Mini Disk Infiltrometer

Decagon Devices, Inc.

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1 Introduction

Welcome to the Mini Disk Infiltrometer for measuring soil hydraulic conductivity. The Infiltrometer enables you to measure the unsaturated hydraulic conductivity of any soil accurately and affordably. This manual includes instructions for setting up your instrument, verifying its calibration, preparing samples, and care or maintenance. Please read these instructions before operating the Mini Disk Infiltrometer to ensure that the instrument performs to its full potential.

1.1 Customer Support

If you ever need assistance with your instrument or have any questions or feedback, there are several ways to contact us. Decagon has Customer Service Representatives available to speak with you Monday through Friday, between 8 am and 5 pm Pacific time.

Note: If you purchased your instrument through a distributor, please contact them for assistance.

Email:
support@decagon.com or **sales@decagon.com**

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If contacting us by email or fax, please include as part of your message your instrument serial number, your name, address, phone number, fax number, and a description of your problem or question.

1.2 Warranty

The Mini Disk Infiltrometer has a one year warranty on parts and labor. Your warranty is automatically validated upon receipt of the instrument.

1.3 Seller's Liability

Seller warrants new equipment of its own manufacture against defective workmanship and materials for a period of one year from the date of receipt of equipment.

Note: We do not consider the results of ordinary wear and tear, neglect, misuse, accident and excessive deterioration due to corrosion from any cause as defects.

The Seller's liability for defective parts shall in no event exceed the furnishing of replacement parts Freight On Board the factory where originally manufactured. Material and equipment covered hereby which is not manufactured by Seller shall be covered only by the warranty of its manufacturer. Seller shall not be liable to Buyer for loss, damage or injuries to persons (including death), or to property or things of whatsoever kind (including, but not without limitation, loss of anticipated profits), occasioned by or arising out of the installation, operation, use, misuse, nonuse, repair, or replacement of said material and equipment, or out of the use of any method or process for which the same may be employed. The use of this equipment constitutes the buyer's acceptance of the terms set forth in this warranty. There are no understandings, representations, or warranties of any kind, express, implied, statutory or otherwise (including, but without limitation, the implied warranties of merchantability and fitness for a particular purpose), not expressly set forth herein.

2 About the Infiltrometer

The Mini Disk Infiltrometer is ideal for field measurements; due to its compact size, the water needed to operate it can easily be carried in a personal water bottle. It is also practical for lab and classroom use, in demonstrating basic concepts of unsaturated soil hydraulic conductivity.

2.1 Specifications

Total Length: 32.7 cm

Diameter of tube: 3.1 cm

Sintered stainless steel disc: 4.5 cm diameter, 3 mm thick

Length of suction regulation tube: 10.2 cm

Suction range: 0.5 to 7 cm of suction

Length of water reservoir: 21.2 cm

Length of mariotte tube: 28 cm

Volume of water required to operate: 135 ml

2.2 How it Works

The upper and lower chambers of the Infiltrometer are both filled with water. The top chamber (or bubble chamber) controls the suction. The lower chamber contains a volume of water that infiltrates into the soil at a rate determined by the suction selected in the bubble chamber. The lower chamber is labeled like a graduated cylinder with volume shown in mL. The bottom of the Infiltrometer has a porous sintered stainless steel disk does not allow water to leak in open air. The small diameter of the disk allows for undisturbed measurements on relatively level soil surfaces.

Once you place the Infiltrometer on a soil, water begins to leave the lower chamber and infiltrate into the soil at a rate determined by the hydraulic properties of the soil. As the water level drops, you record the volume at specific time intervals (like every 30 seconds for a silt loam soil). You can then plot this data using the Microsoft excel spreadsheet, available at www.decagon.com/macro, to calculate the hydraulic conductivity (see Section 5.1 for more information about using the spreadsheet macro).

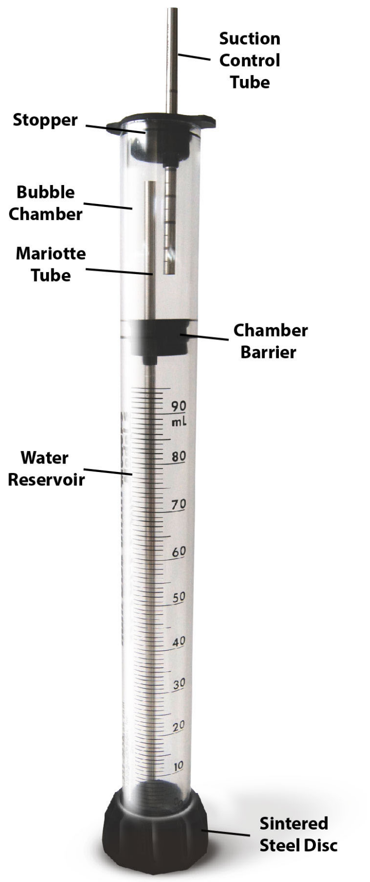

Figure 1: Infiltrometer Diagram

3 Theory

Hydraulic Conductivity

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.

Because the Mini Disk Infiltrometer is a tension Infiltrometer, it measures the unsaturated hydraulic conductivity of the medium it is placed on at different applied tensions. Flow through an unsaturated soil is more complicated than flow through continuously saturated pore spaces. Macropores generally fill with air, leaving only the finer pores to accommodate water movement. Therefore, the hydraulic conductivity of the soil is strongly dependent on the detailed pore geometry, water content, and differences in matric potential. (Rose, 1966; Brady and Weil, 1999)

The Mini Disk Infiltrometer measures the hydraulic conductivity of the medium it is placed upon. Because the Infiltrometer has an adjustable suction (0.5 to 7 cm) you can get additional information about the soil by eliminating macropores with an air entry value smaller than the suction of the Infiltrometer. This is done by controlling the infiltration with a small negative pressure or suction. When the water is under tension or suction, it does not enter macropores such as cracks or wormholes, but goes further into and through the soil as determined by the hydraulic forces in the soil.

Saturated conductivity occurs when all the pores, including the large ones (such as cracks or wormholes), are filled. Macropore flow, however, is extremely variable from place to place, and therefore difficult 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 becomes smaller and more tortuous, and flow becomes more difficult.

4 Preparation

To prepare the Infiltrometer for measurement, do the following

1. Fill the bubble chamber three quarters full by running water down the suction control tube or removing the upper stopper.(Figure 2)

   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

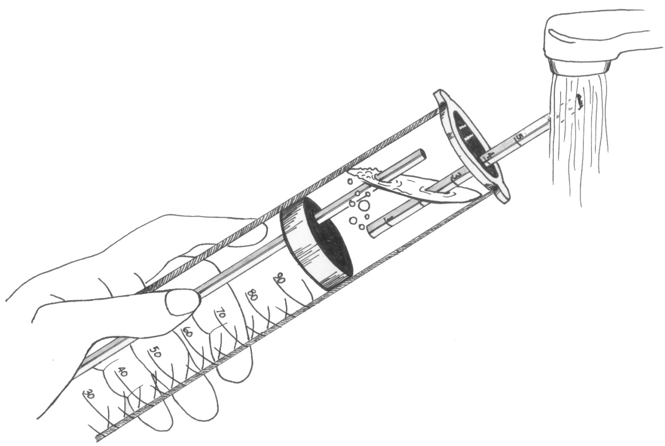

Figure 2: Filling Bubble Chamber

2. Once the upper chamber is full, slide the suction control tube all the way down, invert the Infiltrometer, remove the bottom elastomer with the porous disk, and fill the water reservoir.

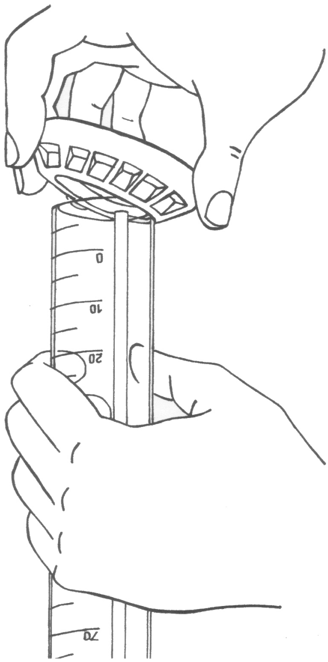

Figure 3: Removing Bottom Elastomer

3. We carefully set the position of the end of the mariotte tube with respect to the porous disk to ensure a zero suction offset while the tube bubbles. If this dimension is changed accidentally, the end of the mariotte tube should be reset to 6 mm from the end of the plastic water reservoir tube.

4. Replace the bottom elastomer, making sure the porous disk is firmly in place.

5. If the Infiltrometer is held vertically, no water should leak out.

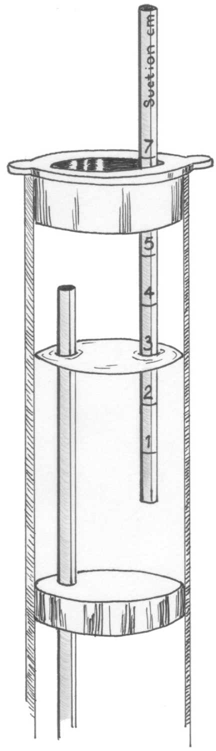

Figure 4: Upper Chamber and Suction Tube

4.1 Choosing the Suction Rate

Since different soil types infiltrate water at different rates, measuring the change of volume vs. time can often be difficult, particularly in a sandy soil where the water infiltrates rapidly. Therefore, you can adjust the suction rate to better accommodate measuring infiltration for the type of soil you are measuring. (See Figure 5) For most soils, a suction rate of 2 cm should be adequate. In sandy soils where infiltration occurs very quickly, an adjustment to 6 cm may be helpful, and we recommend a suction rate of 0.5 for more compact soil with slower infiltration.

However, we generally recommend that adjusting the suction to rates

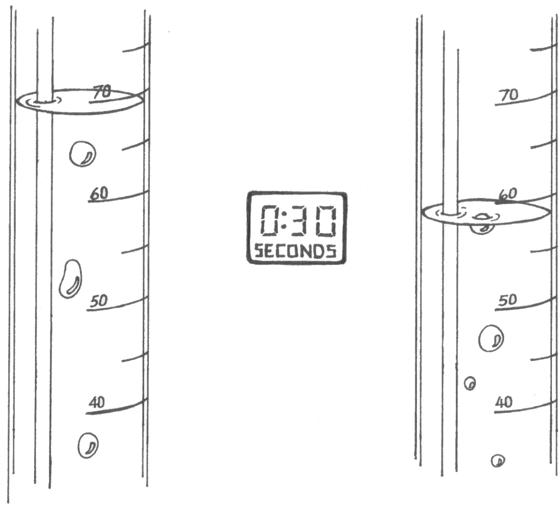

Figure 5: Suction Rate

other than 2 cm should be reserved for more advanced users who are comfortable with the instrument and theory of operation.

To adjust the suction rate, move the suction tube up or down so the water level is even with the desired suction rate marked on the side of the tube. If the suction tube is difficult to move, apply a small amount of vacuum grease on the tube to ease movement.

4.2 Placement

The Infiltrometer should be applied to a smooth spot on the soil surface. If the surface is not smooth, a thin layer of fine silica sand or diatomaceous earth can be applied to the area directly underneath the Infiltrometer stainless steel disk. This ensures good contact between the soil and the Infiltrometer. When possible, we also recommend using a ring stand and clamp to hold the Infiltrometer in place.

5 Collecting Data

To make the hydraulic conductivity measurement, make sure you have first prepared the instrument as described in Section 4. Then do the following:

1. Record the starting water volume.
2. At time zero, place the Infiltrometer on the surface, assuring that is makes solid contact with the soil surface.
3. Record volume at regular time intervals as the water infiltrates. The time interval you choose is based on both the suction rate you select and the soil type being measured. For example, sand typically require two to five seconds between readings, a silt loam every 30 seconds, and a tight clay 30 to 60 minutes. A typical data set looks like the first and third columns of Table 1.
4. For the calculation of hydraulic conductivity to be accurate at least 15 to 20 mL of water needs to be infiltrated into the soil during each measurement.

Table 1: Sample Infiltrometer Data

Time (s)	sqrt (t)	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

5.1 Use the Spreadsheet Macro

Decagon has created a basic Microsoft Excel$_r$ spreadsheet to help calculate the slope of the curve of the cumulative infiltration versus the square root of time based on the data gathered in the above steps. You can download the spreadsheet at http:/www.decagon.com/macro. Follow steps 1 through 3 to use this spreadsheet.

1. Open the file to see a table similar to Table 1.
2. Input the volume levels you recorded into the corresponding volume column, and correlated with the time column on the left. You may need to extend the columns depending on how much data you have recorded. The square root of time column and infiltration column changes automatically based on your data, and the graph on the right of the table updates to reflect the changes.
3. Save the data as a new spreadsheet on your hard drive.

5.2 Calculate Infiltration

A number of methods are available for determining soil hydraulic conductivity from these 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.

$$I = C_1 t + C_2 \sqrt{t} \tag{1}$$

Where $C_1(\overset{\alpha}{m}\ \mathrm{s}^{-}1)$ and $\mathrm{C}_2(\mathrm{m\ s}^{\frac{-1}{2}})$ are parameters. C_1 is related to hydraulic conductivity, and C_2 is the soil sorptivity. The hydraulic conductivity for the soil (k) is then computed form.

$$k = \frac{C_1}{A} \tag{2}$$

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. Compute A from equations. 3 and 4.

$$A = \frac{11.65(n^{0.1} - 1)\exp[2.92(n - 1.9)\alpha h_o]}{(\alpha r_o)^{0.91}} \quad (3)$$

$$A = \frac{11.65(n^{0.1} - 1)\exp[7.5(n - 1.9)\alpha h_o]}{(\alpha r_o)^{0.91}} \quad (4)$$

where n and a 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. The van Genuchten parameters for the 12 texture classes were obtained from Carsel and Parrish (1988). Values of A computed for the Mini Disk Infiltrometer are given in Table 2.

Table 2: Van Genuchten parameters for 12 soil texture classes and A values for a 2.25 cm disk radius and suction values from 0.5 to 6 cm.

			h_o						
			-0.5	-1	-2	-3	-4	-5	-6
Texture			A						
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	4.24	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

A quadratic equation is included in the Excel spreadsheet. Columns 2 and 4 from the table are used to produce an XY (scatter) plot to the right of the table. This is used to calculate C_1, which is the slope of this line, denoted as "y" The following graph gives an example.

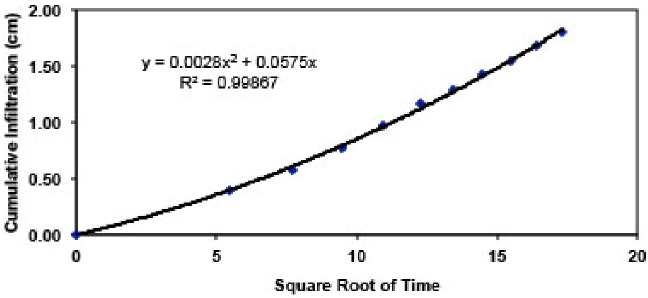

Figure 6: Quadratic Equation Graph

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 (at 2 cm suction) is therefore.

$$k = \frac{0.0028 \text{ cm } s^{-1}}{7.93} = 3.53 \times \frac{10^{-4} \text{ cm}}{s} \tag{5}$$

Occasionally Infiltrometer data gives a negative C_1 value. Negative hydraulic conductivity is a physical impossibility, so such valves indicate a problem with the data set. Usually such data comes from 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) p. 888-896.

If you are measuring hydraulic conductivity on a soil with a 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.

$$K = \frac{C_1(\alpha r_0)^{0.6}}{11.65(n^{0.82} - 1)\exp[34.65(n - 1.19)\alpha h_o]} \tag{6}$$

6 Water Repellency Index

Lichner, et al. (2007) proposed an index of soil water repellency, R, can be determined from the sorptivities of 95% ethanol and water. The Mini Disk Infiltrometer can be used for these measurements. To do this, make sure you have first prepared the instrument as described in Section 4. Please note that the water reservoir has to be filled with ethanol to make the ethanol sorptivity measurements, and with fresh or tap water to make the water sorptivity measurements. The bubble chamber is filled with fresh or tap water in both cases, and the suction rate of 2 cm is selected (Section 4). Then follow steps 1 through 5.

1. Record the starting ethanol volume.
2. At time zero, place the Infiltrometer on the surface, ensuring that it makes solid contact with the soil surface.
3. Record volume at regular time intervals as the ethanol infiltrates. The time interval necessary for different soil types is presented in Section 5. Use the Microsoft Excel spreadsheet (www.decagon.com/macro) to calculate the cumulative infiltration I (cm) and square root of time t (s) based on the data gathered in the above steps. Use the Excel spreadsheet to estimate the slope (S_e) of the cumulative infiltration versus square root of time relationship:

$$I = S_e\sqrt{t} \tag{7}$$

   where S_e (cm $\mathrm{s}^{-1/2}$) is the sorptivity of ethanol.

4. Repeat steps 13 for water instead of ethanol, making sure to place the Infiltrometer far enough away from the wetted zone of the previous measurement. The time intervals used for the water infiltration should be the same as for the ethanol infiltration. Again, use the linear approximation to estimate the slope (S_w) of the cumulative infiltration versus the square root of the time relationship.

$$I = S_w\sqrt{t} \tag{8}$$

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

5. The repellency index R is computed from R=1.95 $\frac{S_e}{S_w}$. It should be mentioned that ethanol can damage the numbering on the water/ethanol reservoir so care must be taken to avoid spillage.

Note: Only the Infiltrometers with polycarbonate water reservoirs (produced after....2005) should be filled with ethanol.

7 Maintenance

7.1 Cleaning

All of the 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 is stainless steel, it does not rust, cleans easily, and should not snag or tear on rags when washing.

7.2 Suction Tube

If the suction regulation tube is difficult to move, use a small amount of vacuum grease to allow it to move more freely.

8 References and Reading

References

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Additional Reading

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