In situ Permeability Testing with the BAT Permeameter

Quick Manual
Clay Liner Testing

BAT Geosystems AB
Sweden

www.batgeosystems.com

Warranty details

BAT Geosystems AB (BAT) warrants all new BAT products against defects in materials and workmanship for a period of 12 months from the date of invoice. During the warranty period, we will repair or, at our option, replace at no charge a product that proves to be defective provided that it is returned, shipping cost prepaid, to BAT.

BAT´s liability and obligations in connection with any defects in materials and workmanship are expressly limited to repair or replacement, and the sole and exclusive remedy in the event of such defects shall be repair or replacement. BAT´s obligations under this warranty are conditional upon it receiving prompt written notice of claimed defects within the warranty period and it´s obligations are expressly limited to repair or replacement.

This warranty does not apply to products or parts thereof which have been altered or repaired outside of the BAT factory, or products damaged by improper installation or application, or subjected to misuse, abuse neglect or accident.

BAT Geosystems AB will not be liable for any incidental or consequential damage or expense incurred by the user due to partial or incomplete inoperability of it´s products for any reason whatsoever or due to inaccurate information generated by its products.

All warranty service will be completed as soon possible. If delays are inavoidable customers will be contacted immediately.

Contents

Pre-test measures

1) Installation of BAT MKIII Filter Tip

Install a BAT MKIII Filter Tip at desired depth and location. Follow the instructions from the "Installation of the BAT MKIII Filter Tip"-guide.

2) Measurement of pore pressure

Measure the actual pore pressure. Follow the instructions given in the "BAT Pore Pressure Guide".

Dissipation of disturbance effects

When the BAT Filter Tip is pushed into the soil, excess pore pressures will be generated due to disturbance effects. The time needed for dissipation of these disturbance effects varies with the type soil. In soft, plastic clays lays it may take several days until the original pore pressure is restored. On the contrary, in stiff clay, silt and fine sand the dissipation of the excess pressures goes much quicker. The process of dissipation of excess pore pressures can be logged by the BAT Sensor.
Make sure that the installation disturbance pore pressure has dissipated, before starting a permeability test. If unsure, leave the sensor connected to the BAT Filter Tip for 10 minutes. If , during this period, the he reading is stable (±0.01m H_2O) a permeability test can be performed.

3) Checking BAT Sensor

Make sure that the battery unit of the sensor contains a fresh, akaline battery. If unsure, change the battery. Normal life time of a battery when constant logging (1 minute interval) is about 3-4 weeks.

Introduction of BAT Permeameter

The BAT Permeameter can measure **permeabilites, *k*, in the range from $1*10^{-7}$m/s and lower.**

An example of typical *k*-values for different soil types:

Fine gravel:	$1 - 1*10^{-2}$m/s
Coarse sand:	$1*10^{-1}$m/s - $1*10^{-3}$m/s
Medium sand:	$1*10^{-2}$m/s - $1*10^{-4}$m/s
Fine sand:	$1*10^{-3}$m/s - $1*10^{-5}$m/s
Coarse silt:	$1*10^{-4}$m/s - $1*10^{-6}$m/s
Medium silt:	$1*10^{-6}$m/s - $1*10^{-7}$m/s
Fine silt:	$1*10^{-7}$m/s - $1*10^{-8}$m/s
Clay:	$<1*10^{-8}$m/s

Typical time for stabilization for different *k*-values, i.e. time of testing, see also APPENDIX 2.

$k \approx 10^{-7}$ m/s ; $t_{stab} \approx$ 5 minutes
$k \approx 10^{-8}$ m/s ; $t_{stab} \approx$ 0,5 hours
$k \approx 10^{-9}$ m/s ; $t_{stab} \approx$ 5 hours
$k \approx 10^{-10}$ m/s ; $t_{stab} \approx$ 50 hours

Theory of the BAT Permeability Test

´The BAT Permeability Test is a type of ”falling head” test. The evaluation of the test is made by using Hvorslev´s equation *):

$$k = P_0 \cdot V_0/(F \cdot t \cdot 10^3) \cdot \{1/U_0 \cdot P_0 - 1/U_0 \cdot P_m + 1/U_0^2 \cdot \ln[(P_0 - U_0)/P_0 \cdot P_m/(P_m - U_0]\}$$

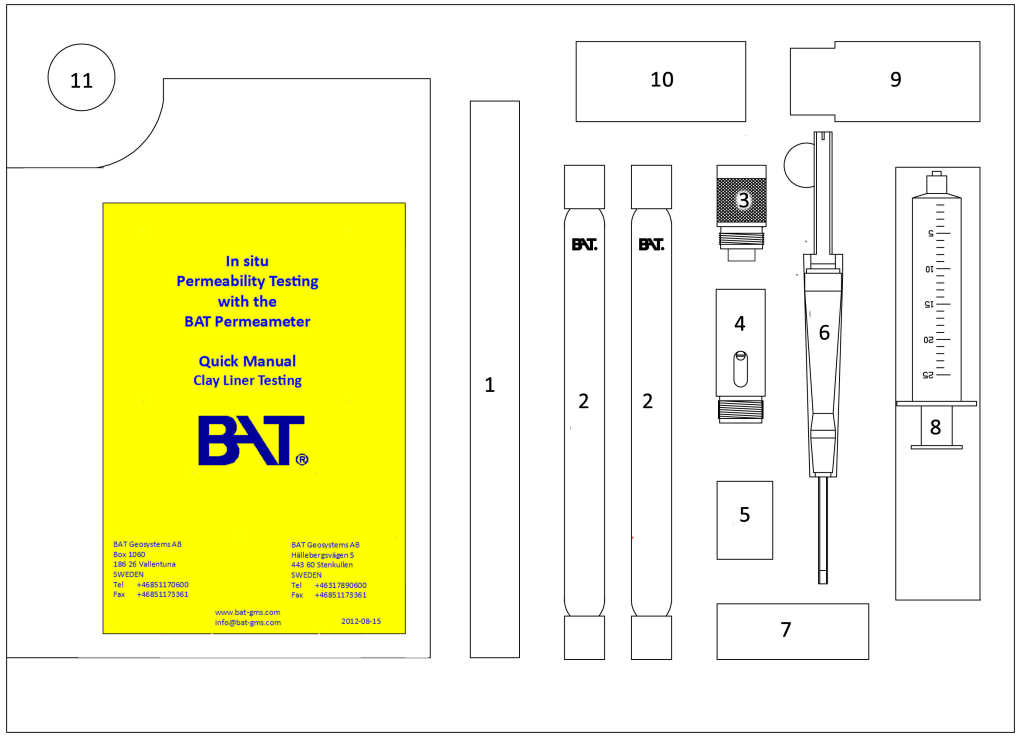
Parameters:

F	=	Hvorslev´s flow factor BAT MKIII Standard: 230 mm BAT MKIII Vadose: 194 mm	mm
k	=	coefficient of permeability	m/s
U_0	=	equilibrium pore pressure in-situ (absolute)	m H_2O
P_0	=	initial system pressure (absolute)	m H_2O
P_m	=	system pressure at time *t* (absolute)	m H_2O
V_0	=	initial system volume of air	ml
t	=	time for the test	s

At any time ***t*** the corresponding coefficient of permeability ***k*** can be calculated using Hvorslev´s equation* .

*) Hvorslev, M.J. 1951. ”Time lag and soil permeability in ground water observations”. Bull. No. 36, Waterways Exper. Sta. Corps of Engrs, U.S. Army, Vicksburg, pp.1-50.

BAT Permeameter Equipment

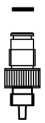


Contents:

1. Test container housing
2. Test container (35 ml)
3. Extension adapter
4. Quick coupling sleeve
5. Spare screws and springs
6. Screwdriver for mounting of double ended needle
7. Spare septas
8. Syringes (25 ml & 10 ml)
9. Container for used needles
10. Double ended needles
11. Blue & Yellow needles

BAT Permeameter Kit & Equipment Parts

BAT-sensor
#1-200

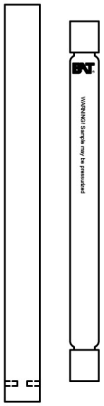


O-ring 11.1x1.78mm
#3-212

Transfer nipple
#3-202

Blue needle
#4-401

Extension adapter
#3-304



Test container housing
#3-302

Test container, 35ml, double ended
#3-303

Double ended needle
#4-403

Quick coupling
#3-305

PRECAUTIONS

- Handle all parts carefully, especially the glass containers.
- Use only sharp needles. In general do not re-use needles, especially in case the set is used for sampling.
- Store the set in a dry climate.
- Do not use any tools to assemble the set. Finger tight is enough.

Assembly of equipment - Stepwise

Transfer nipple & extension adapter

- screw the transfer nipple until it seats in the sensor cavity. Firstly, make sure the parts all are dry.
- Attach a blue needle onto the transfer nipple.
- Mount the extension adapter onto the transfer nipple.

Test container

***Outflow test* - unsaturated soil conditions**

- Open the test container in one end by removing the screw cap and the septum.
- Fill the test container with a selected volume of water, using a syringe. See **PAGE 7** for more details.
- Close the test container. Finger tight is enough!

Container housing assembly and connection of IS Field Unit

- Carefully insert the test container into the container housing.
- Screw the extension adapter onto the open end of the container housing .
- Connect the IS Field Unit, choose Display Mode (**see page** 7).
- The pressure in the test container can now be measured with the IS Field Unit.
- After assembly hold the test unit horisontally or pointing downwards.

Application of initial system pressure P_0
Outflow test

- The initial system pressure P_0 is applied by injecting or extracting a volume of air, ΔV, to/from the test container, using a syringe, equipped with a blue, hypodermic needle. The applied pressure P_0 is directly displayed by the IS Field Unit.
- For calculation of P_0 and W_0, see Page 7.

N.B. Normally, when the test equipment is lowered down the extension pipe the temperature will drop. Accordingly the applied initial pressure will be changed. For example a temperature drop of 10°C will reduce the applied intial pressure P_0 by about 5%.

Double ended needle & Quick coupling sleeve

- Prepare the double ended needle for mounting.
  N.B. Remove the small rubber hose.
- By using the needle adapter in the handle of the screwdriver, screw the double ended needle until it seats into the quick coupling sleeve. IMPORTANT! Make sure that the needle seats properly in the thread. However, DO NOT overtighten which might damage the thread!
- Finally, screw the quick coupling sleeve onto the container housing.

Unsaturated soil conditions & negative pore pressure situation

For unsaturated soil conditions the BAT Permeability test must be carried out as an outflow test. It is also assumed that a negative pore pressure situation is prevailing, i.e.: $U_0 \le p_{atm}$. This condition is normally prevailing for *compacted clay liners*.
For outflow tests in unsaturated conditions the BAT MKIII Vadose is needed.

The outflow test starts with a **partly water-filled** Test Container.

Initial water volume W_0

Porewater pressure interval $\mathbf{8 \le U_0 \le p_{atm}}$

For the porewater pressure interval of $\mathbf{8 \le U_0 \le p_{atm}}$: $\mathbf{W_0 = 10}$ (ml)

Porewater pressure interval $\mathbf{1 \le U_0 < 8}$

The water volume, $\mathbf{W_0}$, for pressure interval $\mathbf{1 \le U_0 < 8}$ is calculated as follows:

$$W_0 \approx (35 - 3{,}1 \cdot U_0) \quad \text{(ml)}$$

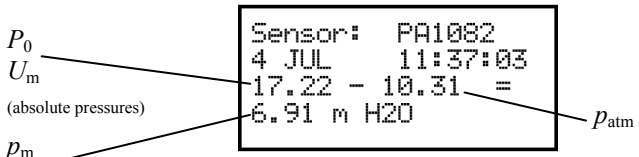
The volume W_0 is injected in an **open** Test container, see Page 5.
APPENDIX 1 shows the water volume $\mathbf{W_0}$ as a function of $\mathbf{U_0}$.

Depending on the magnitude of the equilibrium pore pressure $\mathbf{U_0}$ the following initial system pressures $\mathbf{P_0}$ are recommended:(**NB. All pressures are in absolute values).**

Equilibrium pore pressure interval (m H_2O):	$9 \le U_0 \le p_{atm}$	$8 \le U_0 < 9$	$1 \le U_0 < 8$
Recommended initial system pressure (m H_2O):	$P_0 = 1{,}15 \cdot U_0$	$P_0 = 1{,}25 \cdot U_0$	$P_0 = p_{atm}$

Application of system pressure P_0

With the sensor and field unit connected the system pressure P_0 is adjusted by injecting a volume of air using a syringe and blue needle. **NB.** For the pore pressure interval $\mathbf{1 \le U_0 < 8}$ the system pressure $P_0 = p_{atm}$ is applied just by puncture the septum using a blue needle. (Continue to page 8 for further details!)



BAT Field Unit Display

P_0 = System pressure in Test Container
U_m = sensor pressure (if BAT Permemeter not connected)
U_0 = pore pressure = U_m + 0.2m H2O (pressure head compensation)

With the system pressure P_0 and W_0 for the outflow test set correctly the next steps are as follows (see page 8).

NB. Risk of hydraulic fracturing for pore pressure interval $9 \le U_0 \le p_{atm}$
See comments in APPENDIX 2 .

Starting the BAT Permeameter test

Temperature equilibrium
Before starting a permeability test the BAT Permeameter equipment must reach temperature equilibrium with the actual environment.This procedure is described in APPENDIX 6. With the BAT/IS-Field Unit connected you can monitor the temperature equalization process. This process normally takes about 15 to 20 minutes.When the system pressure P_0 is stable **note the P_0** value in the Test Protocol.

Starting the test
1) Prior to the start of the test, prepare the Field Unit by opening the "Start Measure" menu. Select both *sensor* and *temperature* logging (sensor+temp) and a suitable time interval. To start with it is recommended to use **1 min logging** interval. At a later stage of the test the logging interval can be changed (increased) without any inteferece with the ongoing logging of test data.

2) Thereafter, return once more to the "Start Measure" menu and just place the marker on the OK-option, without starting the logging.

3) The next step is to connect the test equipment to the BAT Filter Tip, see APPENDIX 6. At the same moment the equipment connects to the Filter Tip, **press** OK on the Field Unit and the test is running. Open the "Display" menu of the Field Unit to have a visual check that the test is running, i.e the pressure in the Test Container shall gradually change.

4) Depending on soil type the testing time may vary from about 15 minutes up to 24 hours or more.
After about one hour of logging it is recommended to increase the measuring interval of the sensor to 10 minutes or more. This is simply done by activating the "Start measure" function of the BAT/IS-Field Unit and select a new logging interval.

5) The test can normally be evaluated at a pressure equalization of 80% (P_{80}), see Test Protocol.

Finalizing the BAT Permeameter test

Finalizing the permeability test
As mentioned it is recommended to run the test up to a **pressure equalization of 80 % (P_{80}) .**

When finalizing the test the following steps shall be taken:

1) Note the values of system pressure P_{end} and atmospheric pressure p_{atm} in the Test Protocol.

NB. In case a substantial change of the atmospheric pressure p_{atm} has occurred during the test this has to be taken into account when evaluating the test results.

2) Gently pull up the equipment. Disassemble the equipment and measure the volume of water W_{end} in the Test Container. The W_{end}-value shall be noted in the Test Protocol. The W_{end} value can be measured by pouring the liquid into a syringe sealed with a rubber septa to the needle. It can also be measured more accurately using a scale at the office at a later stage.

3) Now the field part of the test is completed.
Processing of test data and evaluation of the coefficient of permeability k_{80} can be done by using an Excel sheet as shown enclosed.

NB. If running more tests before downloading the data to a PC, just remember **do not clear the data between the tests**. Keep notes on the starting time and starting pressures of each test and each set of test data is easily separated when processing it on a PC.

4) Checking the quality of the permeability test
The quality of the permeability test can be checked by calculation of the water volume ratio:

$$W_{end} / W_{calc}$$

in which: W_{end} = measured water volume in the Test Container (ml)
W_{calc} = calculated water volume in the Test Container (ml)

For approval of the test the water volume ratio ought to fulfil the following requirement:

$$0{,}9 \leq W_{end} / W_{calc} \leq 1{,}1$$

NB. In case of gassy soils the water volume ratio will normally be less than 0,9.

Test Protocol - Outflow Test

Site:…… Date:……..

Measuring point.: …….. BAT/IS sensor nr.: ……

Installation depth of filter tip:…… Test performed by :…….

Initial atmospheric pressure : ……m H_2O time: …… (Measured by IS Field Unit).

Final atmospheric pressure : ……m H_2O time: ...…..

Type of Filter Tip: BAT MKIII Vadose Filter Tip, form factor F = 194 mm

U_0, pore pressure at equilibrium, m H_2O:……..
$U_0 = (U_m + 0.2$ m$H_2O)$ in which U_m is displayed absolute pore pressure

NOTE! ALL PRESSURES ARE IN ABSOLUTE VALUES!

W_0 , initial water volume in Test Container: ml: .....

V_0 , initial volume of air in Test Container: $V_0 = (35 - W_0)$ ml

P_0, system pressure at start of test (at temperature equilibrium), m H_2O:……...
(displayed P_m value)

P_{80}, system pressure at 80% pressure recovery, m H_2O: …….
$P_{80} = P_0 - 0{,}8*(P_0 - U_0)$

P_{end}, final system pressure, m H_2O:…….

W_{calc}, calculated volume liquid in system at end of test, ml:……
$W_{calc} = 35 - P_0*(35- W_0)/ P_{end}$

W_{end}, measured volume liquid in sample container at end of test, ml: ……...

Coefficient of permeability, k = ……*10^{-} m/s, calculated at …….% pressure equalization.

Notes:_____

_____

Input data sheet - Outflow Test

Site	ET Clay Liner		In these columns you paste data from the IS-sensor. If needed, replace all dots with commas.
Point	3		
Date	2008-05-07		
Installation depth of filtertip	2"		
BAT/IS sensor no.	PA2976		Fill these cells with the starting parameters before calculation
Operator	ST		
Length of filter, mm	35	BAT MKIII Vadose = 35 mm	
Diameter of filter, mm	25	BAT MKIII Vadose = 25 mm	
Flow factor, mm	193,2		
P_0, m H2O	10,580	Initial system pressure	k_{final}= m/s @ [hrs] Equalisation P_x [%]
W_0, ml	10,0	Initial liquid volume	k_{80}= 4,75E-10 m/s @ [hrs] 13:04:57
V_0, ml	25	Initial air volume	
U_0, m H2O	9,2	Static pore pressure	
Air pressure, Pa	102100		
starting temperature, K	290		Uend: 9,48 Pend: 9,23
V_{calc}, ml	5,90	Calculated volume water remaining after test	
V_{end}, ml	6,0	Measured volume water remaining after test	
P_{80}	9,48	P80 = System pressure at 80% equalisation. It is **recommended** to evaluate k-value at this pressure level	
P_{50}	9,41	P50: System pressure at 50% equalisation.	

Date	Date & Time	Pressure Pa	Temp, T °C	Time elapsed	Time elapsed seconds	Atm pressure	eff. Pressure m H2O	Pressure m H2O	Remaining volume of water in vial, ml	Permeability k [m/s]	Temp T Kelvin
	2	3	4	5	6	7	8	9	10	11	12
2008-05-07	10:25:03	1,04E+05	16,7	0:00:00	0	102100,0	10,58	10,58	10,00		289,7
2008-05-07	10:30:00	1,03E+05	16,8	0:04:57	297	102100,0	10,52	10,45	9,69	1,83E-09	289,8
2008-05-07	10:45:00	1,02E+05	17	0:19:57	1197	102100,0	10,45	10,39	9,55	9,95E-10	290
2008-05-07	11:00:00	1,02E+05	17,1	0:34:57	2097	102100,0	10,41	10,35	9,44	7,95E-10	290,1
2008-05-07	11:15:00	1,01E+05	17,1	0:49:57	2997	102100,0	10,37	10,31	9,34	7,05E-10	290,1
2008-05-07	11:30:00	1,01E+05	17,2	1:04:57	3897	102100,0	10,32	10,27	9,25	6,58E-10	290,2

Downloading of and processing of measurement data
The procedure for downloading and processing of measurement data is described in BAT´s manual for pore pressure measurement ”BAT/IS– system for Pore pressure measurement. Make sure **macros** are activated.

Insertion of measurement data in Excel calculation sheet
1) Insert the the data from the Test Protocol into Input sheet.

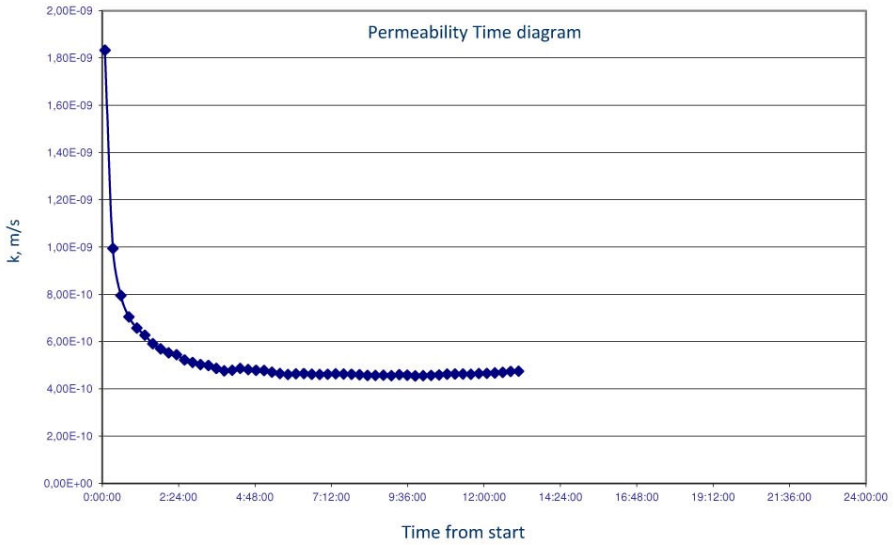
2) Paste the downloaded data in the columns 1, 2 and 3.

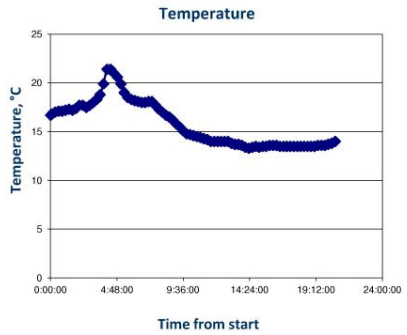
If present, change the ”dots” to ”commas” in the pressure column.

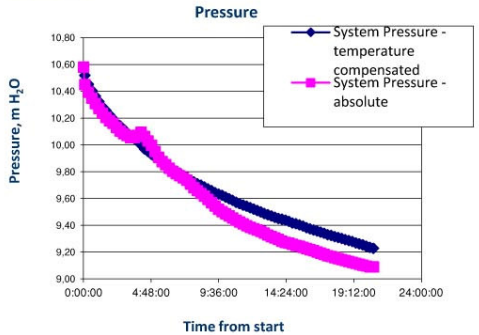
Output data sheet from PC-calculation

Site	ET Clay Liner	Filter Type	BAT MKIII Vadose
Point	3	Sensor #	PA2976
Installation depth	2"	BAT Geosystems AB	BAT Permeameter test
Date	2008-05-07		info@bat-gms.com
Operator	ST		www.bat-gms.com

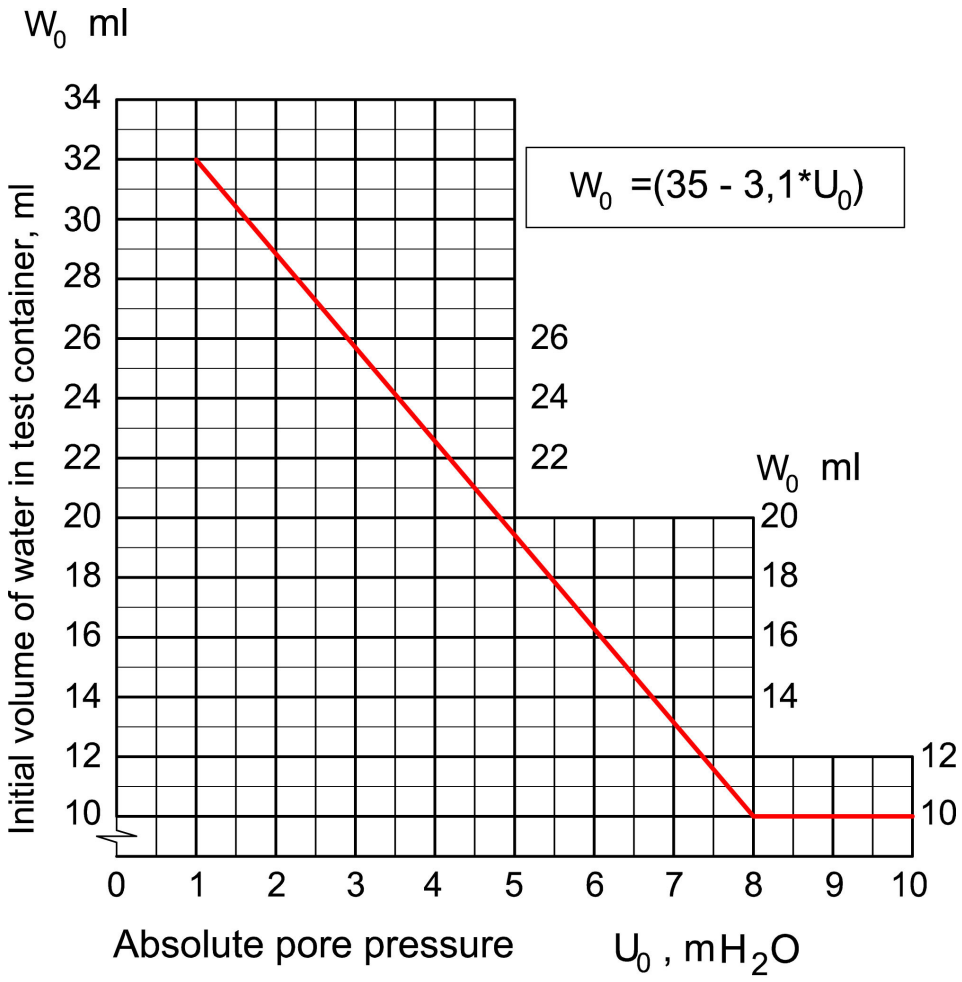
Initial pore pressure	U_0	9,2	mH_2O
Initial system pressure	P_0	10,58	mH_2O
Initial water volume	W_0	10,0	ml
Final water volume (measured)	W_{end}	6,0	ml
Final water volume (calculated)	W_{calc}	5,9	ml
Final pressure	P_{end}	9,23	mH_2O
Pressure equalisation		97%	
Water volume ratio		1,0	(W_{end}/W_{calc})
Calculated permeability:	k_{80}	4,75E-10 m/s @	13:04:57 hrs







Water volume, ΔW_0, in Test Container



Water volume, ΔW_0, in Test Container as a function of U_0 (See also APPENDIX 2).

Guide values of t_{80} and ΔW_{80} for BAT Outflow Permeability Tests, performed in soils having negative pore pressures

U_0 m H_2O	P_0 m H_2O	W_0 ml	ΔW_{80} ml	t_{80},*hrs* ***k80=1,0E-8 m/s***	t_{80},*hrs* ***k80=5,0E-9 m/s***	t_{80},*hrs* ***k80=1,0E-9 m/s***	t_{80},*hrs* ***k80=5,0E-10 m/s***	t_{80},*hrs* ***k80=1,0E-10 m/s***
10	**11,5**	**10,0**	**3,0**	0,6	1,1	5,6	11,0	56,0
9	**10,4**	**10,0**	**3,0**	0,6	1,1	5,6	11,0	56,0
8	**10,0**	**10,0**	**5,0**	0,6	1,1	5,6	11,0	56,0
7	**10,0**	**13,0**	**6,0**	0,6	1,1	5,6	11,0	56,0
6	**10,0**	**16,5**	**7,5**	0,6	1,1	5,6	11,0	56,0
5	**10,0**	**19,5**	**9,0**	0,5	1,0	5,0	10,0	50,0
4	**10,0**	**22,5**	**11,0**	0,5	0,9	4,6	9,0	46,0
3	**10,0**	**25,5**	**13,5**	0,4	0,8	3,9	8,0	39,0
2	**10,0**	**29,0**	**17,0**	0,4	0,7	3,5	7,0	35,0
1	**10,0**	**32,0**	**23,0**	0,3	0,6	2,8	6,0	28,0

Parameters

t_{80} time needed for 80% of pressure dissipation (*h*)
U_0 measured equilibrium pore pressure (*m H_2O*)
P_0 initial pressure in Test Container (*m H_2O*)
W_0 intial volume of water in Test Container (*ml*)
ΔW_{80} calculated outflow of water from the Test Container at t_{80} (*ml*)
k_{80} coefficient of permeability calculated at 80% of pressure dissipation (*m/s*)

Comments

The above table shows calculated guide values of t_{80}, i.e time needed for 80% of pressure dissipation in an outflow BAT Permeability test, performed in accordance with the recommendations given in the BAT user manual.
The table also shows recommended values of the parameters P_0 and W_0 as a function of U_0.
Calculated values of ΔW_{80}, are also shown in the table.
For intermediate k_{80} values the corresponding t_{80} values can simply be calculated by linear interpolation.

Risk of hydraulic fracturing pore pressure interval: $9 \leq U_0 \leq 10$ mH_20

When conducting an outflow permeability it is very important to consider the risk of hydraulic fracturing in the soil surrounding the filter tip in case too high initial system pressure P_0 is applied. Hydraulic fracturing of the soil surrounding the filter tip will give misleading results of the permeability testing. The risk of hydraulic fracturing is especially pronounced within the pore pressure interval 9≤ U_0 ≤10 m H2O (absolute pressure). The recommended P_0 values in the above table have been tentatively chosen with respect to the risk of hydraulic fracturing. However, due to specific site and soil conditions the user of the BAT Permeameter may need to reconsider the choice of a safe value of P_0 with respect to the actual risk of hydraulic fracturing.

BAT MkIII Vadose Filter Tip Assembly & Water Saturation

BAT MkIII Vadose Filter Tip (2-102).

ASSEMBLY

1) Assemble the Rubber seals and the Ceramic Filter onto the axle of the Tip. Seals: (i) 17.5x26x3mm at the top of filter and (ii) 17.5x23x3mm at the bottom of the filter. Put a few drops of water on the rubber seals in order to reduce friction.

2) Screw the Tip into the inner thread of the Body. DO NOT use any tools, finger-tight is enough (NB. Fairly strong fingers are needed)! Over-tightening may damage the filter.

WATER SATURATION OF FILTER TIP

1) Lower the Filter Tip into a bucket, containing clean de-aired water.

2) Fit a blue needle to a 20 ml syringe.

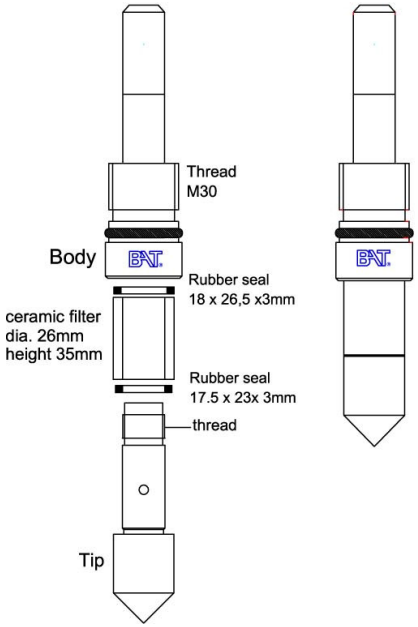
3) Penetrate the rubber septum of the of the Filter Tip.

4) Use the syringe for drawing water through the Ceramic Filter and the Filter Tip.

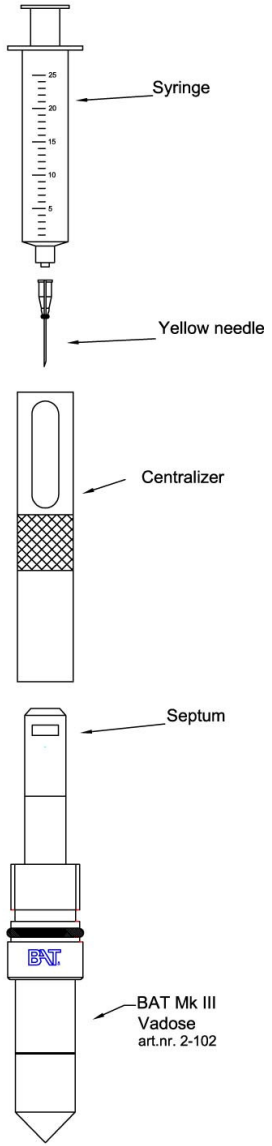
5) Draw a total volume of approx. 10ml through the Filter Tip.

6) IMPORTANT! Finish the water saturation procedure by SLOWLY PULLING OUT the needle, while SIMULTANEOUSLY MAINTAINING THE SUCTION in the syringe.

7) Maintain the Filter Tip submerged in water until installation in soil.



Water saturation of the Filter Tip using a syringe and a blue needle.



Installation of BAT MkIII Vadose Filter Tip

PRE-AUGERING

1) The installation of the BAT Vadose Filter Tip requires pre-augering of a hole to the full installation depth.
The augered hole shall have a diameter sligthly smaller than the diameter (26mm). the BAT Vadose Filter Tip.

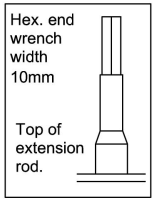
2) The BAT Vadose Filter Tip is supplied together with two augers having the following dimensions:

dia.	22	25	mm
length	300	300	mm

Extension rods (dia. 19mm) to the augers are supplied, having the lengths of 700mm and 1100mm.

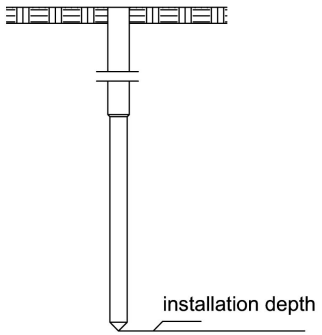
Depending on the soil type, the 22mm auger (soft soil) or the 25mm auger (stiff soil) is used for pre-augering for the BAT Vadose Filter Tip.

The top of the extension rod has a hexagonal fitting with a "wrench-width" of 10 mm. Depending on the the soil type it might be possible to use a strong electric drill for the pre-augering.



Pre-augering.

N.B. Pre-auger successively 0.3m depths in each turn. Measure and note the depth of pre-augering.



INSTALLATION OF BAT FILTER TIP

1) Fill the pre-augered hole with water to reduce the friction along the 1-inch adapter pipe (#3-107)

2) Connect the BAT Vadose Filter Tip to the 1-inch adapter pipe. N.B. Hand tighten only - no tools are needed.

Make sure that the O-ring at the shoulder of the Filter Tip fully seals inside the 1-inch pipe.

Mark the pre-augered depth on the adapter/ extension pipe (distance to be measured from the tip of the Filter Tip).

3) Push the 1-inch pipe gently down to the pre-augered depth.

Two pipe wrenches and the weight of two men would normally be enough for pushing down the extension pipe to the pre-augered depth.

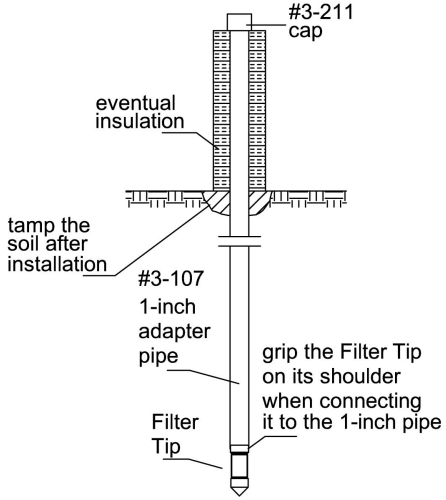
Tamp the soil at the surface around the 1-inch pipe to prevent surface water from . running down around the 1-inch pipe.

4) Connect the BAT IS Sensor to the Filter Tip directly after installation to check the function the Filter Tip.

5) Wait for stabilization of the pore pressure. The stabilization process can be monitored by logging the pore pressure. Depending on the soil type the time needed for stabilization will normally be in the interval of approx. 1 - 24h.

6) When conducting permeability testing it is recommended to fill the adapter/extension pipe with clean water to reduce influence of eventual temperature fluctuations.

7) Seal the pipe with a cap for prevention against vandalism.



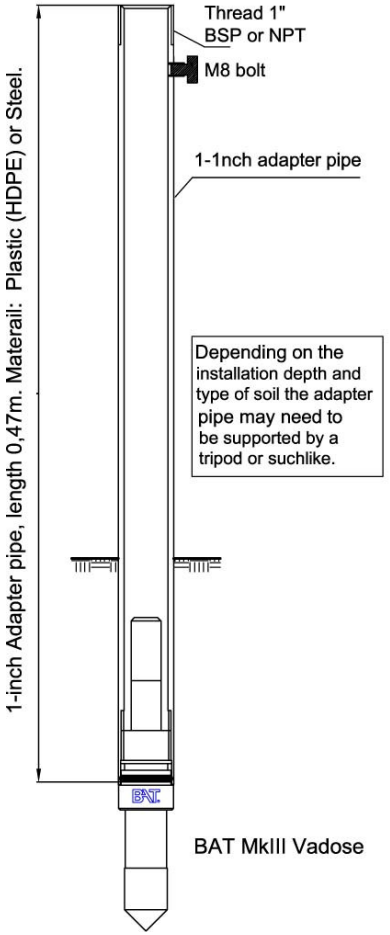
BAT Piezometer & Pore Pressure Measurement

NB. The installation of the BAT Filter Tip disturbs the initial pore pressure situation in the soil.
The dissipation of this disturbance can be monitored by the BAT Piezometer.

BAT MkIII Vadose Filter Tip is installed in a predrilled hole using a 1"-inch adapter pipe of plastic (HDPE) or steel.

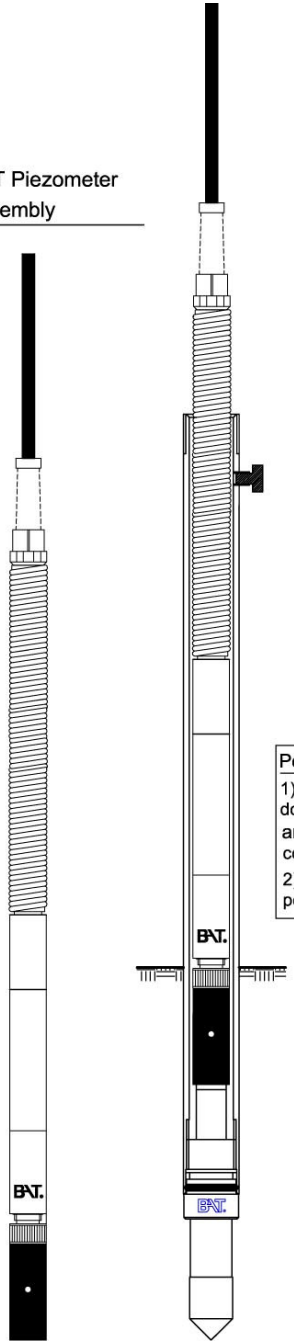
The standard adapter pipe can be used for a maximum installation depth of 0,5 m.

The adapter pipe is furnished with a 1-inch thread (BSP or NPT) which makes possible the use of an extension pipe during installation of the BAT Filter Tip.



Depending on the installation depth and type of soil the adapter pipe may need to be supported by a tripod or suchlike.

BAT Piezometer Assembly



Pore pressure measurement

1) Lower the BAT Piezometer down the adapter pipe and push it carefully in contact with the BAT Filter Tip.

2) Lock the equipment in position using the M8 bolt.

Permeability Testing

A) Temperature stabilization

Before starting a test the BAT Permeamter must reach equilibrium with the temperature in the adapter pipe.

This is done by partly lower the equipment down the adapter pipe as shown in the adjacent figure. The equipment is locked with a M8 bolt. The stabilization process can be monitored by the IS Field Unit. This process normally takes 15 to 20 minutes.

B) Permeability Testing

After reaching temperature equilibrium the permeability test is started.

1) Firstly, prepare the IS Field Unit for logging of "sensor & temperature" data with 1 min interval (see the "Quick Manual").

2) Unlock the M8 Bolt and lower the equipment down the adapter pipe and push it carefully in contact with with the BAT Filter Tip.

3) Lock the equipment in position using the M8 Bolt

4) Activate the IS Field Unit for logging "sensor & temperature" with an interval of 1 min.