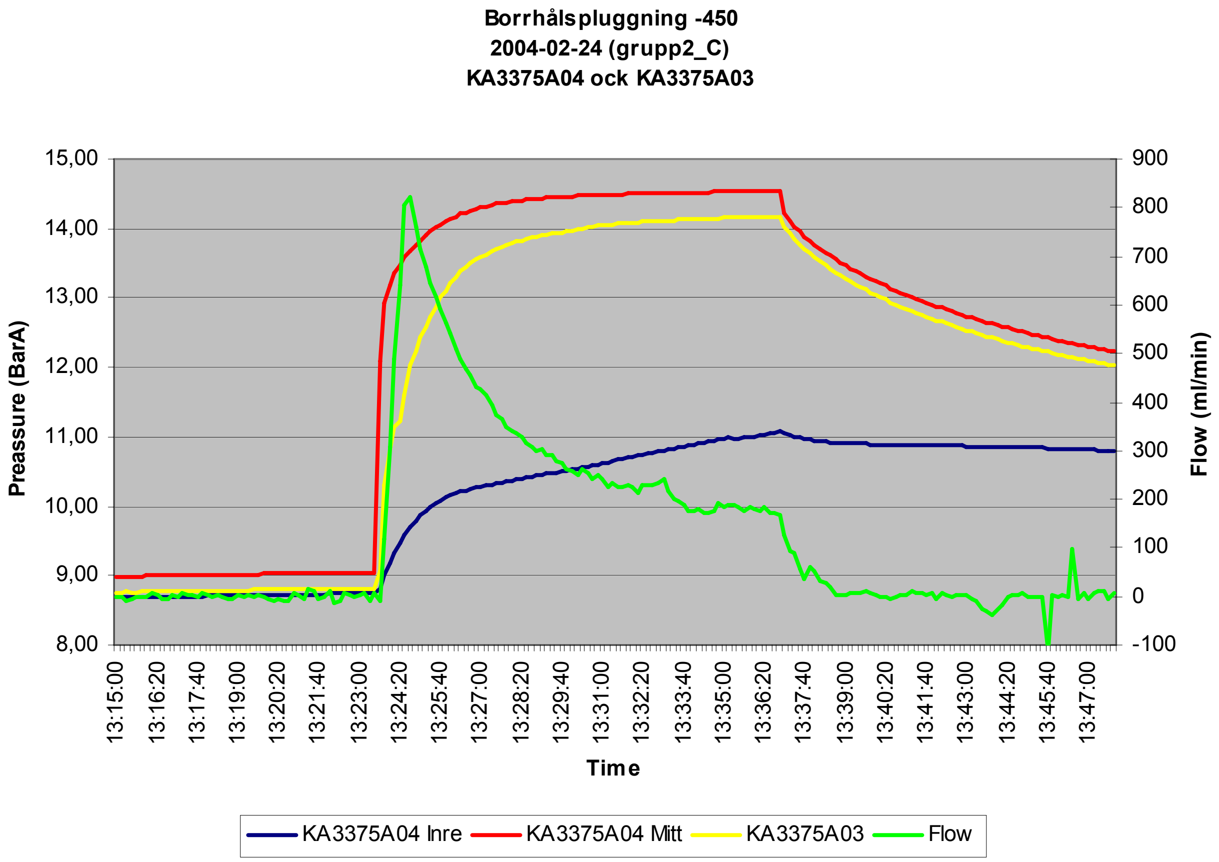
IDCODE (borrhål)	Sektion	Datum/Tid	Flödestid (min,sek)	20:40 min ml	10 min ml	Kommentar
KA 3375A04	4,1-5,5	060224	20:40	1270,19	25,22	

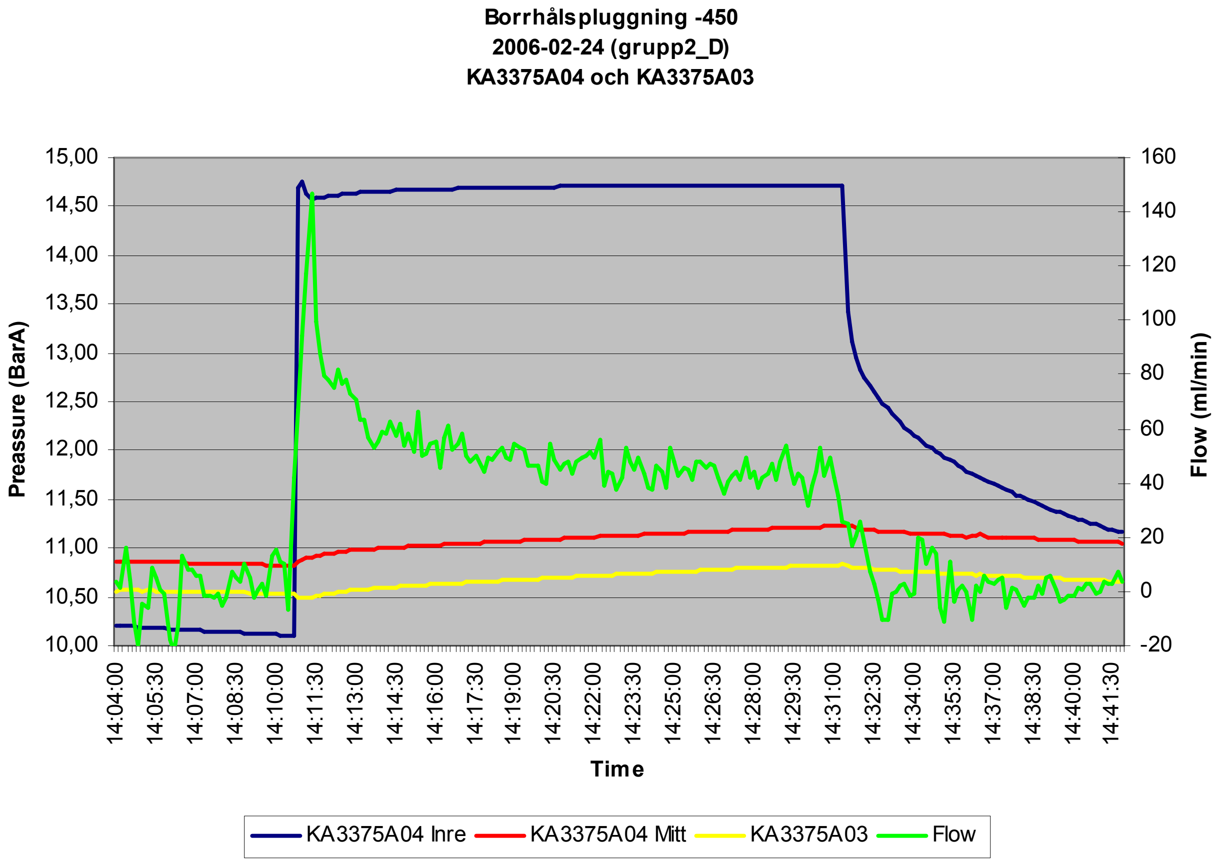
IDCODE (borrhål)	Section	Datum/Tid	(min,sec)	Tryck (bar)		Kommentar
KA3375A01	Se ritning	060224 14:10:40		4		Innan trycksättning
KA3375A05	Se ritning	060224 14:10:40		0		Innan trycksättning
KA3377A01	Se ritning	060224 14:10:40		0		Innan trycksättning
KA3375A01	Se ritning	060224 14:31:20		4,2		Efter 20 min trycksättning
KA3375A05	Se ritning	060224 14:31:20		0		Efter 20 min trycksättning
KA3377A01	Se ritning	060224 14:31:20		0		Efter 20 min trycksättning

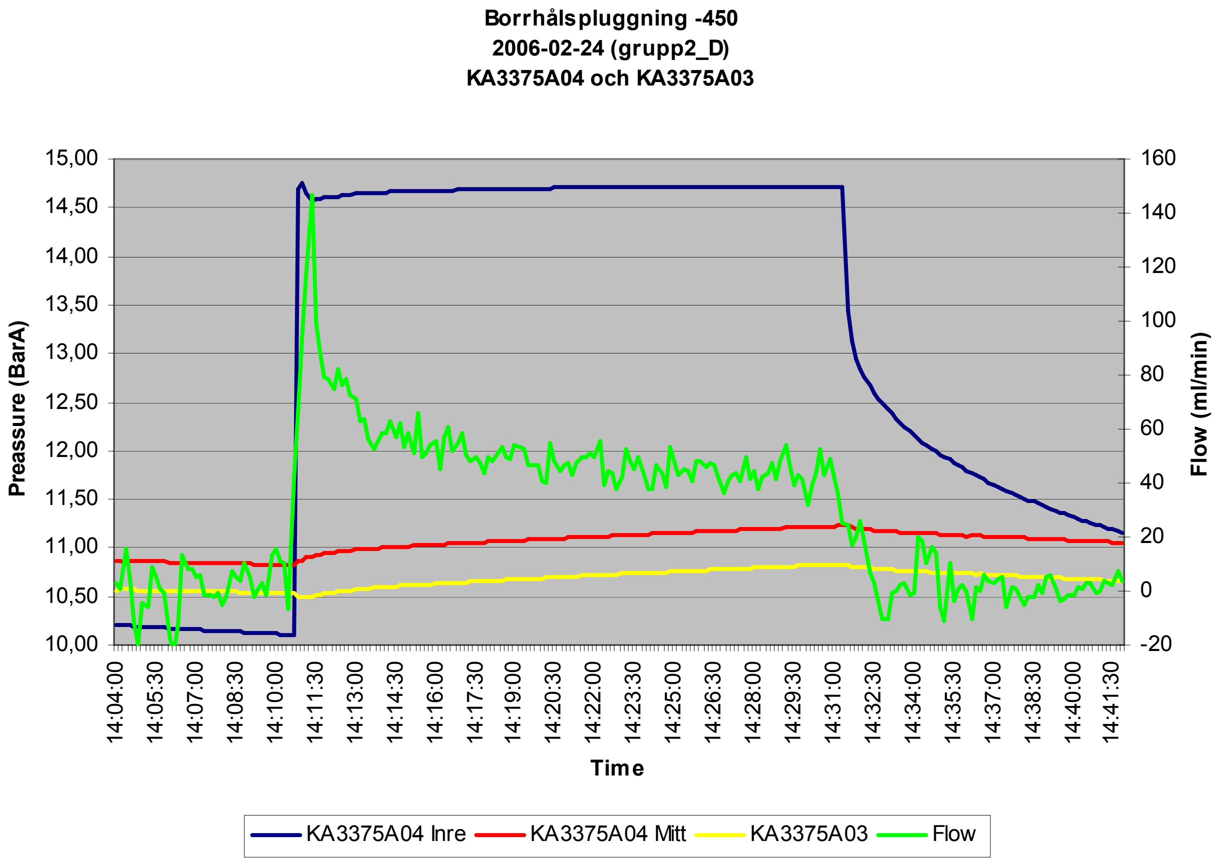
Uppdragstagares signaturer samt datum		SKBs signaturer samt datum	
Upprättad av	Kvalitetsgodkänd för leverans	Leverans godkänd	Införd i SICADA


Borrhålspluggning -450
2006-02-24 (grupp2_A)
KA3375A04 och KA3375A03
Preassure (BarA)
Flow (ml/min)
Time
KA3375A04 Inre
KA3375A04 Mitt
KA3375A03
Flow


Borrhålspluggning -450
2006-02-24 (grupp2_B)
KA3375A04 och KA3375A03
Preassure (BarA)
Flow (ml/min)
Time
KA3375A04 Inre
KA3375A04 Mitt
KA3375A03
Flow


Borrhålspluggning -450
2004-02-24 (grupp2_C)
KA3375A04 ock KA3375A03
Preassure (BarA)
Flow (ml/min)
Time
KA3375A04 Inre
KA3375A04 Mitt
KA3375A03
Flow


Borrhålspluggning -450
2006-02-24 (grupp2_D)
KA3375A04 och KA3375A03
Preassure (BarA)
Flow (ml/min)
Time
KA3375A04 Inre
KA3375A04 Mitt
KA3375A03
Flow


Borrhålspluggning -450
2006-02-24 (grupp2_D)
KA3375A04 och KA3375A03
Preassure (BarA)
Flow (ml/min)
15,00
14,50
14,00
13,50
13,00
12,50
12,00
11,50
11,00
10,50
10,00
160
140
120
100
80
60
40
20
0
-20
14:04:00
14:05:30
14:07:00
14:08:30
14:10:00
14:11:30
14:13:00
14:14:30
14:16:00
14:17:30
14:19:00
14:20:30
14:22:00
14:23:30
14:25:00
14:26:30
14:28:00
14:29:30
14:31:00
14:32:30
14:34:00
14:35:30
14:37:00
14:38:30
14:40:00
14:41:30
Time
KA3375A04 Inre
KA3375A04 Mitt
KA3375A03
Flow

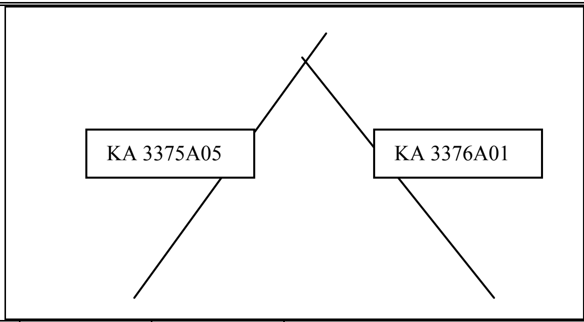
Version 1.0.0

Protokoll flödes och tryck mätning

Protokoll ______av______

Område Äspö tunneln -450	Projekt Pluggning av borrhål
Grupp ID Borrhåls grupp tre mätning ett	Aktivitetsplansnummer
Uppdragsansvarig på plats Hans Wimelius	Besättning (fullständiga namn) Anders Wikman, Anders Holm, Hans Wimelius

IDCODE (borrhål)	Längd Från-till	Dimension
KA 3376A01	0-4,3 m	80 mm
KA 3376A01	4,3-4,8	76 mm
KA 3375A05	0-5,1	76 mm



IDCODE (borrhål)	Section	Datum/Tid	Grundvatten tryck (bar)	Injekterat övertryck		Kommentar
KA 3376A01	1,1-2,1	060223/ 10:20:20	1,83			Innan trycksättning
KA 3376A01	3,1-4,8	060223/ 10:20:20	4,37			Innan trycksättning
KA 3375A05	1,1-3,6	060223/ 10:20:20	1,66			Innan trycksättning
KA 3376A01	1,1-2,1	060223/ 10:40:20	10,32	8,62		Efter 20 min trycksättning (Trycksatt sektion)
KA 3376A01	3,1-4,8	060223/ 10:40:20	5,14			Efter 20 min trycksättning
KA 3375A05	1,1-3,6	060223/ 10:40:20	1,71			Efter 20 min trycksättning
KA 3376A01	1,1-2,1	060223/ 10:50:20	4,08			Efter 10 min innestängt tryck
KA 3376A01	3,1-4,8	060223/ 10:50:20	5,41			Efter 10 min innestängt tryck
KA 3375A05	1,1-3,6	060223/ 10:50:20	1,72			Efter 10min innestängt tryck
IDCODE (borrhål)	**Sektion**	**Datum/Tid**	**Flödestid (min,sec)**	**20 min ml**	**10 min ml**	**Kommentar**
KA 3376A01	1,1-2,1	060223/ 10:20:30	20:00	359	7	
IDCODE (borrhål)	**Sektion**	**Datum/Tid**	**(min,sec)**	**Tryck (bar)**		**Kommentar**
KA3375A01	Se ritning	060223/		3,8		Innan trycksättning
KA3375A03	Se ritning	060223/		9		Innan trycksättning
KA3378A01	Se ritning	060223/		0		Innan trycksättning
KA3375A01	Se ritning	060223/		3,8		Efter 20 min trycksättning
KA3375A03	Se ritning	060223/		9		Efter 20 min trycksättning
KA3378A01	Se ritning	060223/		0		Efter 20 min trycksättning

Uppdragstagares signaturer samt datum		SKB:s signaturer samt datum	
Upprättad av	Kvalitetsgodkänd för leverans	Leverans godkänd	Införd i SICADA

Version 1.0.0

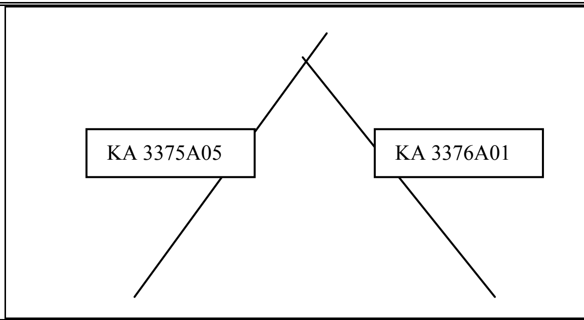
SKB

Protokoll flödes och tryck mätning

Protokoll ______av______

Område Äspö tunneln -450	Projekt Pluggning av borrhål
Grupp ID Borrhåls grupp tre mätning två	Aktivitetsplansnummer
Uppdragsansvarig på plats Hans Wimelius	Besättning (fullständiga namn) Anders Wikman, Anders Holm, Hans Wimelius

IDCODE (borrhål)	Längd Från-till	Dimension
KA 3376A01	0-4,3 m	80 mm
KA 3376A01	4,3-4,8	76 mm
KA 3375A05	0-5,1	76 mm



IDCODE (borrhål)	**Section**	**Datum/Tid**	**Grundvatten tryck (bar)**	**Injekterat övertryck**		**Kommentar**
KA 3376A01	1,1-2,1	060223/ 11:10:40	2,33			Innan trycksättning
KA 3376A01	3,1-4,8	060223/ 11:10:40	5,87			Innan trycksättning
KA 3375A05	1,1-3,6	060223/ 11:10:40	1,77			Innan trycksättning
KA 3376A01	1,1-2,1	060223/ 11:30:10	2,14			Efter 20 min trycksättning
KA 3376A01	3,1-4,8	060223/ 11:30:10	10,45	4,69 bar		Efter 20 min trycksättning (Trycksatt sektion)
KA 3375A05	1,1-3,6	060223/ 11:30:10	1,76			Efter 20 min trycksättning
KA 3376A01	1,1-2,1	060223/ 11:40:10	2,07			Efter 10 min innestängt tryck
KA 3376A01	3,1-4,8	060223/ 11:40:10	9,05			Efter 10 min innestängt tryck
KA 3375A05	1,1-3,6	060223/ 11:40:10	1,76			Efter 10 min innestängt tryck
IDCODE (borrhål)	**Section**	**Datum/Tid**	**Flödestid (min,sec)**	**20 min ml**	**10 min ml**	**Kommentar**
KA 3376A01	3,1-4,8	060223 11:10:40	19:20	187,40	56,45	
IDCODE (borrhål)	**Section**	**Datum/Tid**	**(min,sec)**	**Tryck (bar)**		**Kommentar**
KA3375A01	Se ritning	060223		3,8		Innan trycksättning
KA3375A03	Se ritning	060223		9		Innan trycksättning
KA3378A01	Se ritning	060223		0		Innan trycksättning
KA3375A01	Se ritning	060223		3,8		Efter 20 min trycksättning
KA3375A03	Se ritning	060223		9		Efter 20 min trycksättning
KA3378A01	Se ritning	060223		0		Efter 20 min trycksättning

Uppdragstagares signaturer samt datum		SKB:s signaturer samt datum	
Upprättad av	Kvalitetsgodkänd för leverans	Leverans godkänd	Införd i SICADA

Version 1.0.0

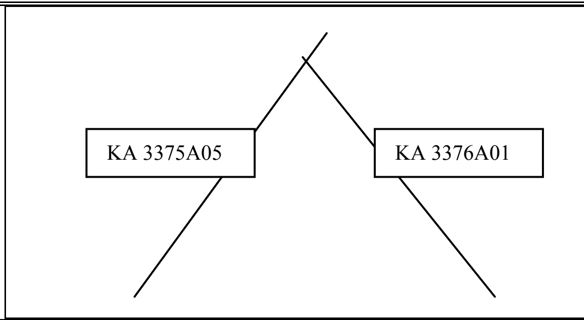
SKB

Protokoll flödes och tryck mätning

Protokoll ______av______

Område Äspö tunneln -450	Projekt Pluggning av borrhål
Grupp ID Borrhåls grupp tre mätning tre	Aktivitetsplansnummer
Uppdragsansvarig på plats Hans Wimelius	Besättning (fullständiga namn) Anders Wikman, Anders Holm, Hans Wimelius

IDCODE (borrhål)	Längd Från-till	Dimension
KA 3376A01	0-4,3 m	80 mm
KA 3376A01	4,3-4,8	76 mm
KA 3375A05	0-5,1	76 mm



IDCODE (borrhål)	Section	Datum/Tid	Grundvatten tryck (bar)	Injekterat övertryck		Kommentar
KA 3376A01	2,1-3,1	060223 13:40:20	4,94			Innan trycksättning
KA 3376A01	4,1-4,8	060223 13:40:20	7,07			Innan trycksättning
KA 3375A05	1,1-3,6	060223 13:40:20	1,74			Innan trycksättning
KA 3376A01	2,1-3,1	060223 14:00:30	12,72	7,81 bar		Efter 20 min trycksättning (Trycksatt sektion)
KA 3376A01	4,1-4,8	060223 14:00:30	7,21			Efter 20 min trycksättning
KA 3375A05	1,1-3,6	060223 14:00:30	1,76			Efter 20 min trycksättning
KA 3376A01	2,1-3,1	060223 14:10:30	12,46			Efter 10 min innestängt tryck
KA 3376A01	4,1-4,8	060223 14:10:30	7,25			Efter 10 min innestängt tryck
KA 3375A05	1,1-3,6	060223 14:10:30	1,77			Efter 10 min innestängt tryck

IDCODE (borrhål)	Section	Datum/Tid	Flödestid (min,sec)	20 min ml	10 min ml	Kommentar
KA 3376A01	2,1-3,1	060223/ 14:00:30	20	316,17	0	

IDCODE (borrhål)	Section	Datum/Tid	(min,sec)	Tryck (bar)		Kommentar
KA3375A01	Se ritning	060223		3,8		Innan trycksättning
KA3375A03	Se ritning	060223		9		Innan trycksättning
KA3378A01	Se ritning	060223		0		Innan trycksättning
KA3375A01	Se ritning	060223		3,8		Efter 20 min trycksättning
KA3375A03	Se ritning	060223		9		Efter 20 min trycksättning
KA3378A01	Se ritning	060223		0		Efter 20 min trycksättning

Uppdragstagares signaturer samt datum		SKB:s signaturer samt datum	
Upprättad av	Kvalitetsgodkänd för leverans	Leverans godkänd	Införd i SICADA

Version 1.0.0

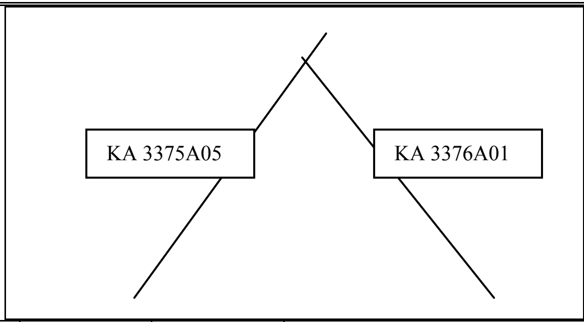
SKB

Protokoll flödes och tryck mätning

Protokoll ______av______

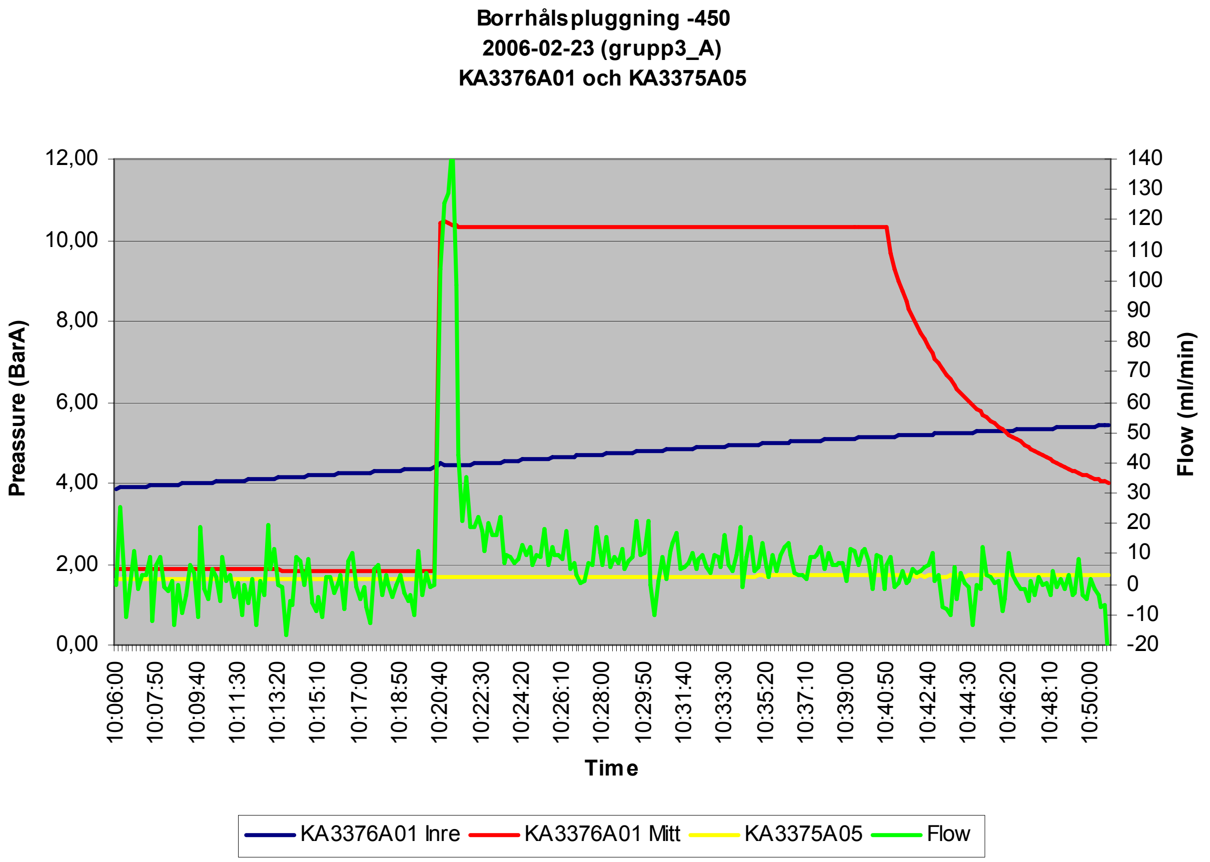
Område Äspö tunneln -450	Projekt Pluggning av borrhål
Grupp ID Borrhåls grupp tre mätning fyra	Aktivitetsplansnummer
Uppdragsansvarig på plats Hans Wimelius	Besättning (fullständiga namn) Anders Wikman, Anders Holm, Hans Wimelius

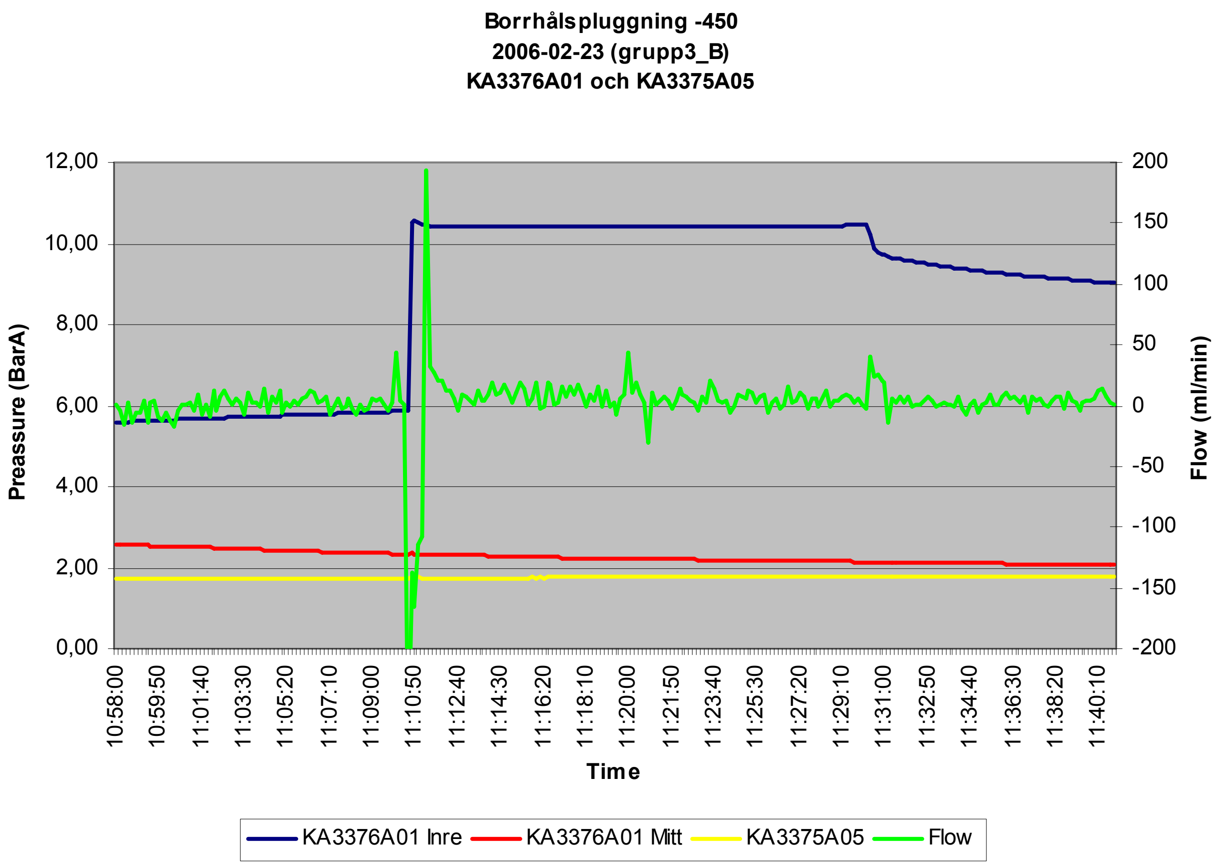
IDCODE (borrhål)	Längd Från-till	Dimension
KA 3376A01	0-4,3 m	80 mm
KA 3376A01	4,3-4,8	76 mm
KA 3375A05	0-5,1	76 mm

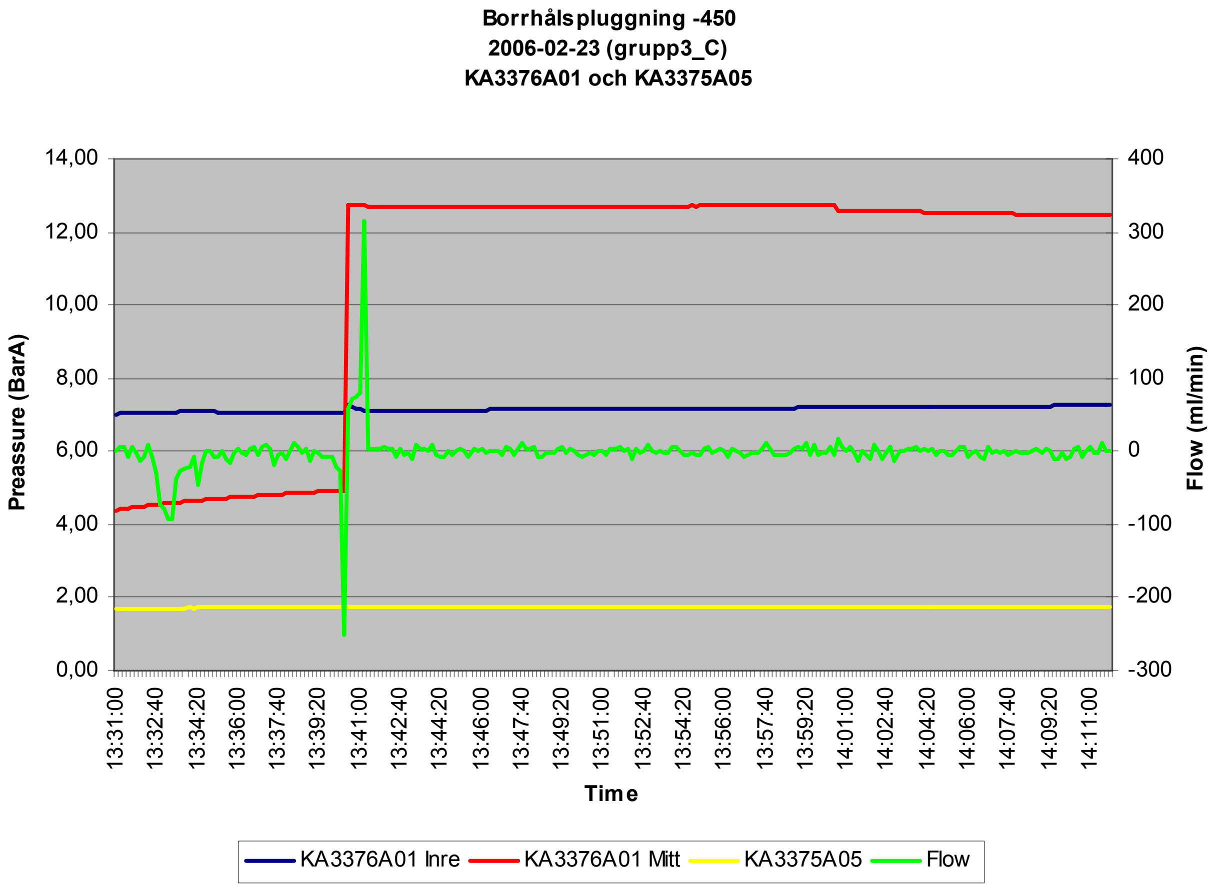


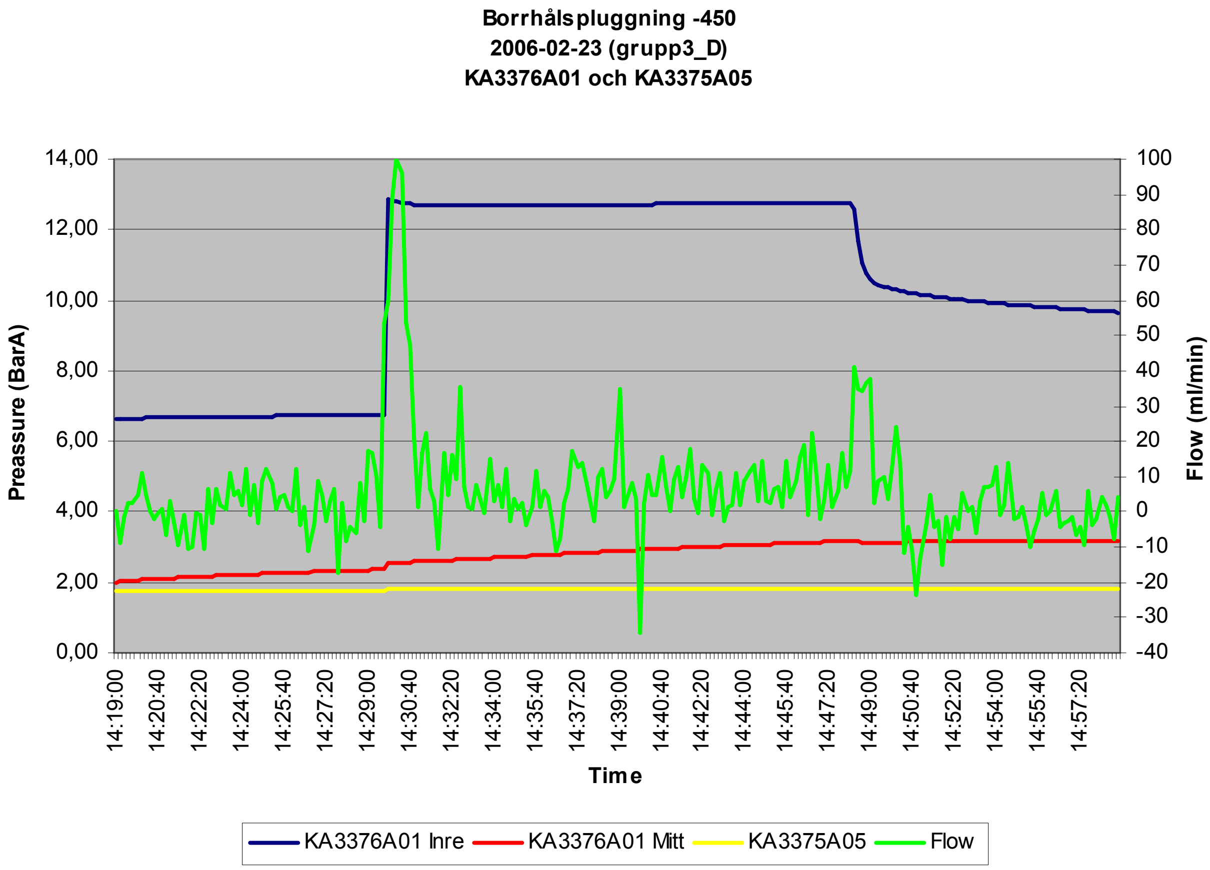
IDCODE (borrhål)	Section	Datum/Tid	Grundvatten tryck (bar)	Injekterat övertryck		Kommentar
KA 3376A01	2,1-3,1	060223 14:29:40	2,35			Innan trycksättning
KA 3376A01	4,1-4,8	060223 14:29:40	6,75			Innan trycksättning
KA 3375A05	1,1-3,6	060223 14:29:40	1,77			Innan trycksättning
KA 3376A01	2,1-3,1	060223 14:48:00	3,17			Efter 20 min trycksättning
KA 3376A01	4,1-4,8	060223 14:48:00	12,75	6,11 bar		Efter 20 min trycksättning (Trycksatt sektion)
KA 3375A05	1,1-3,6	060223 14:48:00	1,8			Efter 20 min trycksättning
KA 3376A01	2,1-3,1	060223 14:58:00	3,19			Efter 10 min innestängt tryck
KA 3376A01	4,1-4,8	060223 14:58:00	9,70			Efter 10 min innestängt tryck
KA 3375A05	1,1-3,6	060223 14:58:00	1,79			Efter 10 min innestängt tryck
IDCODE (borrhål)	**Section**	**Datum/Tid**	**Flödestid (min,sec)**	**20 min ml**	**10 min ml**	**Kommentar**
KA 3376A01	4,1-4,8	060223/ 14:29:50	18:10	195,77	32,49	
IDCODE (borrhål)	**Section**	**Datum/Tid**	**(min,sec)**	**Tryck (bar)**		**Kommentar**
KA3375A01	Se ritning	060223		3,8		Innan trycksättning
KA3375A03	Se ritning	060223		9		Innan trycksättning
KA3378A01	Se ritning	060223		0		Innan trycksättning
KA3375A01	Se ritning	060223		3,8		Efter 20 min trycksättning
KA3375A03	Se ritning	060223		9		Efter 20 min trycksättning
KA3378A01	Se ritning	060223		0		Efter 20 min trycksättning

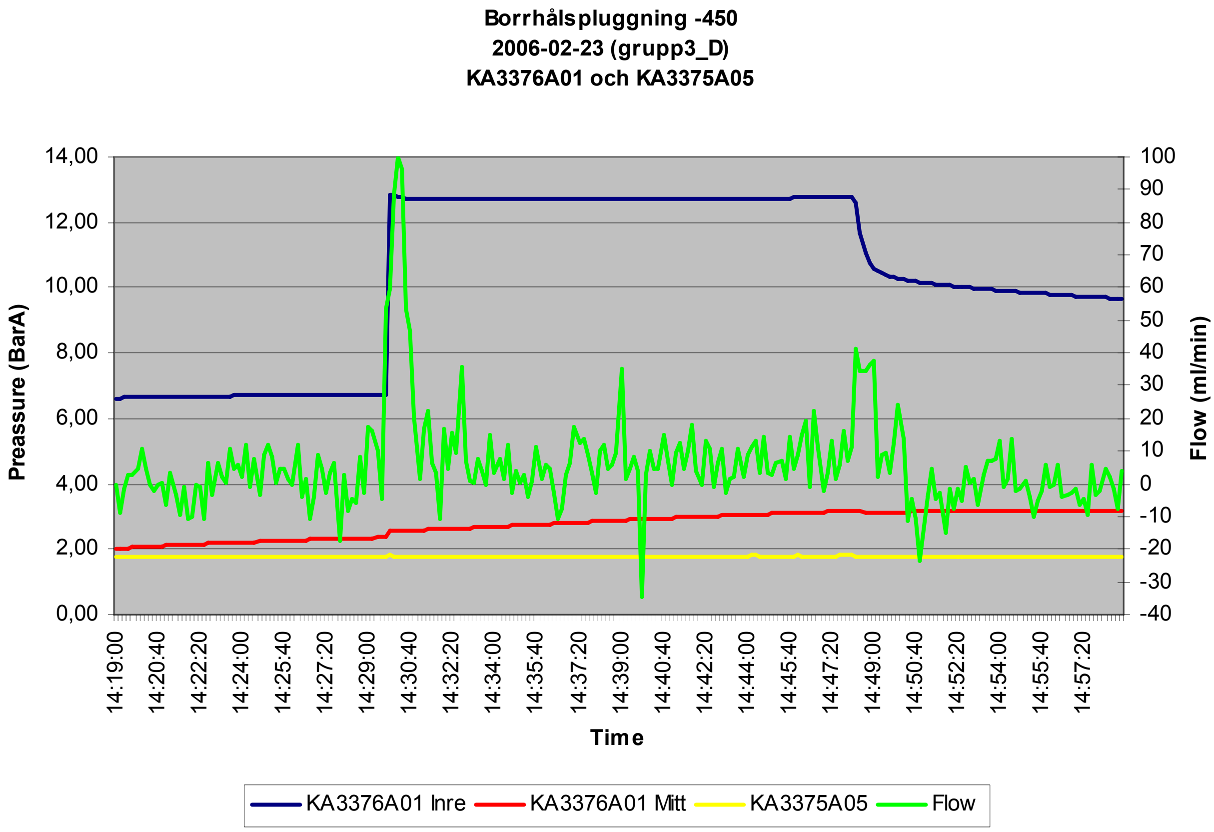
Uppdragstagares signaturer samt datum		SKB:s signaturer samt datum	
Upprättad av	Kvalitetsgodkänd för leverans	Leverans godkänd	Införd i SICADA


Borrhålspluggning -450
2006-02-23 (grupp3_A)
KA3376A01 och KA3375A05
Preassure (BarA)
Flow (ml/min)
Time
KA3376A01 Inre
KA3376A01 Mitt
KA3375A05
Flow


Borrhålspluggning -450
2006-02-23 (grupp3_B)
KA3376A01 och KA3375A05
Preassure (BarA)
Flow (ml/min)
Time
KA3376A01 Inre
KA3376A01 Mitt
KA3375A05
Flow


Borrhålspluggning -450
2006-02-23 (grupp3_C)
KA3376A01 och KA3375A05
Preassure (BarA)
Flow (ml/min)
Time
KA3376A01 Inre
KA3376A01 Mitt
KA3375A05
Flow


Borrhålspluggning -450
2006-02-23 (grupp3_D)
KA3376A01 och KA3375A05
Preassure (BarA)
Flow (ml/min)
Time
KA3376A01 Inre
KA3376A01 Mitt
KA3375A05
Flow


Borrhålspluggning -450
2006-02-23 (grupp3_D)
KA3376A01 och KA3375A05
Preassure (BarA)
Flow (ml/min)
Time
14,00
12,00
10,00
8,00
6,00
4,00
2,00
0,00
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
14:19:00
14:20:40
14:22:20
14:24:00
14:25:40
14:27:20
14:29:00
14:30:40
14:32:20
14:34:00
14:35:40
14:37:20
14:39:00
14:40:40
14:42:20
14:44:00
14:45:40
14:47:20
14:49:00
14:50:40
14:52:20
14:54:00
14:55:40
14:57:20
KA3376A01 Inre
KA3376A01 Mitt
KA3375A05
Flow

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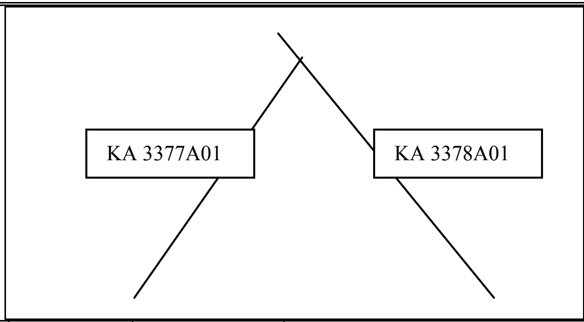
Protokoll flödes och tryck mätning

Protokoll ______av______

Område Äspö tunneln -450	Projekt Pluggning av borrhål
Grupp ID Borrhåls grupp fyra Mätning 1	Aktivitetsplansnummer
Uppdragsansvarig på plats Hans Wimelius	Besättning (fullständiga namn) Anders Wikman, Anders Holm, Hans Wimelius

IDCODE (borrhål)	Längd Från-till	Dimension
KA 3378A01	0-5,0 m	80 mm
KA 3378A01	5,0-5,3	76 mm
KA 3377A01	0-5,1	76 mm



IDCODE (borrhål)	Section	Datum/Tid	Grundvatten tryck (bar)	Injekterat övertryck		Kommentar
KA 3378A01	1,1-2,1	060222 12:13:20	2,09			Innan trycksättning
KA 3378A01	3,1-5,3	060222 12:13:20	1,19			Innan trycksättning
KA 3377A01	1,1-3,6	060222 12:13:20	3,59			Innan trycksättning
KA 3378A01	1,1-2,1	060222 12:32:10	9,91	7,6 bar		Efter 20 min trycksättning (Trycksatt sektion).
KA 3378A01	3,1-5,3	060222 12:32:10	1,21			Efter 20 min trycksatt sektion
KA 3377A01	1,1-3,6	060222 12:32:10	5,25			Efter 20 min trycksättning
KA 3378A01	1,1-2,1	060222 12:42:10	4,63			Efter 10 min innestängt tryck
KA 3378A01	3,1-5,3	060222 12:42:10	1,21			Efter 10 min innestängt tryck
KA 3377A01	1,1-3,6	060222 12:42:10	4,95			Efter 10 min innestängt tryck
IDCODE (borrhål)	**Sektion**	**Datum/Tid**	**Flödestid (min,sek)**	**20 min [ml]**	**10 min [ml]**	**Kommentar**
KA3378A01	1,1-2,1	060222/ 12:13:30	20:00	5279	20,9	
IDCODE (borrhål)	**Sektion**	**Datum/Tid**	**(min,sek)**	**Tryck (bar)**		**Kommentar**
KA3375A01	Se ritning	060222		3,8		Innan trycksättning
KA3375A03	Se ritning	060222		9		Innan trycksättning
KA3375A05	Se ritning	060222		0		Innan trycksättning
KA3375A01	Se ritning	060222		3,8		Efter 20 min trycksättning
KA3375A03	Se ritning	060222		9		Efter 20 min trycksättning
KA3375A05	Se ritning	060222		0		Efter 20 min trycksättning

Uppdragstagares signaturer samt datum		SKB: s signaturer samt datum	
Upprättad av	Kvalitetsgodkänd för leverans	Leverans godkänd	Införd i SICADA

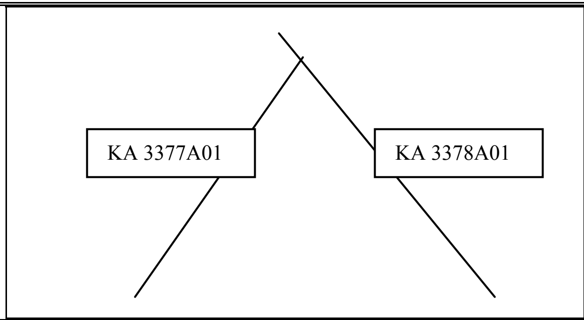
Version 1.0.0

Protokoll flödes och tryck mätning

Protokoll ______av______

Område Äspö tunneln -450	Projekt Pluggning av borrhål
Grupp ID Borrhåls grupp fyra Mätning 2	Aktivitetsplansnummer
Uppdragsansvarig på plats Hans Wimelius	Besättning (fullständiga namn) Anders Wikman, Anders Holm,

IDCODE (borrhål)	Längd Från-till	Dimension
KA 3378A01	0-5,0 m	80 mm
KA 3378A01	5,0-5,3	76 mm
KA 3377A01	0-5,1	76 mm



IDCODE (borrhål)	Section	Datum/Tid	Grundvatten tryck (bar)	Injekterat övertryck		Kommentar
KA 3378A01	1,1-2,1	060222 13:44:30	2,67			Innan trycksättning
KA 3378A01	3,1-5,3	060222 13:44:30	1,20			Innan trycksättning
KA 3377A01	1,1-3,6	060222 13:44:30	2,98			Innan trycksättning
KA 3378A01	1,1-2,1	060222 14:03:30	2,53			Efter 20 min trycksättning.
KA 3378A01	3,1-5,3	060222 14:03:30	9,87	8.88 bar		Efter 20 min trycksättning (Trycksatt sektion)
KA 3377A01	1,1-3,6	060222 14:03:30	2,88			Efter 20 min trycksättning.
KA 3378A01	1,1-2,1	060222 14:13:30	2,47			Efter 10 min innestängt tryck
KA 3378A01	3,1-5,3	060222 14:13:30	8,28			Efter 10 min innestängt tryck
KA 3377A01	1,1-3,6	060222 14:13:30	2,83			Efter 10 min innestängt tryck

IDCODE (borrhål)	Sektion	Datum/Tid	Flödestid (min,sek)	20 min [ml]	10 min [ml]	Kommentar
KA 3378A01	3,1-5,3	060222/ 13:44:40	20:00	4310	5.14	

IDCODE (borrhål)	Sektion	Datum/Tid	(min,sek)	Tryck (bar)		Kommentar
KA3375A01	Se ritning	060222		3,8		Innan trycksättning
KA3375A03	Se ritning	060222		0		Innan trycksättning
KA3375A05	Se ritning	060222		9		Innan trycksättning
KA3375A01	Se ritning	060222		3,8		Efter 20 min trycksättning
KA3375A03	Se ritning	060222		0		Efter 20 min trycksättning
KA3375A05	Se ritning	060222		9		Efter 20 min trycksättning

Uppdragstagares signaturer samt datum		SKB: s signaturer samt datum	
Upprättad av	Kvalitetsgodkänd för leverans	Leverans godkänd	Införd i SICADA

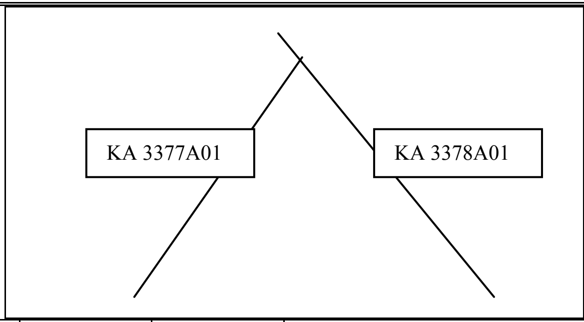
Version 1.0.0

Protokoll flödes och tryck mätning

Protokoll ______av______

Område Äspö tunneln -450	Projekt Pluggning av borrhål
Grupp ID Borrhåls grupp fyra Mätning 3	Aktivitetsplansnummer
Uppdragsansvarig på plats Hans Wimelius	Besättning (fullständiga namn) Anders Wikman, Anders Holm

IDCODE (borrhål)	Längd Från-till	Dimension
KA 3378A01	0-5,0 m	80 mm
KA 3378A01	5,0-5,3	76 mm
KA 3377A01	0-5,1	76 mm



IDCODE (borrhål)	Sektion	Datum/Tid	Grundvatten - tryck (bar)	Injekterat övertryck		Kommentar
KA 3378A01	2,1-3,1	060222 14:44:00	2,29			Innan trycksättning
KA 3378A01	4,1-5,3	060222 14:44:00	2,90			Innan trycksättning
KA 3377A01	1,1-3,6	060222 14:44:00	2,58			Innan trycksättning
KA 3378A01	2,1-3,1	060222 15:03:10	10,23	7,93 bar		Efter 20 min trycksättning (Trycksatt sektion).
KA 3378A01	4,1-5,3	060222 15:03:10	2,74			Efter 20 min trycksättning
KA 3377A01	1,1-3,6	060222 15:03:10	3,53			Efter 20 min trycksättning
KA 3378A01	2,1-3,1	060222 15:13:10	4,32			Efter 10 min innestängt tryck
KA 3378A01	4,1-5,3	060222 15:13:10	2,66			Efter 10 min innestängt tryck
KA 3377A01	1,1-3,6	060222 15:13:10	3,63			Efter 10 min innestängt tryck

IDCODE (borrhål)	Sektion	Datum/Tid	Flödestid (min,sek)	20 min [ml]	10 min [ml]	Kommentar
KA 3378A01	2,1-3,1	060222/ 14:44:10	20:00	3567	112	

IDCODE (borrhål)	Sektion	Datum/Tid	(min,sek)	Tryck (bar)		Kommentar
KA3375A01	Se ritning	060222		3,8		Innan trycksättning
KA3375A03	Se ritning	060222		0		Innan trycksättning
KA3375A05	Se ritning	060222		9		Innan trycksättning
KA3375A01	Se ritning	060222		3,8		Efter 20 min trycksättning
KA3375A03	Se ritning	060222		0		Efter 20 min trycksättning
KA3375A05	Se ritning	060222		9		Efter 20 min trycksättning

Uppdragstagares signaturer samt datum		SKB: s signaturer samt datum	
Upprättad av	Kvalitetsgodkänd för leverans	Leverans godkänd	Införd i SICADA

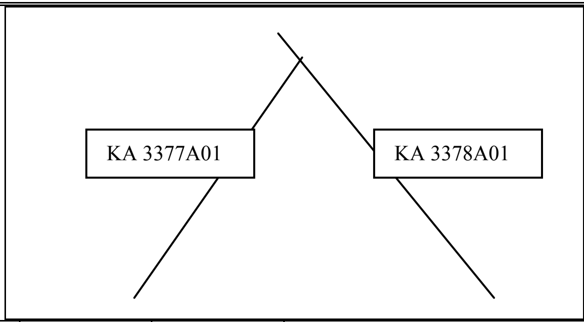
Version 1.0.0

Protokoll flödes och tryck mätning

Protokoll ______av______

Område Äspö tunneln -450	Projekt Pluggning av borrhål
Grupp ID Borrhåls grupp fyra Mätning 4	Aktivitetsplansnummer
Uppdragsansvarig på plats Hans Wimelius	Besättning (fullständiga namn) Anders Wikman, Anders Holm

IDCODE (borrhål)	Längd Från-till	Dimension
KA 3378A01	0-5,0 m	80 mm
KA 3378A01	5,0-5,3	76 mm
KA 3377A01	0-5,1	76 mm



IDCODE (borrhål)	Sektion	Datum/Tid	Grundvatten -tryck (bar)	Injekterat övertryck		Kommentar
KA 3378A01	2,1-3,1	060222 15:33:30	3,25			Innan trycksättning
KA 3378A01	4,1-5,3	060222 15:33:30	2,51			Innan trycksättning
KA 3377A01	1,1-3,6	060222 15:33:30	3,35			Innan trycksättning
KA 3378A01	2,1-3,1	060222 15:53:20	2,93			Efter 20 min trycksättning
KA 3378A01	4,1-5,3	060222 15:53:20	10,32	7,89		Efter 20 min trycksättning (Trycksatt sektion).
KA 3377A01	1,1-3,6	060222 15:53:20	3,08			Efter 20 min trycksättning
KA 3378A01	2,1-3,1	060222 16:03:20	2,83			Efter 10 min innestängt tryck
KA 3378A01	4,1-5,3	060222 16:03:20	6,00			Efter 10 min innestängt tryck
KA 3377A01	1,1-3,6	060222 16:03:20	2,96			Efter 10 min innestängt tryck
IDCODE (borrhål)	**Sektion**	**Datum/Tid**	**Flödestid (min,sek)**	**20 min [ml]**	**10 min [ml]**	**Kommentar**
KA3378A01	4,1-5,3	060222/ 15:33:40	20:00	82,5	3	
IDCODE (borrhål)	**Sektion**	**Datum/Tid**	**(min,sek)**	**Tryck (bar)**		**Kommentar**
KA3375A01	Se ritning	060222		3,8		Innan trycksättning
KA3375A03	Se ritning	060222		0		Innan trycksättning
KA3375A05	Se ritning	060222		9		Innan trycksättning
KA3375A01	Se ritning	060222		3,8		Efter 20 min trycksättning
KA3375A03	Se ritning	060222		0		Efter 20 min trycksättning
KA3375A05	Se ritning	060222		9		Efter 20 min trycksättning

Uppdragstagares signaturer samt datum		SKB: s signaturer samt datum	
Upprättad av	Kvalitetsgodkänd för leverans	Leverans godkänd	Införd i SICADA

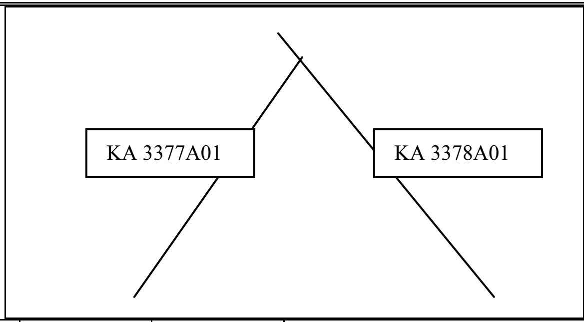
Version 1.0.0

Protokoll flödes och tryck mätning

Protokoll ______av______

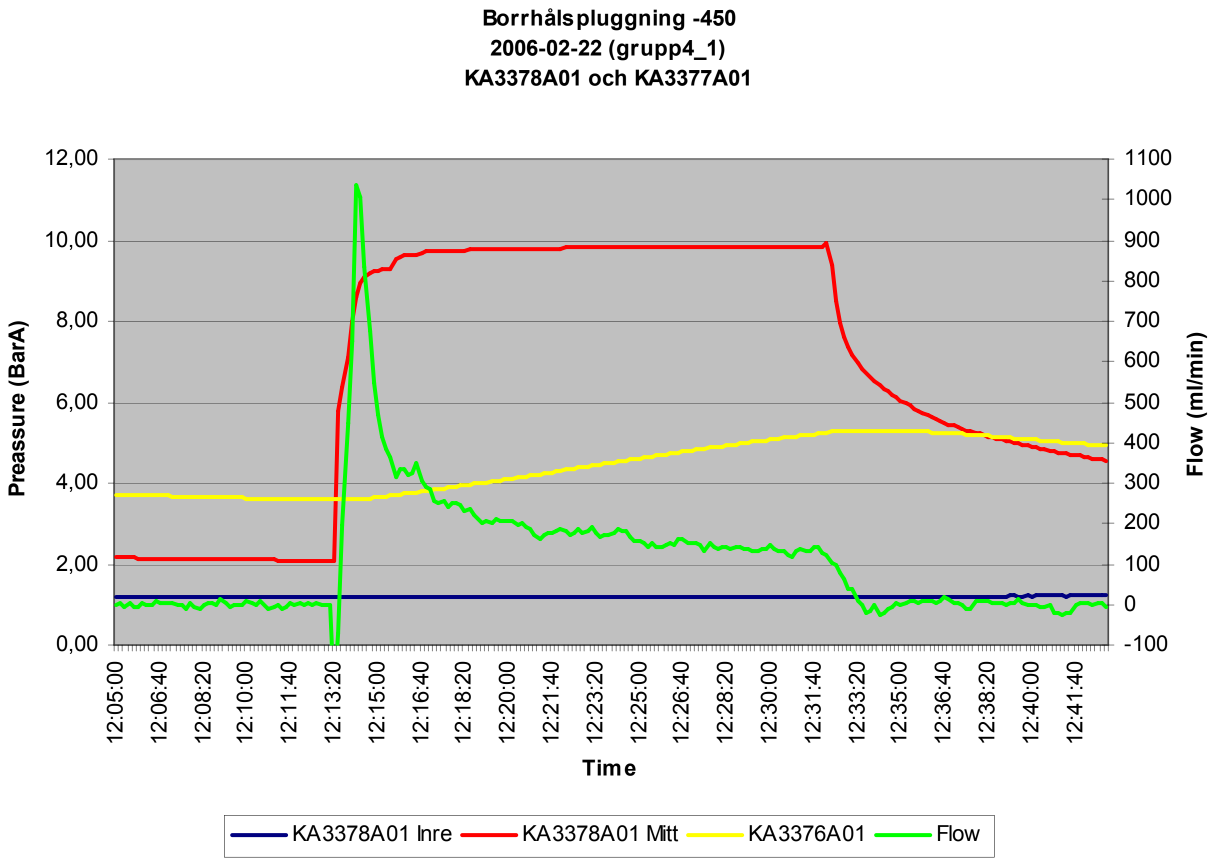
Område Äspö tunneln -450	Projekt Pluggning av borrhål
Grupp ID Borrhåls grupp fyra Mätning 4	Aktivitetsplansnummer
Uppdragsansvarig på plats Hans Wimelius	Besättning (fullständiga namn) Anders Wikman, Anders Holm

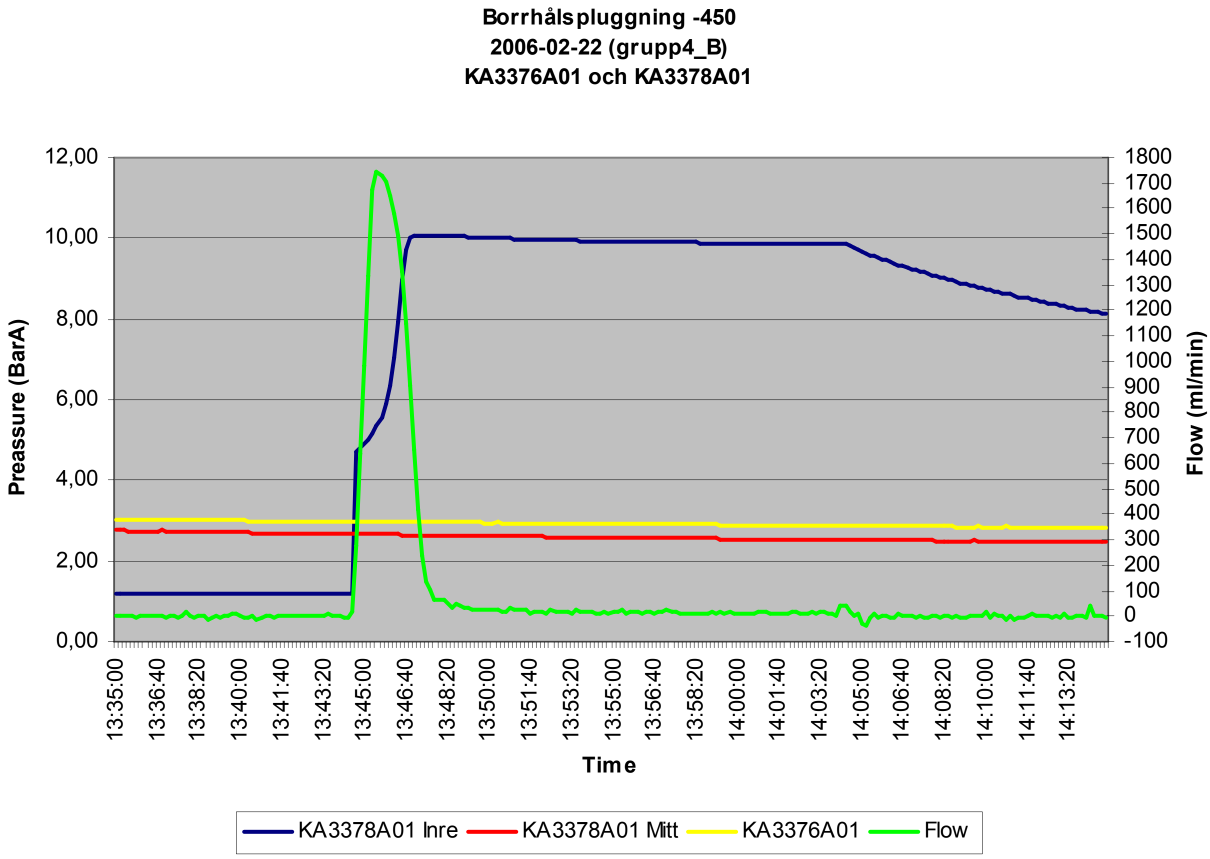
IDCODE (borrhål)	Längd Från-till	Dimension
KA 3378A01	0-5,0 m	80 mm
KA 3378A01	5,0-5,3	76 mm
KA 3377A01	0-5,1	76 mm

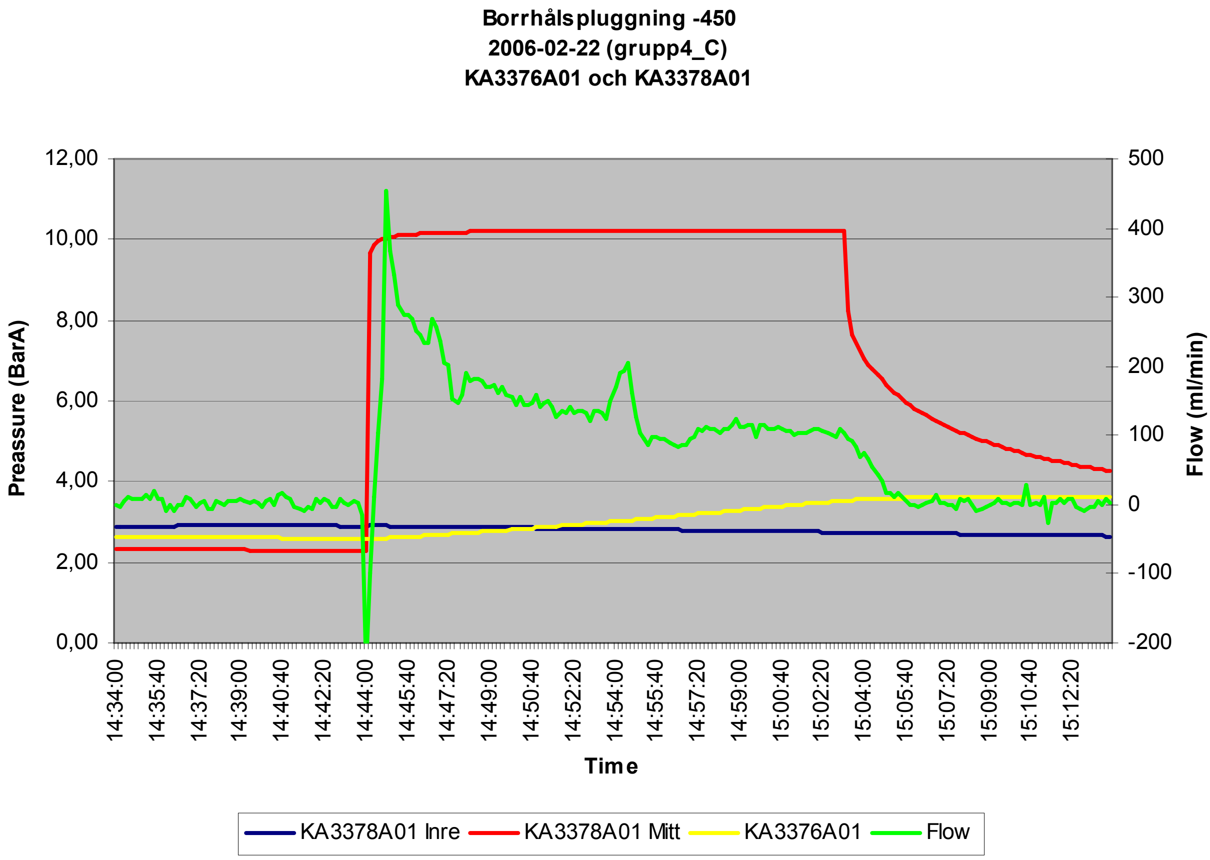


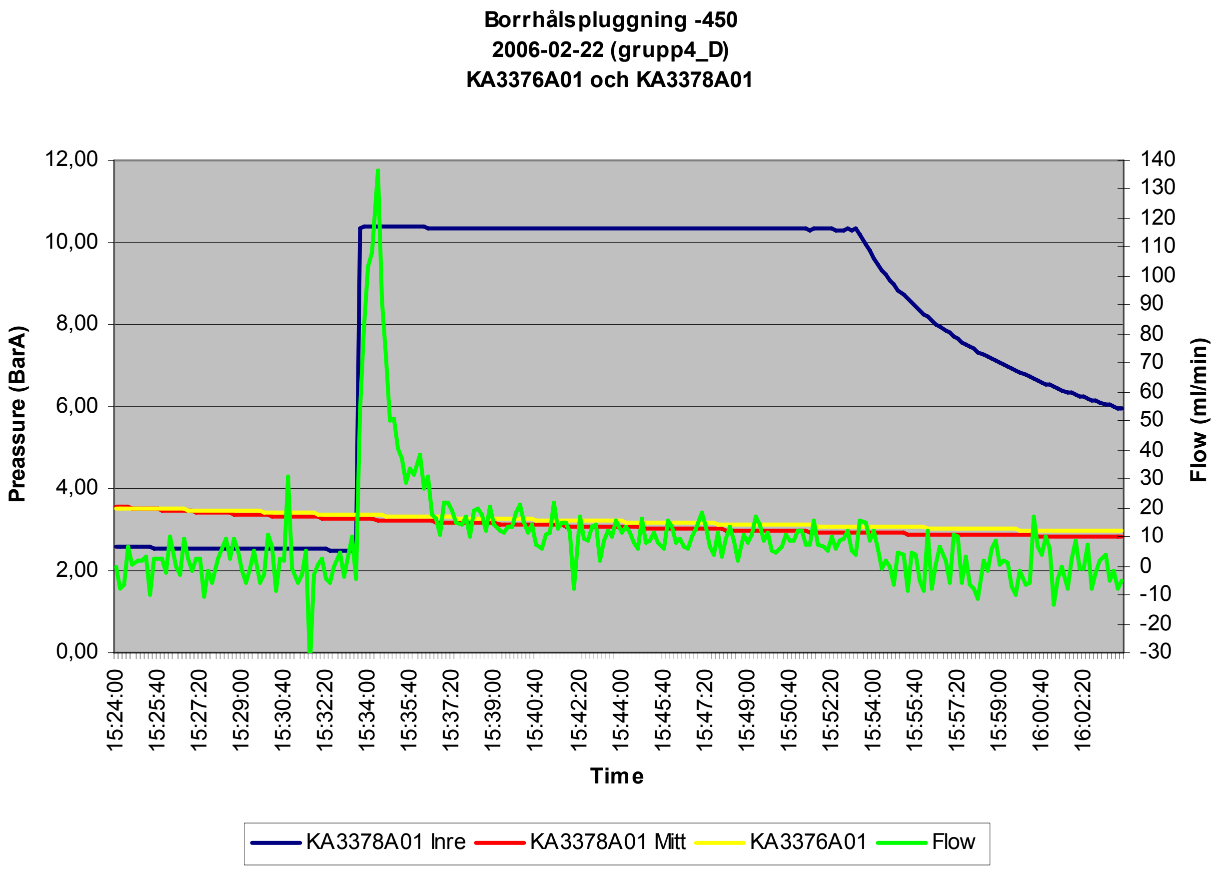
IDCODE (borrhål)	Sektion	Datum/Tid	Grundvatten -tryck (bar)	Injekterat övertryck		Kommentar
KA 3378A01	2,1-3,1	060222 15:33:30	3,25			Innan trycksättning
KA 3378A01	4,1-5,3	060222 15:33:30	2,51			Innan trycksättning
KA 3377A01	1,1-3,6	060222 15:33:30	3,35			Innan trycksättning
KA 3378A01	2,1-3,1	060222 15:53:20	2,93			Efter 20 min trycksättning
KA 3378A01	4,1-5,3	060222 15:53:20	10,32	7,89		Efter 20 min trycksättning (Trycksatt sektion).
KA 3377A01	1,1-3,6	060222 15:53:20	3,08			Efter 20 min trycksättning
KA 3378A01	2,1-3,1	060222 16:03:20	2,83			Efter 10 min innestängt tryck
KA 3378A01	4,1-5,3	060222 16:03:20	6,00			Efter 10 min innestängt tryck
KA 3377A01	1,1-3,6	060222 16:03:20	2,96			Efter 10 min innestängt tryck
IDCODE (borrhål)	**Sektion**	**Datum/Tid**	**Flödestid (min,sek)**	**20 min [ml]**	**10 min [ml]**	**Kommentar**
KA3378A01	4,1-5,3	060222/ 15:33:40	20:00	82,5	3	
IDCODE (borrhål)	**Sektion**	**Datum/Tid**	**(min,sek)**	**Tryck (bar)**		**Kommentar**
KA3375A01	Se ritning	060222		3,8		Innan trycksättning
KA3375A03	Se ritning	060222		0		Innan trycksättning
KA3375A05	Se ritning	060222		9		Innan trycksättning
KA3375A01	Se ritning	060222		3,8		Efter 20 min trycksättning
KA3375A03	Se ritning	060222		0		Efter 20 min trycksättning
KA3375A05	Se ritning	060222		9		Efter 20 min trycksättning

Uppdragstagares signaturer samt datum		SKB: s signaturer samt datum	
Upprättad av	Kvalitetsgodkänd för leverans	Leverans godkänd	Införd i SICADA


Borrhålspluggning -450
2006-02-22 (grupp4_1)
KA3378A01 och KA3377A01
Preassure (BarA)
Flow (ml/min)
Time
12,00
10,00
8,00
6,00
4,00
2,00
0,00
1100
1000
900
800
700
600
500
400
300
200
100
0
-100
12:05:00
12:06:40
12:08:20
12:10:00
12:11:40
12:13:20
12:15:00
12:16:40
12:18:20
12:20:00
12:21:40
12:23:20
12:25:00
12:26:40
12:28:20
12:30:00
12:31:40
12:33:20
12:35:00
12:36:40
12:38:20
12:40:00
12:41:40
KA3378A01 Inre
KA3378A01 Mitt
KA3376A01
Flow

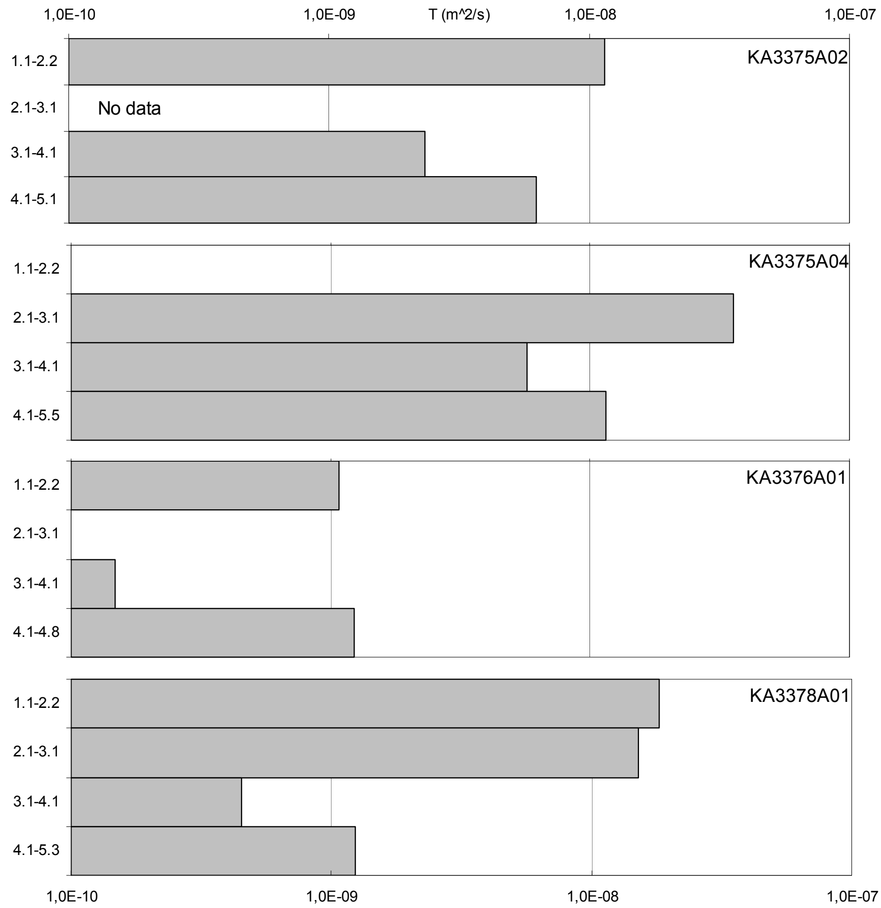

Borrhålspluggning -450
2006-02-22 (grupp4_B)
KA3376A01 och KA3378A01
Preassure (BarA)
Flow (ml/min)
Time
12,00
10,00
8,00
6,00
4,00
2,00
0,00
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
-100
13:35:00
13:36:40
13:38:20
13:40:00
13:41:40
13:43:20
13:45:00
13:46:40
13:48:20
13:50:00
13:51:40
13:53:20
13:55:00
13:56:40
13:58:20
14:00:00
14:01:40
14:03:20
14:05:00
14:06:40
14:08:20
14:10:00
14:11:40
14:13:20
KA3378A01 Inre
KA3378A01 Mitt
KA3376A01
Flow


Borrhålspluggning -450
2006-02-22 (grupp4_C)
KA3376A01 och KA3378A01
Preassure (BarA)
Flow (ml/min)
12,00
10,00
8,00
6,00
4,00
2,00
0,00
500
400
300
200
100
0
-100
-200
14:34:00
14:35:40
14:37:20
14:39:00
14:40:40
14:42:20
14:44:00
14:45:40
14:47:20
14:49:00
14:50:40
14:52:20
14:54:00
14:55:40
14:57:20
14:59:00
15:00:40
15:02:20
15:04:00
15:05:40
15:07:20
15:09:00
15:10:40
15:12:20
Time
KA3378A01 Inre
KA3378A01 Mitt
KA3376A01
Flow


Borrhålspluggning -450
2006-02-22 (grupp4_D)
KA3376A01 och KA3378A01
Preassure (BarA)
Flow (ml/min)
12,00
10,00
8,00
6,00
4,00
2,00
0,00
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
15:24:00
15:25:40
15:27:20
15:29:00
15:30:40
15:32:20
15:34:00
15:35:40
15:37:20
15:39:00
15:40:40
15:42:20
15:44:00
15:45:40
15:47:20
15:49:00
15:50:40
15:52:20
15:54:00
15:55:40
15:57:20
15:59:00
16:00:40
16:02:20
Time
KA3378A01 Inre
KA3378A01 Mitt
KA3376A01
Flow

Borehole	Secup (m)	Seclow (m)	T ($m^2 s^{-1}$) [a]
KA3375A02	1.1	2.1	$1.1 \cdot 10^{-8}$
KA3375A02	2.1	3.1	– [b]
KA3375A02	3.1	4.1	$2.3 \cdot 10^{-9}$ [c]
KA3375A02	4.1	5.1	$6.2 \cdot 10^{-9}$
KA3375A04	1.1	2.1	$\leq 1 \cdot 10^{-10}$
KA3375A04	2.1	3.1	$3.6 \cdot 10^{-8}$
KA3375A04	3.1	4.1	$6 \cdot 10^{-9}$ [c]
KA3375A04	4.1	5.5	$1.2 \cdot 10^{-8}$
KA3376A01	1.1	2.1	$1.1 \cdot 10^{-9}$
KA3376A01	2.1	3.1	$\leq 1 \cdot 10^{-10}$
KA3376A01	3.1	4.1	$1 \cdot 10^{-10}$ [c]
KA3376A01	4.1	4.8	$1.2 \cdot 10^{-9}$
KA3378A01	1.1	2.1	$1.8 \cdot 10^{-8}$
KA3378A01	2.1	3.1	$1.5 \cdot 10^{-8}$
KA3378A01	3.1	4.1	$5 \cdot 10^{-10}$ [c]
KA3378A01	4.1	5.3	$1.2 \cdot 10^{-9}$

[a] Evaluated for stationary conditions according to Moye (1967) following SKB MD 320.004
[b] Missing data.
[c] Calculated as the difference in transmissivity between tested overlapping sections.



Response matrix

Tested section	KA3375A01-KA3375A02	KA3375A01 1.1-3.8	KA3375A02 1.1-2.1	KA3375A02 2.1-3.1	KA3375A02 3.1-5.1	KA3375A02 4.1-5.1	KA3375A03-KA3375A04	KA3375A03 1.1-3.6	KA3375A04 1.1-2.1	KA3375A04 2.1-3.1	KA3375A04 3.1-5.5	KA3375A04 4.1-5.5	KA3375A05-KA3376A01	KA3375A05 1.1-3.6	KA3376A01 1.1-2.1	KA3376A01 2.1-3.1	KA3376A01 3.1-4.8	KA3376A01 4.1-4.8	KA3377A01-KA3378A01	KA3377A01 1.1-3.6	KA3378A01 1.1-2.1	KA3378A01 2.1-3.1	KA3378A01 3.1-5.3	KA3378A01 4.1-5.3
	Monitored section																							
KA3375A02 1.1-2.1	na	no response	na	na	no response	na	no response	na	na	na	na	na	no response	na	na	na	na	na	no response	na	na	na	na	na
KA3375A02 2.1-3.1	na	no response	na	na	na	no response	no response	na	na	na	na	na	no response	na	na	na	na	na	no response	na	na	na	na	na
KA3375A02 3.1-5.1	na	0,98	0,05	na	na	na	no response	na	na	na	na	na	no response	na	na	na	na	na	no response	na	na	na	na	na
KA3375A02 4.1-5.1	na	0,98	na	0,06	na	na	no response	na	na	na	na	na	no response	na	na	na	na	na	no response	na	na	na	na	na
KA3375A04 1.1-2.1	0,06	na	na	na	na	na	na	no response	na	na	no response	na	no response	na	na	na	na	na	no response	na	na	na	na	na
KA3375A04 2.1-3.1	0,09	na	na	na	na	na	na	0,98	na	na	na	0,40	no response	na	na	na	na	na	no response	na	na	na	na	na
KA3375A04 3.1-5.5	0,06	na	na	na	na	na	na	0,36	0,03	na	na	na	no response	na	na	na	na	na	no response	na	na	na	na	na
KA3375A04 4.1-5.5	0,04	na	na	na	na	na	na	0,07	na	0,09	na	na	no response	na	na	na	na	na	no response	na	na	na	na	na
KA3376A01 1.1-2.1	no response	na	na	na	na	na	no response	na	na	na	na	na	na	no response	na	na	no response	na	no response	na	na	na	na	na
KA3376A01 2.1-3.1	no response	na	na	na	na	na	no response	na	na	na	na	na	na	no response	na	na	na	0,03	no response	na	na	na	na	na
KA3376A01 3.1-4.8	no response	na	na	na	na	na	no response	na	na	na	na	na	na	no response	no response	na	na	na	no response	na	na	na	na	na
KA3376A01 4.1-4.8	no response	na	na	na	na	na	no response	na	na	na	na	na	na	no response	na	0,14	na	na	no response	na	na	na	na	na
KA3378A01 1.1-2.1	no response	na	na	na	na	na	no response	na	na	na	na	na	no response	na	na	na	na	na	na	0,22	na	na	no response	na
KA3378A01 2.1-3.1	no response	na	na	na	na	na	no response	na	na	na	na	na	no response	na	na	na	na	na	na	0,13	na	na	na	no response
KA3378A01 3.1-5.3	no response	na	na	na	na	na	no response	na	na	na	na	na	no response	na	na	na	na	na	na	no response	no response	na	na	na
KA3378A01 4.1-5.3	no response	na	na	na	na	na	no response	na	na	na	na	na	no response	na	na	na	na	na	na	no response	na	no response	na	na

na
no response
low response (<0.25)
high response (>0.25)

Response = max pressure response/applied over pressure

Appendix II. Protocols from plugtesting at Äspö (5 m holes)

PROTOKOLL ÖVER MÄTNINGAR I 5-M HÅLEN (SUBPROJECT 2) Pellets

Hole number	**Day**	**Time**	**Pressure, [kg/cm^2] (hydr. jack)**	**Force, [kg]**	**Strain, [mm]**	**Number of strokes**	**Displacement of bottom [mm] Strokesx0,3**
D (KA3375A04)	060719	09:25	25	830	0	8	2,4
	060719	09:30	31	1029	0,01	15	4,5
	060719	09:34	50	1660	0,01	22	6,6
	060720	10:03	50	1660	0	16	4,8
	060724	12:40	60	1992	0.02	32	9.6
	060823	10:15	55	726	2	18	5,4

Cross section area 33.2 cm² of hydraulic jack. 16.6 kg axial force per 0.5 bar. 1 stroke is equal to about 1 cm³.

PROTOKOLL ÖVER MÄTNINGAR I 5-M HÅLEN (SUBPROJECT 2) Basic

Hole number	**Day**	**Time**	**Pressure, [kg/cm^2] (hydr. jack)**	**Force, [kg]**	**Strain, [mm]**	**Number of strokes**	**Displacement of bottom [mm] Strokesx0,3**
B (Ka3375A02)	060719	09:48-09:50	35	1162	0,45	4	1,2
	060720	10:10	80	2656	0,52	5	1,5
	060724	12:47	300 med momentat hopp till 250	9960	0,05	?	
	060823	10:24	500	16600	0	20	6

Cross section area 33.2 cm² of hydraulic jack. 16.6 kg axial force per 0.5 bar. 1 stroke is equal to about 1 cm³.

PROTOKOLL ÖVER MÄTNINGAR I 5-M HÅLEN (SUBPROJECT 2) Couronne

Hole number	Day	Time	Pressure, [kg/cm^2] (hydr. jack)	Force, kg	Strain, [mm]	Number of strokes	Displacement of bottom [mm] Strokesx0,3
E (Ka3375A05)	060719	10:00	35	1162	0,01	4	1,2
	060719	10:01	70	2324	0,03	10	3
	060719	10:02	85	2822	0,04	12	3,6
	060719	10:03	105	3486	0,055	14	4,2
	060719	10:04	100	3320	0,07	14	4,2
	060719	10:06	0	0	0,08	14	4,2
	060720	10:16	165	5478	0,09	7	2,1
	060724	12:58	300	9960	0,04	7	2.1
	060823	10:31	400	13280	0	20	6
	060823	10:32	100	3200	0,03	24	7,2 Hydraulic failure
	060823	10:33	200	6640	0,08	60	18 Hydraulic failure
	060823	10:36	200	6640	0,10	67	20,1 Hydraulic failure
	060823	10:37	200	6640	0,11	75	22,5 Hydraulic failure

Cross section area 33.2 cm² of hydraulic jack. 16.6 kg axial force per 0.5 bar. 1 stroke is equal to about 1 cm³.

PROTOKOLL ÖVER MÄTNINGAR I 5-M HÅLEN (SUBPROJECT 2) Container

Hole number	Day	Time	Pressure, [kg/cm^2] (hydr. jack)	Force, [kg]	Strain, [mm]	Number of strokes	Displacement of bottom [mm] Strokesx0,3
H (KA3378A01)	060719	10:15	55	1826	0,01	7	2,1
	060719	10:16	60	1992	0,03	9	2,7
	060719	10:18	70	2324	0,065	12	3,6
	060720	10:26	105	3486	0,02	14	4,2
	060720	10:27	130	4316	0,05	24	7,2
	060720	10:30	165	5478	0,08	34	10,2
	060720	10:33	180	5976	0,105	44	13,2
	060724	13:06	360	11952	0,05	40	12
	060823	10:42	250	8300	0,01	16	4,8
	060823	10:45	500	16600	0,02	44	13,2

Cross section area 33.2 cm² of hydraulic jack. 16.6 kg axial force per 0.5 bar. 1 stroke is equal to about 1 cm³.