MINI DISK INFILTROMETER

METER®

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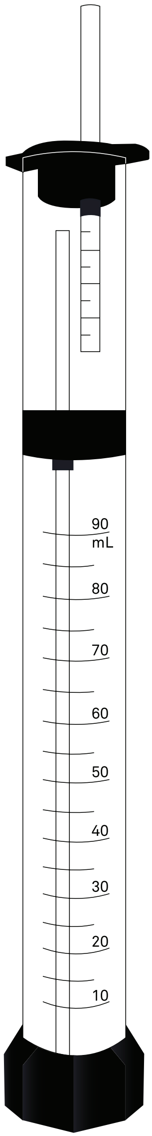
90
mL
80
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60
50
40
30
20
10

1. INTRODUCTION

Thank you for choosing the Mini Disk Infiltrometer from METER Group. The Mini Disk Infiltrometer measures soil hydraulic conductivity and enables measurements of the unsaturated hydraulic conductivity of any soil accurately and affordably.

Prior to use, verify the sensor arrived in good condition.

2. OPERATION

Please read all instructions before operating the Mini Disk Infiltrometer to ensure it performs to its full potential.

PRECAUTIONS

METER sensors are built to the highest standards, but misuse, improper protection, or improper installation may damage the sensor and possibly void the manufacturer's warranty. Before using the Mini Disk Infiltrometer, follow the recommended installation instructions and have the proper protections in place to safeguard sensors from damage.

2.1 FILLING THE INFILTROMETER

To prepare the infiltrometer for measurement, use the following procedure.

1. Remove the upper stopper and suction control tube.
2. Fill the mariotte chamber three-quarters full with water (Figure 1).

   NOTE: Do not use distilled water. Soil water has solutes and clays have salts on the exchange sites. Using distilled water changes the ionic balance and may flocculate or disperse the clay in the soil.

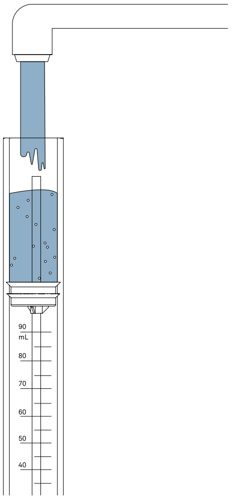

Figure 1 Fill mariotte chamber

3. Replace the upper stopper and suction control tube.
4. Slide the suction control tube all the way down into the mariotte chamber.
5. Invert the infiltrometer.
6. Remove the bottom elastomer with the sintered stainless steel disk (Figure 2).

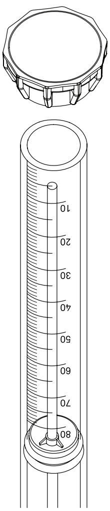

Figure 2 Remove stainless steel disk

7. Fill the reservoir.

   The end of the mariotte tube is carefully set with respect to the porous disk to ensure a zero suction offset while the tube bubbles. If this is changed accidentally, reset the end of the mariotte tube to 6 mm inside from the end of the plastic reservoir tube.

8. Replace the stainless steel disk, ensuring it is firmly in place.

If the infiltrometer is held vertically, no water should leak out. The infiltrometer is now ready to take measurements.

2.2 CHOOSING THE SUCTION RATE

Since different soil types infiltrate water at different rates, the infiltrometer suction rate should be adjusted for different types of soil. For most soils, a suction rate of 2 cm is adequate. However, the suction rate may need to be adjusted for sandy soils (up to 6.0 cm) or more compact soils (0.5 cm). METER recommends only advanced users who are comfortable with the instrument and its theory of operation should adjust the suction rate.

To adjust the suction rate, move the suction control tube up or down so the water level in the mariotte chamber is even with the desired suction rate marked on the side of the suction control tube (Figure 3).

NOTE: If the suction control tube is diffcult to move, apply a small amount of vacuum grease to ease movement.

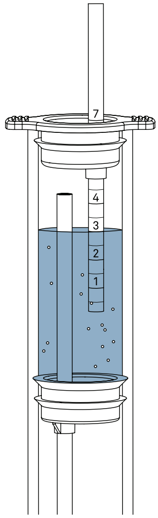

Figure 3 Mariotte chamber and suction tube at 3-cm suction rate

2.3 CHOOSING THE TIMING INTERVAL

The time interval is based on both the chosen suction rate and the soil type being measured. METER recommends choosing a time interval that allows approximately 5 mL of water to be infiltrated per measurement. For example, sand typically require 2 to 5 s between readings, a silt loam every 30 s, and a tight clay 30 to 60 min. Soils with higher flow rate should use shorter measurement intervals.

2.4 MEASURING UNSATURATED HYDRAULIC CONDUCTIVITY

Prior to making a hydraulic conductivity measurement, fill the instrument with water (Section 2.1) and decide the appropriate suction rate (Section 2.2) and time interval (Section 2.3).

1. Choose a smooth spot on the soil surface.

   NOTE: If the surface is not smooth, apply a thin layer of fine silica sand or diatomaceous earth directly underneath the infiltrometer stainless steel disk to ensure good contact between the two surfaces.

   If the device cannot stand up on its own, set up a ring stand and clamp to keep it upright.
2. Record the starting water volume of the reservoir.
3. At time zero, place the infiltrometer on the soil surface.
4. Ensure the infiltrometer makes solid contact with the soil surface.
5. Record the water volume in the reservoir at regular time intervals as the water infiltrates (Figure 4).
6. Repeat step 5 until at least 30 to 40 mL of water has infiltrated the soil.

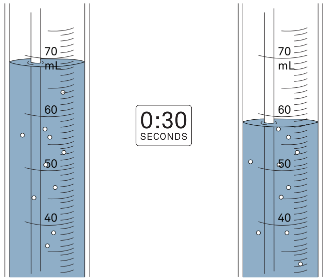

Figure 4 Observing infiltration volume at an example timing interval

2.5 CALCULATING INFILTRATION

METER created a basic Microsoft® Excel® spreadsheet to help calculate the slope of the curve of the cumulative infiltration versus the square root of time.

Follow step 1 through step 5 to use this spreadsheet.

1. Download the file from metergroup.com/minidisk-support.
2. Open the file.

   A sample data set like Table 1 will be in the spreadsheet.

Table 1 Sample infiltrometer data

Time (s)	Square Root of Time (s)	Volume (mL)	Infiltration (cm)
0	0.00	95	0.00
30	5.48	89	0.39
60	7.75	86	0.58
90	9.49	83	0.77
120	10.95	80	0.97
150	12.25	77	1.16
180	13.42	75	1.29
210	14.49	73	1.42
240	15.49	71	1.55
270	16.43	69	1.68
300	17.32	67	1.81

3. Input the recorded time values in the Time column.

   Extend the column lengths as needed.
4. Input the corresponding recorded volume levels into the Volume column.

   The square root of time column and infiltration column will change automatically based on the added data, and the graph will update to reflect the changes.
5. Save the data as a new spreadsheet on the computer.

The calculations used in the Excel macro are explained in Section 3.3.

2.6 MEASURING WATER REPELLENCY

Lichner, et al. (2007) proposed an index of soil water repellency (R) that can be determined from the sorptivities of 95% ethanol and water. The Mini Disk Infiltrometer can be also used for these measurements.

For water repellency index measurements, there will need to be two measurements: one with the reservoir filled with ethanol and one with the reservoir filled with water. The mariotte chamber is filled with fresh or tap water for both measurements.

NOTE: Only the infiltrometers with polycarbonate reservoirs (produced after 2005) should be filled with ethanol.

Filling instructions are described in Section 2.1. Set the suction rate to 2 cm (Section 2.2) and select an appropriate timing interval (Section 2.3). The time interval should be the same for both the ethanol and water infiltrations.

NOTE: Ethanol can damage the numbering on the reservoir so handle carefully to avoid spills.

Then follow steps 1 through 5.

1. Choose a smooth spot on the soil surface.

   NOTE: If the surface is not smooth, apply a thin layer of fine silica sand or diatomaceous earth directly underneath the infiltrometer stainless steel disk to ensure good contact between the two surfaces.

   If the device cannot stand up on its own, set up a ring stand and clamp to keep it upright.
2. Record the starting ethanol volume of the reservoir.
3. At time zero, place the infiltrometer on the soil surface.
4. Ensure the infiltrometer makes solid contact with the soil surface.
5. Record the ethanol volume in the reservoir at regular time intervals as the ethanol infiltrates.
6. Continue recording volume measurements until at least 30 to 40 mL of ethanol has infiltrated the soil.
7. Repeat step 1 through step 6 using water in the infiltrometer, making sure to place the infiltrometer far enough away from the wetted zone of the previous measurement

After the measurements are completed, use the Excel spreadsheet (Section 2.5) to calculate the cumulative infiltration I (in centimeters) and square root of time t (in seconds) based on the gathered data. Use the Excel spreadsheet to estimate the slope (S_e) of the cumulative infiltration versus square root of time relationship:

$$I = S_e \sqrt{t} \qquad \textbf{Equation 1}$$

where S_e (cm × s^{-1} = 2) is the sorptivity of ethanol.

Use the linear approximation to estimate the slope (S_w) of the cumulative infiltration versus the square root of the time relationship.

$$I = S_w \sqrt{t} \qquad \textbf{Equation 2}$$

where S_w (cm × s^{-1} = 2) is the sorptivity of water.

Compute the repellency index (R) from Equation 3:

$$R = 1.95\ S_e S_w \qquad \textbf{Equation 3}$$

3. SYSTEM

This section describes the Mini Disk Infiltrometer.

3.1 SPECIFICATIONS

PHYSICAL SPECIFICATIONS

Total Dimensions	
Height	32.7 cm (12.9 in)
Diameter	3.1 cm (1.2 in)
Stainless Steel Disk	
Height	3.0 mm (1.2 in)
Diameter	4.5 cm (1.8 in)
Mariotte Chamber	
Volume	40.0 mL
Reservoir Chamber	
Volume	95.0 mL
Suction Range	
Minimum	0.5 cm (0.2 in)
Maximum	7.0 cm (2.8 in)

COMPLIANCE

Manufactured under ISO 9001:2015
EM ISO/IEC 17050:2010 (CE Mark)

3.2 COMPONENTS

The Mini Disk infiltrometer is ideal for field measurements due to its compact size and the small amount of water needed to operate it. It is also practical for lab and classroom use to demonstrate basic concepts of unsaturated soil hydraulic conductivity.

The upper and lower chambers of the infiltrometer are both filled with water. The upper chamber (or mariotte chamber) controls the suction. The lower chamber (or reservoir) contains a volume of water that infiltrates into the soil at a rate determined by the suction control tube in the mariotte chamber. The reservoir is labeled like a graduated cylinder with volume shown in milliliters. The bottom of the infiltrometer has a porous sintered stainless steel disk that does not allow water to leak when in open air. The small diameter of the disk allows for undisturbed measurements on relatively level soil surfaces. Once the infiltrometer is on soil, water begins to leave the lower chamber and infiltrate into the soil at a rate determined by the hydraulic properties of the soil. These measurements are used to calculate hydraulic conductivity.

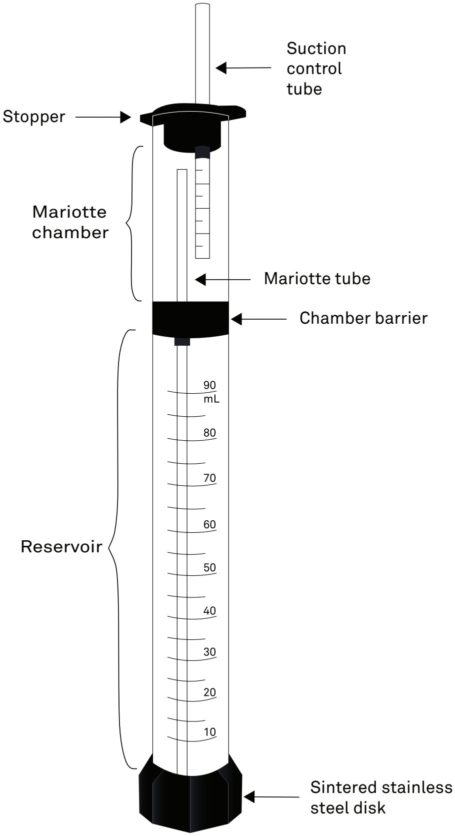

Figure 5 Mini Disk Infiltrometer diagram

3.3 THEORY

The knowledge of hydraulic conductivity benefits scientists, land managers, and growers, by indicating how quickly water infiltrates when applied to a given field or soil type. Infiltration is also relevant in contaminant transport, ground water recharge, and ecosystem sustainability.

The hydraulic conductivity of the soil is the rate at which water can move through the soil under certain conditions and hydraulic gradients. Water movement through soil typically happens under saturated and unsaturated conditions.

Saturated conductivity occurs when all pores, including the large ones (such as cracks or wormholes), are filled. Macropore flow, however, is extremely variable from place to place, and therefore diffcult to quantify. Infiltrating water under a tension prevents the filling of the macropores and gives a hydraulic conductivity characteristic of the soil matrix and is less spatially variable.

Unsaturated soil hydraulic conductivity is a function of water potential and water content of the soil. The decrease in conductivity as the soil dries is due primarily to the movement of air into the soil to replace the water. As the air moves in, the pathways for water flow between soil particles become smaller and more tortuous and flow becomes more diffcult.

A number of methods are available for determining soil hydraulic conductivity from observed data. The method proposed by Zhang (1997) is quite simple and works well for measurements of infiltration into dry soil. The method requires measuring cumulative infiltration versus time and fitting the results with the function:

$$I = C_1\sqrt{t} + C_2 t$$ **Equation 4**

where C_1(m × s^{-1}) and C_2(m × s^{-1}) are parameters. C_1 is related to soil sorptivity, and C_2 is the hydraulic conductivity. The hydraulic conductivity for the soil (K) is then computed from

$$K = \frac{C_1}{A}$$ **Equation 5**

where C_1 is the slope of the curve of the cumulative infiltration versus the square root of time and A is a value relating the van Genuchten parameters for a given soil type to the suction rate and radius of the infiltrometer disk. The van Genuchten parameters for the 12 texture classes were obtained from Carsel and Parrish (1988). Compute A from Equation 6 and Equation 7.

$$A = \frac{11.65(n^{0.1}-1)\exp[2.92(n-1.9)\alpha h_0]}{(\alpha r_0)^{0.91}} \qquad n \geq 1.9$$ **Equation 6**

$$A = \frac{11.65(n^{0.1}-1)\exp[7.5(n-1.9)\alpha h_0]}{(\alpha r_0)^{0.91}} \qquad n < 1.9$$ **Equation 7**

n and α are the van Genuchten parameters for the soil, r_o is the disk radius, and h_o is the suction at the disk surface. The Mini Disk Infiltrometer infiltrates water at a suction of −0.5 to −6 cm and has a radius of 2.25 cm. Values of A computed for the Mini Disk Infiltrometer are in Table 2.

Table 2 Van Genuchten parameters for soil texture classes and A values for the 2.25-cm disk radius and suction values from 0.5 to 6 cm

Soil Texture	α	n/h_o	A						
			−0.5	−1	−2	−3	−4	−5	−6
Sand	0.145	2.68	2.84	2.40	1.73	1.24	0.89	0.64	0.46
Loamy Sand	0.124	2.28	2.99	2.79	2.43	2.12	1.84	1.61	1.40
Sandy Loam	0.075	1.89	3.88	3.89	3.91	3.93	3.95	3.98	4.00
Loam	0.036	1.56	5.46	5.72	6.27	6.87	7.53	8.25	9.05
Silt	0.016	1.37	7.92	8.18	8.71	9.29	9.90	10.55	11.24
Silt Loam	0.020	1.41	7.10	7.37	7.93	8.53	9.19	9.89	10.64
Sandy Clay Loam	0.059	1.48	3.21	3.52	3.24	5.11	6.15	7.41	8.92
Clay Loam	0.019	1.31	5.86	6.11	6.64	7.23	7.86	8.55	9.30
Silty Clay Loam	0.010	1.23	7.89	8.09	8.51	8.95	9.41	9.90	10.41
Sandy Clay	0.027	1.23	3.34	3.57	4.09	4.68	5.36	6.14	7.04
Silty Clay	0.005	1.09	6.08	6.17	6.36	6.56	6.76	6.97	7.18
Clay	0.008	1.09	4.00	4.10	4.30	4.51	4.74	4.98	5.22

METER developed the Excel spreadsheet table to interpret this data using a quadratic equation (Section 2.5). After inputting observed data, columns 2 and 4 from the table are used to produce an XY (scatter) plot. This is used to calculate C_1, which is the slope of this line, denoted as y. Figure 6 is an example.

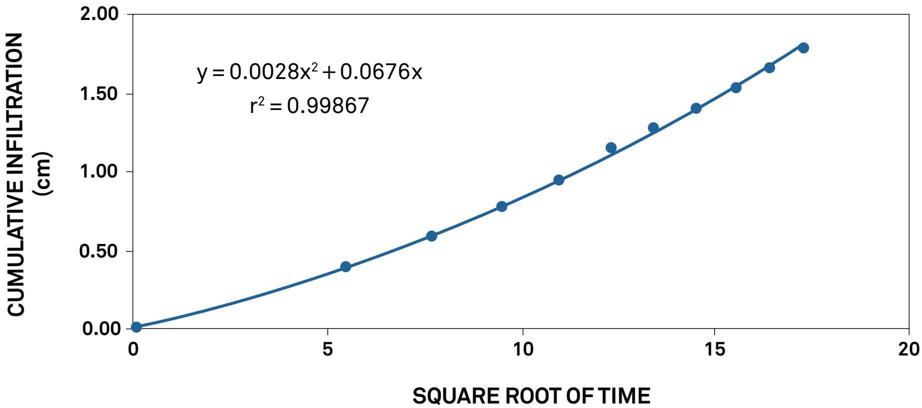

Figure 6 Quadratic equation graph

In this example, the value of C_1 is 0.0028 cm × s^{-1}. The soil is a silt loam, so from Table 2, for 2-cm suction, A = 7.93. The hydraulic conductivity is therefore

$$K = \frac{0.0028\ \mathrm{cm \cdot\ s^{-1}}}{7.93} = 3.53 \times 10^{-4}\,\mathrm{cm \cdot\ s^{-1}}$$ **Equation 8**

NOTE: A negative C_1 value (negative hydraulic conductivity) is a physical impossibility. Negative values indicate a problem with the data set, such as shallow flow restricting layers or jiggling the infiltrometer during the measurement.

A much more extensive discussion of tension infiltrometer measurement and analysis is given in Dane and Topp (2002).

If measuring hydraulic conductivity on a soil with an n < 1.35, changes to the Zhang (1997) equation proposed by Dohnal et al. (2010) have improved estimates of K as compared to the previous equation.

$$K = \frac{C_1(\alpha r_0)^{0.6}}{11.65(n^{0.82} - 1)\exp\left[34.65(n - 1.19)\alpha h_0\right]}$$ **Equation 9**

4. SERVICE

This section contains maintenance instructions, troubleshooting guidelines, customer support contact information, and terms and conditions.

4.1 MAINTENANCE

All infiltrometer parts can be cleaned using mild soap and water. The stainless steel disk can be cleaned with a brush or even run in a dishwasher since it will not rust.

If the suction control tube is diffcult to move, apply a small amount of vacuum grease to allow it to move more freely.

4.2 TROUBLESHOOTING

Table 3 lists common problems and their solutions. If the problem is not listed or these solutions do not solve the issue, contact Customer Support.

Table 3 Troubleshooting the Mini Disk Infiltrometer

Problem	Possible Solutions
Negative C_1 value	There was a problem with the data set, such as shallow flow or moving the infiltrometer during measurement. Rerun the test.

4.3 CUSTOMER SUPPORT

NORTH AMERICA

Customer service representatives are available for questions, problems, or feedback Monday through Friday, 7:00 am to 5:00 pm Pacific time.

Email: support.environment@metergroup.com
sales.environment@metergroup.com

Phone: +1.509.332.5600

Fax: +1.509.332.5158

Website: metergroup.com

EUROPE

Customer service representatives are available for questions, problems, or feedback Monday through Friday, 8:00 to 17:00 Central European time.

Email: support.europe@metergroup.com
sales.europe@metergroup.com

Phone: +49 89 12 66 52 0

Fax: +49 89 12 66 52 20

Website: metergroup.de

If contacting METER by email, please include the following information:

Name	Email address
Address	Instrument serial number
Phone	Description of the problem

NOTE: For products purchased through a distributor, please contact the distributor directly for assistance.

4.4 TERMS AND CONDITIONS

By using METER instruments and documentation, you agree to abide by the METER Group, Inc. USA Terms and Conditions. Please refer to metergroup.com/terms-conditions for details.

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METER Group, Inc. USA
2365 NE Hopkins Court Pullman, WA 99163
T: +1.509.332.2756 **F**: +1.509.332.5158
E: info@metergroup.com **W**: metergroup.com

METER Group AG
Mettlacher Straße 8, 81379 München
T: +49 89 1266520 **F**: +49 89 12665220
E: info.europe@metergroup.com **W**: metergroup.de