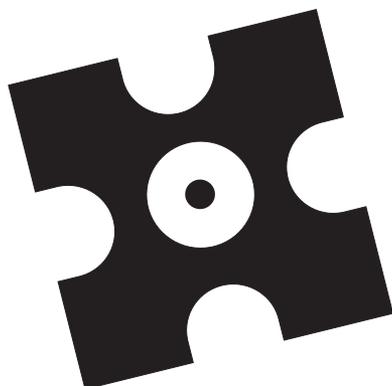


# ***ThermoLink*** **for Soils**

**Soils Multimeter**

---



---

**Operator's Manual**

**Decagon Devices, Inc**  
**Version 2.6**

# Table of Contents

---

## Welcome

### 1. Introduction

<b>Warranty</b> .....	<b>2</b>
<b>Customer Service and Tech Support</b> .....	<b>2</b>
<b>Seller's Liability</b> .....	<b>3</b>
<b>Repair Instructions</b> .....	<b>4</b>

### 2. Specifications

<b>Thermal Properties Sensor</b> .....	<b>6</b>
<b>Matric Potential Sensor</b> .....	<b>6</b>
<b>ThermoLink Meter</b> .....	<b>6</b>
<b>Accessories</b> .....	<b>7</b>

### 3. Getting Started

<b>Components of the ThermoLink system</b> .....	<b>8</b>
--	----------

### 4. Getting to Know ThermoLink

<b>Turning it On</b> .....	<b>15</b>
<b>How does ThermoLink work? A brief description</b> .....	<b>16</b>
<b>Definitions</b> .....	<b>17</b>
Matric Potential:.....	17
Thermal Conductivity (K).....	17
Thermal Diffusivity (D).....	18
Thermocouple.....	18
Volumetric Specific Heat (C).....	18
The ALPHA-NUM key.....	19
Typing numbers and letters .....	20
Function Keys .....	21

Arrow Keys.....	21
<b>5. The Menus</b>	
<b>Main Menu.....</b>	<b>23</b>
<b>F1: SETUP.....</b>	<b>23</b>
Setting the Time.....	24
F1: TIME.....	24
Setting the Date.....	24
F2: DATE.....	24
F1: US DATE.....	25
F2: INTL DATE.....	25
Changing Matric Units.....	26
Programming the Function Keys.....	27
<b>F2: READ.....</b>	<b>29</b>
<b>F3: DATA.....</b>	<b>29</b>
F1: Downloading to your PC.....	30
F2: Clearing Data From Memory.....	31
F3: Viewing the Data.....	32
<b>F4: OFF.....</b>	<b>33</b>
<b>6. F1: Thermal Properties</b>	
<b>Preparations.....</b>	<b>34</b>
<b>Reading.....</b>	<b>35</b>
Single Readings.....	35
F1: Unattended.....	40
<b>7. F2: Water Content</b>	
<b>Preparations.....</b>	<b>46</b>
<b>Reading.....</b>	<b>47</b>
Single Readings.....	48
F1: Unattended Mode.....	52
<b>8. F3: Matric Properties</b>	

---

<b>Before you start .....</b>	<b>57</b>
Equilibrating.....	57
Saline soils.....	57
Preparations.....	58
Configuring the Matric Sensor.....	58
<b>Making Readings.....</b>	<b>60</b>
Single Readings.....	60
FI: Unattended.....	62
<b>9. Theory</b>	
<b>Thermal Properties and the Dual Probe Technique.....</b>	<b>64</b>
<b>Thermal Conductivity .....</b>	<b>66</b>
<b>Thermal Diffusivity and Volumetric Specific Heat .....</b>	<b>67</b>
<b>Matric Potential and Water Content:</b>	
<b>Determined from Thermal Properties.....</b>	<b>67</b>
Matric Potential.....	68
Water Content.....	69
<b>Further Reading .....</b>	<b>70</b>
<b>10. Care and Maintenance</b>	
<b>Charging the Batteries.....</b>	<b>72</b>
<b>Caring for the Dual-Needle Probe.....</b>	<b>74</b>
<b>Cleaning and Maintenance .....</b>	<b>76</b>
<b>Appendix A: Installing Firmware</b>	
<b>Connecting and Downloading .....</b>	<b>77</b>
<b>Appendix B: Miscellaneous Features</b>	
<b>F1: Serial, Gain.....</b>	<b>80</b>
<b>F2: Wait Time.....</b>	<b>81</b>
<b>F3: Heat on Time.....</b>	<b>81</b>
<b>F4: Clear Probes.....</b>	<b>81</b>

---

**ThermoLink**  
*Table of Contents*

---

# Welcome

---

Welcome to Decagon's ThermoLink for Soils. ThermoLink is a hand-held soil multimeter designed to measure thermal conductivity, thermal diffusivity, specific heat, water content, and matric potential. We hope you find this manual useful in understanding and maximizing your instrument's capability to help you in your application.

## **1. Introduction**

---

### **Warranty**

ThermoLink carries a 30-day satisfaction guarantee and a one-year warranty on parts and labor from the date of purchase. To validate your warranty, please take some time to fill out the registration card enclosed with this manual and return it to us. You can mail, fax, telephone, or e-mail your registration information back to us. Please include all the information requested on the registration card. It is important for us to have your current mailing address and telephone number so we can send you updated product information.

### **Customer Service and Tech Support**

If you have questions about ThermoLink or need assistance with your instrument, don't hesitate to contact us for technical support. This can be done in several ways:

1. Our toll-free number is available for our customers in the U.S. and Canada, Monday through Friday, 8a.m.- 5p.m. PST.

1-800-755-2751

Our regular number is (509) 332-2756. This is available for those outside of the U.S. and Canada.

2. **Fax us at (509) 332-5158.** Please include your name, current address, phone number and return fax number as well as the serial number of your instrument.

3. **E-mail.** You can also e-mail us with your question or problem at [support@decagon.com](mailto:support@decagon.com). Again, please include as part of your message your name, address, phone and fax numbers, and serial number. This will better help us to be able to contact you and meet your needs. If you have specific questions regarding ThermoLink applications, address them to [ThermoLink@decagon.com](mailto:ThermoLink@decagon.com).

## **Seller's Liability**

Seller warrants new equipment of its own manufacture against defective workmanship and materials for a period of one year from date of receipt of equipment (the results of ordinary wear and tear, neglect, misuse, accident and excessive deterioration due to corrosion from any cause not to be considered a defect); but Seller's liability for defective parts shall in no event exceed the furnishing of replacement parts f.o.b. the factory where originally manufactured. Material and equipment covered hereby which is not

## **ThermoLink**

### *Introduction*

---

manufactured by the Seller shall be covered only by the warranty of its manufacturer. Seller shall not be liable to Buyer for loss, damage, or injuries to persons (including death), or to property or things of whatsoever kind (including, but not without limitation, loss of anticipated profits), occasioned by or arising out of the installation, operation, use, misuse, nonuse, repair, or replacement of said material and equipment, or out of the use of any method or process for which the same may be employed. The use of this equipment constitutes Buyer's acceptance of the terms set forth in this warranty. There are no understandings, representations, or warranties of any kind, express, implied, statutory or otherwise, (including, but without limitation, the implied warranties of merchantability and fitness for a particular purpose), not expressly set forth herein.

## **Repair Instructions**

If your ThermoLink needs to be sent in for service or repair, call Decagon at (509) 332-2756 or 1-800-755-2751. We will ask you for your address, phone number, and serial number. For non-warranty repairs, we will also ask for a purchase order number, a repair budget, and billing address.

When you ship your instrument back to us, please include with it a document with the complete

shipping address, name and department of the person responsible for the instrument, and (most importantly) a description of the problem. This information will better help our technicians and our shipping department to quickly expedite repair on your instrument and ship it back to you.

Pack your ThermoLink system carefully. Ship it back in the black Pelican carrying case, inside a well-padded cardboard box. Ship to:

**Decagon Devices Inc.  
950 NE Nelson Court  
Pullman, WA 99163**

**Repair Costs:**

Manufacturer's defects and instruments under warranty will be repaired at no cost. For non-warranty repairs, costs for parts, labor, and shipping will be billed to you. We have a \$50 minimum repair charge. Decagon will provide an estimated repair cost, if requested.

## 2. Specifications

---

### **Thermal Properties Sensor**

Sensor Body: Epoxy, 10mm dia., 30mm long.

Sensor Needles: Stainless steel, 30mm long, 6mm spacing.

Wiring: Standard PVC-coated Type “E” thermocouple.

Shipping Weight: 57g.

Cable Length: 80 cm.

### **Matric Potential Sensor**

Sensor Material: Porus-ceramic™.

Sensor Size: 50mm long, 14mm dia.

Wiring: Type “E”, Polyethylene jacket (TPE outer jacket).

Shipping Weight: 66g.

Cable length: 1m.

Range: -0.01 to -10MPa.

### **ThermoLink Meter**

Case size: 150 mm x 95mm x 60mm.

Input: RS-232 cable with charger.

Output: 4-pin probe connector with cap.

Display: 16 x 4 alphanumeric dot matrix. Contrast automatically adjusts with temperature.

**Keypad:** 16-key sealed dome.

**Clock:** 24-hour • 2 min/ month at 25 °C.

**Date:** Calendar, US and International format.

**Comments:** 16 alphanumeric entries.

**Data memory:** 48K nonvolatile static RAM, maximum of 999 readings.

**Operating environment:** 5-40 °C.

**Rechargeable:** Internal NiCad battery packs.

## **Accessories**

**Carrying Case:** Pelican 1200 watertight case; 27cm x 24cm x 12cm, wt. 6.6kg, capacity: 2 probes and 1 ThermoLink controller.

**Interface cable:** Combination RS-232 cable and battery charging jack. 122cm long.

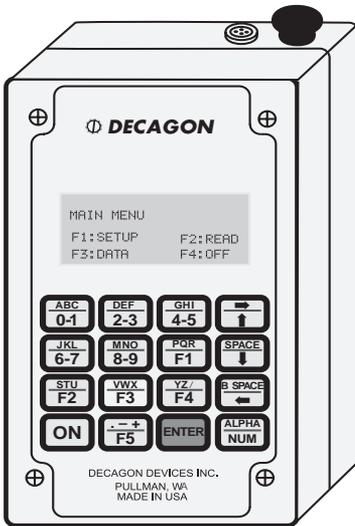
## **3. Getting Started**

---

### **Components of the ThermoLink system**

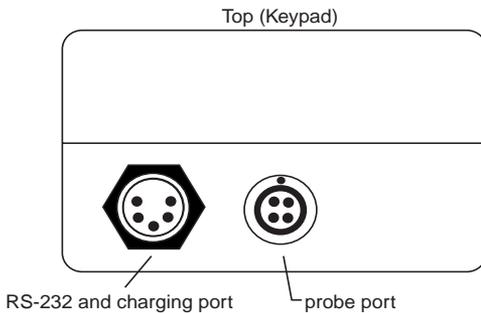
ThermoLink comes to you in a durable, watertight Pelican case. As you open the case, you should find the following items inside:

- (1) ThermoLink Meter
- (1) dual-needle thermal properties sensor w/  
probe guide  
and/or
- (1) matric potential sensor
- (1) RS-232 downloading/charging cable
- (1) 25-9 pin adapter
- (1) AC adapter
- (1) ThermoLink Firmware diskette (3.5")
- (1) Calibration certificate
- (1) Delrin testing/storage block



The ThermoLink Meter is a microprocessor-controlled nanovoltmeter. The operating program is contained in the instrument's RAM and can be updated as new versions of ThermoLink firmware become available. New firmware upgrades are free from Decagon to

each registered user.



There are two ports located at the top end of the microcontroller. The five-pin port is for interfacing to a computer

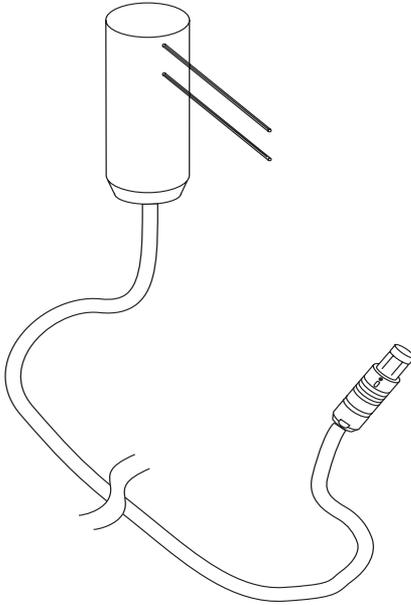
via the RS-232 cable, and the metal four-pin port is for connection to the probe. The microcontroller is powered by two packs of rechargeable NiCad batteries. As data is taken and stored, it is backed up

## **ThermoLink**

### *Getting Started*

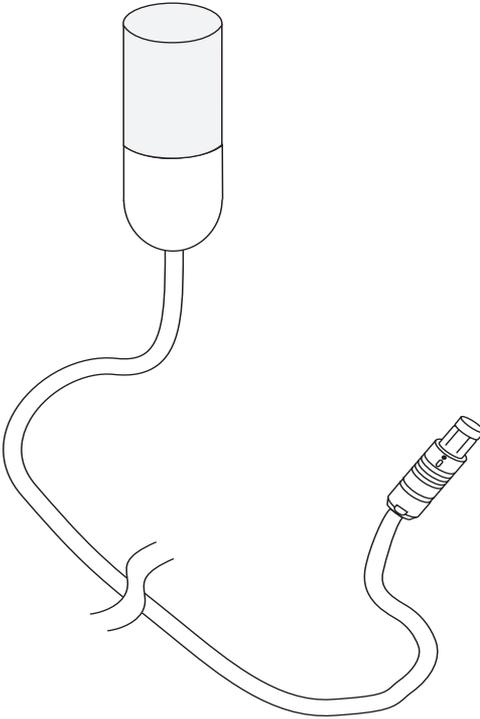
---

by semi-permanent lithium cells.



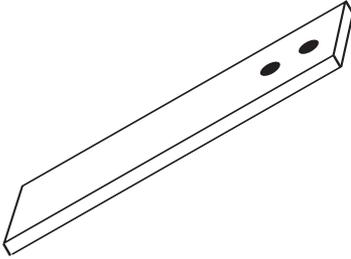
The Thermal Properties Sensor has an 80 cm-long cable with a connecting plug on one end and the probe head on the other. The probe needles are stainless steel, mounted in an epoxy body and spaced 6mm apart. One needle contains a heater, and the

other is connected to a type E chromel/constantan thermocouple. It is crucial that they maintain the 6mm spacing (remain parallel) in order to keep an accurate reading. The reason for this will be addressed later in the theory section of this manual.



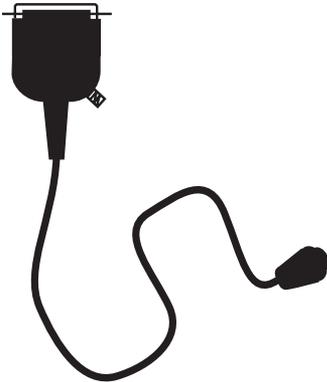
The Matric Potential Sensor is also a one meter-long probe; this one has a ceramic end for measuring soil matric potential, and a metal connector on the other end. Within the ceramic there is a heater and

a thermocouple. The sensor's serial number is located on a white label that is heat-shrunk around the cable. The calibration constants are on the yellow tag.



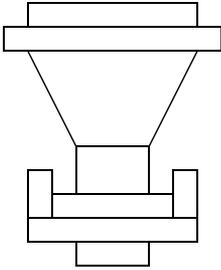
A **Probe guide** is included as part of an effort to keep your probe needles straight and properly spaced when inserting the probe into samples. The length and spacing of the needles

are intrinsic to the thermal properties calculations. Therefore, it is vitally important to keep them straight in order to expect accurate calculations.

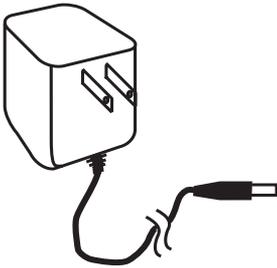


The **RS-232 cable** serves three basic functions. First of all, it is used to download saved data to your PC. Secondly, it is used to upload new operating firmware to your instrument when upgrades become available. Its third function is to be an

interface between the AC adapter and your ThermoLink to recharge the NiCad batteries.



The **25-9 pin adapter** is included in the system to be used in conjunction with the RS-232 cable if your PC doesn't have a 25-pin serial port to use with the cable.

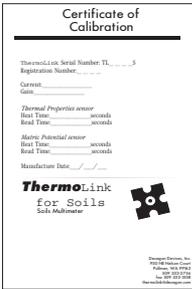


As mentioned before, the **AC adapter** is used along with the RS-232 cable to recharge the NiCad batteries in the instrument. You should always wait until the batteries run down before recharging again in order to preserve the long-term life of the batteries.

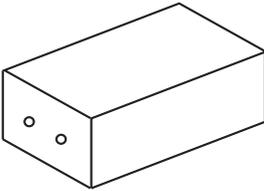
# ThermoLink

## Getting Started

---



The **calibration certificate** is very important...do not lose it! It contains the calibration constants and the serial number for your particular instrument. You will need this information if you ever download new versions of firmware to your Thermolink.



The **Delrin block** is included for two reasons. First, it serves as a testing medium. The thermal properties of your Delrin block are on your calibration certificate, so if you ever want to check the functionality of your instrument, you can plug the probe into it and check its thermal properties to see how close it comes to the value on your calibration certificate. The block also serves as a protective storage unit for the probe when not in use, since it covers the entire length of the needles.

## **4. Getting to Know ThermoLink**

### **Turning it On**

When you press the ON button for the first time, the screen will display the following:

```
Thermolink  
for Soils Science  
ver. 1.3  
Serial #TLS
```

Then:

```
MAIN MENU  
  
F1: SETUP F2: READ  
F3: DATA F4: OFF
```

This is the ThermoLink's main menu, from where you can branch off to go to the sampling menus, system setup, or data management menus.



WARNING! DO NOT PRESS F2: READ IF THE PROBE IS NOT INSTALLED IN A MEDIUM OR THE SENSOR WILL BURN OUT!

## **How does ThermoLink work? A brief description**

The ThermoLink for Soils uses two different types of probes to measure properties of soils. The first is the dual-needle probe, consisting of a heater and type E (chromel/constantan) thermocouple. This finds the thermal properties of the medium that the probe is inserted into. The heating element is enclosed within one of the stainless steel probe needles, and the thermocouple is connected to the other. The probe equilibrates to within .0030 °C of the temperature of the medium it is measuring, then begins the reading.

To make the reading, the heater needle emits a heat pulse for a duration of 8 seconds. At this point, the other needle begins reading the temperature for 60 seconds. The characteristics of the resulting temperature curve allow the instrument to derive the thermal conductivity, thermal diffusivity, and specific heat of the medium it is measuring. If you know the bulk density of your medium, ThermoLink can also measure its water content.

The Matric Potential probe consists of a heater and

---

thermocouple embedded in a ceramic medium that is buried *in situ* with the soil that is being sampled. Once it is in equilibrium with the soil, it can be used to find the soil's matric potential. A heat pulse is generated by the heater, and the thermocouple measures how quickly the heat is dissipated. Since the pore size of the probe's ceramic matrix is known, the rate of dissipation will indicate the matric potential of the soil it is measuring, since the relationship between temperature change and the logarithm of the matric potential is virtually linear.

## **Definitions**

Below are a few definitions to clarify some terminology used in this manual regarding the ThermoLink.

### **Matric Potential:**

Matric Potential is a measure of the adsorptive forces binding water to a soil matrix. ThermoLink can measure it in Bars, in MPa (megapascals), or in J/kg (joules per kilogram).

### **Thermal Conductivity (K)**

Thermal conductivity measures the rate at which energy is transferred through a given medium. This is measured by ThermoLink in  $\text{W m}^{-1} \text{C}^{-1}$  (Watts per meter-degree C), which are the standard units for

## **ThermoLink**

*Getting to Know ThermoLink*

---

thermal conductivity.

### **Thermal Diffusivity (D)**

This is the ratio of thermal conductivity to specific heat. It is the ability of a material to conduct thermal energy relative to its ability to store thermal energy. A medium with a high thermal diffusivity will respond quickly to its thermal environment. Conversely, a medium with a low thermal diffusivity will respond slowly to its thermal environment, and will be slow to reach thermal equilibrium. It is measured in  $\text{mm}^2 \text{s}^{-1}$  (millimeters squared per second).

### **Thermocouple**

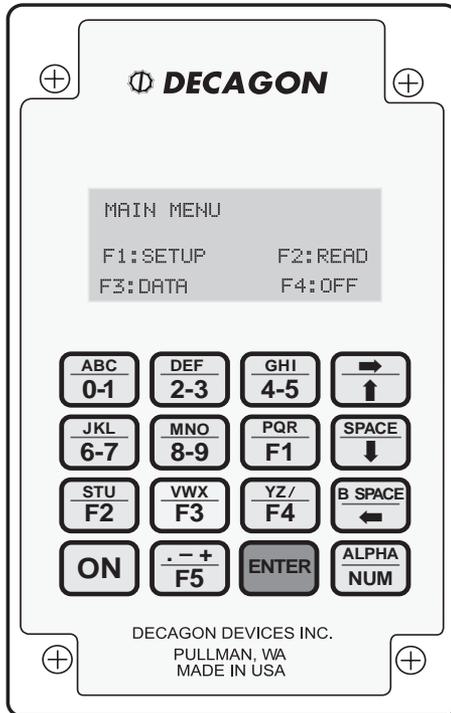
A welded junction between two dissimilar metals (in this case, chromel and constantan), over which a voltage is generated when the temperature changes at the junction. By measuring the voltage produced, you can then derive a value for the temperature.

### **Volumetric Specific Heat (C)**

This is the energy it takes to raise the temperature of a given volumetric amount of a substance to a unit degree. It is strictly based on how much energy is needed, not the rate at which it takes to raise the temperature. This volumetric measurement indicates that substances with large densities typically have

small specific heat. The ThermoLink reads specific heat in units of  $\text{joules cm}^{-3} \text{C}^{-1}$  (Joules per cubic centimeter per unit degree C).

## Using the Keypad



### **The ALPHA-NUM key**

The Thermolink Controller keypad is a 16-key panel with full alphanumeric capability. Note that each key is divided in half, with the top half in green and the lower half in blue. The green half is activated when

---

## **ThermoLink**

### *Getting to Know ThermoLink*

---

the instrument is in ALPHA mode, and the blue section is active when in the NUM mode. The ALPHA/NUM key located in the lower right corner is a toggle switch to allow you to use both of these functions. When you are in a mode wherein you are entering information, you will notice that there is either a letter “N” or “A” in the bottom right corner of the screen, to indicate that it is in either “number” or “alpha” mode. If you are in number mode, when you press any of the keys, the blue functions associated with that key will be entered (either numbers or F-keys). When you press the ALPHA/NUM button, it will toggle to “A,” indicating that it is now in alpha mode, allowing you to enter the green functions associated with the keys (letters, symbols, etc.). If you keep pressing the ALPHA/NUM button, it will toggle between the two modes.

### **Typing numbers and letters**

Numbers are grouped two to a key. Push the key once for the first number, twice for the second. Keep pushing the key to toggle back and forth between the numbers. Similarly, letters are grouped in threes. Push once for the first letter, twice for the second, and three times for the third. If you push a fourth time, you will rotate back to the first letter. When you press a different key, the cursor will move forward and you can select the next letter. If the number or word you are entering is such that two numbers or

characters are next to each other consecutively and are represented by the same key, (e.g., the number 45, the word “bad,” etc.) you can move the cursor to the next space by pressing the ⇒ button.

*Note: when typing in numbers, you will need to press the ALPHA/NUM key before using the ⇒ button.*

### **Function Keys**

The function keys (F1-F4) are used to select menu options. They can also be used as “macros” to designate preset comments (assigned in the Function Key option of the Setup/System menu).

### **Arrow Keys**

↑ The up arrow is probably the most useful and most used of all the keys on the keypad. It allows you to move back to previous menus from your current screen, until you ultimately come to the main menu.

⇐ ⇒ The left and right directional arrows allow the cursor to move back and forth without having to overwrite what you have written.

↑ ↓ The up and down arrows allow you to scroll through your saved data when you are in the VIEW DATA option of the VIEW menu.

## **ThermoLink**

### *Getting to Know ThermoLink*

---

The SPACE key allows you to move the cursor forward one position, and the B SPACE key backs up and erases one character.

## 5. The Menus

---

### Main Menu

When you turn on ThermoLink, it will always bring you to the following base menu:

```
MAIN MENU  
F1:  SETUP  F2:  READ  
F3:  DATA  F4:  OFF
```

### F1: SETUP

```
F1:  TIME  
F2:  DATE   INTL  
F3:  UNITS  BARS  
F4:  FUNCTION KEYS
```

The setup menu gives you four options: Time, Date, Units, and Function Keys. The F5: CAL menu is used to input your calibration constants when installing upgrades to your instrument.

## **Setting the Time**

### **F1: TIME**

```
Set Time:
      09:58
                                     N
```

Use this option to set the instrument to your local time. Use the up and down arrows to change the number value, and the left arrow to move the cursor. Once you have the time set to where you want, press ENTER to exit this menu. ThermoLink will keep time even if the batteries are removed. The time is displayed in a 24-hour format (also known as military time), so keep that in mind when setting the time.

## **Setting the Date**

### **F2: DATE**

```
Set date format:
F1: US date
F2: INTL date
```

Use F2 in the Setup Menu to set the date format that

---

you prefer. Note that either the US or INTL appears after the word DATE in the Setup menu. This indicates which particular date format that your ThermoLink is currently operating in. To change the format, select the desired format (F1 or F2) and change the date, then press ENTER. The date format you selected will now appear in the setup menu.

**F1: US DATE**

```
Set Date:
MM/DD/YEAR
04/21/1997
N
```

For users who prefer the US format—MM/DD/YEAR, this format is available. Use the up and down arrows to change the number values, and the left arrow to move the cursor. When you have entered the correct date, press ENTER to exit back to the Setup Menu.

**F2: INTL DATE**

```
Set Date:
DD/MM/YEAR
21/04/1997
N
```

## **ThermoLink**

### *Menus*

---

The international date option is for users who prefer the normal DD/MM/YEAR date format. As with the US DATE, use the up and down arrows to change the number values, the left arrow to move the cursor, and ENTER when you are finished.

### **Changing Matric Units**

At the main menu, press F3: UNITS

```
Set Matric Units
F1: BARS
F2: MPa
F3: J/kg
```

ThermoLink measures matric potential in three types of units: Bars, MegaPascals (MPa), and Joules per kilogram (J/kg). You can choose which unit you wish to read in with this menu. Press F3: UNITS, then press the desired unit (either F1, F2, or F3). You will then be returned to the main menu:

```
F1: TIME
F2: DATE INTL
F3: UNITS MPa
F4: FUNCTION KEYS
```

Notice that the unit you just selected is displayed next to F3: UNITS.

## **Programming the Function Keys**

At the main menu, press F4: FUNCTION KEYS  
After each reading, you are given the option of adding comments. If you find that you are repeatedly using the same comment, you may wish to assign that comment to a function key to make it more convenient. Therefore, at the “Comment” prompt, you could then press the programmed function key to recall your comment.

For example: Say you are measuring the thermal properties of soil samples from different plots under different conditions, and there are 30 or so samples per plot that you want to read. After the first 5 or 6 readings you get tired of typing “Plot 1” after each reading. Therefore, you decide to assign that term to the F1 button. Thereafter, you just press the F1 button at the comment prompt.

To program the function key, press F4: FUNCTION KEYS. The following screen will appear:

## ThermoLink

### Menus

---

```
Set Fn Key:  
Select F-Key  
N
```

At this point, enter the function key that you want to use as your macro. Any of the five function keys may be used. For this illustration we'll use F1. The following screen will then appear:

```
Set F1 Key:  
Enter macro:  
- A
```

Type in your desired comment at the prompt and then press ENTER. Each comment may be up to 15 characters long. The key will be programmed and then it will take you back to the main menu.

### Caution!

*If you already have a comment assigned to this function key, it will not be displayed here.*

*Therefore, if you don't wish to overwrite the current comment (if any) that is assigned to this key, use the ↑ key to escape this menu and use a different F-key.*

## **F2: READ**

When you are ready to make readings of thermal properties, water content, or matric potential of your particular sample, use this menu. When you press F2 from the main menu, the following screen will appear:

```
READ MENU
F1: THERMAL PROP
F2: WATER CONT.
F3: MATRIC PROP
```

For detailed descriptions of each of these options, each are explained in further chapters.

## **F3:DATA**

```
DATA      999 Free
F1: DOWNLOAD
F2: CLEAR DATA
F3: VIEW DATA
```

The Data menu is used to view your stored data, erase it from memory, or download it to a computer. Notice that the upper right corner of the display shows how many more readings can be stored. This number will decrease as you store more readings.

## **ThermoLink**

### *Menus*

---

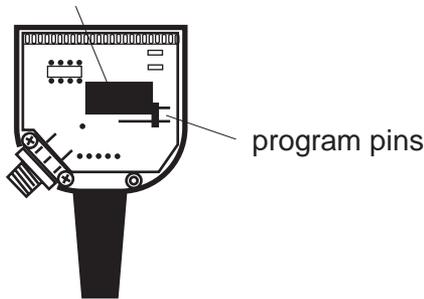
## **F1: Downloading to your PC**

ThermoLink can be linked to the serial port of any personal computer. This enables you to store your data in your PC for further analysis. All you need to download data is your computer's terminal program.

### **To download:**

1. Attach the RS-232 cable to the 5-pin connector on the ThermoLink. Open the plastic shell on the end of the RS-232 cable. Make sure that the black shorting block is attached to only one of the two program pins as shown. Attach the other end of the cable to a serial port on your computer.

shorting block on one pin



2. Open your computer's terminal program and make sure you designate the COM port that the RS-232 cable is connected to.

3. Set the communications settings as follows: baud rate: 9600, 8 data bits, no stop bits, no parity.

4. Once your terminal file is set up, press F1:DOWNLOAD in the DATA menu to download all the current data in your ThermoLink's memory to your computer.

## **F2: Clearing Data From Memory**

Once you have downloaded data to your own computer, you will probably want to clear that data from your ThermoLink's memory to make room for new data sets. Before doing so, make sure that you have either downloaded the data to your computer or you want to discard the data without downloading it. To clear the memory, press F2: CLEAR DATA in the DATA menu. The following screen will appear:

```
WARNING ALL DATA  
WILL BE DELETED!  
F1: CLEAR NOW  
F2: ABORT
```

If you decide not to clear the data, you can press F2: ABORT at this point, which will bring you back to the main menu. If you wish to continue to erase the memory, press F1: CLEAR NOW. The following screen appears:

```
CLEARING DATA  
STORAGE. . .
```

Then you will be brought back to the main menu. All the data that was stored in memory is now gone, and you are now ready to take more samples.

### **F3: Viewing the Data**

To review the data that you have collected, you can press F3: VIEW DATA in the DATA menu. Sample data will be displayed in the order that it was taken. Use the  $\uparrow$   $\downarrow$  arrows to scroll up and down through the data. Following is an example:

```
C=2.856      K=0.45  
D=0.156      T=22.18  
03/11/97      9:10  
Sample #:      1
```

The time displayed is the time when the sample was stored. The temperature displayed is the endpoint temperature.

*Note: If you don't add your own comments to the data sets you store, ThermoLink will automatically*

*number them Sample 1, Sample 2, etc. If you add comments, your comments will appear in the space where the Sample # is normally displayed.*

*Therefore, if you are making comments, remember that your sample will not be automatically numbered by the ThermoLink, though it will place it in the sequential order that it belongs.*

When you are done reviewing the data, press ENTER to go back to the DATA menu.

#### **F4: OFF**

From the main menu, press F4 to turn the power off. Data that has been stored will be maintained while the power is off.

## 6. Fl: Thermal Properties

---

### Preparations

Before you begin thermal properties sampling, make sure you are in a temperature-stable environment, preferably a temperature-controlled room. This will minimize equilibration time and make your sample times faster. If the temperature in your environment is variable, the probes will take a much longer time to equilibrate, and the accuracy of your readings may be affected. The thermal probe is very sensitive! We recommend placing your sample in a temperature-controlled environment (such as a styrofoam box) and using the unattended mode to get the most accurate results possible.

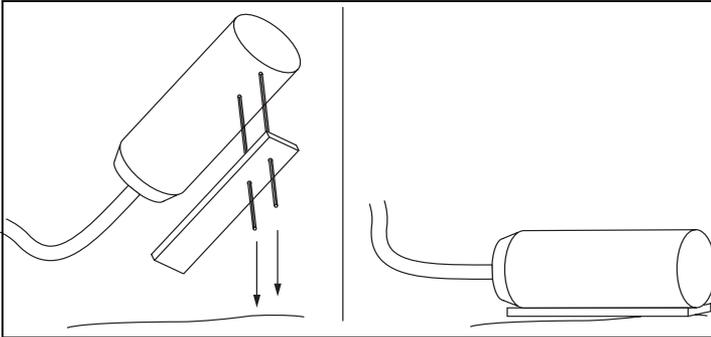


### **CAUTION!**

*Do not begin the read mode unless you have the probes inserted into a sample of some kind, or you will risk burning out the heater element inside the probe!*

## Reading

1. Place the probe guide on the end of the probe needles and then gently insert them all the way into your sample:



2. Press F1: THERMAL PROP. The following screen will appear:

```
CONNECT THERMAL  
PROPERTIES PROBE  
PRESS <ENTER>  
OR F1:UNATTENDED
```

From here you can either press ENTER to choose manual single readings, or press F1 to sample in unattended mode.

## **Single Readings**

If you are doing single individual readings (not

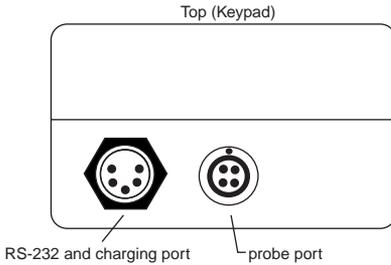
---

# ThermoLink

## Fl: Thermal Properties

---

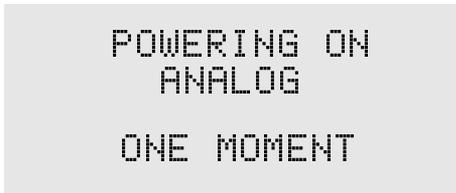
unattended) read the next section before pressing ENTER



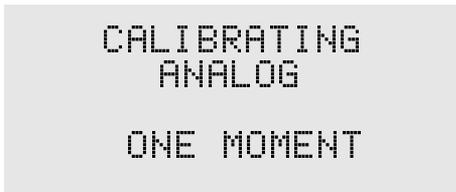
Make sure you have the probe cable securely attached to the ThermoLink's metal 4-pin connector and press

enter.

The following screen will appear:



Then:



Then:

```
VERIFYING ANALOG  
PERFORMANCE  
ONE MOMENT
```

Then:

```
stabilizing  
sensors  
please wait.....
```

Then:

```
EQUILIBRATING  
PROBE TEMP= 21.94  
 $\Delta T = 0.0237$  wait  
F1:SKIP F4:ABORT
```

This screen indicates that the probe's thermocouple is trying to equilibrate its temperature with the medium you are measuring. During this time, try not to move the probe cord or head, as soft samples can allow the needles to widen their holes. The change in temperature between the thermocouple and your sample is displayed. Once the temperature difference reaches 0.003 or lower it begins the measurement process. If you wish, you may press F1 to skip the

## **ThermoLink**

### *F1: Thermal Properties*

---

equilibrating process, but your results will not necessarily be accurate. When it is finished equilibrating, the next screen will appear:

```
HEATING PROBE  
PLEASE WAIT....  
  
2 sec      F4:ABORT
```

The probe will heat the sample for 8 seconds, then the next screen will appear:

```
READING PROBE  
PLEASE WAIT...  
  
14 sec     F4:ABORT
```

The instrument will now read for 60 seconds, after which it will give you the final display:

```
C= 4.027   K= 0.48  
D= 0.119   T= 21.92  
F1: SAVE   F2: COMNT  
F4: DISCARD
```

Here ThermoLink shows the Specific Heat (C), the Thermal Conductivity (K), the Thermal Diffusivity (D) and the Temperature in C (T). From here you

---

have three options. You can save the reading without making a comment by pressing F1, and the ThermoLink will automatically number the sample, then bring you back to the sampling menu. To add comments, press F2. The following display will appear:

```
COMMENT: <ENTER>  
—  
A
```

Type in your comment at the prompt. If you find that you are repeatedly entering the same phrase for each sample, you may want to assign that phrase to a function key. Refer to the section titled “Programming the Function Keys” in this chapter.

Your third option is to press F4 to discard the reading and try again. All the options will eventually bring you back to the first screen:

```
CONNECT THERMAL  
PROPERTIES PROBE  
PRESS <ENTER>  
OR F1:UNATTENDED
```

You may either take another reading or use the up

---

## **ThermoLink**

*F1: Thermal Properties*

---

arrow ↑ to back up to the main menu.

### **F1: Unattended**

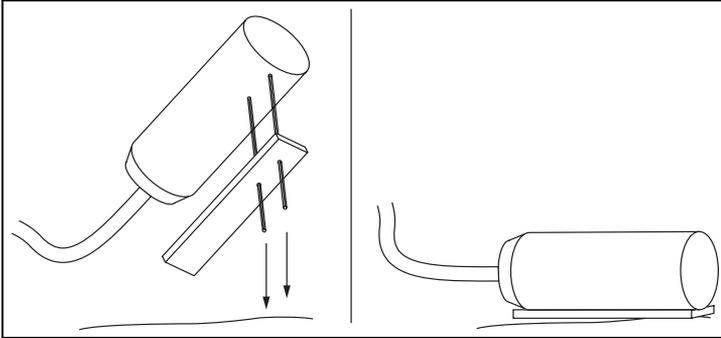
If you want to make continuous unattended readings, press F1:UNATTENDED and the following screen will appear:

```
ENTER NUMBER OF  
READINGS  
  
_      N
```

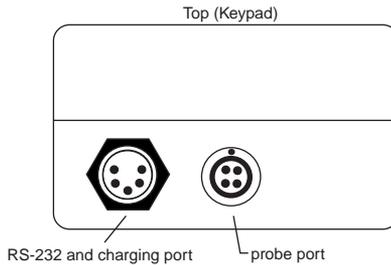
At the prompt, enter the number of readings you wish to take in the unattended mode. It must be a number between 2 and 300. ThermoLink will make measurements every 30 minutes accordingly. When you press ENTER the following screen will appear:

```
CONNECT THERMAL  
PROBE AND PRESS  
  
<ENTER>
```

1. Place the probe guide on the end of the probe needles and then gently insert them all the way into your sample:



2. Make sure you have the probe securely attached to ThermoLink's metal 4-Pin connector and press ENTER at the "CONNECT THERMAL PROBE" prompt.



The following screen will appear:

## **ThermoLink**

### *F1: Thermal Properties*

---

```
POWERING ON  
ANALOG
```

```
ONE MOMENT
```

Then:

```
CALIBRATING  
ANALOG
```

```
ONE MOMENT
```

Then:

```
VERIFYING ANALOG  
PERFORMANCE
```

```
ONE MOMENT
```

Then:

```
stabilizing  
sensors
```

```
please wait...
```

Then:

```
EQUILIBRATING  
PROBE TEMP = 21.94  
 $\Delta T = 0.0237$  wait  
F1:SKIP    F4:ABORT
```

This screen will appear to indicate that the probe's thermocouple is trying to equilibrate its temperature with the medium you are measuring. During this time, try not to move the probe cord or head, as soft samples can allow the needles to make gaps in the sample. The change in temperature between the thermocouple and your sample is displayed. Once the temperature difference reaches 0.003 or lower it begins the measurement process. If you wish, you may press F1 to skip the equilibrating process, but your results will not necessarily be accurate. When it is finished equilibrating, the next screen will appear:

```
HEATING PROBE  
PLEASE WAIT...  
  
2 sec    F4:ABORT
```

The probe will heat the sample for 8 seconds, then the next screen will appear:

## **ThermoLink**

### *F1: Thermal Properties*

---

```
READING PROBE  
PLEASE WAIT...  
  
14 sec    F4:ABORT
```

The instrument will now read for 60 seconds, after which it will give you the final display:

```
COMPUTING  
RESULT  
PLEASE WAIT
```

At this point, the screen will turn off, and it will resume unattended logging. If you press ON, the following screen will appear:

```
UNATTENDED MODE  
1 OF 8  
READINGS TAKEN  
F4:ABORT
```

This screen will indicate how many readings have been taken and stored. If you wait for 15 seconds, this screen will disappear. If you wish to abort the readings, press F4 and the following screen will

appear:

```
UNATTENDED MODE  
ABORTED. PRESS  
ANY KEY TO  
CONTINUE
```

Press any key and you will be returned to the main menu.

## 7. F2: Water Content

---

In the READ menu, press F2: WATER CONT. to make water content measurements. The following screen will appear:

```
CONNECT THERMAL  
PROPERTIES PROBE  
PRESS <ENTER>  
OR F1:UNATTENDED
```

From here you can either press ENTER to choose manual single readings, or press F1 to sample in unattended mode.

### **Preparations**

Before you begin sampling, make sure you are in a temperature-stable environment, preferably a temperature-controlled room. This will minimize equilibration time and make your sample times faster. If the temperature in your environment is variable, the probes will take a much longer time to equilibrate, and the accuracy of your readings may be affected. The thermal probe is very sensitive! We

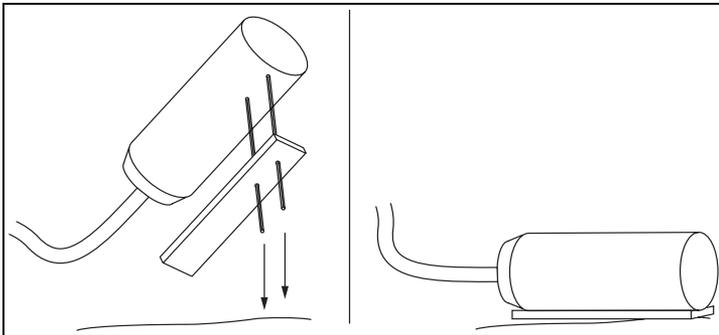
recommend placing your sample in a temperature-controlled environment (such as a styrofoam box) and using the unattended mode to get the most accurate results possible.

**!** **CAUTION!**

*Do not begin the read mode unless you have the probes inserted into a sample of some kind, or you will risk burning out the heater element inside the probe!*

**Reading**

1. Place the probe guide on the end of the probe needles and then gently insert them all the way into your sample:

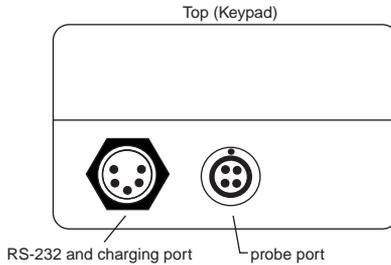


2. Make sure you have the probe securely attached to ThermoLink's metal 4-Pin connector.

# ThermoLink

## F2: Water Content

---



### Single Readings

If you are doing single individual readings (not unattended), connect the dual-element thermal probe and press ENTER. The following screen will appear:

```
ENTER
BULK DENSITY

>0.000g/cc      N
```

At this point, you will need to enter a value for the bulk density of the sample you are measuring. It needs to be in the units of grams per cubic centimeter, and it must be a value greater than 0.5g/cc and less than 2.0g/cc. When you are done, press Enter. The following screen will appear:

```
CALIBRATING  
ANALOG  
  
ONE MOMENT
```

Then:

```
VERIFYING ANALOG  
PERFORMANCE  
  
ONE MOMENT
```

Then:

```
stablizing  
sensors  
  
please wait.....
```

Then:

```
EQUILIBRATING  
PROBE TEMP = 21.94  
 $\Delta T = 0.0237$  wait  
F1:SKIP F4:ABORT
```

This screen indicates that the probe's thermocouple is trying to equilibrate its temperature with the medium you are measuring. During this time, it is important that you don't move the probe cord or

## **ThermoLink**

### *F2: Water Content*

---

head, as soft samples can allow the needles to widen their holes. The change in temperature between the thermocouple and your sample is displayed. Once the temperature difference reaches 0.003 or lower it begins the measurement process. If you wish, you may press F1 to skip the equilibrating process, but your results will not necessarily be as accurate. When it is finished equilibrating, the next screen will appear:

```
HEATING PROBE  
PLEASE WAIT.....  
  
2 sec      F4:ABORT
```

The probe will heat the sample for 8 seconds, then the next screen will appear:

```
READING PROBE  
PLEASE WAIT...  
  
14 sec     F4:ABORT
```

The instrument will now read for 60 seconds, after which it will give you the final display:

```
C= 4.327   K= 0.48  
WC= 0.119  T= 21.92  
F1: SAVE   F2: COMNT  
F4: DISCARD
```

This display shows you the different values ThermoLink has measured. C is the specific heat, K is thermal conductivity, WC is water content, and T is temperature. From here you have three options. You can save the reading without making a comment by pressing F1, and ThermoLink will automatically number the sample, then bring you back to the sampling menu. To add comments, press F2. The following display will appear:

```
COMMENT: <ENTER>
```

```
—
```

```
A
```

Type in your comment at the prompt. If you find that you are repeatedly entering the same phrase for each sample, you may want to assign that phrase to a function key. Refer to the section titled “Programming the Function Keys” in Chapter 5.

Your third option is to press F4 to discard the reading and try again. All the options will eventually bring

## **ThermoLink**

### *F2: Water Content*

---

you back to the first screen:

```
CONNECT THERMAL  
PROPERTIES PROBE  
PRESS <ENTER>  
OR F1:UNATTENDED
```

You may either take another reading or use the up arrow ↑ to back up to the main menu.

### **F1: Unattended Mode**

If you want to make continuous unattended readings of water content, press F1:UNATTENDED and the following screen will appear:

```
ENTER NUMBER OF  
READINGS  
  
_      N
```

At the prompt, enter the number of readings you wish to take in the unattended mode. It must be a number between 2 and 300. ThermoLink will make measurements every 30 minutes accordingly. When you press ENTER the following screen will appear:

```
CONNECT THERMAL  
PROBE AND PRESS  
  
<ENTER>
```

Press ENTER and the following screen will appear:

```
ENTER  
BULK DENSITY  
  
>0.000g/cc      N
```

At this point, you will need to enter a value for the bulk density of the sample you are measuring. It needs to be in the units of grams per cubic centimeter, and it must be a value greater than 0.5g/cc and less than 2.0g/cc. When you are done, press Enter. The following screen will appear:

```
POWERING ON  
ANALOG  
  
ONE MOMENT
```

## **ThermoLink**

### *F2: Water Content*

---

Then:

```
CALIBRATING
ANALOG

ONE MOMENT
```

Then:

```
VERIFYING ANALOG
PERFORMANCE

ONE MOMENT
```

Then:

```
stabilizing
sensors

please wait...
```

Then:

```
EQUILIBRATING
PROBE TEMP = 21.94
 $\Delta T$  = 0.0237 wait
F1:SKIP      F4:ABORT
```

This screen will appear to indicate that the probe's thermocouple is trying to equilibrate its temperature with the medium you are measuring. During this time, try not to move the probe cord or head, as soft

samples can allow the needles to make gaps in the sample. The change in temperature between the thermocouple and your sample is displayed. Once the temperature difference reaches 0.003 or lower it begins the measurement process. If you wish, you may press F1 to skip the equilibrating process, but your results will not necessarily be accurate. When it is finished equilibrating, the next screen will appear:

```
HEATING PROBE  
PLEASE WAIT...  
  
2 sec      F4:ABORT
```

The probe will heat the sample for 8 seconds, then the next screen will appear:

```
READING PROBE  
PLEASE WAIT...  
  
14 sec     F4:ABORT
```

The instrument will now read for 60 seconds, after which it will give you the final display:

```
COMPUTING  
RESULT  
PLEASE WAIT
```

At this point, the screen will turn off, and it will resume unattended logging. If you press ON, the following screen will appear:

```
UNATTENDED MODE  
1 OF 8  
READINGS TAKEN  
F4:ABORT
```

This screen will indicate how many readings have been taken and stored. If you wait for 15 seconds, this screen will disappear. If you wish to abort the readings, press F4 and the following screen will appear:

```
UNATTENDED MODE  
ABORTED. PRESS  
ANY KEY TO  
CONTINUE
```

Press any key and you will be returned to the main menu.

---

## **8. F3: Matric Properties**

---

### **Before you start**

#### **Equilibrating**

Before making matric potential readings, make sure that your matric probe has sufficiently equilibrated with the soil you are measuring, and is fully buried. For arid soils, equilibration time should be from 24 to 48 hours. Moister soils require shorter equilibration time (4-12 hours), but it is important to give the probe as much time as possible to equilibrate.

#### **Saline soils**

Soils with high salinity may not be compatible with the matric probe. Too high of a salt content will cause the sensor to give inaccurate readings. To avoid this when sampling in saline soil, use the matric probe only in places where plants are growing.

\*Note: once you use the matric potential probe in saline soil, you cannot use it in any other type of soil and get accurate readings, due to the saturation of salt in the ceramic matrix.

## **ThermoLink**

### *F3: Matric Properties*

---

### **Preparations**

Press F3: MATRIC PROP in the Data Menu. The following screen will appear:

```
MATRIC POTENTIAL
PROBE #123456 ↑↓
<ENTER>  F5:BACK
F1:UNATTENDED
```

From here you have three options. You can press the arrow keys to scroll to other probes you have set up, or you can set up a new probe; you can press ENTER to begin sampling with the probe currently selected; you can press F5 to go to the previous menu; or you can select F1 to enter the unattended sampling mode.

### **Configuring the Matric Sensor**

Each matric sensor has a specific calibration constant, located on a yellow label next to the end of the plug (not the white heatshrink label). When using the matric sensor, you will need to enter that number in this menu before proceeding. If no probes have ever been set up for your system, a zero will appear next to the words “Matric Potential Probe #.”

To configure a new probe, press the up or down arrow until a zero appears next to the # symbol and press ENTER. The following screen will appear:

---

```
ENTER FIRST 3  
DIGITS OF PROBE  
NUMBER  
> ___ N
```

At the prompt, enter the first three digits that appear on the matric sensor's label, and press ENTER. The next screen will appear:

```
ENTER LAST 3  
DIGITS OF PROBE  
NUMBER  
      > ___N
```

Enter the last three digits that appear on the matric sensor's label, and press ENTER. The following screen will appear:

```
YOU ENTERED  
PROBE # 120579  
F1: REJECT  
F2: ACCEPT
```

Check the number on the matric sensor's yellow label to make sure it matches the number that appears on

---

## **ThermoLink**

### *F3: Matric Properties*

---

your screen. If the number is incorrect, press F1 and you will be prompted to re-enter the number again. If the number is correct, press F2, and the read cycle will begin.

## **Making Readings**

### **Single Readings**

If you are doing single individual readings (not unattended), make sure the matric sensor is attached to ThermoLink's 4-pin connector and then press ENTER at the Matric Potential sampling menu. Some dialogue displays will appear to show that it is testing the analog board's performance and heating the probe, and then the final display will appear:

```
MP=  -5.00 BAR
ΔT=0.50      T=19.0
F1:SAVE   F2:COMNT
F4:DISCARD
```

This display shows you the matric potential values it has measured. MP is the matric potential reading in units of Bars, T is the temperature of your sample, and  $\Delta T$  is any perceived change in temperature during the reading. This is displayed because if the temperature change is too dramatic, the reading will be inaccurate, and you should re-read your sample.

From here you have three options. You can save the reading without making a comment by pressing F1, and ThermoLink will automatically number the sample, then bring you back to the sampling menu. To add comments, press F2. The following display will appear:

```
COMMENT: <ENTER>  
--  
A
```

Type in your comment at the prompt. If you find that you are repeatedly entering the same phrase for each sample, you may want to assign that phrase to a function key. Refer to the section titled “Programming the Function Keys” in Chapter 5.

Your third option is to press F4 to discard the reading and try again. All the options will eventually bring you back to the first screen:

```
MATRIC POTENTIAL  
PROBE #123456 ↑↓  
<ENTER> F5:BACK  
F1:UNATTENDED
```

You may either take another reading or use the up

---

## **ThermoLink**

### *F3: Matric Properties*

---

arrow ↑ to back up to the main menu.

### **F1: Unattended**

If you want to make continuous unattended readings of your sample, select F1: UNATTENDED at the matric potential sensor sampling menu. The following screen will appear:

```
ENTER NUMBER OF
READINGS
          _      N
```

At the prompt, enter the number of readings you wish to take in the unattended mode. It must be a number between 2 and 300. ThermoLink will make measurements every 30 minutes accordingly. When you press ENTER the following screen will appear:

```
CONNECT MATRIC
PROPERTIES
PROBE AND PRESS
<ENTER>
```

Make sure the matric sensor is attached to ThermoLink's 4-pin connector and then press ENTER. Some dialogue displays will appear to show that it is

testing the analog board's performance and heating the probe, the screen will turn off, and it will commence unattended logging. If you press ON, the following screen will appear:

```
UNATTENDED MODE
1 OF 8
READINGS TAKEN
F4: ABORT
```

This screen will indicate how many readings have been taken and stored. If you wait for 15 seconds, this screen will disappear. If you wish to abort the readings, press F4 and the following screen will appear:

```
UNATTENDED MODE
ABORTED. PRESS
ANY KEY TO
CONTINUE
```

Press any key and you will be returned to the main menu.

## **9. Theory**

---

This section will describe more in-depth the theory and importance of the measurements that ThermoLink makes: Thermal Conductivity, Thermal Diffusivity, Volumetric Specific Heat, and Matric Potential. Additional information can be found in the references at the end of this chapter.

### **Thermal Properties and the Dual Probe Technique**

After considerable work to find techniques to measure thermal conductivity of porous materials, most researchers in soil science and other fields have accepted the line-source thermal conductivity probe as the method of choice, especially for in-situ measurements. The most accurate and accepted measuring technique used with the line-source is the short-duration heat pulse method. By using the short-duration heat-pulse method, the thermal diffusivity, heat capacity, and thermal conductivity can all be derived from one reading. This is the method employed by ThermoLink to find the thermal properties of your samples. Campbell et al. (1991) gives the equation for the temperature rise at some

distance,  $r$ , from a pulsed line heat source as

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

*equation 1*

where  $r$  is the distance between the line heat source and the temperature sensor,  $\Delta T$  is the temperature rise measured by the thermocouple,  $q$  is the power dissipated by the heater,  $K$  is the thermal conductivity,  $D$  is the thermal diffusivity, and  $t$  is time.

ThermoLink's dual probe needles are spaced 6mm apart and are 30mm long. A heating wire is inside one probe, and a type E (chromel/constantan) thermocouple is placed in the other. The two needles are placed in the sample, and a known amount of current is passed through the heater wire, causing the heater needle to emit an 8 second-long heat pulse. The needles have previously equilibrated with the temperature of the sample, so the temperature rise above ambient is then monitored by the thermocouple for 60 seconds. The total power dissipated by the heater is the product of the voltage applied to it and the current going through it. This is divided by the length of the heater and multiplied by the heat pulse length to get  $q$ .

## **ThermoLink**

### *Theory*

---

Equation 1 is used with a mathematical inverse method to find  $K$  and  $D$  from a set of measurements of  $\Delta T$  vs.  $t$  for a sample. There exists some combination of  $K$  and  $D$  in *eq. 1* which will make its predictions of  $\Delta T$  closely match the measured temperatures from a reading with the dual-pin probe. Those will be the thermal conductivity and diffusivity of the sample. Once conductivity and diffusivity are known, then volumetric specific heat can be found from

$$C = \frac{K}{D}$$

*equation 2*

## **Thermal Conductivity**

Thermal conductivity measures the rate at which energy is transferred through a medium per unit temperature gradient. ThermoLink measures thermal conductivity in  $\text{W m}^{-1} \text{C}^{-1}$  (Watts per meter-degree Celsius). Several factors affect the thermal conductivity of a sample. One of particular significance is the moisture content and air content of the sample. Studies have shown that for most mediums, the relationship between water content and thermal conductivity is linear. Therefore, the thermal conductivity of two soil samples taken from the same plot could vary, depending on how wet each

sample was. Another important factor to keep in mind is the direction of grain or structure of the sample with respect to the direction of heat flow.

## **Thermal Diffusivity and Volumetric Specific Heat**

Volumetric specific heat is a measure of the energy needed to raise the temperature of a given medium to a unit degree. It is related to heat capacity, or the amount of thermal energy a material can store.

Thermal Diffusivity is the ratio of thermal conductivity to specific heat. It is essentially the rate at which a thermal disturbance will propagate through a medium. It is measured by the ThermoLink in millimeters squared per second ( $\text{mm}^2 \text{s}^{-1}$ ). A sample with a high thermal diffusivity will respond quickly to its thermal environment. Similarly, a sample with a low thermal diffusivity will respond slowly to its thermal environment.

## **Matric Potential and Water Content: Determined from Thermal Properties**

Since the thermal properties of a porous medium depend mainly on water content, the thermal properties measurements that ThermoLink makes can be used to determine water content of the porous

## **ThermoLink**

### *Theory*

---

medium.

For a given porous medium, there exists a relationship between its water content and its matric potential. One can therefore monitor the matric potential of a soil by measuring the thermal properties of a porous ceramic block buried in the soil. Since ThermoLink measures thermal properties, it can therefore be used to measure matric potential and water content of soil.

### **Matric Potential**

Matric Potential is a measure of the adsorptive forces binding water to a soil matrix. It can be measured by ThermoLink in Bars, MPa (megapascals), or Joules/kg. Matric Potential is a value that expresses the difference in the potential of water held by a soil matrix and that of free water at the same elevation and salt concentration. Since free water is not being held by a soil matrix, its matric potential is zero. However, in order to convert soil-held water to free water, work must be performed, along with an increase of the energy level of the water. Therefore, the matric potential of water being held by matric forces is negative, and the more tightly bound the water is to the soil, the more negative the matric potential value will be. The operating theory of ThermoLink's matric potential sensor is explained on page 15 of this manual. For more information on this

type of sensor, see C.F. Reece's reference at the end of this chapter.

### **Water Content**

Water Content is a volumetric measure of the amount of water in a given system. Since the thermal properties of soils change depending on the amount of water in the system, water content can be derived from measuring the thermal properties of the soil. ThermoLink measures this as a ratio of  $\text{m}^3$  of water per  $\text{m}^3$  of soil. It is related to volumetric specific heat by the equation

$$\theta = \frac{C - \rho_b c_s}{\rho_w c_w}$$

*equation 3*

where  $C$  is the volumetric specific heat,  $\rho_b$  is the soil bulk density,  $c_s$  is the soil's specific heat,  $\rho_w$  is the water density, and  $c_w$  is the water's specific heat. Any errors in  $\Theta$  will result primarily from uncertainties in  $C$  and  $\rho_b$ . If, however, we are only interested in water-content changes (measurements made without changing the location of the probe), and  $\rho_b$  therefore does not change, the resolution in water content should be around 0.005.

## **Further Reading**

- Bristow, Keith L., Kluitenberg, Gerard J., and Horton, Robert, "Measurement of Soil Thermal Properties with a Dual-Probe Heat-Pulse Technique." *Soil Science Society of America Journal*, Vol.58, no. 5, pp.1288-1294 September-October 1994.
- Bristow, K.L., Campbell, G.S., and Calissendorff, K., "Test of a Heat-Pulse Probe for Measuring Changes in Soil Water Content." *Soil Science Society of America Journal*, Vol. 57, No. 4, pp 930-934. July-August 1993.
- Campbell, G.S., Calissendorff, C., and Williams, J.H., "Probe for Measuring Soil Specific Heat Using a Heat-Pulse Method." *Soil Science Society of America Journal*, Vol. 55, No.1., pp 291-293. January-February 1991.
- Campbell, G.S. and Wilson, A.M., "Water Potential Measurements of Soil Samples." pp-142-149, in Brown, R.W. and VanHaveren (eds.), *Psychrometry in Water Relations Research*. 1972. Utah Agric. Exp. Stn., Logan, Utah.
- Papendick, R.I., and Campbell, G.S., "Theory and Measurement of Water Potential." pp 1-22 in *Water Potential Relations in Soil*
-

*Microbiology*. 1980. Soil Science Society of America. Madison, Wisconsin

Reece, C.F., "Evaluation of a Line Heat Dissipation Sensor for Measuring Soil Matric Potential." *Soil Science Society of America Journal*, Vol. 60, pp. 1022-1028. 1996.

## **10. Care and Maintenance**

---

As with any scientific instrument, it is important to take care of your ThermoLink and probes in order to ensure accuracy and reliability. This chapter describes a few things you can do to make sure your ThermoLink is always working properly.

### **Charging the Batteries**

ThermoLink uses two 5-cell battery packs, which last for about 16 hours of normal use. When they become low on charge, you will get the following message on power-up:



LOW BATTERY COND.  
SHUTTING DOWN

When this screen appears, it means there is not sufficient battery charge to adequately support all the functions, so it will shut down. If you are logging in the unattended mode and the power is insufficient, it will abort the reading cycle and turn off.

Therefore, it is important to recharge the batteries on a regular basis to avoid this. Do not, however, recharge the batteries too frequently (like after each use) or they will quickly lose their storage capacity.

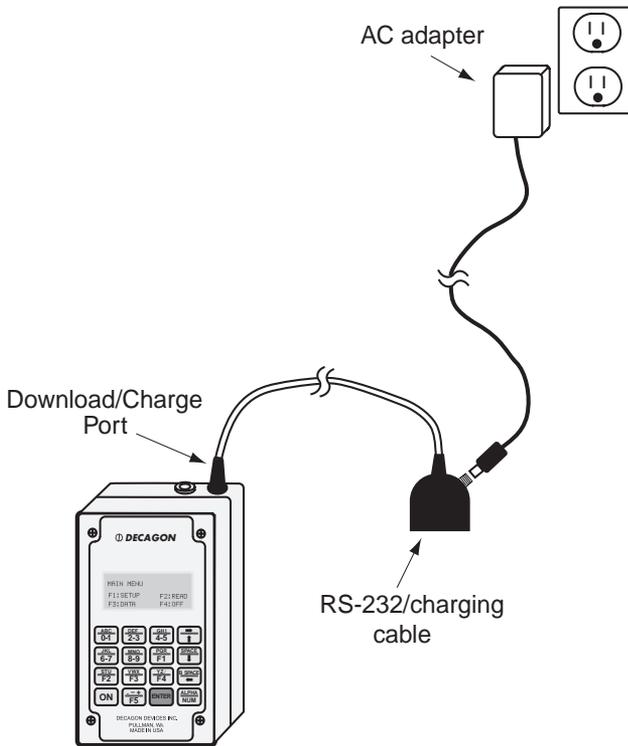
To Charge the Batteries:

1. Attach the charging jack on the ThermoLink's RS-232 cable to the AC Adapter.
2. Plug the 5-pin port on the end of the RS-232 cable to the 5-pin connector on the ThermoLink microcontroller.
3. Plug the AC Adapter into an outlet. Let it charge for at least 10 hours, but no more than 16 hours at a time!

If the batteries no longer hold their charge, contact Decagon for replacements.

*NOTE: ThermoLink will not operate while*

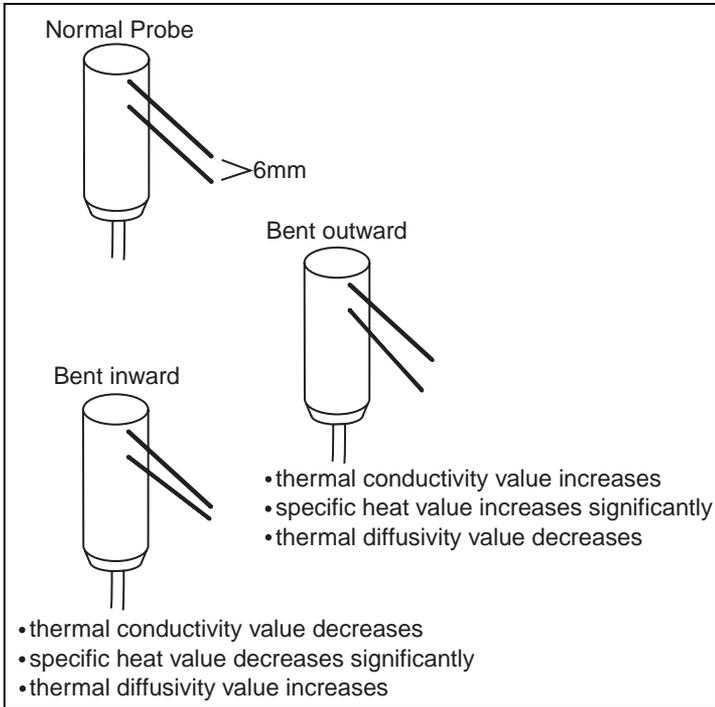
*recharging!*



## **Caring for the Dual-Needle Probe**

Due to the nature of the dual-probe measuring method, it is very important to keep the needles of the probe straight and perfectly spaced. Any bends in either of the needles can cause significant changes in the thermal property readings of your samples. Here

is an illustration:



To avoid bending the needles, always store the dual-needle head in the black plastic storage block that came with your unit when not using the probe.

When you are sampling, always use the probe guide, even in a relatively soft sample medium. The slightest variance of hole spacing upon entry of the sample can skew the probe spacing. Also, if the probe moves while plugged into the sample, the holes can widen and render the sampling inaccurate.

 **CAUTION!**

*Do not begin the read mode unless you have the probes inserted into a sample of some kind, or you will risk burning out the heater element inside the probe!*

## **Cleaning and Maintenance**

For sanitary purposes and ease of use, it is important to clean all the components of your ThermoLink.

**ThermoLink Microcontroller:** To clean the microcontroller, use non-abrasive cleaners like ethanol, household ammonia, mild detergents, etc. and a soft cotton cloth. When cleaning the display window, do not use wood-based tissues, or they will cause scratches.

**Thermal Probe:** Obviously, the cleaner your probe needles are, the better results you will get. The probe needles can be cleaned as you wish, but make sure you don't bend the needles!

**Matric Probe:** The matric probe doesn't need extensive cleaning; it is made to be in the soil. Try to brush off excess soil that may dry on the probe. Also, be extremely careful not to drop or hit the probe end, as it is brittle and can break easily.

## **Appendix A: Installing Firmware**

This section is for your reference when you receive an upgrade in operating firmware for the ThermoLink microcontroller. You will need the following items for this procedure:

- ThermoLink microcontroller (probe is not necessary)
- RS-232 cable
- ThermoLink firmware (available from Decagon's website or by contacting Decagon)
- Your PC

### **Connecting and Downloading**

Here are the steps involved:

1. Open the head of the RS-232 cable and move the jumper block so it is on both program pins.
2. Connect the RS-232 cable to your PC.
3. Connect the other end of the cable to the 5-pin connector of the ThermoLink microcontroller.

4. Open your computer's terminal program and adjust the settings as follows: no parity, 8 data bits, one stop bit. Set the baud rate to no higher than 38400.
5. Turn on the ThermoLink. On your computer terminal, press Enter a few times until the following message appears on your computer screen:

```
>DS5001 LOADER VERSION 0.1 COPYRIGHT(C) 1991  
DALLAS SEMICONDUCTOR
```

If this message doesn't appear, disconnect the RS-232 cable and make sure the shorting block is attached to both pins. Reconnect it and turn the ThermoLink on again.

6. Type the following commands, making sure to include the spaces, and entering after each line. Note that the first "O" is the letter O and the subsequent ones are zeroes.

```
U <ENTER>  
W MCON FA <ENTER>  
F O O FFFF <ENTER>  
W MSL 0 <ENTER>  
F O O FFFF <ENTER>  
W MSL 1 <ENTER>  
L <ENTER>
```

7. In your terminal program, select “Send Text File” under the Transfers menu. Select the file you acquired from Decagon named “tsoil.hex” to send.
8. Type the following:

```
W CRC F1      <ENTER>
I              <ENTER>
W CRC 00      <ENTER>
Z              <ENTER>
E              <ENTER>
```

9. Remove the RS-232 cable from the ThermoLink and return the shorting block to connect to one pin, as it was before.

## Appendix B: Miscellaneous Features

---

In addition to the options given you at the main menu, there are other options available that let you change the way your ThermoLink operates. These options are accessed from the Main Menu.

```
MAIN MENU
F1: SETUP  F2: READ
F3: DATA  F4: OFF
```

At the Main menu, press the F5 key. The following menu will appear:

```
F1: Serial, Gain
F2: Wait Time
F3: Heat on time
F4: Clear Probes
```

### **F1: Serial, Gain**

This menu is used to change the current, gain, serial

number, and heater resistance. You should never use this menu unless directed to do so by a Decagon technician.

**Caution!** *Changing any of the values here will affect your calibration constants! If you have questions about this menu, contact Decagon!*

## **F2: Wait Time**

This menu is used to change the heating and waiting time for the matric potential sensor. Again, don't change the values in this menu unless directed to do so by a technician at Decagon.

## **F3: Heat on Time**

This menu is used to change the heating time and the acceptable temperature difference between the sensor and the sample for the thermal properties and water content read functions. It also allows you to download your current calibration settings to a computer for review.

## **F4: Clear Probes**

This menu is for use with the matric properties probes. Each probe comes with a specific calibration constant, which also serves as its identification number. This number is entered when you configure the probe as described in Chapter 8. If you wish to clear these configurations from memory, use this menu.

# Index

---

## Numerics

**25-9 pin adapter** 13

## A

**AC adapter** 13

**alph-num** 19

**arrow keys** 21

## B

**batteries**

charging 72

**bent needles** 74

**BSPACE key** 22

**bulk density** 48

## C

**C (volumetric specific heat)** 18, 38, 67

**calibration certificate** 14

**care** 72

**charging batteries** 72

**cleaning** 76

**clearing memory** 31

**comments** 39

**configuring matrix sensor** 58

**customer service** 2

## D

**D (thermal diffusivity)** 18, 38, 67

**data**

downloading 30

viewing 32

# **ThermoLink**

## *Index*

---

**data menu (F3)** 29  
**date, setting** 24  
**definitions** 17  
**download cable** 12  
**downloading** 30  
**dual needle probe**  
    caring for 74

## **E**

**e-mail address** 3  
**equilibration** 37

## **F**

**fax number** 3  
**firmware, installing** 77  
**function keys** 21  
    programming 27

## **I**

**installing firmware** 77  
**international date** 25

## **K**

**K (thermal conductivity)** 17, 38, 66  
**keypad** 19

## **L**

**letters, typing** 20  
**liability** 3

## **M**

**main menu** 23  
**maintenance** 72  
**matric potential** 17, 67

**matric properties sampling** 57

- making single readings 60
- unattended mode 62

**matric sensor** 11

- clearing from memory 81
- configuring 58
- equilibration of soil with 57

**matric units** 26

- changing 26

**memory**

- erasing 31

**menus** 23**microcontroller** 9**N****numbers, typing** 20**O****off (F4)** 33**P****ports** 9**probe guide** 12**R****read menu (F2)** 29**recharging cable** 12**references** 70**repair** 4

- costs 5

**RS-232 cable** 12**S****saline soils** 57

---

# **ThermoLink**

## *Index*

---

**seller's liability** 3

**setting the date** 24

**setting the time** 24

**setup (F1)** 23

**SPACE key** 22

**specific heat** 38, 67

**specifications** 6

## **T**

**technical support** 2

**telephone number** 2

**temperature**

influencing data 34

**temperature of sample** 38

**testing block** 14

**theory** 64

dual probe technique 64

matric potential 67

thermal conductivity 66

thermal diffusivity 67

thermal properties 64

volumetric specific heat 67

water content 67

**thermal conductivity** 17, 38, 66

**thermal diffusivity** 18, 38, 67

**thermal properties**

making single readings 35

unattended sampling 40

**thermal properties menu** 34

**thermal properties sensor** 10

**thermocouple** 18

**ThermoLink meter** 9

**time, setting** 24

**toll-free number** 2

## **U**

**unattended mode**

for matric properties 62

for thermal properties 40

for water content sampling 52

**US date** 25

## **V**

**viewing data** 32

**volumetric specific heat** 18, 67

## **W**

**warranty** 2

**water content** 67, 69

**water content sampling** 46

making single readings 48

unattended mode 52