Operating Manual

Ku-pF Single Place

Version: 24/06/19

Umwelt-Geräte-Technik GmbH

Eberswalder Str. 58 | D-15374 Müncheberg

phone: +49 (0) 33 43 2 - 89 575 | fax: +49 (0) 33 43 2 - 89 573

e-Mail: info@ugt-online.de | www.ugt-online.de

Content

1. Introduction

Thank you for choosing the ku-pF Single Place. This manual can help you understand the ku-pF Single Place features.

The ku-pF SP is used to determine the unsaturated hydraulic conductivity and the pF curve of soil samples in the laboratory. The measurement method is based on the theoretical approach of Schindler (1980).

According to this approach the soil samples of investigation are completely saturated at the beginning of the experiment and basal sealed, whereas the top of the samples are exposed to evaporation. In a suitable time interval the weight loss due to evaporation is recorded by a balance. The soil samples are also equipped with two tensiometers which are horizontally installed at a distance of three centimeters. Thus, the hydraulic gradient can be calculated by using the tensiometer readings and the vertical distance between both tensiometers. With the ku-pF apparatus both, disturbed and undisturbed soil samples can be examined. The experiment operation and primary data recording is performed by an integrated process computer. Communication with the process computer takes place via a PC.

There are several ways to contact UGT if you need a quote or product information please contact

Email: info@ugt-online.de

For any technical assistance or feedback or in case of problems with your product please contact

Email: support@ugt-online.de

We look forward to your inquiries or questions and are with pleasure at your disposal.

Phone: + 49 (0) 33432 – 89 575

Fax: + 49 (0) 33432 – 89 573

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

Please read these instructions before operating your ku-pF Single Place to ensure that it performs to its full potential.

2. Technical Parameter

Volume / Diameter sample ring	250 cm³ / 41 cm²
Measurements sample ring (∅ x H)	7,2 x 6,1 cm
Cycle time of data acquisition	1 - 4 min
Resolution of the weighing	0,01 g
Range of tension measurement	0 - ca. 900 hPa
Weight of the device	ca. 16 kg
Dimensions device (L x B x H)	ca. 30 x 45 x 40 cm
Power consumption	230V / 1A
PC-connection	Serial Interface (115200 Baud)
Time of the tensiometer readings	Measuring Position[1]
Time of the weight measurements	in Weighing Position[2]
Memory	210 up to 840 days

3. Physical Basics

The hydraulic conductivity in the saturated soil zone can be calculated according to the DARCY equation (1).

$$Q = -k \cdot A \cdot \frac{d\psi}{dz} \Rightarrow v = -k \cdot \frac{d\psi}{dz} \quad (1)$$

$$v = \frac{Q}{A} \quad (2)$$

$$grad\ \psi = \frac{d\psi}{dz} \quad (3)$$

$$k = -\frac{v}{grad\ \psi} \quad (4)$$

v	specific flow rate (amount of water flowing through a fixed cross-section per unit time)	[cm/s]
Q	Total flow through the soil sample	[cm³/s]
A	flow cross-section area of the cylinder	[cm²]
k	hydraulic conductivity (permeability coefficient, k-value)	[cm/s]
ψ	driving potential for water movement (also hydraulic potential ψ_H, as sum of matrix potential	

[1] During the measuring position the sample holder is located on the support arm. Thus, the sample holder is connected to the device and the tension measurements are taken.

[2] The weight is recorded immediately after the tension readings. The balance is moved into the weighing position. Thus, the sample holder is completely separated from the instrument.

	ψ_m and gravitational potential ψ_z)	[cm]
z	flow length	[cm]
$grad\ \psi$	hydraulic gradient of the potential (describes the change of the potential along the flow path)	[-]

In the unsaturated zone, the (unsaturated) hydraulic conductivity is no longer constant, but depends on the matrix potential ($k(\psi)$). In addition, even under stationary conditions, the hydraulic gradient (3) is no longer spatially constant. Therefore, the Schindler (1980) calculation is done by assuming quasi-steady flow conditions, which means that v and $grad\ \psi$ are assumed to be constant over a specified length of time and flow length. The hydraulic gradient as the sum of matrix and gravitational potential is given by equation (5):

$$grad\ \psi = \frac{\Delta\psi}{\Delta z} = \frac{\Delta(\psi_m + \psi_z)}{\Delta z} = \frac{\Delta\psi_m}{\Delta z} + \frac{\Delta\psi_z}{\Delta z} = \frac{\Delta\psi_m}{\Delta z} + 1 \tag{1}$$

$\Delta\psi$	Gradient of the hydraulic potential	[-]
$\Delta\psi_m$	Gradient of the matrix potential	[-]
$\Delta\psi_z$	Gradient of the gravitational potential	[-]
Δz	Distance between upper T_o and lower T_u tensiometer (=3 cm)	[cm]

The change of the gravitational potential with the z-coordinate corresponds to the unit gradient. The z-axis is directed upwards. The matrix potential values are negative under unsaturated conditions. The gradient of the matrix potential is calculated according to equation (6).

$$\frac{\Delta\psi_m}{\Delta z} = \frac{\psi_{m_o} - \psi_{m_u}}{\Delta z} \tag{2}$$

ψ_{m_o}	Tension of upper tensiometer	[cm]
ψ_{m_u}	Tension of lower tensiometer	[cm]

As a result of the evaporation, a flow velocity v_o (filter velocity or specific flow) is formed on the free sample surface. The basal sealing of the sample causes, as a lower boundary condition, the flow velocity v_u= 0. For the sample center between the tensiometer positions, a mean flow velocity can be calculated under quasi steady flow conditions:

$$v_m = \frac{1}{2} \cdot (v_o - v_u) = \frac{1}{2} \cdot v_o = \frac{1}{2} \cdot \frac{Q}{A} = \frac{\Delta V}{2 \cdot A \cdot \Delta t} \tag{3}$$

v_m	average flow rate in the middle of the sample	[cm/s]
v_o	Flow rate at the top of the sample	[cm/s]

$\boldsymbol{v_u}$	Flow rate at the bottom of the sample	[cm/s]
$\boldsymbol{Q}$	Evaporation amount out of the sample per second	[cm^3/s]
$\Delta\boldsymbol{V}$	During time $\Delta\boldsymbol{t}$ evaporated water volume	[cm^3]
$\Delta\boldsymbol{t}$	Measuring interval for the soil sample	[s]

Under quasi-stationary conditions, the (unsaturated) hydraulic conductivity $\boldsymbol{k}(\boldsymbol{\psi})$ for the range between the tensiometers can be calculated from equations (4), (5), (6) and (7):

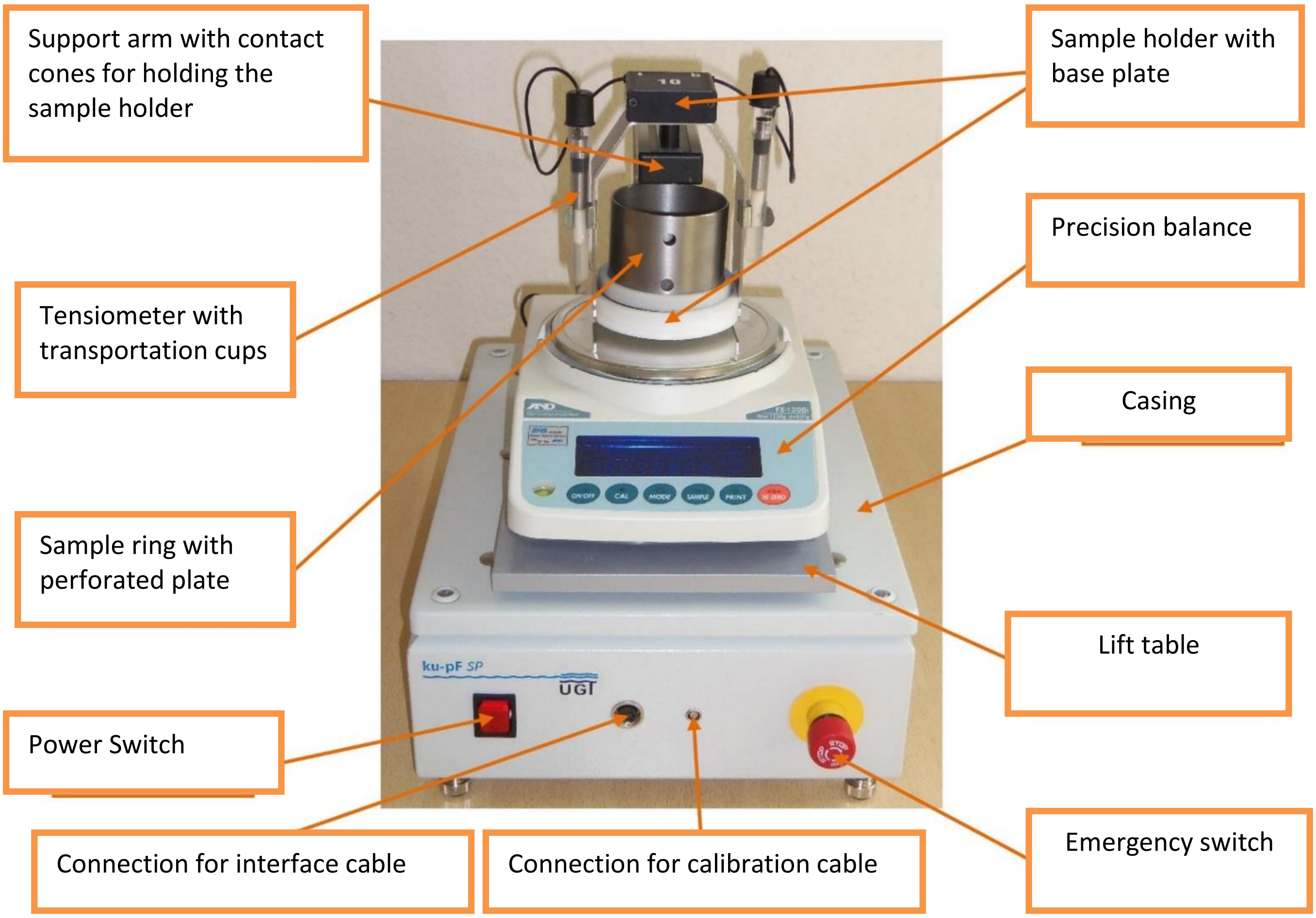
$$k(\psi) = \frac{\Delta V}{2 \cdot A \cdot \Delta t} \cdot \frac{\Delta z}{\psi_{m_o} - \psi_{m_u} + \psi_z} = v_m \cdot grad\ \psi \tag{4}$$

$k(\psi)$	unsaturated hydraulic conductivity as a function of the matrix potential	[cm/s]

The (unsaturated) hydraulic conductivity is a function of the matrix potential and thus also a function of the water content. To calculate the water content, the dry weight of the soil sample must be determined after the experiment. For the representation of the pF curve (relationship between water content and matrix potential), the water content of the sample is assigned to the mean of the two tensiometer values for each time intervalΔt.

4. Device set up and basic operations

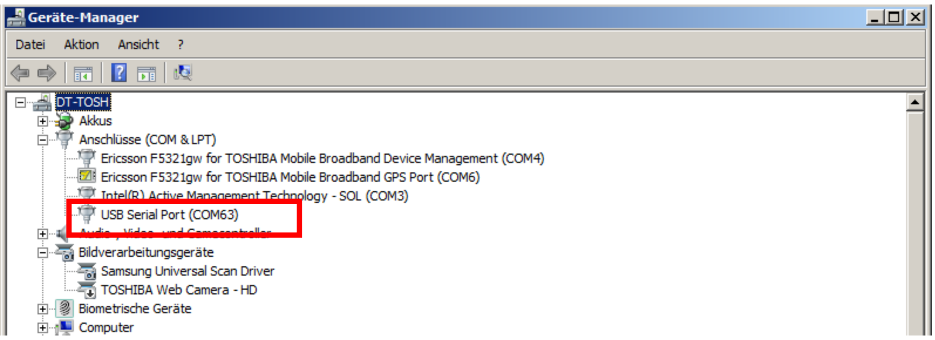
The single place ku-pF consists of a casing, a support arm for the sample holder and a lift table, where the balance is located. The electronic components (power supply unit, transformer, engine with controller and logger) are located in the casing.
The sample holder carries the soil sample and is equipped with two tensiometers and an electronic assembly that digitizes the tensiometer values and sends them to the data logger via a two-wire cable. The connection to the data logger is made via contacts in the contact cones on the support arm.
During the evaporation experiment, the tensiometer values are transmitted to the data logger in the selected time interval. After that, the balance receives the command to "set to zero". When the balance is lifted, the sample holder is disconnected from the support arm and only the weight of the soil sample and the sample holder is recorded.



5. Software and COM-Port Settings

5.1. First start and ComPort Settings

Install the supplied software by following the installation guide. Connect your computer via the connection cable with the ku-pF. When plugging in the USB adapter cable to the computer for the first time, Windows automatically searches for a suitable driver (An internet connection might be needed. The installation process of the driver can also take some time).
Open the ku-pF software. A *'Could not open ComXY!'* may appear on the screen. In this case the correct ComPort must be specified within the software. The ComPort is automatically assigned by Windows when the USB adapter cable is plugged in and can be looked up in your computer's Control Panel. Open the device manager of your computer and open the row: *Ports (Com & LPT)*. Under 'USB Serial Port' you can see the ComPort number.
The ComPort of the connection cable is only listed in the Device Manager if the cable is connected to the computer and the appropriate USB driver is installed.



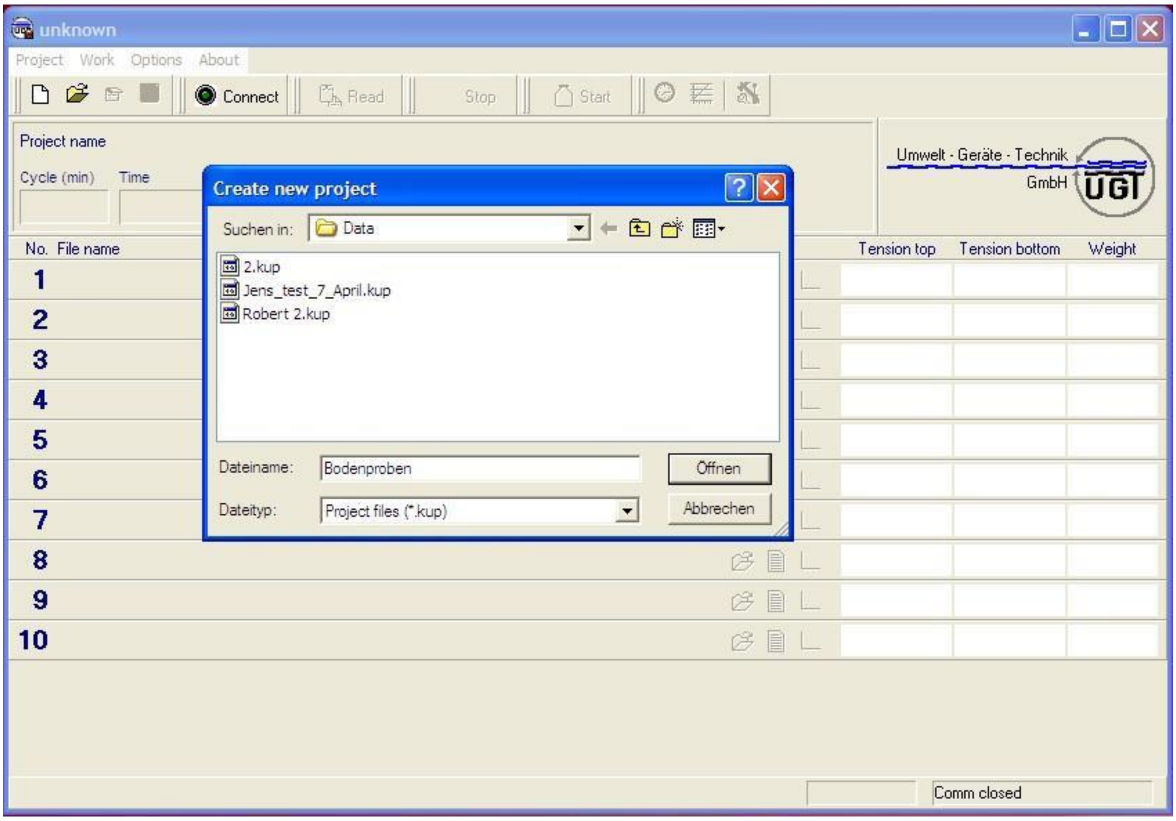
Reading the ComPort number in the Device Manager.

Enter the ComPort number in ku-pF Software under *Options → Set com.*

Note, that in some cases high values of the ComPort number can lead to problems when trying to build a connection to the ku-pF. In case you encounter some trouble building a connection to the ku-pF despite the correct Comport number, rename the Comport number in the Device Manager. We recommend selecting a number between 1 and 4.

5.2. Creating a new project

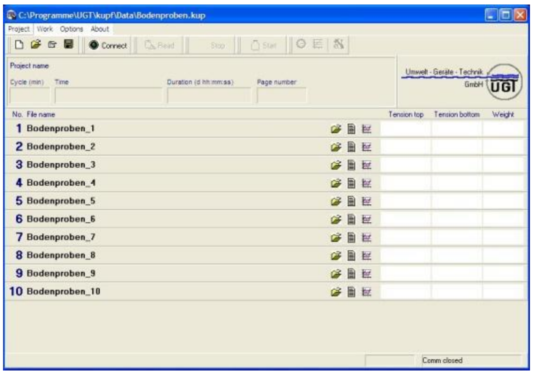
Create a new project by either using the icon in the ku-pf software menu or select ‘Project→New’ and insert the name of the new project.



In case of the single place ku-pF only the row with the number 1 is of interest.

Supplementary notes, e.g. sample names, site criteria or distinctive features of saturation or of the installation of the tensiometers can be entered using the button.

The project can be saved and used later by pressing if you do not wish to begin the measurements immediately.



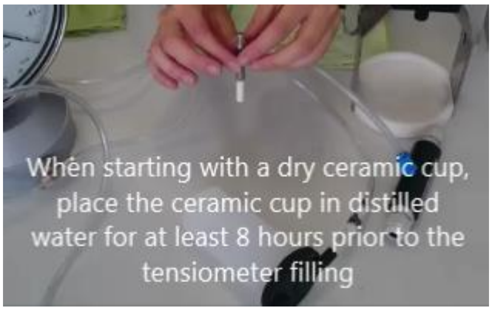
5.3. General information about the software

The software used for the single place ku-pF is the same as for the multi place ku-pF. By default, the sample holder has the number 1 and is therefore also ranked 1st in the software. Sample holders with other numbers (2 - 10) are assigned accordingly. Thus sample holders of the multi place version of the ku-pF can also be used. The data is stored in a txt-file and is available by default at the following address: "C: \ Program Files \ Umwelt-Geräte-Technik GmbH \ kupf-device \ Data". You can close the program at any time as the measurements are performed independently by an external computer that is included in the ku-pF.

6. Preparation

Before starting the experiment the tensiometers have to be filled and calibrated.

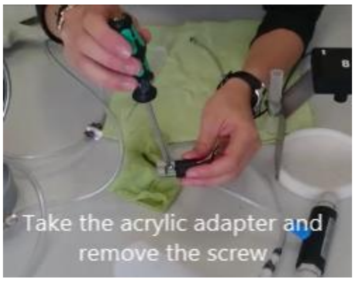
6.1. Filling and Venting of the Tensiometers



Use the filling and calibration kit supplied with the ku-pF to fill the tensiometers. In addition, distilled and degassed water is required. Before filling the tensiometer, the ceramic cup must be saturated. Place the ceramic cups in distilled water over night or for at least 8 hours. When working with the tensiometer, be careful not to touch the cups with bare hands. Use a damp paper towel if it is necessary to touch the ceramic cup. This prevents blocking of the pores by sebum or other deposits.

Fill the saturated tensiometer tip with distilled and degassed water. Use the supplied syringe. Insert the syringe into the shaft as far as possible and slowly remove the syringe while pushing the water into the shaft.

Take one of the transport tubes with rubber lid and fill it with distilled and degassed water. Insert the tensiometer tip into the transport tube so that no air remains in the tube.



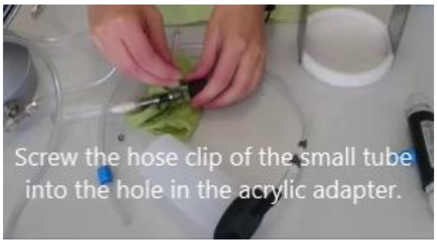
Take the acrylic adapter and remove the screw.

Cover the screw hole in the tensiometer head with your thumb and fill the tensiometer head with water using the syringe. Make sure that neither the tip of the syringe nor the water jet hit the center of the sensor head, because that’s where the pressure sensor is located.

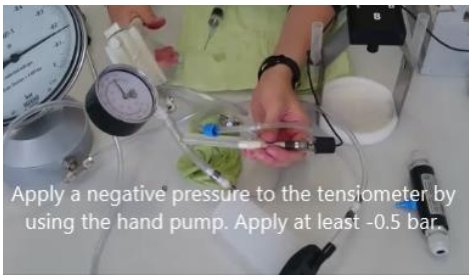
Screw the tensiometer shaft into the acrylic adapter. To do this, turn the tensiometer head that the screw hole points upwards. Leave the screw hole uncovered that excess water can escape.

It is not a problem if water gets lost during this step.

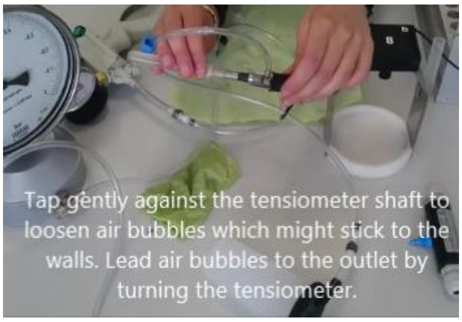
Take the supplied calibration chamber of the ku-pF and carefully remove the tube.



Screw the small hose with the hose olive (hose clip) into the screw opening in the tensiometer head.



Now connect the small tube on the tensiometer to the tube of the calibration chamber. So you can apply a vacuum to the tensiometer via the hand pump. Apply the highest possible negative pressure (at least 500 hPa). The vacuum sucks the water from the transport tube into the tensiometer. Make sure there is always enough water in the tube. If necessary, push the tensiometer slightly deeper into the tube to equalize the volume.

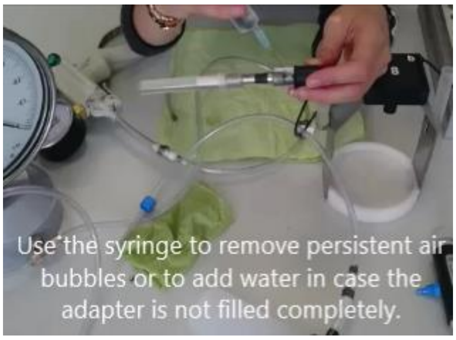


Possible air bubbles in the tensiometer tip are thus transported out of the tensiometer. Slightly move the tensiometer and lightly tap the shaft to release any air bubbles. Then hold the tensiometer with the ceramic cup pointing downwards that possible air bubbles rise upwards and become visible in the tensiometer head. If air bubbles are present, guide them to the screw opening by moving the tensiometer accordingly. Thus, all air bubbles can be removed and the tensiometer is completely filled with water.

Attention!

If permanent air bubbles appear in the tensiometer, check whether the shaft and the tensiometer head are screwed tight. Too loose screwing can lead to leaks.

If there is a permanent drop in pressure or if no water is transported out of the tensiometer, check not only the screw connection of the shaft and the tensiometer head, but also the fit of the hose clip and the tightness between the hose and the hose clip. If the tightness between the hose and hose clip is no longer existent, remove the hose clip from the hose and shorten the hose slightly before reinserting the hose clip into the hose.



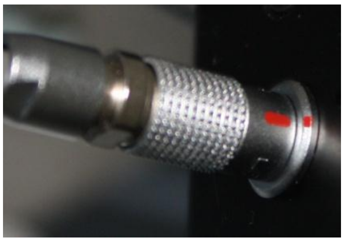
If no air bubbles are visible in the tensiometer, slowly release the pressure from the tensiometer. Remove the hose clip from the tensiometer. For this it may be necessary to first loosen the connection between the hose with the clip and the second hose.

Fill missing water into the tensiometer using the syringe.

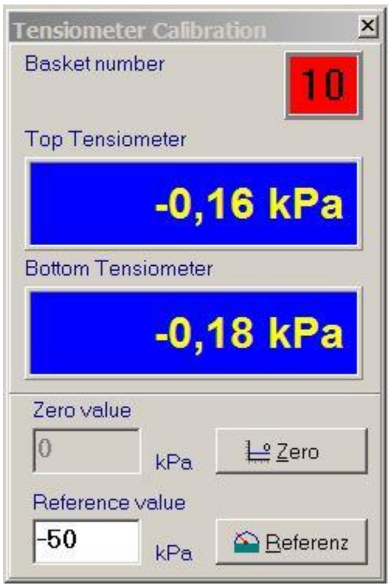
Seal the tensiometer. To do this, carefully screw the screw into the tensiometer head.

Note: A video tutorial for filling the tensiometer can also be found on our website.

6.2. Calibration



For the calibration of the tensiometers use the calibration cable to connect the sample holder with the ku-pF. When connecting, care must be taken to ensure the correct connection position (red marks).



To calibrate the tensiometers connect the computer with the ku-pF using the Connect button in the software. Then switch to the calibration menu by selecting 'Work→Calibration' or the Calibration icon in the software menu.

The current tensiometer readings are shown in the calibration menu. In the first calibration step, the zero value is set.

To set the zero value, hold both tensiometers in a horizontal position (with the ceramic cup exposed to air, but completely wetted) and press the Zero-Button in the calibration menu. In the second step the reference value has to be specified.

Put both tensiometers into the calibration chamber and secure them by using the PG plugs. Lay the chamber and the tensiometers down in a horizontal position.

Apply a vacuum of for example -50 kPa to the calibration chamber by using the manual hand pump. Insert the applied pressure value into the calibration menu und store the value by pressing the Reference-Button.

To check the calibration, apply a random pressure value to the calibration chamber and compare this value with the tensiometer readings shown in the calibration menu. After venting the manual pump, the measured value should fall back to 0 kPa.

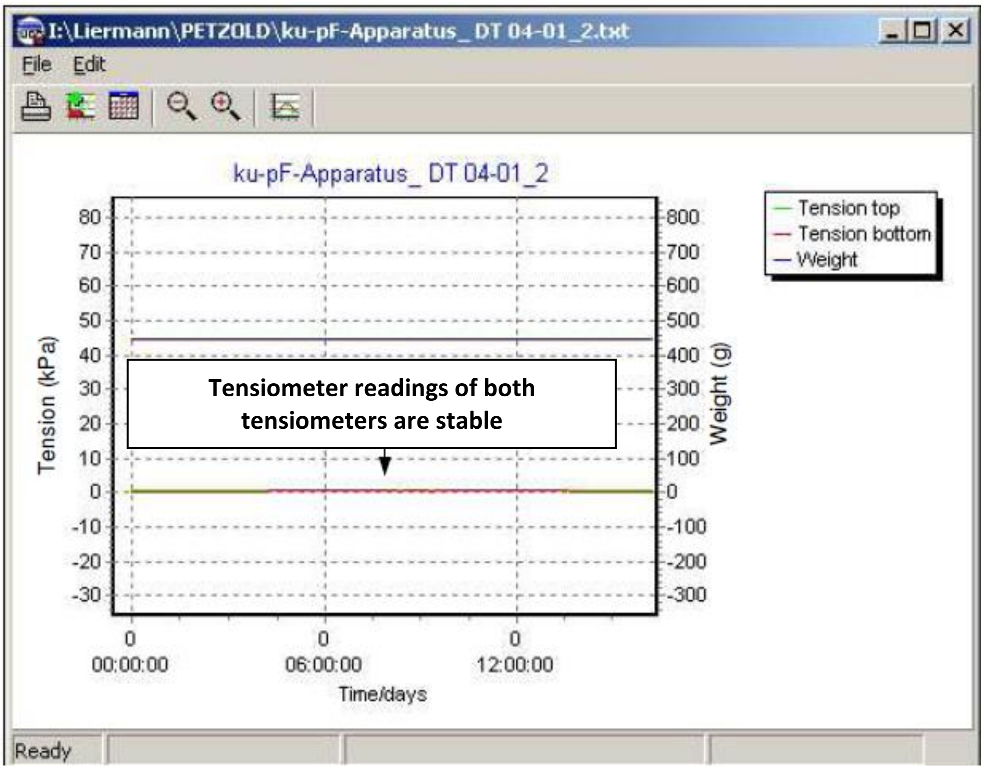
Store the prepared tensiometers in the storage cups attached to the sample holder.

6.3. Checking the zero point drift

To prevent incorrect measurements, check the zero point drift of the tensiometers after the venting and calibration and before installation in the soil samples. This step can be carried out during the saturation of the soil samples (duration approx. 12 hours).

Place the sample holder without soil a sample on the ku-pF and start a new project. The tensiometers are inserted in the storage cups filled with (bi) distilled water.

Let the test run for at least 12 hours. With fully functional tensiometers, the tensiometer readings are constant at approximately 0 kPa.



When retrieving undisturbed soil samples in the field or when creating disturbed soil samples, it is useful to seal the tensiometer holes in the sample rings with adhesive tape. At the beginning of the experiment the soil samples have to be saturated.

To saturate the samples, place the ring with the cutting edge pointing downwards on the perforated bottom plate lined with filter paper.

For saturation, the samples are placed in a water bath. Fill a suitable container up to a water level of 2-3 cm. Place the samples in the container. Hold the sample slightly tilted when submerged in the water. During this process, the holes in the bottom plate can be moistened with the aid of a spray bottle. This, and the slightly inclined position, results in the displacement of air bubbles from the holes in the bottom plate during settling of the sample. At the beginning the water level should be a little bit higher than the top edge of the perforated plate. Raise the water level about a few centimetres every few hours. For sandy samples the time interval can be chosen rather small (e.g. raise about 2 cm every hour). Clayey soils require much longer time periods. With this procedure the sample is saturated without entrapped air in the pore space. The top lid can be removed during the saturation procedure. After saturating the sample put the top lid back on. Remove the sample from the water bath and put it briefly on a (paper-) towel to remove excess water.

Remove the cover of the boreholes. Use the provided auger to pre-drill the holes for the tensiometer installation. To determine the saturated water content, weigh the soil sample together with the top lid and the perforated plate. The weights of the top lid, the sample ring, and the bottom plate have to be determined individually after the experiment. Place the soil sample with the bottom plate into the sample holder and install the tensiometers. Make sure the tensiometers have a sufficient connection to the soil. The tensiometers should be pressed in as far as the sealing ring on the tensiometer shaft can go.

Note if the material of the soil samples is prone to collapse, measure the weight of the sample first and then pre drill the holes and install the tensiometer.

Remove the transportation cups from the sample holder (evaporation) before starting the experiment.

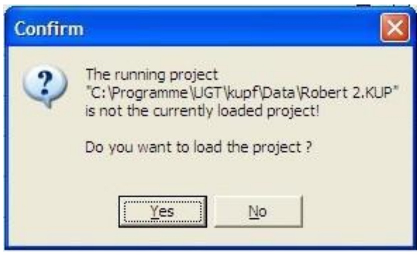
Put the sample holder on the support arm. Remove the top lid after the start of the experiment.

8. Start and run the experiment

8.1. Start measurements

Use the [Connect] button to connect the software to the device if a connection was not already built.

You may now be informed that an older project is still present in the device memory. Press “NO” to load the newly created project in the apparatus memory.



If you want to open the existing project (here: "Robert 2.kup") from the memory of the device, press “YES”. You can now save this project by pressing . After saving, press to close the already existing object and to disconnect.

Then open the newly created project and connect software and device again by pressing [Connect].

In the tool menu select the time interval for the measurements. Note that the evaporation performance can lead to a different duration of the experiment according to the soil type.

- Clay soil (short test duration) – small cycle time
- Sandy soil (medium to long test duration) – average cycle time

For the single place version of the ku-pF the time interval can be 1 (10), 2 (20), 3 (30), or 4 (40) minutes. For a one minute time interval select 10 from the popup menu.

Start measurements by pressing [Start].

You will be warned that this will overwrite all stored project data. Confirm with “YES”.

A second warning then appears, reminding you to take the tensiometer cups of the out of the baskets. Click on "OK". The measurements will now begin until they are interrupted. The test time starts at “0” again.

You can close the program, as the measurements will also be conducted without the PC connected. If you wish to stop the measurements, switch off the ku-pF apparatus on the toggle switch.

New – Generates a new project.

Open – Opens an existing project and provides the corresponding files. The existing data can be viewed in the graph.

Close – Closes an open project and simultaneously ends the connection to the ku-pF.

Save – Saves the open project. This has no influence on the files.

Connect – Establishes the connection to the ku-pF. If an ongoing project is running in the ku- pF and if no project is open in the software (or if the open project does not correspond to the ongoing project), the ongoing project is searched for in the current directory and in the standard directory.

If it is present, it is opened on request. If it is not present, a message appears with the following options:

- To search for the project yourself
- To generate a new project with the name of the ongoing project.

Break – The connection to the ku-pF apparatus is interrupted. The connection is established again by pressing CONNECT.

Read – All data are read out and written onto a file with the name of the project name +“000n” and the file extension “TMP”. If the reading out proceeds without fault, the data are then written in the data files assigned to the baskets.

You can view the current readings in the graphs.

Stop – Interrupts and ends an ongoing test. The commands CONTINUE, START, CLOCK, CALIBRATION and TOOLS are released. Only stop when the balance moved down.

Continue – The interrupted experiment is continued.

Start – A new experiment is started with the data from the open project. The start time is saved in the project file and use to display the experiment duration.

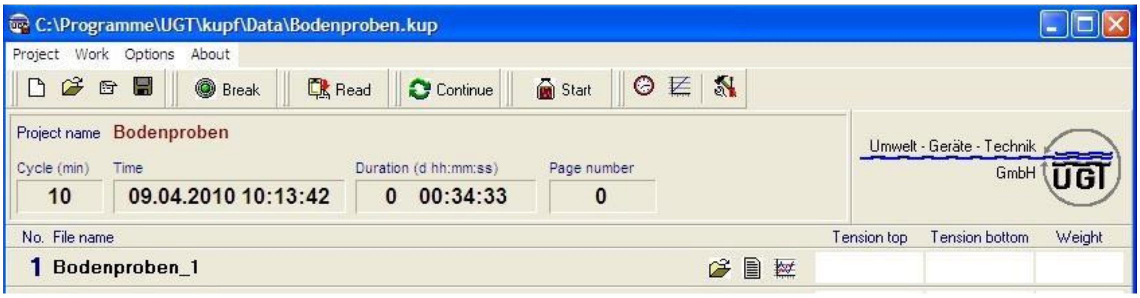
Clock – The ku-pF clock is set to the time on the PC.

Calibration – The ku-pF is switched to calibration mode and the calibration window is opened.

Tools

The Tools window is opened.

In the main menu three command buttons are available

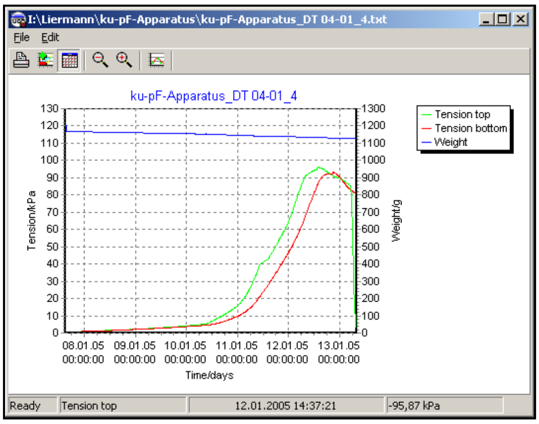


Open	Opens a file to store the read data and enables a separate file to be imported in the “.TXT” format. Caution: importing causes the existing file to be overwritten.
Text	Permits text to be entered for a more detailed description of the sample.
Graph	Displays the data as graph.

Right-clicking on the file name enables the file name (but not the file) to be deleted if the basket is not in use.

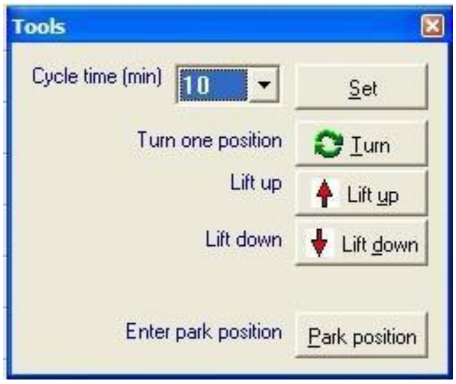
8.3. Graph menu

Several graph windows can be open at the same time. If data are being read with open window, these will only be displayed after closing the file and opening it again.



Print	Prints the graph. The graph is formatted to the size of the sheet.
Print install	Printer set-up.
Add/Remove	Individual curves can be added to or removed from the graph.
Calendar	The date and time are shown on the X-axis. If the button is not pressed, the test duration is shown on the X-axis.
Undo Zoom	Cancels the enlargement and returns to the levels set in the zoom window.
Zoom	Opens a window to set the display areas.
Points	Shows a small rectangle for each reading.
Copy	Saves a copy of the graph in the clipboard as bitmap or metafile. From there it can be inserted in other programs, e.g. Word.
The following functions can be executed using the mouse:	
Zoom	Click the left mouse button on the top-left corner of the zoom area and hold down to drag a rectangle up to the bottom right-hand corner of the desired zoom area.
Undo Zoom	Click the left mouse button and hold down to drag a window up and to the left.
Horiz. scrolling	Click the right mouse button on the graph and hold down to scroll the graph to the left or right.
Display value	Switch points on and click on the desired reading with the left mouse button. Time and reading appear in the status bar.

In addition to actuation of the buttons using the mouse, the following buttons can be used:



S	Set cycle time
T	Turn the rotating carrier
U	Scales up, D scales down
P	Park position
ESC	Close window

Variable sampling rates can be set with the cycle time according to the expected experiment duration and depending on the type of soil selected.

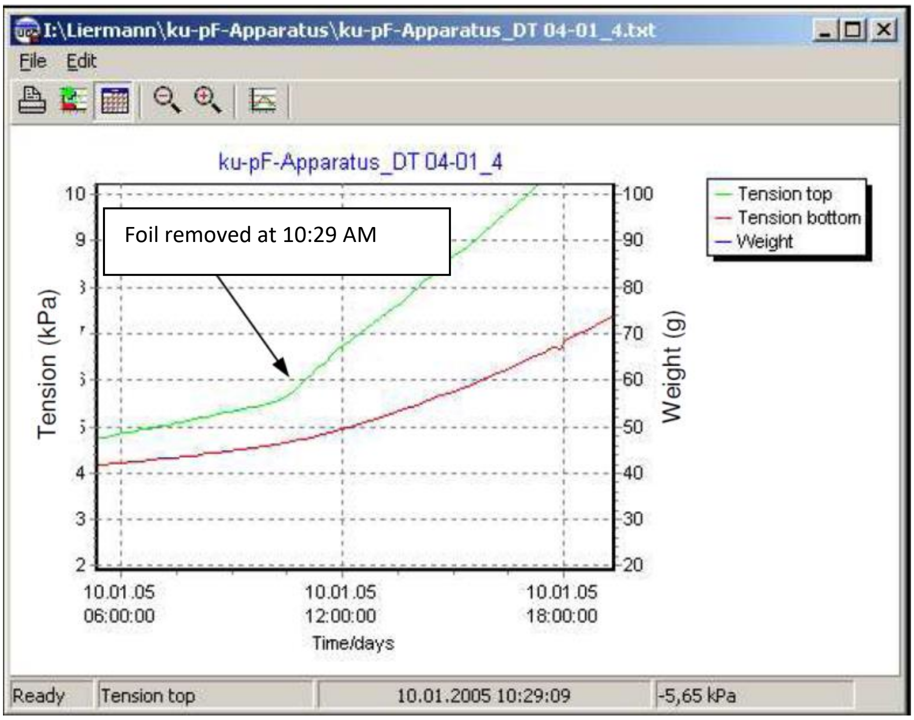
The park position of the scales platform serves as transport protection and should only be applied for this purpose. When putting into operation for the first time, the balance moves to the measurement position once the "Lift up" button has been actuated twice.

The experiment should always be started with covered soil samples. Under these conditions the flow velocity is zero and the pressure difference on the tensiometers is approx. 0.3 kPa.

After approx. 3 hours, these initial values have been recorded with sufficient statistical reliability. The covers can be removed from the samples. The mass loss is displayed in the graph menu. The flow of water through the samples begins with the start of evaporation.

The current test data are displayed during the test in the main menu. For optimal test control, the difference between the water tensions (gradient) in a sample should not exceed a magnitude of approx. 5kPa. This difference can be controlled by varying the current evaporation rate on the sample surface. The sample surface is partially covered by a perforated sheet for this purpose. When the perforated sheet is completely removed, it should be kept on the sample holder and its weight also included in the weight record.

The evaporation protection measures can be seen on the tension curve. Relevant comments should also be entered in the text box as supplementary information.

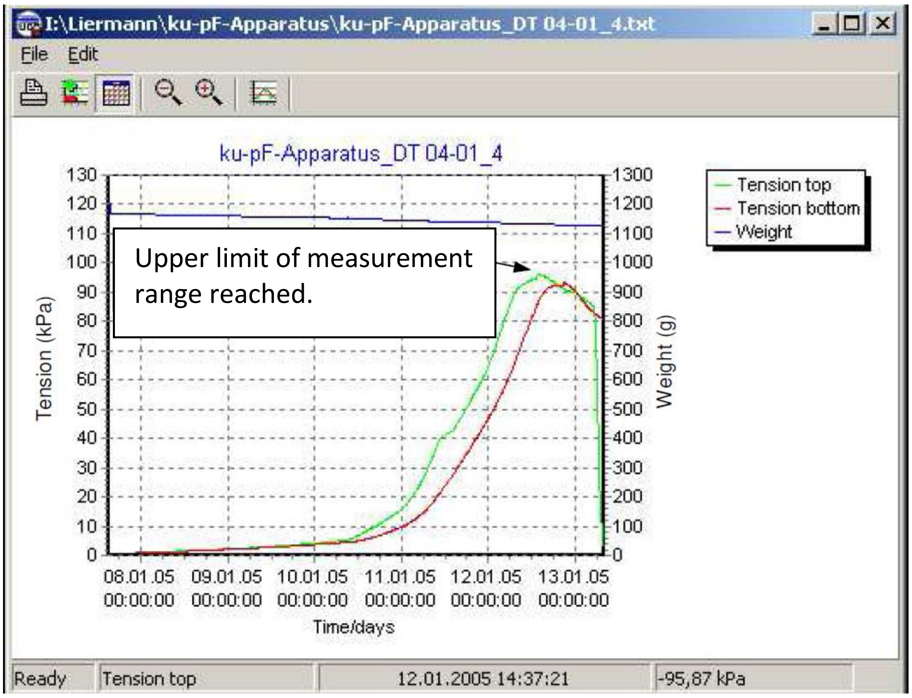


Clicking on a data point displays the tensiometer, the measurement time and the reading.

The measurement data can be transferred to the connected PC during the ongoing experiment using "READ" and can be presented online. The graphic depiction always corresponds to the last read-out date.

Establish the connection to the ku-pF by means of "Connect" the current project is loaded and the data can be read out.

The progress of the evaporation can be checked in the graph menu.



In the area of the maximum limit of the measurement range, the venting of the tensiometer starts (release of dissolved air, expansion of air bubbles). In the direct vicinity of the tensiometers, the increase in water tension is reduced by the release of water. This reduced increase in the tension curve can be explained by the measurement principle of the tensiometers and the low conductivity of the samples when discharging the water from the tensiometer.

For the evaluation of the experimental data the enclosed excel spread sheet can be used (see *Evaluation kupF SP.xlxs*).

In the first step the raw data should be double checked for measurement errors. Remove all data that may contain errors. Insert the checked raw data into the spread sheet in the tab 'Overview raw data'. Use only the data that were recorded after the lid has been removed from the sample and before air entered the tensiometers. Insert also the weight of the sample holder, sample ring, bottom plate, and the dry weight of the soil.

The spread sheet displays the entered tension values of both tensiometers and calculates the retention curve and the hydraulic conductivity curve based on the entries.

The retention curve is derived from the mean pressure head and the sample weight at each time step.

The hydraulic conductivity is derived by inverting Darcy's law:

$$K_i(\bar{\bar{h}}_i) = -\frac{q_i}{\frac{\Delta h_i}{\Delta z}+1}, \tag{9}$$

whereby

$$q_i = zl \cdot \Delta\theta_i / \Delta t_i \tag{10}$$

with

$$\Delta\theta_i = \theta_i - \theta_{i-1} \tag{11}$$

$$\Delta t_i = t_i - t_{i-1} \tag{12}$$

and

$$\Delta h_i = 0.5 \cdot \left(\left(h_2^{i-1} - h_1^{i-1} \right) + \left(h_2^i - h_1^i \right) \right)$$

$$\bar{\bar{h}}_i = 0.25 \cdot \left(h_2^{i-1} + h_1^{i-1} + h_2^i + h_1^i \right).$$

Zl and Δz represent the distance from the bottom of the sample to the centre between the two tensiometers and the distance between both tensiometers, respectively. Both values are 3 cm.

The meanings of the other variables are listed below:

Parameter	Description
K_i	Hydraulic conductivity
$\bar{\bar{h}}_i$	Mean pressure head between two time steps
Δh_i	Mean difference between tensiometer readings
$\Delta\theta_i$	Mean water content change
q_i	Specific flow rate

For the evaluation of the conductivity curve, it is sometimes advisable to carry out the evaluation on the basis of data with a coarser temporal resolution, especially when the water fluxes are very small. This can be achieved by using only every tenth measured value of the measurement series for the evaluation.

12. Further Notes

When handling the ku-pF SP please note the following:

- Every tensile load on the data cables must be avoided!
- It is absolutely essential to avoid any lifting load on the lift table!

- The lift table can be transferred to the measuring position in the "Tools" submenu by pressing the "Lift up" button twice.

- Position the ku-pF SP evenly. Align the scale.

- Before the starting the experiment, make sure that the transport cups for the tensiometers are empty or removed from the sample holder.

- When filling the tensiometers, no water should enter the hand vacuum pump.

- Do not forget to weigh the saturated samples to calculate the saturated water content.

- Check the tensiometer readings from time to time. If the upper tensiometer tends to dry out faster than the lower tensiometer, cover the top of the soil sample with a perforated foil. This can be an issue especially for sandy soils. In case of sandy soils it is recommended to create an environment with a rather small evaporation rate or to cover the soil sample with perforated foil. In sandy soil the upper tensiometer tends to dry very fast which leads to a sharp decrease in hydraulic conductivity. As a result the soil in the lower part is still very moist, which leads to a fairly huge gap between the tensiometer readings. If the difference between both tensiometers is too big the assumptions of the evaluation theory are no longer valid and the evaluation therefore not trustworthy. Try to avoid a difference higher than 10 kPa.

- Avoid any load on the measuring station during the measurement.

- Avoid drafts or fluctuations in the room temperature.

- After the end of the experiment (air inlet in the "top" tensiometer), immediately remove the tensiometers from the soil samples and rinse in distilled water.

MINASNY, B. & D. FIELD (2004):

INVERSE MODELLING OF THE EVAPORATION METHOD FOR ESTIMATING SOIL HYDRAULIC PROPERTIES USING STOCHASTIC SIMULATION. POSTER AT EUROSOIL 2004. FREIBURG I. BREISGAU. GERMANY.

MINASNY, B. & A. B. MCBRATNEY (2000):

ESTIMATION OF SORPTIVITY FROM DISC-PERMEAMETER MEASUREMENT. IN: GEODERMA 95:305-324.

PLAGGE, R. (1991):

BESTIMMUNG DER UNGESÄTTIGTEN HYDRAULISCHEN LEITFÄHIGKEIT IM BODEN DETERMINATION OF THE UNSATURATED HYDRAULIC CONDUCTIVITY IN THE SOIL). IN: BODENÖKOLOGIE UND BODENGENESE. NO. 3. BERLIN. (

SCHINDLER, U. (1980):

EIN SCHNELLVERFAHREN ZUR MESSUNG DER WASSERLEITFÄHIGKEIT IM TEILGESÄTTIGTEN BODEN AN STECHZYLINDERPROBEN (A QUICK METHOD FOR MEASURING THE WATER CONDUCTIVITY IN PARTIALLY SATURATED SOIL USING SAMPLES IN SAMPLE RINGS).