METER

5TE

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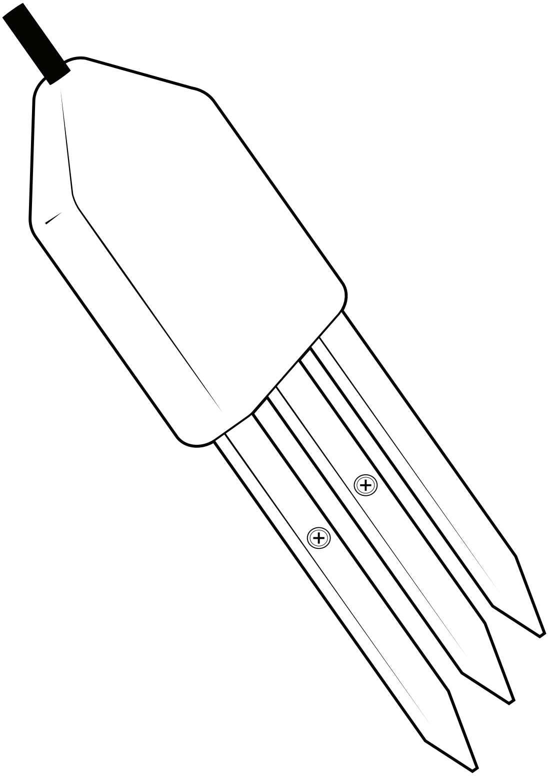

1. INTRODUCTION

Thank you for choosing the ECH$_2$O 5TE Volumetric Water Content (VWC), Temperature, and Electrical Conductivity (EC) sensor from METER Group.

This manual guides the customer through the sensor features and describes how to use the sensor successfully. METER hopes the contents of this manual are useful in understanding the instrument and maximizing its benefit.

Prior to use, verify the 5TE arrived in good condition.

2. OPERATION

Please read all instructions before operating the 5TE to ensure it performs to its full potential.

⚠ **PRECAUTIONS**

METER sensors are built to the highest standards, but misuse, improper protection, or improper installation may damage the sensor and possibly void the manufacturer's warranty. Before integrating 5TE into a system, make sure to follow the recommended installation instructions and have the proper protections in place to safeguard sensors from damage.

2.1 INSTALLATION

When selecting a site for installation, remember that the soil adjacent to the sensor surface has the strongest influence on the sensor reading and that the sensor measures the VWC of the soil. Therefore, any air gaps or excessive soil compaction around the sensor and in between the sensor prongs can profoundly influence the readings.

- If installing sensors in a lightning-prone area with a grounded data logger, please read Lightning surge and grounding practices.
- Test the sensors with the data logging device and software before going to the field.

Do not install the sensor adjacent to large metal objects such as metal poles or stakes. This can attenuate the sensor's electromagnetic field and adversely affect readings. In addition, the 5TE sensor should not be installed within 5 cm of the soil surface, or the sensing volume of the electromagnetic field can extend out of the soil and reduce accuracy.

Because the 5TE has gaps between its prongs, it is also important to consider the particle size of the medium. It is possible to get sticks, bark, roots or other material stuck between the sensor prongs, which will adversely affect readings. Finally, be careful when inserting the sensors into dense soil, as the prongs can break if excessive sideways force is used when pushing them in.

When installing the 5TE, it is imperative to maximize contact between the sensor and soil. The sensor body needs to be completely covered by soil (Figure 1).

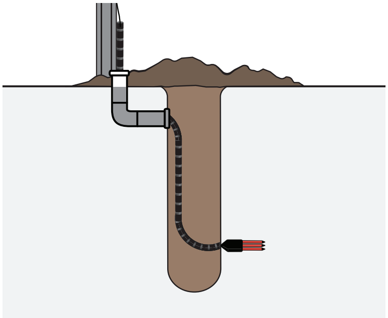

Figure 1 Example of 5TE proper installation

For most accurate results, the sensor should be inserted into undisturbed soil. There are two basic methods to accomplish a high-quality installation.

With either of these methods, the sensor may still be difficult to insert into extremely compact or dry soil.

NOTE: Never pound the sensor into the soil! If there is difficulty inserting the sensor, loosen or wet the soil. This will result in inaccurate VWC measurements until the water added during installing redistributes into the surrounding soil

METHOD 1. HORIZONTAL INSTALLATION

1. Excavate a hole or trench a few centimeters deeper than the depth at which the sensor is to be installed.
2. At the installation depth, shave off some soil from the vertical soil face exposing undisturbed soil.
3. Insert the sensor into the undisturbed soil face until the entire sensor is inserted. The tip of each prong has been sharpened to make it easier to push the sensor into the soil. Be careful with the sharp tips!
4. Backfill the trench taking care to pack the soil back to natural bulk density around the sensor body of the 5TE.

METHOD 2. VERTICAL INSTALLATION

1. Auger a 3-in hole to the depth at which the sensor is to be installed.
2. Insert the sensor into the undisturbed soil at the bottom of the auger hole using a hand or any other implement that will guide the sensor into the soil at the bottom of the hole. Many people have used a simple piece of PVC pipe with a notch cut in the end for the sensor to sit in, with the sensor cable routed inside the pipe.
3. After inserting the sensor, remove the installation device and backfill the hole taking care to pack the soil back to natural bulk density while not damaging the black overmolding of the sensor and the sensor cable in the process.

View a visual demonstration on proper installation of the sensor in How to install soil moisture sensors.

The sensor can be oriented in any direction. However, orienting the flat side perpendicular to the surface of the soil will minimize effects on downward water movement. The sensor measures the average VWC along its length, so a vertical installation will integrate VWC over a 10-cm depth while a horizontal orientation will measure VWC at a more discrete depth.

The 5TE sensor makes EC measurements by exciting one screw on the sensor and measuring the current that moves from that screw to the adjacent grounded screw. The distance between the screws is an important part of the EC calculation. If 5TE sensors are placed close together (within 20 cm), it is possible for some of the current that leaves the excited screw to pass through the nearby sensor ground screw, thus producing an erroneous sensor reading.

This problem occurs regardless of which logging system is being used if the ground wires are connected at all times. If sensors must be close together (e.g., column experiments), consider a multiplexing option that would isolate the ground wires.

If installing sensors vertically at short depth intervals, do not bury them directly over the top of each other. Although at times the vertical distance may be less than 20 cm, the sensors can be staggered horizontally so they are not directly above each other, thus meeting the distance requirement.

2.2 REMOVING THE SENSOR

When removing the sensor from the soil, do not pull it out of the soil by the cable! Doing so may break internal connections and make the sensor unusable.

2.3 CONNECTING

The 5TE works most efficiently with METER ZENTRA, EM60, or Em50 data loggers, and it can also be used with other data loggers, such as those from Campbell Scientific, Inc.

5TE sensors require an excitation voltage in the range of 3.6 to 15 VDC.

The 5TE sensors come with a 3.5-mm stereo plug connector (Figure 2) to facilitate easy connection with METER loggers. 5TE sensors may be ordered with stripped and tinned wires to facilitate connecting to some third-party loggers (Section 2.3.2).

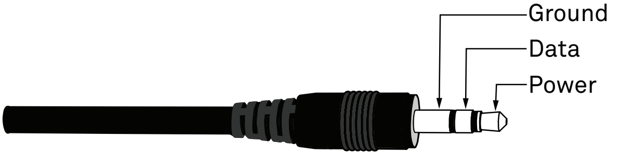

Figure 2 Stereo plug connector

The 5TE sensor comes standard with a 5-m cable. It may be purchased with custom cable lengths for an additional fee (on a per-meter basis). This option eliminates the need for splicing the cable (a possible failure point). However, the maximum recommended length is 75 m.

2.3.1 CONNECT TO METER DATA LOGGER

The 5TE sensor works seamlessly with METER ZENTRA, EM60, or Em50 data loggers. Check the METER download webpage for the most recent data logger firmware. Logger configuration may be done using either ZENTRA Utility (desktop and mobile application) or ZENTRA Cloud (web-based application for cell-enabled ZENTRA data loggers).

1. Plug the 3.5-mm stereo plug connector into one of the sensor ports on the logger.
2. Using the appropriate software application, configure the chosen logger port for 5TE.
3. Set the measurement interval.

2.3.2 CONNECT TO A NON-METER DATA LOGGER

The 5TE sensor can be used with non-METER (third-party) data loggers. Refer to the third-party logger manual for details on logger communications, power supply, and ground ports. 5TE sensors can be ordered with stripped and tinned (pigtail) connecting wires for use with screw terminals. Connect the 5TE wires to the data logger as illustrated in Figure 3 and Figure 4, with the power supply wire (brown) connected to the excitation, the digital out wire (orange) to a digital input, and the bare ground wire to ground.

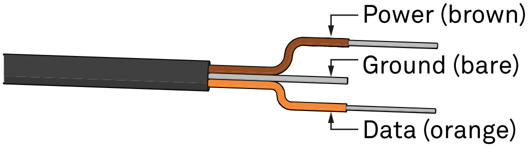

Figure 3 Pigtail wiring

NOTE: Some 5TE sensors may have the older Decagon wiring scheme where the power supply is white, the digital out is red, and the bare wire is ground.

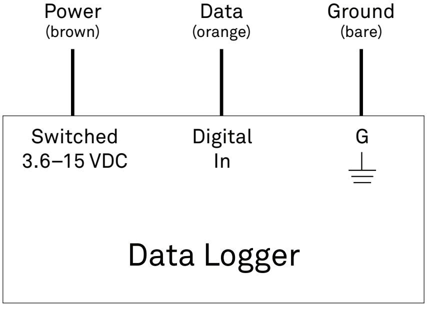

Figure 4 Wiring diagram

NOTE: The acceptable range of excitation voltages is from 3 to 15 VDC. To read 5TE sensors with Campbell Scientific data loggers, power the sensor from a switched 12-V port or a 12-V port if using a multiplexer.

If the 5TE cable has a standard 3.5-mm stereo plug connector and will be connected to a non-METER data logger, please use one of the following two options.

Option 1

1. Clip off the 3.5-mm stereo plug connector on the sensor cable.
2. Strip and tin the wires.
3. Wire it directly into the data logger.

This option has the advantage of creating a direct connection with no chance of the sensor becoming unplugged. However, it then cannot be easily used in the future with a METER readout unit or data logger.

Option 2

Obtain an adapter cable from METER.

The adapter cable has a connector for the female stereo plug connector on one end and three wires (or pigtail) for connection to a data logger on the other end. The stripped and tinned adapter cable wires have the same termination as seen in Figure 4: the brown wire is excitation, the orange is output, and the bare wire is ground.

NOTE: Secure the stereo plug connector to the pigtail adapter connections to ensure the sensor does not become disconnected during use.

Because 5TE sensors use digital communication, they require special considerations when connecting to an SDI-12 data logger. Read SDI-12 example programs to view sample Campbell Scientific programs.

2.4 COMMUNICATION

The 5TE sensor communicates using two different methods, DDI serial and SDI-12. Please see the 5TE Integrator Guide for detailed instructions.

When using serial communication, the 5TM makes a measurment when excitation voltage is applied. Within about 120 ms of excitation, three measurement values are transmitted to the data logger as a serial stream of ASCII characters. The serial out is 1200 baud asynchronous with 8 data bits, no parity, and 1 stop bit. The voltage levels are 0 to 3.6 V and the logic levels are TTL (active low). The power must be removed and reapplied for a new set of values to be transmitted.

The ASCII stream contains three numbers separated by spaces. The stream is terminated with the carriage return character. The first number is raw dielectric output. The second number is 0 (ignore this value), and the third number is raw temperature. The following explains how to convert the raw values into their standard units.

The raw dielectric value (ε_{Raw}) is valid in the range 0 to 4094. This corresponds to dielectric permittivity values 0.00 to 81.88. The 5TM uses the ε_{Raw} value of 4095 to indicate the dielectric permittivity portion of the sensor is not working as expected.

The ε_{Raw} value is converted to dielectric permittivity (ε_a) with the Equation 1:

$$\varepsilon_a = \frac{\varepsilon_{Raw}}{50}$$ **Equation 1**

The raw temperature value (T_{Raw}) is valid in the range 0 to 1022. The 5TM uses a compression algorithm to extend the range of temperatures that can be represented by a 10-bit value. The sensor sends temperature with 0.1 of 1 °C resolution for the range –40 to 50.0 °C. For the range 50.5 to 111.0 the sensor sends temperature with a 0.5 of 1 °C resolution. Temperatures outside this range are truncated to the maximum or minimum values as appropriate.

The 5TM uses the T_{Raw} value of 1023 to indicate the temperature portion of the sensor is not working as expected.

If $T_{Raw} \leq 900$, then $T_{Raw2} = T_{Raw}$.

If $T_{Raw} > 900$, then $T_{Raw2} = 900 + 5(T_{Raw} - 900)$.

Temperature (°C)=$(T_{Raw2} - 400)/10$.

3. SYSTEM

This section describes the 5TE sensor.

3.1 SPECIFICATIONS

MEASUREMENT SPECIFICATIONS

Volumetric Water Content (VWC)	
Range	
Mineral soil calibration	0.0–1.0 m^3/m^3
Soilless media calibration	0.0–1.0 m^3/m^3
Apparent dielectric permittivity (ε_a)	1 (air) to 80 (water)
Resolution	0.0008 m^3/m^3 from 0%–50% VWC
Accuracy	
Generic calibration	± 0.03 m^3/m^3 typical
Medium-specific calibration	±0.02 m^3/m^3
Apparent dielectric permittivity (ε_a)	1–40 (soil range), ±1 ε_a (unitless) 40–80, 15% measurement
Temperature	
Range	−40 to +60 °C
Resolution	0.1 °C
Accuracy	±1 °C
Bulk Electrical Conductivity (EC)	
Range	0–23 dS/m (bulk)
Resolution	0.01 dS/m from 0–7 dS/m 0.05 dS/m from 7–23 dS/m
Accuracy	±10% from 0–7 dS/m User calibration required from 7–23 dS/m

COMMUNICATION SPECIFICATIONS

Output

DDI serial or SDI-12 communication protocol

Data Logger Compatibility

Data acquisition systems capable of 3.6- to 15.0-VDC power and serial or SDI-12 communication

PHYSICAL SPECIFICATIONS

Dimensions

Length	10.9 cm (4.3 in)
Width	3.4 cm (1.3 in)
Height	1.0 cm (0.4 in)

Prong Length

5.0 cm (1.9 in)

Operating Temperature Range

Minimum	–40 °C
Typical	NA
Maximum	+60 °C

NOTE: Sensors may be used at higher temperatures under certain conditions; contact Customer Support for assistance.

Cable Length

5 m (standard)
75 m (maximum custom cable length)

NOTE: Contact Customer Support if a nonstandard cable length is needed.

Connector Types

3.5-mm stereo plug connector or stripped and tinned wires

ELECTRICAL AND TIMING CHARACTERISTICS

Supply Voltage (VCC to GND)

Minimum	3.6 VDC
Typical	NA
Maximum	15.0 VDC

Digital Input Voltage (logic high)	
Minimum	2.8 V
Typical	3.0 V
Maximum	3.9 V
Digital Input Voltage (logic low)	
Minimum	–0.3 V
Typical	0.0 V
Maximum	0.8 V
Power Line Slew Rate	
Minimum	1.0 V/ms
Typical	NA
Maximum	NA
Current Drain (during measurement)	
Minimum	0.5 mA
Typical	3.0 mA
Maximum	10.0 mA
Current Drain (while asleep)	
Minimum	NA
Typical	0.03 mA
Maximum	NA
Power-Up Time (DDI serial)	
Minimum	NA
Typical	NA
Maximum	100 ms
Power-Up Time (SDI-12)	
Minimum	100 ms
Typical	150 ms
Maximum	200 ms

Measurement Duration	
Minimum	NA
Typical	150 ms
Maximum	200 ms

COMPLIANCE

Manufactured under ISO 9001:2015
EM ISO/IEC 17050:2010 (CE Mark)

3.2 ABOUT 5TE

The 5TE is designed to measure the water content, EC, and temperature of soil (Figure 5). The 5TE uses an oscillator running at 70 MHz to measure the dielectric permittivity of soil to determine the water content. A thermistor in thermal contact with the sensor prongs provides the soil temperature, while the screws on the surface of the sensor form a two-sensor electrical array to measure EC. The polyurethane coating on the 5TE circuit board protects the components from water damage and gives the sensor a longer life span.

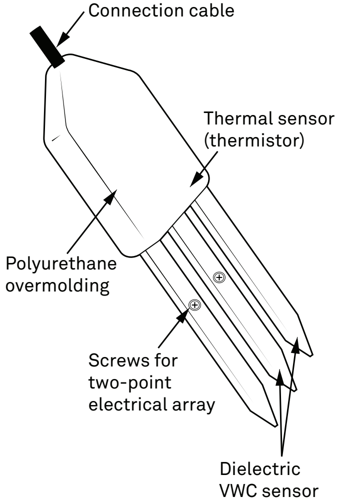

Figure 5 5TE components

3.3 THEORY

The following sections explain the theory of VWC, temperature, and EC measured by 5TE.

3.3.1 VOLUMETRIC WATER CONTENT

The 5TE sensor uses an electromagnetic field to measure the dielectric permittivity of the surrounding medium. The sensor supplies a 70 MHz oscillating wave to the sensor prongs that charges according to the dielectric of the material. The stored charge is proportional to soil dielectric and soil VWC. The 5TE microprocessor measures the charge and outputs a value of dielectric permittivity from the sensor.

3.3.2 TEMPERATURE

The 5TE uses a surface-mounted thermistor to take temperature readings. The thermistor is underneath the sensor overmold, next to one of the prongs, and it reads the temperature of the prong surface. The 5TE outputs temperature in degrees Celsius unless otherwise stated in the software preferences file.

If the black polyurethane overmold of the sensor body is in direct sunshine, the temperature measurement may read high. Do not install the sensor with the overmold in the sun.

3.3.3 ELECTRICAL CONDUCTIVITY

EC is the ability of a substance to conduct electricity and can be used to infer the amount of charged molecules that are in solution. Measure EC by applying an alternating electrical current to two electrodes and measuring the resistance between them. Conductivity is then derived by multiplying the inverse of the resistance (conductance) by the cell constant (the ratio of the distance between the electrodes to their area).

The 5TE uses a two-sensor array to measure the EC. The array is located on the screws of two of the 5TE prongs. 5TE EC measurements are normalized to 25 °C. See Section 4.2 for instructions on cleaning the sensors if contamination occurs.

NOTE: Small amounts of oil from skin contact with the screws will cause significant inaccuracy in the EC measurement.

The 5TE uses a two electrode array to measure the bulk EC of the surrounding medium. METER calibrates the bulk EC measurement to be accurate within 10% from 0 to 7 dS/m. This range is adequate for most field, greenhouse, and nursery applications. However, some special applications in salt-affected soils may require measurements with bulk EC greater than the specified range. The 5TE can measure up to 23.1 dS/m bulk EC but requires user calibration above 7 dS/m. Additionally, EC measurements above 7 dS/m are sensitive to contamination of the electrodes (e.g., skin oils). Read Section 4.2 if measuring the EC of salty soils.

3.3.4 CONVERTING BULK EC TO PORE EC

For many applications, it is advantageous to know the EC of the solution contained in the soil pores (σ_p), which is a good indicator of the solute concentration in the soil. Researchers have traditionally obtained σ_p by extracting pore water from the soil and measuring σ_p directly. However, this is a time-consuming and labor-intensive process.

The 5TE measures the EC of the bulk soil surrounding the sensors (σ_b). METER has conducted a considerable amount of research to determine the relationship between σ_b and σ_p. Work by Hilhorst (2000) takes advantage of the linear relationship between the soil bulk dielectric permittivity (ε_b) and σ_b to allow accurate conversion from σ_b to σ_p if the ε_b is known. The 5TE measures ε_b and σ_b nearly simultaneously in the same soil volume, so it is well suited to this method.

Use Hilhorst (2000) to derive the pore water conductivity (Equation 2).

$$\sigma_p = \frac{\varepsilon_p \sigma_b}{\varepsilon_b - \varepsilon_{\sigma b=0}}$$

Equation 2

where:

σ_p = pore water EC (dS/m)

ε_p = real portion of the dielectric permittivity of the soil pore water (unitless)

σ_b = bulk EC (dS/m) measured directly by the 5TE

ε_b = the real portion of the dielectric permittivity of the bulk soil (unitless)

$\varepsilon_{\sigma b=0}$ = the real portion of the dielectric permittivity of the soil when bulk EC is 0 (unitless)

ε_p can be calculated from soil moisture using a simple formula (Equation 3).

$$\varepsilon_p = 80.3 - 0.37\left(T_{soil} - 20\right)$$

Equation 3

The 5TE measures T_{soil} or soil temperature (°C) and ε_b. Convert raw VWC counts to bulk dielectric with the 5TE dielectric calibration (Equation 4).

$$\varepsilon_b = \frac{\varepsilon_{raw}}{50}$$

Equation 4

Finally, $\varepsilon_{\sigma b=0}$ is an offset term loosely representing the dielectric of the dry soil. Hilhorst (2000) recommends using $\varepsilon_{\sigma b=0}$ = 4.1 as a generic offset. However, METER research in several agricultural soils, organic, and inorganic growth media indicates that $\varepsilon_{\sigma b=0}$ = 6 results in more accurate determinations of σ_p. Hilhorst (2000) offers a simple and easy method for determining for individual soil types, which will improve the accuracy of the calculation of σ_p in most cases.

METER testing indicates that the above method for calculating σ_p results in good accuracy (20%) in moist soils and other growth media. In dry soils where VWC is less than about 0.10 m^3/m^3, the denominator of pore water conductivity equation becomes very small, leading to large potential errors. METER does not recommend this method to calculate σ_p in soils with VWC < 0.10 m^3/m^3.

3.3.5 PORE WATER VERSUS SOLUTION EC

Pore water EC can be calculated from bulk EC using the sensor-measured dielectric permittivity of the medium. However, pore water EC is not the same as solution EC. Pore water EC is the EC of the water in the pore space of the soil. One could measure this directly by squeezing the soil under high pressure to force water out of the soil matrix and test the collected water for EC.

Solution EC is the EC of pore water removed from a saturated paste. In this case, wet the soil with distilled water until the soil saturates, then place the soil on filter paper in a vacuum funnel and apply suction. An EC measurement on the removed sample water gives the solution EC. Theoretically, the two are related by the bulk density. An example calculation illustrates this relationship. If a soil is at 0.1 m^3/m^3 VWC, has a pore water EC of 0.7 dS/m, and a bulk density of 1.5 Mg/m^3. Calculate the solution EC (dS/m) with Equation 5 and Equation 6.

$$\phi = 1 - \frac{\rho_b}{\rho_s} = 1 - \frac{1.5}{2.65} = 0.43$$

Equation 5

$$Solution\ EC = \frac{\sigma_p \theta + \sigma_d (\phi - \theta)}{\phi} = \frac{0.7(0.1) + 0}{0.43} = 0.162$$

Equation 6

In this example, ϕ is the porosity, ρ_b is bulk density, ρ_s is the density of the minerals (assumed to be 2.65 Mg/m^3), the subscript d is distilled water, and θ is VWC. It is assumed that the EC of the distilled water is 0 dS/m. In practice, solution EC calculated from this method and solution EC taken from a laboratory soil test may not correlate because wetting soil to a saturated paste is very imprecise.

4. SERVICE

This section contains calibration and recalibration information, calibration frequencies, cleaning and maintenance guidelines, troubleshooting guidelines, customer support contact information, and terms and conditions.

4.1 CALIBRATION

METER software tools automatically apply factory calibrations to the sensor output data. However, this general calibration may not be applicable for all soil types. For added accuracy METER encourages customers to perform soil-specific calibrations.

4.1.1 DIELECTRIC PERMITTIVITY

METER factory calibrates each 5TE sensor to measure dielectric permittivity (ε_a) accurately in the range of 1 (air) to 80 (water). The unprocessed raw values reported by the 5TE in standard serial communication have units of $50\varepsilon_a$. When used in SDI-12 communication mode, the unprocessed values have units of ε_a (for 5TE board versions R2.04 and older, units are $100\varepsilon_a$).

4.1.2 MINERAL SOIL CALIBRATION

Numerous researchers have studied the relationship between dielectric permittivity and VWC in soil. As a result, numerous transfer equations that predict VWC from measured dielectric permittivity. Use any of these various transfer equations to convert raw dielectric permittivity data from the 5TE into VWC. If using the mineral soil calibration option in METER ProCheck reader, DataTrac 3, or ECH2O Utility, they convert raw dielectric permittivity values with the Topp equation (Topp et al. 1980).

$$VWC = 4.3\times10^{-6}\varepsilon_a^3 - 5.5\times10^{-4}\varepsilon_a^2 + 2.92\times10^{-2}\varepsilon_a - 5.3\times10^{-2}$$ **Equation 7**

METER tests show that in a properly installed 5TE sensor in a normal mineral soil with saturation extract EC <10 dS/m, the Topp equation results in measurements within ±3% VWC of the actual soil VWC. If a more accurate VWC is required, such as working in a soil with very high EC or nonnormal mineralogy, then it may be necessary to conduct a soil-specific calibration for the 5TE sensor to improve the accuracy to 1% to 2% for any soil.

There are two options for soil-specific calibration.

- Follow the step-by-step instructions for calibrating soil moisture sensors in the application note Calibrating ECH2O soil moisture probes.
- METER offers a service providing soil specific calibrations.

This calibration service also applies to soilless materials, such as compost or potting materials. Contact Customer Support for more information.

4.1.3 CALIBRATION IN NONSOIL MEDIA

METER has performed calibrations with the 5TM in several nonsoil growth media. The following are suggested calibration equations for some common materials.

Potting Soil

$$VWC = 2.25\times10^{-5}\varepsilon_a^3 - 2.06\times10^{-3}\varepsilon_a^2 + 7.24\times10^{-2}\varepsilon_a - 0.247$$

Equation 8

Rockwool

$$VWC = 1.68\times10^{-3}\varepsilon_a^2 + 6.56\times10^{-2}\varepsilon_a + 0.0266$$

Equation 9

Perlite

$$VWC = -1.07\times10^{-3}\varepsilon_a^2 + 5.25\times10^{-2}\varepsilon_a - 0.0685$$

Equation 10

METER continually develops additional calibration equations for various other growth media as opportunities arise. Contact Customer Support for the status of this ongoing research.

The 5TM can accurately read VWC in virtually any porous medium if a custom calibration is performed. Contact Customer Support for more information.

4.2 CLEANING AND MAINTENANCE

The EC measurement is very sensitive to the presence of nonconducting contamination on the screws, especially at high EC. The most common source of contamination is skin oil from handling the screws with bare hands. Figure 6 shows the simplied electrical circuit resulting from a fingerprint on the screw in a low EC soil and high EC soil, respectively. It is apparent that in a low EC soil, the effects of contamination are relatively small, because the resistance in the soil dominates the total resistance. However, in a high EC soil, the effects of contamination become very large. This demonstrates the need to keep the screws clean, especially when the sensor is to be used in high EC soil. Contamination of the screws during handling and shipping prevent the factory calibration from being valid past 8 dS/m, although the sensors will measure accurately at much higher EC with proper cleaning and calibration by the user.

Figure 6 shows a contaminated sensor in low EC (high resistance) soil, where R_{total} = 101 Ω and a fingerprint causes a 1% error, and a simplied circuit for a contaminated sensor in high EC (low-resistance) soil, where R_{total} = 5 Ω and a fingerprint causes a 25% error.

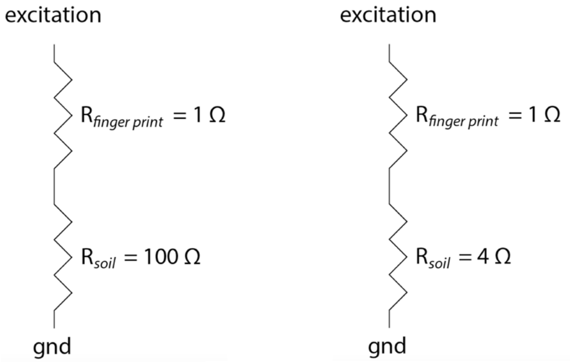

Figure 6 Simplified circuit in low EC soil (left) and in high EC soil (right)

Use the following steps to clean the sensor:

1. Clean the screws using a mild detergent such as liquid dish soap and a nonabrasive sponge or cloth.

   NOTE: Avoid detergents that contain lotions or moisturizers.

2. Rinse the sensor and screws thoroughly with tap or DI water.

Do not touch the screws without gloved hands and never contact the sensors with any source of oil or other nonconducting residue.

4.3 TROUBLESHOOTING

If problems with the 5TE are encountered, they most likely manifest themselves in the form of incorrect or erroneous readings. Review the information in Table 1 and the Troubleshooting METER soil moisture sensors video to identify the problem. Contact Customer Support for more information.

Table 1 Troubleshooting the 5TE

Problem	Possible Solution
Sensor not responding	Check power to the sensor. Check sensor cable and stereo plug connector integrity. Check data logger wiring to ensure brown is power supply, orange is digital out, and bare is ground. **NOTE: Some 5TE sensors may have the older Decagon wiring scheme where the power supply is white, the digital out is red, and the bare wire is ground.**

Table 1 Troubleshooting the 5TE (continued)

Problem	Possible Solution
Sensor reading too low (or slightly negative)	Check for air gaps around sensor needles. These could be produced below the surface of the substrate when the needle contacts a large piece of material and pushes it out of the way or if the sensor is not inserted perfectly linearly. Ensure the calibration equation being used is appropriate for the media type. There are significant differences between substrate calibrations, so be sure to use the one specific to the substrate.
Sensor reading too high	Check to make sure that the media was not packed excessively or insufficiently during sensor installation. Higher density can cause sensor reading to be elevated. Ensure the calibration equation being used is appropriate for the media type. There are significant differences between calibrations, so be sure to use the one most suitable to the substrate, or consider developing a substrate-specific calibration for the particular medium. Some substrates have an inherently high dielectric permittivity (soils of volcanic origin or high titanium, for instance). If the substrate has a dry dielectric permittivity above 6, a custom calibration may need to be performed. Soils with a bulk EC >10 dS/m require substrate-specific calibrations (Section 4.1).
Cable or stereo plug connector failure	If a stereo plug connector is damaged or needs to be replaced, contact Customer Support for a replacement connector and splice kit. If a cable is damaged, follow these guidelines for wire splicing and sealing techniques.

4.4 CUSTOMER SUPPORT

Customer service representatives are available for questions, problems, or feedback Monday through Friday, 7 am–5 pm Pacific time.

Email: support.environment@metergroup.com
sales.environment@metergroup.com

Phone: +1.509.332.5600

Fax: +1.509.332.5158

Website: metergroup.com

If contacting METER by email, please include the following information:

Name	Email address
Address	Instrument serial number
Phone	Description of the problem

NOTE: For 5TE sensors purchased through a distributor, please contact the distributor directly for assistance.

4.5 TERMS AND CONDITIONS

CONTRACT FORMATION. All requests for goods and/or services by METER Group, Inc. USA (METER) are subject to the customer's acceptance of these Terms and Conditions. The Buyer will be deemed to have irrevocably accepted these Terms and Conditions of Sale upon the first to occur of the Buyer's issuance of a purchase order or request for goods or services. Unless expressly assented to in writing by METER, terms and conditions different are expressly rejected. No course of dealing between the parties hereto shall be deemed to affect or to modify, amend, or discharge any provisions of this agreement.

PRICES AND PAYMENT. Invoice prices will be based upon METER prices as quoted or at METER list price in effect at the time an order is received by the Seller. Prices do not include any state or federal taxes, duties, fees, or charges now or hereafter enacted applicable to the goods or to this transaction, all of which are the responsibility of the Buyer. Unless otherwise specified on the invoice, all accounts are due and payable 30 days from the date of invoice. Unpaid accounts extending beyond 30 days will be subject to a service charge of 2% per month (24% per annum). Should Seller initiate any legal action or proceeding to collect on any unpaid invoice, Seller shall be entitled to recover from Buyer all costs and expenses incurred in connection therewith, including court costs and reasonable attorney's fees.

RISK OF LOSS AND DELIVERY TITLE. Liability for loss or damage passes to the Buyer when the Seller delivers the goods on the Seller's dock or to the transporting agent, whichever occurs first. The Seller has the right to deliver the goods in installments. Shipping and delivery dates communicated by the Seller to the Buyer are approximate only.

SHIPMENT. In the absence of specific shipping instructions, the Seller, if and as requested by the Buyer, will ship the goods by the method the Seller deems most advantageous. Where the Seller ships the goods, the Buyer will pay all transportation charges that are payable on delivery or, if transportation charges are prepaid by the Seller, the Buyer will reimburse the Seller upon receipt of an invoice from the Seller. The Buyer is obligated to obtain insurance against damage to the goods being shipped. Unless otherwise specified, the goods will be shipped in the standard Seller commercial packaging. When special packing is required or, in the opinion of the Seller, required under the circumstances, the cost of the special packaging shall be the responsibility of the Buyer.

INSPECTION AND ACCEPTANCE. Goods will be conclusively deemed accepted by the Buyer unless a written notice setting out the rejected goods and the reason for the rejection is sent by the Buyer to the Seller within 10 days of delivery of the goods. The Buyer will place rejected goods in safe storage at a reasonably accessible location for inspection by the Seller.

CUSTOM GOODS. There is no refund or return for custom or nonstandard goods.

WARRANTIES. The Seller warrants all equipment manufactured by it to be free from defects in parts and labor for a period of one year from the date of shipment from factory. The liability of the Seller applies solely to repairing, replacing, or issuing credit (at the Seller's sole discretion) for any equipment manufactured by the Seller and returned by the Buyer during the warranty period. SELLER MAKES NO SEPARATE OR OTHER WARRANTY

OF ANY NATURE WHATSOEVER, EXPRESS OR IMPLIED, INCLUDING THE WARRANTY OF MERCHANTABILITY OR FOR A PARTICULAR PURPOSE. There shall be no other obligations either expressed or implied.

LIMITATION OF LIABILITY. Seller will not be liable to the Buyer or any other person or entity for indirect special, incidental, consequential, punitive, or exemplary damages in connection with this transaction or any acts or omissions associated therewith or relating to the sale or use of any goods, whether such claim is based on breach of warranty, contract, tort, or other legal theory and regardless of the causes of such loss or damages or whether any other remedy provided herein fails. In no event will the Seller's total liability under this contract exceed an amount equal to the total amount paid for the goods purchased hereunder.

WAIVER. In the event of any default under or breach of the contract by the Buyer, the Seller has the right to refuse to make further shipments. The Seller's failure to enforce at any time or for any period of time the provisions of this contract will not constitute a waiver of such provisions or the right of the Seller to enforce each and every provision.

GOVERNING LAW. The validity, construction, and performance of the contract and the transactions to which it relates will be governed by the laws of the United States of America. All actions, claims, or legal proceedings in any way pertaining to this contract will be commenced and maintained in the courts of Whitman County, State of Washington, and the parties hereto each agree to submit themselves to the jurisdiction of such court.

SEVERABILITY. If any of the Terms and Conditions set out in this contact are declared to be invalid by a court, agency, commission, or other entity having jurisdiction over the interpretation and enforcement of this contract, the applications of such provisions to parties or circumstances other than those as to which it is held invalid or unenforceable will not be affected. Each term not so declared invalid or unenforceable will be valid and enforced to the fullest extent permitted by law and the rights and obligations of the parties will be construed and enforced as though a valid commercially reasonable term consistent with the undertaking of the parties under the order has been substituted in place of the invalid provision.

SET-OFF. The Buyer may not set-off any amount owing from the Seller to the Buyer against any amount payable by the Buyer to the Seller whether or not related to this contract

REFERENCES

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