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TensioMark®

Manual for installation and use of Tensiomarks

May 2014

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Content

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1 General

Tensiomarks measure a special aspect of soil moisture, the soil matric potential. The matric potential (synonyms: pressure head, tension, or water potential) is an expression for the binding forces of water to the soil matrix and indicates the energy acting on the soil water and keeping it against the force of gravity inside the soil matrix. Because of adsorption and capillary forces the soil causes a water tension on the soil water. This matric potential is the highest at low water contents and decreases with increasing water content. The relation between matric potential and water content is shown in Fig. 1 for three different soil textures:

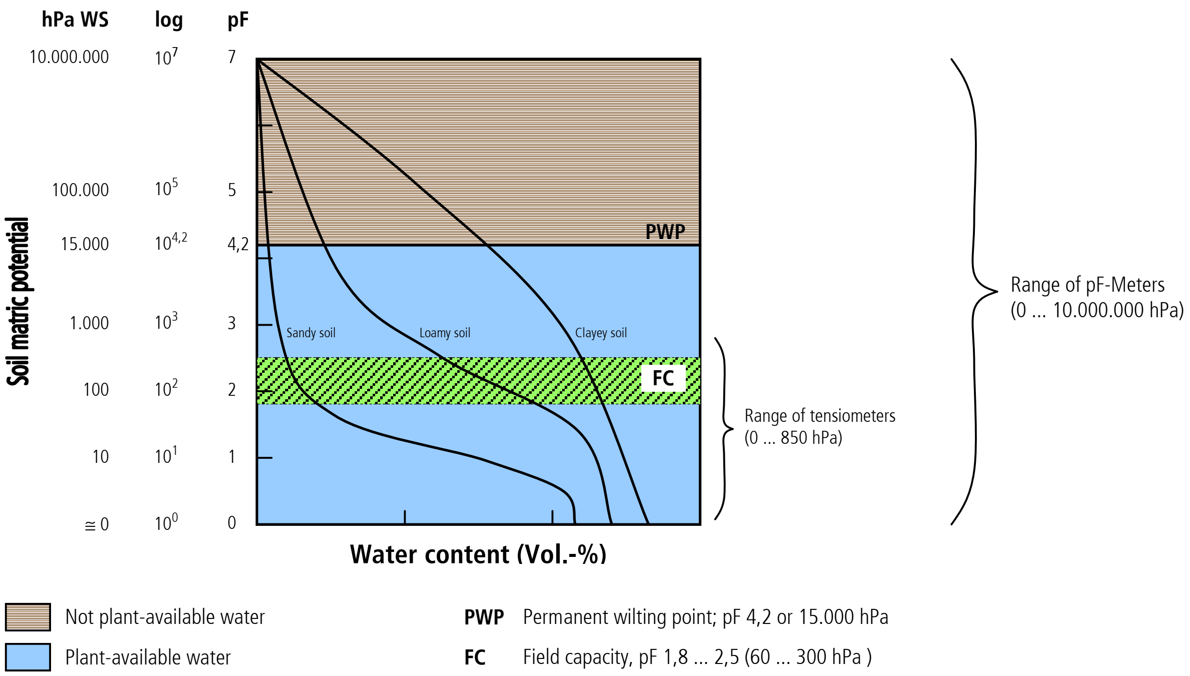

Fig. 1: Relation between matric potential and water content of different soils (Scheffer & Schachtschabel, Lehrbuch der Bodenkunde)

The matric potential is often measured in hPa. Because of the extremely wide measuring range of Tensiomarks (0 up to 10.000.000 hPa) the readings are logarithmized and then (analogous to the pH value) expressed as pF value. Plants are able to extract water out of the soil up to a pF value of 4,2 (15.000 hPa, Fig. 1), but they have to cope with the binding forces of the soil water and therefore have to establish identical suction forces. Hence, in studies of plant physiology the matric potential is rather used as a benchmark for the soil moisture than the water content.

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As presented in Fig. 1, the measuring range of a tensiometer, which is often used for matric potential measurements, is limited to approx. 850 hPa. That is because a tensiometer needs water as transmitting medium. Since water begins to boil at matric potentials of about 850 hPa even at low temperatures, it vaporizes completely at higher matric potentials than 850 hPa. The consequence is that measurements are interrupted and no readings can be done until the soil is re-wetted by precipitation and the porous cup is re-filled with water by the user. To be able to measure matric potentials above 850 hPa, the Tensiomark employs a new patented measuring principle, which is described in the following.

2 Technical description of the Tensiomark

2.1 Sensor construction

The sensor element is imbedded between two porous ceramic plates. The actual matric potential of the surrounding soil is – as it is with Tensiometers – leading to wetting or draining of the porous ceramic plate and thus of the sensor element. The sensor head is glued into a approx. 125 long plastic case, in which the entirely sealed electronics is situated. The sensor case is equipped with a cable screw connection, its screw thread acts as coupling element when using an installation shaft.

2.2 Measuring principle

With any change of the soil moisture the water content of the porous ceramic of the Tensiomark and simultaneously its heat capacity is varying. This varying heat capacity of the sensor head is measured with the help of an artificially generated heat pulse, which is leading to a raise of temperature in the sensor head. The amount of temperature increase is depending on the actual matric potential of the soil, because a higher water content needs more energy for warming up the sensor head and thus the temperature increase of a sensor head with a high water content is less than in a sensor head with low water content.

Within the calibration process of the Tensiomark, the heat capacity is measured exactly at different given water potentials. A list of raw values is created which is characteristic for any sensor and which is stored in the sensor electronic. To cover the great range from pF 0 up to pF 7, different methods to produce pressures have to be used.

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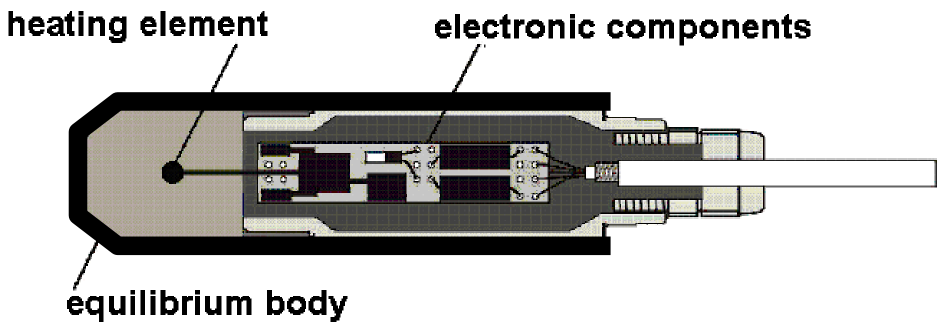

Fig. 2: Structure of the Tensiomark

While small matric potentials can be simulated by a hanging water column and pressure chambers, these methods are not employable for the establishment of matric potentials above pF 4,2. To fill this gap, the Tensiomark can be calibrated at different defined air moisture values. For example, a soil sample in equilibrium with air at 90 % relative air moisture corresponds with a pF value of 5. Only the pF value 7 is a theoretical reading, because it can only be generated under completely dry conditions in the drying oven at 105 °C. Therefore the sensors are calibrated up to a pF value of about pF 6,59 and the range up to pF 7 is covered by extrapolation.

3 Measuring range

In principle, the Tensiomark is capable to measure the whole range of water tension in the soil (pF 0 ... pF 7,0 ≙ 1 ... 10.000.000 hPa). But this wide measuring range is not needed for all kinds of applications, for example in certain applications in horticulture and irrigation agriculture, it is enough to cover a measuring range between pF 0 und pF 2,9 ≙ 1 ... 800 hPa.

Since the calibration procedure to cover the whole range is very elaborate and different techniques are needed during this process, the resulting production costs and therefore the final price of the sensor are higher.

To reduce the costs on the user side it can be reasonable to reduce the measuring range of the probe, which results in a lower end price.

Due to this mentioned reason, we offer sensors with three different measuring ranges:

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All-year-round use without limitation of the measuring range:

Tensiomark 1 (4244/1) pF 0 ... pF 7,0 ≙ 1 ... 10.000.000 hPa

Soil hydrology and catchment studies:

Tensiomark 2 (4244/2) pF 0 ... pF 3,8 ≙ 1 ... 6.500 hPa

Horticulture and irrigation agriculture

Tensiomark 3 (4244/3) pF 0 ... pF 3,0 ≙ 1 ... 1000 hPa

Important: The measuring range of each Tensiomark in delivery status is not a permanent property. The calibration of sensors with a measuring range smaller than pF 0 ... pF 7,0 can be extended by ecoTech GmbH. Please make an appointment for the recalibration in our facilities.

4 Installation

- Best results are achieved when the sensor is installed by slurrying (Details Chapter 4.1).
- Before installation Tensiomarks have to be moistened (placing the porous equilibrium body vertically into water for 10 seconds is enough).
- Completely wetted Tensiomarks must be transported very carefully and only vertically.
- The sensor has to be installed vertically or diagonally into the soil, so air can flow through the ventilation capillary.

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4.1 Sensor installation

To install the probe at the designated area a hole has to be made with an auger (e.g. gauge or Edelman auger) down to desired depth. The lower end of the hole should be made with a narrow auger, to disturb the soil around the probe as less as possible. A conical shaped Puerckhauer auger, with a pin bit diameter of approx 25 mm, is ideal for the bore whole preparation (Art.-Nr. 441/1000, 1 m effektive length or 441/1500, 1 m 1,5 m effektive length). A small quantity of stone-free soil material which has been drilled out (if possible from the installation depth) is mixed with water to generate a more or less viscous suspension and than poured into hole until its bottom, immediately for sensor installation. The amount of slurry must be sufficient to surround the probe completely. It can happen that the moisture of the slurry is sucked into the soil very rapidly, if the soil at the installation depth is very dry. This causes a thickening of the slurry, which in circumstances may not allow an optimal connection between the sensor head and the soil matrix. The water content of the slurry should be adjusted to the prevalent moisture content of the surrounding soil, in extreme case it is recommend to water the soil before installation.

Then the Tensiomark has to be pushed into the hole with the prepared slurry speedily, but very **carefully**. After installation the cavity above the probe has to be refilled with slurry or – for vertical isolation – with bentonite pellets.

4.2 Cable installation

The cables are UV- and temperature resistant (–30 und + 95 °C) and generally designed for long-term installation in the soil (see Technical Data). It is recommended to put them into cable channels (Art. 2175/KS) especially when damages by animals or high compressive load (especially in stony soils) are expected. Please note that to achieve good pressure compensation within the cable a minimal bending radius of 72 mm should be guaranteed.

Tensiomark purchased from us with connectors, come with a plastic protective cover for this plug. Please do not remove this cover during the installation of the sensor until connecting it into the matching socket. When having purchased Tensiomark from us with open cable ends (end ferrules), the ventilation capillary, visible between the singes cable wires of the Tensiomark cable, must be protected against kinking, dirt and water.

In measuring systems with ecoTech´s "envilog" data logger, Tensiomarks are normally connected to the data logger by a SDI-12 multiple socket (see chap. 5). These multiple sockets have to be protected against precipitation water. The same applies to the pressure compensation filter at the

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cable end, near the sensor plug (chap. 5.1.3). This filter has to be protected against water and contamination. If the free air flow through the filter is blocked or decreased, the response time of the sensor after moisture fluctuations in the soil can be inhibited significantly.

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5 Measuring operation

5.1 Measuring operation in the Digital mode (SDI-12)

5.1.1 What is SDI-12?

SDI-12 stands for the communication of microprocessor driven environmental sensors with data loggers via a serial data interface at 1200 baud. The SDI-12 bus system has got three important advantages:

1. Multi-parameter sensors, which measure two or more parameters simultaneously, can transmit all their readings via one single cable to a SDI-12 data logger (e.g. enviLog Maxi). For example, the Tensiomark measures not only the matric potential but also the temperature and can transmit both values consecutively to the data logger.
2. Many multi-sensors and SDI-12 multiple sockets can be connected via one single SDI-12 cable to the data logger (see below).
3. Any SDI-12 sensor type can be connected to the plugs of the SDI-12 multiple sockets (sensors for soil moisture and temperature, multi-parameter sensors for weather, water quality and others). Further information: www.sdi-12.org.

5.1.2 Setup of a measuring system with Tensiomarks in the SDI-12-Mode

To set up a monitoring station with several Tensiomarks they are connected to the SDI-12-data logger (enviLog) via a SDI-12-multiple socket (Fig. 4):

Fig. 4:

SDI-12-multiple socket to connect up to 7 sensors and/or further multiple sockets

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These multiple sockets have got 7 SDI-12-junctions to connect either 7 SDI-12 sensors or 6 SDI-12-sensors and another multiple socket, for example (Fig. 5):

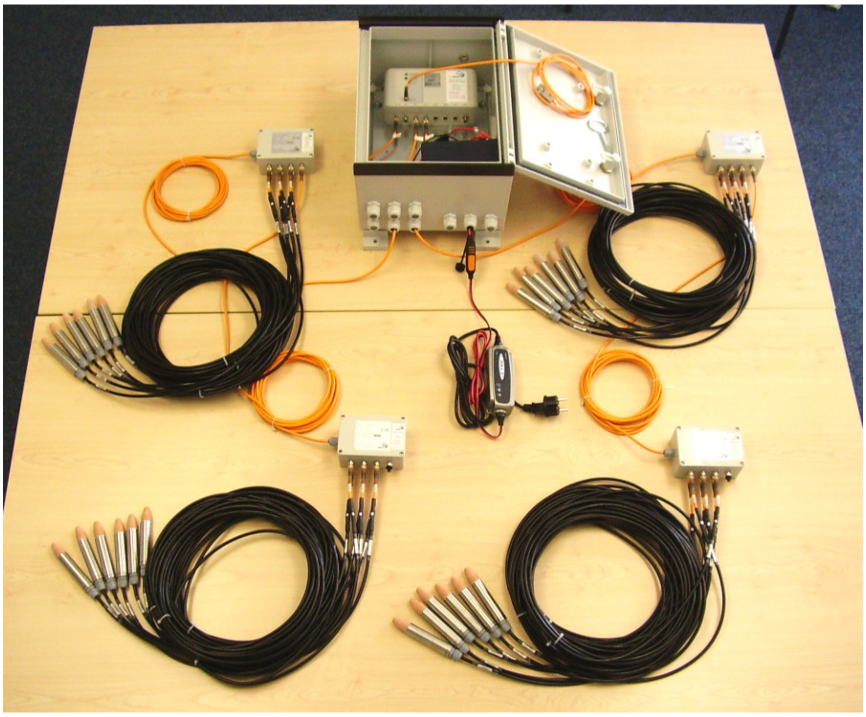

Fig. 5: Measuring system, consisting of a data logger enviLog Maxi, 4 SDI-12-multiple sockets and 24 pF-Meters

The picture shows a measuring system with 24 pF-Meters, which are connected to the data logger enviLog Maxi via 4 SDI-12-multiple sockets. The yellow data transmission cables of the upper two multiple sockets are plugged directly into the data logger's SDI-12-ports. The lower two SDI-12-multiple sockets are each connected with the seventh SDI-12-Port of the upper two multiple sockets. If the seventh socket of each lower multiple socket is free as presented here, these two sockets could be employed by further two SDI-12-multiple sockets or SDI-sensors.

In the presented compilation 48 readings from 24 sensors are transmitted to the data logger via 2 SDI-12-cables. Within such a setup, the arrangement of connected sensors on the four multiple sockets is irrelevant, because any sensor has got its own serial number and SDI-address number. By means of this each sensor is recognized by the data logger and its readings are stored in a data table in a previously defined sequence.

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Connection of Tensiomark to data-logger from other manufacturers

Our sensors are checked to be 100 % SDI-12 compatible. The Tensiomark can therefore also be connected to other SDI-12-compatbile logger systems than the enviLog logger from ecoTech. When working with long cable lengths and/or a high number of sensors it can sometimes occur, that problems with the data transmission to loggers of specific brands arise: The pulse edge of the signal flattens with increasing cable length caused by electronic dispersion and disturb the communication between the logger and sensor. To avoid this, we recommend to connect a standard metal or carbon-film resistor with 4,7 or 10 kOhm parallelly to the GND- and the SDI-12-signal wire. This increases the edge steepness and the sensor(s) are again available.

If you have questions regarding this issue, please get in touch with us.

5.1.3 Sensor identification

The end of the sensor cable is labeled with the SDI-12-address (e.g. SDI 2). Next to this sticker there is a white shrink-wrapped filter for pressure compensation (see below) and finally the serial number of the sensor (e.g. B1014B).

In operation with ecoTech data loggers, the SDI-12 address no. of each Tensiomark is combined with its serial number, which is important for the setup of the logging channels and the storage of readings in a data table (see manual of the data logger). After nomination of a sensor with a SDI-12 code number, the serial number itself is not used any more while the normal measuring process and will not be presented in the stored data.

Fig. 6: Tensionmark-cable with index numbers

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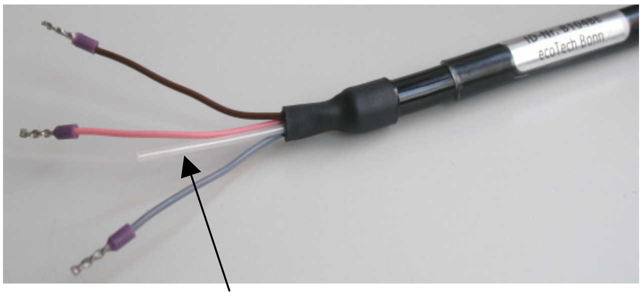
5.1.4 Wire assignment (SDI-12 mode)

Wire assignments of Tensiomarks for digital operation and for analog operation are different. All Tensiomarks have got a cable with four wires, but only three are employed. In the SDI-12 mode these are:

Brown Voltage supply (+12 V DC)

Pink Output signal SDI-12

Grey Ground / GND



Pressure compensation tube

Risk of voltage reversal!

Fig. 7: Wire assignment of a Tensiomark in the SDI-12-Mode

When using the Tensiomark with our data logger enviLog Maxi the cable is mounted to a quadripolar M8-plug. The assignment of the three wires then is as follows (SDI-12 mode):

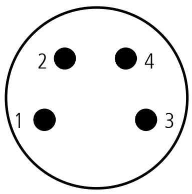
Sketch of the quadripolar sensor plug (Male part, M8)

Pin 1 Ground / GND

Pin 2 Output signal SDI-12

Pin 3 Voltage supply +12 V DC

Pin 4 not assigned



5.1.5 SDI-12 communication with Tensiomarks

There is no chronological order when (up to 7) Tensiomarks are plugged into a SDI-multiple socket, because of the data communication in a bus system (see above). The sensors are recognized automatically by the data logger because of their serial number and SDI-12 address number.

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In the following the SDI-12 commands "a" and "b" stand for the SDI-12 sensor address. Possible addresses are 0 … 9, a … z and A … Z. Factory-set value is SDI-12 address "0" for all sensors, others on demand.

Commands for the communication with SDI-12 sensors

- aI! sensor transmits identification and serial number
- aAb! change SDI-12 address from a to b
- aM! measure pF value and temperature; answer: 0082 (2 values within 8 seconds)
- aM9! measure supply voltage; answer 0011 (1 value within 1 seconds)
- aD0! display readings
- aR0! same properties as aD0!

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5.2 Measuring operation in the analog mode

5.2.1 Wire assignment

To measure the matric potential in the analog mode the cable assignment of the Tensiomark has to be as follows (see fig.):

Brown Voltage supply +12 V DC

Grey Ground / GND

White Analog output signal

Reference base for analog output white (+) is wire grey (-)

Risk of voltage reversal!

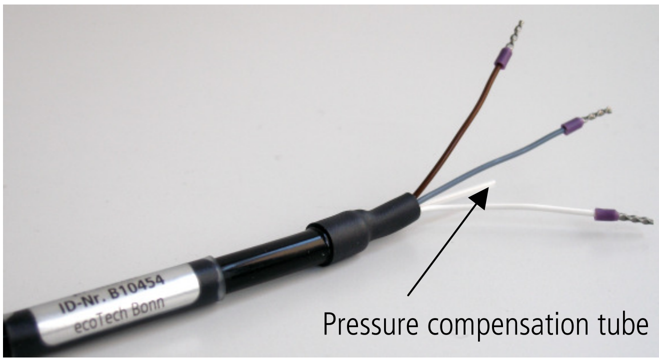

Fig. 8: Wire assignment of a Tensiomark in the analog mode

Firstly the power supply brown (+) and grey (-) have to be connected. After ca. 15 seconds of power supply the reading can be measured with the help of a Voltmeter/Multimeter [between white (+) and grey (-)]. The displayed voltage of 0 … 2.5 V corresponds to a pF value of 0 … 7.

5.2.2 Reading output

Theoretically, a Tensiomark in analog mode can be connected to a 12-V-power supply permanently. In this (rather rare) case the Tensiomark is programmed to measure the pF value not constantly but once in 15 minutes. Between the single readings – and permanently connected voltage supply – the last measured pF value is stored in the sensor and can be displayed/measured by a data logger or a multimeter/voltmeter at any time (see above, 0 … 2.5 V corresponds to a

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pF value of 0 … 7). If the sensor is powered permanently, there is always a pF value that can be read out. The only exception is the recurring measuring process (for about 5 seconds within 15 minutes).

5.2.3 Sensing cycle

In monitoring stations normally sensing cycles of minutes or hours are programmed. At this moment the data logger "awakes" from the standby mode, switches on its power supply for the sensors and stores – after a warm-up period (see below) – the readings. **Attention:** the sensing cycle of Tensiomarks must not be shorter than 15 minutes (explanation see chap. 6), but can be chosen as long as desired. Please note that the highest accuracy is reached when using a cycle of 15 min., because this is also the cycle used while the calibration process.

5.2.4 Power consumption

When the data logger is powered up, each Tensiomark consumes 55 mA, thus 20 sensors consume more than 1 A of current. It has to be ensured that the data logger can supply this current, otherwise the powers supply has to be realized with external equipment.

5.2.5 Warm-up period

"Warm-up period" means the period between the moment of "awaking" (power up) of the logger and storing the readings of the connected sensors. With any power-up of the logger the sensors are supplied with voltage. In this moment the heating period of the Tensiomark begins, and after its duration of 5 seconds, the reading is calculated by the sensor and can be logged.
The length of the warm-up period normally can be chosen in the software of a data logger. Our experiences with different kinds of analog data loggers during the last years show that a warm-up period of 5 seconds is not sufficient for Tensiomarks in many cases. Hence, a warm-up period of 15-20 seconds has to be set up and afterwards it has to be assured that the measurement is working properly. To minimize the power consumption, however, it should be examined if this period can be chosen to be shorter, but this may depend on each type of data logger and must be checked again in any single case.

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6 Important operating instructions for Tensiomarks

A. Sensing cycles should be 15 minutes!

Explanation: the measuring principle is based on the emission of a heat pulse and its effect on the temperature in the sensor head. If these artificial heat pulses come one after each other in short distances, the sensor element will be warmed up stepwise and hence the readings would be affected. To avoid this adding up of heat pulses, the sensing cycle should not be shorter 15 minutes. In general, best results will be produced with sensing cycles of 15 minutes because 15 minutes cycles are used in the calibration process.

B. The installation depth is at least 10 cm!

Explanation: conditioned by its measuring principle the Tensiomark reacts sensitively on temperature variations. Normally, temperature fluctuations in a soil depth of 20 cm are damped sufficiently to enable measurements even in soils without any vegetation and therefore with direct solar radiation. A vegetation canopy dampens temperature fluctuations in soil additionally in order that a Tensiomark beyond it will provide reliable readings even in soil depths from 10 up to 15 cm.

C. Tensiomark must not be carried in water saturated condition!

Explanation: the sensor cable is equipped with a pressure compensation tube. This tube takes care that the air inside of a fully dried sensor head can escape backwards through the cable when the soil and therefore the sensor head gets wet again. By this means, the enclosure of air is prevented in case the sensor head is wetted on its whole surface simultaneously. Otherwise, it would react slowly on a varying matric potential.

When completely wetted sensors are moved suddenly or shaken, it is possible that water films and air bubbles are formed in the pressure compensation tube, which would obstruct the air flow and only can be removed by an exhaustive dehydration of sensor and cable by overpressure (only in agreement with us).

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D. Tensiomark have to be installed vertically or sloped (sensor head at the bottom), to avoid accumulations of water in the pressure compensation tube!

Explanation: the reason for this is also based on the function of the pressure compensation tube as described in section „C". To enable the airflow through this tube properly, no water must intrude into the capillary what could happen when sensors are installed horizontally and temporary water saturation of the soil. The trapped water in the capillary could remain for a longer time period and block or hinder the air flow, leading again to a slowed response time of the sensor on moisture fluctuations.

E. The shrink-wrapped filter in the cable (Fig. 6, chap. 5.1.3) has to be housed dryly and must not be touched, soiled or blocked mechanically.

F. The cable has minimal bending radius of 72 mm. Kinking the cable leads to a sealing of the ventilation capillary and therefore to a malfunction of the sensor.

G. Please fasten the cable gland cap only hand-tight, never with a wrench/spanner, because the cable could become constriceted, causing a hinderd pressure compensation.

H. Avoid damages while installation by proper preparation of installation holes! Further information on this see chap. 4 „Installation".

I. The sensor cable must not be extended without first consulting ecoTech GmbH!

J. Projects with a special risk of overvoltage (Lysimeter, exposed sites with elevated number of thunderstorms) should include a high invest in overvoltage protection.

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7 Technical data

• Ranges	
Tensiomark 1 (4244/1)	pF 0 ... pF 7,0 ≙ 1 ... 10.000.000 hPa
Tensiomark 2 (4244/2)	pF 0 ... pF 3,8 ≙ 1 ... 6.500 hPa
Tensiomark 3 (4244/3)	pF 0 ... pF 3,0 ≙ 1 ... 1000 hPa -40 ... +80 °C
• Output signal	digital (SDI-12), optional analog
• SDI-12-Signal	pF-Wert 0 ... 7, Temp. in °C
• Analog signal	0 ... 2500 mV DC for pF 0 ... pF 7
• Power supply	7 - 14 V DC (12 V recommended)
• Power consumption	inactive: 1,5 mA active: 55 mA (during measurement)
• Duration of measurement	4 sec
• Automatic sensing cycle	15 min, only in analog mode with permanent power supply
• Waiting time	15-20 sec (Duty cycle of the data logger before measurement)
• Shortest sensing cycle	15 min
• Measuring principle	Heat capacity
• Resolution:	0,01 pF, 0,1 °C
• Accuracy:	ca. +/- 30 hPa & 5 % FS = 0,35 pF Note: In general, best results will be produced with sensing cycles of 15 minutes because 15 minutes cycles are used in the calibration process.
• Dimensions	L = 125 mm, D = 20 mm
• Cable	Standard length: 5 m. Min. bending radius: 72 mm Sheath: PUR, UV-resistant, temperature range –30 ... +95 °C
• Body	Stainless steel
• Sensor head	Ceramic

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