How to drill and equip a performing well? What are the technological constraints?

Study Day Shallow Geothermy BLUG-UBLG and SBGIMR-BVIGRM

Jörg Uhde
BAUER Resources GmbH

Contents

- The BAUER Group
- Dimensioning and planning
- Drilling methods
- Installation of borehole heat exchangers
- Grouting
- Connection of borehole heat exchangers
- Results

History

For More Than Two Centuries

After World war II: beginning of **construction business**

At the end of the 1970ies: beginning of **Internationalisation**

Beginning of 1990ies: Development of business area **civil engineering/environmental technology**

July 4th 2006: **initial public offering**
Sep. 2006: initial listing on **SDAX**

2007 **Formation** of **BAUER Resources GmbH**

1790 | 1950's | 1960's | 1970's | 1980's | 1990's | 2000+ | 2006 | 2007

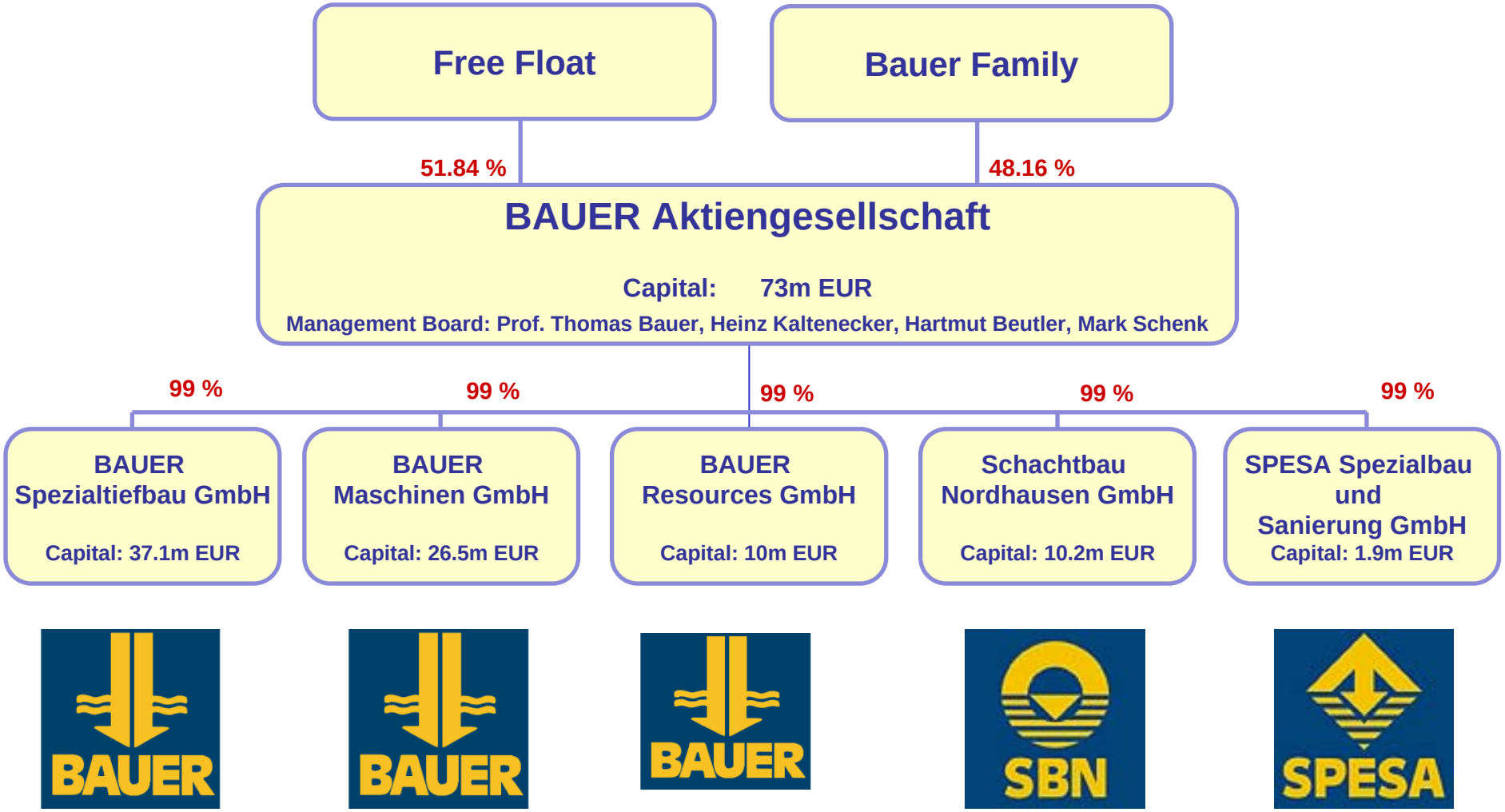
Company foundation as **blacksmith**

Beginning of the 1970ies: start of **equipment construction business**

Beginning of the 1980ies: **Selling equipment to external customers**

Business year 2006: **EUR 980 Mio. result BAUer Group, 5,541 employees**

BAUER Group


Free Float
Bauer Family
51.84 %
48.16 %
BAUER Aktiengesellschaft
Capital: 73m EUR
Management Board: Prof. Thomas Bauer, Heinz Kaltenecker, Hartmut Beutler, Mark Schenk
99 %
99 %
99 %
99 %
99 %
BAUER Spezialtiefbau GmbH
Capital: 37.1m EUR
BAUER Maschinen GmbH
Capital: 26.5m EUR
BAUER Resources GmbH
Capital: 10m EUR
Schachtbau Nordhausen GmbH
Capital: 10.2m EUR
SPESA Spezialbau und Sanierung GmbH
Capital: 1.9m EUR

BAUER Spezialtiefbau GmbH

Egypt - Alexandria San Stefano Complex

BAUER Spezialtiefbau GmbH

Dubai - Burj Dubai

BAUER Maschinen GmbH

Péribonka Cutter

BAUER Maschinen GmbH

Deep drilling rig TBA 300

BAUER Resources GmbH - Materials Division

Products for well drilling

BAUER Resources GmbH - Materials Division

GWE Flashing material and sealing compound

- Bentonites
- Polymer protecting colloides
- Loading agent
- Chemicals
- Additive flashing material
- high expension cement
- Seal suspensions

BAUER Resources GmbH - Materials Division

Duplex Probe

BAUER Resources GmbH - Materials Division

GF-Tec Development and Production of geothermal components

GF-Tec
Development, Products & Solutions

New subsidiary
from 1 st Jan 2009 onwards

BAUER Resources GmbH - Exploration & Mining

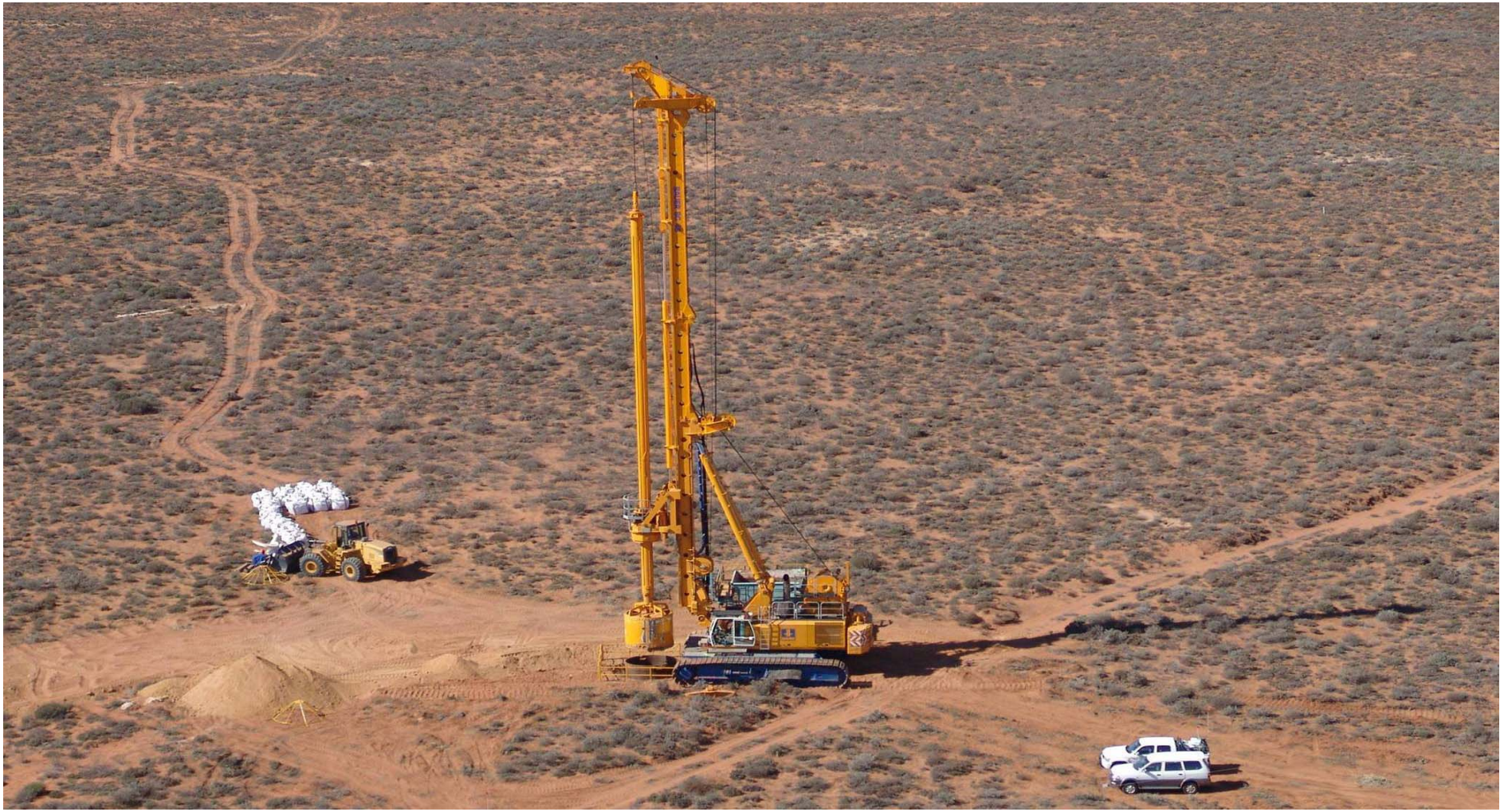
Foralith AG 700 m well drilling in the East of Switzerland

BAUER Resources GmbH - Exploration & Mining

RC LDD 18" - Kimberlite - RG 40 - Lesotho - South Africa

BAUER Resources GmbH - Exploration & Mining

Bulk Sampling - BG 48 South Africa De Beers

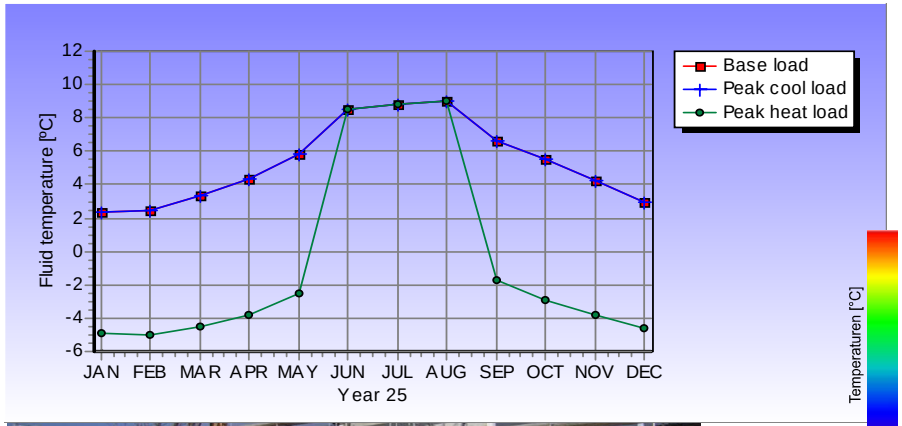


BAUER Resources GmbH - Exploration & Mining

Geothermal energy - energy pile

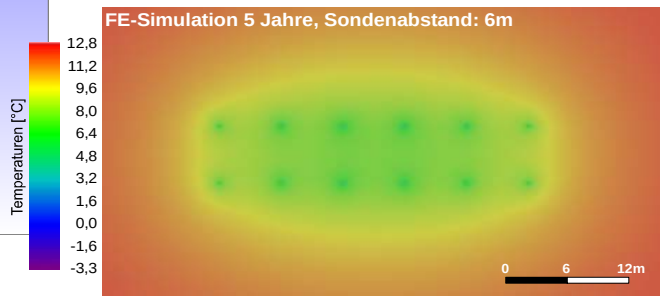
Dimensioning and planning

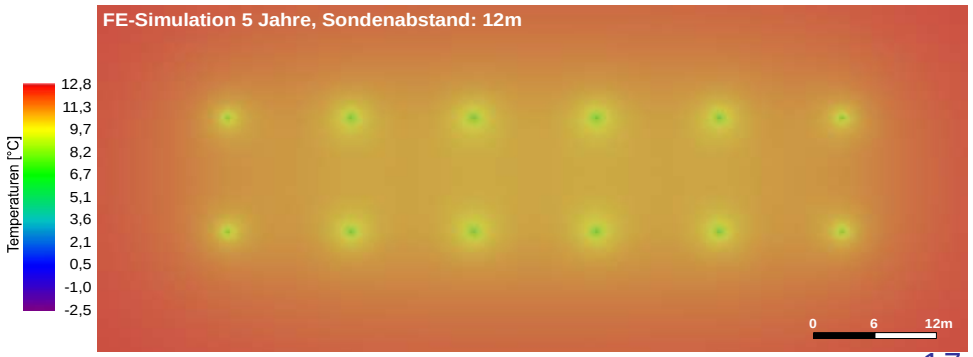
Proper design is required in particular for large installations



Calculation with simple soft-ware (EED, left) or numerical simulation (below)

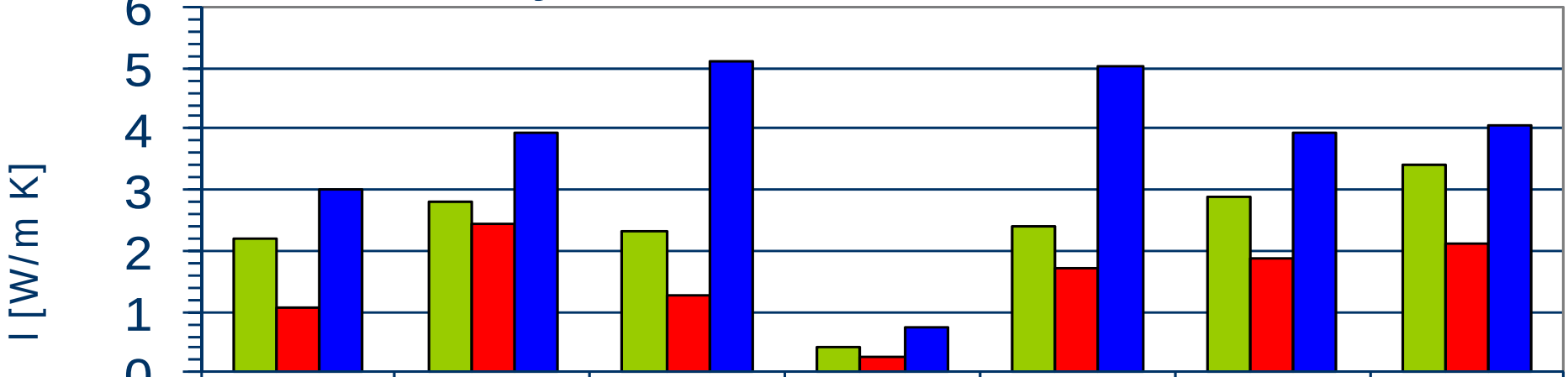
Thermal Response Test to determine ground parameters





Dimensioning and planning

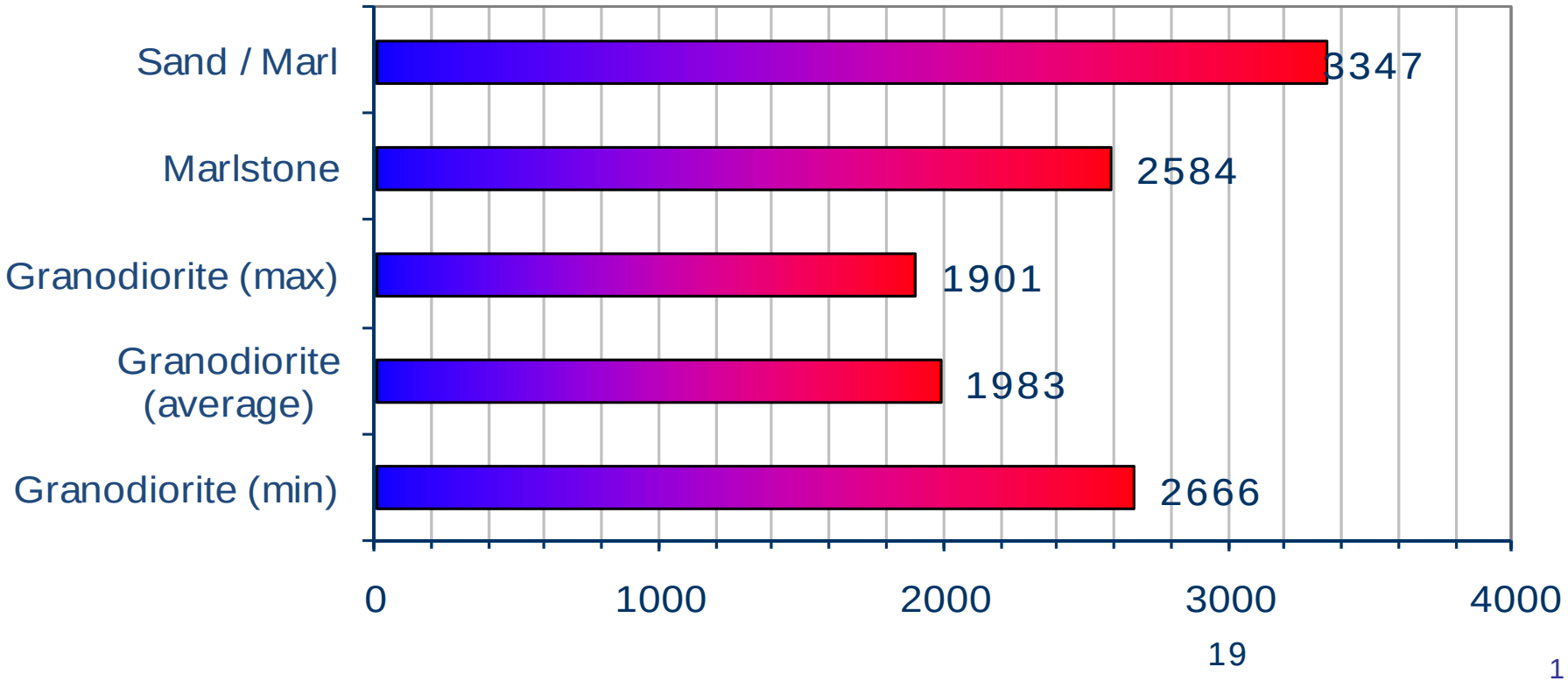
Thermal conductivity of selected rocks



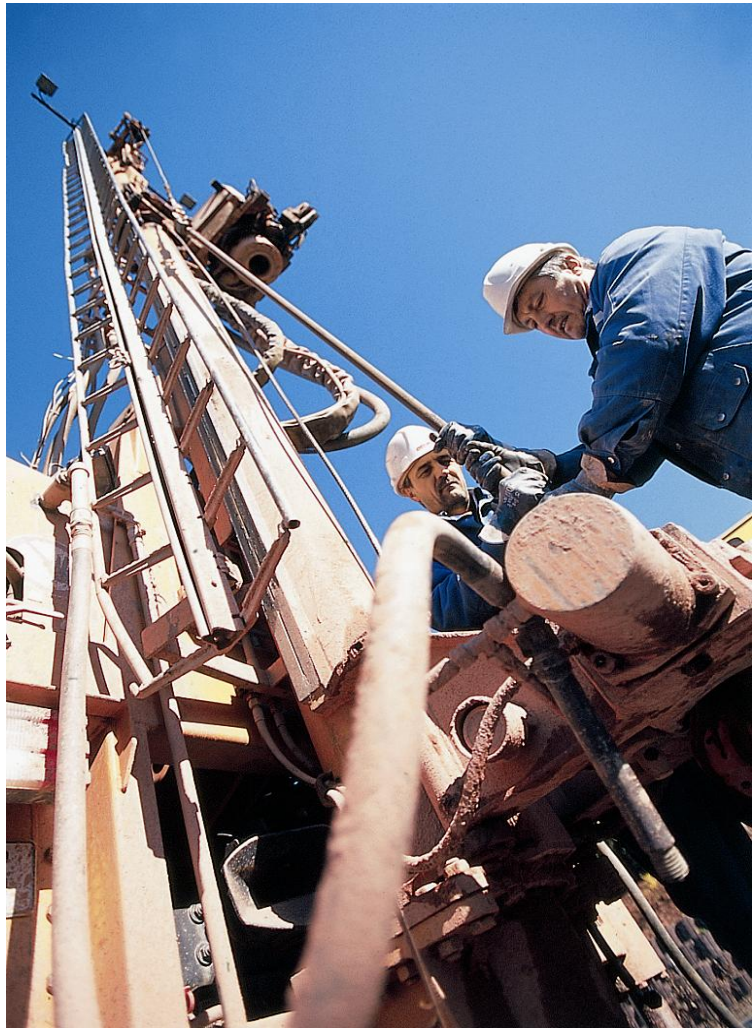
	Mudstone	Limestone	Sandstone	Sand (dry)	Sand (wet)	Gneiss	Granite
average	2,2	2,8	2,3	0,4	2,4	2,9	3,4
min.	1,05	2,46	1,28	0,27	1,73	1,89	2,1
max.	3,02	3,93	5,1	0,75	5,02	3,95	4,07

Dimensioning and planning

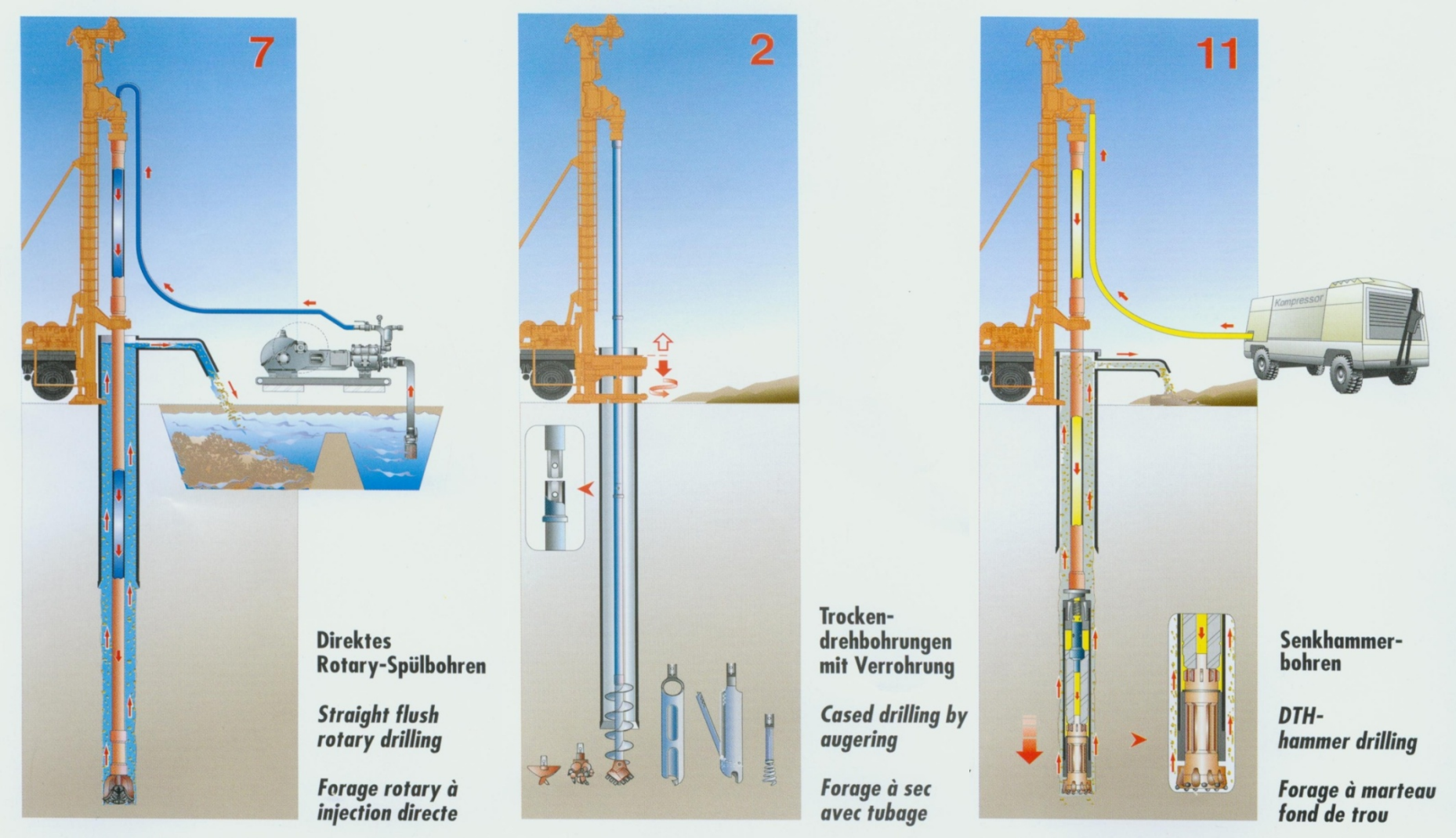
Required meters drilled depending on thermal conductivity



Drilling methods



Drilling methods

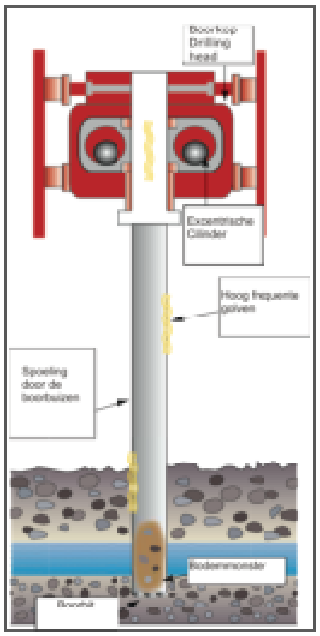


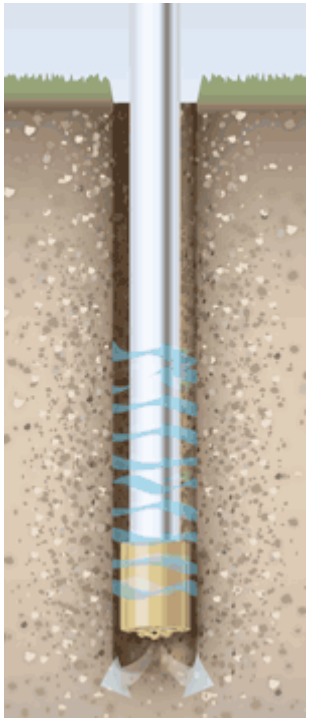
Drilling methods

Drilling methods with circulating mud

- DTH drilling
- Rotarydrilling
- Overburden drilling

Drilling methods





Drilling methods without circulating mud

- Auger drilling
- Sonic drilling
- High water pressure drilling (Geojetting)

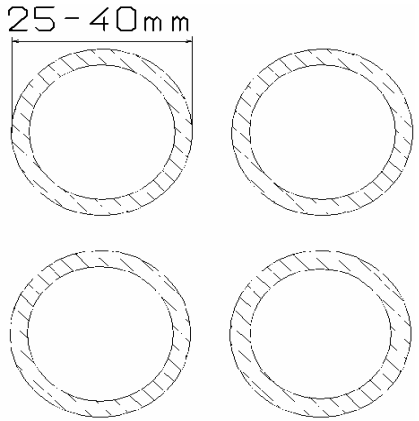
Drilling methods

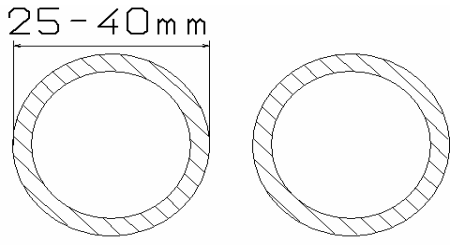
Drilling methods

Mobile drilling rig Bauer-Prakla RB 30 GT

Installation of Borehole heat exchangers

Installation of Borehole heat exchangers





Installation of Borehole heat exchangers

Placing the BHE in the borehole, it serves no purpose to use force above ground to push the U-pipes into the borehole, instead a suitable device should be used to ensure that any pressure required is directly applied to the foot of the BHE and the BHE is therefore drawn into a straight position.

Generally a water filled BHE must be hold back initially when placed in the borehole to avoid it from sliding in too quickly.

Installation of Borehole heat exchangers

At the same time the BHE is placed in the borehole, the grouting pipe must be fed in.

Dependent on the borehole depth under certain circumstances several grouting pipes must be used to ensure continous grouting.

After the BHE has been inserted, but before grouting of the annular space, a pressure test on the water-filled BHE is recommended.

Installation of Borehole heat exchangers

Probe installation in wells drilled with mud technology

- Before running-in the probe, the borehole condition has to be checked with an appropriate survey, like a single shot run
- To reduce lifting forces during installation, the heat pipes should be filled up with water
- The mud density has to be checked to calculate lifting forces and required installation weights
- If necessary reduce mud density by adding unweighted polymer fluid or use a desilter to separate fine solids from the fluid.
- An appropriate method to overcome lifting forces is to use steel installation pipes which are connected at the probe foot

Installation of Borehole heat exchangers

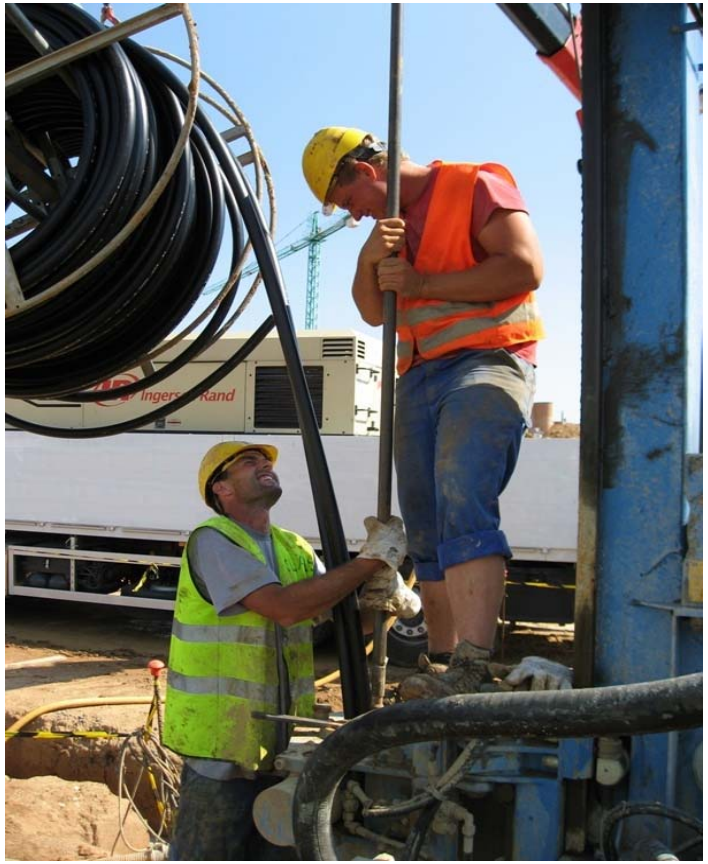
Preliminary measurements before installation

- Check the pipes carefully of any damages like rabbles, grooves etc.
- To avoid the entry of any impurities in the pipe system, seal the pipes tightly before the are running down in the borehole
- Always use a reel for the installation work

Installation of Borehole heat exchangers

Stabilize the first probe meters with a steel rod and a tape, to minimize frictional force during the installation and to avoid stuck of the probe foot especially when the well shows different borehole diameters.

Installation of Borehole heat exchangers



At the same time as the BHE is placed in the borehole, the grouting pipe / installation pipe must be fed in.

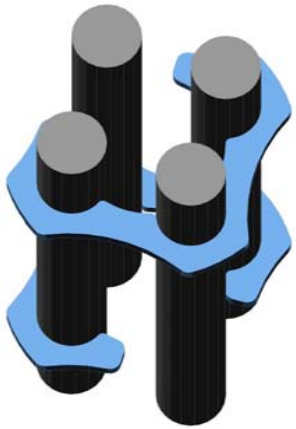
We recommend a pressure test with the water filled BHE, before starting the grouting job of the annular space.

Installation of Borehole heat exchangers

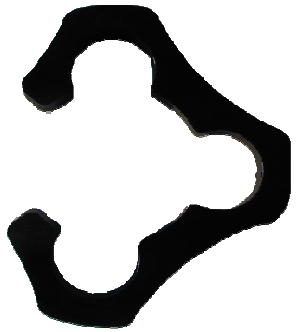
•Not allowable: Pulling the BHE over the surface ground!

Installation of Borehole heat exchangers

- **Probe Centralizer to avoid thermal shorts between the pipes are recommended or sometimes mandatory**



- **Probe Double Centralizer**
- Easy click positioning.
- 50 mm free space for cementing pipe.
- Installation with 90°/180° offset.



- Probe Centralizer

Installation of Borehole heat exchangers

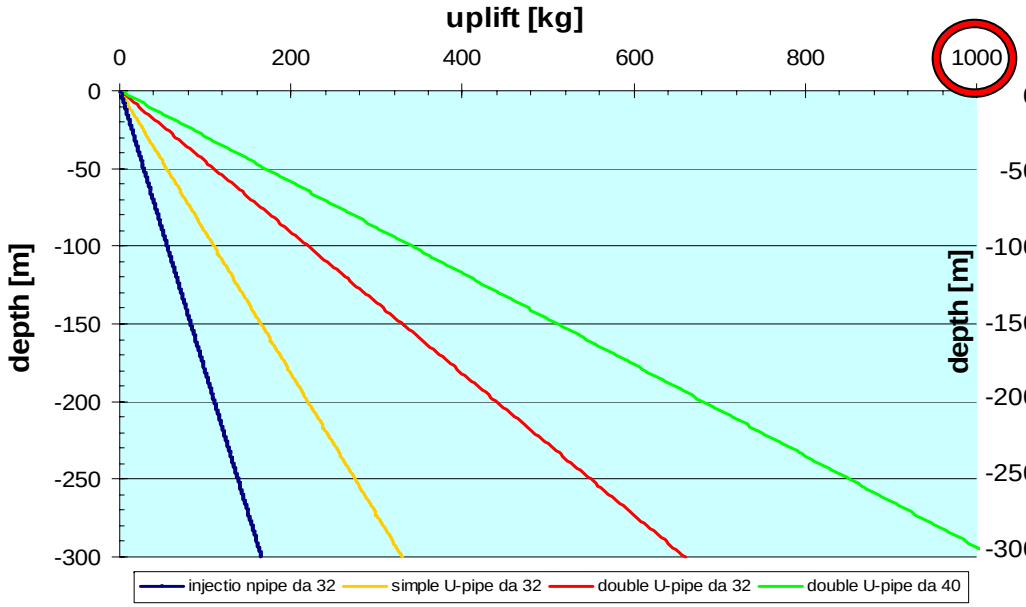
To make the installation of the borehole heat exchanger easier, ist is filled with water before being installed. Even for dry boreholes the BHE must be filled with water before the borehole is grouted at the latest, to prevent it from rising up.

It should be checked wether an additional weight is required at the foot of the BHE.

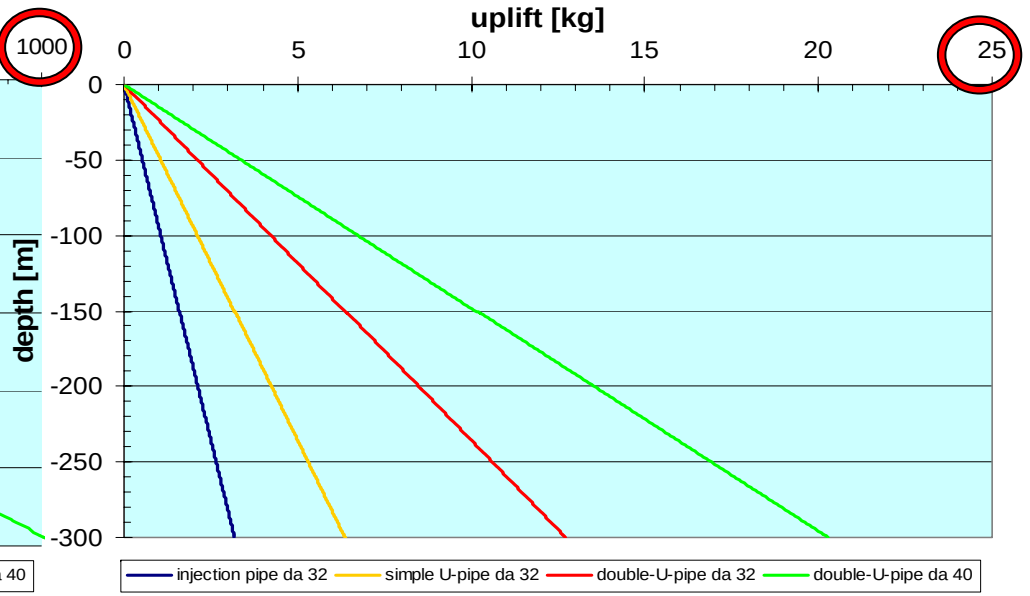
Installation of Borehole heat exchangers

Probe installation in wells drilled with mud technology

- *Buoyancy of an **unfilled** BHE (PEHD) in water*



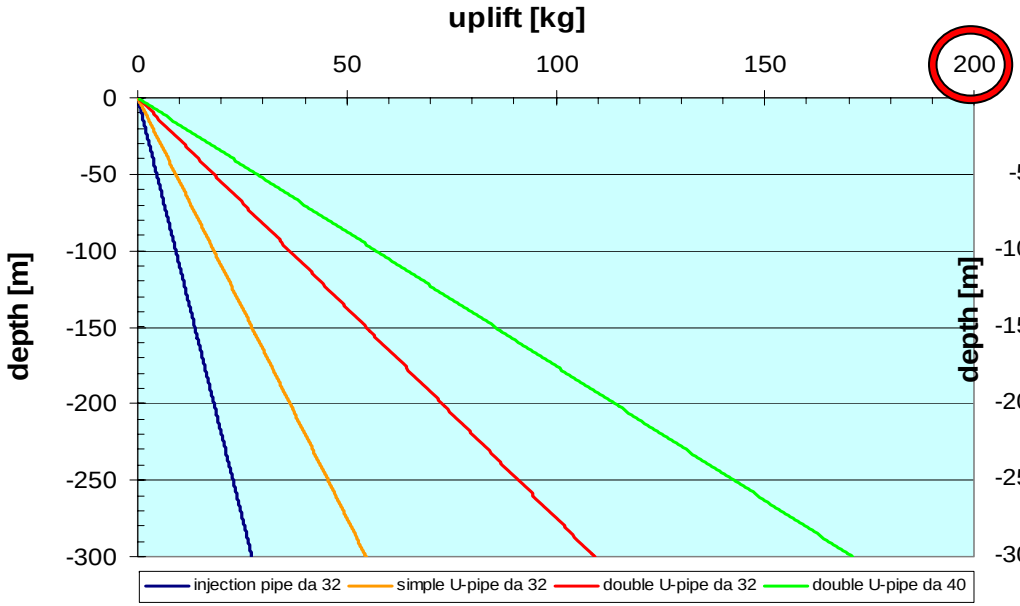
- *Buoyancy of a **water filled** BHE (PEHD) in water*



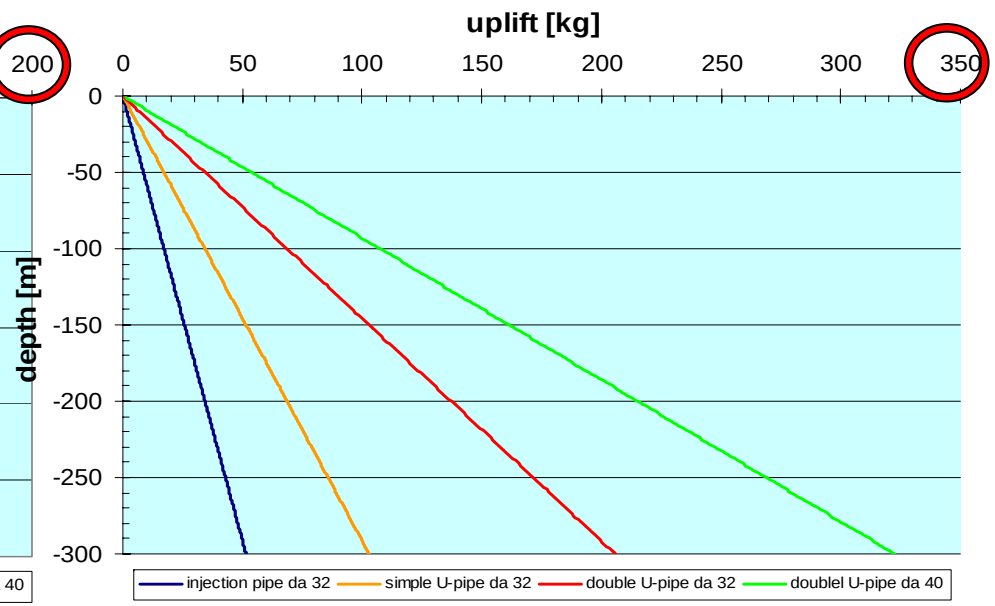
Installation of Borehole heat exchangers

Probe installation in wells drilled with mud technology

- *Buoyancy of a water filled BHE (PEHD) in drilling mud with a density of 1,10 kg/dm³*



- *Buoyancy of an unfilled BHE (PEHD) in drilling mud with a density of 1,20 kg/dm³*



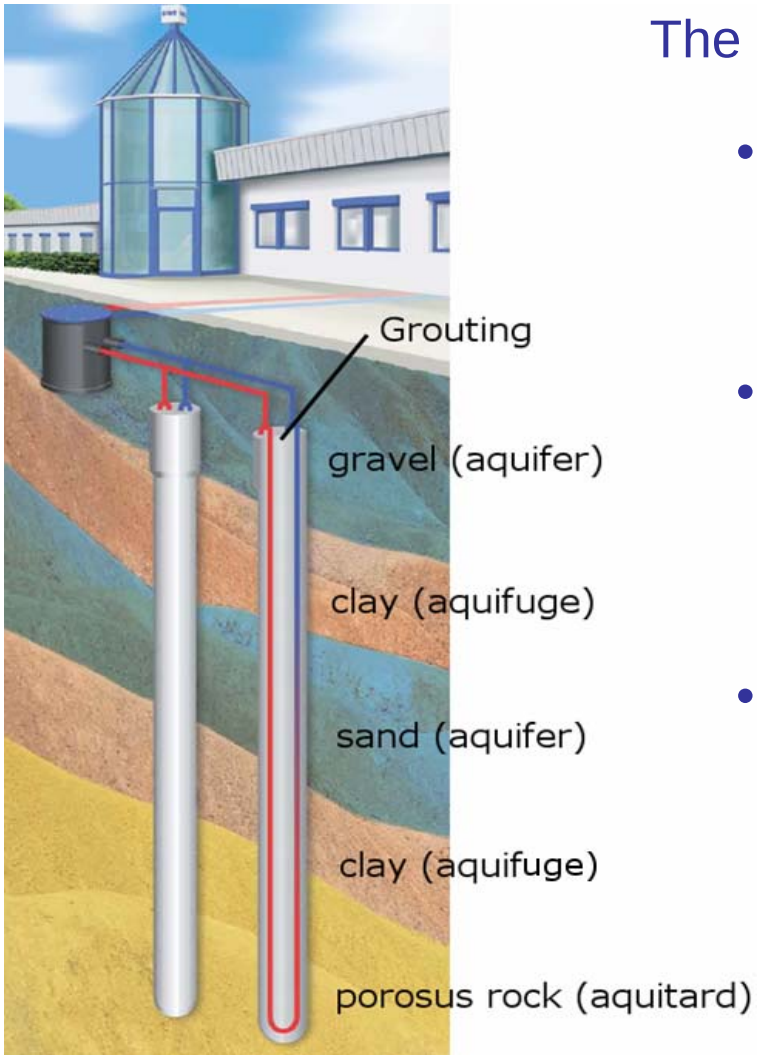
Grouting

Grouting the boreholes is a standard procedure

Grouting of double- or single-U-pipes after installing in an open borehole is a standard procedure to ensure

- thermal flow between the bedrock and the U-pipes
- protection of the U-pipes
- groundwater protection

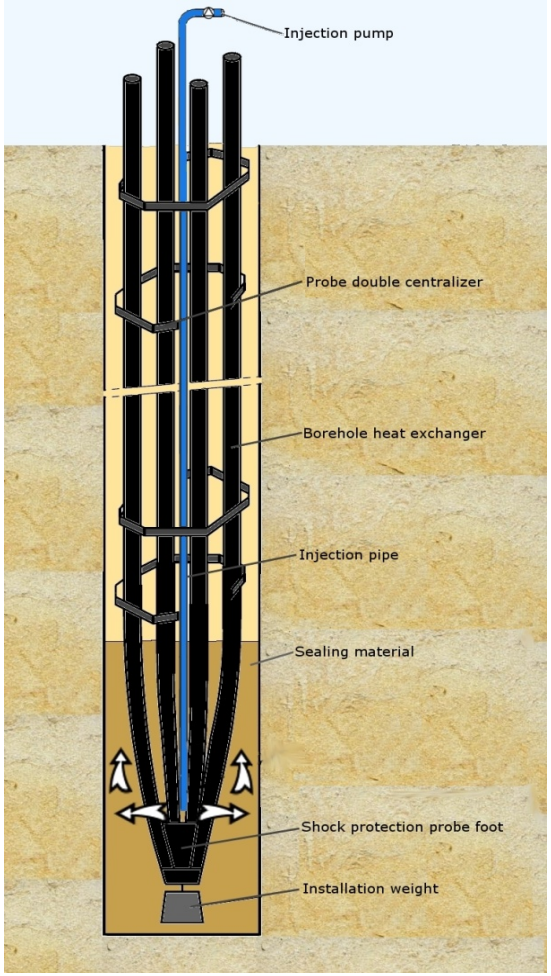
Grouting



The reasons for grouting are:

- Ensure thermal flow from the bedrock to the heat carrier fluid during heat extraction or vice versa for heat injection.
- Sealing the borehole to the surface to prevent contaminants from entering and seal aquifers that may have been penetrated.
- The grouting must guarantee a watertight and durable, physically and chemically stable incorporation of the borehole heat exchanger in the bedrock.

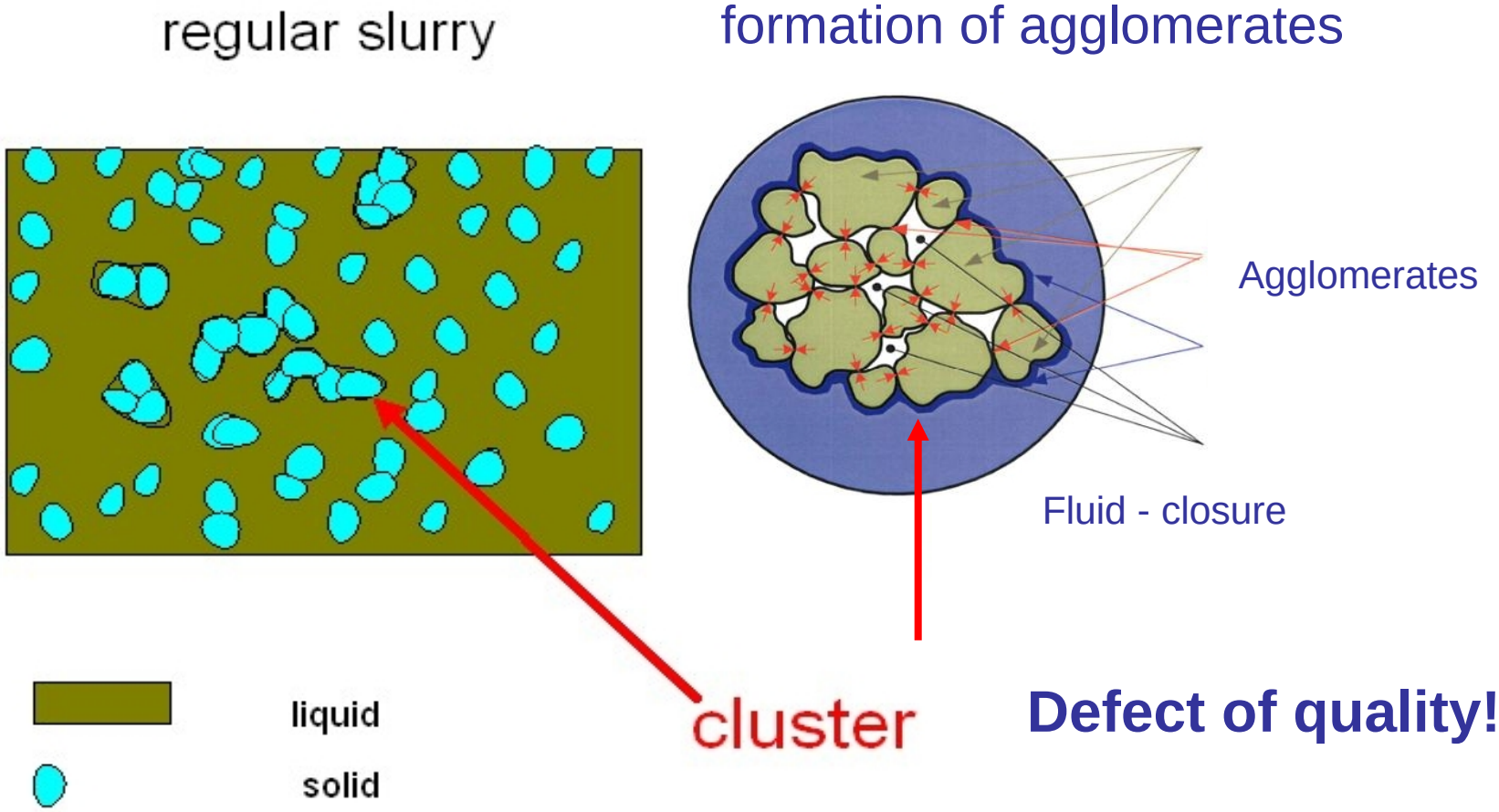
Grouting



- After the borehole heat exchanger has been put in place and after short pressure test, the connection of the BHE to the underground must be produced by means of a perfect grouting.
- This means the borehole must be completely filled up from the footpiece to the surface without any gaps.

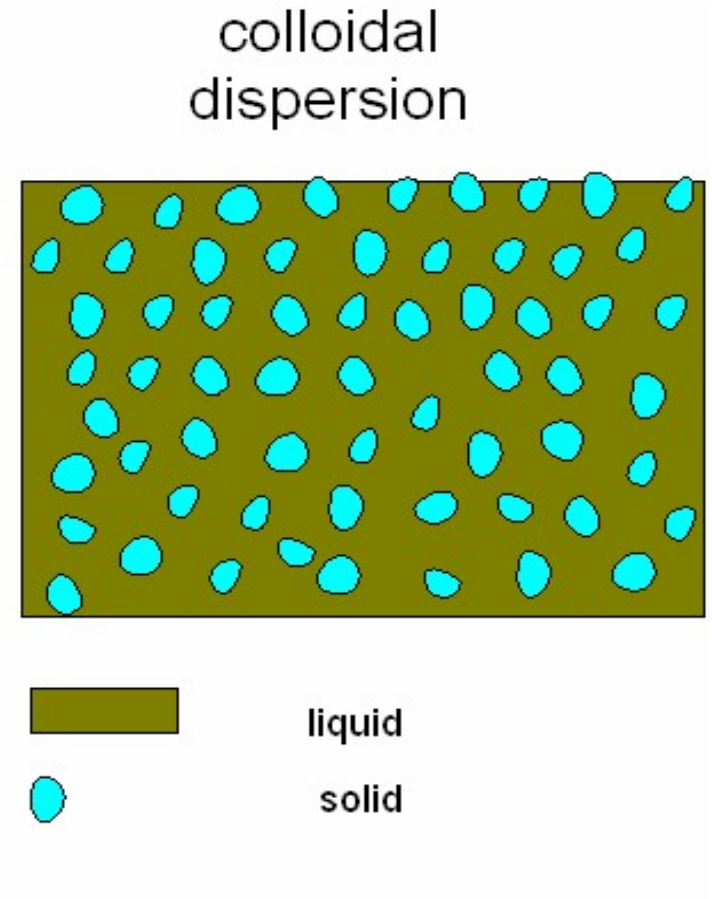
Grouting

The prime concern is prevention of formation of agglomerates



Defect of quality!

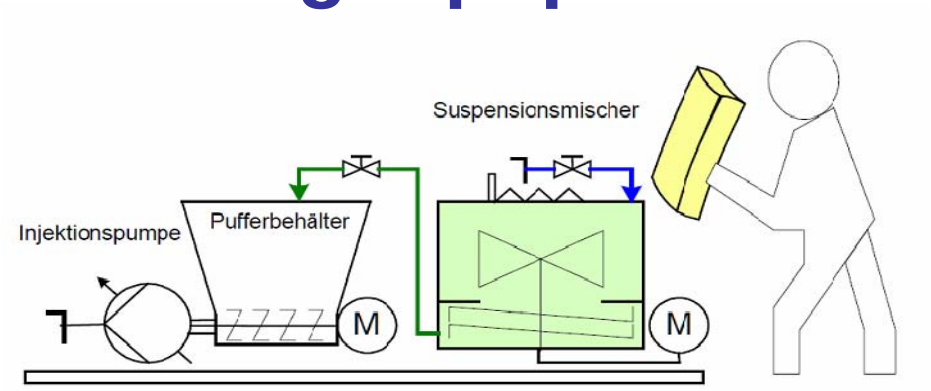
Grouting



Tiling the Bathroom for the Crossword Puzzle Editor

Grouting

Grouting equipment



- Compact injection plant with external hydraulic drive
- Maximum processable solids grains size: 1,0 mm
- Maximum processable slurry density: 1,9 kg/l
- Maximum processable Marsh visc.: 100 s
- Max. pump rate: 2,4 cbm/h

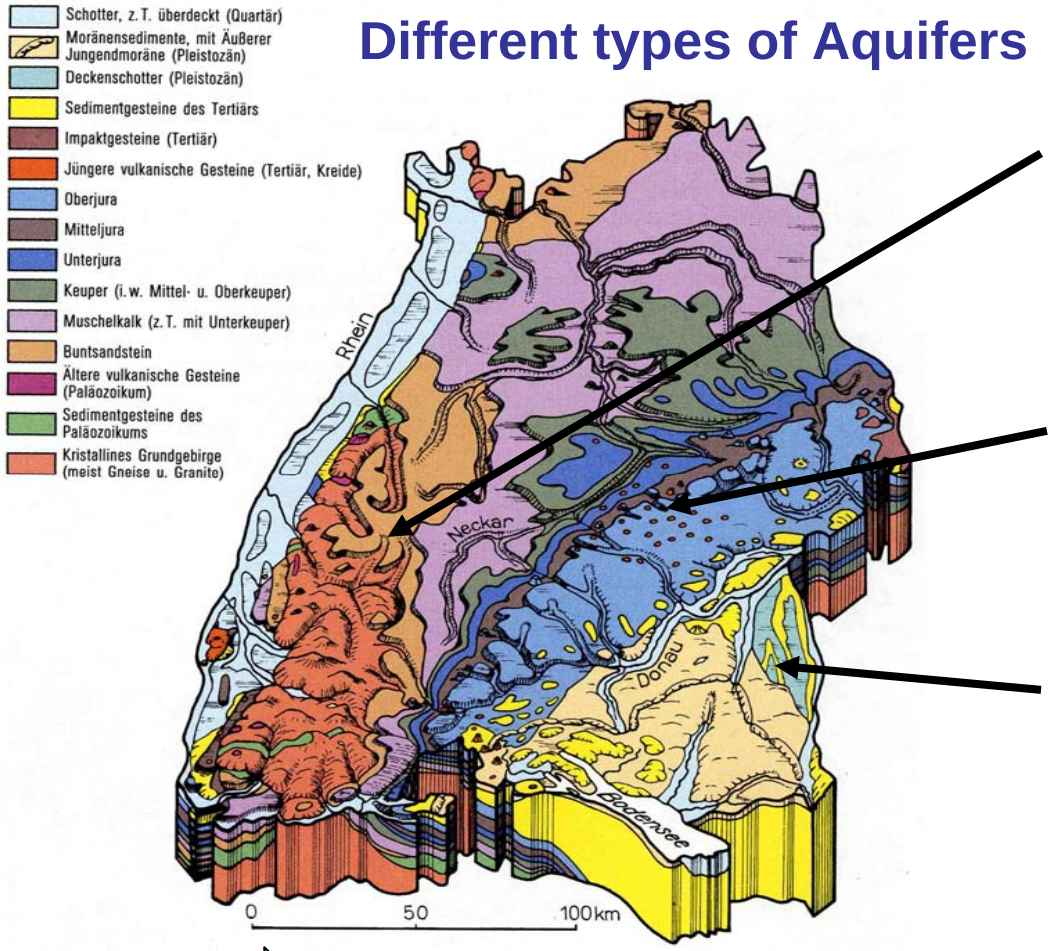
Grouting

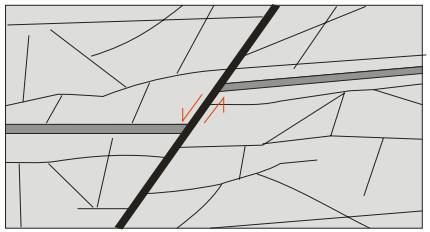
Grouting materials as ready made “One sack products”

- **Thermocem®** Mixture of Cement/Clay/Graphite
- Medium density/very high thermal conductivity/freezing stable
- **GWE- GeoTherm®** Mixture of Cement/Clay/Quarzite
- Medium density/high thermal conductivity/freezing stable
- **GWE- Thermokontakt®** Mixture of Cement/Bentonite/Quarzite
- Low density (high yield)/moderate thermal conductivity/low water permeability
- One sack products shows advantages compared to mixtures prepared from different components at the drill site. Dosages and grout slurry values are defined in the data sheets of the suppliers. Product quality is controlled by certified producers.

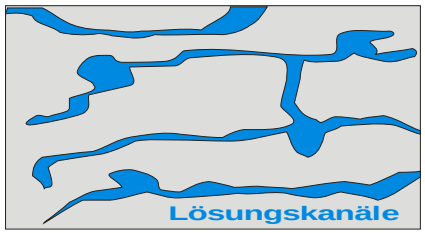
Grouting

Different types of Aquifers

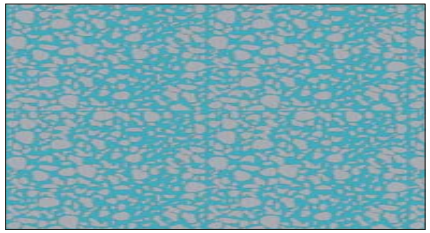




- Fissure
- rock aquifer



- Carbonate
- rock aquifer

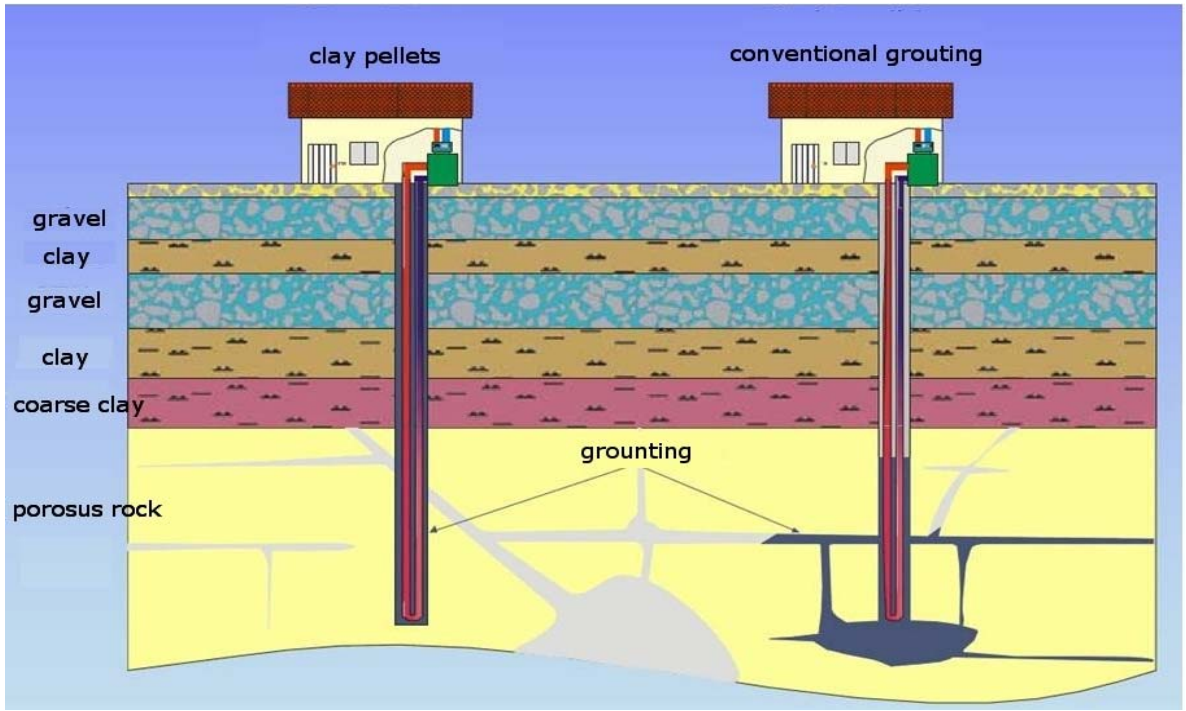


- porous aquifer

Different standards for grouting materials

Grouting

Porous rock formations



The grouting of the annular space must guarantee a watertight and durable, physically and chemically stable incorporation of the borehole heat exchanger in the surrounding rock.

Grouting

Problem !

In cavernous rocks and unconsolidated sediments like coarse gravel, common grout slurries shows the tendency to run away. The borehole can not be filled up to top!

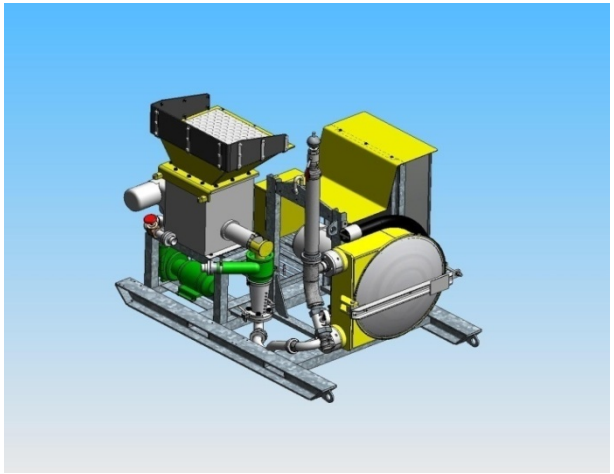
Grouting

Solution: GWE ThermoSeal

Parameter	GWE ThermoSeal
Pellet dimension	∅8mm; 2–12 mm
Settling velocity	21 m/min
Bulk density	1,1 t/m^3
Swelling capacity	40,60 %
Start swelling	15 min
Swelling pressure	9 kN/m^2
Permeability	10^{-11} m/s

New grouting material with enhanced thermal conductivity

Grouting



New Injection pump for the installation of clay pellets

Technical Specifications:

Max. Pressure Hose Pump:	8,0 bar
Clay Pellets:	Ø 8 mm, L = 5-12 mm
Capacity:	about 5,5 cbm
Supply line:	PEHD pipe 32x2,9 mm

Grouting

GWE pumpenboese SBF-HAGUSTA

GWE-ThermoSeal®

GWE-ThermoSeal®

Swellable clay pellets with improved thermal conductivity for annular backfill of geothermal probes.

Product characteristics:

- Seals made from water and GWE-Thermo-Seal have high thermal conductivity. They guarantee excellent thermal transfer in the underground and increase the efficiency of geothermal probes in comparison to standard materials.
- The material demonstrates coefficients of permeability to the order of 10^{-11} m/s. The swelling capacity of the clay pellets ensures a firm, gap-free join to the geothermal system and the surrounding geology. This results in excellent system sealing and a low thermal borehole resistance.
- The clay pellets have smooth, rounded surfaces, thus minimizing the risk of bridge formation when placed.
- Due to the complex annular geometry in holes fitted with duplex probes, we recommend that the clay pellets are inserted using a hose pump via a polythene tremie line.
- In contrast to free flowing clay/cement slurries GWE-Thermoseal® can also be used to fill up and seal fissured or cracked bore hole sections.
- The material is highly resistant to concrete-aggressive waters.

Material characteristics:

Appearance	Pellets
External dimensions	Ø approx. 8 mm, L 2-12 mm
Sinking speed in water	20 m/min.
Bulk density	approx. 1,1 kg/l
Coefficient of permeability K_f	10^{-11} m/s
Max. swelling pressure at constant volume	9 N/cm²
Thermal conductivity	2,5 W / m K

Determination of requirements:

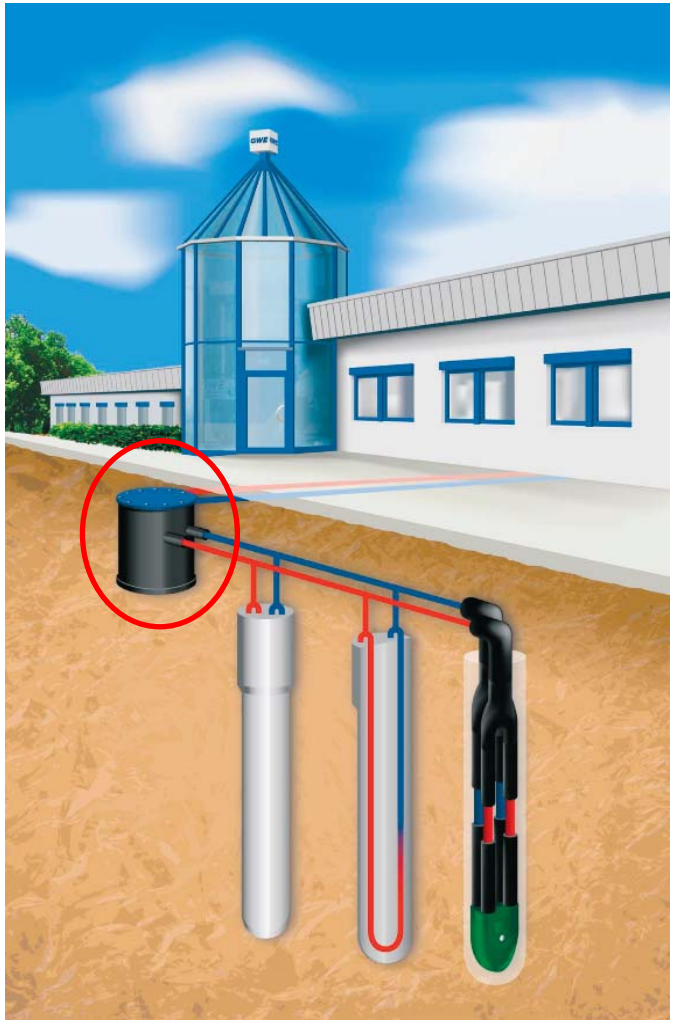
Borehole: [kg/m] Ø hole² [dm] x 8,64

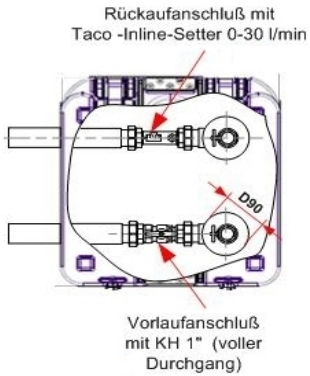
Form of delivery:

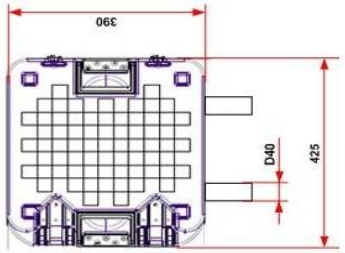
Package: 40 x 25 kg plastic bags on pallets
Big bags available on request

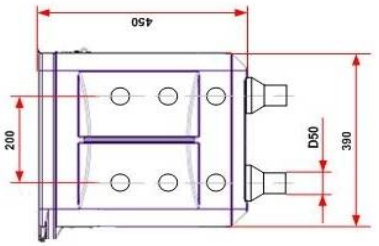
Telefon +49(0)5171 294-0
Telefax +49(0)5171 294-177
info@gwe-gruppe.de
www.gwe-gruppe.de

Connection of BHE

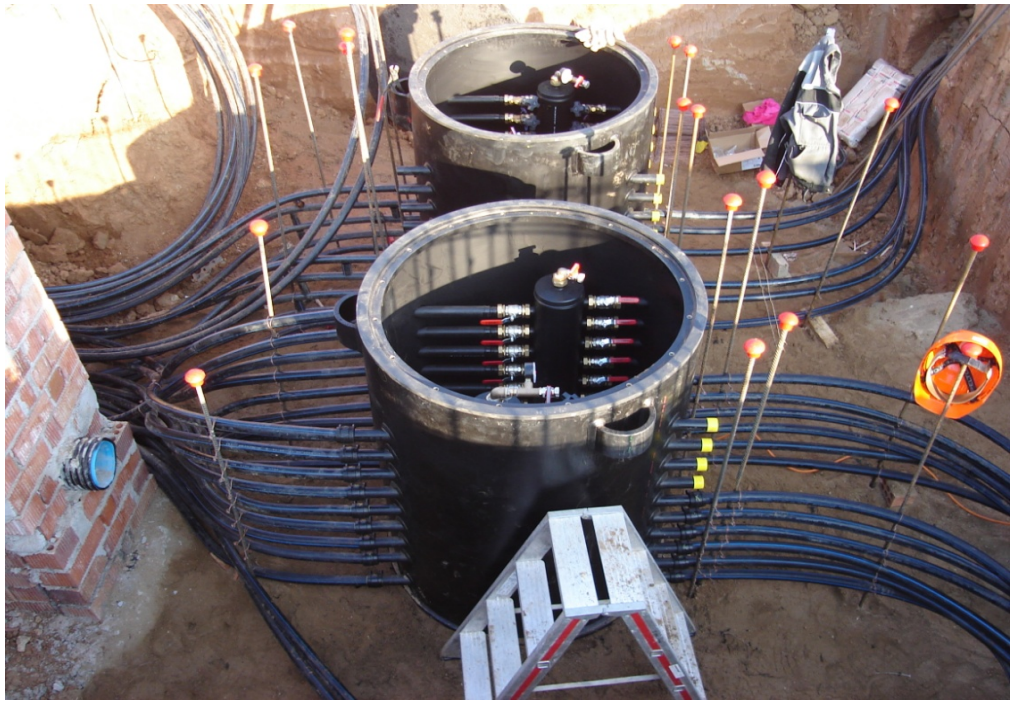








Connection of BHE



- http://www.gwe-gruppe.de/en/index.html
- http://www.gf-tec.com/

Connection of BHE

Connection of BHE

Horizontal connection is defined as the junction of single BHE to common collector-distributor units. The pipes shall be connected with parallel circuits to the distributor. The probe shall be equipped with valves for deaeration an regulation.

Connection of BHE

Respect the minimum bend radius

SDR	Dimension	Temperature	minium bend radius
11	DA 25	20°	25 x DA 25 = 625 mm
11	DA 25	0°	25 x DA 25 x 2,5 = 1562,5 mm
11	DA 32	20°	25 x DA 32 = 800 mm
11	DA 32	0°	25 x DA 32 x 2,5 = 2000 mm
11	DA 40	20°	25 x DA 40 = 1000 mm
11	DA 40	0°	25 x DA 40 x 2,5 = 2500 mm

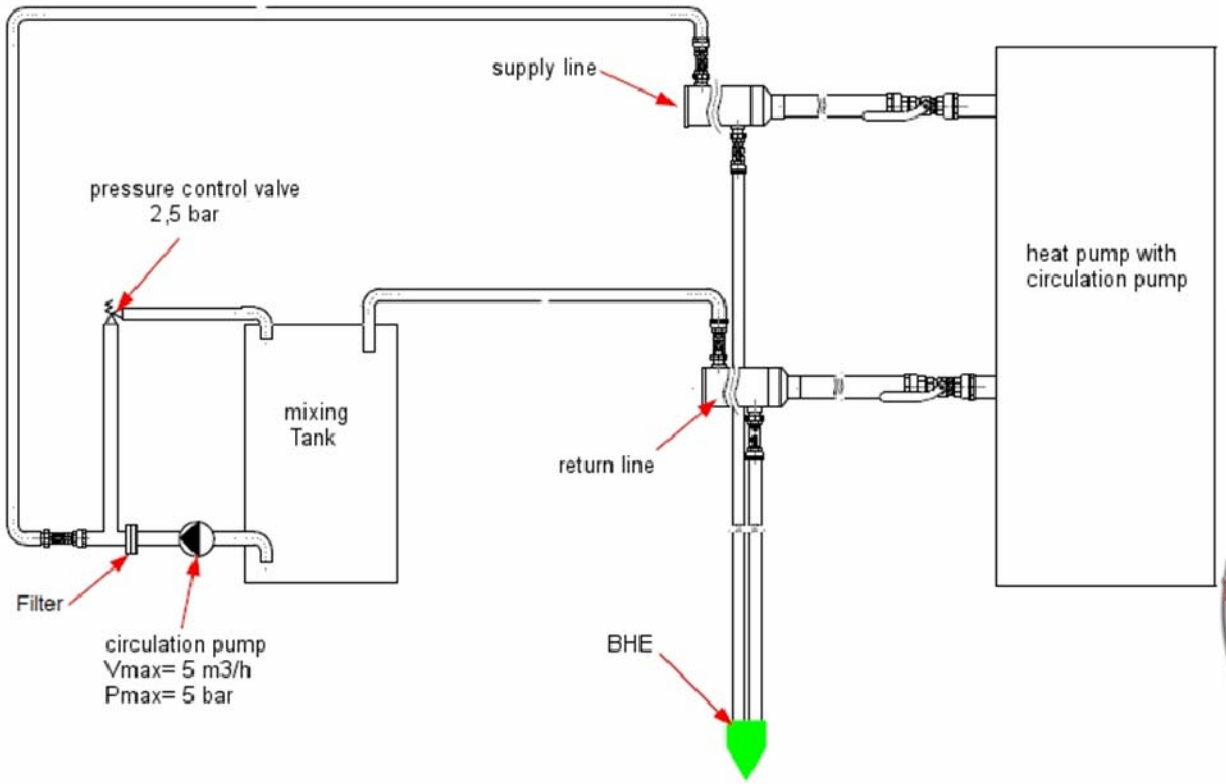
Filling and de-aeration

The filling of the heat exchanger system should be carried out by using the ready-mixed heat carrier fluid.

Common antifreeze agents for heat transfer media:

Name	Synonym	Chemical formula	WGK	Comments
Commonly used antifreezes				
Ethanediol	Ethylene glycol	$C_2H_6O_2$	1*)	
1.2-Propanediol	Propylene glycol	$C_3H_8O_2$	1*)	
Other antifreezes				
Calcium chloride		$CaCl_2$	1*)	corrosive
Ethanol	Ethyl alcohol	C_2H_5OH	1*)	

Filling and de-aeration



•http://www.zuwa.de/pumps/flushpro.html

Filling and de-aeration

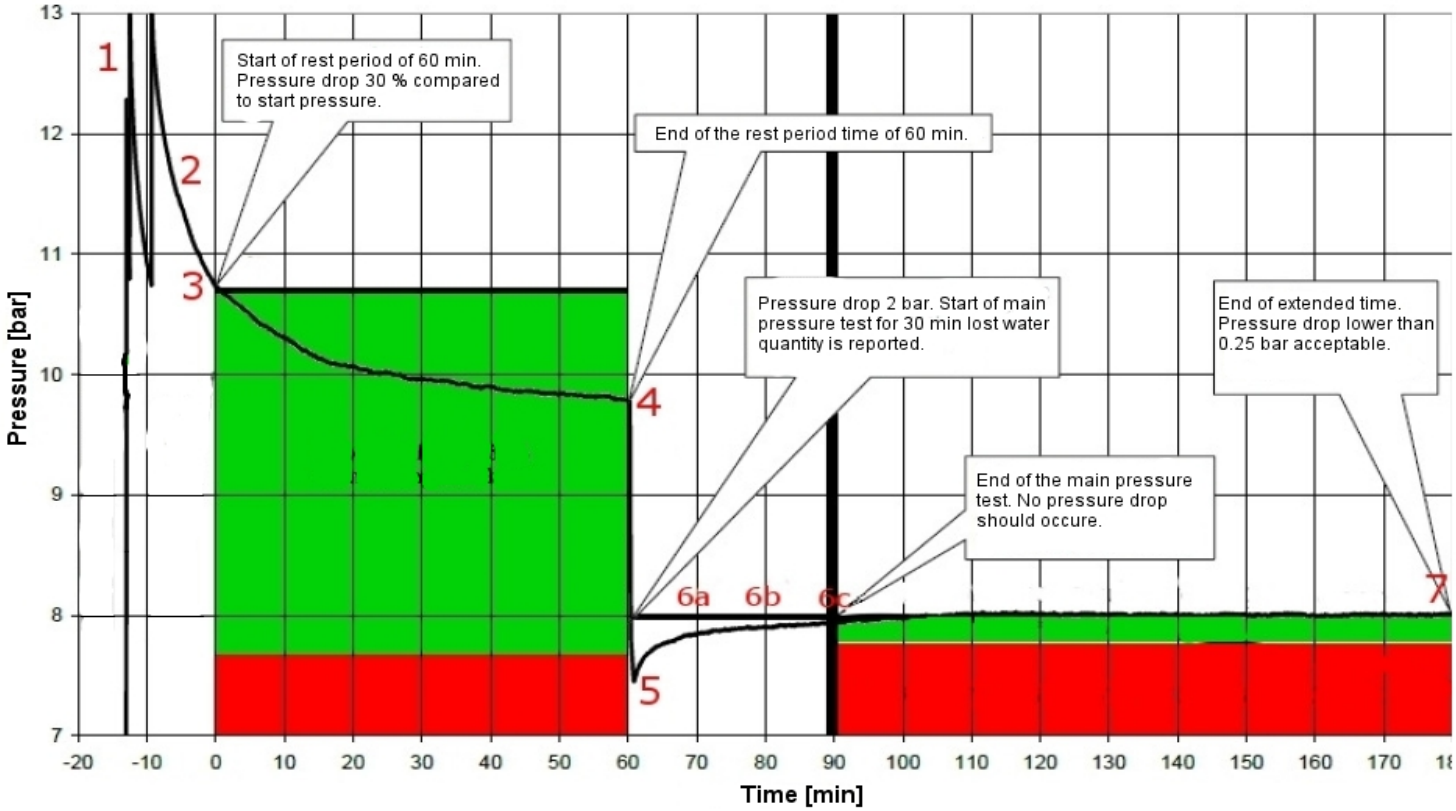
- **Calculation of the needed quantity of heat carrier fluid:**
  Example tabulation

Pipe diameter [mm]	Volume [l/m]
D_A 25 (D_I 20,4)	0,327
D_A 32 (D_I 26,2)	0,541
D_A 40 (D_I 32,6)	0,836
D_A 90 (D_I 79,2)	4,932

- **The filling up procedure is finished after the water in the BHE is completely displaced by heat carrier fluid**
- **The concentration of the moving in and leaving out fluid should be alike.**

Filling and de-aeration

Before commissioning, the whole system must be subjected to a pressure test

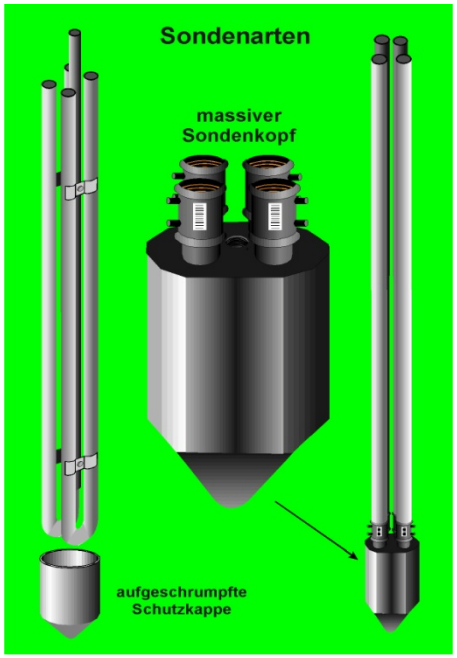


Quality management

Also for drilling and installation good quality work is crucial

Quality management

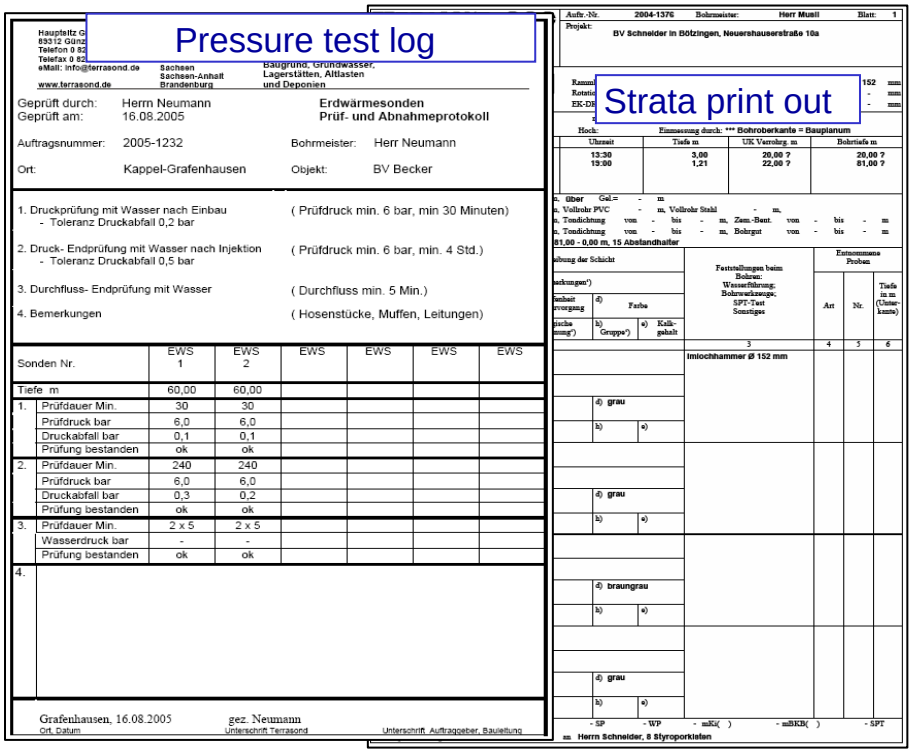
Comprehensive quality



- Quality management
- first class and modern machines
- qualified employees
- permanent further training
- use of high quality materials
- Guaranty of service and price

Quality management

Documentation of procedure



Pressure test log

Geprüft durch: Herrn Neumann
Geprüft am: 16.08.2005

Erdwärmesonden
Prüf- und Abnahmeprotokoll

Auftragsnummer: 2005-1232
Bohrmeister: Herr Neumann
Ort: Kappel-Grafenhausen
Objekt: BV Becker

1. Druckprüfung mit Wasser nach Einbau
   - Toleranz Druckabfall 0,2 bar
   (Prüfdruck min. 6 bar, min 30 Minuten)
2. Druck- Endprüfung mit Wasser nach Injektion
   - Toleranz Druckabfall 0,5 bar
   (Prüfdruck min. 6 bar, min. 4 Std.)
3. Durchfluss- Endprüfung mit Wasser
   (Durchfluss min. 5 Min.)
4. Bemerkungen
   (Hosenstücke, Muffen, Leitungen)

Sonden Nr.		EWS 1	EWS 2	EWS	EWS	EWS	EWS
Tiefe m		60,00	60,00				
1.	Prüfdauer Min.	30	30				
	Prüfdruck bar	6,0	6,0				
	Druckabfall bar	0,1	0,1				
	Prüfung bestanden	ok	ok				
2.	Prüfdauer Min.	240	240				
	Prüfdruck bar	6,0	6,0				
	Druckabfall bar	0,3	0,2				
	Prüfung bestanden	ok	ok				
3.	Prüfdauer Min.	2 x 5	2 x 5				
	Wasserdruck bar	-	-				
	Prüfung bestanden	ok	ok				
4.							

Grafenhausen, 16.08.2005 (Ort, Datum) gez. Neumann (Unterschrift Terrasond) Unterschrift Auftraggeber, Bauleitung

Strata print out

Auftr.-Nr. 2004-1376 Bohrmeister: Herr Muell Blatt: 1
Projekt: BV Schneider in Bötzingen, Neuershauserstraße 10a

Einmessung durch: *** Bohrboberkante = Bauplanum

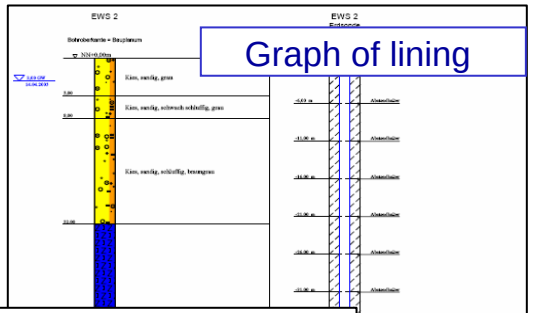
Uhrzeit	Tiefe m	UK Verrohrg. m	Bohrtiefe m
13:30	3,00	20,00 ?	20,00 ?
13:00	1,21	22,00 ?	81,00 ?

a. über Gel.= - m
a. Vollrohr PVC - m, Vollrohr Stahl - m,
a. Tondichtung von - bis - m, Zem.-Bent. von - bis - m
a. Tondichtung von - bis - m, Bohrgut von - bis - m
81,00 - 0,00 m, 15 Abstandhalter

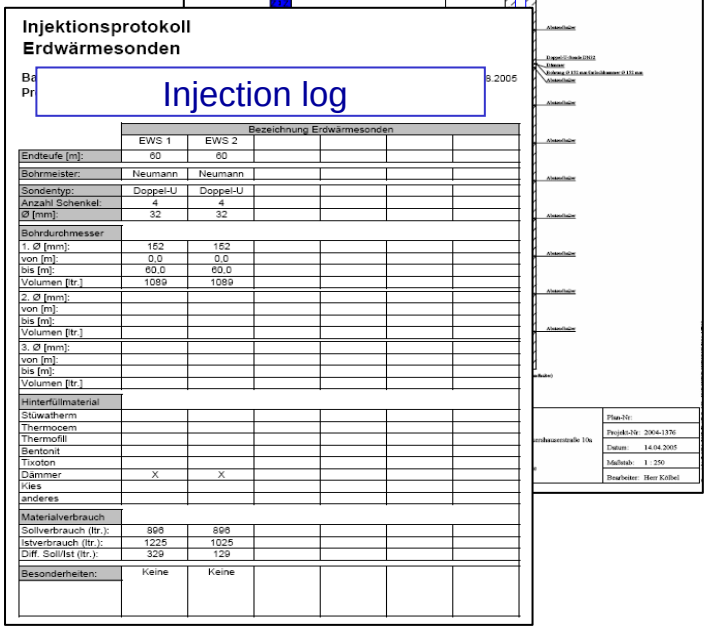
Imlochhammer Ø 152 mm

d) grau
d) grau
d) braungrau
d) grau

- SP - WP - mKG( ) - mBKB( ) - SPT
m Herr Schneider, 8 Styroporkisten



Graph of lining



Injektionsprotokoll
Erdwärmesonden

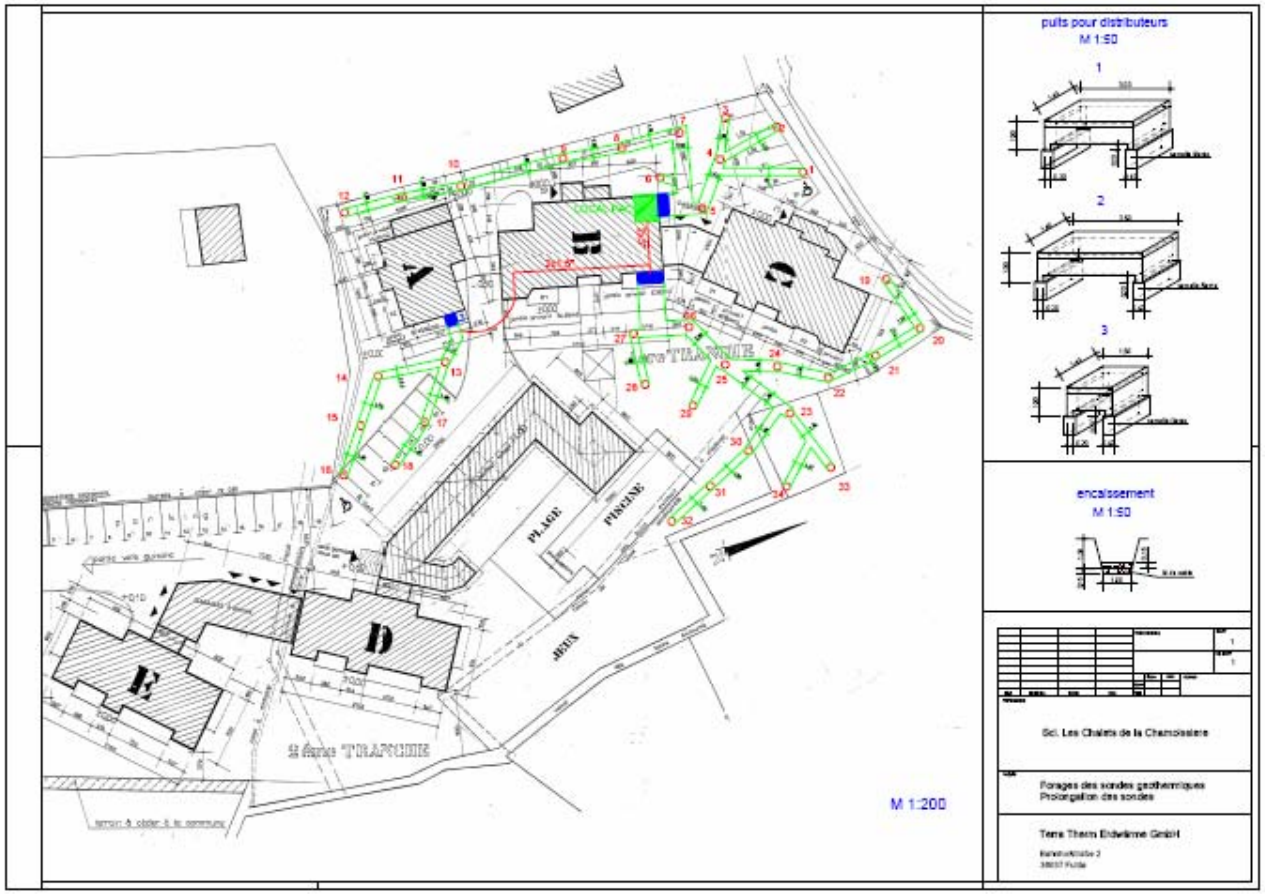
Injection log

	Bezeichnung Erdwärmesonden					
	EWS 1	EWS 2				
Endteufe [m]:	60	60				
Bohrmeister:	Neumann	Neumann				
Sondentyp:	Doppel-U	Doppel-U				
Anzahl Schenkel:	4	4				
Ø [mm]:	32	32				
Bohrdurchmesser						
1. Ø [mm]:	152	152				
von [m]:	0,0	0,0				
bis [m]:	60,0	60,0				
Volumen [ltr.]	1089	1089				
2. Ø [mm]:						
von [m]:						
bis [m]:						
Volumen [ltr.]						
3. Ø [mm]:						
von [m]:						
bis [m]:						
Volumen [ltr.]						
Hinterfüllmaterial						
Stüwatherm						
Thermocem						
Thermofill						
Bentonit						
Tixoton						
Dämmer	X	X				
Kies						
anderes						
Materialverbrauch						
Sollverbrauch (ltr.):	898	898				
Istverbrauch (ltr.):	1225	1025				
Diff. Soll/Ist (ltr.):	329	129				
Besonderheiten:	Keine	Keine				

Quelle: Dr. Simone Walker-Hertkom

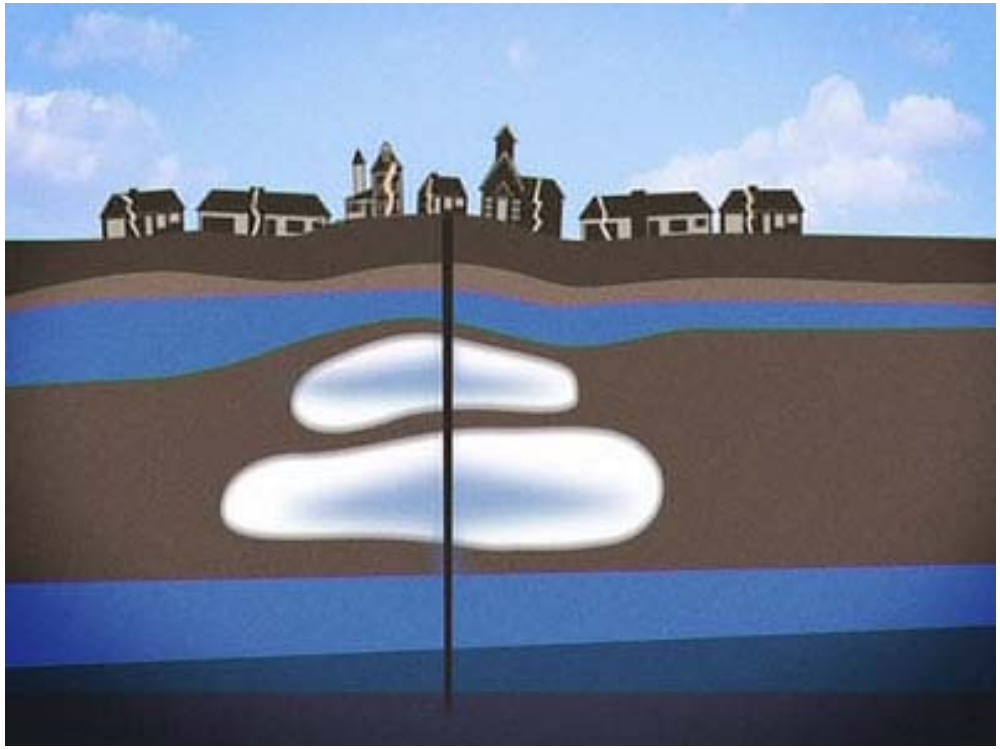
Quality management

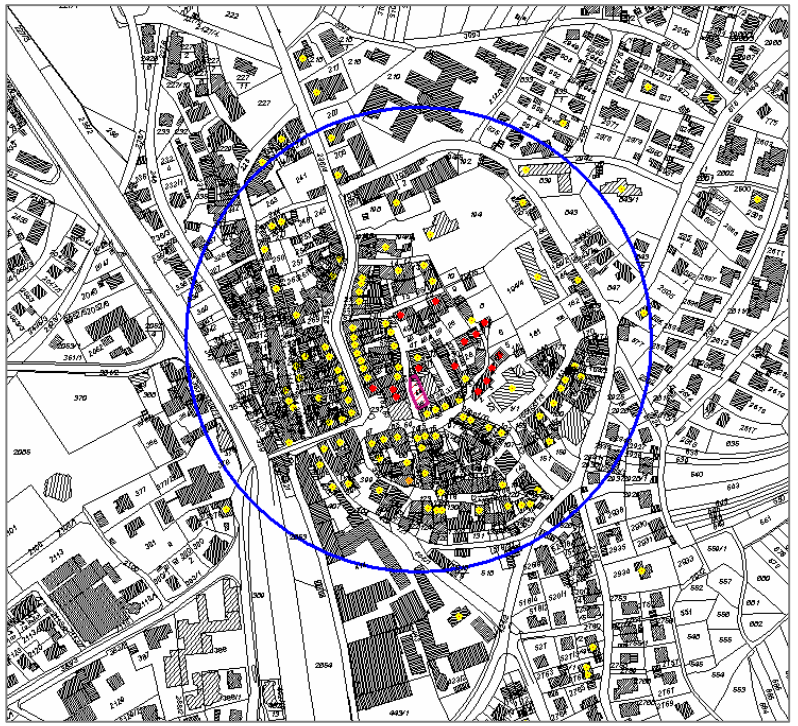
Documentation of procedure



Quality miss - management

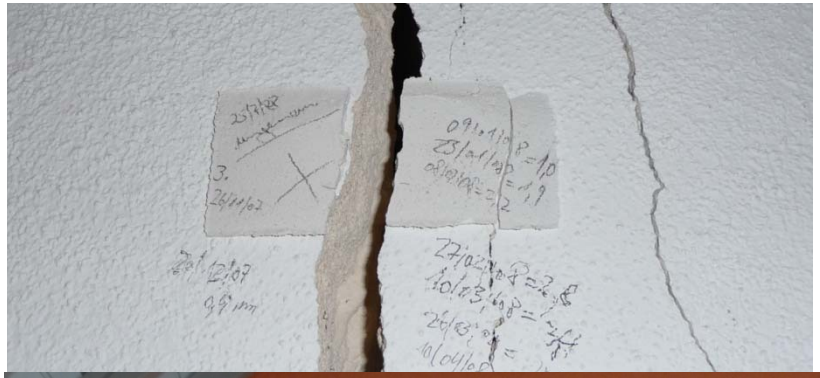
Staufen, Soutern Germany





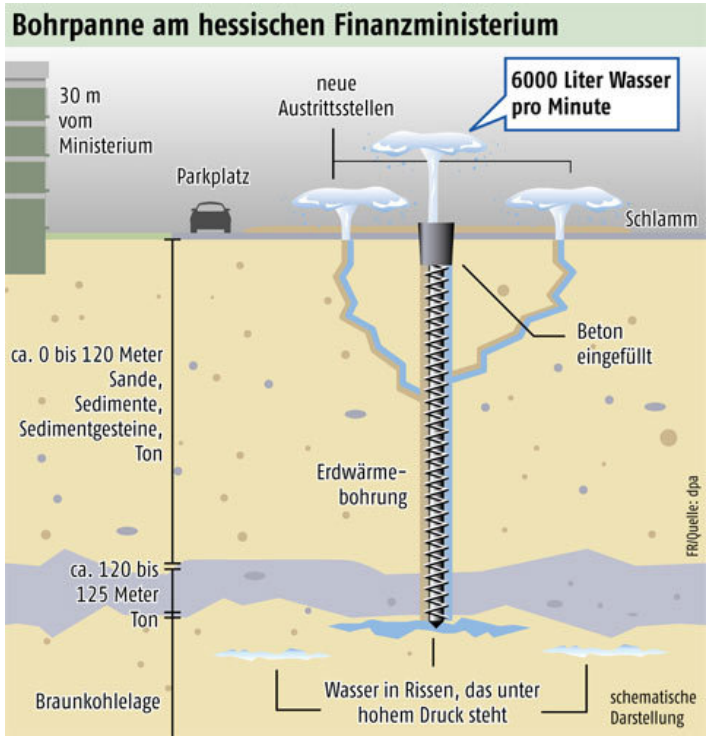
Quality miss - management

Staufen, Soutern Germany



Quality miss - management

Wiesbaden, Germany



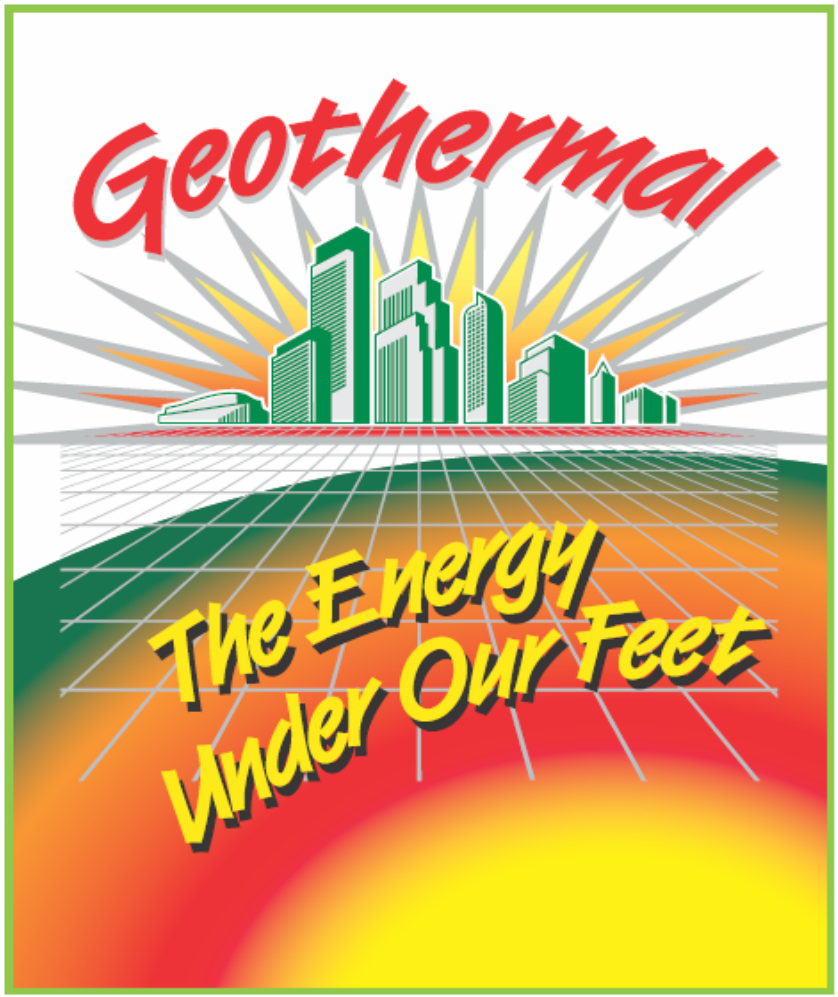
Quality miss - management

Wiesbaden, Germany

Quality miss - management

Kamen, Germany

Thank you for your attention !



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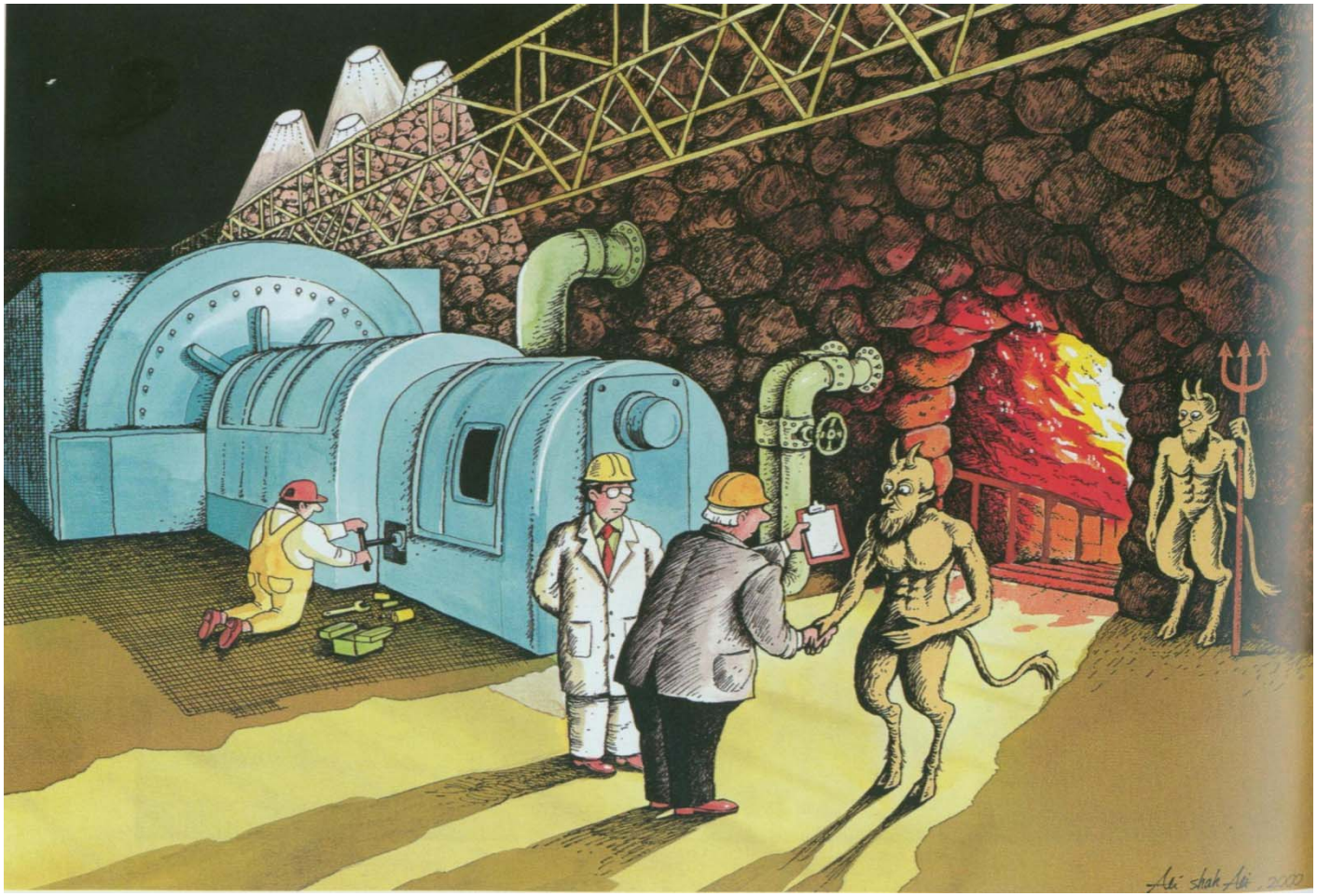
- www.bauer.de

Shallow geothermal energy systems



Thank you for your attention !

Passionate about progress

BAUER Drilling Services