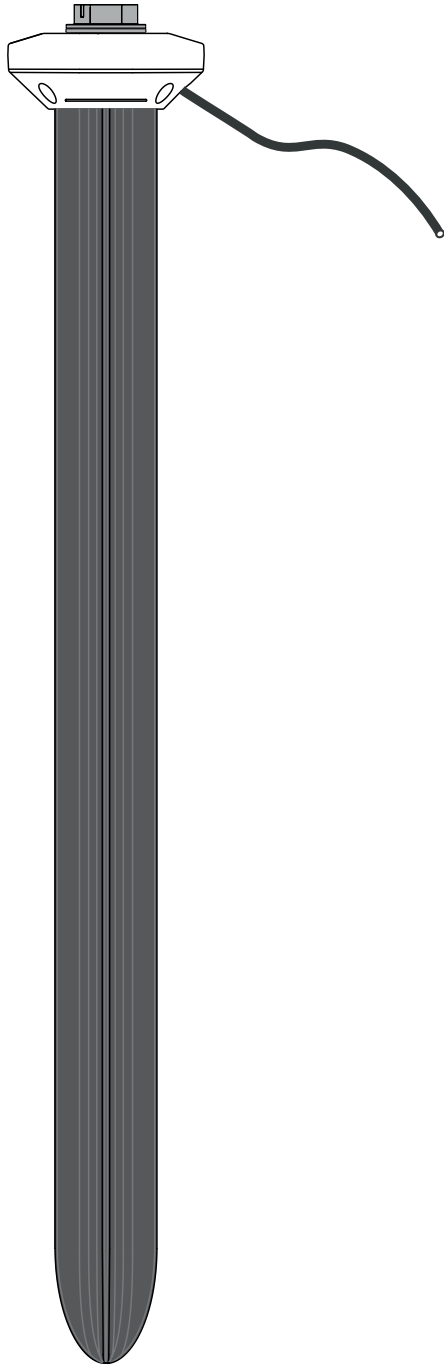


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1. INTRODUCTION

Thank you for choosing the TEROS 54 Soil Water Content Profile probe from METER Group.

The TEROS 54 probe is designed to be installed in mineral soils, a variety of growing media, and other porous materials. This manual describes how to use the probe and guides the customer through the probe features.

The TEROS 54 probe is an accurate tool for monitoring volumetric water content (VWC) using capacitance and frequency-domain technology. The sensors use a 70 MHz frequency to minimize textural and salinity effects that makes the TEROS 54 accurate in most mineral soils.

The TEROS 54 uses four precision-integrated temperature sensors to measure temperature in soil and soilless substrates.

Verify all TEROS 54 components are included and appear in good condition:

1. TEROS 54 probe
2. Protective cap

METER recommends testing sensors with the data acquisition device and software before going to the field.

2. OPERATION

Please read all instructions before operating the TEROS 54 to ensure it performs to its full potential.

PRECAUTION

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 TEROS 54 into a system, make sure to follow the recommended installation instructions and have the proper protections in place to safeguard sensors from damage. If installing sensors in a lightning-prone area with a grounded data logger, see the application note [Lightning surge and grounding practices](#).

2.1 INSTALLATION

This sections contains an overview of the TEROS 54 installation procedure ([Section 2.1.1](#)) and detailed information about the pile (slide) hammer ([Section 2.1.2](#))

2.1.1 OVERVIEW

[Table 1](#) contains information needed to install the TEROS 54 and start collecting data.

Table 1 Installation

Tools Needed	TEROS 54 auger Dead blow hammer Pile hammer (slide hammer) PVC casing or flexible conduit (to protect cables) Level (to check that the auger is level while digging the hole for the probe)
Preparation	<p>Consider the Surroundings When selecting a suitable location for the TEROS 54, make sure that it is a representative location in the measurement area.</p> <p>Avoid installation in very rocky soils, if possible, to prevent damage to the TEROS 54.</p> <p>Conduct System Check Plug the probe into the logger (Section 2.2) to make sure the probe is functional.</p> <p>Check Sensor Functionality Verify all sensors read within expected ranges. To validate both probe and logger functionality, take probe measurements in air and water. The value of permittivity in air should be 1.</p> <p>NOTE: The sensors will not read 100% water content in water.</p>

Table 1 Installation (continued)

Create Hole

To install the TEROS 54 into the soil, use the TEROS 54 auger available from METER ([Section 2.1.2](#)) to drill a vertical hole in the soil. Use a level on the auger to make sure the hole is drilled vertically to prevent damage to the probe.

NOTE: METER recommends using the TEROS 54 auger and slide hammer that are designed specifically for installing the TEROS 54 in compact, firm soil. This method will result in good soil contact. The TEROS 54 can only be installed in very loose, sandy, and soft soils without using the TEROS 54 auger.

- Avoid interfering with large objects like roots or rocks that could potentially damage the probe housing.
- Installations near large metal objects can affect the sensor's function and distort readings.

NOTE: Never drill to the final depth in one step. Remove the soil from the auger approximately every 30 cm.

Mark the required drilling depth on the TEROS 54 auger extension rod. The maximum depth the auger can go is 70 cm.

Installation

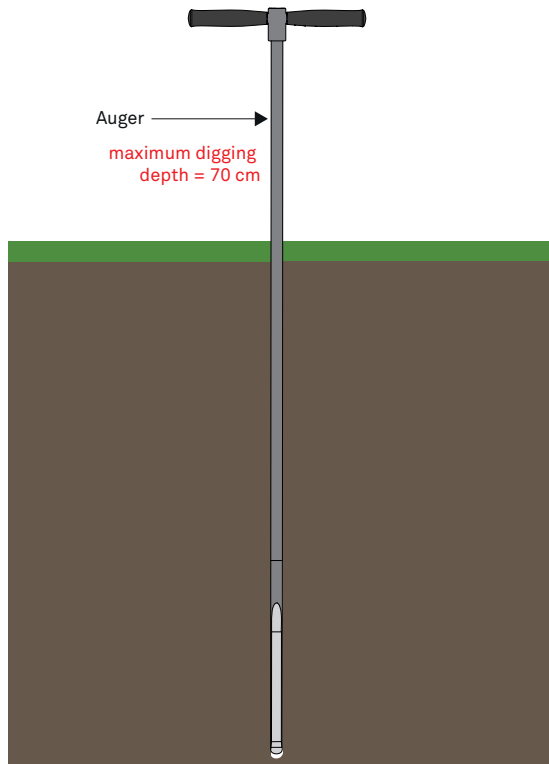


Table 1 Installation (continued)

Installation Tool

⚠ CAUTION

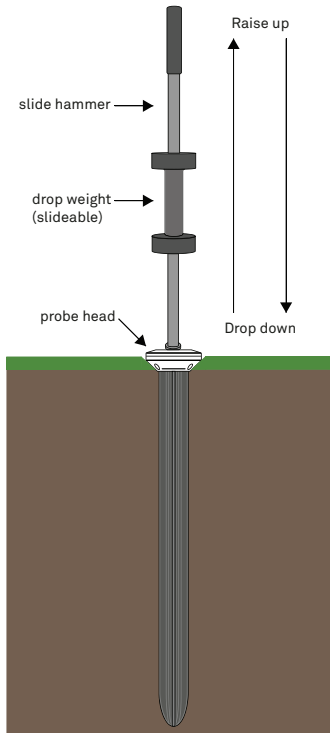
When using the slide hammer to install the TEROS 54 probe, please wear proper ear protection to prevent hearing damage because the hammer is quite loud. Please wear gloves to protect hands from being pinched.

When the hole has been drilled to its final depth, position the TEROS 54 centered over the hole, tip-first, and press it down vertically.

NOTE: Do not try to insert the TEROS 54 to the desired depth by pushing down by hand.

For installation, METER highly recommends the slide hammer, available from METER.

Place the slide hammer with the attachment on the TEROS 54 probe head and drop the weight several times to install the TEROS 54 gradually into the soil.



NOTE: During installation, make sure that no air gaps occur between soil and the probe housing. Gaps, such as air pockets near the probe housing, can have a negative effect on the measurement and falsify the measured values.

Installation
(continued)

Table 1 Installation (continued)

Installation
(continued)

Finally, screw the protective cap into the thread to protect it from environmental influences.

NOTE: Do not hit the probe head directly with a hammer. This can damage the probe head.

Secure and Protect Cables

NOTE: Improperly protected cables can lead to severed cables or disconnected probes. Cabling issues can be caused by many factors such as rodent damage, driving over probe cables, tripping over cables, not leaving enough cable slack during installation, or poor probe wiring connections ([Section 2.1.2](#)).

Install cables in conduit or plastic tubing when near the ground to avoid rodent damage.

Gather and secure cables between the TEROS 54 and the data logger to the mounting mast in one or more places.

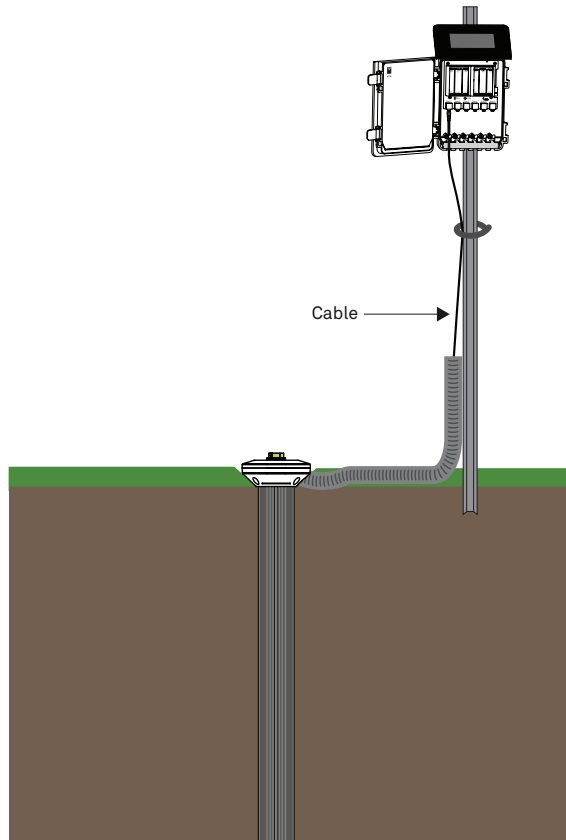
Installation
(continued)

Table 1 Installation (continued)

Installation (continued)	<p>Connect to Logger</p> <p>Plug the probe into a data logger.</p> <p>Use the data logger to make sure the sensors are reading properly.</p> <p>Verify that these readings are within expected ranges.</p> <p>For more instructions on connecting to data loggers, refer to Section 2.2.</p>
-------------------------------------	---

2.1.2 INSTALLATION METHODS

This section explains installation methods METER recommends for different soil conditions ([Figure 1](#)).

The TEROS 54 probe can only be installed in very loose, sandy, and soft soils without the TEROS 54 auger.

METER recommends using the TEROS 54 auger and slide hammer that are designed specifically for installing the TEROS 54 in compact, firm soil. This method will result in good soil contact.

- The TEROS 54 auger is shaped to prevent soil compaction near the probe elements ([Figure 2](#)).
- The slide hammer ([Figure 3](#)) consists of four parts: handle, rod, weight (approx. 4 kg [8.82 lbs]) and connector (put on the TEROS 54 head). Because there is a predetermined distance that the slide hammer weight travels when dropped, there is an even distribution of force delivered.

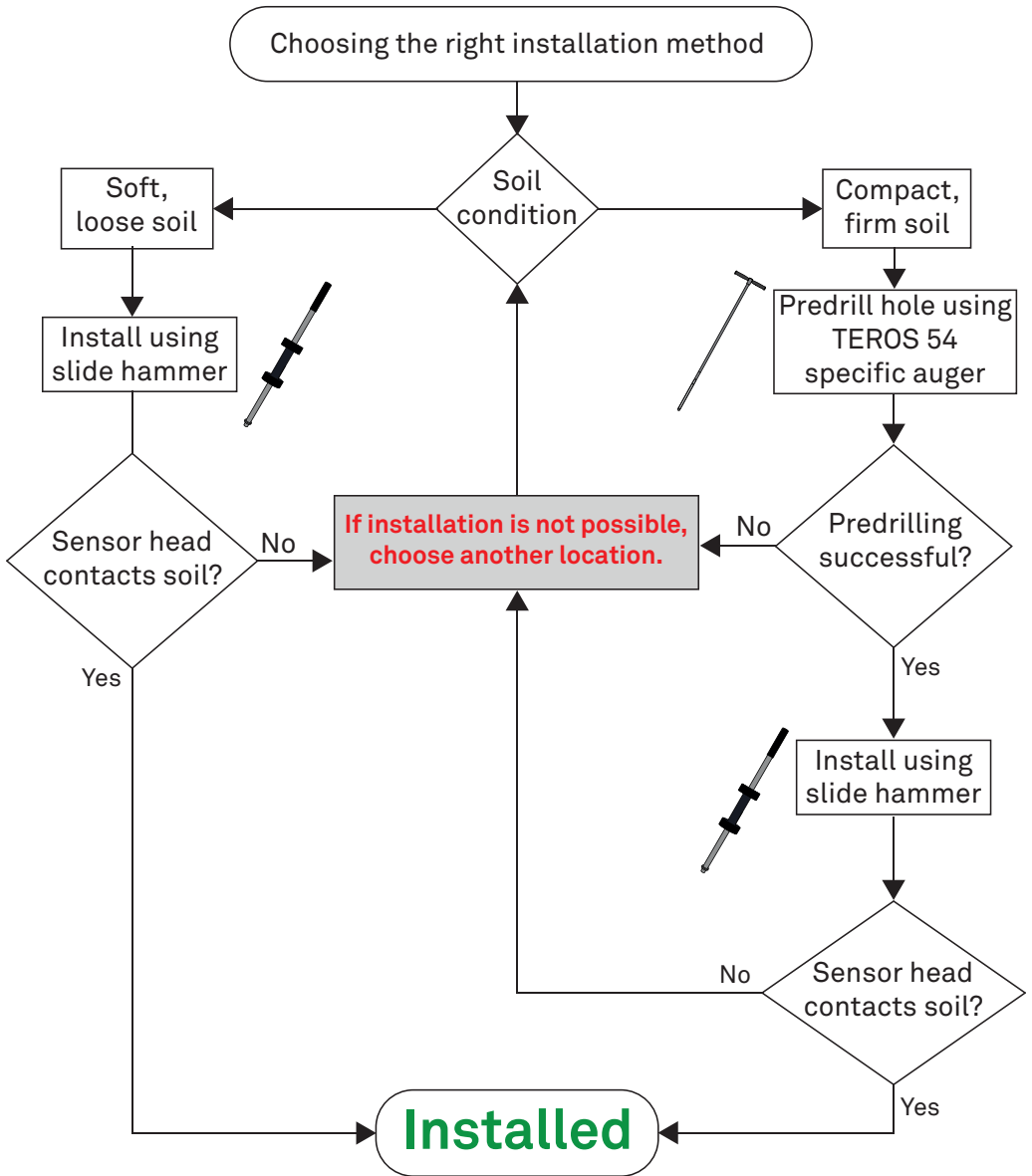


Figure 1 Choosing the right installation method

OPERATION

⚠ CAUTION

When using the slide hammer to install the TEROS 54 probe, please wear proper ear protection to prevent hearing damage because the hammer is quite loud. Please wear gloves to protect hands from being pinched.

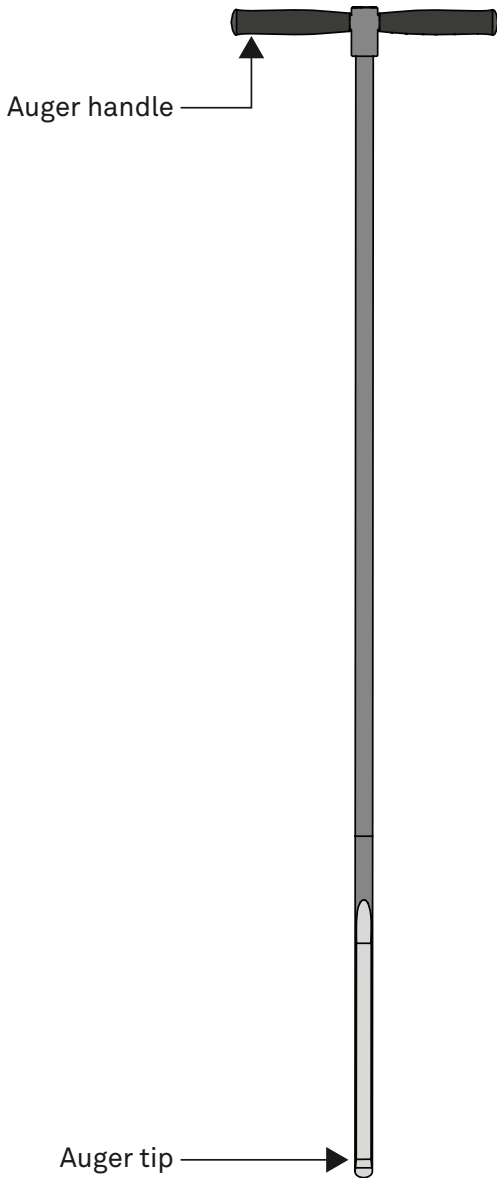


Figure 2 TEROS 54 auger

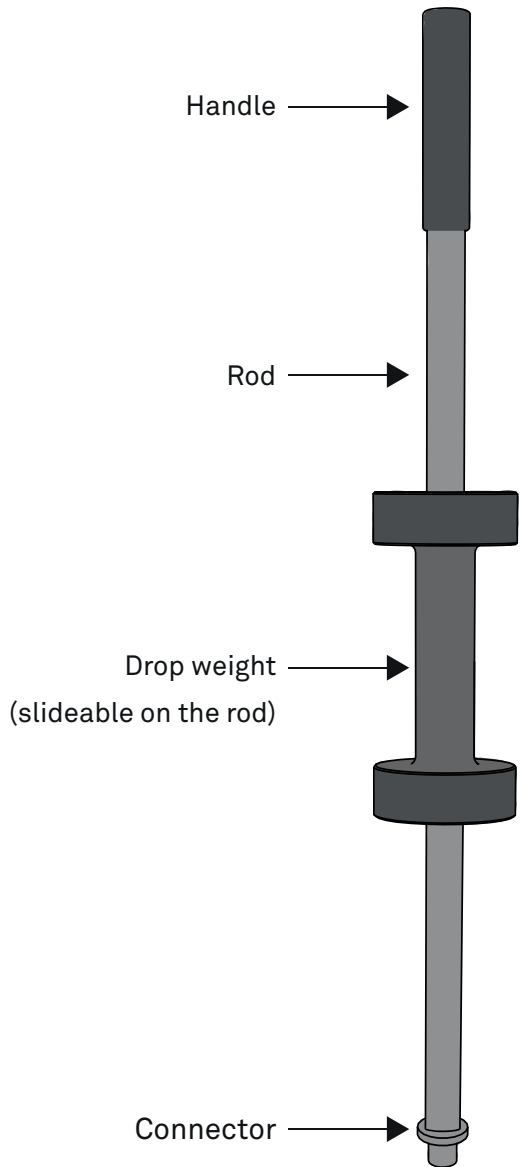


Figure 3 TEROS 54 slidehammer

CAUTION

Never hit the head of the TEROS 54 with a regular hammer. This can damage the probe. Only use the dedicated slide hammer tool from METER.

The following steps detail how to use the TEROS 54 auger:

1. Assemble the auger using the handle and auger tip.
2. Mark the probe length 70 cm on the auger rod.
NOTE: Do not dig deeper than 70 cm to ensure that the probe is in good contact with the soil after installation.
3. Place the auger tip on the ground.
4. Place a level vertically on the rod of the auger.
5. Check the level for the proper angle until the auger tip is in far enough so the angle does not change.
6. Hit the handle gently a few times with a dead blow hammer until the auger tip is 30 cm in the soil.
7. Rotate the auger one revolution to cut off the soil in the borehole.
8. Pull the auger out of the borehole after 30 cm to avoid soil compaction.
9. Remove the soil inside the auger tip.
10. Place the auger back into the borehole to the previous depth.
11. Repeat [step 6](#) through [step 10](#) until the desired depth (maximum is 70 cm) is reached.

After drilling a hole for the TEROS 54, place the TEROS 54 with the pointed side (probe tip) centered over the hole. Press the TEROS 54 as deep as possible into the soil and use the slide hammer (available from METER) to help with installation in firm, compact soils.

1. Place the slide hammer vertically and centered on the head of the TEROS 54.
2. Bring the weight to approx. half the drop height.
3. Release the weight.
4. Repeat [step 2](#) and [step 3](#) until the TEROS 54 has reached its intended depth.

NOTE: The TEROS 54 should be driven approximately 1.0 cm (0.39 in) deep into the soil per drop. Increase the drop height only if the installation comes to a standstill or the probe is being driven less than 1.0 cm per drop. In that case, lift the weight all the way up to its maximum height.

NOTE: Allow the weight of the drop hammer to fall by gravity only, do not extend the drop distance or increase the impact force by pushing or using a heavier weight.

NOTE: If the TEROS 54 cannot be installed to the intended depth due to rocky compact soil conditions, do not use force, but change the installation location to avoid damaging the probe!

After installing the TEROS 54 in the soil to its maximum installation depth (the head of the TEROS 54 should be approximately 5 mm deep in the soil), attach the protective cap ([Figure 5](#)) to the sensor head and connect the TEROS 54 to a data logger ([Section 2.2](#)).

OPERATION

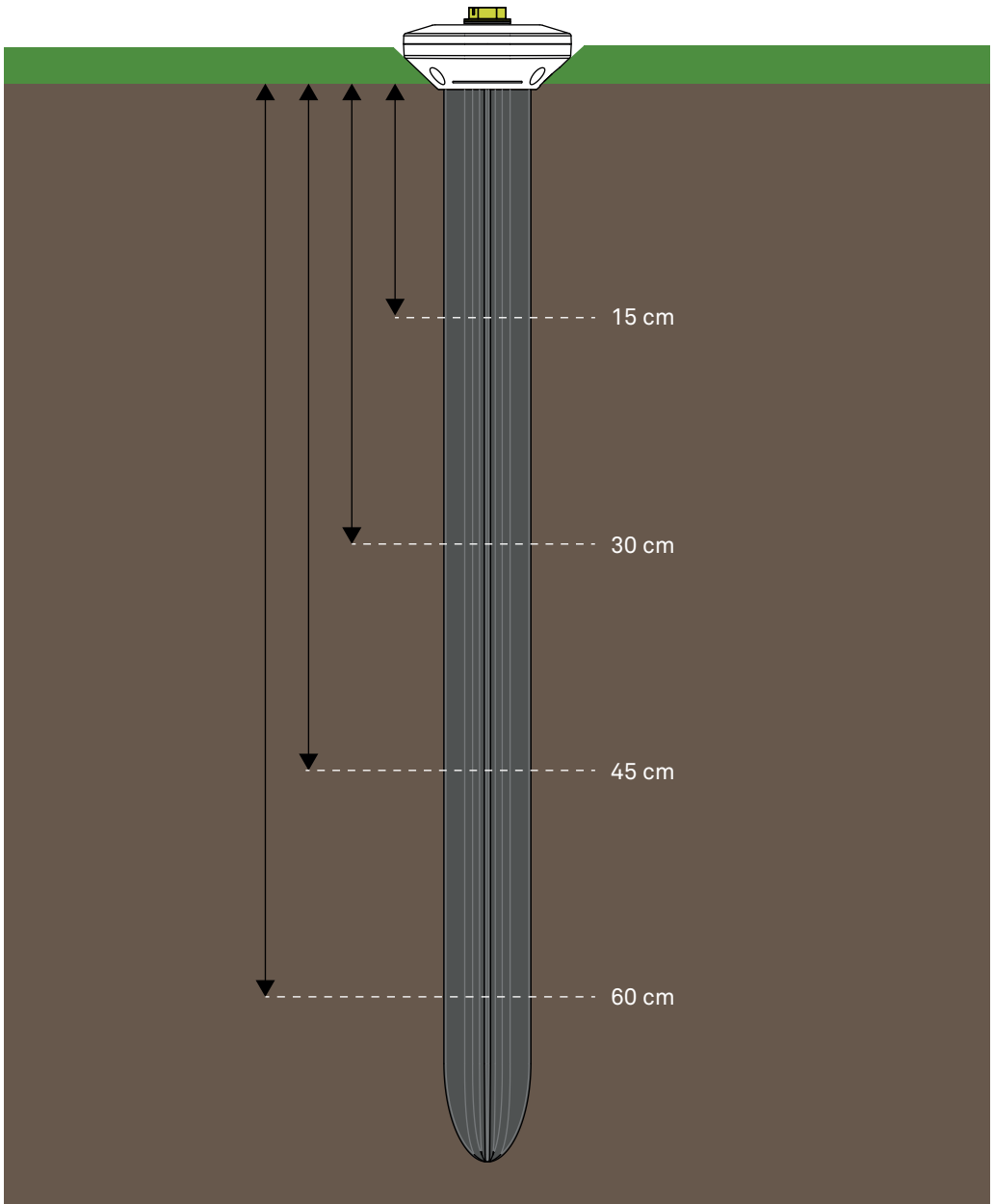


Figure 4 TEROS 54 measurement depths

NOTE: Insert the TEROS 54 deep enough into the soil that the head of the TEROS 54 is approximately 5 mm deep into the soil (Figure 4).

TEROS 54

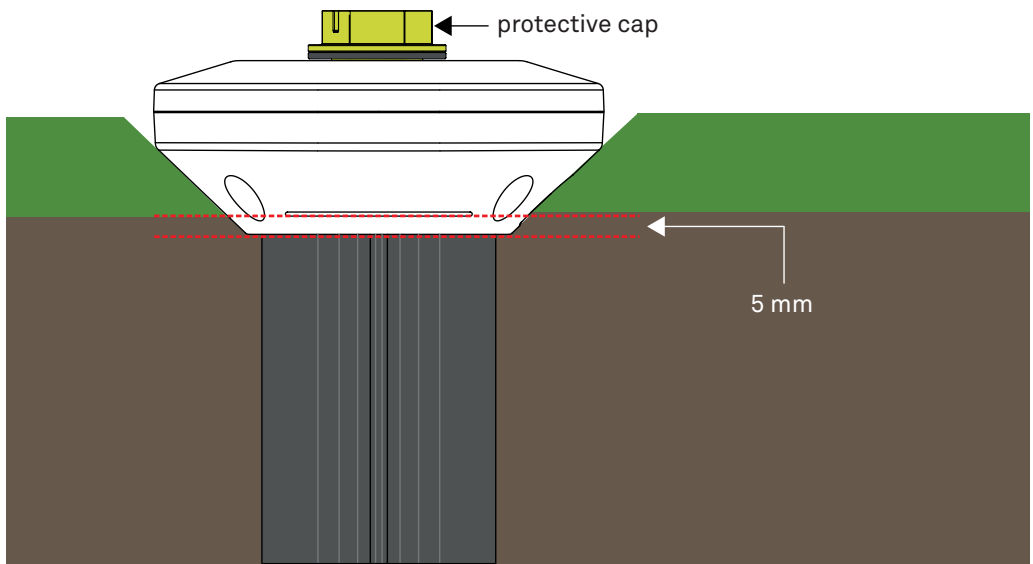


Figure 5 TEROS 54 head installation view

2.2 CONNECTING

The TEROS 54 works seamlessly with METER ZENTRA data loggers, and it can also be used with other data loggers, such as those from Campbell Scientific, Inc. For extensive directions on how to integrate the sensors into third-party loggers, refer to the [TEROS 54 Integrator Guide](#).

TEROS 54 probes require an excitation voltage in the range of 4.0- to 24.0 VDC and operate at a 3.6-VDC level for data communication. TEROS 54 can be integrated using DDI Serial, SDI-12, Modbus RTU, or tensioLINK communications protocol. Refer to the [TEROS 54 Integrator Guide](#) for details on interfacing with data acquisition systems.

TEROS 54 probes come with a 3.5-mm stereo plug connector ([Figure 6](#)) to facilitate easy connection with METER loggers. TEROS 54 probes may be ordered with stripped and tinned wires to facilitate connecting to some third-party loggers ([Section 2.2.2](#)). A 1.5 M cable is also available for use with an M12 connector.

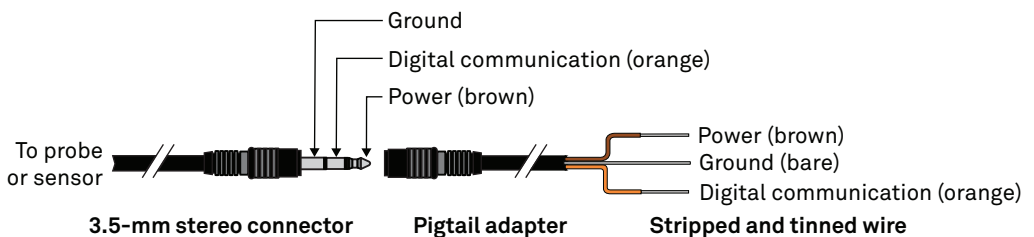


Figure 6 Three-wire stereo connector and pigtail adapter

The TEROS 54 comes standard with a 5-m cable. It may be purchased with custom cable lengths for an additional fee (on a per-meter basis). In some instances, the cable can be extended beyond 75 m by the user, but this is discouraged for a variety of reasons. Please contact [Customer Support](#) for more details before extending or splicing cables.

2.2.1 CONNECT TO METER DATA LOGGER

The TEROS 54 works most efficiently with METER ZENTRA series 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 the TEROS 54.

METER data loggers will automatically recognize TEROS 54 probes.

3. Set the measurement interval.

METER data loggers measure the TEROS 54 every minute and return the average of the 1-min data across the chosen measurement interval.

TEROS 54 data can be downloaded from METER data loggers using either ZENTRA Utility or ZENTRA Cloud. Refer to the logger user manual for more information about these programs.

2.2.2 CONNECT TO NON-METER DATA LOGGER

The TEROS 54 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. The [TEROS 54 Integrator Guide](#) also provides detailed instructions on connecting sensors to non-METER loggers.

TEROS 54 probes can be ordered with stripped and tinned (pigtail) connecting wires for use with screw terminals. METER recommends using a 4-pin M12 plug connector and a connection cable with open wires for use with a non-METER data logger using either SDI-12, tensioLINK serial, or Modbus RTU communications protocol.

Connect the TEROS 54 wires to the data logger as illustrated in [Figure 7](#) with the supply wire (brown) connected to the excitation, the digital output wire (orange) to a digital input, and the bare ground wire to ground.

NOTE: The acceptable range of excitation voltages is from 4.0 to 24.0 VDC. To read TEROS 54 with Campbell Scientific, data loggers, power the sensors from a switched 12-V port or a 12-V port if using a multiplexer.

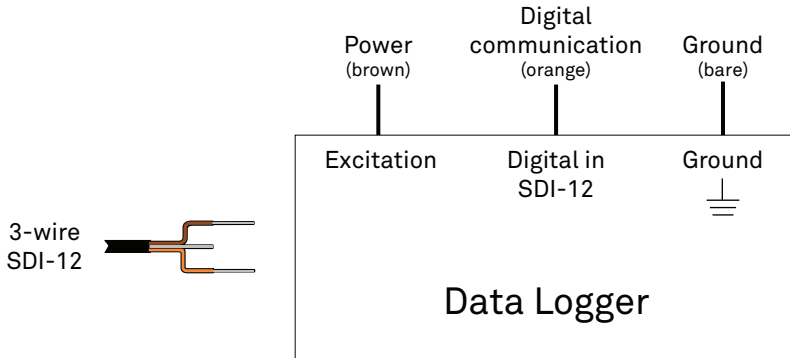


Figure 7 Three-wire SDI-12 pigtail wiring diagram

For RS-485, the power supply wire (brown) will be connected to the excitation, the digital communication + wire (white) to a digital input (high), the digital communication - wire (black) to a digital input (low) and the blue ground wire to ground. For SDI-12, both the digital communication - and ground wires will both be connected to ground.

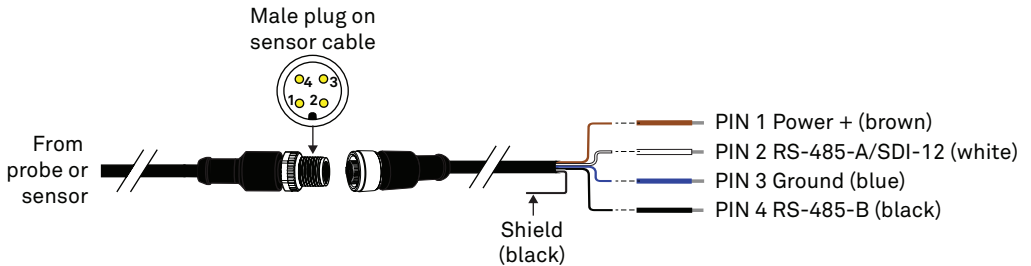


Figure 8 Four-wire M12 connector and pigtail adapter for use with screw terminals

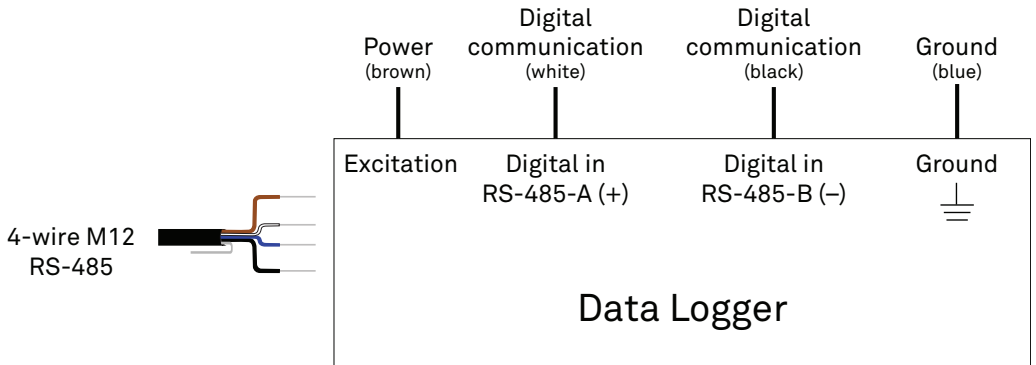


Figure 9 Four-wire M12 connector RS-485 wiring diagram

OPERATION

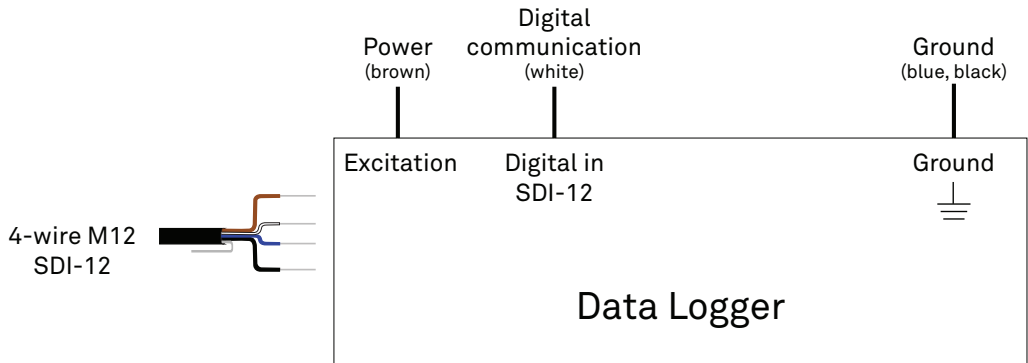


Figure 10 Four-wire M12 connector SDI-12 wiring diagram

If the TEROS 54 cable has a standard stereo plug connector and needs to be connected to a non-METER data logger, use one of the following two options.

Option 1

1. Clip off the stereo plug connector on the probe 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 and minimizes the chance of the probe 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 6](#): 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 using adhesive-lined heat shrink to ensure the probe does not become disconnected during use.

2.3 COMMUNICATION

The TEROS 54 communicates using different methods:

- DDI Serial
- SDI-12 communications protocol
- Modbus RTU communications protocol
- tensioLINK serial

To obtain detailed instructions, refer to the [TEROS 54 Integrator Guide](#).

The SDI-12 protocol requires that all sensors have a unique address. The TEROS 54 sensor factory default is an SDI-12 address of 0. To add more than one SDI-12 sensor to a bus, the sensor address can be changed using a METER ZSC Bluetooth® sensor interface and the ZENTRA Utility Mobile app as described below:

NOTE: The sensor SDI-12 address must be returned to 0 to work with ZENTRA loggers.

1. Using a mobile device, open the ZENTRA Utility Mobile app.
2. Connect the sensor to the ZSC.
3. Under Sensor Information, select the SDI Address dropdown.
4. Scroll through the options and select the desired SDI-12 address.

NOTE: Address options include 0–9, A–Z, and a–z.

Detailed information can also be found in the application note [Setting SDI-12 addresses on METER digital sensors using Campbell Scientific data loggers and LoggerNet](#).

When using the sensor as part of an SDI-12 bus, excite the sensors continuously to avoid issues with initial sensor startup interfering with the SDI-12 communications.

2.4 REMOVAL

Do not shake the TEROS 54 to remove it from the soil. Do not try to pull the TEROS 54 from the borehole with bare hands.

To remove the TEROS 54, only use the TEROS 54 Removal Tool ([Figure 11](#)) available from METER, consisting of an eyebolt, a carabiner, a tensioning strap, a lever tool (pile puller), and a base (serves as a foundation by inserting the lever tool).

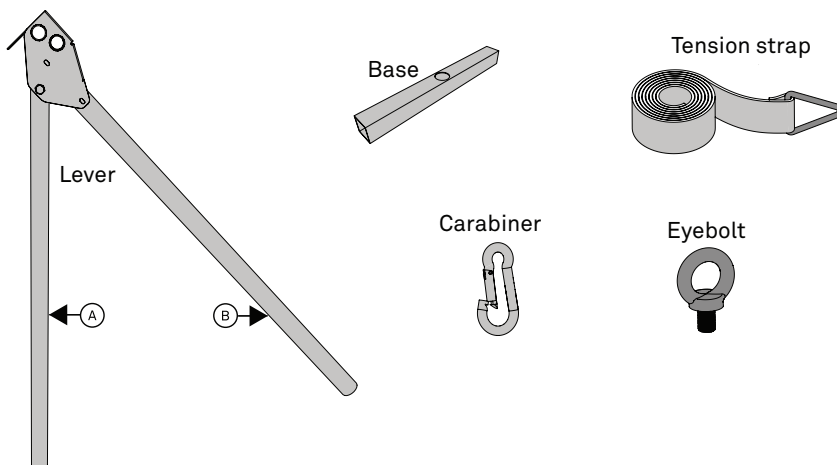


Figure 11 Removal tool components

OPERATION

To operate the TEROS 54 Removal Tool, follow the steps below.

1. Remove the protective cap from the thread of the TEROS 54.
2. Screw the eyebolt into the thread.
3. Insert the vertical leg (A) of the lever tool into the base.
4. Connect the carabiner to the eyebolt.
5. Gently pull the TEROS 54 out of the soil by pressing down on the lever arm several times.
Retighten the tension strap.

NOTE: If the tension strap has slipped out of the lever tool, reinsert the tension strap into the lever tool according to [Figure 12](#).

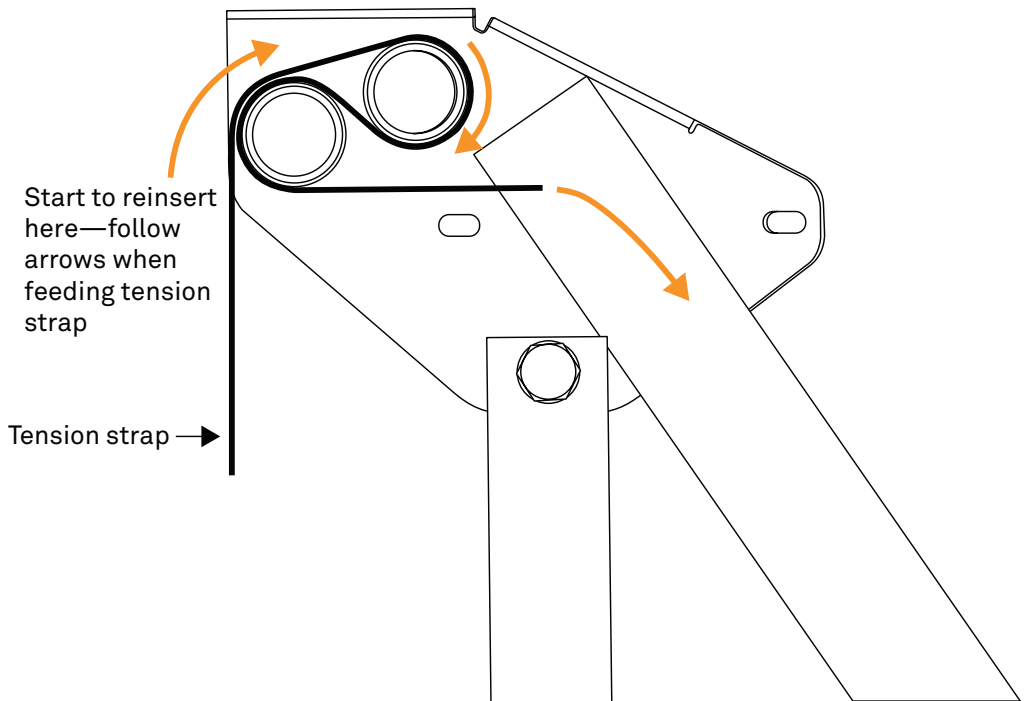


Figure 12 Insert tensioning strap into lever tool

! Removal Safety Guidelines

One person only

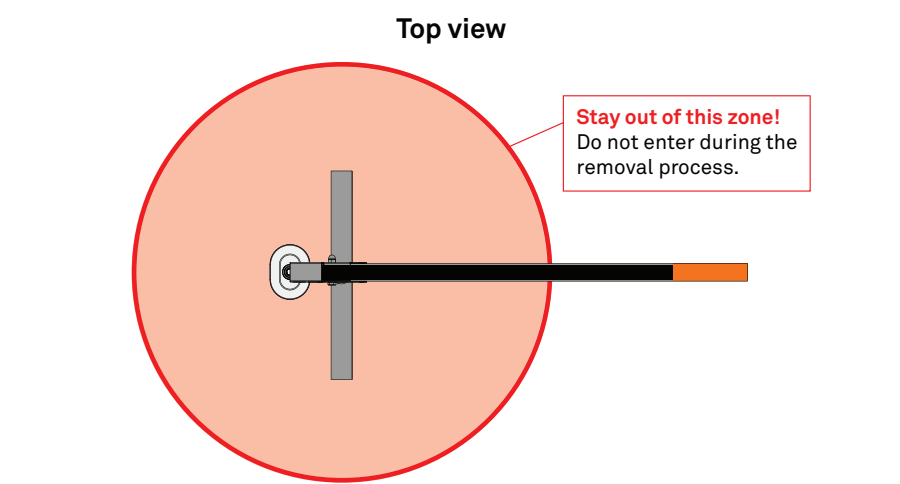
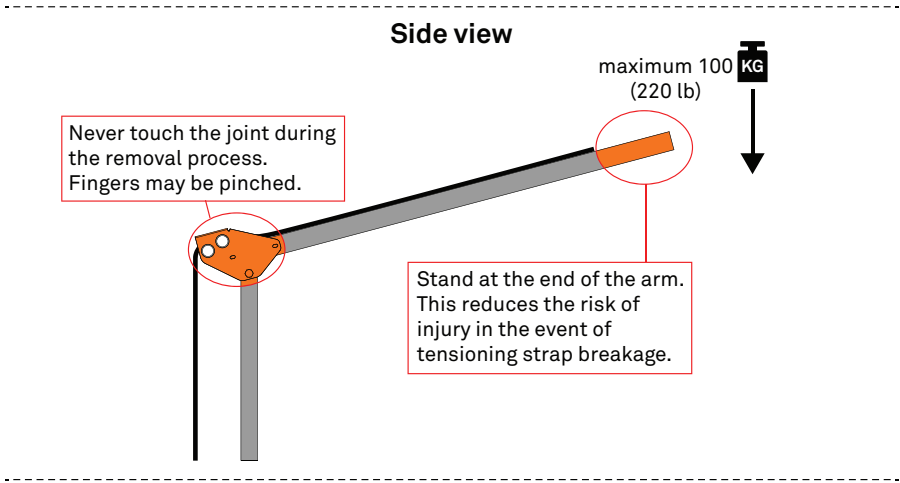


Figure 13 Removal safety guidelines

OPERATION

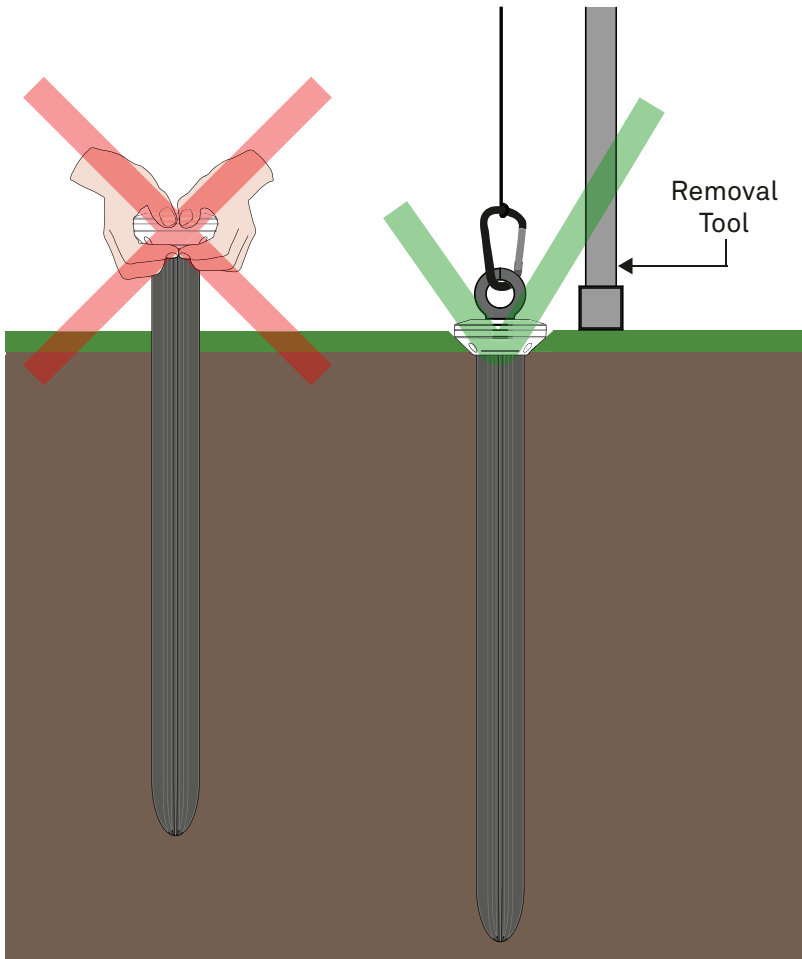


Figure 14 Correct removal method

CAUTION

Do not pull by the cable! Doing so may break internal connections and make the probe unusable.

NOTE: If the soil where the TEROS 54 is installed is very dry, water it thoroughly before removing the TEROS 54. Make sure that the soil directly around the TEROS 54 absorbs the water. This may take several days depending on the type of soil. Otherwise, the TEROS 54 may be damaged during removal.

TEROS 54

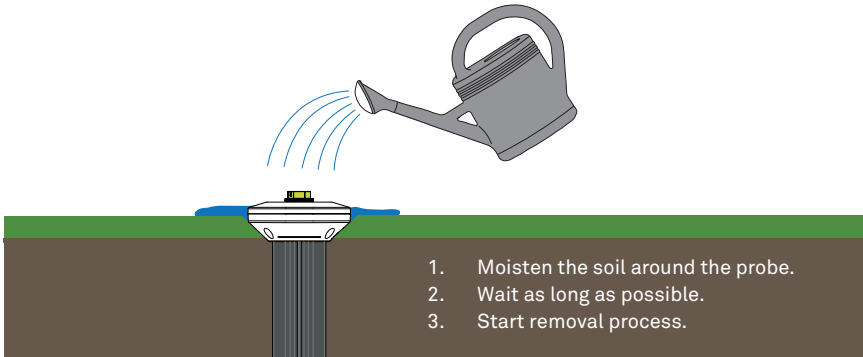


Figure 15 Moisten soil

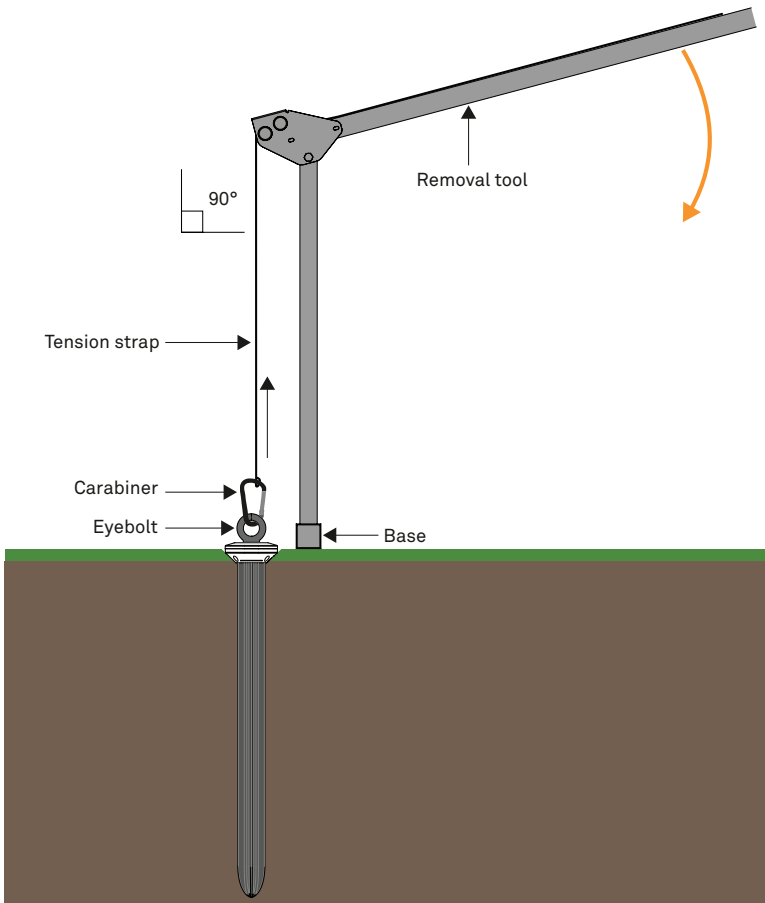


Figure 16 Removal tool connected to TEROS 54

3. SYSTEM

This section describes the specifications, components, and theory of the TEROS 54.

3.1 SPECIFICATIONS

MEASUREMENT SPECIFICATIONS

Volumetric Water Content (VWC)

Range

Mineral soil calibration	0.00–0.70 m ³ /m ³
--------------------------	--

Apparent dielectric permittivity (ϵ_a)	1–50 (soil range) 1 (air) to 80 (water)
---	--

NOTE: The VWC range is dependent on the media the sensor is calibrated to. A custom calibration will accommodate the necessary ranges for most substrates.

Resolution	0.001 m ³ /m ³
------------	--------------------------------------

Accuracy

Generic calibration	±0.05 m ³ /m ³ typical in mineral soils that have solution EC < 8 dS/m
---------------------	--

Medium specific calibration	±0.02–0.03 m ³ /m ³ in any porous medium
-----------------------------	--

Apparent dielectric permittivity (ϵ_a)	1–40 (soil range), ±1 (ϵ_a) (unitless) 40–80, 15% of measurement
---	--

Dielectric Measurement Frequency

70 MHz

Temperature

Range	–20 to +60 °C
-------	---------------

Resolution	0.03 °C
------------	---------

Accuracy	±0.35 °C from –20°C to 0 °C ±0.25 °C from 0°C to 60 °C
----------	---

COMMUNICATION SPECIFICATIONS

Output

DDI Serial and SDI-12 communications protocol

3-wire cable version (Figure 6)

4-wire cable version (Figure 10)

RS-485 Modbus RTU and tensioLINK serial communications protocol

4-wire version (Figure 9)

Data Logger Compatibility

METER ZL6 and EM60 data loggers or any data acquisition system capable of 4.0- to 24.0-VDC power and serial interface with SDI-12; and/or RS-485 interface, Modbus RTU, or tensioLINK communication.

PHYSICAL SPECIFICATIONS

Dimensions

Length 75.0 cm (29.53 in)

Diameter (shaft) 6.0 cm (2.36 in)

Width (head) 11.0 cm (4.33 in)

Operating Temperature

Minimum -20 °C

Maximum +60 °C

Standard Cable Length

5.0 m (stereo plug and stripped and tinned wires)

75.0 m (maximum custom cable length)

1.5 m (M12 connector)

NOTE: Contact [Customer Support](#) if a nonstandard cable length is needed.

Cable Diameter

Stereo Plug 4.2 ±0.2 mm (0.16 ±0.01 in)
with minimum jacket of 0.8mm (0.031 in)

M12 Plug 5.5 ±0.2 mm (0.22 ±0.01 in)
with minimum jacket of 1.0 mm (0.039 in)

Connector Size

3.50 mm (diameter)

14.4 mm (diameter M12)

Connector Types

Stereo plug connector or stripped and tinned wires

4-pin M12 connector or stripped and tinned wires

Conductor Gauge

Stereo Plug 22-AWG / 24-AWG ground wire

M12 Plug 22-AWG

ELECTRICAL AND TIMING CHARACTERISTICS**Supply Voltage (power to ground)**

Minimum 4.0 VDC

Typical NA

Maximum 24.0 VDC

Digital Input Voltage (logic high)

Minimum 2.8 V

Typical 3.6 V

Maximum 5.0 V

Digital Input Voltage (logic low)

Minimum -0.3 V

Typical 0.0 V

Maximum 0.8 V

Digital Output Voltage (logic high)

Minimum NA

Typical 3.6 V

Maximum NA

Power Line Slew Rate

Minimum	1.0 V/ms
Typical	NA
Maximum	NA

Current Drain (during 500-ms measurement)

Minimum	3 mA
Typical	35 mA
Maximum	50 mA

Current Drain (while asleep)

Minimum	0.03 mA
Typical	0.1 mA
Maximum	NA

Power-Up Time (DDI Serial)

Minimum	500 ms
Typical	NA
Maximum	800 ms

Power Up Time (SDI-12)

Minimum	NA
Typical	1,000 ms
Maximum	NA

Power Up Time (SDI-12, DDI Serial disabled)

Minimum	500 ms
Typical	600 ms
Maximum	800 ms

Measurement Duration (4 depths)

Minimum	500 ms
Typical	NA
Maximum	800 ms

COMPLIANCE

EM ISO/IEC 17050:2010 (CE Mark)

3.2 COMPONENTS

The TEROS 54 consists of the probe and a protective cap for the thread of the probe head.

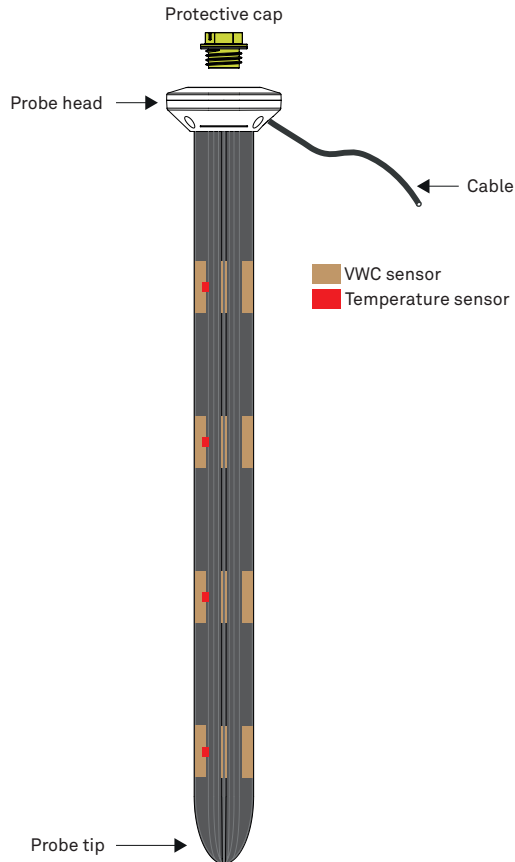


Figure 17 TEROS 54 components

The TEROS 54 measures the volumetric water content (VWC) and soil temperature at four defined depths: 15 cm, 30 cm, 45 cm, and 60 cm. Each depth represents the center point of the measuring sensors. At every measuring depth, the TEROS 54 is equipped with four independent VWC sensors for a 360° measurement (Figure 19). Because the TEROS 54 is equipped with four sensors per depth, it gives an accurate representation of the soil at that depth.

TEROS 54

For the best output, the measured values of all four sensors are calculated together. If the measurement at one of the four sensors is disturbed, for example, because a root or a stone interferes with the sensor, the 360° measurement coverage of the TEROS 54 compensates for this. In this case the other three sensors provide correct data.

The most accurate measurement results are obtained very close to the TEROS 54 shaft in each area between the wings. As the distance from the shaft increases, the strength of the sensors also decreases. The measuring volume is approximately 300 cm³ per depth.

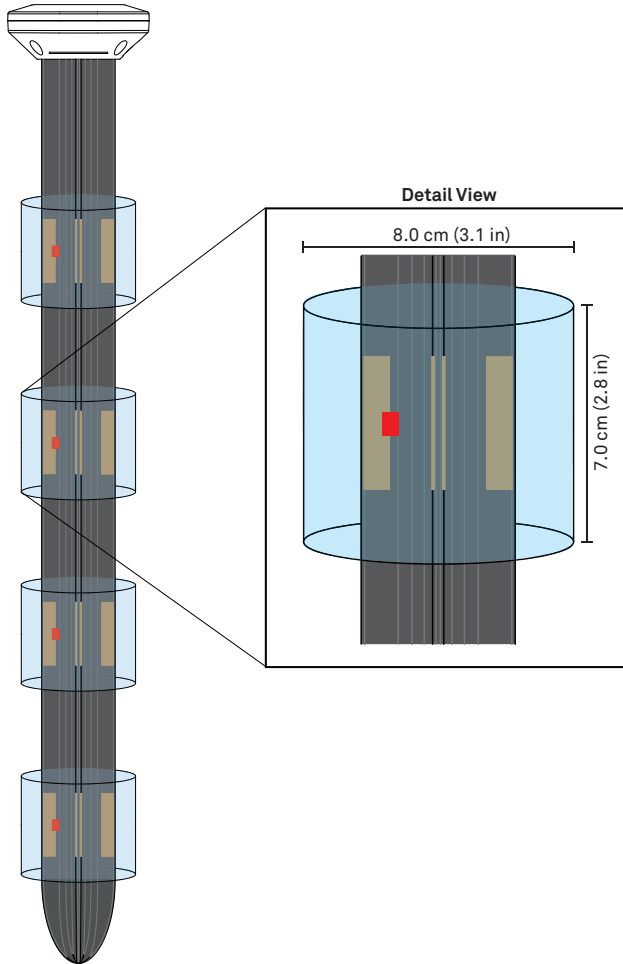


Figure 18 Volume of influence

SYSTEM

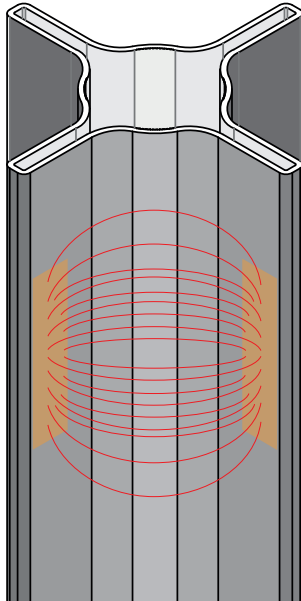
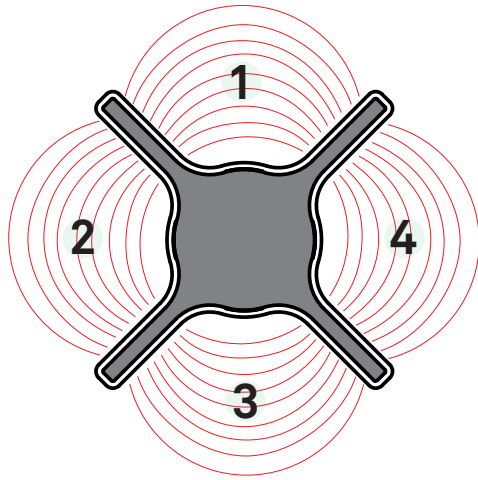


Figure 19 Measurement method

3.3 THEORY

The following sections explain the theory of VWC and temperature measured by TEROS 54.

3.3.1 VOLUMETRIC WATER CONTENT

TEROS 54 sensors use an electromagnetic field to measure the dielectric permittivity of the surrounding medium. The sensors supply a 70 MHz oscillating wave that charges according to the dielectric of the material. The charge time is proportional to substrate dielectric and substrate VWC. The TEROS 54 microprocessor measures the charge time and outputs a raw value based on the substrate dielectric permittivity. The raw value is then converted to VWC by a calibration equation specific to the substrate.

3.3.2 TEMPERATURE

The TEROS 54 uses four temperature sensors mounted on the PCB near the VWC sensors.

TEROS 54 temperature measurement is optimized to be accurate when the TEROS 54 is buried in soil or substrate.

The TEROS 54 temperature output is in degrees Celsius unless otherwise stated in the data logger program, such as in preferences in the ZENTRA Utility software.

4. SERVICE

This section describes the calibration and maintenance of the TEROS 54. Troubleshooting solutions and customer service information are also provided.

4.1 CALIBRATION

METER software tools automatically apply factory calibrations to the sensor output data. Calibration by the customer is not provided. Please contact [Customer Support](#) if a TEROS 54 needs to be recalibrated.

This section includes the mineral soil and dielectric calibrations for TEROS 54, where Θ is the VWC (in m^3/m^3), ε is dielectric and RAW is the raw sensor output when read with a METER or third-party data logger.

The TEROS 54 is not sensitive to variation in soil texture and electrical conductivity (EC) because it runs at a high measurement frequency. Therefore, its generic calibration equation should result in high accuracy for most instances; $0.05 \text{ m}^3/\text{m}^3$ for most mineral soils up to 8 dS/m saturation extract. Its calibration equations are shown below for mineral soil and dielectric permittivity. However, for added accuracy, customers are encouraged to perform soil-specific calibrations. For more information on how to calibrate sensors or to learn about METER calibration service (calibrations performed for a standard fee), contact [Customer Support](#).

4.1.1 MINERAL SOILS

According to METER tests, a single calibration equation will generally suffice for most mineral soil types with ECs from 0 to 8 dS/m saturation extract. VWC Θ is given by [Equation 1](#):

$$\Theta (\text{m}^3/\text{m}^3) = 1.8543\text{E-}08 \times \text{mV}^3 - 4.1231\text{E-}05 \times \text{mV}^2 + 3.1015\text{E-}02 \times \text{mV} - 7.7224\text{E+}00 \quad \text{Equation 1}$$

A third order polynomial is used for the mineral soil calibration because it provides the best VWC predictions in the VWC range found in mineral soils, but this equation reaches a maximum at approximately $0.70 \text{ m}^3/\text{m}^3$ in pure water. To display data on a scale from 0.0 to $1.0 \text{ m}^3/\text{m}^3$, VWC should be modeled with a quadratic equation (which would result in a $1.0 \text{ m}^3/\text{m}^3$ in water). However, METER does not recommend this for mineral soils because it often makes the calibration in the VWC range found in mineral soil less accurate.

4.1.2 APPARENT DIELECTRIC PERMITTIVITY

Apparent dielectric permittivity ϵ_a (can be used to determine VWC using external published equations such as the Topp equation (Topp et al. 1980). Dielectric permittivity is also used for calculating pore water EC. Dielectric permittivity is given by [Equation 2](#):

$$\epsilon = -1.0898E-04 \times RAW^4 + 2.0718E-02 \times RAW^3 - 1.4095E+00 \times RAW^2 + 4.2535E+01 \times RAW + 4.7540E+02 \quad \text{Equation 2}$$

4.2 MAINTENANCE

TEROS 54 may be returned to METER for maintenance in the following areas: system inspection, parts replacement, and instrument cleaning. Replacement parts can also be ordered from METER. Contact [Customer Support](#) for more information. The nominal lifespan for outdoor usage is 10 years, but the lifespan can be substantially extended by proper and careful usage and by protecting the sensor against ultraviolet (UV) radiation and frost.

NOTE: Do not use any solvents for cleaning TEROS 54.

4.3 TROUBLESHOOTING

[Table 2](#) lists common problems and their solutions. If the problem is not listed or these solutions do not solve the issue, contact [Customer Support](#).

Table 2 Troubleshooting the TEROS 54

Problem	Possible Solutions
TEROS 54 not responding	<p>Check power to the probe.</p> <p>Check probe cable and stereo plug connector integrity.</p> <p>Try a different port on the data logger.</p> <p>Check data logger wiring to ensure the following connections:</p> <p>3-wire SDI-12 Power (brown), Data (orange), Ground (bare)</p> <p>4-wire SDI 12 Power (brown), Data (white), Ground (blue and black)</p> <p>4-wire M12 Power (brown), Data (white), Data (black), Ground (blue)</p> <p>If the probe does not respond, use the ZSC to rule out damage to the logger.</p>
TEROS 54 reading too low (or slightly negative)	<p>Check for air gaps around the probe.</p> <p>Ensure the calibration equation being used is appropriate for the media type.</p> <p>There are significant differences between substrate calibrations, so be sure to use the one specific to the substrate.</p>

Table 4 Troubleshooting the TEROS 54 (continued)

Problem	Possible Solutions
TEROS 54 reading too high	<p>Check to make sure that the media was not packed excessively or insufficiently during probe installation. Higher density can cause sensor reading to be elevated.</p> <p>Ensure the calibration equation being used is appropriate for the media type.</p> <p>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.</p> <p>Some substrates have an inherently high dielectric permittivity (soils of volcanic origin or high in titanium, for instance). If the substrate has a dry dielectric permittivity above 6, a custom calibration may need to be performed.</p>
Cable or stereo plug connector failure	<p>If a stereo plug connector is damaged or needs to be replaced, contact Customer Support for a replacement connector and splice kit.</p> <p>If a cable is damaged follow the guidelines in the Wire Splicing and Sealing Technique for Soil Moisture Sensors for wire splicing and sealing techniques.</p>
Data logger is not recognizing probe	<p>If using a METER logger, update logger firmware. Check the logger configuration for a non-METER data logger using its user manual.</p>
Data logger is not receiving readings from the sensors	<p>Check that the connections to the data logger are both correct and secure. Ensure that data logger batteries are not dead or weakened. Check configuration of the data logger through software to ensure TEROS 54 is selected. Ensure the software and firmware is up to date.</p>
High fluctuations of the values	<p>If there are high fluctuations in the values, this may be because the TEROS 54 has larger gaps to the soil. This can cause air or water to collect and falsify the values.</p> <p>In such a case, check whether the TEROS 54 is firmly seated in the soil.</p> <p>If the TEROS 54 sits too loosely in the soil, it must be removed and reinstalled so that there is as little gap as possible between the sensor shaft and the soil.</p>

4.4 CUSTOMER SUPPORT

NORTH AMERICA

Customer service representatives are available for questions, problems, or feedback Monday through Friday, 7:00 am to 5:00 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

EUROPE

Customer service representatives are available for questions, problems, or feedback Monday through Friday, 8:00 to 17:00 Central European time.

Email:	support.europe@metergroup.com sales.europe@metergroup.com
Phone:	+1.509.332.5600
Fax:	+1.509.332.5158
Website:	metergroup.de

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

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

NOTE: For products purchased through a distributor, please contact the distributor directly for assistance.

4.5 TERMS AND CONDITIONS

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

REFERENCES

Topp, G. Clarke, J.L. Davis, and A. Peter Annan. 1980. "Electromagnetic Determination of Soil Water Content: Measurement in Coaxial Transmission Lines." *Water Resources Research* 16, no.3: 574–582.

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