

OPERATING INSTRUCTIONS

09.04 DOUBLE RING INFILTROMETER SET



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On these operating instructions



If the text follows a mark (as shown on the left), this means that an important instruction follows.

Introduction

The double ring infiltrometer is a simple instrument used for determining water infiltration of the soil. The rings are partially inserted into the soil and filled with water, after which the speed of infiltration is measured. The double ring limits the lateral spread of water after infiltration.

The standard set consists of three pairs of inner and outer rings, allowing synchronic measuring. This saves time and produces reliable average data.

Infiltration is the process of water penetrating the ground surface. The intensity of this process is called the *infiltration rate*. The infiltration rate is expressed in terms of the volume of water per ground surface and per unit of time [L/T, for instance mm/min]. The *infiltration capacity* of the soil indicates the maximum infiltration rate at a certain moment. Under certain circumstances, it may be necessary to determine the infiltration capacity of the soil, for instance in infiltration areas or infiltration basins.

The double ring infiltrometer is suitable for almost any type of soil and is applied in irrigation and drainage projects, groundwater and infiltration basins, in optimising water availability for plants and to determine the effects of cultivation.

1. Soil water

1.1 Soil water energy

Soil water is subjected to forces caused by gravity, capillarity, adsorption and osmosis. Capillary forces and osmosis in conjunction act as matrix force to the soil water (osmotic forces, in particular in areas low in salt, are negligible).

The soil water energy is expressed in terms of potential energy or *potential*. The soil water potential is made up of the gravitational potential and the pressure potential (comprising a negative pressure or "suction" in the unsaturated zone and a positive pressure in the saturated zone). Under the influence of the potential differences, water flows in a certain direction at a certain speed. The rate of flow also depends on the *hydraulic conductivity* of the soil.

The hydraulic conductivity [L/T] varies with moisture content of the soil: the dryer the soil, the lower the level of hydraulic conductivity; soil pores filled with air do not conduct water. Saturated soil has the highest level of hydraulic conductivity (*saturated hydraulic conductivity*). This hydraulic conductivity is mainly determined by the geometry and the distribution of pores.

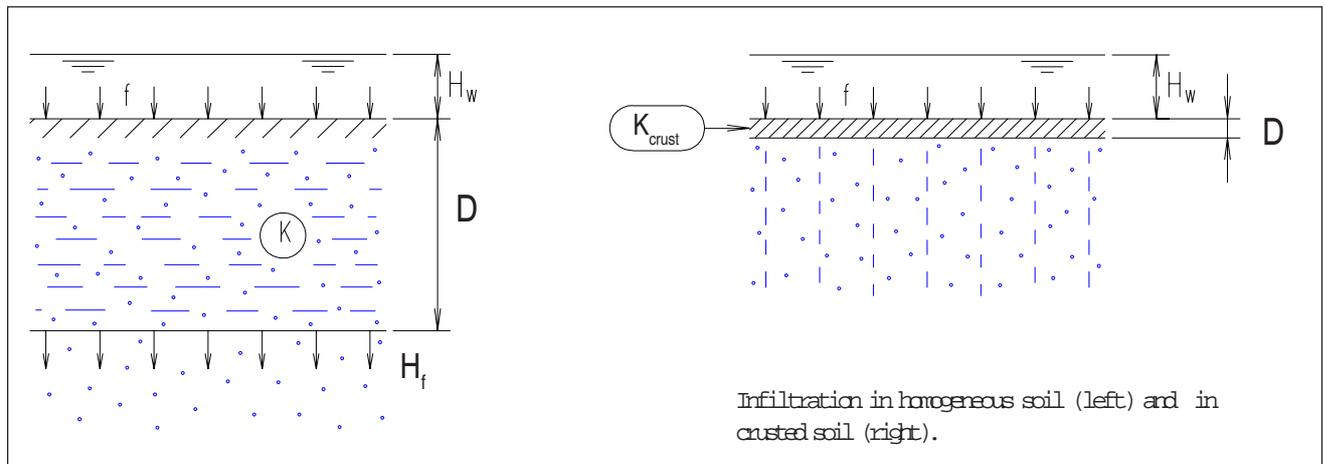
1.2 Infiltration

Water infiltrates the soil during a shower or irrigation. If moistening exceeds the infiltration capacity, water ponds the ground surface. In that case, the infiltration rate equals the infiltration capacity. This will cause in homogeneous soils a saturated top layer, with below a near-saturated zone which will expand by wetting of the underlying soil.

The theory of Green & Ampt (1911) describes the process of infiltration. The theory is derived from Darcy's Law, formulated as:

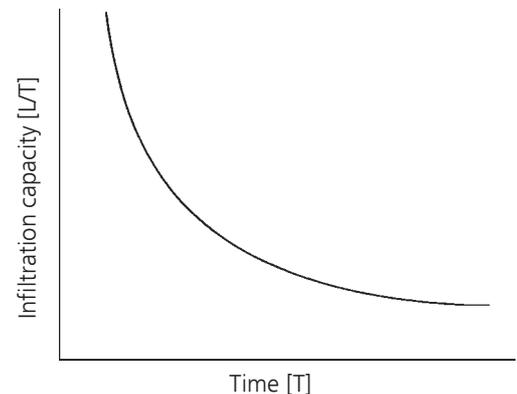
$$f = K (H_w + D - H_f) / D$$

where (see figure below): f refers to the infiltration capacity [L/T], K to the near-saturated hydraulic conductivity [L/T], H_w is the thickness of the water layer [L], D refers to the depth of the wetting front [L] and H_f refers to the pressure head at the wetting front [L].



The infiltration capacity of a soil decreases rapidly over time during infiltration. The course of infiltration capacity in time is expressed in terms of the *infiltration curve* (see figure).

The initial infiltration capacity in dry grounds is high, which is caused by a large matrix suction of the soil. In the near-saturated zone, potential differences are less; the water content hardly causes any variance in matrix suction. Consequently, the infiltration capacity decreases usually within a couple of hours until it reaches a constant value almost equalling the saturated hydraulic conductivity (the enclosure of air bubbles during infiltration prevents maximum saturation).



Some factors affecting the infiltration capacity at the soil surface are: soil compaction caused by ruts and treading, washing of fine particles into surface pores, and cracks and fissures (macro pores). These factors may lead to crusted soils. In addition, the vegetation and soil cultivation may affect infiltration capacity. The thickness of the ponded water layer will only affect the onset of infiltration.

The downward speed of infiltrating water depends on the texture, the structure and stratification (heterogeneity) of the soil, the soil moisture content and the groundwater level. A high groundwater level will cause stagnation of infiltrating water and the infiltration capacity will decrease, approaching zero.

A heterogeneous soil is often perceived as a succession of single, homogeneous soil layers. In a heterogeneous soil with downward decreasing permeability, the infiltration capacity equals the weighted average infiltration rate of the separate layers. A heterogeneous soil with downward increasing permeability, for example a crusted soil, will at a certain stage no longer be saturated (see figure above). The infiltration capacity will be affected if this occurs in a near-surface soil layer.

Some examples of constant infiltration rates (or near-saturated hydraulic conductivity) for different soil types are listed in the table.

See Bouwer (1986), ILRI (1974), Ward & Robinson (1990) for further information concerning soil water, infiltration and the use of the double ring infiltrometer.

Soil type	Constant infiltration rate [mm/h]
Sand	< 30
Sandy loam	20 - 30
Loam	10 - 20
Clayey loam	5 - 10
Clay	1 - 5

2. Description

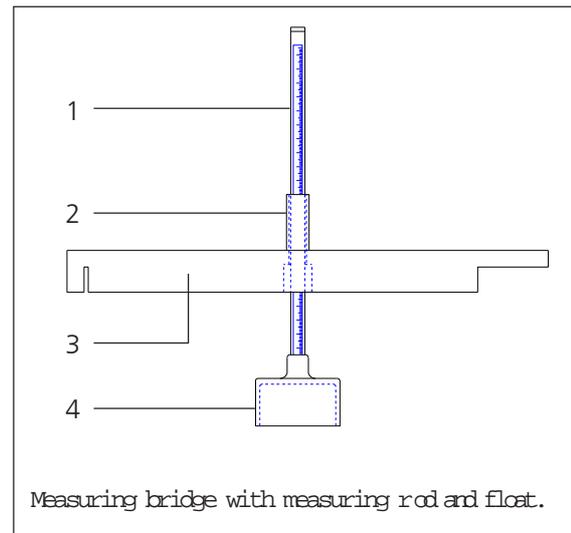
The standard double ring infiltrometer set consists of three pairs of inner and outer rings, a driving plate, an impact-absorbing hammer, measuring bridges and measuring rods with floats.

The pairs of stainless steel infiltration rings have the following diameters: 28/53 cm, 30/55 cm and 32/57 cm. The ring's height is 25 cm and it has one cutting edge (after DIN 19682-7). The purpose of the outer ring is to have the infiltrating water act as a buffer zone against infiltrating water straining away sideways from the inner ring (this applies in particular for heterogeneous soils). Steel pull-out hooks allow removal of the rings. The varying diameters make them easy to stow and transport.

Each inner ring has a synthetic measuring bridge (3), the measuring rod (1) with float (4) moves freely up and down through a small tube (2) in the measuring bridge (see figure). The measuring rod indicates the water level. The float is positioned in the middle of the inner ring. As the measuring rod moves freely through the tube, the wind hardly affects measuring. The measuring rods have a millimeter calibration.

The galvanized steel driving plate is cross-shaped with a beating head in the middle. It is used for hammering in the 28-57 cm infiltration rings. Pins located at the bottom of the ring ensure proper placement and allows the outer ring to be centrally positioned. The shape of the driving plate spreads the effect of the hammering and does not damage the rim. This also ensures undisturbed insertion into the soil.

The steel hammer is impact-absorbing; its head contains lead bullets flowing in the direction of the stroke upon impact. Its nylon cups prevent damage to the driving plate.



3. The use of the double ring infiltrometer

3.1 Installation

1. Place the inner ring with the cutting edge facing down on the ground. Remove small obstacles such as stones or twigs. When measuring below the ground surface, a profiled pit should be made.
2. Put the driving plate on top of the inner ring. Depending on its diameter the ring will fit over, between or within the pins located on the bottom side of the driving plate.
3. Use the impact-absorbing hammer to insert the infiltration ring about 5 cm vertically into the soil. Make sure to disturb the soil as little as possible. In stiff soils have someone stand on the driving plate while another person drives it in. Remove the driving plate from the inserted infiltration ring.



Keep the depth of placement as limited as possible so as not to disturb the top layer. Insert the rings in any case to below a particular top layer, such as a disturbed or crusted top layer or layer with macro-pores.



In the case you should encounter any play between the ring and the ground, push the ring back in its place. A disturbed crust can be healed using bentonite or other soil material.

4. Place the outer ring with the cutting edge facing down around the inner ring and put the driving plate on top of it.

5. Repeat step 3. (see figure). The shape of the driving plate will ensure a depth identical to that of the inner ring.

6. The standard double ring infiltrometer set allows simultaneous measuring in threefold. Place the rings 2 - 10 m apart, depending on the field situation, and repeat steps 1 to 5.



 **Place all rings at a similar depth to allow comparison of the results. Differing ring diameters are not supposed to produce differing results.**

7. Place the measuring bridge with measuring rod and float on the inner ring. Remove, without disturbing the soil structure, any vegetation that may hamper free movement of the float or affect the measuring.

8. Fill the outer ring with water, then the inner ring, to approximately 5 - 10 cm. Start measuring immediately to determine the infiltration curve (see paragraph 3.2).

 **The water level within the infiltration rings should be as low as possible to ensure vertical infiltration. The rings should not go dry. It is recommended to fill to 5 - 10 cm.**

 **To protect the ground surface when pouring the water, use plastic foil, a jute cloth, sponge or a 1-2 cm layer of sand or gravel. It is also possible to pour the water via your hand on the ground.**

 **Make sure to have sufficient water at hand. Filling one set of rings requires approx. 25 litre.**

Some remarks:

- To measure only the infiltration capacity of saturated soil it will suffice to saturate the soil (by pouring water in the rings) without measuring.
- To obtain optimal results in determining the infiltration capacity, use water of a similar quality and temperature to that of the real system you are examining.

3.2 Measuring

1. Start the measuring by noting the time and the water level in the inner ring (reference level) as indicated on the measuring rod. Use columns A and B on the field list. When carrying out synchronic measuring, use several field lists.

 **Always use copies of the field list; use the original only for reproduction.**

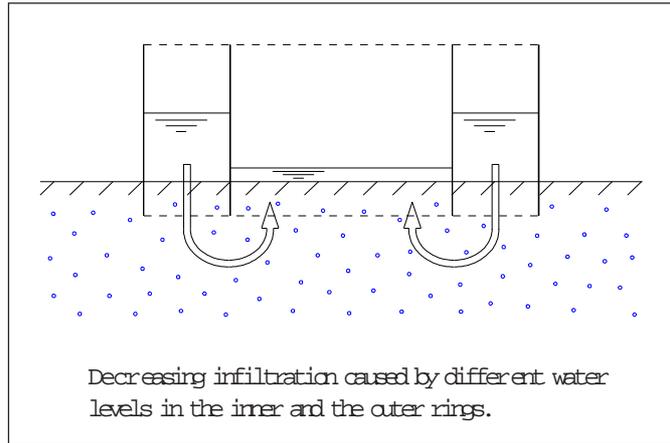
2. Determine the drop in the water level in the inner ring during a certain interval. Note the time and the water level in column A and B on the field list. Start with short intervals (for instance 1-2 min) and conclude measuring with a longer interval (20 - 30 min, depending on the type of soil).

 **Make sure the infiltration rings do not go dry during measuring. Add water when only a few centimetres of water are left in the rings. Write the new levels in column B of the list.**





Keep the water in the inner and outer ring at a similar level. A higher water level in the outer ring will lead to a decreasing infiltration rate in the inner ring. A lower water level in the inner ring will cause the buffering against lateral spreading to decrease.



3. Stop measuring only if the infiltration rate has reached a constant value. A change of < 10% in a certain phase is often considered as constant. Depending on the type of soil this may occur within 1 or 2 hours, in exceptional cases only after a day.

4. Remove the rings using the pull-out hooks.

5. Rinse the rings, make sure no earth sticks and sets to the rings. Proper maintenance will prevent unnecessary disturbance of the soil upon installation.

3.3 Computation of the measuring data

1. Calculate the cumulative time and time steps in columns C and D using the data in columns A and B. Determine the infiltration in column E by calculating the water level differences between intervals in column B.

2. Calculate the infiltration capacity (mm/min) in column F by dividing for each interval the infiltration (column E) by the time step (column D). If necessary, convert the infiltration capacity to e.g. [m/hour] in column G.

3. The tabulated data can be used to determine the infiltration curve. Plot out the calculated infiltration capacity (column F or G) on the y-axis of a graph and the cumulative time (column C) on the x-axis.

4. The near-saturated hydraulic conductivity equals the more or less constant infiltration capacity established toward conclusion of the measuring. Use multiple measurements to calculate a reliable mean value for a certain type of soil or landscape unit.

5. Determine, if necessary, the cumulative infiltration for a certain period. The cumulative infiltration is the total amount of water infiltrating over a certain period of time (L, for instance mm). Fill in column H of the field list by adding the total infiltration (column E) for each interval from the starting of measuring on.

4. Applications

The double ring infiltrometer is suitable for almost any type of soil with the exception of clogging soils, stony soils or the soil of steep slopes. The outer ring causes almost vertical infiltration of water from the inner ring. A number of soil-hydrological features can be determined (per soil layer):

- Infiltration capacity.
- Near-saturated hydraulic conductivity.
- Infiltration curve.
- Cumulative infiltration over a certain period.

The double ring infiltrometer is applied, among other things, in determining the infiltration capacity of flooded soils for:

- Surface irrigation and drainage projects.
- Infiltration or water purification basins.
- Seepage from watercourses, canals, basins or wastewater lagoons.
- Soil leaching at waste storage sites.
- Research into the effects of cultivation.
- Research into drainage effects.
- Research into badly permeable layers of sports fields.

5. Troubleshooting

- If horizontal insertion of the infiltration ring and the driving plate is not successful, a stone or a root might impede the process. Choose another spot for measuring.
- If the infiltration rate proves not to be constant, continue measuring. A variance of less than 10% per interval is considered as constant.
- Increased infiltration is established. This may result from:
 - Macro pores. They tend to occur in soils susceptible to shrinkage (cracks and fissures resulting from drought), as a result of vegetation (rooting), soil fauna, or in strongly disturbed topsoil (ploughing). Insert the ring well into the soil, to below the disturbed top layer. Carry out measuring at several representative spots to obtain a reliable mean infiltration curve of the soil or landscape unit.
 - Disturbance of the soil caused by installation of the ring. Bentonite or other types of clay may be used to heal crusted or disturbed soils. Play between the infiltration ring and the ground can be fixed by applying soil.
 - If the water level in the inner ring exceeds the level in the outer ring, buffering against lateral spreading is insufficient. Make sure the water in both rings has the same level.
 - In well-layered soils, water will tend to strain off sideways, despite the use of the double ring. If necessary, determine the infiltration curve of the underlying layers separately in a pit.
 - Too high a water level in the infiltration rings will cause the water to spread laterally. The maximum water level should be 5 -10 cm.
 - Sustained measuring will increase lateral spreading.
- Infiltration is below expectation. Several factors may be the cause:
 - The soil is crusted. First, establish the infiltration curve of the undisturbed (crusted) soil, then remove the crust and measure again. A large difference in infiltration indicates the occurrence of a crust. Usually the crust will measure less than 1 centimetre (Bouwer, 1986).
 - If the water level in the outer ring exceeds the level in the inner ring, water from the inner ring will hardly infiltrate and may become negative. Make sure the water has the same level in both rings.
 - The water poured into the rings has disturbed the soil structure. Protect the soil and use plastic foil, a jute cloth, sponge, or a 1-2 cm layer of sand or gravel. It is also possible to pour the water on the ground via your hand.
 - Water used for measuring, containing sediments or other suspending agents may cause a low-permeable layer. Use water of a similar quality and temperature to that of the soil of which you are measuring the infiltration capacity.

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