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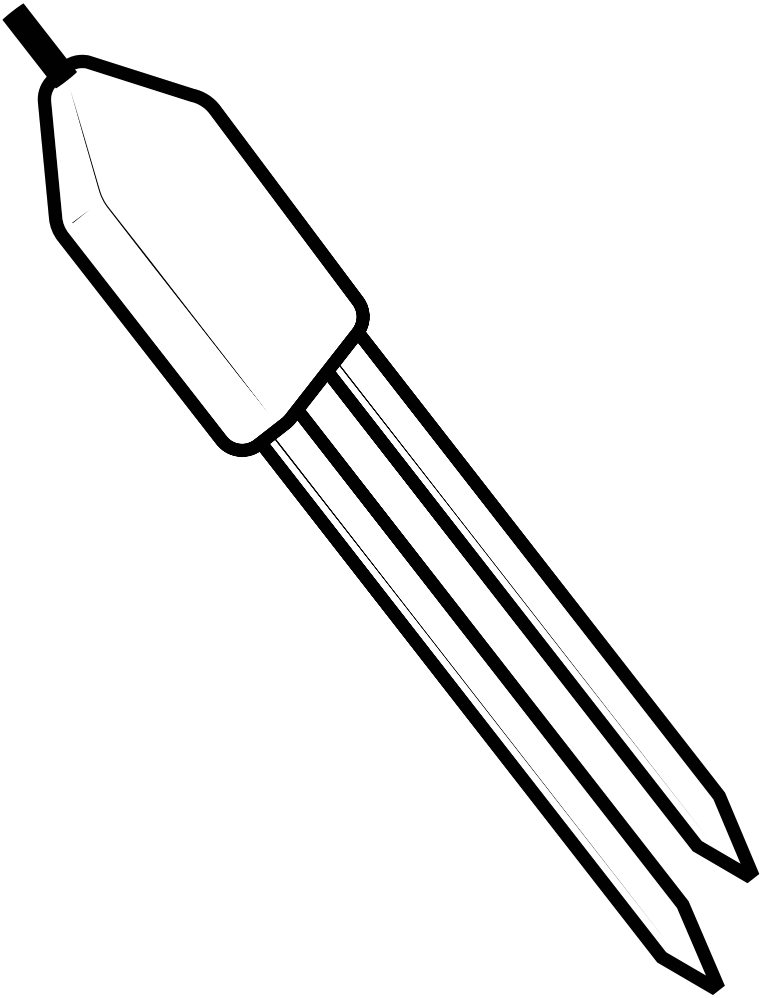

1. INTRODUCTION

Thank you for choosing the ECH$_2$O 10HS Soil Water Content sensor from METER Group. This innovative sensor enables volumetric water content monitoring of soil accurately and affordably.

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 10HS arrived in good condition.

2. OPERATION

Please read all instructions before operating the 10HS 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 10HS into a system, 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 volumetric water content 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 10HS 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 10HS 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 10HS, it is imperative to maximize contact between the sensor and soil. 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 sensing portion of the 10HS 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 10HS.

METHOD 2. VERTICAL INSTALLATION

1. Auger a 4-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 wile a horizontal orientation will measure VWC at a more discrete depth.

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 10HS 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. (Section 2.4).

10HS sensors require an excitation voltage in the range of 3 to 15 VDC.

The 10HS sensors come with a 3.5-mm stereo plug connector (Figure 1) to facilitate easy connection with METER loggers. 10HS sensors may be ordered with stripped and tinned wires to facilitate connecting to some third-party loggers (Section 2.3.2).

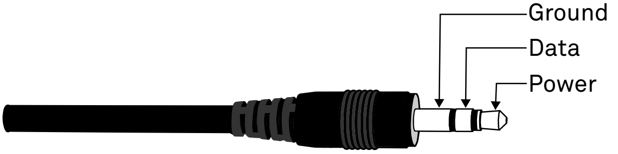

Figure 1 Stereo plug connector

The 10HS 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 40 m.

2.3.1 CONNECT TO METER DATA LOGGER

The 10HS 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) (Section 2.4.2).

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 10HS.
3. Set the measurement interval.

2.3.2 CONNECT TO A NON-METER DATA LOGGER

The 10HS 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. 10HS sensors can be ordered with stripped and tinned (pigtail) connecting wires for use with screw terminals. Connect the 10HS wires to the data logger as illustrated in Figure 2 and Figure 3, with the power supply wire (brown) connected to the excitation, the analog out wire (orange) to a analog input, and the bare ground wire to ground.

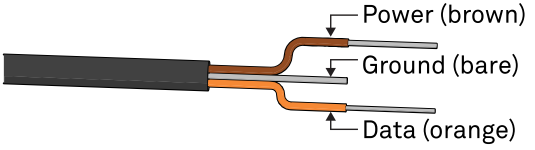

Figure 2 Pigtail wiring

NOTE: Some 10HS sensors may have the older Decagon wiring scheme where the power supply is white, the analog out is red, and the bare wire is ground.

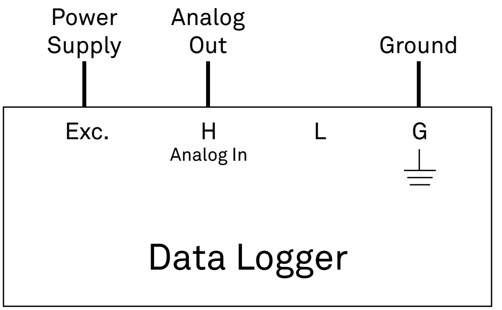

Figure 3 Wiring diagram

NOTE: The acceptable range of excitation voltages is from 3 to 15 VDC. To read 10HS 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 10HS 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 stereo plug connector on one end and three wires (or pigtail adapter) 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 3: 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.

2.4 INTERFACING WITH DATA LOGGERS

2.4.1 DATA LOGGER REQUIREMENTS

The 10HS sensor is designed to work most efficiently with METER data loggers. All METER readout devices use a 3.0-VDC excitation.

The sensors, however, may be adapted for use with other data loggers, such as those from Campbell Scientific, Inc., for example. The 10HS requires an excitation voltage in the range of 3 to 15 VDC. The sensors produce an output voltage that depends on the dielectric constant of the medium surrounding the sensor, and ranges between 10% and 50% of the excitation voltage. Any data logger which can produce a 3- to 15-VDC excitation with approximately 10-ms duration and read a volt level signal with 12-bit or better resolution should be compatible with the 10HS sensor. The current requirement for the 10HS is 12 mA at 3 VDC.

METER designed the 10HS sensor for use with data loggers and readout devices that provide short excitation pulses, leaving the sensors turned OFF most of the time. Continuous excitation not only wastes battery power, but may, under certain circumstances, cause the sensor to exceed government specified limits on electromagnetic emissions. Do not continuously power the 10HS sensor.

2.4.2 METER DATA LOGGERS

METER data loggers can be configured using ZENTRA Utility (a desktop and mobile application) or ZENTRA Cloud (a web-based application for cellular-enabled ZENTRA data loggers). Contact Customer Support for more information about these programs.

2.4.3 NON-METER DATA LOGGERS

Non-METER data loggers may require programming to read the 10HS sensor. METER provides some resources to help interface with Campbell Scientific loggers.

The Campbell Scientific SCWin (Short Cut) program for the 10HS soil moisture sensor is available.

3. SYSTEM

This section describes the 10HS sensor.

3.1 SPECIFICATIONS

MEASUREMENT SPECIFICATIONS

Volumetric Water Content (VWC)	
Range	0–0.57 m^3/m^3 (0%–57% VWC)
Resolution	0.0008 m^3/m^3 (0.08% VWC) in mineral soils from 0–0.50 m^3/m^3 (0%–50% VWC)
Accuracy	With standard calibration equation, 0.03 m^3/m^3 (3% VWC) typical in mineral soils that have solution electrical conductivity <10 dS/m

NOTE: With soil-specific calibration, ±0.02 m^3/m^3 (±2% VWC) is typical in any soil.

COMMUNICATION SPECIFICATIONS

Output

300–1,250 mV, independent of excitation voltage

Data Logger Compatibility

Data aquisition systems capable of switched 3–15 VDC excitation and single-ended voltage measurement at greater than or equal to 12-bit resolution.

PHYSICAL SPECIFICATIONS

Dimensions	
Length	16.0 cm (6.3 in)
Width	3.3 cm (1.3 in)
Height	0.8 cm (0.3 in)
Prong Length	
10 cm (3.94 in)	
Operating Temperature Range	
Minimum	−40 °C
Typical	NA
Maximum	50 °C
NOTE: Sensors may be used at higher temperatures under certain conditions; contact Customer Support for assistance.	
Cable Length	
5 m (standard) 40 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 (VIN to GND)	
Minimum	3 VDC at 12 mA
Typical	NA
Maximum	15 VDC at 15 mA
Measurement Duration	
Minimum	NA
Typical	NA
Maximum	10 ms

COMPLIANCE

Manufactured under ISO 9001:2015
EM ISO/IEC 17050:2010 (CE Mark)
2014/30/EU
2011/65/EU
EN61326-1:2013
EN50581:2012

3.2 ABOUT 10HS

The 10HS determines volumetric water content (VWC) by measuring the dielectric constant of the media using capacitance and frequency domain technology. The 70-MHz frequency minimizes salinity and textural effects, making this sensor accurate in almost any soil or soilless media. It arrives with factory calibration for mineral soils, potting soils, and perlite included in this user manual.

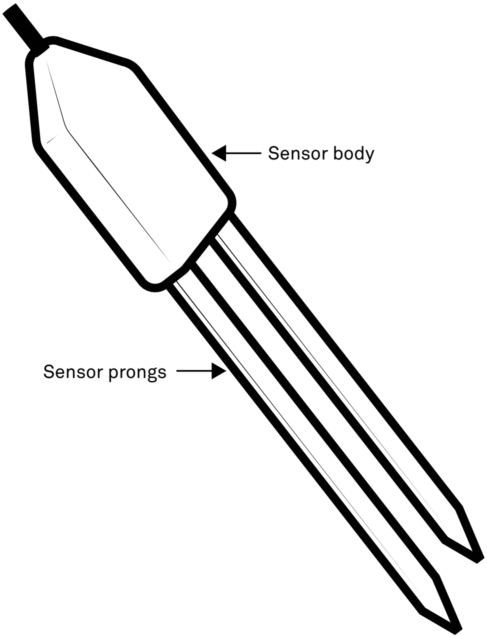

Figure 4 10HS components

4. SERVICE

This section contains calibration information, 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.

Which calibration equation to use depends on where it is used. If the calibration equation is used with sensors connected to a non-METER data logger, use the calibration appropriate to the excitation voltage. If any METER software is used or the user calibration menu in the ProCheck is used, use the RAW calibration.

4.1.1 DIELECTRIC CALIBRATION

The 10HS comes precalibrated to measure the dielectric permittivity of the soil with the accuracy stated in the specification section above. With METER's data loggers, the following standard calibration function can be applied.

$$\varepsilon_a = \left(7.449\times10^{-11}\right)\left(RAW^4\right)-\left(1.969\times10^{-7}\right)\left(RAW^3\right)+\left(1.890\times10^{-4}\right)\left(RAW^2\right)- \left(6.691\times10^{-2}\right)\left(RAW\right)+7.457$$

Equation 1

where RAW is for raw counts.

With non-METER data acquisition equipment, the following calibration can be applied. This calibration function is valid for any sensor excitation between 3 and 15 VDC.

$$\varepsilon_a = \left(2.589\times10^{-10}\right)\left(mV^4\right)-\left(5.010\times10^{-7}\right)\left(mV^3\right)+\left(3.523\times10^{-4}\right)\left(mV^2\right)- \left(9.135\times10^{-2}\right)\left(mV\right)+7.457$$

Equation 2

4.1.2 MINERAL SOIL CALIBRATION

For convenience, METER has also developed a standard calibration equation for mineral soils to be used with the 10HS. With this standard calibration equation and careful sensor installation, accuracy of better than 3% VWC (0.03 m^3/m^3) is possible with most mineral soils. In these soils, it is generally not necessary to calibrate the 10HS for each particular soil type, and the standard mineral calibration can be used with METER data loggers:

$$VWC = \left(1.17\times10^{-9}\right)\left(RAW^3\right)-\left(3.95\times10^{-6}\right)\left(RAW^2\right)+\left(4.90\times10^{-3}\right)\left(RAW\right)-1.92$$

Equation 3

With non-METER data acqusition equipment, the following calibration can be applied. This calibration function is valid for any sensor excitation between 3 and 15 V DC.

$$VWC = \left(2.97\times10^{-9}\right)\left(mV^{3}\right) - \left(7.37\times10^{-6}\right)\left(mV^{2}\right) + \left(6.69\times10^{-3}\right)\left(mV\right) - 1.92$$ **Equation 4**

Because of the complexity of soils, the accuracy of the VWC measurement can be poor despite an accurate measurement for dielectric permittivity. Some examples of this are highly compacted soils, very low bulk density soils, soils with abnormally high organic matter content, and soils with high-dielectric mineral composition (e.g., TiO_2 sands). Additionally, the accuracy of the 10HS may suffer in soils with very high electrical conductivity (>10 dS/m solution EC). In these soils, it may be necessary to calibrate the 10HS to the specific soil type. With a soil-specific calibration, the accuracy of the VWC measurements will be improved to 1% to 2% in any soil or other porous medium.

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 nonsoil materials, such as compost or potting materials. Contact Customer Support for more information.

4.1.3 POTTING SOIL

The following equations can be used to convert 10HS output to water content in potting soil. METER tested several types of potting soil (Sunshine mix, Miracle Grow Potting Mix, and Custom Nursery soil) at several salinities and found that VWC (in m^3/m^3) is given in Equation 5 for a METER data logger

$$\theta = \left(3.78\times10^{-7}\right)\left(RAW^{2}\right) - \left(8.99\times10^{-5}\right)\left(RAW\right) - 3.03\times10^{-2}$$ **Equation 5**

and in Equation 6 for a non-METER data logger

$$\theta = \left(7.05\times10^{-7}\right)\left(mV^{2}\right) - \left(1.23\times10^{-4}\right)\left(mV\right) - 3.03\times10^{-2}$$ **Equation 6**

4.2 TROUBLESHOOTING

If problems with the 10HS 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 10HS

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 analog out, and bare is ground. **NOTE: Some 10HS sensors may have the older Decagon wiring scheme where the power supply is white, the analog out is red, and the bare wire is ground.**
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.

4.3 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 10HS sensors purchased through a distributor, please contact the distributor directly for assistance.

4.4 TERMS AND CONDITIONS

By using METER instruments and documentation, you agree to abide by the METER Group, Inc. USA Terms and Conditions. Please refer to metergroup.com/company/meter-group-inc-usa-terms-conditions for details..

REFERENCES

Bogena HR, Huisman JA, Oberdörster C, Vereecken H. 2007. Evaluation of a low-cost soil water content sensor for wireless network applications. J Hydrol. 344(1–2): 32–42.

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