Equitensiometer

SOIL MATRIC POTENTIAL SENSOR

TYPE EQ2

USER MANUAL

EQ2-UM-1.3

Contents

Patents

The *Equitensiometer* is the result of a joint development between Dr Liu, UP GmbH and Delta-T Devices, and uses novel measurement techniques.

Patent application (# 19629745.1)

Copyright

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Introduction and description

The *Equitensiometer* measures **soil matric potential** - that is the negative pressure (or suction) required to extract water from between the matrix of soil particles. It is an important indication of plant water stress. The value of soil matric potential measured depends mainly on the quantity of water present and the make up of the soil, though it is also affected by temperature and salinity.

The *Equitensiometer* consists of a precision soil moisture sensor (the ThetaProbe) whose measuring rods are embedded in a porous material (the equilibrium body). This material has a known, stable relationship between water content and matric potential. When the probe is inserted into the soil, the matric potential within the equilibrium body rapidly equilibrates to that of the surrounding soils. The water content of the matric material is measured directly by the ThetaProbe, and this can be converted into the matric potential of the surrounding soil using the calibration curve supplied with each *Equitensiometer*.

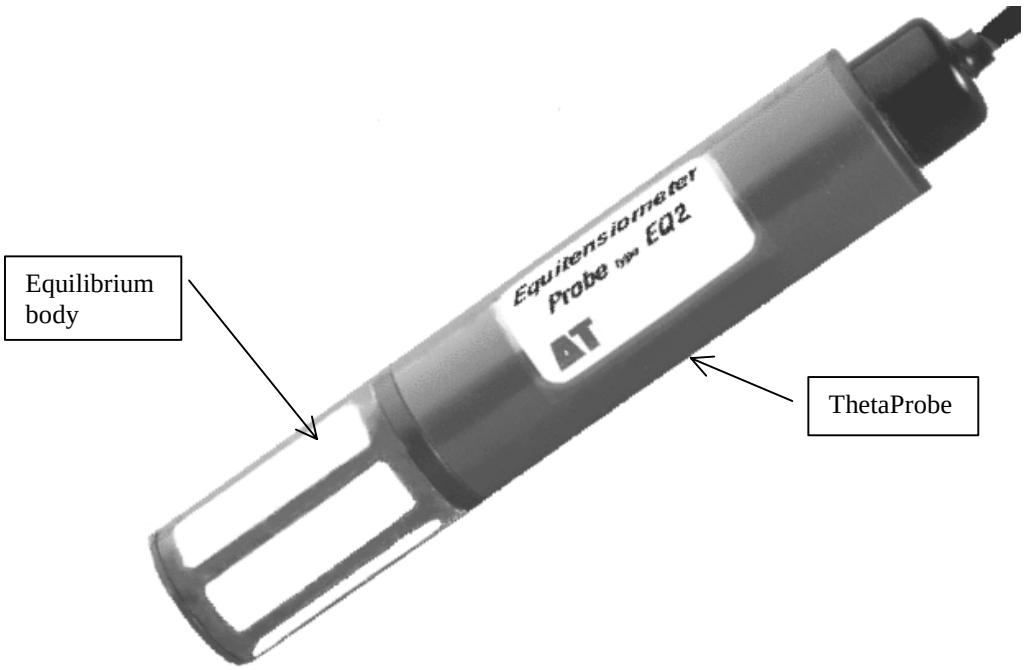


Figure 1

Installation

The *Equitensiometer* should be thoroughly wetted before use, and installed at a horizontal or slanting angle. Vertical installation may slow the response time, and also lead to incorrect readings because rainfall running down the side of the probe housing may wet the soil around the probe excessively. This is particularly important if the probe is being installed below the soil surface using a probe extension tube. Any gaps between the *Equitensiometer* and soil should be filled with quartz powder suspension. Small changes to the soil structure surrounding the probe will not affect readings.

It is important to protect the *Equitensiometer* from strong temperature fluctuations and in particular to avoid exposing the electronics and equilibrium body to different temperatures, e.g. by installing it with the case in strong sunlight. Avoid flexing the PVC cable at low temperatures. It is advisable to protect the cable before burying it in conditions where it may be attacked by soil insects etc.

Soil sampling points

The soil matric potential within a region of soil will be affected by local variations in soil density and composition, rates of percolation, runoff, evaporation and the uptake of water by nearby roots. The resultant differences in pressure will equilibrate over time at a rate which is determined by the local hydraulic conductivity.

It is important to take the degree of variability of these various parameters into account when deciding on the number of probes to use at any particular location. In particular, if the soil is known to be very heterogeneous, or the distribution of roots is very non-uniform, it will be necessary to take measurements from at least three closely-spaced locations.

Extension tubes

Optional extension tubes can be fitted to enable easier withdrawal, and to protect the cable from damage by animals, etc. Two lengths are available. ML/EX50 is 50cms long and ML/EX100 is 100cms long. These can be screwed into each other to make longer lengths, as required. The outside diameter of the extension tubes is 4cms, so an auger of approximately 5cms is recommended.

Instructions for adding extension tubes:

Carefully remove the black plastic, thread protection cover from the *Equitensiometer*. This cover protects the extension tube mating thread when extension tubes are not needed. It can be removed by sliding it up the cable.

Pass the *Equitensiometer* cable through the hole in the extension tube, ensuring that the female thread in the extension tube is towards *Equitensiometer*. Screw the extension tube onto *Equitensiometer* and hand tighten only. Repeat this process for additional extension tubes to make up the length required.

Finally, thread the cable through the black plastic thread protection cover and slide the cover into place over the male thread on the end of the extension tube. This will minimise water ingress into the extension tube.

Frost

The *Equitensiometer* will withstand frosts, but any readings taken when the water inside the probe is frozen will be meaningless.

Connections

Cable Connections

The *Equitensiometer* is supplied with a four core, screened cable which provides these connections:

Red	Power V+
Blue	Power 0V
Yellow	Signal HI, (load resistance 10KΩ minimum)
Green	Signal LO
Braid	Cable screen. Not connected within probe.

The Blue and Green leads are connected internally.

The braid screen should be connected to digital ground on the logger or other measuring unit. If not using Delta-T equipment, please refer to the manufacturer's instructions.

If you simply want to log the probe voltage directly, it can be treated as a differential voltage source of range 0 - 1.5V DC, and the attached meter or logger should be configured accordingly.

Warning: use as a single-ended voltage source will introduce measurement errors due to the sensor power return current and is not recommended.

Some *Equitensiometer* variants have a connector fitted in order to mate to the appropriate Delta-T instrumentation. Connection details are given in the relevant instrumentation User Manual.

Electromagnetic Compatibility (EMC)

The *Equitensiometer* has been assessed for compatibility under the European Union EMC Directive 89/336/EEC and conforms to the appropriate standards, provided the moisture measuring rods and probe body are completely immersed in the soil or other material being measured. The cable connecting the *Equitensiometer* to its associated instrumentation should also be routed along the surface of the soil.

If the probe is not installed in this way, some interference may be experienced on nearby radio equipment. Under most conditions, moving the equipment further from *Equitensiometer* (typically 1-2 metres) will stop the interference.

Equitensiometers installed near to each other will not malfunction due to interference.

Power supply and warm-ups

The *Equitensiometer* requires a power supply of 5 to 15V DC at approximately 20mA. For complete stability, a warm-up time of 5s is recommended, although good repeatability can be achieved using a 1s warm-up.

Battery power consumed by a probe for a single measurement taken with a 5 second warm-up time is typically: 20mA * 5s ≅ 0.03mA.h

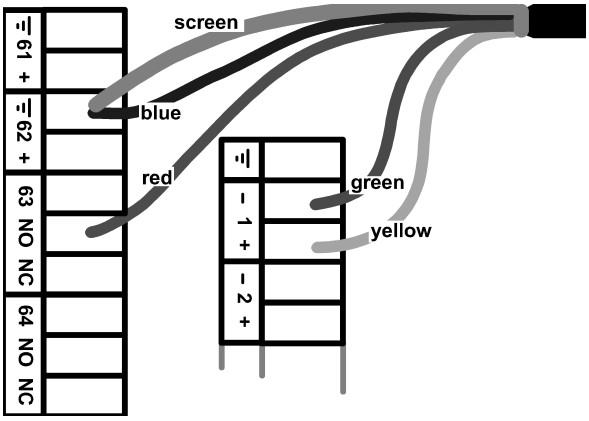
Connection and configuration for Delta-T loggers (DL2 & DL3000)

Equitensiometers can be directly powered by Delta-T loggers using their internal batteries. However, if several probes are to be used, or if the logger has to supply significant power to other sensors or accessories, we recommend powering the logger and sensors from an external power supply. Although the probe can be continuously powered, significant power can be saved by using a warm-up relay to energise the sensor just before and during a log.

The DL2e and DL3000 loggers include a minimum of two relay-controlled outputs to provide and control sensor power. Each relay is capable of switching 1A, which means that each logger can power 60 *Equitensiometers* provided they are the sole warm-up relay contact load.

DL2e connection and configuration

This diagram shows the connections for an *Equitensiometer* connected to channel 1 of a DL2e in differential mode, and powered through the loggers internal power supply. Further details can be found in the SENSORS.TXT file, which is supplied with the DL2e sensor codes for the *Equitensiometer*, and in the DL2e user manual in the Relay Channels section.



Two sensor configuration codes are supplied with the DL2e: **E2D** is intended for linearising the full range of EQ2 output (0 to -1000kPa), and **E2W** which provides more resolution at the wet end only (0 to -350kPa). You will need to enter the individual linearisation table values attached to the calibration data that is supplied with each of your *Equitensiometers*.

DL3000 connection and configuration

Full details, including example connection diagrams, are available in the online help provided with Acquire!. The DL3000 can accept linearisation tables with unequal step sizes, so you can enter the calibration table exactly as supplied, and the DL3000 will then linearise to full resolution over the full range.

Note: each Equitensiometer needs its own linearisation table.

Operational considerations

Hysteresis and response time effects

The *Equitensiometer* only reads correctly once the equilibrium state within the probe is reached. Normally there is a time lag between the change of matric potential of the surrounding soil and the response of the *Equitensiometer*. This time lag is greatest when the matric potential is changing fast, and at large (negative) matric potentials, see Table 1.

Under natural conditions, changes in matric potential are normally less than 0.01 kPa/min, so the associated errors will therefore be much lower than the values in Table 1. As shown

in Fig. 3, in both the wetting and drying phases the time lag is similar to that for transducer tensiometers.

Table 1: Hysteresis of the *Equitensiometer* in a rapid drying test. The values are much higher than under natural conditions.

Matric potential, absolute changes		Errors in kPa after minutes							
kPa	kPa/min	0	10	30	60	120	180	300	360
-98	**-.11**	**2.2**	**0.3**	**0**	**0**	**0**	**0**	**0**	**0**
-215	**-.15**	**5.6**	**5.3**	**2.6**	**0**	**0**	**0**	**0**	**0**
-376	**-.37**	**20.2**	**19.1**	**18.0**	**16.2**	**13.5**	**10.1**	**3.4**	**0**

Soil properties and salinity

The *Equitensiometer* is unaffected (not damaged) by physical soil properties (organic matter, stones, bulk density,) and most chemical soil properties (e.g. pH). No tests have been carried out in saline soils, so the performance of the *Equitensiometer* in saline soils is unknown.

Temperature

The output of the *Equitensiometer* is slightly dependent on temperature. The Calibration certificate gives values correct at 20°C. For regions with strong temperature variations, the following temperature correction should be applied.

$$\boldsymbol{Corrected\_value(mV) = measured\_value(mV) - \left\lceil \frac{temperature(^{\circ}C) - 20}{4} \right\rceil}$$

The *Equitensiometer* will not be damaged by frost, but its sensitivity to ice is very much less than water, so any measurements taken below freezing will be meaningless.

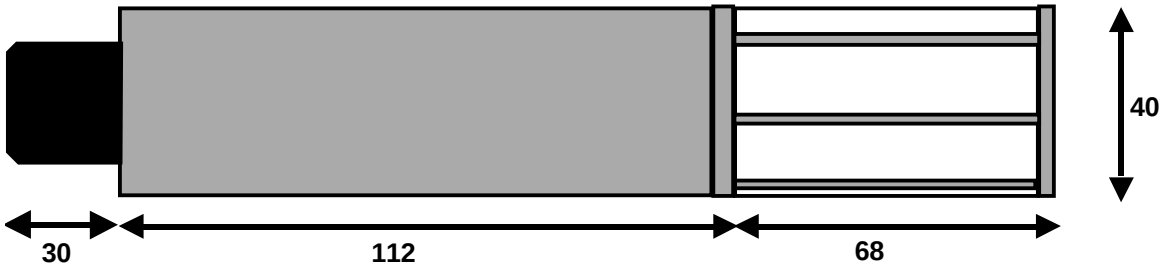
Maintenance

Large concentrations of Sodium ions may affect the calibration curves. If the equilibrium body becomes contaminated, the sodium may be washed out by repeatedly wetting it in de-ionised water, and then drying it out by inserting it into dry non-saline soil. Washing with water does not help, because in that case no exchange of water or solute takes place.

The calibration should be stable for ~2 years. It can be checked by putting the probe into de-ionised water and checking the reading against the 0 kPa value in its calibration table - at 20°C the reading should be within ± 20 mV. If re-calibration is required the probe will need to be returned to Delta-T Devices.

No other maintenance is required.

Specifications



Measurement parameter	**Matric soil water potential.**
Measurement range	**0 to -1000 kPa (-10 bar).**
Accuracy	**±10 kPa from 0 to -100 kPa,** **±5% of reading from -100 to -1000 kPa.**
Hysteresis	**not detectable if the change of matric potential is slower than 0.1 kPa/min.**
Soil types	**Suitable for all non-saline soil types.**
Protection	**Electronics sealed to IP68 (to 5m), all exposed parts suitable for long-term burial.**
Temperature	**0 to 40 °C. (Not damaged by use in frozen soils, but readings will be incorrect)**
Power supply	**5 to15 V DC, 20 mA typical, 1 s stabilisation.**
Output signal	**approximately 150 to 550 mV, non-linear.** **(Calibration data and graph supplied with each sensor)**
Dimensions	**Diameter: 40 mm, Length: 210 mm.**
Cable length	**Standard: 5 m, Maximum: 100 m.**

Definitions

Soil Matric Potential

Studies of plant growth need to characterise the **availability** of water to the plant, and this is usually done using the water potential, Ψ, which measures the suction necessary to extract water from the soil, and has units of pressure, kPa. Components of this water potential are contributed by gravity, atmospheric pressure, osmosis, and the capillary action of the soil particles. This last component, called the Soil Matric Potential, Ψ_M, is highly dependent on the wetness of the soil, and varies from 0 kPa at field capacity, down to approximately -1500 kPa at the permanent wilting point.

Soil Water Content versus **Soil Matric Potential**

The relationship between soil matric potential and soil water content is called the **soil water release curve** (it seems to have about 5 other names as well). It differs enormously form one soil to another, particularly from clay soils at one extreme to sandy soils at the other. There is no generalised method of converting from soil water content to matric potential, though a number of expressions have been found which have been successfully applied to a restricted list of soil types, see for example references 2.

References

1. Gaskin, G.J., and J.D. Miller. 1996. Measurement of soil water content using a simplified impedance measuring technique. J. agric. Engng Res. 63: 153-160

2. Campbell, G.S. 1974. A simple method for determining unsaturated conductivity from moisture retention data. Soil Sci. 117:311-314

Our Conditions of Sale ref: COND/91/11 set out Delta-T's legal obligations on these matters. For your information the following paragraphs summarise Delta-T's position but reference should always be made to our Conditions of Sale which prevail over the following explanation.

Instruments supplied by Delta-T are guaranteed for one year against defects in manufacture or materials used. The guarantee does not cover damage through misuse or inexpert servicing, or other circumstances beyond our control.

For the UK this means that no charges are made for labour, materials or return carriage for guarantee repairs.

For other countries, the guarantee covers free exchange of faulty parts during the guarantee period.

Alternatively, if the equipment is returned to us for guarantee repair, we make no charge for labour or materials but we do charge for carriage and UK. customs clearance.

We strongly prefer to have such repairs discussed with us first, and if we agree that the equipment does need to be returned, we may at our discretion waive these charges.

SERVICE AND SPARES

We recognise that some users of our instruments may not have easy access to technically specialised backup.

Spare parts for our own repairable instruments can be supplied from our works. These can normally be despatched within 1 working day of receiving an order.

Spare parts and accessories for sensors not manufactured by Delta T, but supplied by us individually or as part of the weather station or other system, may be obtained from the original manufacturer. We will endeavour to obtain parts if requested, but a certain amount of additional delay is inevitable.

Should it prove necessary, instruments may be returned to our works for servicing. We normally expect to complete repairs of our own instruments within 2 days of receiving the equipment. Other manufacturers' sensors supplied by us and returned for servicing will take longer. They will have to be returned to the original manufacture for servicing, and may be subject to additional delays of two to four weeks.

Users in countries that have a Delta-T Agent or Technical Representative should contact them in the first instance.

EQ2

interpolation of calibration values for DL2e sensor tables

calibration values

serial No	**EQ2 9/1**

values in the mV column	
used to calc. Interpolated tables	
original calibration table	
"as supplied"	
Output (mV)	Matric Potential (-kPa)
420	0
411	10
402	20
383	40
365	60
346	80
305	100
198	150
170	200
152	300
140	400
132	600
129	1000

	step size (kPa)
	10
interpolated table	
WET range	
mV	Matric Potential (-kPa)
420.0	0
411.0	10
402.0	20
392.5	30
383.0	40
374.0	50
365.0	60
355.5	70
346.0	80
336.5	90
305.0	100
283.6	110
262.2	120
240.8	130
219.4	140
198.0	150
192.4	160
186.8	170
181.2	180
175.6	190
170.0	200
168.2	210
166.4	220
164.6	230
162.8	240
161.0	250
159.2	260
157.4	270
155.6	280
153.8	290
152.0	300
150.8	310
149.6	320

	step size (kPa)
	50
interpolated table	
FULL range	
mV	Matric Potential (-kPa)
420.0	0
374.0	50
305.0	100
198.0	150
170.0	200
161.0	250
152.0	300
146.0	350
140.0	400
138.0	450
136.0	500
134.0	550
132.0	600
131.6	650
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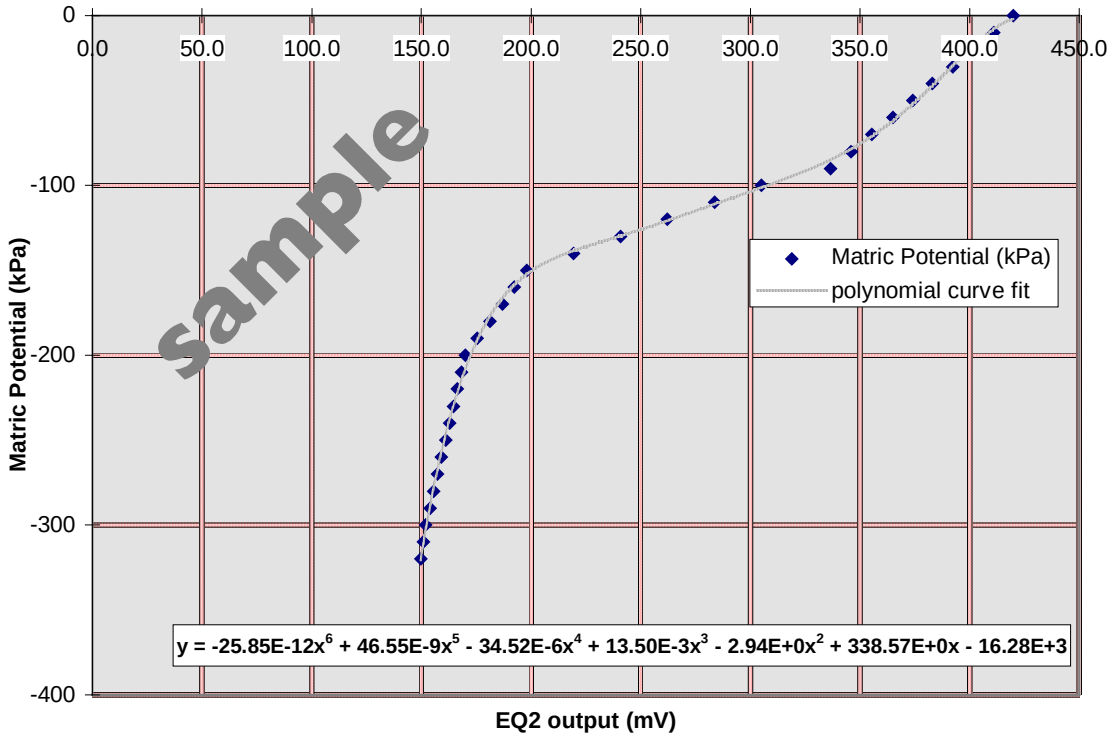
130.9	750
130.5	800
130.1	850
129.8	900
129.4	950
129.0	1000

Wet range



Full range