Umwelt-Geräte-Technik GmbH

Operating Instructions

Hood - Infiltrometer

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1. Principle:

The **hood infiltrometer** is used for measuring the soil hydraulic conductivity in the field. Measurement is effected by infiltration from a water-filled closed **hood** put onto the ground. The **water-covered circular soil surface** under the hood then is the **source area for infiltration flow**.
No contact layer on the soil surface is necessary.

The **hydraulic pressure head** in the water volume under the hood is controlled by a MARIOTTE water supply system. The effective pressure head on the soil surface can be chosen freely at between **zero** and a **negative pressure** up to the **bubble point** (air permeation value) of the soil.

A supplemental **U-tube manometer is used for precise measurement of that pressure head.**

For infiltration tests, two hoods with an infiltration area ratio of about 1:2 are used to **measure and caculate the hydraulic conductivity acc. to WOODING.**

A supplemental **infiltration chamber** together with the MARIOTTE water supply system make up a regular **tension infiltrometer** enabling infiltration tests up to **about 60 hPa water tension**, irrespective of the bubble point of the soil.

2. Underlying theoretical principles:

Hydraulic conductivity k_u as a function of water tension ψ in soils and other open-pored materials can be described acc. to GARDNER (1958):

$$k_u = k_f \cdot \exp(\alpha\psi) \qquad (1)$$

k_f - saturated hydraulic conductivity

Such approach allows an analytical solution for a large number of two- and three-dimensional flow processes. This is the normal basis for the interpretation of tests with the infiltrometer systems common so far.

With this, WOODING (1968) found a solution for the **steady-state flow Q** from a **circular infiltration area (radius a)** into the infinite soil.

$$Q = \pi \cdot a^2 \cdot k_u \cdot \left(1 + \frac{4}{\pi \cdot \alpha \cdot a}\right) \qquad (2)$$

For experimental determination of α, the infiltration test can be made with **different water tensions ψ (tension infiltrometer principle)** or, in case of identical **water tensions**, infiltration gets fed from source areas with **different radii**.

3. Infiltration tests with different water tensions

Using the infiltrometers at different tensions, the test can be made at any water tension up to the bubble point of the soil or the membrane below the infiltration chamber (radius a).
For neighboring values of the chosen water tensions (h_1, h_2) applies after (1, 2):

$$\frac{Q_1}{\pi \cdot a^2} = k_f \cdot e^{\alpha \cdot h_1} \cdot \left(1 + \frac{4}{\pi \cdot \alpha \cdot a}\right) \qquad (3)$$

$$\frac{Q_2}{\pi \cdot a^2} = k_f \cdot e^{\alpha \cdot h_2} \cdot \left(1 + \frac{4}{\pi \cdot \alpha \cdot a}\right) \qquad (4)$$

By way of division we get:

$$\alpha = \frac{\ln\left(\frac{Q_1}{Q_2}\right)}{(h_1 - h_2)} \qquad (h_1, h_2 < 0) \qquad (5)$$

and for the hydraulic conductivities we get:

$$k(h_1) = \frac{\frac{Q_1}{\pi \cdot a^2}}{\left(1 + \frac{4}{\pi \cdot \alpha \cdot a}\right)} \qquad (6)$$

$$k(h_2) = \frac{\frac{Q_2}{\pi \cdot a^2}}{\left(1 + \frac{4}{\pi \cdot \alpha \cdot a}\right)} \qquad (7)$$

4. Infiltration tests with identical water tensions

On infiltration with **identical water tensions** from infiltration hoods with **different radii** applies for the respective flow rates:

$$Q_1 = \pi \cdot a_1^2 \cdot k_u \cdot (1 + \frac{4}{\pi \cdot \alpha \cdot a_1}) \qquad (8)$$

$$Q_2 = \pi \cdot a_2^2 \cdot k_u \cdot (1 + \frac{4}{\pi \cdot \alpha \cdot a_2}) \qquad (9)$$

When choosing the **source areas** with a ratio of

$$F_2 = q \cdot F_1 \qquad \left(F = \pi \cdot a^2\right) \qquad (10)$$

we get:

$$\alpha = \frac{4 \cdot (\sqrt{q \cdot \frac{Q_1}{Q_2}} - 1)}{a_{1.} \cdot \pi \cdot (1 - q \cdot \frac{Q_1}{Q_2})} \qquad (11)$$

Therefore, for an unknown soil k_u and α can be determined from (11) and (8).

Simplified test procedure

In material of **known parameter α**, in single tests with **one** infiltration hood, e.g. with radius a = 0.088m, hydraulic conductivity is determined by:

$$\frac{Q}{\pi a^2} = k_u \cdot (1 + \frac{4}{3{,}14 \cdot \alpha \cdot 0{,}088m}) = k_u \cdot C \qquad (12)$$

Texture	**α (m^-1)**	**C**
	14.5	2.0
	12.4	2.2
	7.5	2.9
	3.6	5.0
	1.6	10.0
	2	8.2
	5.9	3.5
	1.9	8.6
	1	15.5
	2.7	6.4
	0.5	30
	0.8	19.1

5. Structure and operation of the hood infiltrometer [Fig. 1]

A hood [2] with circular base is standing on the soil surface.
The space under the hood is filled with water, hydraulic pressure head getting controlled through a MARIOTTE water supply system [5, 6, 7].
The edge of the hood is sealed with fine water-saturated sand against the soil up to an outer ring [1].
That sealing will be effective only if the pressure in the water volume under the hood is negative.
The negative pressure is adjustable from zero to the soil bubble point.

On the measuring surface the soil pore system remains absolutely undisturbed.

When setting up the test system, first the over-flow chamber [3] under the hood has to be filled - well controlled - with water. Upon overflow of the this chamber begins the infiltration into the soil and the volume under the hood gets filled with water.
In the course of this, the pressure of the enclosed air gets negative. This air then is led through the air-outlet pipe [10] into the air volume of the infiltration reservoir [5].
After the hood has been filled, the **infiltration flow** is delivered directly from the infiltration reservoir of the MARIOTTE water supply system from where the reading can be taken.

The effective **hydraulic pressure head** on the soil surface is determined from the height of the water table in the standpipe [4] and the negative pressure at the U-tube manometer [8].
The zero point of the scale on the standpipe is at soil surface level.

5.1 Preparation of hood infiltrometer

Screw the tripod [12] into the base plate of the infiltrometer.
Fill the bubble tower [6] to mark "B". For this, pull out the air pipe [7] and insert funnel.
Fill the infiltration reservoir [7] to mark "I". V1, V2 and V3 shut.
Fill the U-tube manometer [8] to zero mark.

Connect the hood through the connecting hose [11] to the infiltrometer.
Connect the U-tube manometer through hose [9].
Connect the air escape hose [10].

5.2 Installation of hood infiltrometer

Choose the measuring site as level as possible.
Cut the vegetation down to about 5mm high.
Put the outer ring [1] onto the ground, if necessary, press it a few mm into the ground.
Center the hood into the outer ring, set the infiltrometer up and bring it in vertical position. Bend the connecting hose [11].
Install the U-tube manometer.

5.3 Filling the hood

Set the submergence depth "T" of the air intake pipe about 2cm higher than the infiltration chamber height "Hk".
(The hydraulic pressure head "Zero" will then become effective under the soil surface.)
Open "V1" slowly and fill the connecting hose [11] and the overflow chamber [3].
Evacuate air (use pipette ball) at the hose [9] until the water table in the standpipe [4] is about mid-scale.
Fill the gap between the hood and the outer ring [1] with fine sand and sprinkle (use wash-bottle).
Open "V2" slowly and evacuate air from the hood.
If necessary evacuate additional air through "V3" and keep the negative pressure under the hood at the desired value.
The negative pressure Us at the U-tube manometer must always exceed the water table on the scale at the standpipe [4].
Shut „V2“ when the water table has reached the mark on the hood.
Wait for the aeration of the MARIOTTE water supply system.

5.4 Measurement

The effective water tension on the soil surface can be chosen via the depth of submergence "T":

$$h = Us - Hs \qquad (Us < 0 !) \qquad (11)$$

It is advisable to start the test with water tension "Zero".
Measure the infiltration rate "R" (cm/s)
Determine the steady-state infiltration rate.
Increase the water tension step by step up to the soil bubble point.

5.5 Determination of the bubble point (BP)

Shut "V1".
Watch the pressure rise on the U-tube manometer.
Determine the maximum.

$$BP = Us_{max} - Hs \qquad (12)$$

6. Adjustment of tension infiltrometer

Connect the tension chamber through connecting hoses [11] and [9] with the infiltration vessel and with the U-tube manometer. Shut "V2". No hose connection [10] to the tension chamber.
Smoothen the measuring area and put on the outer ring.
Cover the measuring area inside the ring with fine dry sand about 2mm high.

Spread water-tight plastic film onto the measuring area and put on the tension chamber.
Choose the submergence depth of the air intake pipe "T" somewhat bigger than the chamber height "Hk".
Open "V1" and fill the tension chamber.
Evacuate air (use pipette ball) at the connecting hose [9] until the water table in the standpipe [4] is about mid-scale.

To start the infiltration flow, lift the chamber and remove the plastic film. Put the chamber onto the measuring area and turn slightly to establish contact with fine sand.
Wait for the aeration of the MARIOTTE water supply system.
Adjust the effective water tension on the soil surface through submergence depth "T".
Measure the infiltration rate "R" (cm/s).
Determine the steady-state infiltration rate for water tension h_1.
Change the water tension by changing the depth of submergence.
Determine the steady-state infiltration rate for water tension h_2.

7 Useful information for running the test

To determine a representative *ku* function it is advisable to run the test with the hood infiltrometer between water tension "Zero" (k_f value) and the soil bubble point.
In that case, the coarse and macro-pores involved will not get deformed or washed over.

Measurement with the tension infiltrometer is possible as from the bubble point of the soil. In most cases the fine sand of the contact layer then has but little effect on the infiltration rate.

8 Technical details

Radii of the infiltration areas (outer rings)			**Infiltration areas on the soil**	
Large hood	a_1 =	12.4 cm	F1	484 cm²
Small hood	a_2 =	8.8 cm	F2	242 cm²
Tension chamber	a =	12.4 cm	F	484 cm²

Cross section of infiltration column Qi = 75.1 cm²

Qi/ F1 (small hood)	0.313
Qi/ F2 (large hood)	0.156
Qi/ F (Tens. chamber)	0.156

GARDNER, W.R. 1958. Some steady-state solutions of unsaturated moisture flow equations with application to evaporation from a water table. Soil Sci., 85, 228-232

WOODING,R.A. 1968. Steady infiltration from a shallow circular pond. Water Resour. Res.4; 1259-1273

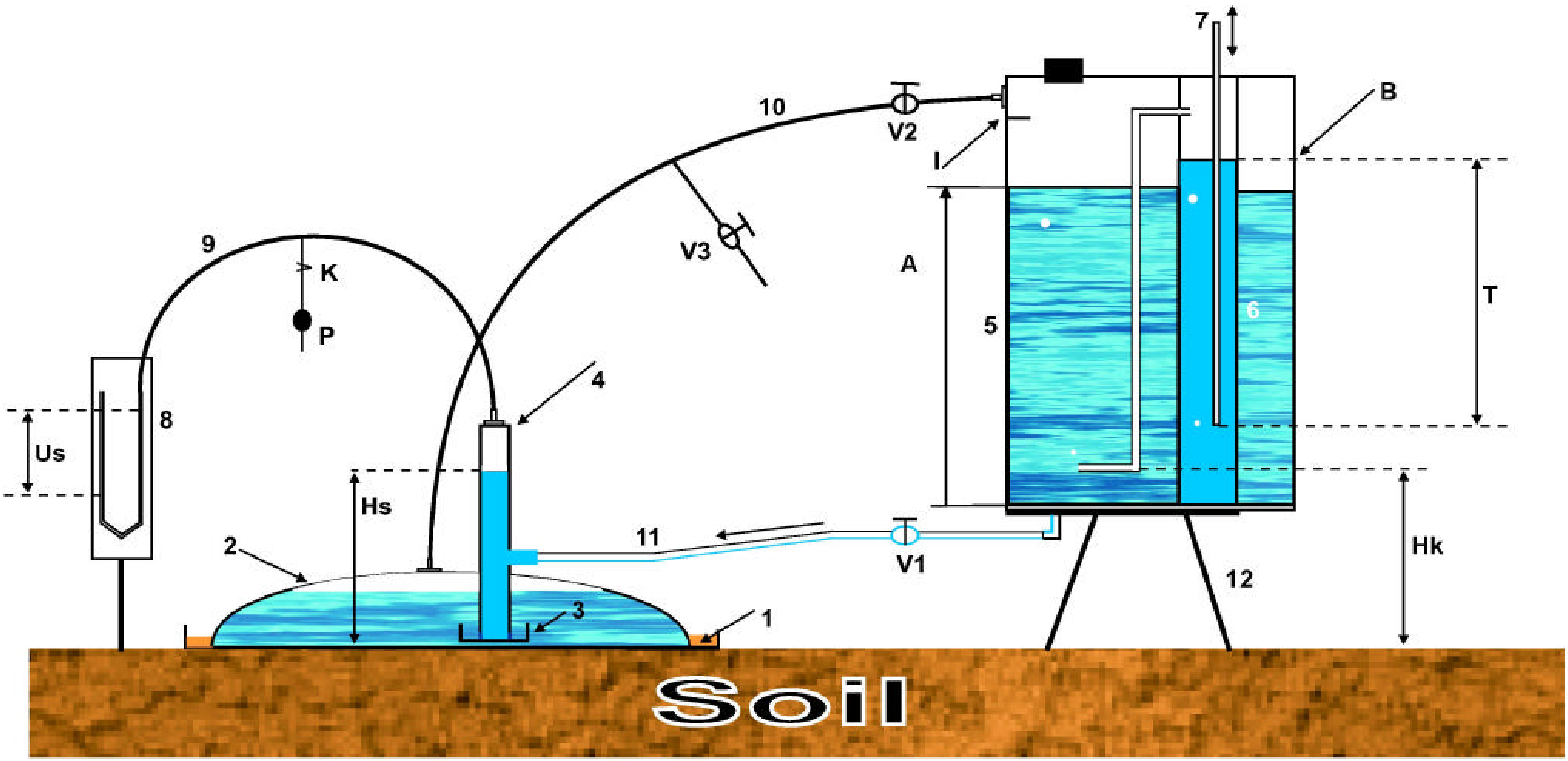

Fig.1 Hood-Infiltrometer