Manual

TS1

Tensiometer

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Foreword

The success of any technical system is directly depending on a correct operation. Moreover, the systems must be reliable, durable and require a minimum of maintenance to achieve target-directed results and keep the servicing low.

At the beginning of a measuring task or research project the target, all effective values and the surrounding conditions must be defined. This leads to the demands for the scientific and technical project management which describes all quality related processes and decides on the used methods, the technical and measurement tools, the verification of the results and the modelling.

The continuously optimised and synergic correlation of all segments and it's quality assurance are finally decisive for the success of a project.

Thus, I would be pleased to receive your comments and suggestions.

Yours,

Georg von Unold

Content

Signal definition of Tensiometers

Tensiometers measure soil water tensions (suction forces), which are negative pressures. Therefore, tension readings of Tensiometers should have a negative sign. In reverse, if soils are saturated and the Tensiometer is below a water level, the readings should have a positive sign (pressure of water).

This changed definition has become effective on 1st January 2006.

This manual uses kPa as the pressure unit: 1 bar = 100 kPa = 1000 hPa

1 Content of delivery

The delivery of a TS1 includes:

- Tensiometer, calibrated and filled, with 8-pin plug
- Plastic bottle protecting the ceramic cup (must be filled to half with water to keep the cup moist for storage)
- Shaft water protection disk

Available accessories: see chapter "Accessories"

2 Safety notes

Tensiometers are instruments for measuring the soil water tension, soil water pressure and soil temperature and are designed for this purpose only.

CAUTION

- **Lightning:** Long cables act as antennas and might conduct surge voltage in case of lightning stroke – this might damage sensors and instruments.
- **Frost:** Tensiometers are filled with water and therefore, are sensitive to frost! In wintertime, do not leave Tensiometers inside your car overnight or in places where it might freeze.. When installed, the TS1 empties the cup automatically only if it is programmed adequately and if the TS1 is powered continuously.
- **Overpressure:** The non destructive maximum pressure is 300 kPa. Higher pressure, which might occur for example during insertion in wet clayey soils or tri-axial vessels, will destroy the pressure sensor! The applied pressure should not exceed 200 kPa (= 2000 hPa)!
- **Electronics:** Any electrical installations should only be executed by qualified personnel!
- **Ceramic cup:** Avoid to touch the cup with your fingers. The ceramic should not have contact with grease or soap as this will influence the hydrophilic performance..

3 Description of the TS1

3.1 General

The TS1 combines the principles of a pressure transducer Tensiometer to measure the soil water tension and a pore water sampler that extracts soil solution through a porous ceramic: inside the TS1 a bidirectional miniature pump is integrated between pressure transducer and ceramic cup. A microcontroller controls the functions of pump and sensors. To refill the cup, a negative pressure, lower than the actual water tension in the surrounding soil, is established to draw water into the ceramic cup. Excess water is released through an exhaust back into the soil.

In a special version the TS1 can be equipped with an additional outlet tube. Then, the excess water is not discharged through the exhaust, but pumped up to a sampling bottle at the surface for later analysis. A complete solution for time-scheduled soil water extraction. Still, the TS1 continuous to work as a normal Tensiometer.

3.2 Power supply

The TS1 is designed for battery-powered in-the-field operation. Average current consumption is less than 3 mA. The TS1 should be powered continuously to ensure the correct performance of automatic refilling and status control.

Alternatively, the TS1 can be powered in intervals controlled by a data logger. Please allow a warm-up time of at least 10 seconds. The observing of the filling status then is limited.

3.3 Output signals

The TS1 offers analog signals for soil water tension and soil temperature, and a digital status of the refilling condition.

Soil water tension and soil temperature are linear voltage signals in a selectable range of 0 to 1V, 0 to 2 V (standard) or 0 to 5 V. This allows the connection to almost any logger or data acquisition device.

If an incorrect refilling is detected, the output signal reading will have an error voltage (default error value -99 kPa or 1 mV). This assures that only correct readings are stored. The filling condition is detected to be insufficient when a bubble of a certain size appears and the soil is too dry for automatic refilling,

The filling status signal itself (on the filling status line) is 0 V for a correct filling condition. If an incorrect filling is detected, the supply voltage is switched through and the status signal is V_{in} (= supply voltage). This can be used for example to switch a visually controllable LED.

Any changes of the signal ranges or the alarm function can be set with the Windows *tensioVIEW* software. The sensor is connected to a PC's USB interface with the *tensioLINK* converter cable. Both are available as accessories.

In the standard configuration, signal ranges and the pin connection is compatible to the T8 Tensiometer.

3.4 Serial interfaces

The TS1 has two serial interfaces. Via the RS485 compatible tensioLINK interface all functions can be carried out. The USB-converter *tensioLINK* with the *tensioVIEW* software allows the direct connection of the Tensiometer to a PC, for taking readings directly, for downloading readings and for the sensor's set-up configuration.

Furthermore, with the RS485 interface a robust and cost-effective bus network for linkage of numerous tensioLINK-sensors can be established. Cable lengths up to several kilometres are possible. Data loggers with RS485 interface can read out the sensors directly. Please ask UMS for details about the RS485 data protocol.

Then, a SDI12 interface is available for connection to adequate systems. SDI12 has to be activated with the tensioVIEW software. Then, one of the two analog lines are disconnected and used for the SDI12 line.

3.5 Sensor body and shaft

The sensor body incorporates the temperature probe and the exhaust. Stainless steel capillary tubes connect to the inside of the ceramic cup. The material is durable glass-fibre reinforced plastic.

The blue shaft houses the electronic components, the pressure sensor and the miniature pump. These parts are accessible for maintenance. Dual sealing rings ensure a reliable moisture protection.

3.6 Pressure transducer

The piezoelectric pressure transducer measures the pressure differentially to atmospheric pressure. The atmospheric pressure is conducted through the white, water-tight but air-permeable membrane on the cable, through the cable and then to the transducer.

- ❗ The white membrane must always have contact to atmosphere . Do not allow that it might be submersed in water or soil.
- ❗ The max. allowed pressure is 200 kPa. Higher pressure will destroy the transducer. Please observe that high pressures can already appear when the Tensiometer is inserted in a wet, clayey soils or in vessels. Always control the pressure during installation, and slow down the insertion.

3.7 Miniature pump

The integrated miniature flexible-tube pump was developed by UMS specially for the TS1. The ability to pump equally in both directions makes this pump quite unique. The current pressure status can be quickly re-established after a soil water extraction. Thus, the soil disturbance is reduced to a minimum.

Before freezing, the ceramic cup can be pumped dry completely.

High precision of gear and pump bearing offer excellent running smoothness and durability.

Flexible-tube pump

The pump can be installed inside a tube with an inner diameter of only 34 mm without loosing it's performance.

3.8 Temperature measurement

A Pt1000 with accuracy class 1/3 DIN B is used as temperature sensor. Additionally, the probe is calibrated to ±0,05 K at 15°C.

The tip of the temperature sensor dips into the Tensiometer cup's water. Thus, the best possible thermal contact to the soil is achieved. A very short measuring pulse excludes errors by self heating.

The correlation of water tension/water content is temperature depended. The influence is low with water tensions from 0 … 10 kPa (0 … 0,6 kPa/K), but with tensions over 100 kPa it is:

$$\Psi = (R\ T/M)\ \ln p/p_o$$

with Ψ = water tension, R = gas constant (8,31J/mol K)
M = molecular weight, p = vapour pressure
p_o = saturation vapour pressure at soil temperature

(see vapour pressure tables by Scheffler/Straub, Grigull)

3.9 Filling status indicator

The filling status is checked with two different methods which are alternatingly executed in regular intervals when the TS1 is connected to power. The threshold value when a filling is determined as insufficient is pre-set, but can be changed in the sensor configuration.

3.9.1 Differential pressure method

During a short pumping cycle the pressure change inside the cup is measured very precisely. With the pressure change the dead volume (air inside the cup) can be determined. With this method the TS1 can determine the size of a bubble, if the cup is empty, and even if the ceramic is saturated or not. This test is the fundamental part for the refilling process. The interval between two tests is micro-controlled, depending on the soil situation. Standard is once a day.

The tension measured before the pumping test is quickly re-established to prevent any soil disturbance of the soil water tension.

3.9.2 Heat flux measurement

The integrated temperature probe is used as a heat flux sensor. As in a fluid the self heating is less than in air, an air bubble can be detected by measuring the heat flux in a defined time. In comparison to the differential pumping method, the heat flux method is less accurate, but absolutely no influence of the soil water tension measurement occurs.

The heat flux method replaces the previously used infra-red indicator in UMS Tensiometers, offering a much more constant accuracy in the long run.

3.10 Ceramic cup

- Do not touch the cup with your fingers. The ceramic should not have contact with sweat, grease or soap as this will influence the hydrophilic performance.

To transfer the soil water tension as a negative pressure into the Tensiometer, a semi-permeable diaphragm is required. This must have good mechanical stability and water-permeability, but also have gas impermeability.

The cup consists of ceramic Al_2O_3 sinter material. The special manufacturing process guarantees homogeneous porosity with good water conductivity and very high firmness. Compared to conventional porous ceramic our cup is much more durable.

The bubble point is higher than 600 kPa. If the soil is dryer than 600 kPa the negative pressure inside the cup decreases and the readings go down to 0 hPa.

With these characteristics this material has outstanding suitability to work as the semi permeable diaphragm for Tensiometers.

3.11 Reference air pressure

The reference atmospheric air pressure is conducted to the pressure transducer via the air permeable (white) Teflon membrane and through the cable. The membrane does not absorb water. Water will not pass through the membrane into the cable, but condensed water inside the cable will leave the cable through the membrane.

- The white membrane on the cable must always have contact to air and should never be submersed into water.

4 Filling and refilling

4.1 Self refilling

For correct soil water tension readings, the TS1 has to be filled bubble-free with water. An air bubble inside the cup would reduce the response to tension changes. If the bubble gets too big, this would lead to false measurements.

After a dry period or many dry-wet cycles, the TS1 will refill itself by reversing the suction process. The TS1 regularly checks the filling status, and in case will perform a self-refilling.. During the dry period as well as during the refilling process the reading will have an error value. The output signal will show a correct tension reading not before the cup is filled correctly again. This ensures that no false readings are stored.

4.2 Filling in the lab

When supplied, the TS1 is filled correctly and ready for installation. The cup is covered with a water filled bottle to keep the ceramic moist. The bottle should be kept on the ceramic when the Tensiometer is stored.

The filling has to be regenerated when the cup is dry or it is obvious that air and bubbles are inside the cup. Theoretically, the TS1 could be installed with an empty cup, but as the saturation of the cup might take a while, it is recommendable to fill the Tensiometer before installation.

Do not remove the cup and fill water into the inside! Insert the TS1 with the empty cup in a beaker with degassed distilled water. Slightly tilt it so the mark on the exhaust points upwards. Connect the power supply. Now, the refilling is executed automatically. When the cup has been completely dry, the procedure might take up to one day. With a still wet ceramic, the refilling will take for a few hours. The procedure is finished when the tension signal shows about 0 kPa.

5 Concept and installation

5.1 Selecting the measuring site

The installation spot should be representative for the soil horizon! Therefore, in heterogenic soils, classifying drillings should be made before or during installation.

On farmed sites with vegetation root spreading and root growth during the measuring period must be considered. Fine roots will grow around the Tensiometer cup as this is a poor but still secure source of water. Therefore, avoid the root zone or move the Tensiometer from time to time depending on the root growth.

Disturbing effects like waysides, the rim of a field, slopes or dints must be avoided or considered in the interpretation of the measuring results.

5.2 Number of Tensiometers per level

To verify the results, at least three Tensiometers per soil level and with the identical soil, vegetation and climatic conditions should be implemented. Thus, irregular values as well as the variableness of the water situation can be determined. Guiding principle: More heterogeneous sites and soil structures require a higher number of Tensiometers.

5.3 Extent of a site

Large distance along with high equidistance between the measuring spots will reduce the influence of sectional heterogeneity. Therefore, equidistant spots are mostly used to measure the heterogeneity of the soil, the cultivation or the observed development.

The following points limit the maximum length for the signal cables:

- Required accuracy: In single-ended applications every meter of cable over 10 m reduces the accuracy. (Please read chapter "Connecting the TS1" on how to compensate the voltage drop of sensors which are connected single-ended.)
- Local danger of lightning stroke: Cables act as antennas and therefore should be as short as possible.

Lengths of more than 100 m are possible for analog signals but not recommendable. The available UMS connecting cables are described in the chapter "Accessories". For long distances the connection with the error-free serial interface is recommendable.

5.4 Jacket tubes

Jacket tubes are useful with shafts longer than 2 m, in pebbly soils or gravel, and for horizontal installations from inside a well or pit hole. The jacket tube should end 30 to 50 cm away from the cup so leaking or condensation water is not conducted to the cup. The inner diameter of the jacket tube should be at least 50 mm.

5.5 Lightning

Measuring instruments in the field are always endangered by over-voltages. Whenever technically feasible, over-voltage and false polarity protection are realised. If you have questions about an optimal integration of the T8 into a measuring system, please contact our system engineers.

Still, there is no absolute certain lightning protection! Lightning strokes are not predictable. The more extensive a site is, the more important is the installation of a protection system which could be passive with ground spears – preferably with groundwater contact, or active with each sensor and logger individually equipped with a lightning protection module. This normally is quite costly but with expensive equipment might be well worthy.

❗ Never create a conductive connection between measuring system and lightning protection!

5.6 Theft and vandalism

The site should be protected against theft and vandalism as well as against any farming or field work. Therefore, the site should be fenced and signposts could give information about the purpose of the site. Cables should be protected against rodents.

5.7 Documentation

For every measuring spot you should:

- Measure out the position where the pressure sensor will be placed. (A must for installations below the ground surface).
- Take documenting photos before, during and after installation.
- Save a soil sample.
- Write down installation depth and angle with each sensor identification (serial number).
- Mark all connecting cables with the corresponding sensor identification on each end.
-

5.8 Selecting the installation angle

An installation position would be ideal if the typical water flow is not disturbed by the Tensiometer. No preferential water flow along the shaft should be created. Therefore, Tensiometers are preferably installed at an angle.

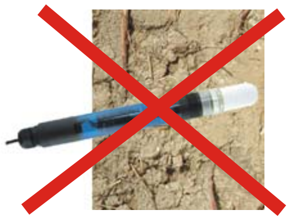
Moreover, the installation in an angel is necessary for a correct self-refilling and for completely removing air bubbles from the cup.

"Vertical" installation from the top

When installed from the surface, an angle of 25° to 65° from the vertical line is optimal for refilling. Still, any angle between 0° and 90° is suitable.

- Turn the shaft so that the red mark beside the exhaust points upwards.

"Horizontal" installation in an upwardly angle



Do not install a TS1 in an upwardly angle because then the self-refilling will not work.

You will need a special version of TS1 if this installation angle is wanted.

5.9 Ideal conditions for installation

For the installation of Tensiometers, the ideal conditions are:

- Frost-free soil.
- Coarse clay or loess.
- In soil types loess, coarse clay, loam or clay as well as in highly organic soils (humus) preferably with a water tension close to saturation (moist).
- In sandy or pebbly soils with a water tension over 10 kPa (rather dry).
- Low skeletal structure (gravel). The more gravel in a soil the more often the drilling has to be repeated to reach the required depth.

5.10 Installation procedure

For the installation in the field the following tools are required:

- Auger with diameter 25 mm, ideally the UMS Tensiometer gouge auger with shaped blade tip
- An auger with 40 mm diameter
- Rule, spirit level, goniometer, marker pen
- Pipe for filling in the slurry paste
- Minute book, maybe camera for documentation of site and soil profile
- Perhaps PE-plastic bags for taking soil samples from the site

Installation procedure

1. Measure and mark the required drilling depth on both augers and the Tensiometer shaft. Drill a hole with diameter 40 mm and a depth that is 20 cm shorter than the final installation depth. Exactly in the centre of the hole drill down another 20 cm with the 25 mm auger. Save the soil from this depth in a bag for documentation.
2. Mix a paste of water and fine, pounded soil material. Use a pipe (diam. 20 mm) to fill the paste into the bottom of the hole.
3. Remove the water filled bottle from the ceramic cup. Pull it off or carefully turn it clockwise.

❗ Turn clockwise only. Do not leave the cup without the water filled bottle for too long as the cup will dry out.

4. Connect the Tensiometer to an Infield7 handheld measuring device or any other read-out unit to control the pressure during insertion. Carefully insert the TS1. Use only light pressure. The red mark on the exhaust must point upwards exactly!.

❗ The pressure must not exceed 200 kPa. Slow down insertion if necessary.

❗ Do not use force or a hammer to insert the Tensiometer

❗ The red mark on the exhaust must point upwards exactly

5. Push down the shaft water retaining disk to a position directly on the soil surface. Water flowing down the shaft will not disturb measurements.
6. Leave on the protective cap on the plug if the plug is not connected.
7. Connect the Tensiometer signal wires as specified or attach the Tensiometer plug to the suitable connecting cable.
8. Note serial number, site position, installation depth and angle, The angle can be stored inside the sensor (with tensioVIEW or the Infield7) for automatic water column compensation.

6 Connecting the TS1

The T8 is fitted with an 8-pin plug. The plug can be connected to a Infield7 handheld measuring device. The Infield7 displays and stores the soil water tension, the soil temperature and the filling status.

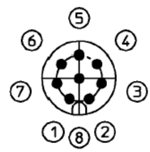
With the extension cables offered by UMS as accessories the T8 can be connected to a data logger or any other data acquisition devices.

Please observe the max. supply voltage of 20 V_{DC}. Never connect the signal outputs of the T8 to a supply voltage source!

❗ Cover Tensiometer plugs with the supplied protective caps anytime it is not connected to an extension cable.

6.1 Wire specifications

8-wire cable and 8-pin plug M12

Signal	Wire	Pin	Function	Plug pins
V_{in}	white	1	Power supply plus, 6 … 20 V_{DC}	
GND	brown	2	Power supply minus	
A-OUT+1	green	3	Analog output 1 (Pressure)	
A-OUT-	yellow	4	Analog minus	
digital OUT	grey	5	Irrigation signal digital	
RS485-A	pink	6	RS485 two-wire A	
RS485-B	blue	7	RS485 two-wire B	
A-OUT+2 / SDI12	red	8	Analog output 2 (temperature) or SDI12	

6.2 Connecting the indicator

Some data logger types require a pull-down resistor (for example 10 kOhm) against ground for the indicator. Other logger types already have an internal pull-down resistor, or a pull-up resistor to 5 V, for example for connecting a reed switch. The external pull-down resistor must be smaller than the logger internal pull-up resistor or at least be in a relation so the logger will recognize the zero level. Please contact UMS for assistance to connect the indicator.

6.3 Offset correction for non horizontal installation

The Tensiometer is calibrated for horizontal installation (for example from a service well). If it is installed from the surface in a non horizontal position, the vertical water column drawing on the pressure sensor has to be compensated. A Tensiometer should not be installed absolutely vertical, but with an angle of at least 5° away from the vertical line. In this case a water column of 5 cm additionally draws on the pressure sensor and causes a shift of 0,5 kPa. This means that a value of 0,5 kPa will be indicated instead of the actual value of 0 kPa. The offset correction can be programmed in the TS1 with the tensioVIEW software. When deliverd, this function is not active as the later installation angle is not known.

Find a manual correction use the folwoing values:

Angle to vertical line	10°	30°	45°	60°	70°	90°
Offset correction in [kPa] = [mV]	-0,49	-0,43	-0,35	-0,25	-0,17	0

! The installation angle can be stored with the TS1 configuration. Then, the compensation is executed automatically. When delivered, the Tensiometer is set for horizontal installation, but the setting can be changed with the tensioVIEW software.

6.4 Measuring error for single-ended connections

In general a data logger with differential inputs should be preferred. This means both the plus signal as well as the minus signal of each sensor are measured. On many data loggers less channels are required for single-ended measurements, which means only the plus signals are measured and related to the common sensor supply ground. In this case, the voltage drop, depending on the current consumption and the cable resistance, influences the reading and must be compensated:

Current consumption: 3 mA; cable resistance: 82 Ω/km

⇒ Voltage drop inside a cable with length 10 m:

$$U_{ERROR} = R \times I = 0{,}82\ \Omega \times 3\ mA = 2{,}5\ mV$$

⇒ Error for water tension (1 mV equal to 0,1 kPa): 2,5 mV = 0,25 kPa

⇒ Error for temperature (1°C equal to 20 mV): 2,5 mV = 0,13 K

This means for a 10 meter cable: 100 kPa = 2,5 mV, -100 kPa = 2002,5 mV and -30°C = 2,5 mV, + 70°C = 2002,5 mV. The characteristic lines are lifted for +025 kPa and +0,13 K per 10 m cable. The incline is not influenced.

For minimising this error the output signal range can be set to a different configuration. Normally it is sufficient to set a tension range of 10 … -90 kPa. Thus, the error is reduced to the half.

7 Service and maintenance

7.1 Calibration

The TS1 is calibrated when supplied. Tensiometers can be sent back to UMS for re-calibration. For re-calibration on your own, the required tools are available as an accessory.

Depending on the time of operation of the pump and the frequency of refilling routines (many periods with dry soil), the pump has to be maintained and the flexible tube has to be replaced. The time of operation can be checked with the tensioVIEW software.

❗ A re-calibration and maintenance is recommended after two years.

7.2 Frost

❗ Tensiometer are filled with water and therefore are endangered by frost! With temperatures below–5°C do not leave filled Tensiometers in your car, in a measuring hut, etc.

❗ Do not fill the Tensiometers with Ethanol, as this is corrosive for some materials (i. e. PMMA) and might destroy them.

Also it is not recommendable to fill the Tensiometers with Decalin, mono-ethylene-glycol, di-ethylene-glycol, etc. These could harm any of the materials, destroy the ceramic cup or leak into the soil.

Specially designed Tensiometers which can be filled with Ethanol are available on request. They can be used to temperatures down to - 20°C.

7.3 Emptying of the TS1 before freezing

If there is the possibility that the cup might freeze, the TS1 has to remain connected to power supply continuously to allow the pump to operate and to empty the cup if necessary. This is executed automatically when temperature drops below a set limit (standard 2°C). When temperature rises again, the cup is refilled automatically.

- If the water inside the cup freezes (for example during a power breakdown) the pressure transducer will be torn and possibly the cup might break..

8 Additional notes

8.1 Interpretation and maximum measuring range

Since no pressure smaller than vacuum can appear in the Tensiometer, the atmospheric pressure (reference pressure) limits the measuring range of the Tensiometers. Additionally the measuring range is reduced by the vapour pressure of the Tensiometer's filling water, depending on the temperature. At 20 °C the vapour pressure is 23.4 hPa. The maximum measuring range at an atmospheric pressure of 95 kPa is calculated as:

95 kPa - 23.4 hPa = 926.6 hPa

The vapour pressure exponentially rises with temperature. A higher ambient temperature and lower atmospheric pressure reduces the measuring range.

The above considerations are ruled out by the boiling point shift, enabling a Tensiometer to measure beyond the vapour pressure. This status is reproducible, but cannot be quantified.

If the soil gets dryer than 85 kPa the reading will halt at the value of the steam point (i. e. 927 hPa at 20°C and 95 kPa atmospheric pressure) By diffusion and minor leakage this value will drop within months.

If the soil gets dryer than 1000 kPa the reading will drop much faster as air will enter the cup. Evaluating this will give further information, especially if measurements are taken with TDR probes at the same time, as with this the extrapolation of the pF-curve in the range of 850 … 1000 kPa determined.

Vapour pressure influence on water tension/water content relation:

If temperature rises from 20°C to 25°C in a soil sample with constant water content, the water tension gets smaller about 8.5 hPa.

Temperature	4°C	10°C	16°C	20°C	25°C	30°C	50°C	70°C
Pressure change per Kelvin in [hPa]	0,6	0,9	1,2	1,5	1,9	2,5	7,2	14

8.2 Correlation of water column and pressure

Please also observe the correlation of pressure and water column if the Tensiometer is used as a piezometer or water level transmitter.

Pressure = density x gravity x height

Density of water at 20°C: 0,998205 kg/cubic decimetres; at 4°C: 1,0 kg/dm^3.

[Pa] = [N]/[qm] [N] = [kg/m qsec]

[kg] = [Pa qm/m] [Pa] = kg/[qqm qsec]

A water column of 1 meter causes a pressure p of:

p [Pa= N/qm] = 998,205 kg/qqm x 9,81 m/qs x 1m

p = 9792,39 [N/qm x Pa qs/m /qqm x m/qs x m] = 9,792 kPa

In reverse a pressure of 10 kPa at 20°C is caused by a water column of 102,15 cm.

8.3 Osmosis

The ceramic used has a pore size of 1 μm. Thus, ions can hardly be kept out. An influence of the measured value by osmotic effect is negligible under normal circumstances. If the TS1 is dipped into saturated NaCl solution 1 kPa are measured. Either consider this fault or fill the water with this solution (after it has been degassed).

9 Accessories

The following equipment is available:

9.1 Connecting and extension cables

Connecting cables for connections to data loggers, etc.. One end with female plug M12/IP67 for connection to a Tensiometer, the other end with loose wires:

UMS-article:	CC-8/5	(length 5 m)
	CC-8/10	(length 10 m)
	CC-8/20	(length 20 m)

Extension cables with one each male and female plug M12/IP67:

UMS-article:	EC-8/10	(length 10 m)
	EC-8/20	(length 20 m)

Clips to mark your cables, set of numbers 1 to 910, 30 pcs. ea.: **KMT**

9.2 Tensiometer augers

Tensiometer gouge auger with specially shaped blade. The tip of the blade has the same shape and diameter as the Tensiometer cup. A set includes a handle with hammering head, gouge auger and extensions (100 cm).

UMS-article: **TB-25, TB-40**

9.3 Handheld measuring device

Infield7 handheld measuring device for taking and storing spot readings of soil water tension, temperature and filling status. For all UMS Tensiometers.

UMS-article: **INFIELD7**

9.4 Expert guide

The TS1 offers many function which are not described in this manual but in a further manual called "Expert guide". Please download this guide from our webpage: www.ums-muc.de . The guide also describes the use of the tensioLINK interface, the bus network linkage and wiring.

9.5 tensioLINK USB converter with tensioVIEW software

With the tensioLINK USB-converter sensors and devices with tensioLINK interface are connected to a PC for configuration, downloading stored readings and performing online measurements with tensioVIEW software.

Sensors and devices are connected to the converter's 8-pin plug, type M12/IP67. Power supply is offered by the USB port.

The tensioVIEW software with manual and driver for the converter are supplied on CD-Rom.

UMS article no. : **tensioLINK-USB**

10 Contact

Please take advantage of our consulting service – we want you to achieve optimal results with our instruments.

With pleasure we would like to receive your comments, inspirations, critics.

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11 Technical specifications

Dimension, material		
Ceramic	Al_2O_3 sinter, length 60 mm, diameter 24 mm	
Sensor body	Acrylic and glass-fibre reinforced PA66GF	
Shaft	Acrylic PMMA, diameter 25 mm	
Cable		
Standard cable length		
with shaft < 120 cm	1,5 m from sensor body	
with shaft > 121 cm	0,6 m from end of shaft	
Plug	8-pin, thread M12, protective rate IP67 (waterproof)	
Sheath	Durable, UV-resistant PUR	
Pressure sensor		
Destructive pressure	max. 2 bar (±200 kPa)	
Pressure sensor, physical	+200 kPa ... -85 kPa	
Measuring ranges		
Soil water tension	0 kPa ... + (-) 85 kPa	Tensiometer
Water pressure	-(+) 100 kPa ... 0 kPa	Piezometer
Soil temperature	-30 ... +70°C	
Standard analog signals		
Soil water tension	0 ... 2 V = +100 kPa ... -100 kPa, linear	
Temperature	0 ... 2 V = -30 ... +70°C	
Warm-up	1 s	
Optional analog signals		
Pressure or temp. signal	0…1 V, 0…5 V (2 x single ended)	
Optional pressure ranges	+200…-200 kPa, 0…-100 kPa, -10…+90 kPa	
Optional temperature ranges	-10…40°C, 0…20°C	

Accuracy	
Soil water tension	± 0,5 kPa
Temperature	± 0,1 K (-10...+30°C); ± 0,4 K (-30…+70°C)
Resolution	16 Bit
Accuracy	±0,5 mV (0,6…1,4 V); ±2 mV (0…2 V); ±5 mV (0...5 V)
Standard alarm output	
Filling status OK	Switch open (high impedance)
Filling status insufficient	Switch closed (supply voltage V_{in} connected through)
Max. Output current	250 mA
Optional alarm output	
Optional functions	Threshold or window comparator switch value for pressure, temperature or supply voltage

Sensors are supplied with standard settings unless ordered differently. Please check the supplied calibration certificate.

All optional settings require the tensioLINK USB-adapter and the tensioVIEW software for programming.

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