TLS-100 PORTABLE METER

User Manual





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INTRODUCTION

Congratulations on the purchase of your TLS-100 Portable Thermal Conductivity/Thermal Resistivity Meter. Please refer to this manual for best results when working with your new TLS-100. For the latest version of this manual, please contact us at **info@thermtest.com**.

The TLS-100 is a portable, lightweight handheld instrument, allowing for simple and accurate measurements of thermal conductivity and thermal resistivity of soils, among other materials, in the field or the laboratory. The TLS-100 is designed to conform to ASTM D5334-22a - Standard Test Method for Determination of Thermal Conductivity of Soil and Soft Rock by Thermal Needle Probe Procedure.

The TLS-100 was designed with ease and convenience in mind, for testing soils and other soft materials with an excellent accuracy of ±5% and reproducibility of ±2%. With the addition of the TLS-100 Rock Needle Kit, measurements on rock and concrete samples can be easily accomplished. Newer additions to the library of TLS sensors employable by the TLS-100 Thermal conductivity meter include the TLS 150 mm and the TLS 100 mm – vCp. The TLS 150mm sensor provides the ability to perform testing that conforms with an additional standard of testing, IEEE 442-2017. The TLS 100 mm – vCp includes a more sophisticated calculation that allows for the measurement of thermal diffusivity along with thermal conductivity. These two properties can be used to calculate the volumetric specific heat capacity, vCp, of the material.

The TLS-100 features built-in data storage which allows one thousand measurements to be stored at a time. These data files can easily be transferred to a PC using a USB connection.



IN THE BOX

When first receiving your new TLS-100 Meter, please take a few moments and check that your shipment includes the following items:



Figure 1. TLS-100 Thermal Conductivity Meter and carrying case.

- TLS-100 Controller
- 100 mm Needle Probe
- Sensor Sheath (Protective)
- 3x Sensor Sleeve
- 2x Drill Bit
- 130 mm Poker Tool
- Thermal Paste (56 g)

- 4x AA Batteries
- Carrying Case
- 6ft USB-A to USB-mini-b cable
- QA Certificate
- USB Flash drive with Software and User Manual

If any of the above items are missing, or have been damaged in transit, please contact Thermtest Inc. at your earliest possible convenience.



WARRANTY

Thermtest Inc. warrants to the original purchaser the following:

- a. The TLS-100 is free from defects in workmanship or materials for a period of one (1) year from the date of purchase, under normal use.
- b. The sensor(s) of the TLS-100 are free from defects in workmanship for a period of 30 days from the date of purchase, under normal use, as indicated on the original invoice.

The sole and exclusive remedy under this limited warranty is repair or replacement of defective products or parts thereof. Repair or replacement products or parts thereof will be furnished solely on an exchange basis and are obtainable only by the original purchaser.

The original purchaser shall return the defective product, or part thereof, properly packaged, with postage or shipping costs prepaid, to Thermtest Inc. Loss or damage during shipment shall be at risk of the purchaser.

This limited warranty does not include repair or replacement necessitated by accident, neglect, misuse, relocation, unauthorized repair, or modification of the product.

The above limited warranty is the sole warranty provided by Thermtest Inc. No other warranties, express or implied, including warranties of merchantability or fitness for a particular purpose, are provided whatsoever. No Thermtest Inc. agent or employee may modify, extend, or add to the above limited warranty.



In no event will Thermtest Inc. be liable for any direct, indirect, consequential, or incidental damages, including lost profits, or for any claim by any third party, arising out of the use, the results of use or the inability to use this product.

CONTACT

♥ Thermtest Inc.
25 Millennium Dr, Unit 2
Fredericton NB, E3C 2N9
Canada

- +1 506 458 5350
- **info@thermtest.com**
- Thermtest.com



SPECIFICATIONS

Operating Environment:

Controller: -10 to 50°C

Sensor: See Sensor Section

Power Options:

- The TLS-100 uses 4 x AA Batteries. The battery status is displayed in the top right corner of the screen. We recommend using Energizer® Ultimate Lithium AA Batteries for optimal results.
- The unit may also be powered by USB. When a USB connection is detected, a USB symbol is displayed in the top-right corner of the screen.

Storage and Interface:

Internal flash storage (.CSV file format), USB Interface

Display:

320x240 TFT Color Display

Accuracy and Repeatability:

Accuracy: Better than 5% | **Repeatability**: Better than 2% *unless otherwise noted on sensor specifications



THE TLS-100 CONTROLLER

The TLS-100 controller is used to conduct and display measurements. The TLS-100 is compatible with a wide variety of sensors: TLS 50 mm, TLS 100 mm, TLS 150 mm, and TLS 100mm - vCp. A sensor connects to the TLS-100 *via* a LIMO connector located on the top of the controller. Measurements are stored onboard via flash memory and can be uploaded to the computer via a mini-USB connection located on the left side of the controller.



Figure 1. TLS-100 Controller

All functions of the TLS-100 controller are driven by the keypad on the front of the device.



TLS-100 CONTROLLER KEYPAD





POWER BUTTON - Press to power the TPS-EFF ON and OFF



MENU BUTTON - Press to open the TPS-EFF Menu. Users can navigate to different screens



UP AND DOWN ARROWS - Press to navigate and change selected items



LEFT ARROW - Press to use for navigation, as well as a Back/Cancel button



RIGHT ARROW - Press to use for navigation, as well as an Enter/Confirm button



POWERING ON THE TLS-100

Before powering ON the TLS-100, make sure to connect the desired sensor to the controller. Align the red dots on the LIMO connection ends (one on the end of the sensor cable and one on the port located at the top of the TLS-100) and then insert the sensor connector into the port on the TLS-100. The power button can then be pressed to power the meter ON.

The sensor type and the temperature of the connected sensor will be displayed in the upper-left hand region of the screen.

AVOIDING SAMPLE DRIFT

Prior to the first test, allow the sensor to become isothermally stable with the sample by waiting for five to ten minutes. Between measurements, a five to ten-minute wait time is advised to allow time for the sample to return to isothermal conditions. If the sample has been heated or cooled in a furnace or other environmental chamber, allow time for the sample to heat/cool uniformly before starting a measurement.

As another precaution to ensure excessive temperature drift does not occur during a measurement, the sensor calculates sample drift by taking 10 temperature readings over 20 seconds prior to every measurement. A significant amount of temperature drift during this time will result in a *drift fault*, preventing the measurement from being conducted. If the measurement is part of an automated testing schedule, the TLS-100 will wait an additional interval of time before trying the measurement again.



MAKING A MEASUREMENT

Before a measurement is made, input a sample identifier into the TLS-100 controller's HOME screen. Use the LEFT and RIGHT arrows to move between character positions while using the UP and DOWN arrows to select and change the alphanumeric characters (A to Z and 0 to 9).

When ready to begin a measurement, hold down the enter/RIGHT arrow for 2 seconds and a measurement will start. Data points of the drift calculation and subsequent measurement will be displayed live on the screen as the measurement takes place. When the test is complete, the result will be displayed on the home screen.

To cancel a measurement that has already begun, simply press and hold cancel/LEFT arrow for two seconds.

AUTOMATED TESTING

The Automated Testing mode allows the user to program a series of measurements which will be performed automatically at a specified time interval.

To enable the Auto Testing mode, press the MENU key and navigate to the AUTO TESTING option. Select the interval of time between tests (in minutes) and number of tests to complete using the arrow buttons. For optimal results, it is recommended to allow a time interval of five to ten minutes between tests. Once an interval and number of tests has been selected, navigate to the Accept option and press enter. The HOME screen will then be displayed, and the first test will start after the interval specified.

At the top of the screen, the following information about the Auto Testing schedule can be observed:



- Upcoming test number/Total number of tests
- Time until the next test (in minutes/ seconds)
- A stopwatch icon to illustrate that auto testing is enabled

After a test is performed, the HOME screen will display the results. To disable the Auto Testing Mode, set Interval (M) to "OFF".

SETTINGS

To change experiment parameters and other settings on the TLS-100 controller, press the MENU button and select SETTINGS. Use the UP and DOWN arrows to select an option and press the enter/RIGHT arrow button to select the setting. Use the UP and DOWN arrows to change the desired setting and then press enter. Be sure to select *SAVE* before leaving this screen to save any changes to the settings. Note: Different settings will be displayed depending on the sensor connected to the TLS-100.

UNITS – Select the units to display. There is a choice between SI units (in °C or K) or Imperial units.

TEST TIME (s) – Set the test duration in seconds. Use the default settings unless otherwise recommended.

HEATING CURRENT – Manually Set the amount of current to be applied during each measurement. The default power, or the power obtained from the detect power setting if the sensor allows it, should be used unless otherwise recommended. THW-L3 and THW-S have Detect THW power functions.

SCREEN SAVER (m) – Set the number of minutes of inactivity before the screen saver is turned on when using battery power. Default is 1 minute. When using USB power, the screen saver is disabled.



DARK MODE – Enable or disable dark mode, which inverts colors on the screen, making the screen darker.

SET DATE & TIME – Set the date and time for the device. A timestamp is recorded when a test is performed. If battery power is lost, date & time will be reset.

REVIEW TEST DATA

To review stored test data, press the MENU button and select VIEW DATA. In this menu, the user will be able to cycle through the test results that are currently stored on the TLS-100. The sample ID, thermal conductivity or effusivity, test duration, and temperature will be displayed for each entry.

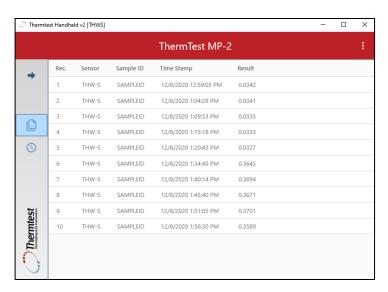
Pressing the RIGHT arrow on the selected test will allow the user to view the corresponding temperature vs. time graph, with correlation (R²) in the upper left. The correlation should be greater than 0.9 in a reliable test. For some sensors, press the UP and DOWN buttons to view the residual graph and the temperature vs log(time) graph for an individual test. Holding the LEFT arrow will return the user to the list of all saved tests.



TLS-100 DATA UTILITY – SAVING & EXPORT

A data utility comes with the TLS-100 to provide a quick and easy way to store measurements on your computer. After plugging in your TLS-100 controller (via USB) to your pc and then turning it on, open the data utility software on your pc. When the data utility opens, select the correct device, click "OK", and you will be directed to the *Tests* tab where you can view all the tests saved on your controller. If you right-click on one or multiple selected tests, you have the option to open, save, or delete the selected test(s). It is also possible to save or delete all tests at once from the same right-click drop down menu.

Test file data is saved to a CSV file format, which is compatible with Excel and other spreadsheet software.



An example of the tests tab.



DATA FILE FORMAT

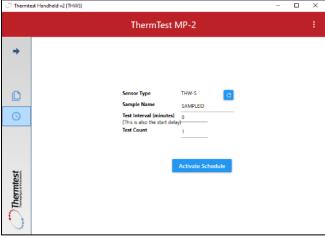
Below is a brief description of each column header in the CSV file.

#	The test number of the stored entry
Sample ID	The sample identifier entered by the user
Date & Time	Time stamp at completion of test (See advanced settings to set date & time)
Test Time	The time in seconds over which the test was conducted
Ambient Temperature	The temperature of the sensor at the time of the test
Conductivity	The thermal conductivity of the sample
Current	The current provided to the sensor during measurement
AVG Drift	The result of the drift calculation that was conducted prior to measurement
Delta T	The total change in temperature over the course of the measurement



TLS-100 DATA UTILITY - SCHEDULING

The tab with the clock icon is the test scheduling tab, where it is possible to send instructions to the connected TLS-100. This tab contains the following:



An example of the scheduling tab

- The type of sensor connected to the TLS-100 controller.
- A sample name field, where the user can name the sample to be measured.
- A test interval field, where the user can indicate the number of minutes to wait between tests in a series of automated tests.
- A test count, where the user can determine the number of tests to perform in a series of automated tests.

Click Activate Schedule to send auto schedule to the TLS-100

*Important. For the scheduling to operate, the corresponding sensor must be plugged in.



TLS 50 mm

(revised) ASTM D5334-14 - Standard Test Method for Determination of Thermal Conductivity of Soil and Soft Rock by Thermal Needle Probe Procedure.

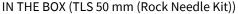
SPECIFICATIONS

50 mm Needle Probe

Materials: Concrete, Rock, and Polymers Thermal Conductivity: 0.3 to 5.0 W/m·K Thermal Resistivity: 0.2 to 3.3 m·K/W Temperature Range: -40 to 100°C

Minimum Sample Size: 50 mm in length, 50 mm diameter

Maximum Sample Size: unlimited



- 50 mm needle with protective sheath
- **QC** Certificate
- Thermal Paste (56 grams)
- 2 x 50 mm Drill Bit (Round Shank, 5/32" Size, 3" Overall Length)

TLS 100 mm

ASTM D5334-22a -Standard Test Method Determination of Thermal Conductivity of Soil and Soft Rock by Thermal Needle Probe Procedure

IEEE 442-1981 – lab testing for A method for measurement of soil thermal resistivity that is based on the theory that the rate of temperature rise of a line heat source is dependent upon the thermal constants of the medium in which it is placed is given.

SPECIFICATIONS 100 mm Needle Probe Materials: Soils, Pastes, Powders, and Solids Thermal Conductivity: 0.1 to 5.0 W/m·K







Thermal Resistivity: 0.2 to 10 m·K/W Temperature Range: -40 to 100°C

Minimum Sample Size: 100 mm in length, 50 mm diameter

Maximum Sample Size: unlimited

IN THE BOX (TLS 100 mm)

- 100 mm needle with protective sheath
- QC Certificate
- Thermal Paste (56 grams)
- Poker Kit:
 - Drill Bit (#45 6" Aircraft)
 - Drill Bit (#45 PTD Taper Length)
 - o 130 mm poker tool
 - o 3 x 100 mm sensor sleeve

TLS 150 mm

ASTM D5334-22a - Standard Test Method for Determination of Thermal Conductivity of Soil and Soft Rock by Thermal Needle Probe Procedure.

IEEE 442-2017 — lab & field testing for A method for measurement of soil thermal resistivity that is based on the theory that the rate of temperature rise of a line heat source is dependent upon the thermal constants of the medium in which it is placed is given.

SPECIFICATIONS

100 mm Needle Probe

Materials: Soils, Pastes, Powders, and Solids Thermal Conductivity: 0.1 to 3.0 W/m⋅K Thermal Resistivity: 0.3 to 10 m⋅K/W Temperature Range: -40 to 100°C

Minimum Sample Size: 150 mm in length, 50 mm diameter

Maximum Sample Size: unlimited

IN THE BOX (TLS 150 mm)

• 150 mm needle with protective sheath





QC Certificate

TLS 100 mm - vCp

ASTM D5334-14 - Standard Test Method for Determination of Thermal Conductivity of Soil and Soft Rock by Thermal Needle Probe Procedure

IEEE 442-1981 – lab testing for A method for measurement of soil thermal resistivity that is based on the theory that the rate of temperature rise of a line heat source is dependent upon the thermal constants of the medium in which it is placed is given.

SPECIFICATIONS:

100 mm Needle Probe

Materials: Soils, Pastes, Powders, and Solids Thermal Conductivity: 0.02 to 5.0 W/m·K Thermal Resistivity: up to 10 m·K/W

Accuracy: 5%

Thermal Diffusivity: 0.1 to 1.5 mm²/s

Accuracy: 10%

Volumetric Specific Heat: up to 3.5 MJ/m³·K

Accuracy: 15%

Temperature Range: -40C to 100°C

Minimum Sample Size: 100 mm in length, 50 mm diameter

Maximum Sample Size: unlimited

IN THE BOX (TLS 100 mm)

- 100 mm vCp needle with protective sheath
- QC Certificate





INSERTING THE TLS SENSOR

The needle should be inserted into the center of the material. Remove the protective needle cover. **If required***, apply a layer of thermal grease to the TLS sensor to minimize any effects of contact resistance, and insert the TLS sensor fully into the sample to be measured.

It is critical for the measurement, to ensure that the TLS sensor is embedded completely in the sample. **BE CAREFUL NOT TO BEND THE SENSOR**. Confirm that the sensor is seated properly in the sample and is not loose in its position.

Included are various tools to assist with safely inserting the TLS sensor into your sample:

- 1. Poker tool used for creating a testing hole in soft materials, where drilling is not required.
- Sensor sleeve (TLS 100 mm and vCp only) used for creating a
 testing hole in materials which are difficult to drill. Most useful
 when sensor insert can be placed into sample before the casting
 or curing process.
- 3. Drill Bit can be used to drill a testing hole in solid samples.

*Thermal paste should be applied to the needle probe whenever testing a drilled, non-uniform, or solid material.



BEST PRACTICES FOR TLS

- Moisture evaporation/condensation (depending on the operating conditions) may affect the repeatability of the results. Operators may use Saran wrap or something similar if they want good moisture control.
- If the sample has been heated or cooled in an oven, or other environmental chamber, allow adequate time for the sample to heat/cool uniformly before starting a measurement.
- 3. In non-uniform or solid materials, space between the sensor and sample will cause contact resistance, which can introduce errors in the test data. Contact resistance can be minimized by making sure the sensor is properly fitted in the sample, and by applying thermal paste to the TLS sensor prior to insertion into the sample.
- 4. TLS 100 vCp. When testing bulk solids (soil or powders), due to increased contact resistance at roughly < 50% moisture, thermal diffusivity and volumetric specific heat may have significant error. There is no negative impact on thermal conductivity. Typical specific heat range for soil is 1 to 3.5 MJ/m³·K.</p>
- 5. TLS 100 vCp Calculation Time. Due to the complexity of multiproperty calculations, when testing with vCp needle, the total measurement time is equals test time (60 sec heating and 60 sec cooling) + calculation time (~ 3 min) + wait time. It is recommended to reduce wait time due to the calculation time accomplishing the same goal to cool sample between repeat measurements.



TROUBLESHOOTING FOR TLS

PROBLEM: The TLS-100 does not turn ON

SOLUTION: Be sure that you have 4 fresh AA Batteries installed in the

correct orientation.

PROBLEM: Poor battery life

SOLUTION: The TLS-100 can run hundreds of tests on a set of batteries. This will depend on several factors, including the batteries used. Recommended batteries are **Energizer®**

Ultimate Lithium AA Batteries.

PROBLEM: Invalid or Inaccurate Sensor Temperature **SOLUTIONS:**

- Be sure the sensor is properly connected into the TLS
- Before you turn on the device, remove the TLS sensor and reconnect.
- Check for damaged pins in the connector.
- Check for damage to the TLS sensor.

PROBLEM: Thermal conductivity is not in the expected range, or is not repeatable

SOLUTIONS:

- Be sure the sensor is fully inserted into the sample. No part of the stainless-steel needle should be visible.
- Many outside sources can affect a measurement, check the error value in the test file, the correlation should be 0.9 or better.
- Check that the sensor is tight in the sample, loose insertion can result is unreliable results.
- When using thermal paste, ensure that the entire needle is coated with paste.
- Be sure the sample is large enough.
- There may be temperature drift present. After inserting the probe into the sample, allow fifteen to twenty minutes before testing to reach thermal equilibrium. If the sample was heated/cooled, be sure enough time has passed for the sample to equalize. Wind or air circulation may affect test results by causing temperature drift in the sample during measurement.
- Lower quality batteries may cause bad test data due to a poor electrical signal. Recommended batteries are Energizer® Ultimate Lithium AA Batteries.



COMPLIANCE TO ASTM D5334

The TLS-100 complies with ASTM D5334 standard in the following ways:

- Includes a needle sensor constructed within the specifications of the standard
- Has the ability to read temperatures at a resolution of 0.001°C
- Has the ability to measure voltage better than 0.01 Volts
- Has the ability to measure current at better than 0.01 amps
- Has the ability to supply constant current to the heating element
- Can measure time with a 1 millisecond resolution
- All on-board math is calculated as per the standard

Note: Due to the length to width ratio of the 50 mm testing needle (50:4), it does not conform to ASTM D5334. The data analysis is still carried out as per ASTM D5334, and in every sense the 50 mm testing needle conforms to ASTM D5334, other than the length to width ratio specified in the standard is not met.



♥ Thermtest Inc.

25 Millennium Dr, Unit 2 Fredericton, NB E3C 2N9 Canada

- +1 506 458 5350
- **info@thermtest.com**
- Thermtest.com

