VARIOS

METER

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1. INTRODUCTION

Thank you for choosing the VARIOS Thermal Properties Analyzer from METER Group.

VARIOS is an automated measurement and evaluation lab system for determining thermal conductivity as a function of water content of soil samples and other suitable materials. This manual will help the user understand and use the VARIOS in its possible combinations to the best of its capability.

Please verify that all components for the VARIOS set ordered are included and appear in good condition. Explanations for all components are located in Section 3.2.

1.1 VARIOS—COMPLETE SET

The most common ordering option is for a VARIOS Complete Set. This option is most often used for the dryout process described in Section 2.3.1. The following items are included in the shipment:

• VARIOS Thermal Properties Analyzer

• HYPROP Balance (VARIOS ready) with USB cable

• TC-S70 needle

Accessories included:

- ◆ Soil sample ring with 2 drilled holes
- ◆ 2 Saturation trays
- ◆ 6 Silicone retaining rings
- ◆ Glycerin verification standard

1.2 VARIOS—EXTENSION SET

The components listed below are available individually to measure thermal conductivity at specific water content points and will not be able to associate the thermal conductivity with water content.

The VARIOS Extension Set does not include the HYPROP Balance (VARIOS ready). If this set will be used with an existing HYPROP Balance (not VARIOS ready), make sure a USB cable and power adapter with cable is included (Figure 3).

• VARIOS Thermal Properties Analyzer

• TC-S70 needle

Accessories included

- Soil sample ring with 2 drilled holes
- 2 Saturation trays
- 6 Silicone retaining rings
- Glycerin verification standard

Items sold separately

- VARIOS USB adapter and cable (order separately if applicable)
- VARIOS power adapter and cable (order separately if applicable)
- Sensor Installation Tool

1.3 VARIOS—STANDALONE SET

The components listed below are available individually. This allows for use of a custom soil sample container, or to measure thermal conductivity at specific water content points. Contact Customer Support for more information.

• VARIOS Thermal Properties Analyzer (1)

• USB-A to USB-B adapter and cable (1)

The following components can be ordered separately, if needed.

- Sensor installation tool
- Thermal conductivity soil sample ring
- Glycerin verification standard
- VARIOS Power supply adapter and cable
- HYPROP Balance (VARIOS ready)
- Sensor with TC-S70 needle
- Sensor with TC-S100 needle

2. OPERATION

Please read all instructions before operating the VARIOS 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 VARIOS 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

Follow the steps listed in Table 1 to set up the VARIOS standalone as well as VARIOS dryout.

Table 1   Installation

Tools Needed	Microsoft® Windows® computer (Windows 10 or newer) LABROS SoilView software LABROS SoilView-Analysis software
Preparation	**⚠ WARNING** **VARIOS is not intended for outdoor use.** **CONSIDER SURROUNDINGS** When the VARIOS is used in combination with the HYPROP Balance, place the Balance on a horizontal, vibration-free, solid surface where the temperature remains fairly stable (away from the air conditioner and heater vents, windows, etc.). **IMPORTANT: Temperature fluctuations or vibrations will strongly affect the accuracy of the measurement results.** Remove the plate of the HYPROP Balance, and place the VARIOS on top of the scale.

Table 1   Installation (continued)

Installation	**Install LABROS SoilView Software and METER USB Driver** Download the LABROS SoilView Software Download.
	Run the `LABROS SoilView.exe` file and follow the installation instructions.
	NOTE: LABROS SoilView software can only be used with Microsoft Windows 10 or newer.
	If there is a problem executing the LABROS SoilView.exe, please download and install Microsoft.NET Framework 4.8.0 manually and have the current version of the Microsoft Windows installer.
	Click on the LABROS SoilView icon to open the program.
	Connect VARIOS to HYPROP Balance (VARIOS ready) Insert the VARIOS connector cable into the back of the HYPROP Balance (Figure 2).
	Connect VARIOS to a HYPROP Balance that is not VARIOS Ready Connect the VARIOS connector cable into the VARIOS power adapter, and plug the power adapter into the HYPROP Balance (Figure 3).
	When the VARIOS is powered, a blinking white light will appear on the front of the unit. See Table 10 for more information regarding the lights and meanings.

2.2 KEY FACTORS TO GET RELIABLE MEASUREMENTS

Getting reliable results from VARIOS measurements is dependent upon the following factors.

• Air gaps in the sample may form if the needle moves around in the sample.

  If an air gap forms, the accuracy of the measurement will be affected. The sensor needle needs to fit tightly in the sample to reduce the chance of the needle moving around.

• Small stones or pebbles in the sample may prevent the sensor needle from being inserted into the sample.

  Try installing the sensor through the second drilling hole when this occurs.

2.3 CONNECT VARIOS CONFIGURATIONS

The VARIOS can be configured two ways depending on the type of measurement data required and the accessories available. This section describes the two configurations and how to connect the accessories.

2.3.1 VARIOS THERMAL DRYOUT CONFIGURATION

The VARIOS Thermal dryout configuration uses both the VARIOS and a HYPROP Balance to calculate the thermal conductivity as a function of water content of soil samples or various suitable materials. Both the VARIOS Complete Set and the Extension Set can be used for the Thermal dryout configuration.

The Extension Set will require an existing HYPROP Balance and VARIOS power adapter to create a thermal dryout curve.

The VARIOS is placed on top of and connected to a HYPROP Balance. The soil sample ring is placed directly on top of the VARIOS. The thermal conductivity and weight data are automatically recorded from the HYPROP Balance and evaluated via the LABROS SoilView and LABROS SoilView-Analysis software. As a result, the correlation between thermal conductivity and water content of the dried-out soil sample is determined by the data collected from the sample during the dryout process.

NOTE: The Complete Set uses a HYPROP Balance (VARIOS ready) and the Extension Set uses a legacy HYPROP Balance. If HYPROP Balance is used, it can mean either version and depends on the equipment being set up.

2.3.1.1 CONNECT USING THE VARIOS COMPLETE SET

The VARIOS Complete Set or the Extension Set with an existing HYPROP Balance can be used for the VARIOS Thermal dryout configuration.

Follow the steps below to connect the VARIOS Complete Set (Figure 2).

1. Place the VARIOS ready HYPROP Balance on a stable surface.
2. Remove the Balance plate.
3. Place the VARIOS on top of the Balance.
4. Plug the VARIOS connection cable on the back of the VARIOS into the connector (Figure 2).
5. Plug the USB-B connector to the back of the VARIOS ready Balance and the USB-A connector to the computer (Figure 2).
6. Turn on the Balance.
7. Open the LABROS SoilView software.

    NOTE: If the LABROS SoilView and SoilView-Analysis software package in not installed, download the latest version from LABROS SoilView Sofware Download.

    Make sure the VARIOS and HYPROP Balance (VARIOS ready) are connected. Connected devices are shown in a device tree on the left side of the LABROS SoilView software screen (Figure 21). Be sure that the device stays connected during the entire measurement.

    NOTE: Make sure that the VARIOS connecting cable is not under any tension or touching anything that may influence the accurate weight data.
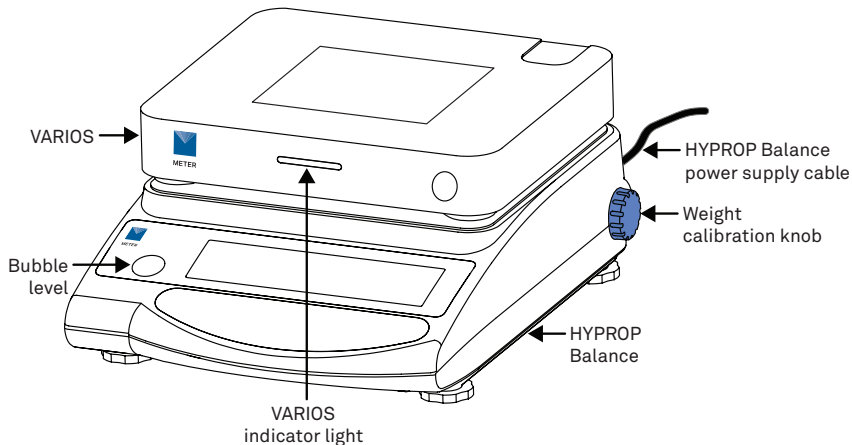
Figure 1   VARIOS Complete Set for thermal dryout configuration—front view
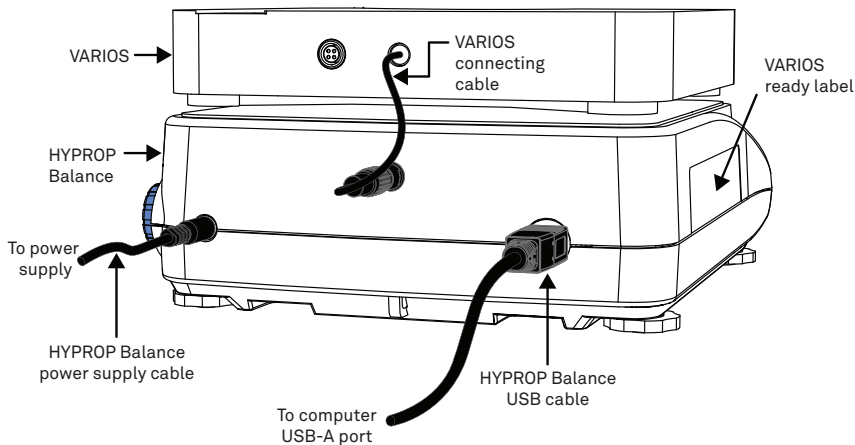
Figure 2   VARIOS Complete Set for thermal dryout configuration—back view

2.3.1.2 CONNECT USING THE VARIOS EXTENSION SET

When using an existing HYPROP Balance (that is not VARIOS ready), the Extension Set should be used. The Extension Set includes a METER power supply that plugs into the back of the Balance to provide enough power to run the VARIOS unit. Contact Customer Support for ordering information if a VARIOS power adapter is needed. Follow the steps below to connect the VARIOS Extension Set (Figure 3).

1.   Place the HYPROP Balance on a stable surface.

2.   Remove the Balance plate.

3.   Place the VARIOS on top of the Balance.

4. Plug the connection cable on the back of the VARIOS into the METER power adapter.

5. Plug the METER power adapter into the connector port on the back of the Balance.

6. Plug the power adapter cable from the METER power adapter into the wall.

7. Plug the USB-B connector end into the back of the Balance and the USB-A connector end to the computer.

8. Turn on the Balance.

9. Open the LABROS SoilView software.

   NOTE: If the LABROS SoilView and SoilView-Analysis software package in not installed, download the latest version from LABROS SoilView Software Download.

   Make sure the VARIOS and the Balance are connected. Connected devices are shown in a device tree on the left side of the SoilView software screen (Figure 18). Be sure that the device stays connected during the entire measurement.

   NOTE: Make sure that the VARIOS connecting cable is not under any tension or touching anything that may influence the accurate weight data.

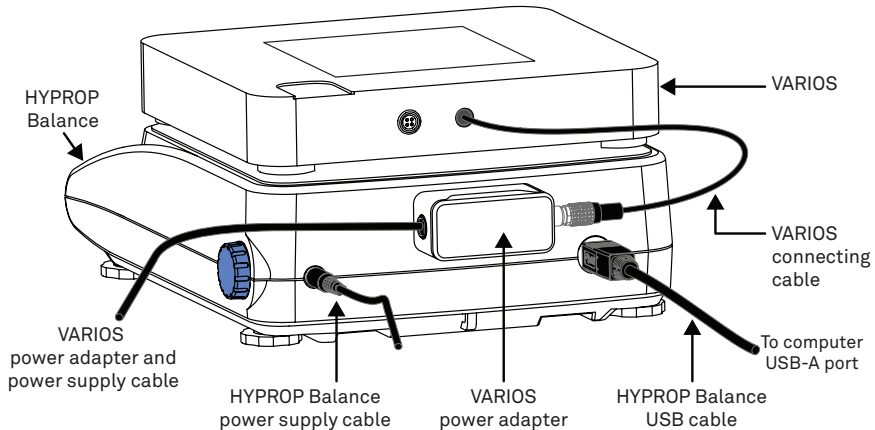**Figure 3   VARIOS Extension Set with VARIOS power adapter for thermal dryout configuration—back view**

2.3.2 VARIOS STANDALONE CONFIGURATION

The VARIOS Standalone Configuration is suitable for continuous or spot measurement of thermal conductivity of various suitable materials where recording the sample weight (water content) is not required (Figure 4).

The Standalone Configuration can be achieved by using either one of the options listed below:

• Purchase the VARIOS and USB power adapter in addition to the Standalone Configuration (Section 1.3).

• Use the VARIOS Extension Set components (Section 1.2) and a VARIOS USB adapter (sold separately).

Follow the steps below to set up the VARIOS Standalone Configuration:

1.   Place the soil sample directly on top of the VARIOS (Section 2.4).

2.   Connect the VARIOS to the VARIOS USB adapter.

>   **NOTE: Make sure that the VARIOS connecting cable is not under any tension or touching anything that may influence the accurate weight data.**

3.   Open LABROS SoilView software.

Make sure the VARIOS is connected and that all connected devices are shown in a device tree on the left side of the SoilView software screen.

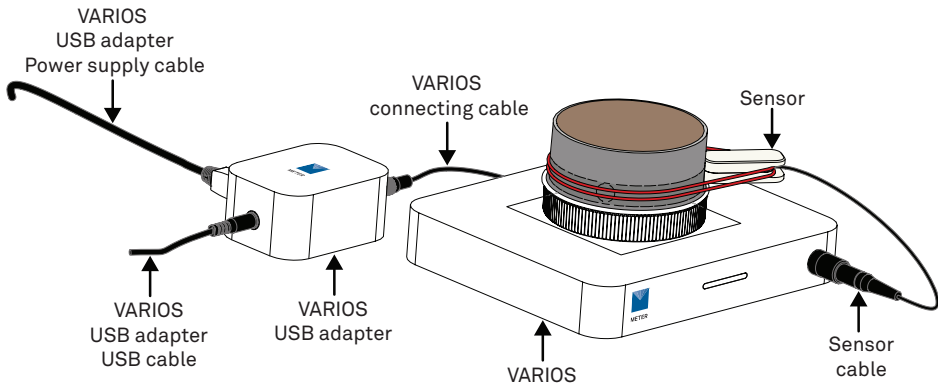Make sure that the devices stay connected during measurement.

Figure 4   VARIOS Standalone setup with USB adapter for taking thermal conductivity measurement

2.4 PREPARE SOIL SAMPLE

There are two methods for preparing a soil sample to measure the thermal conductivity using the VARIOS.

In both cases, it is important that the sample ring is full and the soil surface is flush (planar) with the top and bottom of the sample ring. All calculations are based on the exact volume of the sample ring.

A serial number is laser etched on the sample ring so it can be assigned to the respective measurement. The weight of the sample ring measured to one decimal place is also laser etched on the sample ring and respresents the precise tare weight when using the VARIOS dryout configuration.

2.4.1 UNDISTURBED SOIL SAMPLE

The first option uses an undisturbed soil sample transferred from the field so the measured parameters can be transferred from and be representative of the respective field site. This makes it important to take the soil sample with as little disturbance and change in soil structure as possible.

METER recommends using METER soil sample rings because the highly polished stainless steel surface minimizes friction and soil disturbance. The soil remains intact and air pockets are reduced. The METER soil sample ring volume that is standard for thermal measurements is 250 mL. It is also possible to use other soil sample rings, but the limiting factor is the length of the sensor needle used as well as the maximum weight the Balance can weigh when using VARIOS thermal dryout set up. The HYPROP Balance is able to weigh as much as 2,200 g. If a larger sample ring is used, it could end up weighing more than the Balance can measure.

The tools needed to collect an undisturbed soil sample are:
• duct tape

• spade

• knife

• METER soil sample ring (Figure 5)

• METER hammering adapter (Figure 5)

• PE hammer (Figure 5)

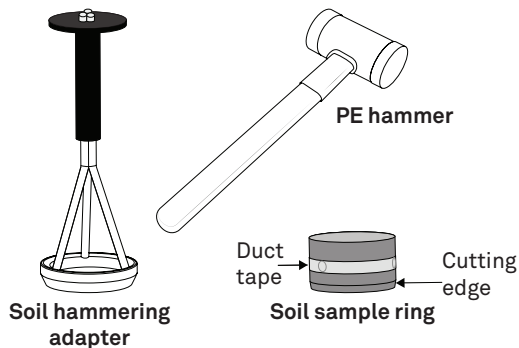• transport box for moving the sample ring from the field to the lab

PE hammer

Duct tape

Cutting edge

Soil hammering adapter

Soil sample ring

Figure 5   METER soil hammering adapter and hammer

The following steps describe how to collect an undisturbed soil sample.

1. Place a piece of duct tape over the drilling holes in the sample ring.
2. Cut off any vegetation to show the bare soil.
3. Dig a hole to the desired depth where the sample will be taken.

    Make sure there are no large stones or roots at the selected location.
4. Place the soil sample ring with the cutting edge down on the ground.
5. Place the METER hammering adapter (available for 250 mL) on the sample ring (Figure 6).
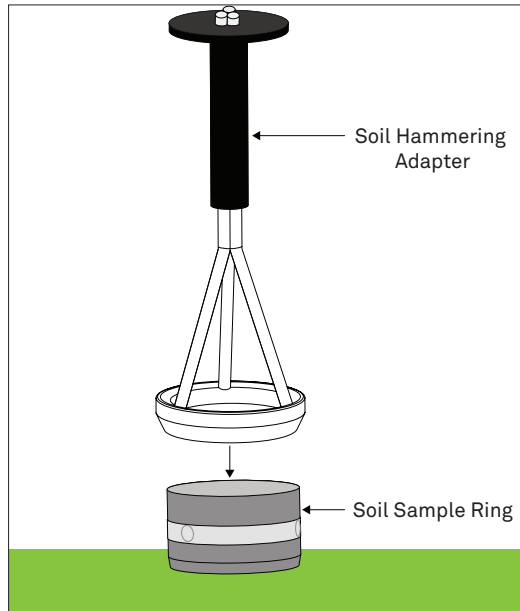

Figure 6   METER soil hammering adapter placement

6. Pound on the METER hammering adapter using the recommended PE hammer until the sample ring is completely buried in the soil (Figure 7).

    Make sure the sample ring goes straight down into the soil, not at an angle.

    Approximately 1 cm of material should protrude above the upper edge of the sample ring.
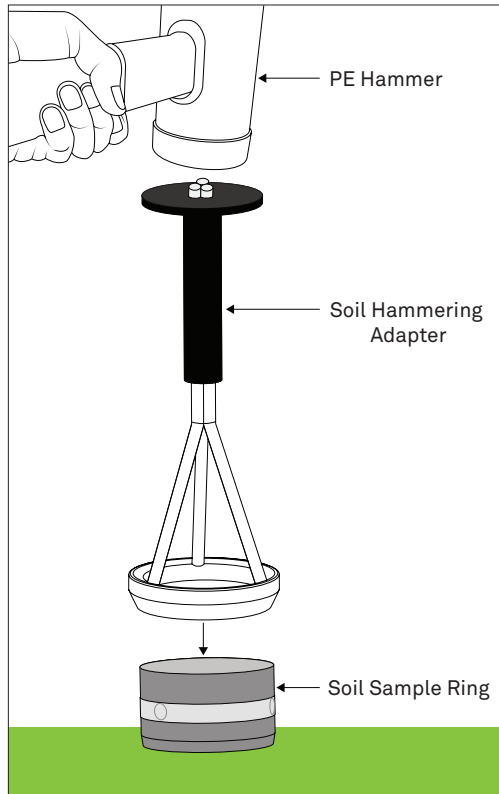
**Figure 7   Pound METER hammering adapter with PE hammer
to drive soil sample ring into ground**

7.   Remove the hammering adapter.

8.   Use a spade to dig the sample ring out of the hole, including the undisturbed soil sample.

Dig generously around the sample ring to avoid losing any sample material.

NOTE: Always take additional replacement samples from the same site in case one is not suitable.

9.   Remove the soil around the sample ring.

10. Use a knife or scissors to cut the protruding material from the top and the bottom side of the soil sample ring so both covers fit on each end.

Cut in little steps along the edge of the sample ring and be careful not to smudge the surface and close the pores (Figure 8).
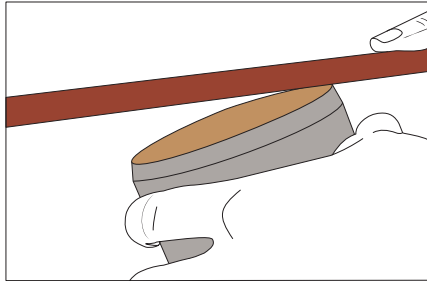
Figure 8   Level soil with top of sample ring

11. Place the sample ring with both covers in the transport box.

This protects the sample from vibrations and high temperature changes. Vibrations and microbiological processes due to high temperatures may change the soil structure.

12. Take the samples out of the transport boxes and store them in the refrigerator in the lab.

2.4.2 DISTURBED SOIL SAMPLE

The second option uses disturbed soil material that is pressed manually into the sample ring until full.

NOTE: If a specific dry density is requested, the amount of native soil material that has to be filled in the sample ring has to be calculated (i.e., more than the quantity that the sample ring holds needs to be collected in order to completely fill the sample ring, even when packing the soil into the sample ring).

The tools needed to collect a disturbed soil sample are listed below:

• duct tape

• METER soil sample ring

• HYPROP Balance

• fork

• knife

The following steps describe how to collect a disturbed soil sample.

1. Place a piece of duct tape over the drilling holes in the sample ring.

2. If requested, calculate the mass of material that has to be filled in the sample ring by using the desired dry density as well as the water content.

3. Weigh the amount of material that has to be filled into the sample ring.

4. Fill the sample ring with material in small steps to prevent air gaps.

Use a fork or something similar to rough up the material to ensure a homogenous passage between the filled in layers.

5. Be sure that the soil sample ring is filled completely and the surface is level.

   If required, cut overlapping material with a knife.

6. If no specific dry density is requested, fill the sample ring until it is completely full and the surface is flush (planar) with the soil sample ring.

   If required, cut overlapping material with a knife.

7. For storage, place the two covers on the sample ring.

8. Place the soil sample ring in the refrigerator in the lab.

2.5 SATURATE SOIL SAMPLE

The next preparation step is to saturate the soil samples. The following sections explain how to properly saturate the different sample types.

Gather the tools listed below prior to saturating the soil sample:

• Filter paper—large

• Filter paper—small

• LABROS Saturation plates (2)

• Weight

• Tray

• Tap water at room temperature

2.5.1 UNDISTURBED SOIL SAMPLE

Follow the steps below to saturate an undisturbed soil sample.

1. Take the soil sample out of the refrigerator.

2. Remove the cover on the noncutting side of the sample ring.

   If soil material is protruding above the top of the sample ring, cut off the protruding material until the surface is flush (planar) with the top of the sample ring.

   Cut a little bit at a time along the edge of the sample ring and be careful not to smudge the surface and close the pores (Figure 9).
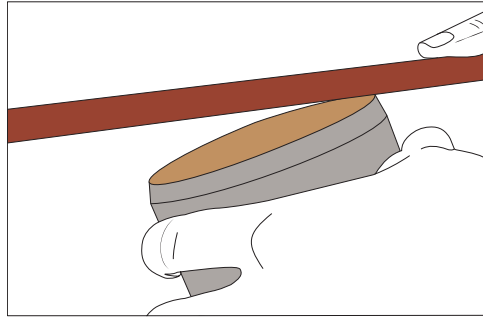
Figure 9   Cut protruding material level with top of sample ring

3.   Examine the cut side for irregularities such as big stones, pebbles, woody debris, roots, and intensive smell.

4.   Estimate the possible lack of volume in mL attributed to the space taken up by irregularities identified in step 3.

5.   Enter the volume in mL under the Information tab in the LABROS SoilView-Analysis software (Figure 10).

     This will affect the calculations that are based on the assumed 250 cm³ volume.
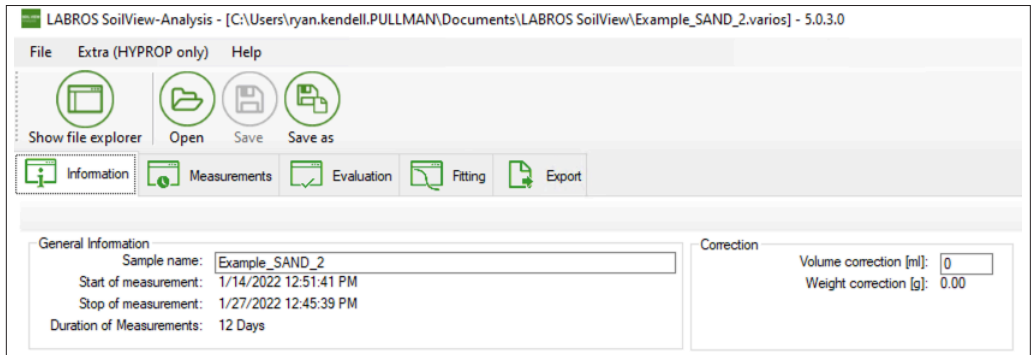
Figure 10   Volume correction in LABROS SoilView-Analysis software

6.   Place one of the large filter papers on the noncutting side of the sample ring.

7.   Place a LABROS saturation plate on the noncutting side of the sample ring.

     NOTE: The sample ring should fit snug in the LABROS saturation plate.

8.   Hold the filter paper and LABROS saturation plate together and turn the sample ring over so that the noncutting side is facing down.
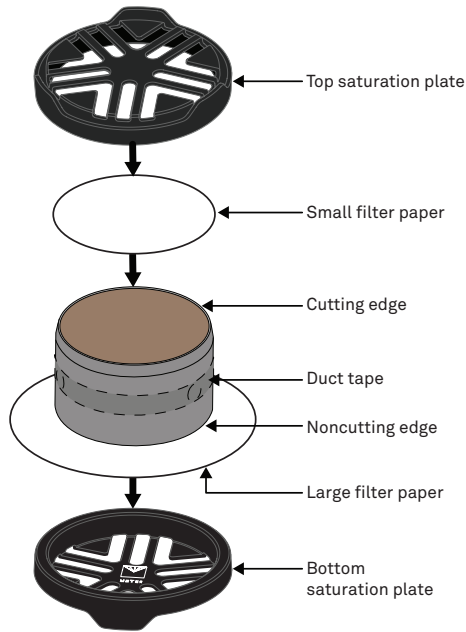
Figure 11   Large filter paper

9. Remove the cover on the cutting side of the sample ring.

10. Place one of the small filter papers on the cutting side of the sample ring.

11. Place the sample ring in a tray.

12. Fill the tray with about 3 cm of room-temperature tap water.

13. Tilt the LABROS saturation plate carefully to every side to remove air bubbles.

14. It is important to let the sample saturate through capillary action.

    Let the sample pull the water from the bottom to the top. Do not pour water on the top of the sample because air enclosures and the pores won't completely fill with water (Figure 12.

15. Be sure that the trough and the soil samples are not directly exposed to sunlight.

16. In case the material swells as it takes in water, place a weight on top of the sample to keep it from floating or tipping.

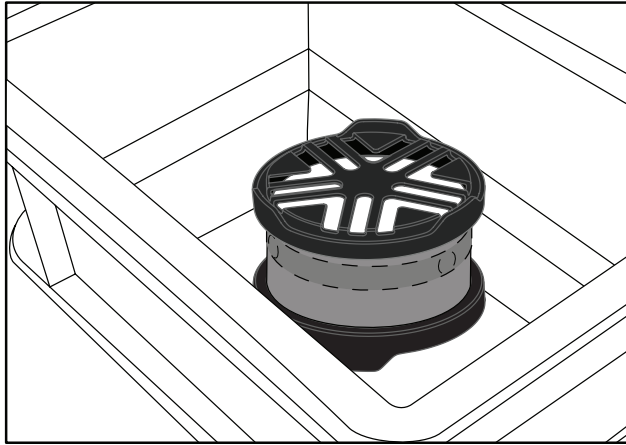17. Saturation is finished when the surface of the sample is glossy.

Figure 12   Saturation plate in water trough

2.5.2 DISTURBED SOIL SAMPLE

The steps below describe how best to saturate the soil sample.

1. Take the soil sample out of the refrigerator.

2. Remove the cover from the noncutting side of the sample ring.

    If soil material is protruding above the top of the sample ring, cut off the protruding material until the surface is flush (planar) with the top of the sample ring.

    Cut a little bit at a time along the edge of the sample ring and be careful not to smudge the surface and close the pores (Figure 13).
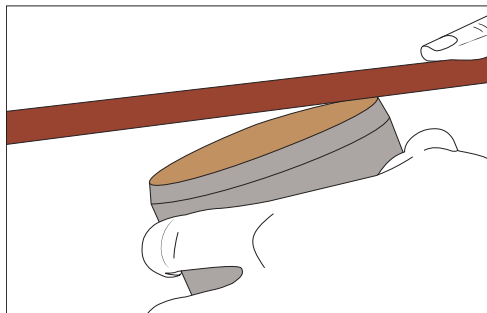

Figure 13   Cut protruding material level with top of sample ring

3.   Place one of the large filter papers on the noncutting side of the sample ring.
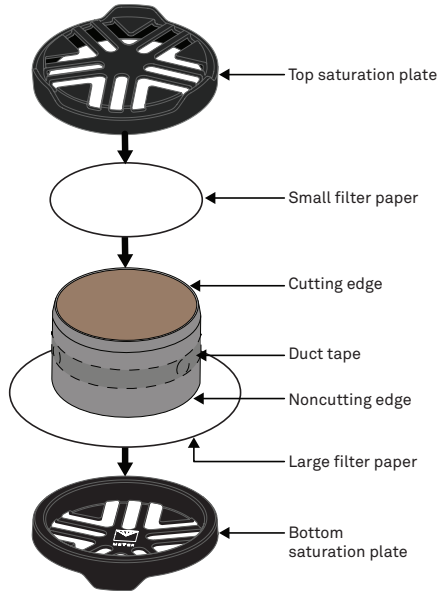
Figure 14   Large filter paper

4.   Hold onto the filter paper and turn the sample ring over so that the noncutting side is facing down.

5.   Place the noncutting side of the sample ring with filter paper onto a LABROS saturation plate (Figure 14).

Figure 15   LABROS Saturation plate

6.   Remove the cover from the cutting side of the sample ring.

7.   Place the sample ring cover upside down on top of the small filter paper.

8.   Place one of the small filter papers on the cutting side of the sample ring.

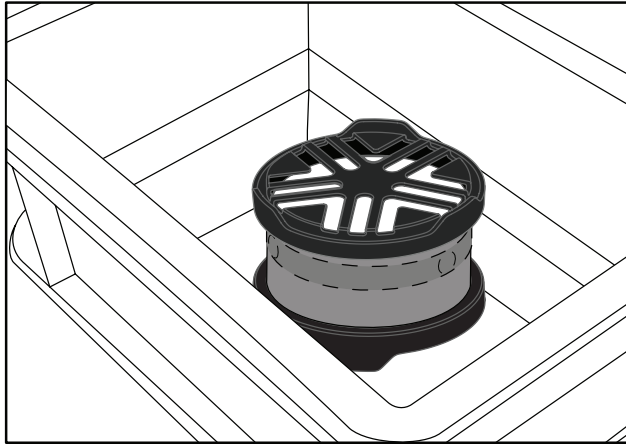9.   Place the LABROS saturation plate and sample ring in a tray.

Figure 16   Saturation plate in water trough

10. Fill the tray with about 3 cm of room-temperature tap water.

11. Tilt the saturation plate carefully to every side to remove air bubbles.

12. It is important to let the sample saturate through capillary action.

    Let the sample pull the water from the bottom to the top. Do not pour water on the top of the sample because air enclosures and the pores won't completely fill with water.

13. Be sure that the tray and the soil samples are not directly exposed to sunlight.

14. In case the material swells as it takes in water, place a weight on top of the sample.

15. Saturation is finished when the surface of the sample is glossy.

2.6 INSERT SENSOR NEEDLE INTO SAMPLE MATERIAL

This section instructs how to use the different types of needles with each sample material.

2.6.1 SOFT MATERIAL SAMPLE (TC-S70 OR TC-S100 SENSOR)

Follow these instructions for use with soil, and other loose material.

METER designed the two VARIOS sensors to be easy to install and use. The sensor needle(s) must be inserted all the way into the sample material. It is easier to get the needles inserted into some materials than others. Please observe the following considerations when installing the sensors.

• Ensure there is a minimum of 1.5 cm of material surrounding the sensor needle in all directions to avoid errors.

• Ensure there are no air gaps around the sensor needle.

• Insert the sensor needle all the way into the sample material (Figure 18).

⚠ CAUTION

Bending the needles can damage any sensor beyond repair. If the needle becomes bent, gently bend it back. If a needle has been bent and is no longer taking good readings, a replacement may be needed. Contact Customer Support for a replacement.

Below is a list of tools needed to install and secure the sensor in the soil sample:

• Installation tool

• Sensor with a TC-S100 or TC-S70 needle

• At least 2 Retaining rings

Using the tools listed above, please follow the steps below to insert the sensor needle into the soil sample.

1. Clean any soil off the sample ring.

2. Cover the sample ring with a clean cover.

3. Place the saturated soil sample in the installation tool (Figure 17).

4. Align one of the soil sample ring drill holes with the installation tool guide rail (Figure 17).
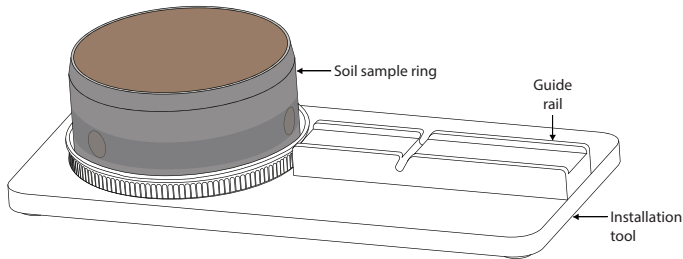

Figure 17   Soil sample ring on installation tool

5. Place a retaining ring around the sample ring and into the notch of the installation tool (Figure 18).

6. Place the sensor on the installation tool guide rail (Figure 18).

7. Insert the sensor needle continuously into the soil sample through the duct tape with even pressure by pushing it forward on the installation tool guide rail.

   NOTE: Avoid movements that will cause the needle to wobble as it is inserted. Secure the installed needle using several retaining rings to prevent the needle from changing positions. If the needle slides around inside the soil sample, air gaps may form that will cause a large error in the measurement readings.

   NOTE: If the sensor cannot be installed because of an irregular object such as a stone, try to install it using the second drilling hole.

8. Secure the sensor in place by positioning the retaining ring in the lower notch of the sensor hull (Figure 18).
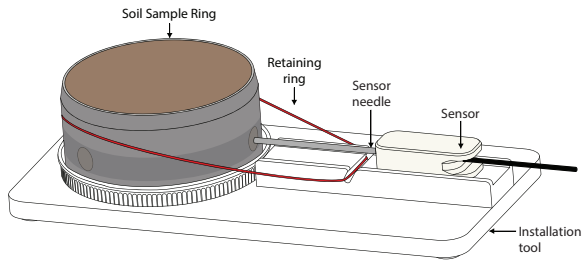
Figure 18   Sensor on installation tool

9. Use a second retaining ring to secure the sensor by placing the retaining ring around the sample ring and positioning it in the upper notch of the sensor hull (Figure 19).
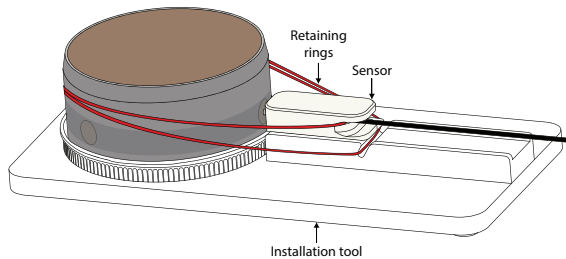
Figure 19   Sensor secured to sample ring on Installation tool

10. Secure the sensor cable connector in the retaining rings (Figure 20).

11. Saturate a small filter paper and place it on top of the soil sample to avoid evaporation before starting the measurement.

12. Place the sample ring cover upside down on top of the small filter paper.

13. Remove the installation tool from under the sensor.

Figure 20   Soil sample ring with sensor installed

14. Leave the sample cover on for at least 30 min to equilibrate before starting the measurement.

15. Remove the cover and saturated filter paper from the top of the soil sample.

16. Start the measurement.

    The measurement should be started as soon as possible after the sample is removed from the water trough and the sensor needle is inserted. The sample loses moisture despite the evaporation protection, which will influence the measurement.
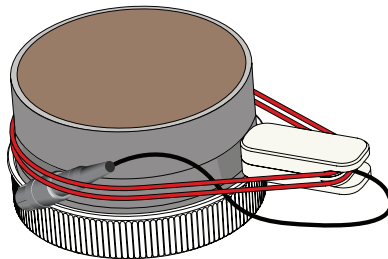
2.6.2 SOLID MATERIAL SAMPLE (TC-S100 SENSOR)

Use the following steps to install a sensor into solid materials, such as wood or hard soil.

1. Drill a pilot hole in solid material using a 2.40-mm (0.0945-in) drill bit (not included) for the TC-S100 sensor.

2. Clean the hole with a swab or compressed air.

3. Put thermal grease into the hole before inserting the sensor needle.

4. Ensure there are no air gaps around the sensor needle.

2.7 SET MEASUREMENT CONFIGURATION IN LABROS SOILVIEW SOFTWARE

This section provides instructions for configuring and processing a measurement using LABROS SoilView software.

2.7.1 POSSIBLE DEVICE COMBINATIONS

The possible device combinations for soil measurements are described in the following sections.

2.7.1.1 VARIOS PLUS BALANCE (COMPLETE SET OR EXTENSION SET)

To measure the thermal conductivity dryout curve, place the VARIOS and sample on a HYPROP Balance (VARIOS ready or existing) to record the weight and thermal data points continuously during the measurement. METER recommends the HYPROP Balance (VARIOS ready), however an existing HYPROP Balance can be used with a power adapter to provide the necessary power to run the VARIOS. Using this method, the Balance automatically records the weight loss of the sample. Therefore the thermal conductivity can be related to the respective water content of the sample.

NOTE: The HYPROP Balance has a weight limit of 2,200 g. Under normal conditions the provided sample ring will not exceed this limitation.

2.7.1.2 VARIOS WITHOUT BALANCE (VARIOS STANDALONE)

To measure the thermal conductivity of various materials, the sample can be placed directly on the VARIOS. Connect the VARIOS to a computer via a METER USB adapter and USB cable (Figure 4). Thermal conductivity data is recorded and evaluated using the LABROS SoilView and LABROS SoilView-Analysis software, respectively. This method does not compare the thermal conductivity as it relates to water content.

2.7.2 CONNECTING DEVICES TO A PC COMPUTER

Connect the devices to a PC as described in Section 2.3. All connected devices should be automatically detected by the LABROS SoilView software and displayed in the device tree on the left side of the user interface main window (Figure 21). If a device is not listed in the device tree after it has been plugged in, search manually by clicking on Show Devices. If a connected device is not found after manually searching, please refer to Section 4.3 for troubleshooting advice or contact Customer Support.
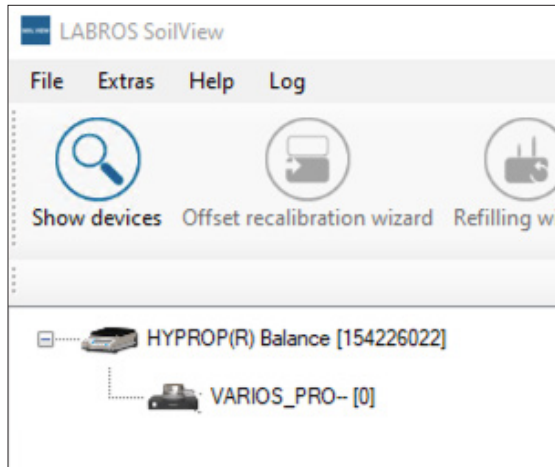

Figure 21   Devices shown in SoilView device tree

2.7.3 PREPARING THE BALANCE

This section provides instructions for balancing and preparing the device.

2.7.3.1 SET UP AND LEVELING

Please follow the steps listed below to set up and level the HYPROP Balance.

1.   Place the HYPROP Balance on a horizontal, vibration-free, solid surface where the temperature remains fairly stable (e.g., away from air conditioner and heater vents, windows).

     Ideally, this place is not used for other laboratory work during VARIOS measurements.

2.   Adjust the Balance by turning the Balance adjusters on the legs of the Balance until the level air bubble rests in the center of the level red circle (Figure 22).

3.   Connect the Balance to the power supply and to the computer via the included USB cable and turn the Balance on (Figure 22).
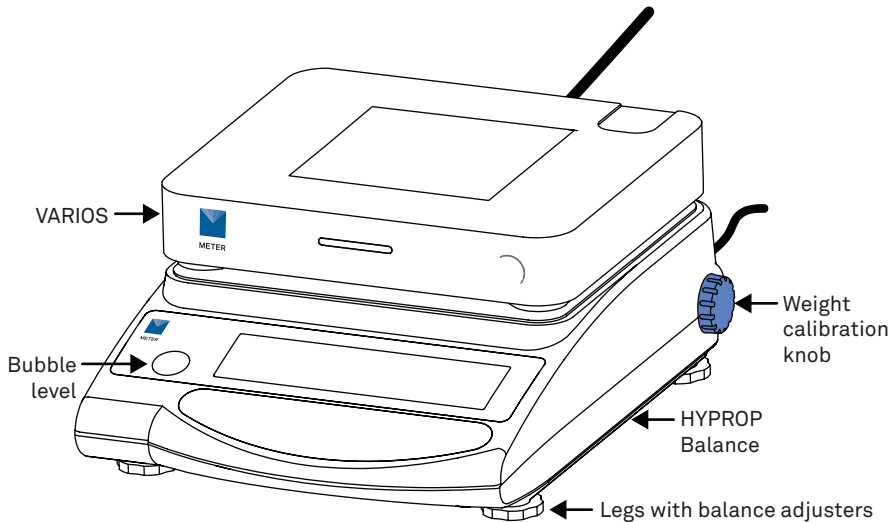
Figure 22   Balance leg adjusters and bubble level

2.7.3.2 CALIBRATION

For precise measurements, the Balance has to be calibrated according to the local conditions. It should be calibrated in the following circumstances:

• After the Balance has been set up.

• After the Balance has changed position.

• After a significant room or environment temperature change.

• After the Balance has gone for long periods without being used.

• If the Balance is generating inaccurate values.

The Balance is equipped with an internal calibration weight. The calibration process should run when there is no wind or vibration near the Balance (i.e., wind and vibration may result in an unsuccessful calibration).

Please follow the instructions below to perform a calibration test:

1.   Remove the VARIOS from the HYPROP Balance for calibration.

2.   Replace the original measurement pan that came with the Balance.

3.   Be sure nothing is placed on the Balance.

4.   Press the **ZERO/TARE** button on the Balance weight.

5.   Press and hold the **FUNCTION** button until **S.A. CAL** appears on the display.

6.   Press the **FUNCTION** and **ZERO/TARE** buttons at the same time.

7.   Release the **FUNCTION** and **ZERO/TARE** buttons at the same time.

8. Wait until `CAL. ON` appears on the display.

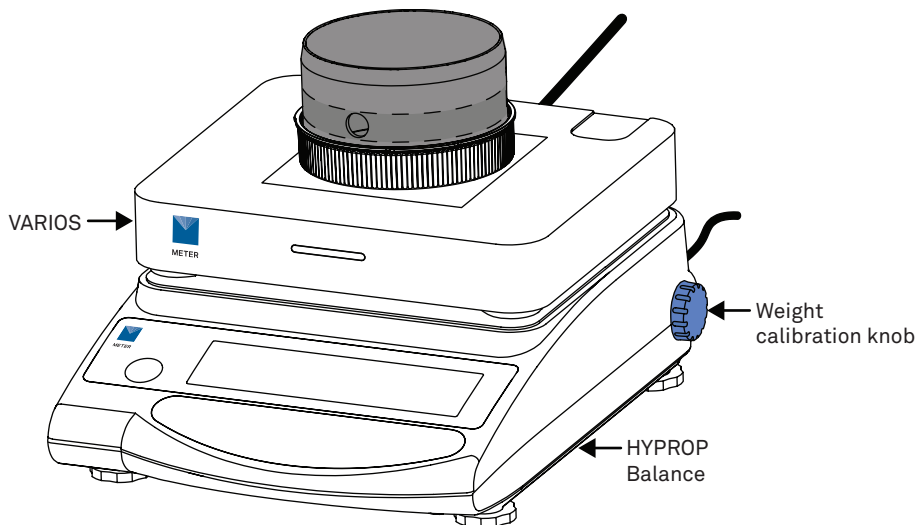9. Turn the blue calibration knob on the right side of the Balance to **CAL.**.

Figure 23   Weight calibration knob (blue)

The internal weight will be activated. The adjustment runs automatically.

10. Turn the calibration knob back to **WEIGH** when the display reads **CAL. OFF**.

Calibration is finished when the display reads **END**.

The calibration can be verified by placing a 1 kg weight on the Balance. The Balance should read within ±0.05 g of the weight.

2.7.3.3 DEFAULT SETTINGS FOR VARIOS MEASUREMENT

Find the HYPROP Balance settings by pressing the **FUNCTION** button until `func` shows on the display. METER recommends using the settings listed in Table 2 for measurements.

Table 2   HYPROP Balance Settings

Settings	Display	Adjustment
Bar graph	1. B.G. 1	1 = on
Limit function	2. SEL 0	0 = off
Auto-zero	3. A.0 1	1 = on
Response speed	5. rE. 3	3 = medium speed
Stability parameters	6. S.D. 2	2 = medium sensitivity
Interface	7. I.F. 1	1 = 6-digit numeric format

- Select a setting by pressing the **FUNCTION** button.

- Change the setting value by using the **ZERO/TARE** button.

- Terminate the function selection by pressing the **SET** button.

Table 11 lists possible error messages and troubleshooting solutions.

2.7.4 CONFIGURE A MEASUREMENT

This section contains information that describes how to configure a soil sample measurement using the LABROS SoilView software.

Remove the measurement pan and place the VARIOS unit on the HYPROP Balance. Place the soil sample ring on the VARIOS, centered on the mark on top of the VARIOS.
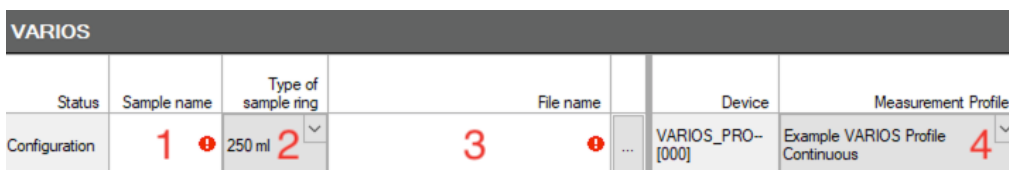

Figure 24   Configure a measurment

To start a measurement do the following:

1.   Enter a sample name.

2.   Select the type of sample ring (250 mL or customized).

> **NOTE: A custom soil container can be used with the VARIOS. The container volume and weight will need to be recorded and entered into the LABROS SoilView-Analysis software. The maximum weight that the balance can read is 2,200 g.**

3.   Choose a folder where the data will be saved.

4.   Select the Measurement Profile defined in the settings.

2.7.4.1 MEASUREMENT PROFILE

Before starting a measurement, a measurement profile that includes all necessary settings has to be selected. The measurement profiles are located in the Settings window in the upper right corner of the LABROS SoilView software screen.

The LABROS SoilView software provides one example profile for each of the following VARIOS measurement types:

- VARIOS continuous measurement mode (Figure 25)

- VARIOS point-by-point measurement mode (Figure 26)

- VARIOS measurement following IEEE 442-2017 standard (Figure 27)

- VARIOS Glycerin verification measurement (Figure 28)

The default settings can always be restored by selecting the **Restore** button.

Figure 25   Example VARIOS continuous measurement profile

Figure 26   Example VARIOS point-by-point measurement profile
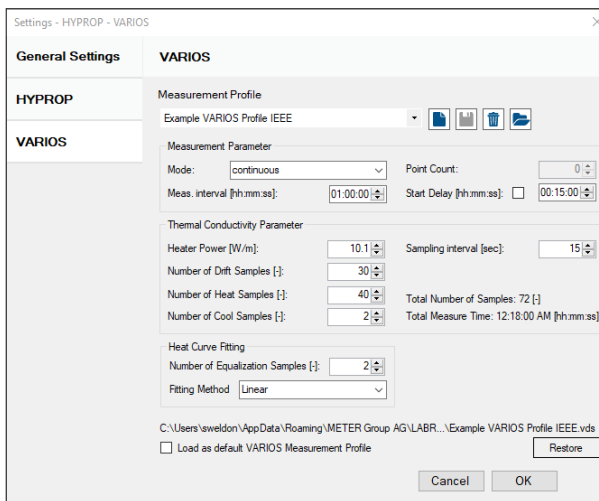
Figure 27   Example VARIOS IEEE 442-2017 standard measurement profile
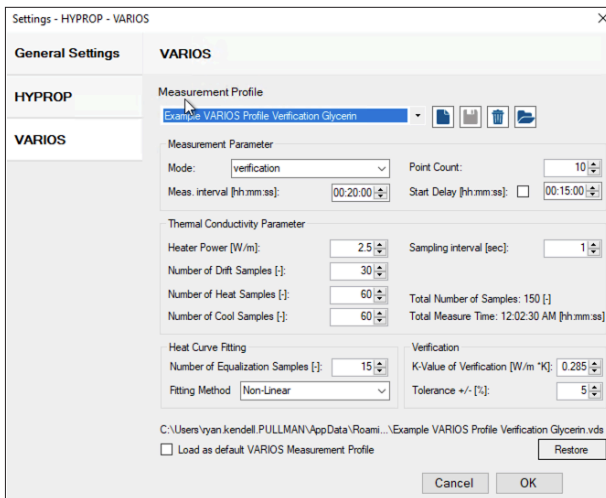
Figure 28   Example VARIOS Glycerin verification measurement profile

To generate a new customized measurement profile, follow the steps below:

1.   Press the **New Profile** button.

2.   Enter all necessary values.

3.   Press the **Save Profile** button to enter a profile name and store it (Figure 29).

     The customized measurement profile can now be selected for measurement configuration.
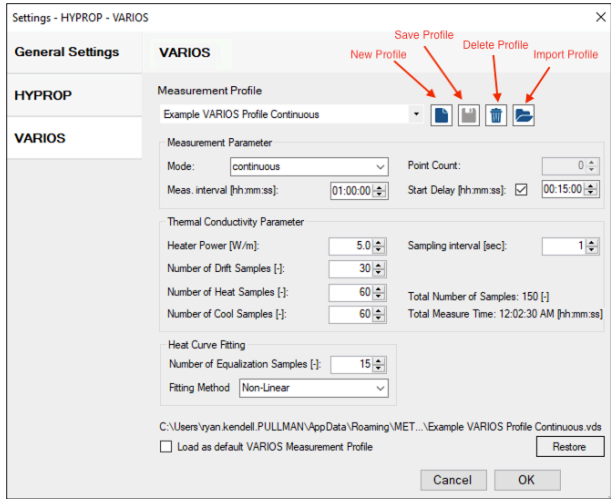
Figure 29   Generating a customized profile

Table 3 lists all parameters that can be defined for the measurement profile.

Table 3   Measurement Profile Parameters

Measurement Parameter	Description

`Mode`
`continuous`
`point by point`
`verification`
	Type of measurement mode

`Measurement interval [hh:mm:ss]`	Time between consecutive conductivity measurements (each with a duration of `Total Measure Time`).
`Point Count`	Number of measuring points for a point-by-point or verification measurement mode.
`Start Delay [hh:mm:ss]`	Define a start delay by selecting the checkbox. The measurement will then only start after the specified time.

Thermal Conductivity Parameter	Description
`Heater Power [W/m]`	Specifies the heating power in W/m values from 1.3 to 10.3 W/m for a TC-S70 needle. 0.8 to 6.0 W/m for a TC-S100 needle in steps of 0.1 W/m.

`Number of Drift Samples [−]`	Number of measurement phase samples recorded before the heating starts.
	Temperature is sampled regularly based on `Sampling Interval [sec]` and the measurement is used to determine and correct ambient temperature drift in the sample.
`Number of Heat Samples [−]`	Number of measurement samples recorded during the heating phase.
	The Heater Power is applied to the sensor needle and temperature is sampled regularly based on `Sampling Interval [sec]`. The recorded temperature data is analyzed to yield the thermal conductivity of the sampled material.
`Number of Cool Samples [−]`	Number of measurement samples recorded during the cool down phase, which immediately follows the heating phase.
	Temperature is sampled regularly based on `Sampling Interval [sec]`.
`Sampling Interval [sec]`	Indicates when a value is recorded during an active conductivity measurement.

Thermal Conductivity Parameter	**Description**
`Total Number of Samples [−]`	Sum of Drift, Heat, and Cool samples.
`Total Measure Time [hh:mm:ss]`	Duration of an active conductivity measurement; i.e., `Total Number of Samples x Sampling Interval [sec]`. Automatically calculated.

Heat Curve Fitting	**Description**
`Number of Equalization Samples [−]`	Number of heat measurement samples recorded at the beginning of the heating period.
	During this time, temperature gradients stabilize and are discarded for the thermal conductivity analysis because the temperature gradients and heater power at the beginning of the heating phase are not stable.
`Fitting Method`	Linear [assuming linear heating over log(t)]
	Nonlinear (assuming nonlinear heating over log(t) and linear heating over $log(t−t_0)$
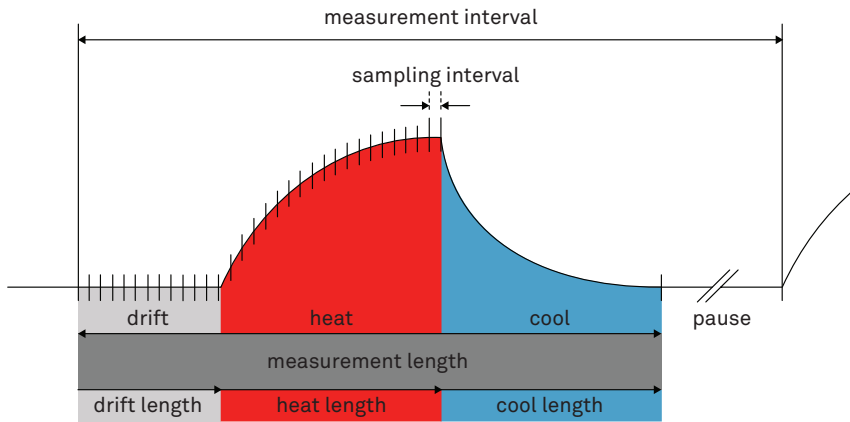
Figure 30   Example measurement cycle

2.7.4.2 MEASUREMENT MODES

There are three different modes that can be set in the measurement profiles.

Figure 31   Select measurement mode

Continuous Mode. This mode continuously performs and records measurements until the user stops the measurement. During continuous measurement, a conductivity value (and weight value) is collected at a previously defined time interval and automatically recorded to the software. This measurement mode is recommended for measuring the thermal conductivity dryout curve (Section 2.1) because the changing conductivity and weight values caused by the evaporation and drying of the sample can be directly monitored.

Point-by-Point Mode. Performs and records a defined number of measurement points using a defined time interval. The point-by-point measurement mode automatically stops after the defined number of measurement readings are recorded and transferred to the software. This measurement mode is recommended when single conductivity (and weight) values at different moisture steps need to be recorded.

Verification Mode. This is a measurement that verifies the sensor needles and VARIOS performance using a Glycerin standard. For more information please refer to Section 4.1.

2.7.5 RUNNING A MEASUREMENT

This section describes how to run a sample measurement after the configuration process (Section 2.7.5) has been completed.

2.7.5.1 START A MEASUREMENT

To start a measurement, click the START button (Figure 32) when the Ready for start (Figure 33) message is shown in the Status column.

The measurement process is started and a new tab in the software screen is created.

Figure 32   Ready for start message

Figure 33   START button

The Start Measurement Wizard in the LABROS SoilView software can also be used to start a measurement.

1. Click on the Start Measurement Wizard icon that appears below the Main menu toolbar.

2. Trigger the Start Measurement Wizard in the drop-down menu under the Extras menu in the Main menu.

Figure 34   Start measurement wizard

Follow the progress of the measurement while it is running in the newly generated tab that is named after the sample name as well as the respective measurement line in the manager.
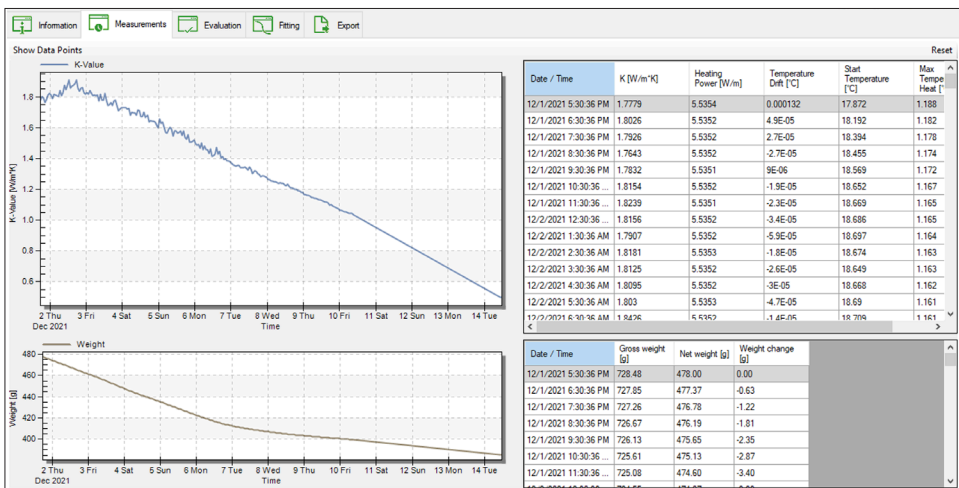
Figure 35   SoilView measurement tab

The measurement tabular information at the top of the Measurement tab (Figure 35) provides an overview of a wide range of information which are listed in Table 7.

Figure 36   SoilView Manager tab

Table 4   Manager Tab in LABROS SoilView Software

First Row–Heading	Second Row–Data
Status	Possible status options:
	Configuration
	Running
	Finished
Sample Name	User-defined sample name is shown.
Type of Sample Ring	The type of sample ring (250 mL or customized) selected during configuration.
Filename	Name user gives to the data file; should include the folder structure.
	By selecting the ellipsis button, a measurement can be continued (Section 2.7.6).
Device	VARIOS_PRO-[000]
	The name of the VARIOS device used.
Measurement Profile	Measurement profile used (Section 2.7.4.1).
Mode	continuous, point by point, or verification (Section 2.7.4.2).
Measurement Interval	Time between consecutive conductivity measurements (Section 2.3.1).
Measure Parameter	Duration of an active conductivity measurement (Section 2.3.1).
[empty]	By clicking on the ellipsis button, switch directly into the settings menu and the selected profile.
Balance	The HYPROP Balance used.
Empty soil sample ring weight [g]	If the soil sample ring weight was already defined during measurement configuration, the value is listed here.
O-ring (3x) weight [g]	The weight of the retaining rings used to fix the sensor needle can be entered here or later for evaluation.

Table 4   Manager Tab in LABROS SoilView Software (continued)

First Row–Heading	Second Row–Data
Sample ring lid weight [g]	The weight of the used lid can be entered here or later for evaluation.
Next Measurement	Date and time of the next measurement reading.
Start Measurement	Date and time of the measurement start.
Durations	Days, hours, minutes and seconds since the measurement is running.
Last readings	
K-Value	Last recorded thermal conductivity value in W/m × K.
Weight	Last recorded weight in g (only for the VARIOS dryout version).
[empty]	Start/Stop/Remove from Manager
[empty]	Select the **SHOW MEASUREMENT TAB** button and the surface jumps to the respective Measurement tab.

In the generated measurement tab all measured values are displayed graphically as well as in tabular form. There are different options and information, listed in Table 6 and Table 7.

Table 5   Measurement Tab Options

First Row–Heading	Second Row–Data
Open in LABROS SoilView-Analysis	The measurement file can be opened in the evaluation software LABROS SoilView-Analysis during measurement to get a snapshot of the running measurement.
Stop Measurement/Restart Measurement	Stop the measurement. Restart a stopped measurement.
Show Data Points	Display the data points graphically. Otherwise, only the graph is displayed.

Table 6   Measurement Tab Data

First Row–Heading	Second Row–Data
Status	View whether a measurement is running or whether the measurement has ended.
Measurement	View the measurement start time, the time of the next reading, the duration, and the Heat Power.
Last Reading	View the K-Value, Start temperature, and weight value of the last recorded reading.
Sample	View the sample name, filename, type of sample ring, and soil sample ring weight (soil sample weight is only shown if it was entered during measurement configuration).
First Row–Heading	Second Row–Data

`Device information`	View the VARIOS serial number, sensor unit name, and device ID, SN needle sensor.
`Balance information`	View the Balance serial number and Balance name.

During the measurement, all determined measurement results are displayed graphically in the LABROS SoilView software. A graph with the individual measurement points plotted (x-axis represents Time; y-axis represents the K-value [W/m × K]) is displayed in the SoilView measurement screen (Figure 35).

On the right side of the SoilView measurement screen next to the graph, is a table that lists all the measurement points (Figure 35). The heading names and description of data in this table are listed below in Table 7.

Table 7   Measurement Table Details

Table Column Headings	Data
`Date/Time`	Date and time of the current measurement value.
`K [W/m x K]`	Recorded thermal conductivity value.
`Heating Power [W/m]`	Specified heating power in W/m.
	Select a value between 1.3 to 10.3 W/m for TC-S70 and 0.8 to 6.0 W/m for TC-S100 in steps of 0.1 W/m.
`Temperature Drift [mK/s]`	Temperature drift measured before sensor heating. Used to correct for ambient temperature drift during heater measurement.
`Start Temperature [°C]`	Recorded temperature before start of an active conductivity measurement (before heating).
`Max Temperature Heat [°C]`	Difference during heat process between start temperature and final temperature value.

Measured values in the Measurement table can be sorted by clicking on one of the table column headings. The weight graph and respective table can be found in Figure 35.

2.7.5.2 STOP A MEASUREMENT

There are three ways to stop a measurement.

• Click on the **STOP** button in the Measurement tab.

• Click on the **STOP** button in the Measurement line.

• Click on **STOP ALL** in the table header to stop ALL measurements for a specific device type.

Each method requires the user to confirm the desire to stop the measurement. Confirm by clicking Yes in the pop-up window that appears.

2.7.6 ADDITIONAL FUNCTION OF LABROS SOILVIEW

This section describes additional options that can be used with the LABROS SoilView.

2.7.6.1 MAIN MENU TOOLBAR

The Main menu toolbar (Figure 37) contains main actions in the software. Table 8 describes the Main menu options.

Figure 37 Main Menu Toolbar

Table 8 Measurement Line

MAIN Menu Option	Description
File	Close the application.
Extras	Open the Refilling wizard (HYPROP measurements only), the Measurement wizard, or the Update firmware wizard.
Help	Open a Quick Start, the User Manual, Help Folder, check for Updates, Info.
Log	Open Error messages and other logbook entries.
Show devices	Shows when connecting more devices in a row to one computer. LABROS SoilView software normally automatically shows all directly connected devices.
Offset recalibration wizard (Only for HYPROP measurements)	Detects offset deviations and sets the zero point. For further information please read the HYPROP User Manual.
Refilling wizard (Only for HYPROP measurements)	Assists when refilling the HYPROP. For further information please read the HYPROP user manual.
Measurement wizard	Displays a menu to help start a measurement and select the right adjustments.
Feedback	Provides feedback.
Settings	Adjust general settings and define measurement profiles for the HYPROP and VARIOS measurements. For more information refer to Section 2.7.4.1.
Manual	View the current manual.

2.7.6.2 CONTINUE A MEASUREMENT AFTER BEING STOPPED OR COMPLETED

A measurement that has completed or has accidentally been stopped can be continued. A step-by-step measurement can also be appended to a continuous measurement or vice versa.

To continue a measurement, follow the steps listed below:

1. Select the ellipsis button next to the File name field in the Measurement line.
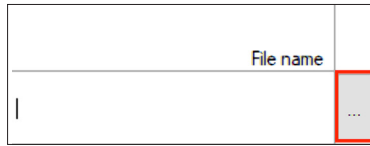

Figure 38   Ellipsis Button example

2. Select the measurement to be continued.

3. Press **SAVE**.

4. After saving the file name, use the pop-up to select whether the measurement shall be continued or overwritten.

NOTE: When continuing a measurement, the same sensor has to be used because the weight of the sensor is a critical parameter for the evaluation. A different VARIOS device may be used when continuing a measurement, as that will not adversely affect the data.

2.7.7 POSTPROCESSING A MEASUREMENT

The weight of the dry soil of the sample has to be determined after a VARIOS dryout measurement configuration because the LABROS SoilView-Analysis software needs the dry soil weight to calculate the volumetric water content based on the weight measurements.

1. Disconnect the sensor cables from the VARIOS.

2. Weigh an oven-safe drying pan.

3. Record the weight for use in step 13.

4. Place the soil sample ring in the oven-safe drying pan.

5. Carefully remove the sensor needle from the soil sample.

6. Hold the sensor needle over the drying pan.

7. Clean the sensor needle with a brush so all particles land in the drying pan..

8. Collect all soil particles in the drying pan.

9. Place the drying pan and soil sample in a drying oven.

10. Let the sample dry in the oven for 24 h at 105 °C (or 65 °C if using soil with high organic content).

11. Take the drying pan out of the oven.

12. Weigh the dried soil sample, sample ring, and drying pan.

    NOTE: Ensure that the soil sample has cooled to room temperature to prevent inaccurate weight readings. Soil samples should be kept in a desiccant chamber while cooling.

13. Subtract the tare weight of the drying pan.

14. Record the dry soil weight for evaluation in LABROS SoilView-Analysis software.

15. Document and enter the weight of the soil sample ring for evaluation in the information tab of LABROS SoilView-Analysis software.

If no weight values have been recorded during the measurement (e.g., a VARIOS Standalone Configuration), and the water content is not needed, the sample does not have to be dried in the oven. In this case, the performance of postprocessing steps are not required.

2.7.7.1 EVALUATION

The LABROS SoilView software generates `*.varios` files. These files can be opened using the LABROS SoilView-Analysis software.

The LABROS SoilView-Analysis software performs the following operations for VARIOS measurements:

• Specify all required parameters for the evaluation of the sample, such as geometric and device parameters, tare weights, etc.

• Visualize the raw data such as thermal conductivity values and weight changes.

• Recalculate thermal conductivity values and net weight data in relation to the volumetric water content calculation.

• Calculate and visualize the data for the thermal conductivity characteristic.

• Fit state-of-the-art thermal functions to the data, visualization of the functions, and listing of the values and confidence limits of the conductivity parameters.

• Export graphs, raw data, calculated data, fitted functions, and other parameters of interest.

The software leads the user through the VARIOS evaluation process using the tabs shown in Figure 39 and defined in Table 9:

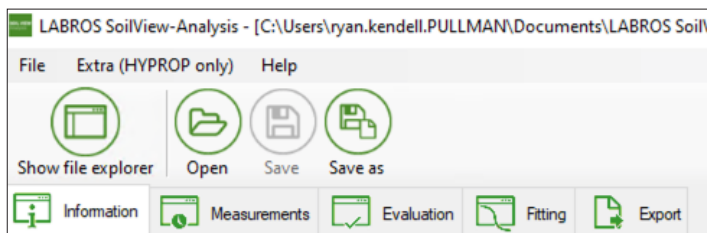Figure 39   LABROS SoilView-Analysis Software Tabs

Table 9   LABROS SoilView–Analysis Software Tabs

Name	Description
Information	View and specify measurement parameters.
Measurements	View and edit the measured data.
Evaluation	Calculate weight and thermal conductivity data; add externally measured data (only available in VARIOS dryout measurement).
Fitting	Apply thermal conductivity model to measured data (only available in VARIOS dryout measurement).
Export	Export data, graphs, function, and parameters.

For more details about how to use LABROS SoilView-Analysis, please read the LABROS SoilView-Analysis User Manual.

2.7.7.2 LED INDICATOR
The status of the VARIOS is indicated by the LED light on the front of the VARIOS unit (Table 10).

Table 10   VARIOS LED Status

MAIN Menu Option	Description
Flashing white light—three times	Powered on.
Permanent white light (not flashing)	LABROS SoilView detected a VARIOS device.
	VARIOS can be configured for measurement.
Flashing white light	Ready for measurement
Pulsing blue light	Measurement is in progress
MAIN Menu Option	**Description**
Constant blue light	Measurement is finished
Permanent red light	Firmware is being updated
Flashing pink light—three times	Error detected (see Troubleshooting)

3. SYSTEM

This section describes the VARIOS system.

3.1 SPECIFICATIONS

MEASUREMENT SPECIFICATIONS

Thermal Conductivity	
Range	
TC-S70 sensor	1.3–10.3 [W/m]
TC-S100 sensor	0.8–6.0 [W/m]
Accuracy	±5%
Temperature Sensor	
Storage/ Drying Range	−50 to +120 °C
Operation Range	−40 to 85 °C
Resolution	0.01 °C
Accuracy	±0.1 °C
Heater Current	
Range	20–200 mA
Resolution	10 µA
Accuracy	±0.05%
Heater Power	
Range	0.5–20 W/m (depending on sensor needle)
Resolution	20 mW/m
Accuracy	±0.1%

COMMUNICATION SPECIFICATIONS

Power Requirements
12 V / 1 A
Computer Compatibility
Microsoft® Windows® 10 operating system or newer

PHYSICAL SPECIFICATIONS

Dimensions	
Length	162.0 mm (6.38 in)
Width	185.0 mm (7.28 in)
Height	30.0 mm (1.18 in)
TC-S70 Sensor Dimensions	
Length	114.0 mm (4.49 in)
Width	19.4 mm (0.76 in)
Height	13.25 mm (0.52 in)
TC-S100 Sensor Dimensions	
Length	144.0 mm (5.67 in)
Width	19.4 mm (0.76 in)
Height	13.25 mm (0.52 in)

HYPROP BALANCE SPECIFICATIONS

Connection to Computer
USB
Weighing Range
2,200 g
Readout
0.01 g
Reproducibility
0.01 g
Linearity
0.01 g
Adjustment
Internally

COMPLIANCE

EM ISO/IEC 17050:2010 (CE Mark)

3.2 COMPONENTS

This section gives a description of other sensors and components that can be used with the VARIOS.

3.2.1 SENSORS

The VARIOS can read the TC-S70 and TC-S100 sensor data. Each sensor is available for sale individually when purchasing a VARIOS. The type of sensor, serial number, and weight is stored in the sensor and automatically transferred to the LABROS SoilView-Analysis software.
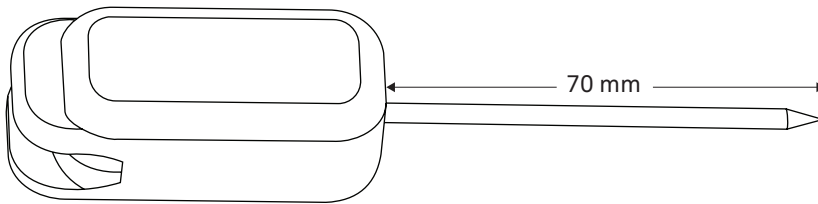

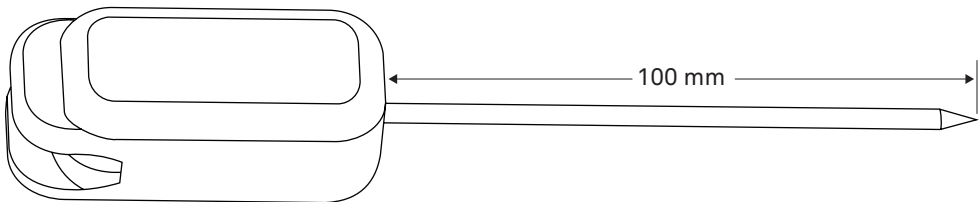
Figure 40   TC-S70 sensor

Figure 41   TC-S100 sensor

The sensors are designed for use in soil and other granular or porous materials, especially if a tight hole can be made to accommodate the sensor needle. The sensors can also be used in harder material by drilling an appropriately sized hole that the needle fits snugly into using a drill bit or a pilot pin (Section 2.6.2).

The large diameter of the sensor needles makes them robust and less likely to be damaged with normal use in soil or other solid materials. The dimensions of the **TC-S100** and **TC-S70** sensors conform to the specifications for the Lab Probe defined by IEEE 442-2017 and ASTM D5334 [1,2], [1] Guide for Soil Thermal Resistivity Measurements, and [2] Standard Test Method for Determination of Thermal Conductivity of Soiled and Soft Rock by Thermal Needle Probe Procedure.

When using the soil sample rings METER recommends using the TC-S70 sensor. The soil sample ring is large enough to use with the TC-S70. The longer TC-S100 needle is too long but is particularly suitable for large-diameter samples.

3.2.2 SOIL SAMPLE RING

The soil sample ring is designed to be pushed in the ground to collect a soil sample that is the appropriate volume for VARIOS testing. There are two holes drilled into the ring to allow for insertion of the VARIOS TC-S70 needle, with one extra hole in case debris is encountered. Two plastic protection caps are included to transport samples from the field to the lab.

3.2.3 HYPROP BALANCE

The HYPROP balance continuously measures the weight of the sample which allows the software to calculate water content of the sample as it dries.

NOTE: USB and HYPROP port weighing range is 2,200 g, resolution 0.01 g, reproducibility 0.01 g, and linearity 0.01 g

3.2.4 SATURATION RING

The VARIOS sample saturation ring assists in soil saturation and prevents soil loss during the saturation process.

3.2.5 SILICONE RETAINING RINGS

The silicone retaining rings hold the sensor in place to prevent movement during the duration of the test. This prevents air gaps between the sensor and the soil.

3.2.6 USB-A TO USB-B ADAPTER AND CABLE

This cable will connect the VARIOS to a computer. This component is required to use the VARIOS.

3.2.7 GLYCERIN VERIFICATION STANDARD

The glycerin standard is used to verify that VARIOS sensors are reading correctly. Glycerin has a known thermal conductivity of 0.285 W/m K as long as it is stored properly. If the standard needs to be replaced, additional glycerin can be purchased from any chemical supply store.

3.2.8 UPPER ADAPTER

The upper adapter guides the sensor into the glycerin verification standard and ensures the sensor is in optimal position for sensor verification.

3.2.9 LOWER ADAPTER

The lower adapter holds the glycerin standard vial in place for sensor verification.

3.3 THEORY

The VARIOS measurement principle is based on the transient line heat source method which has been used to measure thermal conductivity of porous materials for over 60 years. Typically, a probe for this measurement consists of a needle with a heater and temperature

sensor inside, such as the METER TC-S70 and TC-S100 needle sensors. A current passes through the heater located in the sensor needle. The temperature is measured by a thermistor located in the needle and the LABROS SoilView software records the temperature of the sensor over time. Analysis of the sensor temperature time dependence when the needle is in the material under test determines thermal conductivity. An ideal sensor needle has a very small diameter and is approximately 100 times longer than its diameter. The sensor is in direct contact with the surrounding material and measures the temperature of the material during heating and cooling. Ideally, the temperature and composition of the material tested would not change during the measurement.

Actual sensors fall short of these ideals in several ways.

- Using a needle with a small enough diameter to be ideal would be too fragile for most applications.

- Heating moist, unsaturated porous materials causes water to move away from the heat source, thereby altering the water content in the region of measurement.

- Inserting temperature probes often disturb the material around it, causing contact resistance between the sensor and the material.

It is a challenge to design a sensor that gives accurate measurements under all conditions.

- If the sensor is too small, it is fragile, and the contact resistance can be high in dry, porous materials.

- Large sensors require a long heating time, altering the reading by driving water away from the sensor and causing free convection in liquid samples.

- A high heating rate makes temperature changes easier to read and less susceptible to temperature drift errors. However, this results in the same issues mentioned in the previous point.

  Because of this, long heating times at lower temperatures are recommended to minimize contact resistance, but they may result in water movement away from the sensor.

The VARIOS design attempts to optimize thermal property measurements relative to these issues. METER sensors are relatively large and robust making them easy to use. The VARIOS keeps heating times as short as possible to minimize thermally induced water movement and lower the time required for a measurement. The heat input is also limited to minimize water movement and free convection. Use of relatively short heating times and low heating rates requires high resolution temperature measurements and special algorithms to measure thermal properties. The VARIOS resolves temperature to ±0.01 °C and determines the rate of temperature drift prior to the measurement to correct the reading for drift.

The VARIOS is characterized by a very fine adjustment of the heat input and the measuring duration. These parameters can be user-defined with high flexibility. This allows for ideal measurement accuracy for virtually any materials and condition.

SINGLE-NEEDLE ALGORITHM

The thermal conductivity of the VARIOS needle is derived from the following equation for dual needle measurments:

$$\Delta T = \left(\frac{q}{4\pi k}\right) Ei \left(\frac{-r^2}{4Dt}\right)$$

Equation 1

Where:

D_t = the temperature rise at the measuring needle

q = the heat input at the heated needle (W/m)

k = thermal conductivity (W/mK)

r = the distance from heated needle to measuring needle

D = thermal diffusivity (m²/s)

t = time(s)

th = heating time(s)

Ei = the exponential integral and is approximated using polynomials (Abramowitz and Stegun 1972)

The probe temperature is monitored for any user-defined time to determine the temperature drift. The start temperature and the drift are then subtracted from the measurements. Current is then run through the heater for any user-defined time while the probe temperature is monitored. If the needle were an ideal line-heat source, can be used to predict its temperature. When is used for single-needle analysis, the exponential integral is expanded in an infinite series and only the first term in the expansion is retained, as shown in Equation 2.

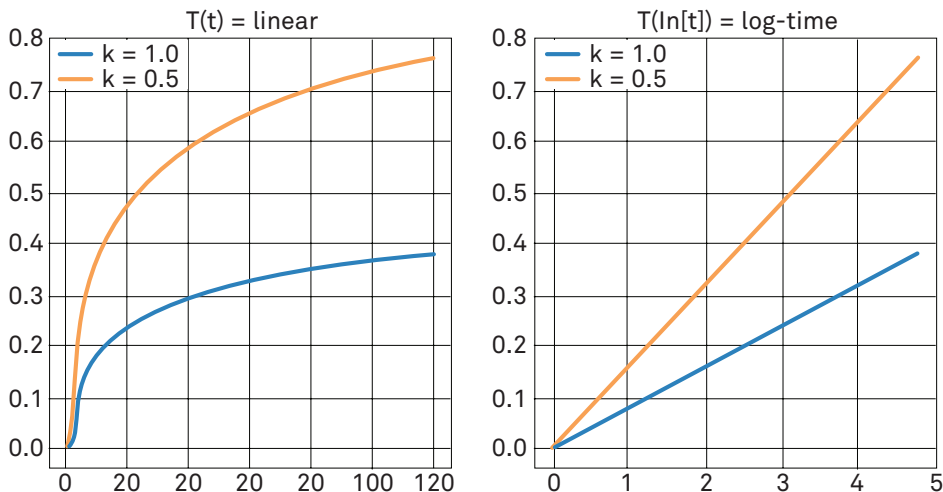$$\Delta T = \left(\frac{q}{4\pi k}\right) ln(t) + C$$

Equation 2

Figure 42 Plotting the values

Using just the first term of the series expansion is only valid at long heating times, so early time data are left out of the analysis. Equation 2 can in fact be shown to give correct results after long enough times, but the times are very long, especially for low-conductivity materials. Equation 2 shows that conductivity is proportional to the inverse of the slope when temperature is plotted versus {ln [t]} (Figure 35). At long times the temperature hardly changes, so noise in the measurements can strongly affect the measurement. Part of the problem with shorter measurement times is that the neglected terms in the exponential integral expansion are functions of diffusivity, so sample diffusivity affects the conductivity estimates. A bigger problem, though, is that an ideal line heat source has no heat capacity while the real probe has significant heat capacity. Another issue is the often significant thermal contact resistance between the probe and the medium in which it is placed.

To investigate these effects, the Knight et al. (2012) model was used to simulate sensor data for a wide range of conductivities, diffusivities, and contact resistances. After fitting Equation 2 to these data, it was determined that the biggest problem is in the time scale. By changing the equation to

$$\Delta T = \left(\frac{q}{4\pi k}\right) \ln\left(t + t_0\right) + C \hspace{2cm} \textbf{Equation 3}$$

where t_0 is a time offset, all of the data fit well. Effects of contact resistance and diffusivity are eliminated or significantly reduced. The values of k, t_0, and C are determined by nonlinear least square fitting. This procedure was used on samples with known conductivity, such as glycerin, ultrasound gel, ceramic, on dry soil, and wet soil. The 1-min readings on all of these samples were more accurate than 10-min readings using Equation 2.

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 SENSOR VERIFICATION

The advantages for using glycerin as a verification standard are listed below:
• Exact thermal conductivity measurement value is known.

• There is good thermal connection to the sensor, and no risk of an air gap between material and needle sensor.

• Material has high viscosity and reliable measurement values even at temperature changes.

The thermal conductivity value of the standard material delivered with the VARIOS sets, is defined by 0.285 W/m $\times$ K at 25 °C.

There are two verification adapters that must be used with the glycerin verification vial: the lower adapter and the the upper adapter.

Lower adapter   Upper adapter   Glycerin vial
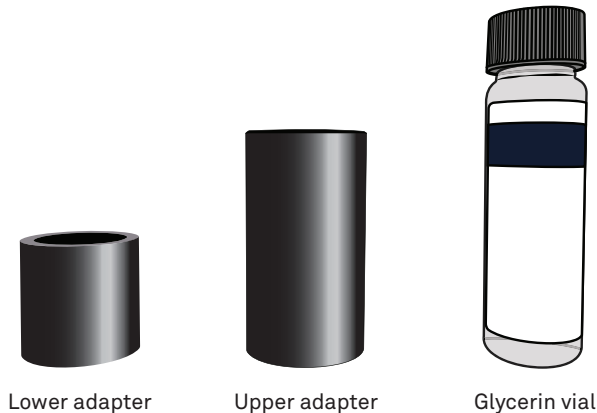
Figure 43   Glycerin verification vial

NOTE: The glycerin needs to be replaced annually, and is labeled with an expiration date. Use USP-grade glycerin, or order a replacement vial. Vials of glycerin can be ordered by contacting Customer Support.

NOTE: Store the glycerin standards in the lab at room temperature and in a dark place (e.g., in a cupboard). Be sure that the standard is not exposed to direct sunlight and heat sources.

Below are instructions for setting up the glycerin, adapters, and the sensor for verification.

1. Place the glycerin vial next to the VARIOS.
2. Connect the sensor needle to be verified next to the VARIOS.
3. Place the base of the glycerin vial into the lower adapter (Figure 44).
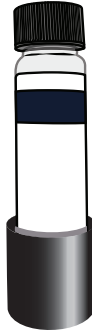
Lower adapter

Figure 44   Lower adapter on Glycerin vial

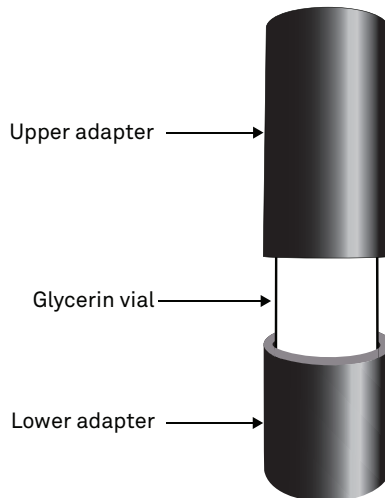4. Place the upper adapter on top of the glycerin vial (Figure 45).

Upper adapter

Glycerin vial

Lower adapter

Figure 45   Upper adapter on top of Glycerin vial

5. Insert the sensor needle into the top of the upper adapter (Figure 46).

Figure 46   Upper adapter top view

6. Push the needle through the upper adapter toward the septum of the glycerin vial.

7. Press the sensor through the glycerin vial septum (Figure 47).

    Be sure that the sensor is inserted completely and no air bubbles are produced near the sensor.
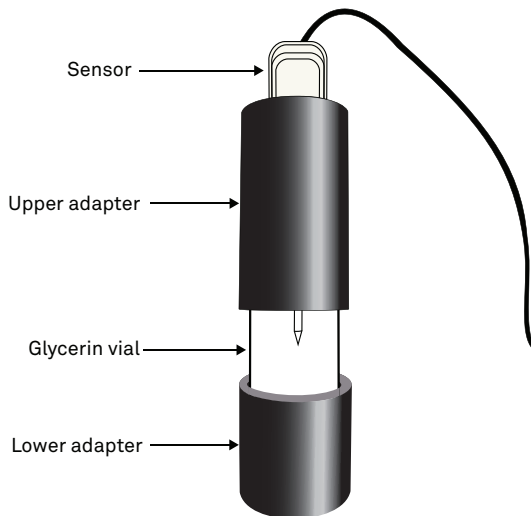
Figure 47   Glycerin file with sensor inserted

8. Open the LABROS SoilView software.

9. Verify that the devices are connected.

10. Configure the measurement by entering a sample, file name, and selecting the measurement profile for verification.

    The recommended and preset parameters are shown in Figure 48:
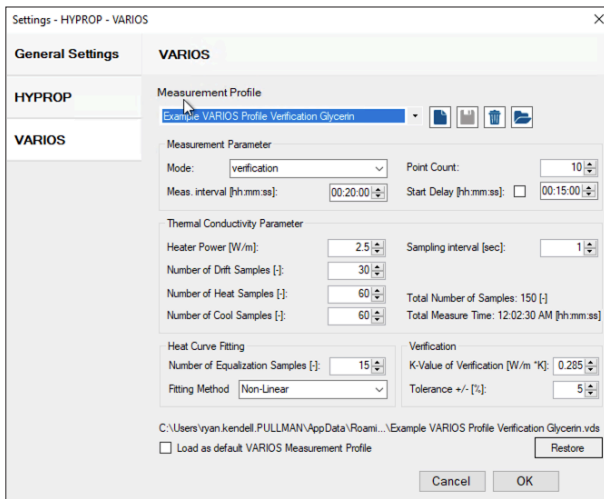
Figure 48   Example VARIOS Profile Verification Glycerin

11. Start the measurement as described in Section 2.7.5.1.

NOTE: If the vial is moved or shaken while the instrument is measuring the glycerin verification standard, the readings will be adversely impacted.

The measurement stops automatically after recording 10 data points.

The software automatically verifies if the recorded values are in the defined range for a successful verification and delivers a corresponding message. Measurements must be within ±5 % of the glycerin standard.

NOTE: After repeated use, the septum may begin to leak. To replace, simply remove the cap, press the old septum out, and replace with a new one.

4.2 CLEANING

The stainless-steel needles can be cleaned with steel wool or other mild abrasives. The needles can also be straightened with a pair of pliers by applying gentle pressure, if needed.

⚠ CAUTION

Be very gentle when bending the needles to avoid damaging the heating element and temperature sensor in the needle.

The VARIOS can be cleaned with a paper towel dampened with water.

NOTE: The VARIOS case and connector plugs are not waterproof. Therefore, DO NOT clean the VARIOS under running water. DO NOT clean the device with other substances such as alcohol to avoid damaging the VARIOS case material.

4.3 TROUBLESHOOTING

Table 11 lists common problems and their solutions. If the problem is not listed or these solutions do not solve the issue, contact Customer Support.

Table 11   Troubleshooting

Problem	Possible Solutions
Measuring data are no longer recorded.	Check connection to the USB port.
	Change the computer power settings to prevent sleep mode in order to prevent data loss.
VARIOS units are not displayed in the LABROS SoilView software.	Disconnect and connect all VARIOS units one by one and have the verify connection in the software device tree.
	Check the USB connection to the computer and the connection cables between the VARIOS and HYPROP Balance.
	If connection between the device and the computer cannot be achieved, contact Customer Support.
Measurement data are not reasonable.	Damage to the sensor needle is the greatest source of data error in the VARIOS system. Please take care when handling and storing the sensor.
	The reason for this failure may not be detectable unless a verification test is performed (Section 4.1). During the verification procedure, look for signs that may indicate a problem with the sensor heating properly. The following verification results may indicate sensor failure. • A slight rise in temperature measurements between the first and last measurement. • A zero or negative temperature reading. • Any unexpected temperatures based on the prevailing conditions during the measurement.
HYPROP Balance screen returns one of the following error messages:	
0-Err	A weight heavier than the capacity was used.
1-Err	The reference weight is less than 50% of the capacity.
2-Err	Calibration produced an error of 1.0% or more.
3-Err	Adjustment was performed with something loaded on the measurement pan.
4-Err	Mechanism was damaged for some reason.

4.4 UPDATING FIRMWARE

The LABROS SoilView software will post a notification if a firmware or software update is available. This will appear as blue text in the upper right hand corner of the screen.

To update the firmware, click on the notification in the top left corner. This will download the latest firmware from the METER website. Next, right-click on the VARIOS unit in the manager tab and select the Update Firmware option.

4.5 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:	+49 89 12 66 52 0
Fax:	+49 89 12 66 52 20
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.

4.6 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.

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