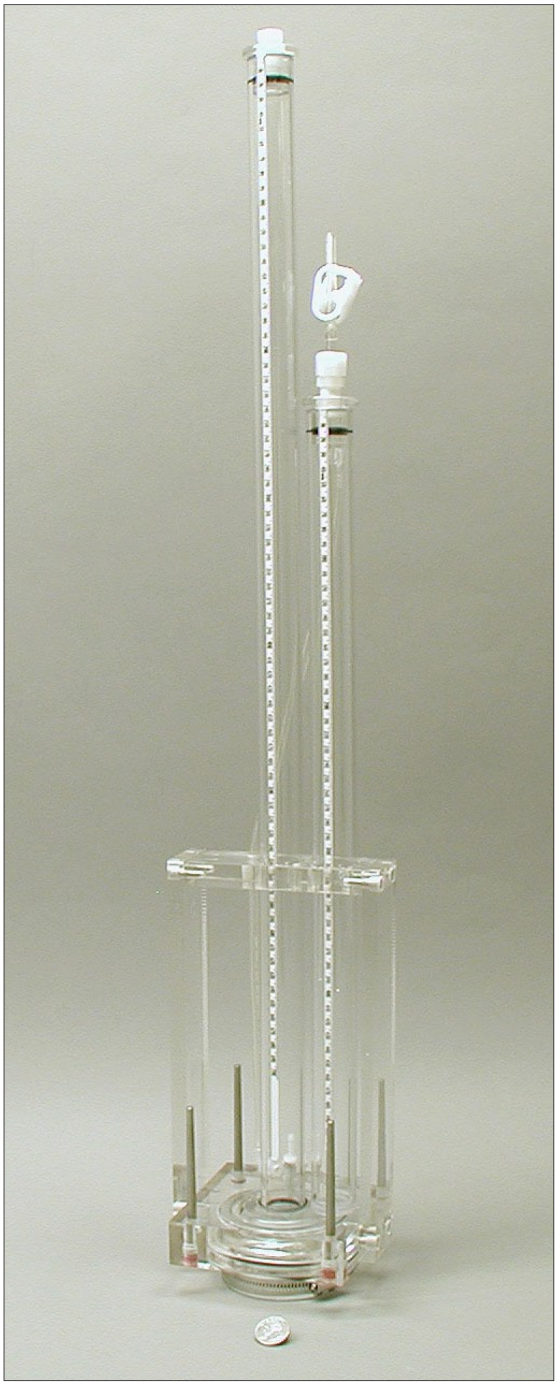
2826D08 OPERATING INSTRUCTIONS

2826D08 Tension Infiltrometer - 8cm base April 2010



The 2826D08 tension infiltrometer is designed to measure the unsaturated flow of water into soil rapidly, accurately, and easily. While many features of the infiltrometer are designed for field use, it can also be used on soil cores in the laboratory.

Fig. 1 2826D08 Tension Infiltrometer 8cm base

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UNPACKING

Please verify that your shipment is complete. The 2826D08 comes fully assembled with a ____oz bag of silica sand.

Remove all packing material carefully. Do not bump or drop Tension Infiltrometer. Although it is constructed for durable field use it could break and will need to be replaced. Take care to protect the nylon mesh that is constructed with the base plate for it can tear and affect proper use of the product. Do not allow the nylon mesh to come in contact with grease or any other similar material that could clog the pores of the mesh.

If this is the first time you have ever ordered the 2826D08 Tension Infiltrometer (TI) from Soilmoisture, it is highly recommended that you order the following items:

- MZL026 Tygon Tubing per post
- 2826D08-002 Marker Ring
- Vacuum hand pump (2005G2)

NOTE: The 2826D08K1 includes a carrying case, 2005G2 Vacuum Hand Pump, 6 Feet tygon tubing, 10oz. of silica sand, 8cm marker ring, and a collapsible 2.5 gallon field container (Model 2038V3). Please see page 15 for a list of Soilmoisture product numbers.

If any of your order is damaged, call the carrier immediately to report it. Keep the shipping container and all evidence to support your claim.

WARRANTY & LIABILITY

Soilmoisture Equipment Corp. (SEC) warrants all products manufactured by SEC to be free from defects in materials and workmanship under normal use and service for twelve (12) months from the date of invoice provided the section below has been met.

Soilmoisture Equipment Corp. (SEC) is not liable for any damages, actual or inferred, caused by misuse or improper handling of its products. SEC products are designed to be used solely as described in these product operating instructions by a prudent individual under normal operating conditions in applications intended for use by this product.

INITIAL ASSEMBLY

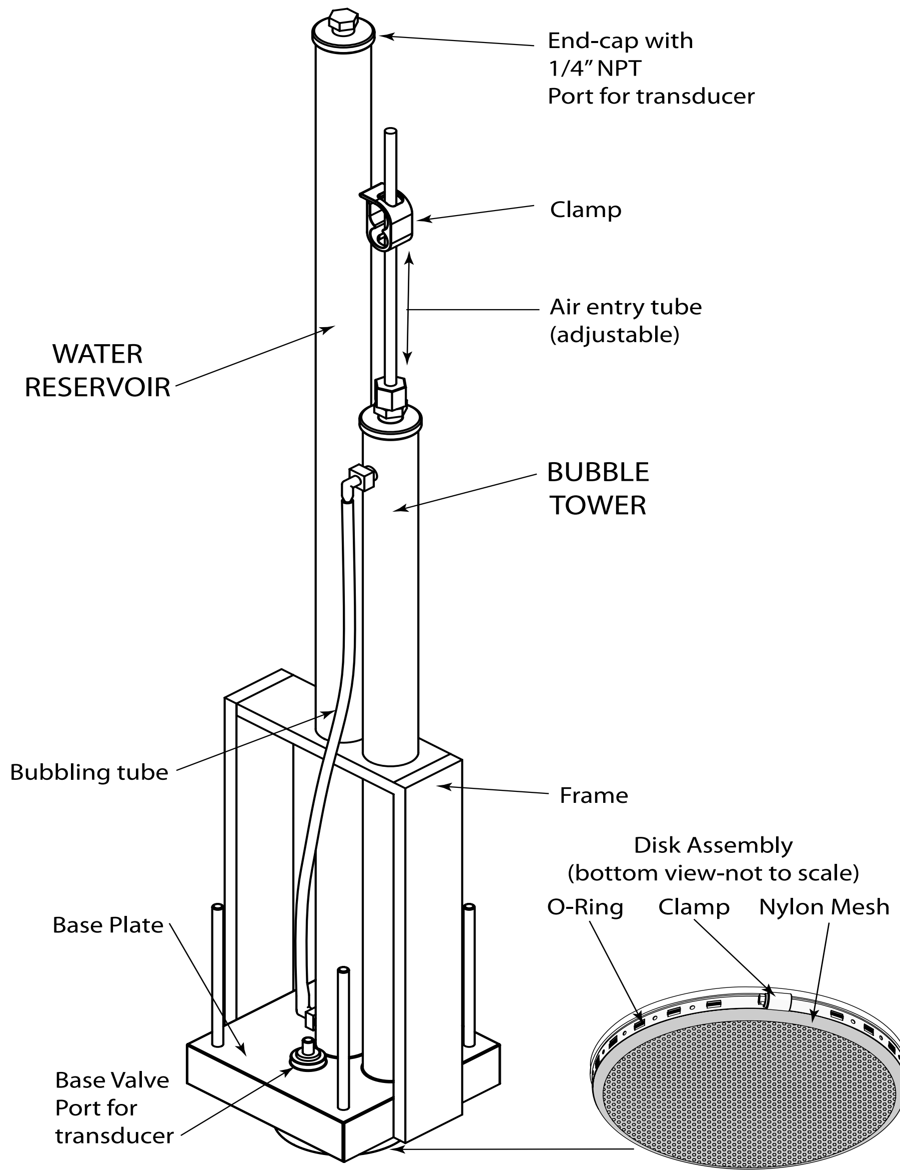
The 2826D08 comes fully assembled, however, the following instructions discuss the assemblage of the 2826D08 Tension Infiltrometer.

To assemble the infiltrometer, apply a small amount of vacuum grease to the o-ring in the base support *(see fig.2)*. Slip the water reservoir tube (longer tube) through the center hole in the top crosspiece of the frame and insert it into the hole in the base support.

Next, slip the bubble tower through the side hole of the frame crosspiece and allow it to come to rest on the base. Now lock both tubes into place by lightly tightening the set screws in the frame crosspiece.

Connect the bubble tower to the water reservoir by connecting the bubbling tube to the elbow tubing connectors near the top of the bubble tower and the bottom of the water reservoir.

AQUAINT YOURSELF WITH THE PARTS



SPECIFICATIONS

Diameter Disc
8 cm

Inside Diameter Water Reservoir
2.54 cm

Inside Diameter Bubbling Tower
2.54 cm

Length Water Reservoir
81 cm

Bubbling Pressure Membrane
20-25 cm

Carrying Case Dimensions
(optional)
230mmx 330mm x 970mm

Made of Polycarbonate and acrylic materials

Replaceable nylon mesh screen membrane

(Figure 2) - 2826D08
Tension Infiltrometer Parts

The major components of the Model 2826D8 Tension Infiltrometer *(fig.2)*:

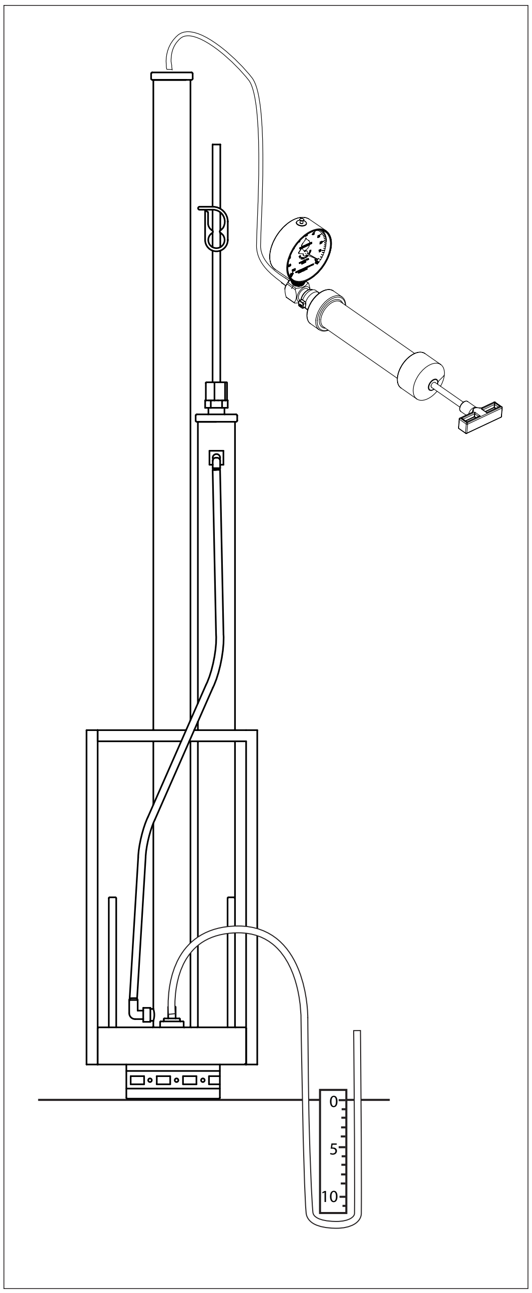
1) The bubble tower (the shorter 1"ID tube) controls tension at the soil surface
2) The water reservoir empties as water flows into the soil
3) The baseplate is assembled with a nylon mesh screen that establishes hydraulic continuity with the soil.
4) The bubbling tube connects the bubble tower and the water reservoir.
5) The air-entry tube is adjustable to provide variable tension to the water reservoir column.
6) The end-cap and base valve supply ports for use with a vacuum pump and/or tranducers.

THEORY OF OPERATION

Tension infiltrometers are designed to measure the unsaturated hydraulic properties of soils. Water is allowed to infiltrate soil at a rate, which is slower than when water is ponded on the soil surface. This is accomplished by maintaining a small negative pressure on the water as it moves out of the infiltrometer baseplate into the soil.

By maintaining a small negative pressure (or tension) on the soil as water is infiltrating, water will not enter the large cracks or wormholes, but will infiltrate through the soil matrix. As a result, the measurements obtained with a tension infiltrometer are more representative of the soil as a whole. The combined data are useful for efficiently characterizing field soil hydraulic properties.

RECOMMENDATIONS PRIOR TO USE



IT IS RECOMMENDED TO PERFORM THE CALIBRATION IN THE LABORATORY BEFORE FIELD USE.

The process of calibrating the Infiltrometer is best done on a bench/ table top surface using a manometer.

- A level base will ensure balance of water levels.
- The bench top is the zero reference which represents the soil surface.

WATER MANOMETER

It is good practice to verify the value of ("X") in the laboratory (typically the value is 4 cm). For this purpose a water manometer is connected to the valve in the base plate.

- The water manometer is simply a water filled tygon tube connected to the valve in the base of the infiltrometer and looped over the bench top adjacent to a meter stick *(Fig.3)*.
- The vertical distance’ between the bench top and the water level in the right arm of the manometer in Fig. 3, represents the tension that will be applied to the soil surface.
- Force all air bubbles out of the manometer tubing to avoid calibration errors.

During calibration, maintain a small vacuum on the water reservoir tube, such that air bubbles are seen rising in the tube. Tension is read directly off the meter stick taped to the bench top edge.

By turning the set screw on top of the bubble tower counter clock wise, the air entry tube is loosened, and can be moved up and down. The air-entry tube slides up or down easiest when wet.

(Figure 3) - Verifying the value of "X" with the use of a manometer.

HOW TO FILL AND CALIBRATE THE UNIT PRIOR TO IN FIELD USE

Following are the step by step instructions on how to fill and calibrate the infiltrometer.

1. Place the infiltrometer in a shallow pan filled with water. There should be enough water to submerge the base plate in order to initially wet the pores of the nylon mesh that is attached to the base plate. Gently bump the base plate on the bottom of the water container until the air bubbles are forced out of the porous base. (Residual air filled pores may result in air leaks through the porous base later.)

2. Close the water reservoir. Also, close the base, and the valve on the base.

3. Remove the end-cap on the bubble tower (twist the cap to make it easier to slide it up). Typically the air entry tube will remain attached to the end cap. Fill the bubble tower till 7 cm below the top, so when the air entry tube is inserted while the end cap is replaced, the water level will be at about 70 mm on the bubble tower scale.
   Close the pinch clamp on the air entry tube.
   Replace the end-cap.

4. Attach one end of a section of tygon tubing to a hand held vacuum pump, and attach the other end to the tubing connector on top of the water reservoir.

5. Start pumping with the hand held pump until water rises to about 100 mm on the scale of the water reservoir column.

6. Take the infiltrometer out of the water and place it on some plastic (to keep the base clean) on top of the bench.

7. Attach tygon tubing to the base valve and bend it under the bench in front to a meter stick to make a manometer (see Figure 3).

8. Apply a small suction on the manometer tubing so it fills completely with water. Then attach it to the meter stick. Make sure there is no air in the base valve, or in the tygon tubing near the base valve.

9. Open clamp of the air entry tube. Apply vacuum with the hand pump until a stream of bubbles appears in the water reservoir column. It is best to use quick, relatively short pump strokes.

10. Set the air entry tube with its outlet at 10 cm below the water level in the bubble tower. Read the water level in the manometer while pumping short quick pump strokes. The difference between the water level in the manometer tube, and the vertical distance of the air entry tube below the water surface is the correction factor X.

11. The correction factor X should be applied to all tension setting. For example, if X=4, and a tension of 20 cm is desired at the membrane, then slide the tube in the bubble tower up or down, untill its outlet is at 24 cm below the water level in the bubble tower.

Now that the unit has been calibrated it is ready for field or column installation.

HELPFUL HINTS DURING USE

Tension at the soil surface is controlled by the relative position of the air-entry tube in the bubble tower.

Tension (negative pressure) in the air pocket at the top of the water reservoir is linearly related to the height of water in the reservoir. A centimeter change in water height means a centImeter change in tension in the air pocket. Thus, infiltration rates can be momitored by recording tension changes measured over time. Flow rates are determined from changes in the water level in the water tower.

Once the tube is set, turn the set screw clockwise till it is finger tight. This will ensure that the closure is airtight. Under normal operating conditions the air entry tube has to be set such that its lower end is at (4.0 + X) cm below the water level in the bubble tower.

For example, if the first measurements are to be taken at a surface tension of -15 cm H20, then the lower end of the tube should be atleast at 19 cm below the water level. If the next readings are to be taken at -10 cm, then the tube outlet should be set at 14 cm below the water level.

The tension infiltrometer is designed to add water to soil at a range of tensions, which can be set by the operator of the instrument. By performing infiltration experiments at multiple tensions, one obtains data on the unsaturated hydraulic conductivity at the various tensions. The range of tensions that can be set is (for practical reasons) limited to tensions between 20 - 25 cm H2O. By setting the tension at or close to zero, one should obtain an infiltration rate close to the saturated hydraulic conductivity of the soil.

ESTIMATING MEASUREMENT TIMES

The time needed to obtain a steady-state rate in unconfined infiltration measurements depends upon initial soil water content and upon hydraulic properties of a given soil.

The change in rate over time should be monitored to confirm that steady-state rates are reached. Data is collected for up to 15 minutes under most conditions except for dry, high bulk density areas. Not reaching steady state results in an overestimate of hydraulic conductivity. In very porous and sandy soils, steady-state rates are reached much earlier and measurement times can be shorter.

As a rule of thumb, if a third of the 1” reservoir tube has emptied, enough water has been added to the soil wetting bulb to approach steady-state. This may aid in deciding when to terminate one measurement and start another. It also may help to reduce the number of refills that must be made.

While tensions can be calibrated to an accuracy of millimeters, the precision of tension control is limited by tension fluctuations due to bubbling (+ /approximately 1 cm for the device in Figure 1). Therefore, at very low tensions, soil surface tension may fluctuate to zero potential. This fluctuation should be given careful consideration before measuring or interpreting infiltration rates less than two or three centimeters tension. The 400 mesh nylon membrane will bubble if tensions are set for greater than 20-25 cm. Tension settings of 3-, 6- and 15 cm have proven convenient across a variety of soils and soil conditions.

By raising or lowering the tube in the bubble tower, the tension that will be maintained at the bottom of the base plate can be set. The maximum tension is generally less than 30 cm. Many researchers start with the highest tension (often 20 cm). One should note that at the highest tension, the hydraulic conductivity is the lowest, and thus it may take some time for the instrument to start "bubbling". If it takes too long for bubbles to appear one may want to reduce the initial tension.

HOW TO OPERATE THE TENSION INFILTROMETER / HELPFUL HINTS / CONT.

If tensions beyond 30 cm tension are to be imposed on the soil surface, the bubbling point of the nylon membrane may be exceeded. Membranes down to submicron pore diameter are available. Nylon filters are recommended because they are thin, tough, and hydrophilic.

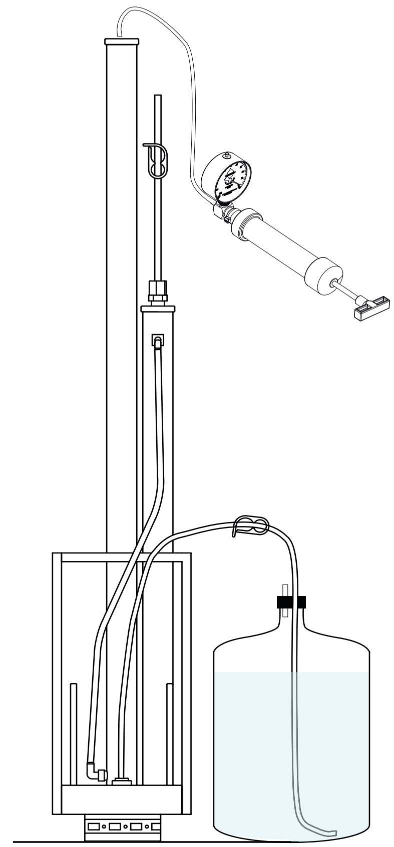
WARNING: High tensions usually mean low flow rates. As flow rates decrease, other factors become more of a problem. Expansion of water due to heating by the sun in the water reservoir may make it difficult to maintain tension. Electronic noise and calibration errors also become more of a problem.

FIELD INSTALLATION

INSTALLATION IN THE FIELD

You will/may need:

- timer or stop-watch for
- pen and paper
- jug of water
- soil sieve set
- pan
- Extra nylon membranes
- clamps



(Figure 3) - Re-filling prior to installation

REFILLING IN THE FIELD PRIOR TO INSTALLATION

For refilling in the field, connect a tygon tube from a water supply jug to the base valve and open the valve.

Fill the infiltrometer by creating a vacuum in the top of the water reservoir (Figure 2). This is most conveniently accomplished using a hand operated vacuum pump with attached tygon tubing.

Replace the plug in the water reservoir end-cap with a 1/ 4”NPT tubing connector. Slip the tygon tubing over the tubing connector, and with the vacuum pump draw water up to about 7 em below the top. Close the base valve, and disconnect the water supply.

A simple water supply jug convenient for field use can be. made by placing a two-hole stopper in a plastic jug and running a piece of tygon tubing from the bottom of the jug through one hole with approximately one meter of tubing outside the jug for connection to the base valve.

Another way of filling the water reservoir is by placing the infiltrometer in a shallow pan with water and creating a vacuum in the top of the reservoir. Keep the base valve closed when using this method.
Fill the unit until the level is at 10cm in the water reservoir and -10 in the bubble tower.

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PREPARE THE SURFACE

Before placing the infiltrometer on the site where a measurement is to be made, the site must be leveled and cleaned of debris. A critically important aspect of the tension infiltrometer measurements is that good hydraulic contact be established and maintained between the infiltrometer and the soil. Poor contact results in poor data.

Note that the effective diameter for calculating the conductivity is the diameter of the sand circle.

A 8cm stainless steel ring (Model Z2826008) is placed on the leveled surface. The area within the ring is filled with fine sifted sand from the testing site or with silica sand (a few mm in thickness). The sand is leveled carefully and the ring removed. A perfect flat surface, 8 cm in diameter, is formed for placement of the infiltrometer. The sand layer and the baseplate that is wetted during filling should result in good contact between the base of the infiltrometer and the soil below.

Gently press the baseplate onto the prepared surface.

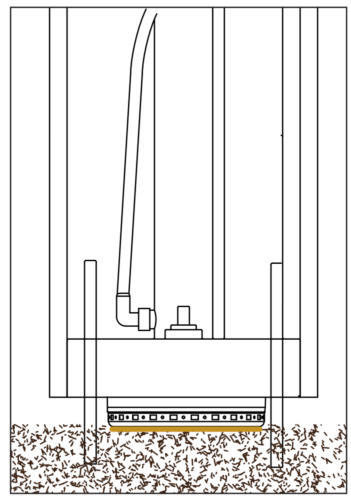
There should be no sand outside the ring. Center the infiltrometer over the ring and gently press the baseplate onto the prepared surface.

Inspect the interface between the baseplate and the prepared surface to assure good contact.

Push the stability pins to the ground surface so that the TI unit is sturdy.

Adjust dip tube to the desired tension, and pull a vacuum to start the natural infiltration rates of the soil through the base plate. The bubble tower will bubble.

Check measurement rates at defined intervals.



(Figure 4) - Field Installation

FLUX CALCULATIONS

The volume of water entering the soil surface in a given time is calculated by multiplying the drop in water level in the water reservoir over a time interval by the cross sectional area of the water reservoir.

For a 1” ID water reservoir, the surface area is 5.07 cm squared. Thus a drop in water level of 5 cm in 20 seconds, results in an infiltrated volume of 75.05 ml in one minute. With a 3.25” diameter porous membrane, the surface area is 52.8 cm squared. Thus a drop in water level of 5 cm·in 20 seconds is equivalent to an infiltration rate or surface flux of 1.42 cm/minutes.

DATA COLLECTION

The water level in the water reservoir can be read directly on the cm scale attached to the water reservoir. A simple timer or stopwatch is useful to obtain readings at regular time intervals.

The water level may also be recorded with a pressure transducer and a data logger. 1 PSI pressure transducers (Model 5305), available from Soilmoisture Equipment Corp. are recommended.

As the water level in the water tower decreases (as it infiltrates into the soil), the negative pressure in the water tower becomes less negative. Thus, the pressure transducer output is linearly related to the water level in the water tower. Output recorded from the pressure transducer therefore provides a continuous record of the infiltration

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rate measured with the infiltrometer. A continuous record with frequent readings is important if one is interested in the early, transient infiltration behavior.

For multiple sites, it is advantageous to use a datalogger to record the data. The water level in the supply tower is then recorded by installing a 1 psi (66 mbar) differential pressure transducer connected to a suitable datalogger.

ATTACHING THE PRESSURE TRANSDUCER *(See fig.5)*

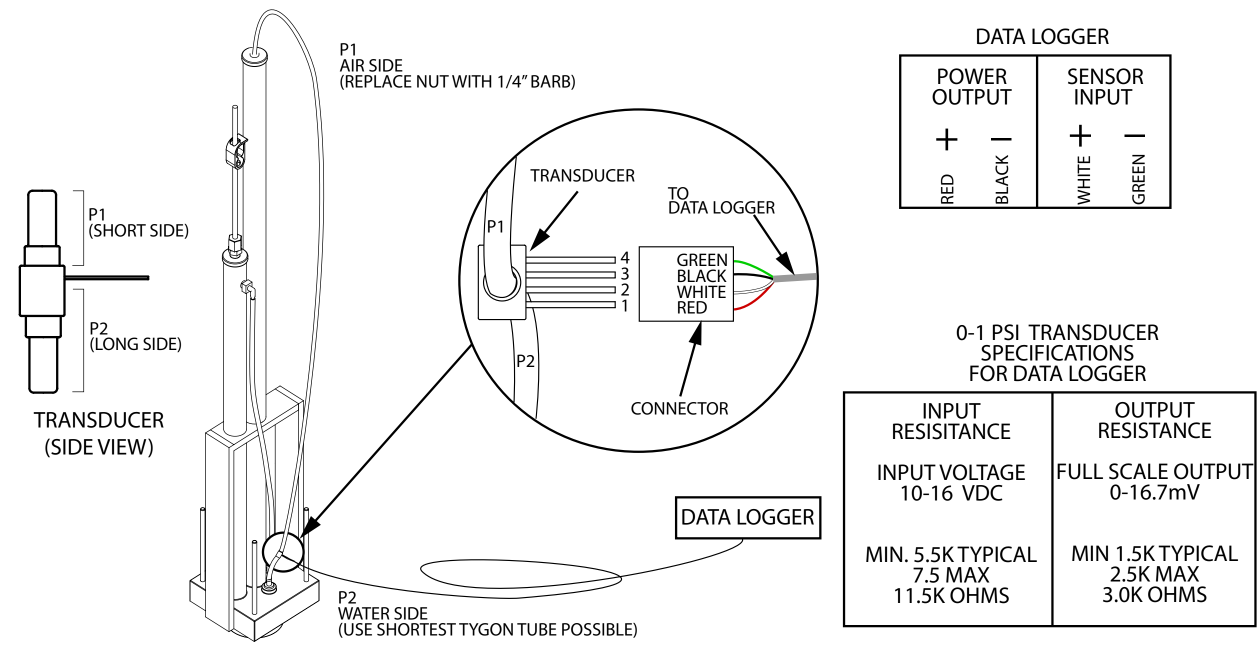
Tygon tubes are positioned from the upper and lower parts of the unit and joined by the transducer.

1. For the lower tygon tube connection (water side) use the shortest possible tube. Connect the tygon tube to the barb port that is assembled on the base plate. Insert the P2 side (long side) of the transducer.

2. Unscrew the plastic hex plug on the water reservoir cap to remove it. Replace it with the plastic barb connector and connect a tygon tube that is long enough to attach to the (P1 side / short side) of the transducer.

3. The transducer is then plugged into the 6 ft. connector that feeds to the data logger.

A suitable data logger should be capable of detecting 16.7 mV.



(Figure 5) - Connecting pressure transducers to a data logger

APPLICATIONS

- Measurement of macropore and preferential flow
- Estimation of soil structure
- Characterization of the soil hydraulic conductivity / water potential relationship

BASE PLATE LEAKING

If the nylon membrane is damaged, the base will leak. If the base leaks, first try to knock any entrapped air out of the membrane by bumping the base into the bottom of a shallow pan of water. If this fails, the membrane will need replacing.

To replace the nylon membrane:

- Unscrew the stainless steel tubing clamp.

- Remove the damaged screen and replace it with new membrane material Z2826D20-001 (available from Soilmoisture). Lay the membrane over the base plate, and force the O-ring over the membrane and the base plate, such that the membrane material is tight.

- Replace and tighten the tubing clamp. Wetting the membrane by soaking it in water will facilitate its installation. Only after testing the new membrane for leaks, should the extra membrane material be cut off. Use a razor blade to trim the membrane on the edges.

TEST INFILTROMETER FOR LEAKS

- Remove bottom disc from the infiltrometer.

- Close hole in bottom of infiltrometer with a # 51/2 stopper.

- Close all the white clamps on the infiltrometer bubble tower and close water reservoir with a septum stopper.

- Inflate the unit to about 60 cm water pressure (60 mbar).

- Hold the complete unit under water and check for leaks.

CHECK DISC FOR LEAKS AS FOLLOWS

- Close the disc with a #141/2 one-hole stopper.

- Connect 1/4” tygon tubing (2 feet long) with connector to the hole in the stopper.

- Immerse the disc and tubing in water. The tubing should be completely full of water. Make sure there is no air under the membrane or in the tubing.

- Remove disc with attached tubing from water.

- Turn the disc, so the screen is facing up.

- Position tubing so end of tubing is at the same level as the top of the screen. Open the tubing, and slowly lower the end of the tubing. Watch for air bubbles to appear below the screen. Air bubbles will start appearing when the open end of the tubing is 25-30 em below the level of the screen on disc. This is the bubbling pressure of the nylon fabric. Check by measuring the distance from the top of the screen to the top of the tubing.

Even, if tests 1 and 2 are fine, there still might be a leak where the O-ring seals the disc to the infiltrometer base. A small amount of vacuum grease around the O-ring should cure this problem. If the screen is leaking, then it should be replaced.

V. INFILTRATION DATA ANALYSIS

1. Theory: from 3-D rates to hydraulic conductivity

The following method based on Wooding's work (1968) can be used to calculate hydraulic conductivities from unconfined infiltration. Wooding proposed the following algebraic approximation of steady-state unconfined saturated infiltration rates into soil from a circular source of radius r

$$Q = \pi r^2 K \left[1 + \frac{4}{\pi r \alpha}\right] \quad (1)$$

where Q is the water flux and K is the hydraulic conductivity given by

$$K(\Psi) = K_{sat} exp(\alpha\Psi) \quad (2)$$

In (2), Ksat and a are constant.

Measuring steady infiltrating fluxes Q(Ψ1) and Q(Ψ2) at two water potentials yields two equations and two unknowns (K_{sat} and α)

$$Q(\Psi_1) = \pi r^2 K_{sat}\, exp(\alpha\Psi_1) \left[1 + \frac{4}{\pi r \alpha}\right] \quad (3)$$

$$Q(\Psi_2) = \pi r^2 K_{sat}\, exp(\alpha\Psi_2) \left[1 + \frac{4}{\pi r \alpha}\right] \quad (4)$$

One can now calculate hydraulic conductivity from any pair of unconfined infiltration rates taken at different tensions. The value of a is obtained by . dividing (4) by (3) and solving for a

$$\alpha = \frac{\ln\left[Q(\Psi_2)1\ Q(\Psi_2)\right]}{\Psi_2 - \Psi_1} \quad (5)$$

An average can be taken where more than one estimate of hydraulic conductivity is made.

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Sample calculation:

With α known, one can calculate Ksat from equations (3) or (4) .

Once K_{sat} and α are known, their values can be substituted in (2), 'yielding the relationship between hydraulic conductivity and tension for the soiL This relationship can be used to calculate the unsaturated conductivity at the desired tensions.

Note, that the K_{sat} value obtained with the above method may be different from the value obtained for K_{sat} if measured directly with double ring infitrometers. One reason is that the relationship of K(h) versus h is often not linear near h=0. A second reason is that the tension infiltrometer measures the matrix conductivity, while conductivity values measured with double ring infiltrometers are representative for the whole soil, including its large pores. Thus with double ring infiltrometers a significant fraction of the water may infiltrate through a few large cracks. Because the water is held under a slight tension, water from the tension infiltrometer will not enter the very large' pores, and thus macropore flow will not overly influence the readings obtained.

Example:

The inside diameter of the water supply tube of the tension infiltrometer is 2.54 cm, and it's radius is 2.54/2=1.27 cm.

Assume that the diameter of the sand layer between the membrane and the soil is 8.2 cm and its radius is 4.1 cm. Assume further that upon reaching steady state, the water level in the supply tube fell on average at a rate of 60 cm/hour for h_1 = -5 cm, and at a rate of 10 cm/hour when the tension was set at -15 cm.

Calculations:

Based on the above date, the infiltration rates were:

$Q_1 = (3.14)\ (2.225)^2\ (60) = 933\ cm^3/hour$ at $h_1 = -5$

$Q_2 = (3.14)\ (2.225)^2\ (10) = 155\ cm^3/hour$ at $h_2 = -15$

Calculate *a* from (5):

$$\alpha = \frac{\ln\ (51/304)}{-15-(-5)} = \underline{0.1792\ cm^{-1}}$$

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From (3) one obtains:

$$304 = (3.14)(4.2)^2 K_{sat} \exp[\, 0.1792(-5)\,] \quad 1 + 4/(3.14)(4.2)(0.1792)$$

K_{sat} = 8.24 cm/hour

With α and K_{sat} known, (2) becomes:

K(h)=8.24 exp (0.1792 h) **(6)**

From (6) one can calculate the unsaturated hydraulic conductivity, as follows:

h = -10 cm, K(-10) = 1.37 cm/hour ID
h = -20 cm, K(-20) = 0.23 cm/hour
h= -40 cm, K(-40) = 0.0064 cm/hour

2. MATRIC FLUX POTENTIAL

Partitioning of unconfined flow in the above method yields both hydraulic conductivity and matric flux potential ϕ = K/α. Note the supply potential does not have to be zero.

3. SORPTIVITY

Estimation of sorptivity, $S(\Psi_{1,} \Psi_2)$ is discussed in detail by White and Perroux (1989). Because sorptivity is often sought as a means of obtaining hydraulic conductivity, this manual focuses on the more direct method above. Note that sorptivity can be calculated directly from the short time behavior following White and Sully, 1987.

4. CAPILLARY LENGTHS

Calculation of capillary lengths is also discussed by White and Perroux (1989). Philip (1985) proposed the use of the macroscopic sorptive length. A length scale simply related to the sorptive length is the macroscopic capillary length, Ac (White and Sully, 1987), where:

$$\lambda_c = [\, K(\Psi_0) - (\Psi_n)\,]^{-1} \int_{\lambda_c}^{0} K(\Psi) d\Psi$$

Wooding's results (1986) were based on (2) for which λ_c is simple α^{-1}. White and Sully (1987) and others have used the more basic definition (7) as a basic soil property, but note that λ_c is a function of the integration limits as well as $K(\Psi)$ for the general case.

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GENERAL CARE AND MAINTENANCE/MINOR ADJUSTMENTS (Optional dependent on product

- During long term storage, the infiltrometer should by emptied to prevent decay of the membrane on the base. A dirty base also promotes short-term decay.

- This device is constructed of poly carbonate (Lexan) and plexiglass. Therefore, the device should withstand normal field abuse. If any piece of plastic does crack or leak, a syrupy solution of plexiglass dissolved in dichloromethylene should seal the pieces together. A glue gun will usually seal a leak, also.
- The tubing on the air entry ports may lose its resiliency over time due to the pinch clamps. Periodic replacement increases ease of use.

REPLACEMANT PARTS/ HELPFUL ITEMS LIST.

	ITEM PART #	DESCRIPTION
1.	Z2826D08-001	NYLON MESH SCREEN
2.	2826D08-002	MARKER RING
3.	1907	SOIL SIEVE SET
4.	2060FG3	GAUGE
5.	MZL055	CLAMPS
6.	5305	TRANSDUCER
7.	2038V3	WATER CONTAINER
8.	MZT026	TYGON TUBE 1/4"
9.	0930W005,10,50	SILICA
10.	2827	GUN PUMP
11.	2005G2	HAND PUMP
12.	MFT012PK	VACUUM GREASE

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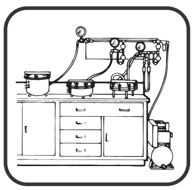
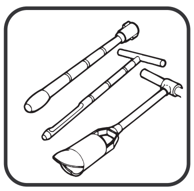
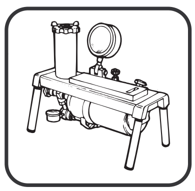
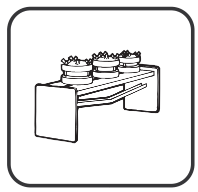

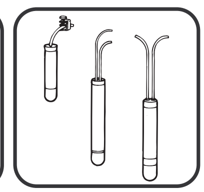
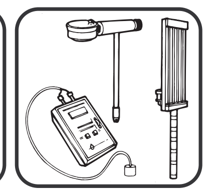

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