Training and Installation

C-THERM TCi™
THERMAL CONDUCTIVITY ANALYZER

C-THERM TECHNOLOGIES

AGENDA

- Who is C-Therm Technologies
- Introducing TCi™ Thermal Conductivity Analyzer
- Theory of Operation
- Overview of Hardware
- Operational Qualification
  - Diagnostic: Communication Check
  - Reference Material Check
- Software Tutorial
- Client Sample Testing
- Schedule Future Follow-up Call
- Questions?

C-THERM TECHNOLOGIES

ABOUT C-THERM

Niche specialists in thermal sensor technology solutions for R&D, production, and QC applications. C-Therm focuses on simple, fast & accurate measurement of thermal conductivity and thermal expansion via innovative technology.

C-THERM TECHNOLOGIES

WHAT WE DO

THERMAL CONDUCTIVITY ANALYSIS




C-THERM TECHNOLOGIES

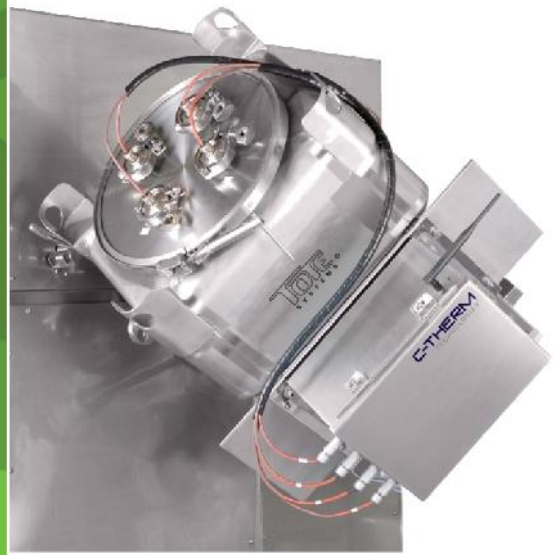
PRODUCT LINES

THERMAL CHARACTERIZATION

C-Therm TCi™ Thermal Conductivity Analyzer

Clients include:

- NASA
- Henkel Tech.
- PolyOne
- Philip Morris
- Huntsman
- US Air Force



PHARMACEUTICAL APPLICATIONS

C-Therm ESP™ Effusivity Sensor System

Clients include:

- Patheon
- Wyeth
- BMS
- Astra Zeneca
- Biovail
- USP

C-THERM TECHNOLOGIES

COMBINED SOLUTION

Up to 40% Savings

C-THERM TECHNOLOGIES

TCi PROPERTY ANALYZER

Thermal Conductivity Range
0 to 500 W/mK

Thermal Effusivity Range
5 to 40,000 $Ws^{1/2}/m^2K$

Temperature Range
-50˚ to 200˚C

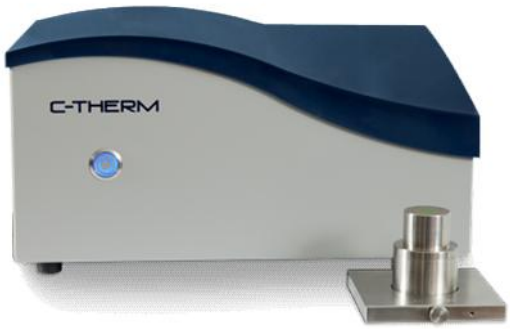
No Sample Preparation
Unlimited sample sizes

Non-Destructive
Leaves sample intact

Versatile
Tests solids, liquids, powders & pastes

Highly Flexible
Designed for lab, QC & at-line testing

Accuracy
Better than 5%



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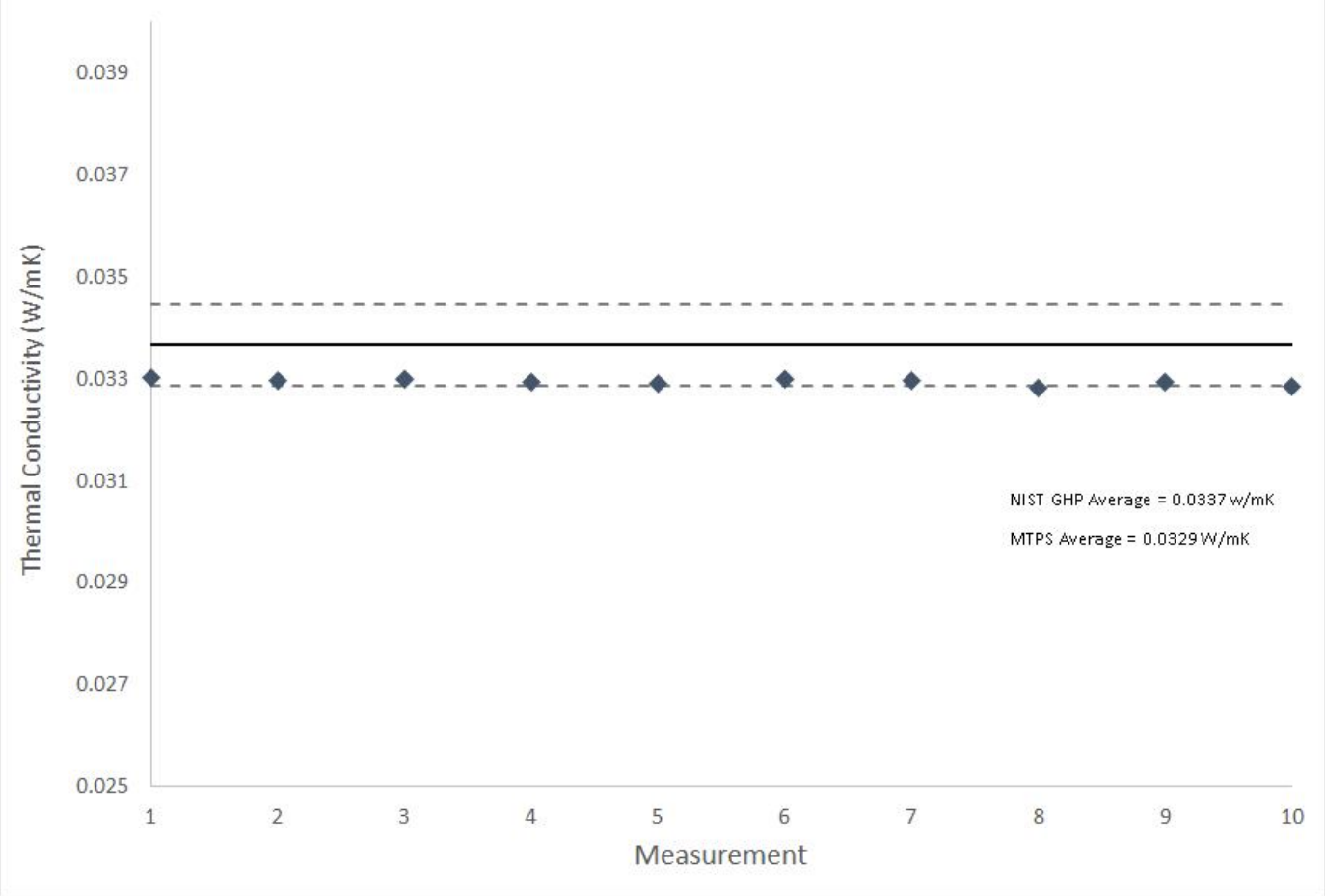
National Institute of Standards and Technology
U.S. Department of Commerce

Reference Sample: EPS



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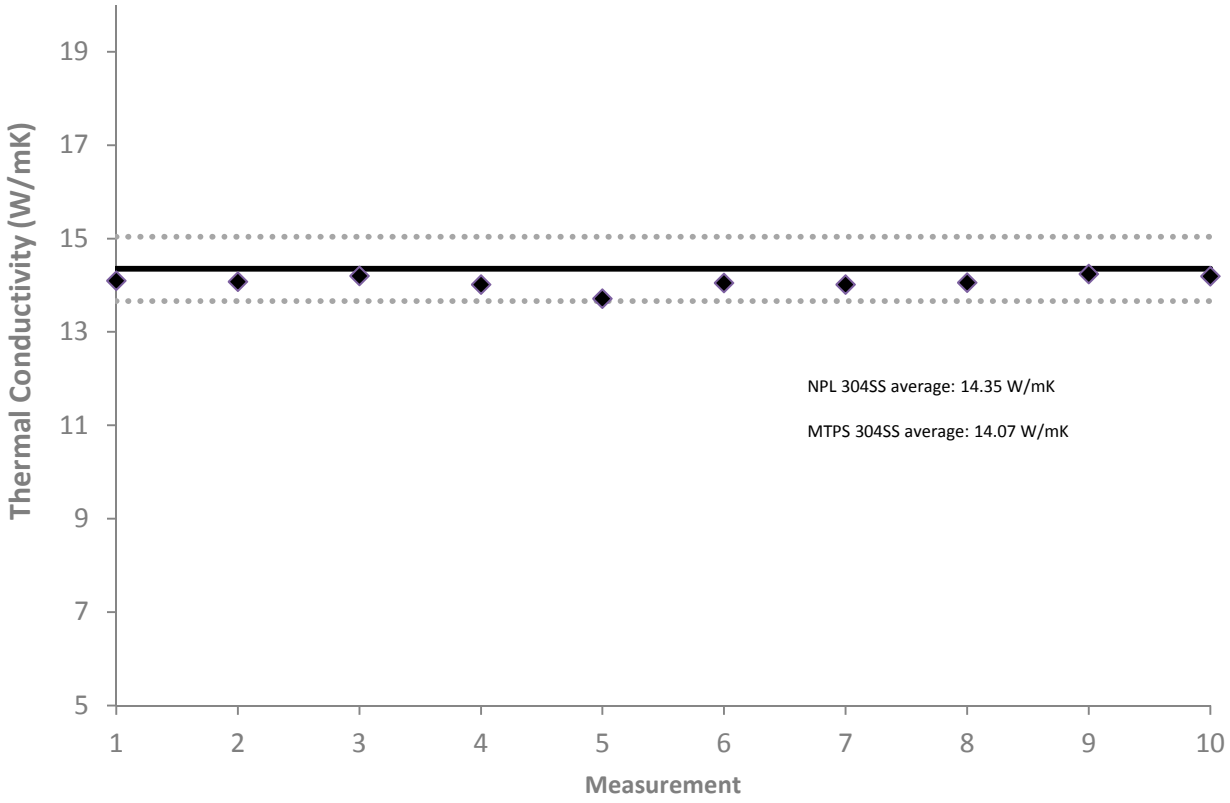
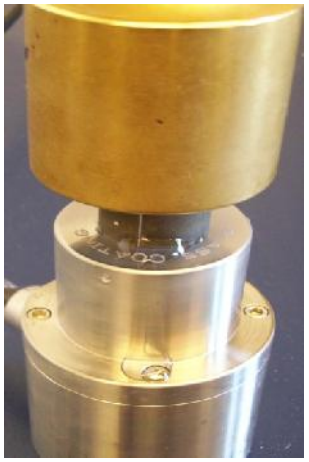
Reference Sample: 304 Stainless Steel





What Does It Measure?

The C-Therm TCi measures two thermal properties primarily:

$$\text{Thermal Conductivity} = (W / m \cdot K)$$

and

$$\text{Effusivity} = \sqrt{k \rho c_p}$$

Where :

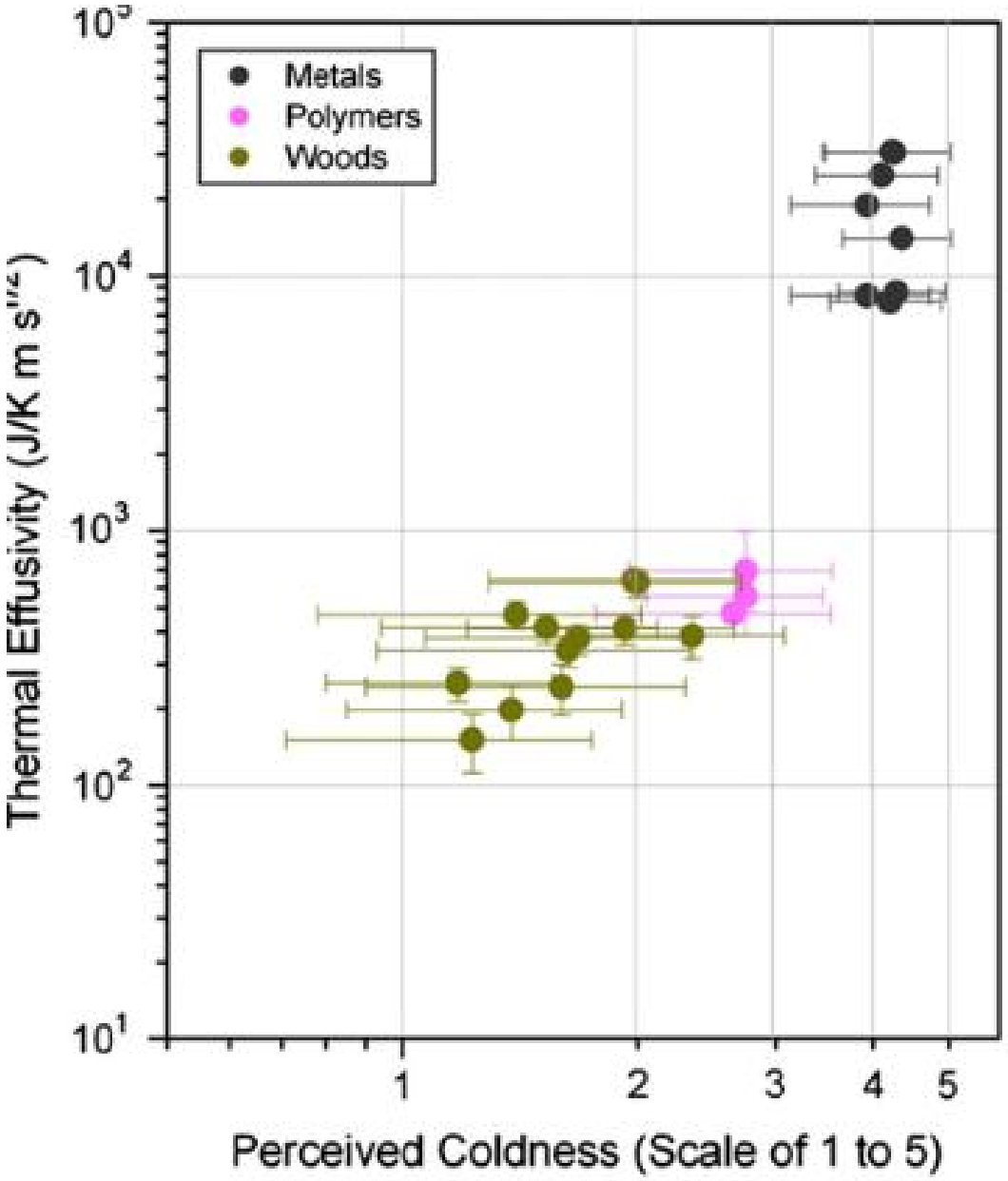
k = Thermal Conductivity (W/m • K)

ρ = Density (kg/m^3)

c_p = Heat Capacity (J/kg • K)

It also indirectly measures (calculated) Thermal Diffusivity and Heat Capacity and has user input capabilities to determine Density

C-THERM TECHNOLOGIES



Source: "The use of physical property data to predict the touch perception of materials" *Materials & Design* 42 (2012) 238–244

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WHEN IS EFFUSIVITY HELPFUL?

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P&G PATENT US 8245876 B2: LOW DENSITY FOAM WIPES CONTAINER HAVING GOOD EFFUSIVITY

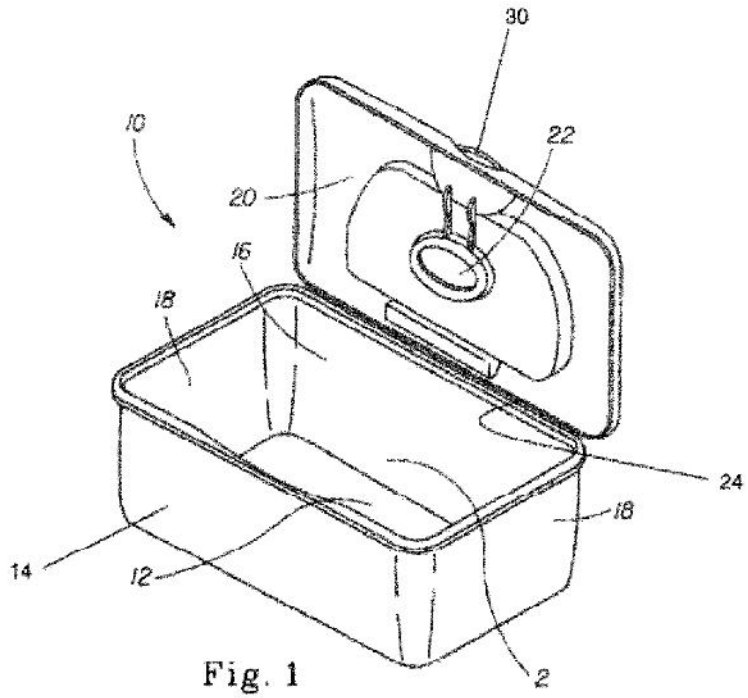

Fig. 1

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What is Thermal Conductivity?

Definition : Thermal conductivity (k) is the rate at which heat flows through a material under a temperature gradient. It is a physical property of a material. The value of thermal conductivity determines the quantity of heat passing per unit of time per unit area at a temperature drop of 1-degree C per unit length. In the limit of infinitesimal thickness and difference in temperature, the fundamental law of heat conduction is:

$$Q = \lambda A dT / dx$$

Where:

Q	is a measure of the heat flow
A	is a the cross sectional area
dT / dx	is the temperature / thickness gradient
k	is defined as the thermal conductivity

Thermal conductivity differs with each substance and may depend on the structure, density, humidity, pressure and temperature. Materials having a large thermal conductivity value are good conductors of heat; one with a small thermal conductivity value is a poor heat conductor i.e. good insulator. Hence, knowledge of the thermal conductivity value (units W/m•K) allows for quantitative comparisons to be made between the thermal insulation efficiencies of different materials.

TCi™ Thermal Conductivity Analyzer

THEORY OF OPERATION

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MODIFIED TRANSIENT PLANE SOURCE

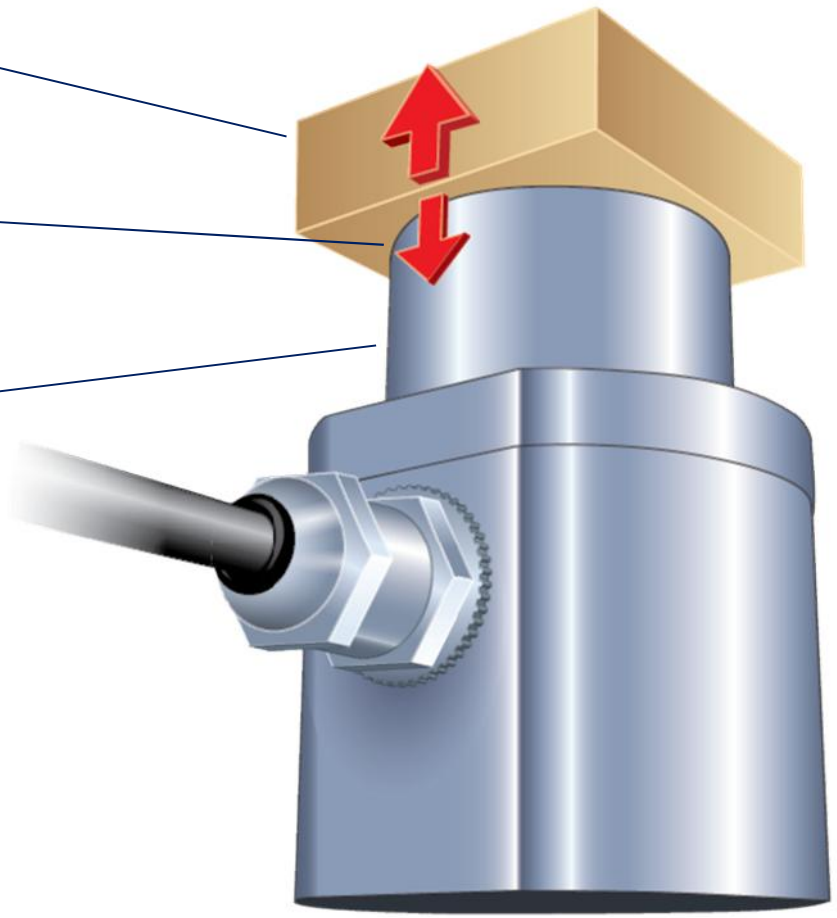
Sample material can be solid, liquid, powder or paste.

A known current is applied to the sensor's heating element, providing a small amount of heat.

The heat provided results in a rise in temperature at the interface between the sensor and the sample – typically less than 2˚C.

This temperature rise at the interface induces a change in the voltage drop of the sensor element.

The rate of increase in the sensor voltage is used to determine the thermo-physical properties of the sample material.



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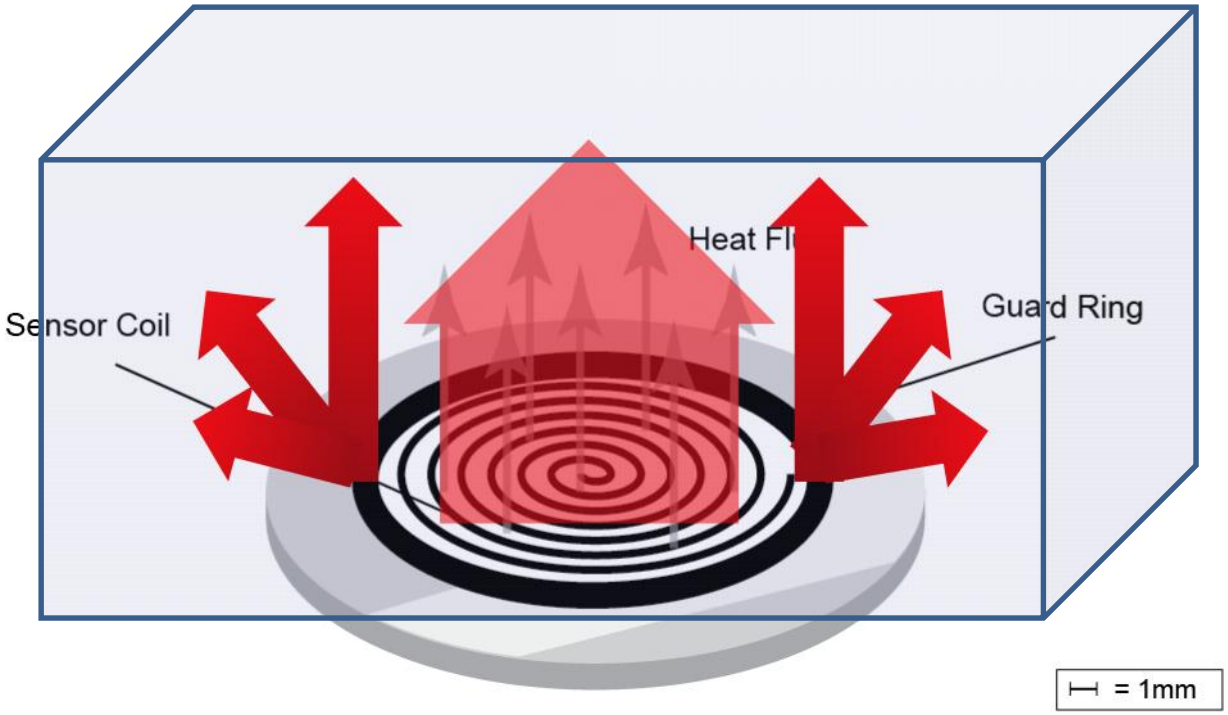
MODIFIED TRANSIENT PLANE SOURCE

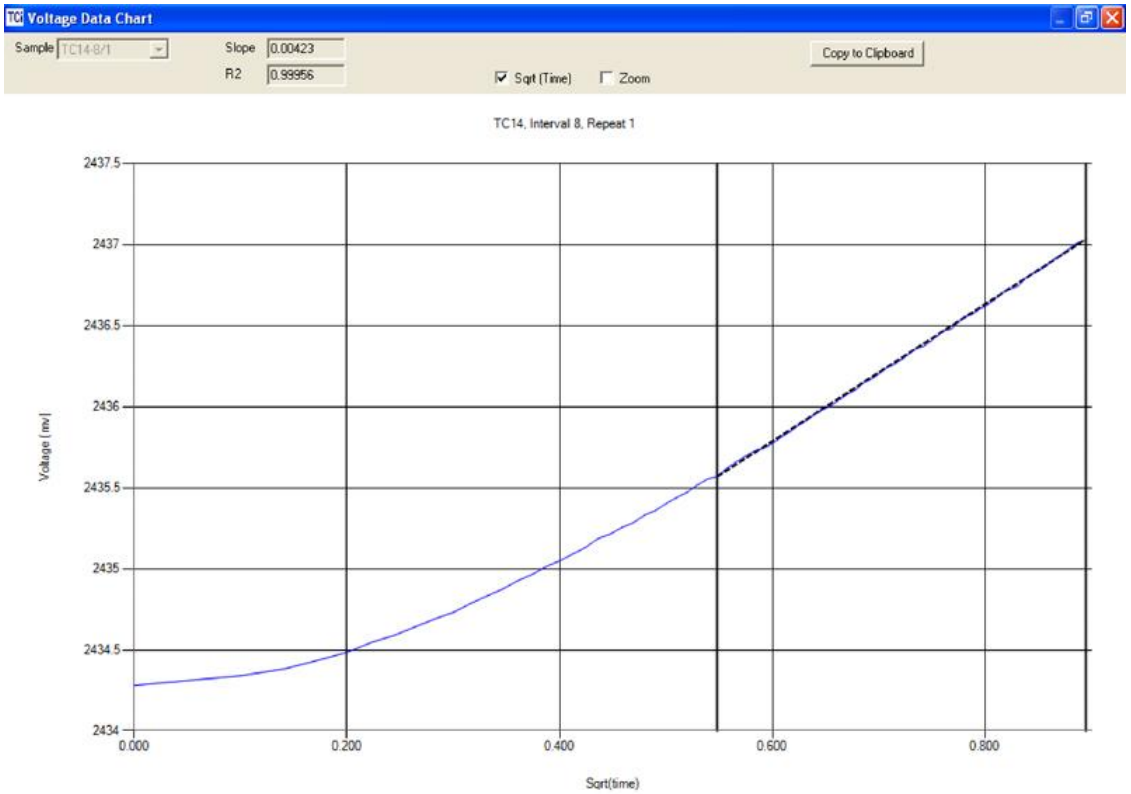
MTPS
GUARD RING
TECHNOLOGY



C-THERM
TECHNOLOGIES

How Does It Work?

Voltage (but think Temperature)



Time

First 0.3 Seconds:
Addressing Contact Resistance,
Non-Linear

0.3 – 0.8 Seconds:
Within Sample, Linear

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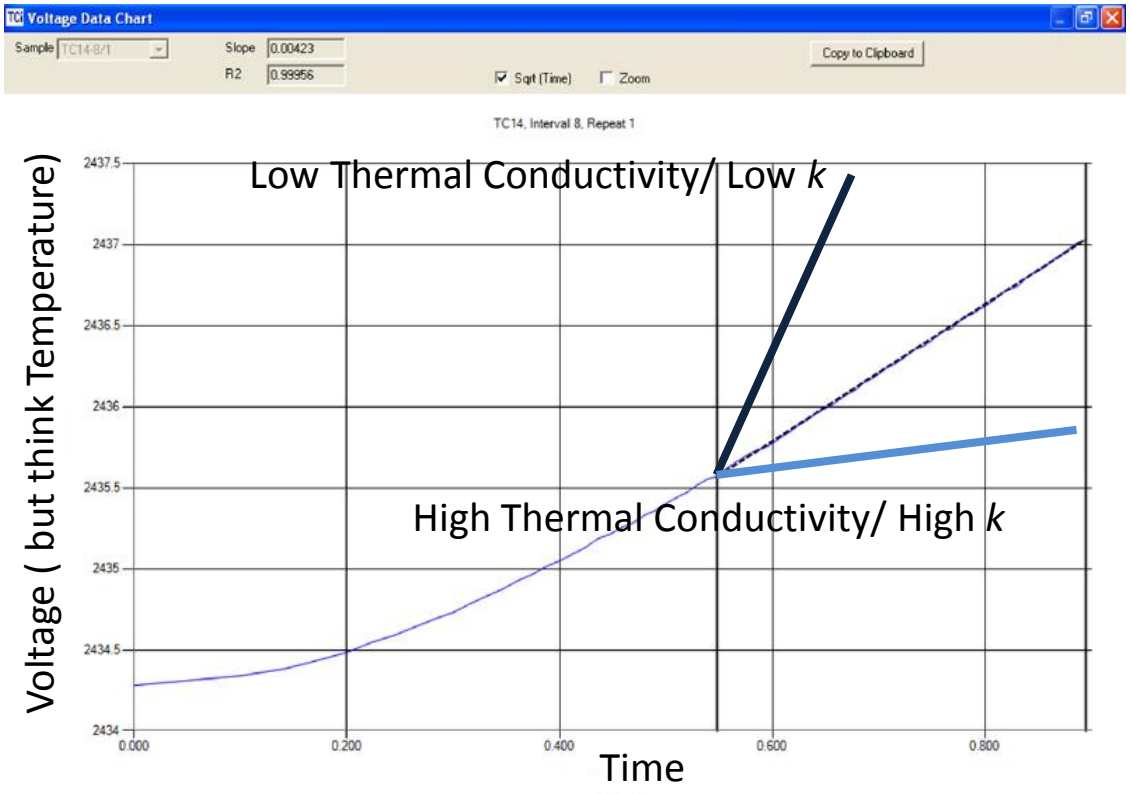
HOW THE SENSORS WORK

The thermal conductivity of the sample material is inversely proportional to the rate of increase in sensor voltage. The change in voltage drop correlates with an increase in temperature at the sensor interface.

The more thermally insulative the material is – the steeper the voltage rise.

Results are displayed on the system's laptop computer in real time.



First 0.5 Seconds:
Addressing Contact Resistance,
Non-Linear

0.5 – 1.0 Seconds:
Within Sample, Linear

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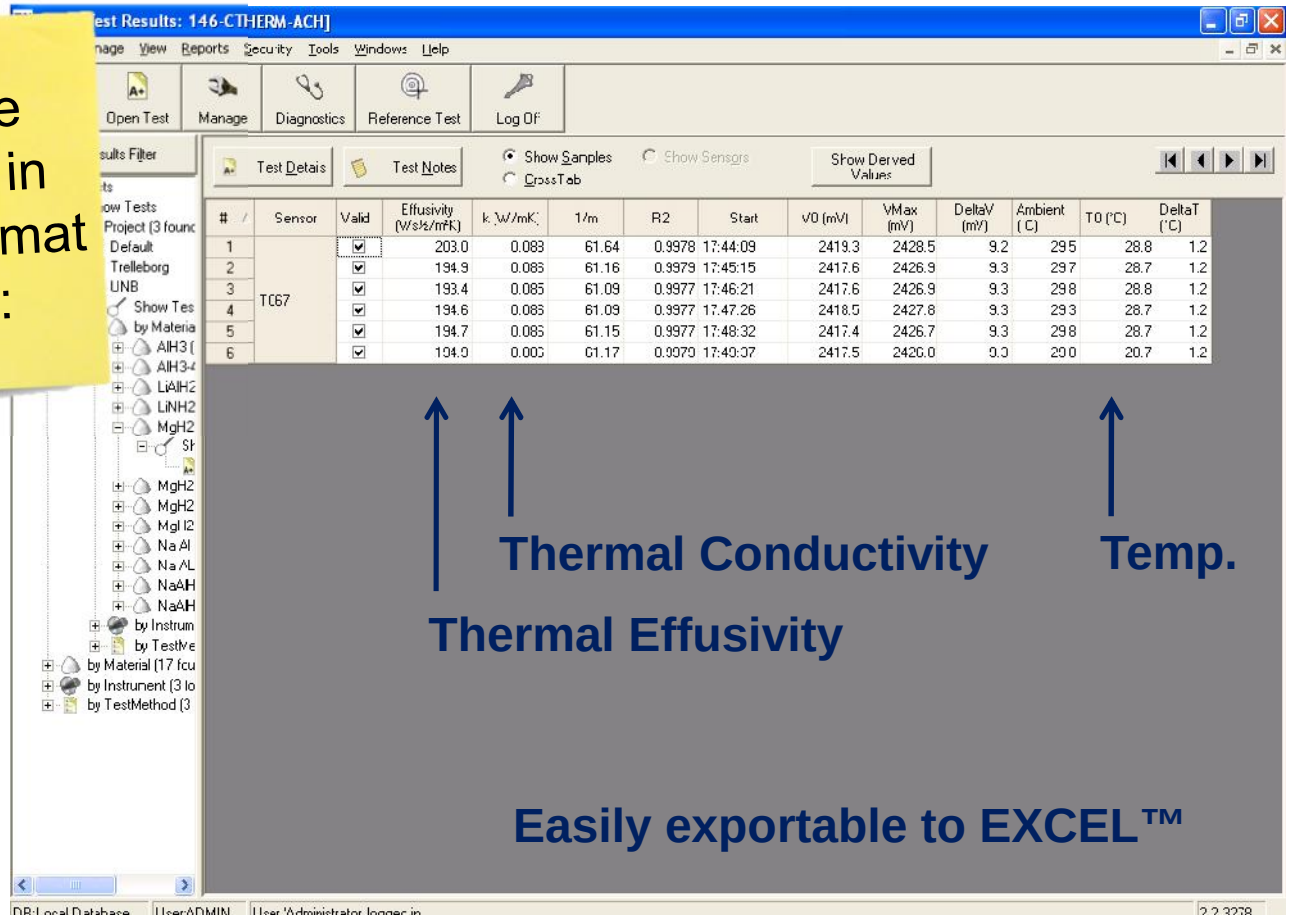
Easy Results

Results are presented in tabular format displaying:



C-THERM TECHNOLOGIES

HOW THE MTPS SENSOR WORKS

Heat always flows from a hot object to a cold object.

Wood is not a good conductor of heat, so it is **slow** to absorb the heat.

Metal has higher **"thermal conductivity"** so the heat from your hand flows into the metal **quickly** - creating the sensation of it being cold.

C-Therm sensors work like your hand, by **rapidly** determining the **rate** of heat flow from one material to another. Like your hands, our sensors **supply** the heat source *and* **detect** the heat flow. They also have no **sample size** issues, and do not destroy the sample being tested.

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PLAY VIDEO: UNDERSTANDING THERMAL CONDUCTIVITY METHODS

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APPLICATION REFERENCES

Application Area	Client(s)
Thermoelectric Materials	Alphabet Energy (US), Beijing National Laboratory for Molecular Sciences (China)
Plastics / Polymers	3M (France), Epic Resins (US), PolyOne (Germany)
Thermal Interface Materials	Advanced Applied Adhesives (US),Henkel Technologies (US), Honeywell (US), Huntsman (US), Raytheon (US),
Contract Labs	AQura (Germany), PMIC (US), LTP Oldenburg (Germany), Axel Physical Testing (US), Southwest Research Institute (US)
Nuclear	Centre for Atomic Energy (France), Idaho National Labs (US), Atomic Weapons Est (UK)
Paints / Coatings	Barrier Ltd. (UK), Huntsman (US), ICI (UK)
Textiles / Fabrics	Liberec University (Czech Rep.), CTT Group (Canada), Gore (UK), P&G (US)
Explosives	Army, Navy and Air Force (US), Canadian Explosives Research Lab (Canada)
Nano Materials	Centro de Investigación en Materiales Avanzados (Mexico), Chimie de la Matière Condensée de Paris (France), NanoComposix (US), NanoSteel (US)
Heat Transfer Fluids	Dupont (Japan), Army TARDEC (US), SouthWest Research Centre (US)
Thin Films	Kodak (UK), Philips (Netherlands)
Automotive	Electrifil Automotive (France), Hyundai (South Korea), Toyota (Japan)
Tires / Rubber	Hutchinson (France)
Oil & Gas	Total (France), GTT Gas Transport (France), Haliburton (US), King Fahd University of Petroleum & Minerals (Saudi Arabia), Jilin Petroleum (China), Rohm & Haas (US), Schlumberger (Canada)
Food	Philip Morris (Switzerland & US), P&G (US)
Batteries	Samsung (South Korea)
Asphalt / Concrete	Texas Department of Transportation (US), SoongSil University (South Korea)
Geological	Alberta Geological Survey (Canada), CNR IGG Istituto di Geoscienze e Georisorse (Italy)
Foams / Insulation	Trelleborg (USA)
Metal Hydrides	Hydrogen Research Centre (Canada), University of Pavia (Italy)

FAQ'S

Q: How does the sensor heat the sample to 200 deg C? How does it cool the sample to -50 deg C?

A: The sensor does NOT heat the sample more than a 1-2 deg C above ambient environmental conditions. If high-temperature or sub-ambient thermal conductivity measurement is desired – the use of a thermal chamber is required. C-Therm recommends the Tenney Jr. Thermal Chamber. Click here for link to Tenney website.

Q: What maintenance is required for the system?

A: The sensors are factory-calibrated and warrantied for one year. The software will automatically warn the user on expiration of the calibration. It is the manufacturer's recommendation that the sensors are re-calibrated once per year although this is not required. Only the sensors need be returned for calibration. The sensors are consumables and will also periodically need replacing depending on the user profile.

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FAQ'S (CONTINUED)

17mm diameter: active area of the sensor

Q: What are the sample requirements?

A: One of the major advantages the TCi™ provides users is the sample flexibility. The active area of the sensor is 17mm diameter and the basic requirements is that this area of the sensor form a good intimate contact with the sample material. A good "rule of thumb" to relay to clients is that if they can take nickel coin and balance it smoothly on the surface of the sample – then they will likely get an excellent measurement from the TCi™. (See also next question.)

Q: How thin of a sample can I test?

A: As the TCi™ employs a transient test methodology, it requires that the heat generated at the interface does not totally penetrate the tested material or object. It is suggested to be 2 mm (0.08") thick for a 1.0 second test for materials under 2 W/mK but the minimum thickness depends on the properties of the material and the length of the test. Insulative material can be thinner than conductive materials. A Blotter Test can be performed to ensure the sample is sufficiently thick and a user can stack thin samples such as film to produce a thicker cross section for testing.

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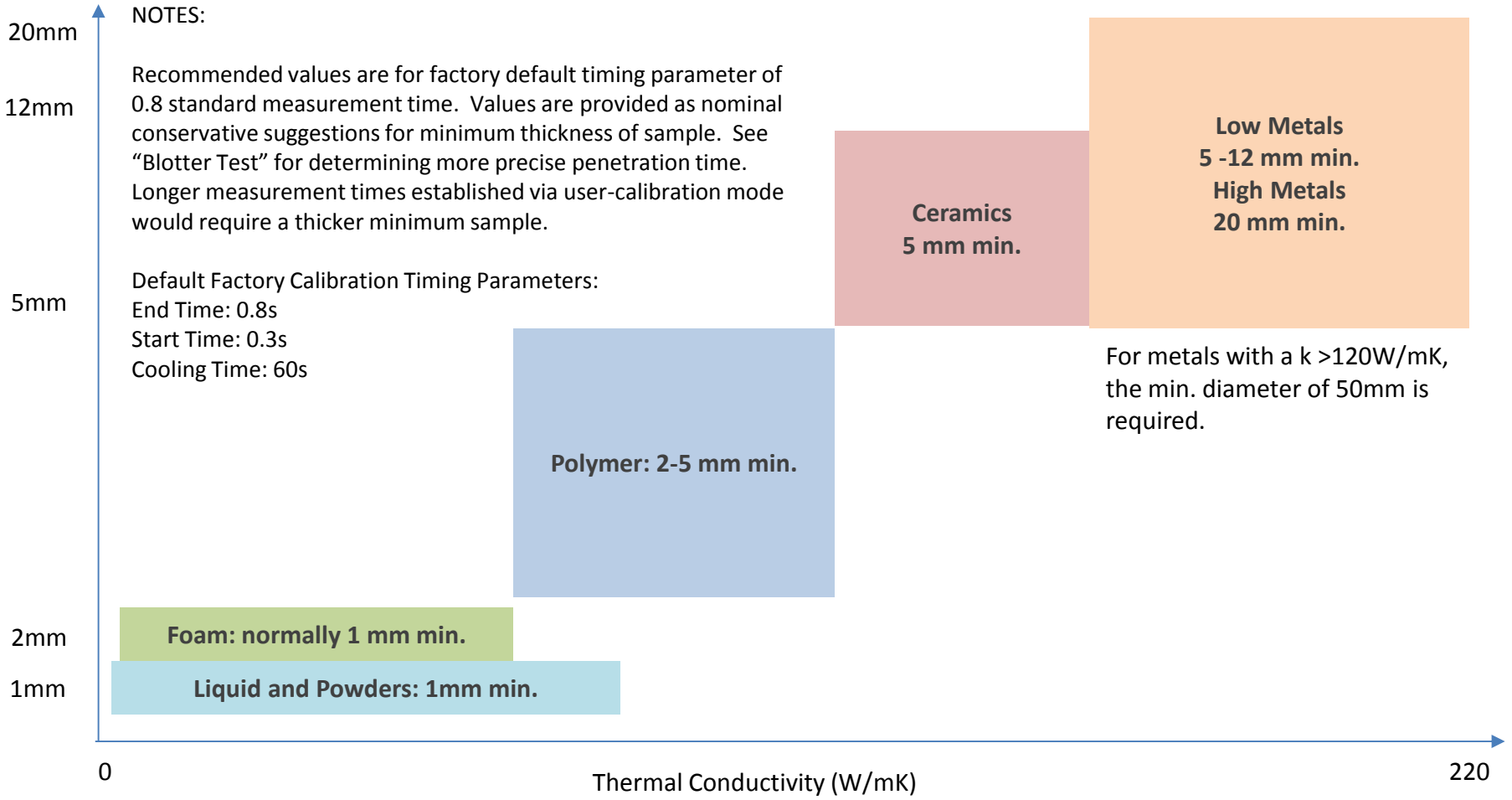
SUGGESTED MINIMUM SAMPLE THICKNESS



NOT TO SCALE

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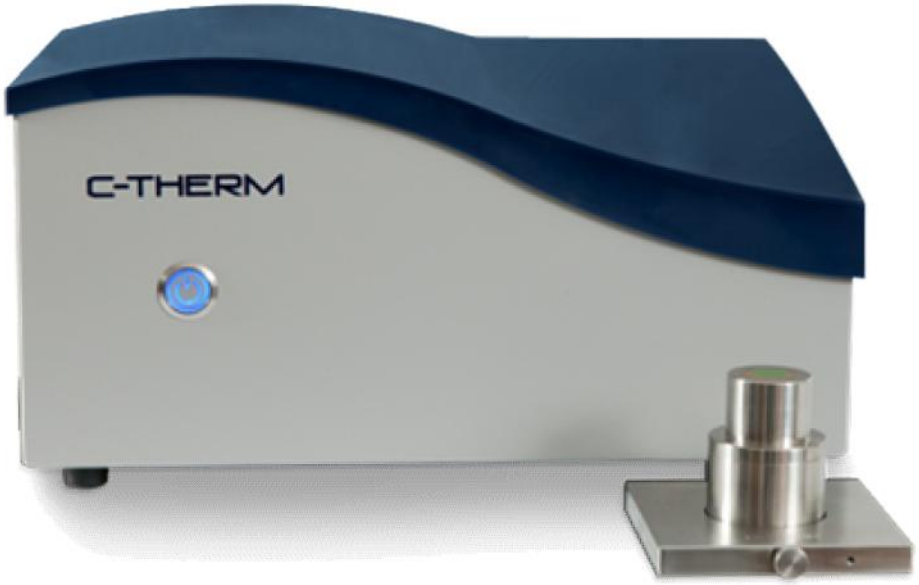
TCi™ Thermal Conductivity Analyzer

HARDWARE REVIEW

C-THERM TECHNOLOGIES℠

TCi™ THERMAL CONDUCTIVITY ANALYZER



TCi ™ System Protection
Pelican ™ Case

C-THERM TECHNOLOGIES

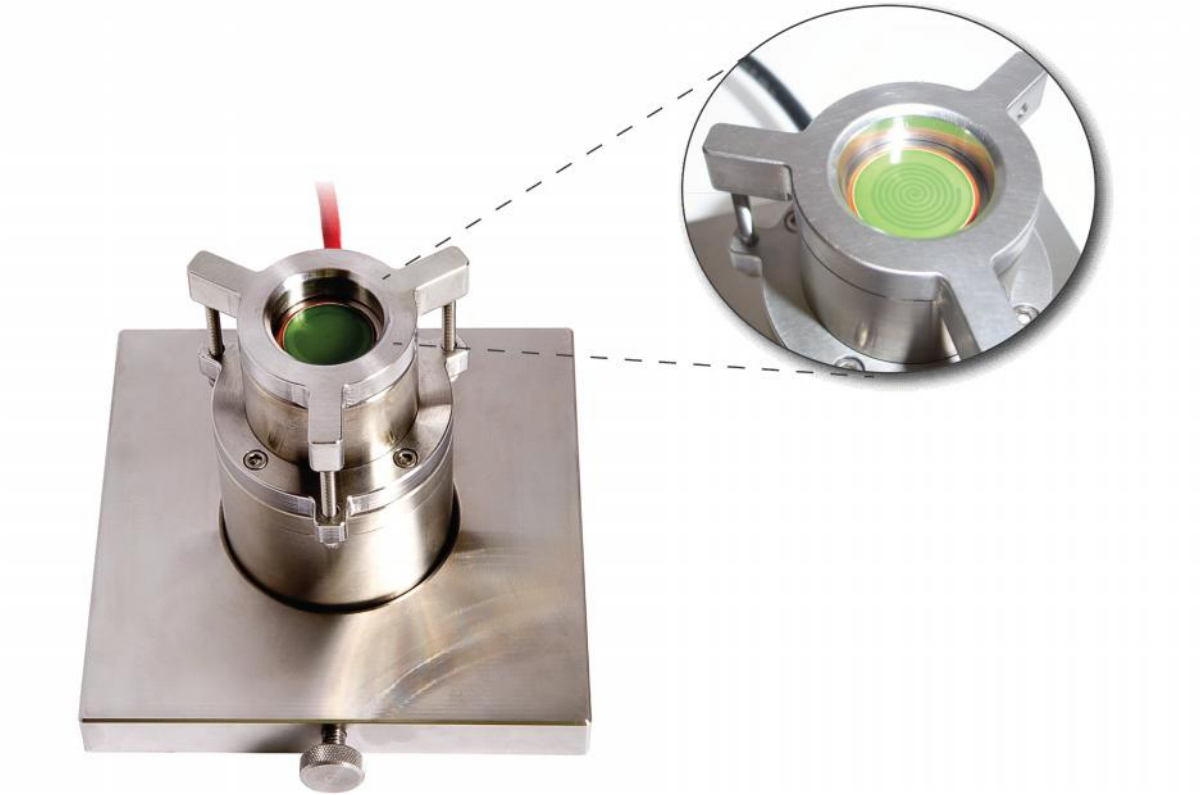
TCi™ SENSOR

TCi ™ Sensor Protection
Pelican ™ Case

TCi™ ACCESSORIES

Small Volume Test Kit (SVTK)

Designed for liquids and powders tests



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TCi™ ACCESSORIES

TCi ™ Extension Plate

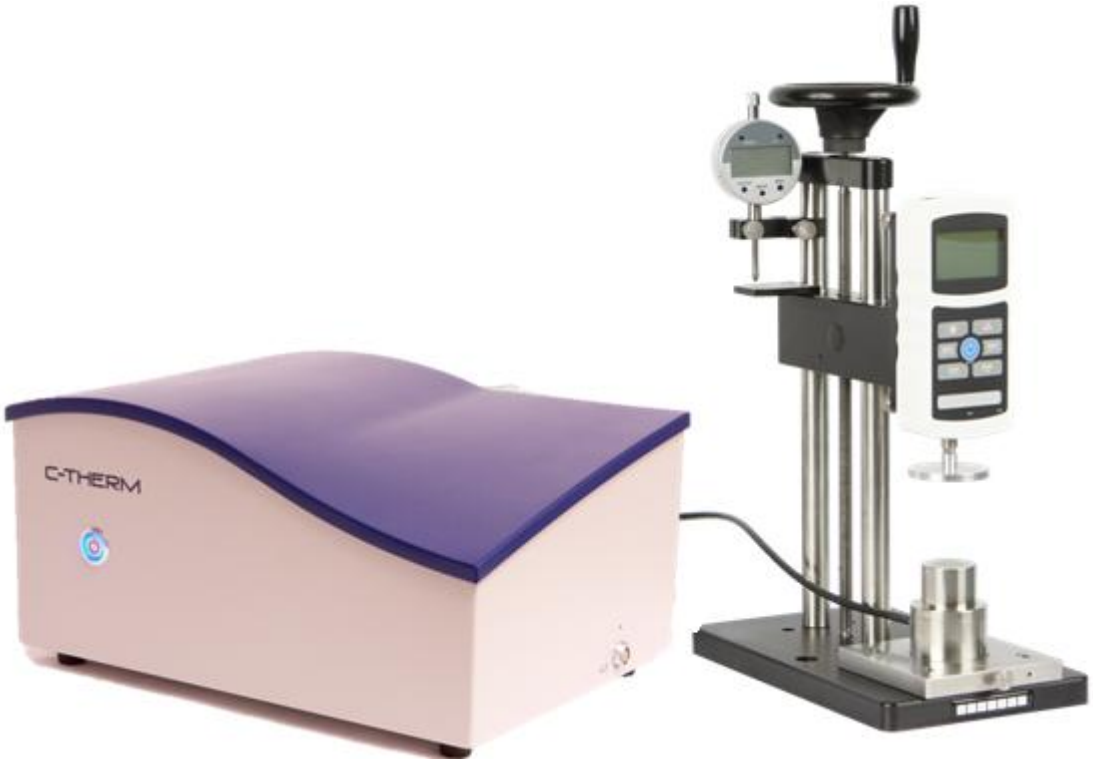
Designed for large solids tests

C-THERM TECHNOLOGIES

TCi™ ACCESSORIES (CONTINUED)

Compression Testing Accessory (CTA)

Designed for textiles/fabrics/powders tests



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TCi™ ACCESSORIES (CONTINUED)

High Pressure Cell (HPC)

Up to 2000 Psi (~137 bar)

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TCi™ ACCESSORIES (CONTINUED)

Tenney Junior Thermal Chamber

Thermal Chamber &
Glove Box TCi ™ Sensor Connectors
with extended sensor cables

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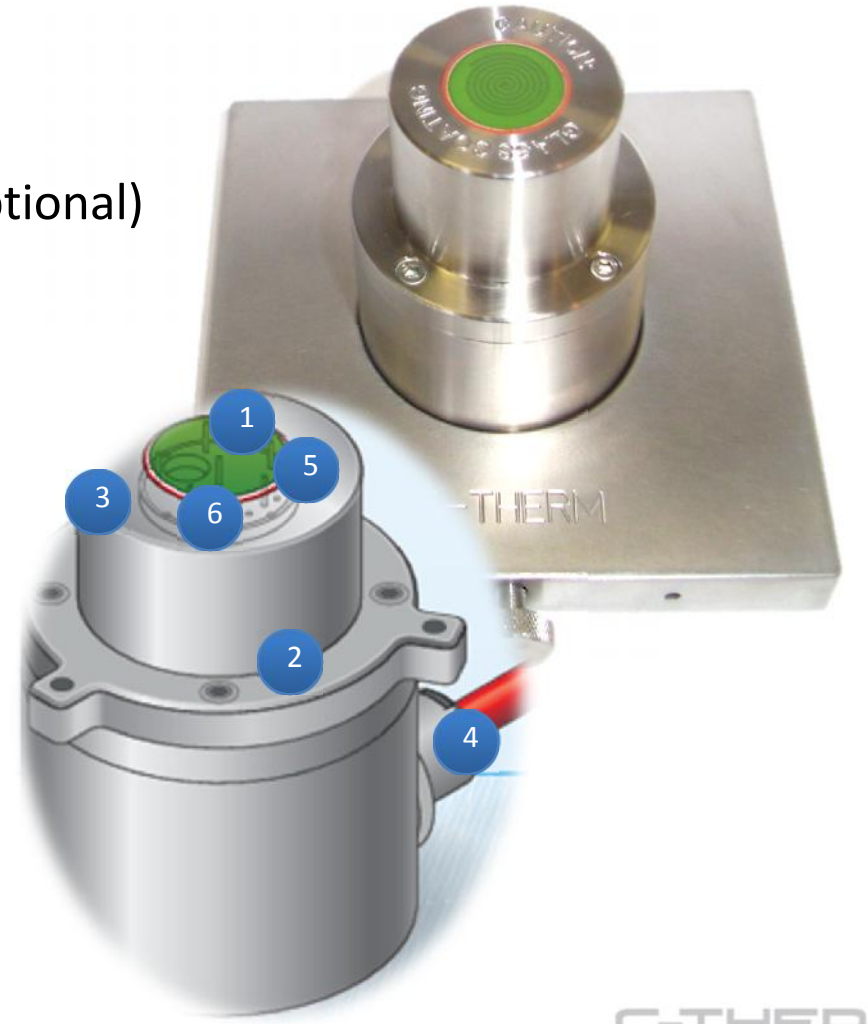
OVERVIEW OF HARDWARE (TCi™ SENSOR)

1. RTV Sealant (or FRV Sealant)
2. Small-Volume Test Kit Collar (Optional)
3. Stainless Steel Housing
4. Strain Relief Cable Connection
5. Gold Pins (electrical contacts & mechanical support for sensor chip)
6. Ceramic Substrate



C-THERM TECHNOLOGIES

IMPORTANT NOTICE REGARDING SENSOR -- ABOUT SEALANT

The RTV sealant provides a protective barrier around the glass surface of the sensor and is necessary to protect the internal components of the sensor housing. The sealant can however be damaged by certain chemically-aggressive substances and users must be careful in protecting the integrity of the sensor by exerting caution in the materials they place in direct contact with the sensor surface. The sensor has been thoroughly tested across a broad range of materials and an extensive list of the materials which are safe to test directly with the sensor are provided in the appendix of the TCi™ Operator's Manual. Should users wish to test a material which is not listed on the safe list - C-Therm advises them to administer a test on the RTV test tabs to ensure the sample material is chemically non-aggressive to the RTV sealant and will be safe to place in direct contact with the sensor.

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IMPORTANT NOTICE REGARDING SENSOR -- ABOUT WEIGHT ON SENSOR

The sensor should not be exposed to excessive weight as the sensor's glass surface may fracture. No more than 4 kg of weight should be permitted on the sensor.

Each TCi™ includes a 500 gram weight for ensuring good contact between solid samples and the sensor surface. If the sample to be measured weighs more than 150 grams, omit the weight. The sample is heavy enough to ensure good contact.

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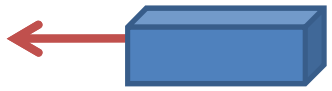
IMPORTANT NOTICE REGARDING SENSOR -- ABOUT SAMPLE REMOVAL

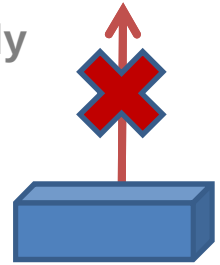
Sample Removal:

Users must avoid any blunt force or trauma being directly applied to the glass surface of the sensor. Care should be taken in placing and removing samples. Smooth samples may adhere strongly to the sensor surface when the contact agent is applied. To avoid pulling force on the sensor surface, it is recommended to remove the mass (sample and weight) from the sensor by a shear lateral motion rather than a vertical motion to the sensor surface.

Remove Samples Horizontally



Avoid Lifting Sample Straight Vertically



IMPORTANT NOTICE REGARDING SENSOR -- ABOUT BONDING SAMPLE REMOVAL

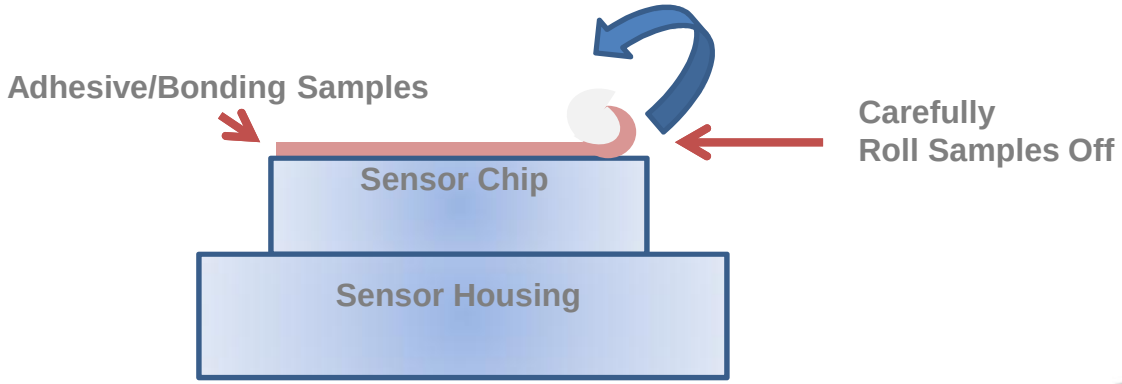
Adhesive Bonding Sample Removal: DO NOT DIRECTLY RIP SAMPLES OFF TCi™ SENSOR

Please refer to TCi™ Operator Manual 8.3 for more cleaning procedures.

Due to the unique design of C-Therm TCi™ High Resistance Sensor, the glass coating and the chip is embedded in the sensor and sealed by the RTV or FRV sealant.

Special caution needs to be taken when removing adhesive bonding sample from the sensor top. It is suggested to always gently and slowly roll the bonding materials off the sensor to prevent the sensor top glass part from ripping off by the tackiness samples.

It is also helpful to make sure the contact agent is properly applied in between the sample and sensor, because it may help reduce the tackiness.



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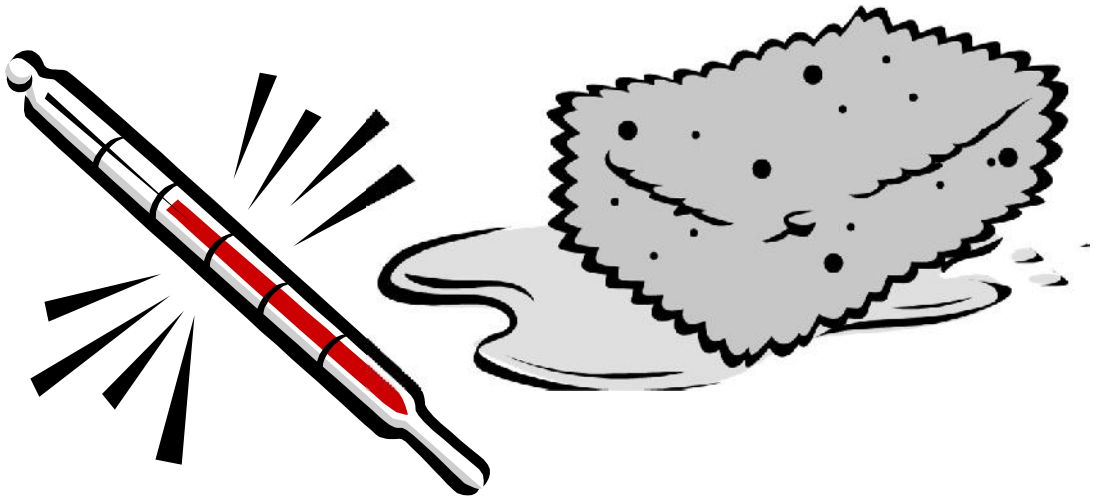
IMPORTANT NOTICE REGARDING SENSOR -- ABOUT PHASE CHANGE/TRANSATION

Special caution should also be exerted in testing a material through a phase change or transition. During a phase change or transition, materials can bond to the surface of the sensor and special care is required in the sample's removal and cleaning of the sensor. Materials should not be permitted to cool from a liquid to solid state while on the sensor OR should be reheated and removed while in their molten phase if the material was permitted to solidify on the surface of the sensor.



C-THERM TECHNOLOGIES

OVERVIEW OF HARDWARE (CONTROLLER)

1. USB A-B Cable (used for connecting TCi™ to Computer)
2. Power Plug
3. Serial Com Port for Optional Dilatometer
4. Sensor Port and Running Light

ALERT

ALERT! Turn power OFF before connecting or disconnecting sensors. Damage can occur to system.

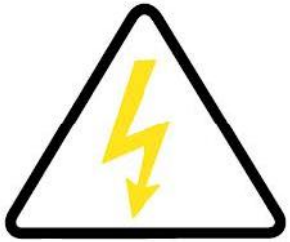
ALERT

ALERT! Environment for controller should be kept to under 27 deg Celsius during operation.

C-THERM TECHNOLOGIES

GENERAL SETUP CONSIDERATIONS

- Setup system on a stable table or test bench (Vibration may cause errors in the measurements)
- Avoid placing the system in the direct path of any major vents or drafts (keep away from air conditioners, windows, etc.)
- Strongly recommended to use a surge protector in connecting power to the system



C-THERM TECHNOLOGIES

TCi™ Thermal Conductivity Analyzer

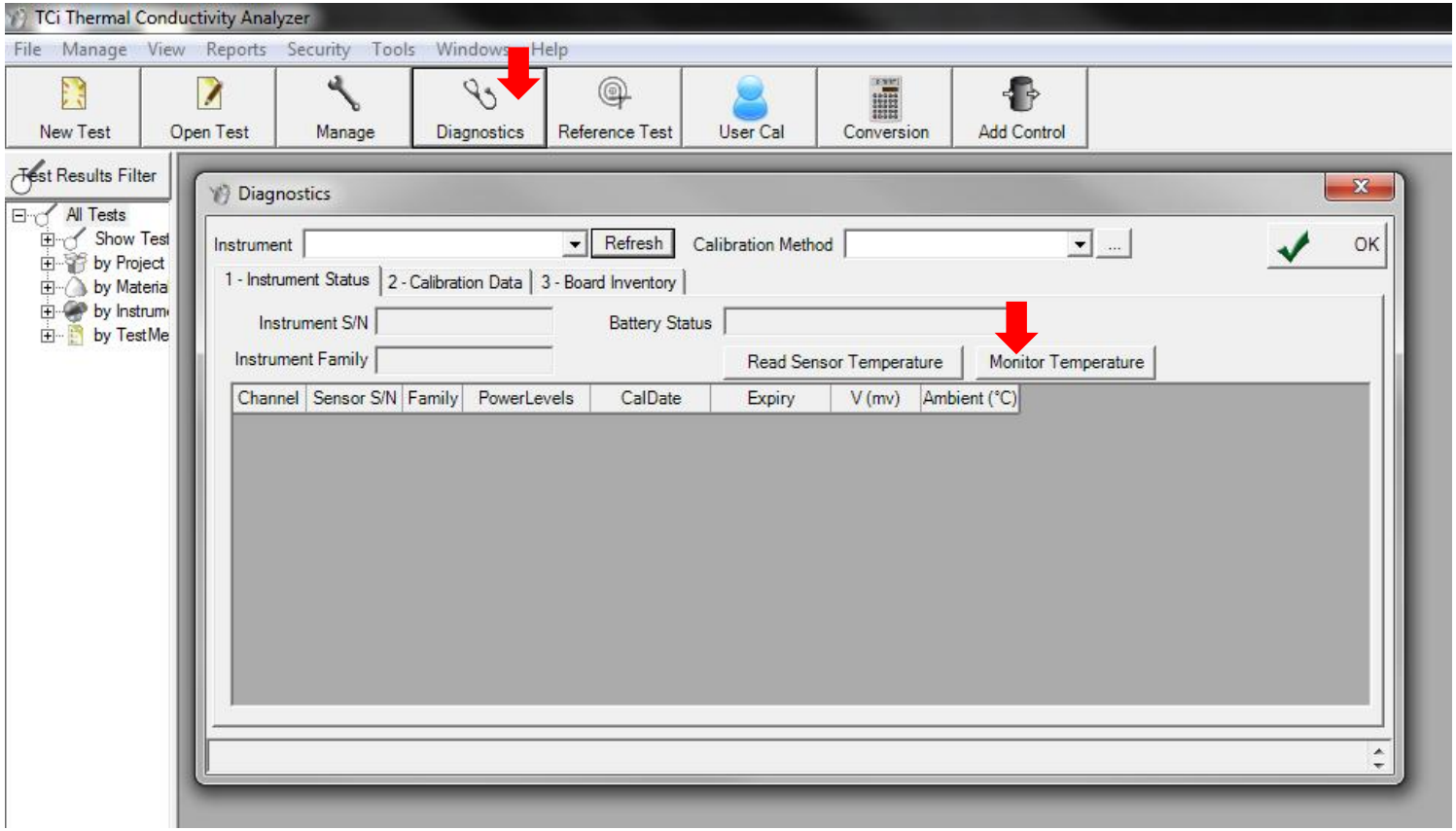
OPERATIONAL QUALIFICATION

C-THERM TECHNOLOGIES℠

COMMUNICATION CHECK

Run full diagnostics

- Communication check
- Explain use of temperature diagnostic tool for verifying integrity of sensor



C-THERM TECHNOLOGIES

REFERENCE MATERIAL CHECK

Run all reference materials for purchased calibration module(s)

NOTE: unit may not include all reference materials depending on calibration module purchased.

NPL and NIST Certified Reference Material are available, please contact us for quotation.

C-Therm Reference Material Standard Values

C-Therm Reference Material*	Thermal Conductivity (25˚C), W/mK
Distilled Water	0.609
LAF 6720 - A	0.061
LAF 6720 - B	0.059
LAF 6720 - C	0.058
LAF 6720 - D	0.055
Pyrex	1.143
Pyroceram	3.967
Phosphor Bronze - A	81.356
Phosphor Bronze - B	76.751
Phosphor Bronze - C	86.237
Phosphor Bronze - D	68.308
Phosphor Bronze - E	64.441
Aluminum - A	210
Aluminum - B	135

*Note: Due to variability between batches, there are multiple calibration material records for certain reference material. When performing a test, select the record matching the label on the reference sample.

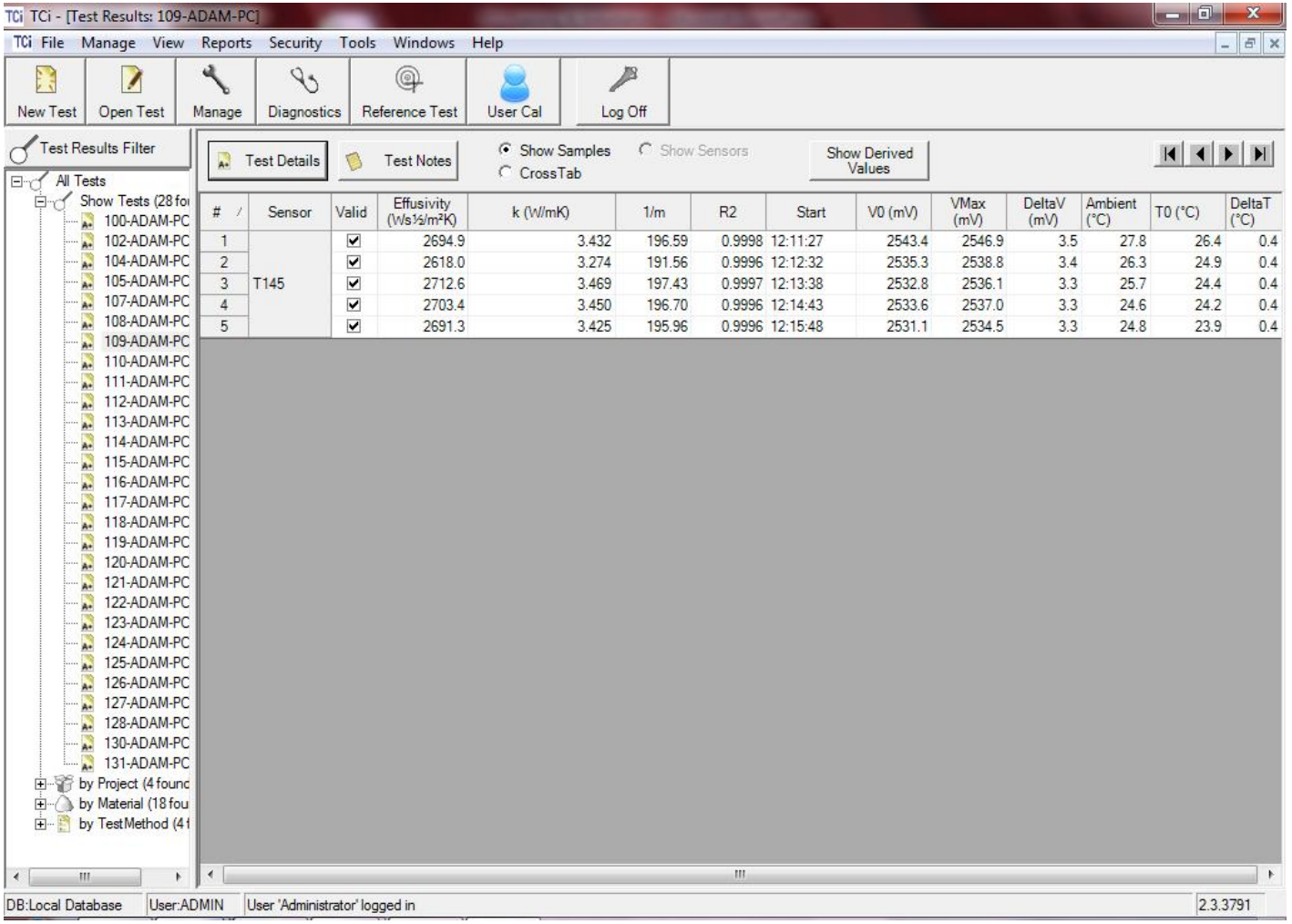
C-THERM TECHNOLOGIES

TCi™ Thermal Conductivity Analyzer

SOFTWARE TUTORIAL

C-THERM TECHNOLOGIES℠

SOFTWARE REVIEW

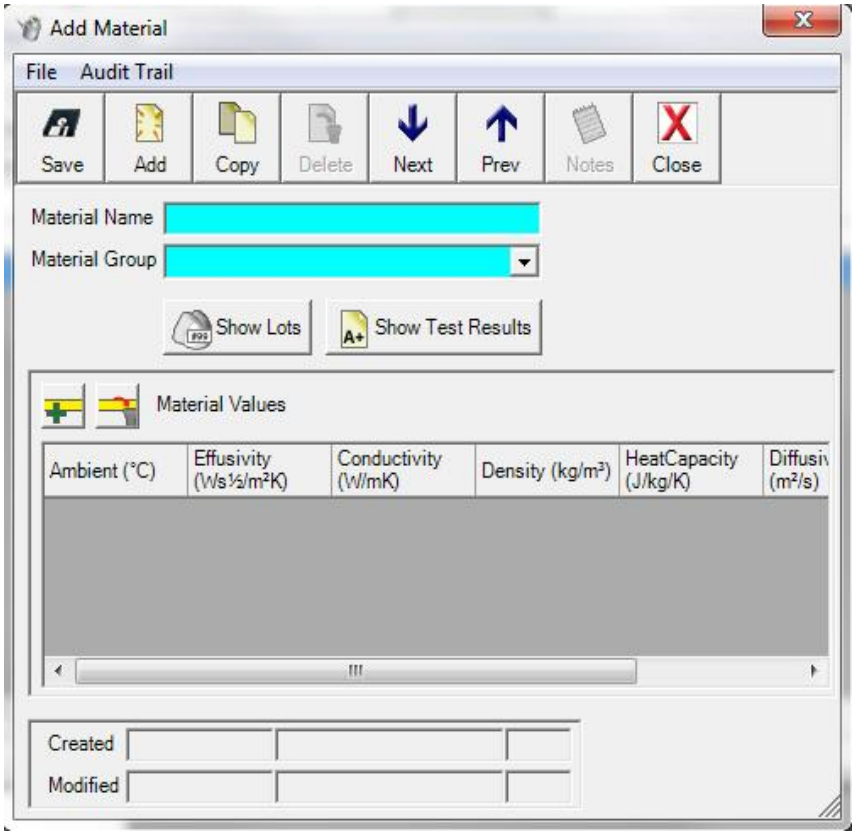


#	Sensor	Valid	Effusivity (Ws½/m²K)	k (W/mK)	1/m	R2	Start	V0 (mV)	VMax (mV)	DeltaV (mV)	Ambient (°C)	T0 (°C)	DeltaT (°C)
1	T145	☑	2694.9	3.432	196.59	0.9998	12:11:27	2543.4	2546.9	3.5	27.8	26.4	0.4
2		☑	2618.0	3.274	191.56	0.9996	12:12:32	2535.3	2538.8	3.4	26.3	24.9	0.4
3		☑	2712.6	3.469	197.43	0.9997	12:13:38	2532.8	2536.1	3.3	25.7	24.4	0.4
4		☑	2703.4	3.450	196.70	0.9996	12:14:43	2533.6	2537.0	3.3	24.6	24.2	0.4
5		☑	2691.3	3.425	195.96	0.9996	12:15:48	2531.1	2534.5	3.3	24.8	23.9	0.4

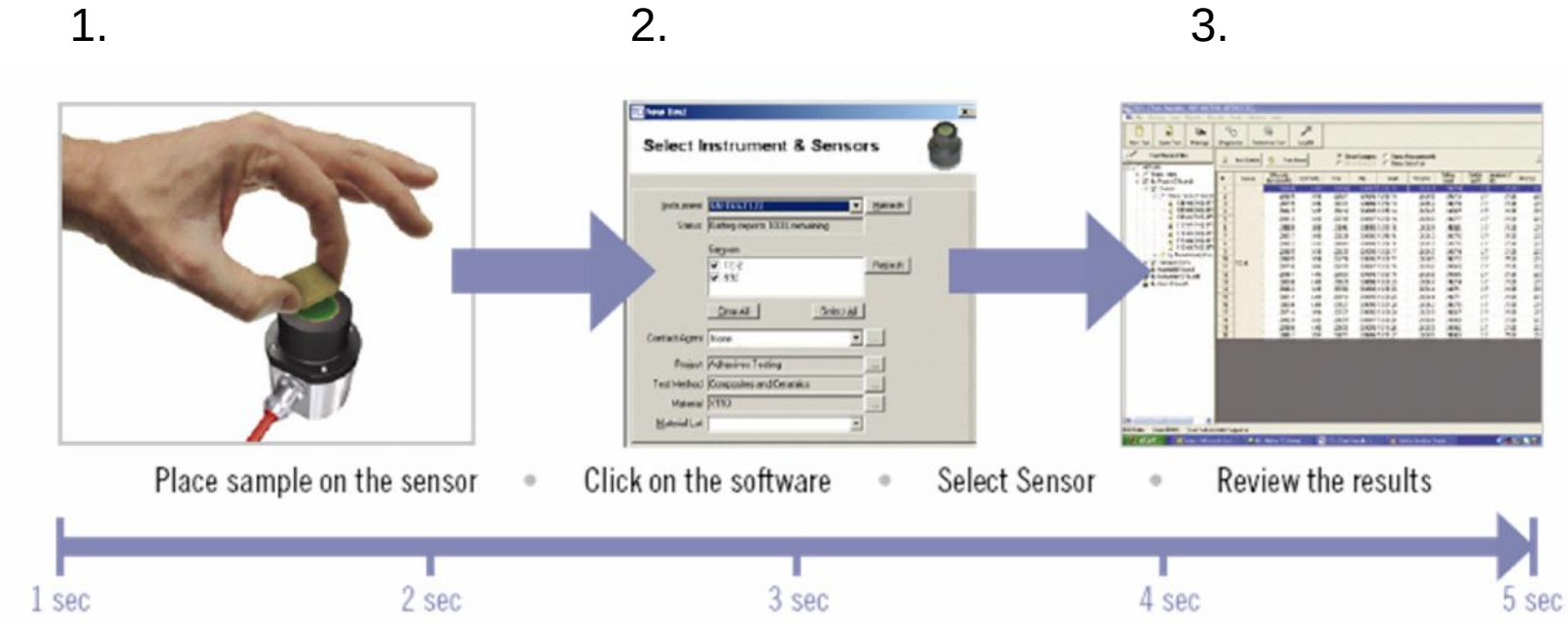
C-THERM TECHNOLOGIES

HOW TO GET DERIVED THEMAL PROPERTIES

Step 1 – Open the material table.
Step 2 – Click the Add button.
Step 3 – Enter the material name.
If multiple grades of the material are in use, indicate the grade in the material name. Do not specify the material lot as this is covered separately.
Step 4 – Select a material group.
If no group is selected, the material group is set to the default material group by the software.
Step 5 – Click the Add Material Values button (optional).
Step 6 – Enter material properties (optional).
Enter a temperature, then the effusivity, thermal conductivity, density, diffusivity, heat capacity, and the source of the values. Not all values must be entered.
When values are entered, indirect values (diffusivity, heat capacity, R-value, and depth of penetration) can be calculated. Heat capacity and diffusivity can be entered, or calculated if the density is entered.
For diffusivity, density and heat capacity must be entered.
For heat capacity, density must be entered.
For density, heat capacity must be entered.
The R-value and depth of penetration can be calculated without additional values.
Step 7 – Click the Save button.



CLIENT SAMPLE TESTING



Encourage client to conduct sample measurements on their materials:

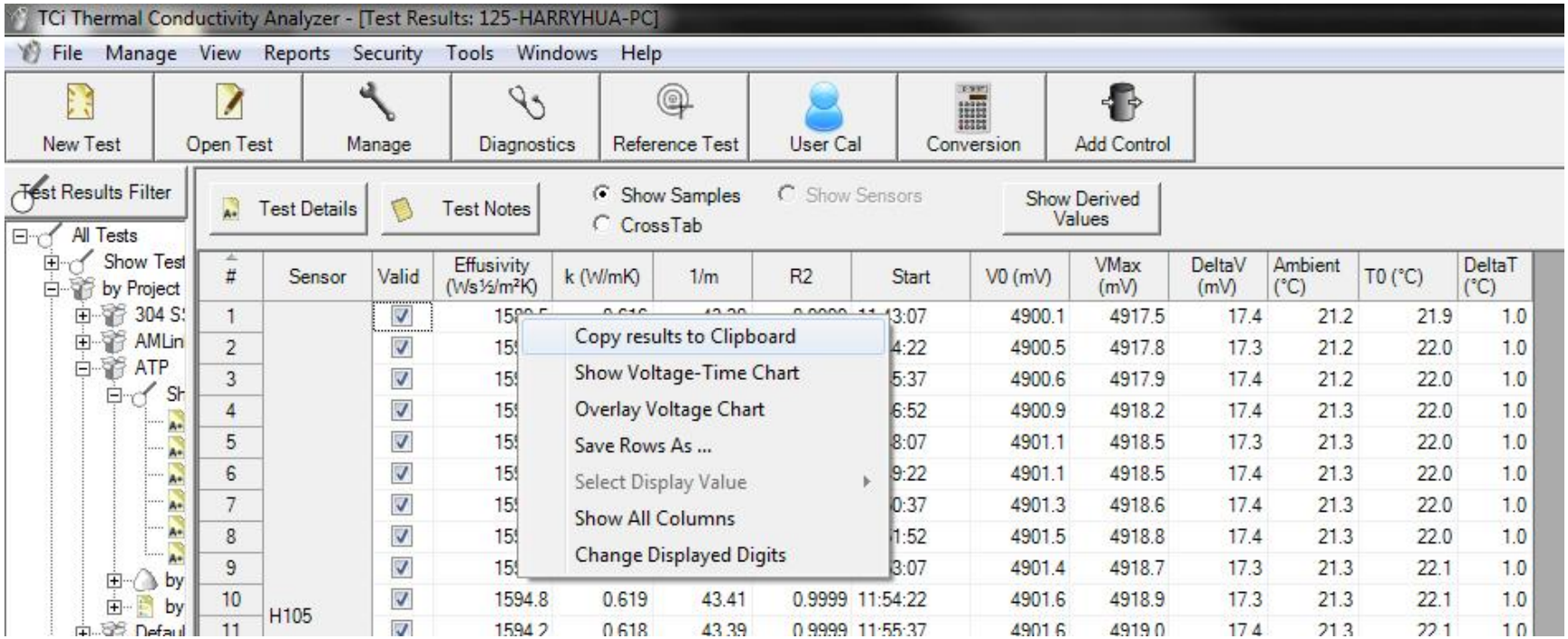
Step 1. Place sample on sensor.
Step 2. Follow Easy Testing Wizard
Step 3. Wait a few seconds for your first result.

Note: Do NOT forget to apply proper contact agent when necessary.

C-THERM TECHNOLOGIES

HOW TO EXPORT TEST RESULT TO MS EXCEL

Step 1 – when test is over, right click anywhere on the result table
Step 2 – Choose **Copy results to Clipboard**
Step 3 – Open MS EXCEL
Step 4 – Simply use **Ctrl+V** to paste the result in its original format

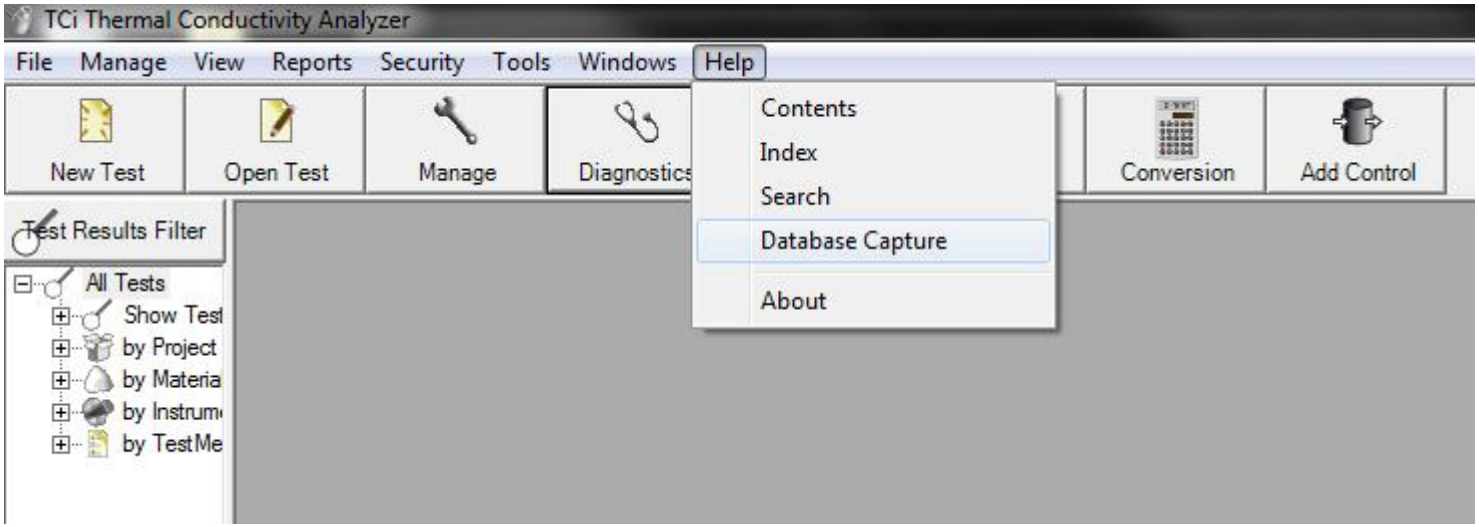


Optional – Export test report by TCi™ software
Go to **Reports** label and choose **Test Results**, locate the Test Results by Test ID and Click on **Report** button, a report will be generated.

C-THERM TECHNOLOGIES

HOW TO EXPORT DATABASE IN TCi™ SOFTWARE

Step 1 – Go to **Help**
Step 2 – Choose **Database Capture**
Step 3 – Save Database zip file to local drive
Step 4 – Email the zip database for tech. support



C-THERM TECHNOLOGIES

SCHEDULE FOLLOW-UP CALL

Suggestion to schedule a follow-up call for 1-week from date of installation to review any questions users may have encountered in their first week of using the equipment.

C-THERM TECHNOLOGIES

THANK YOU!

Any question, please feel free to contact us.

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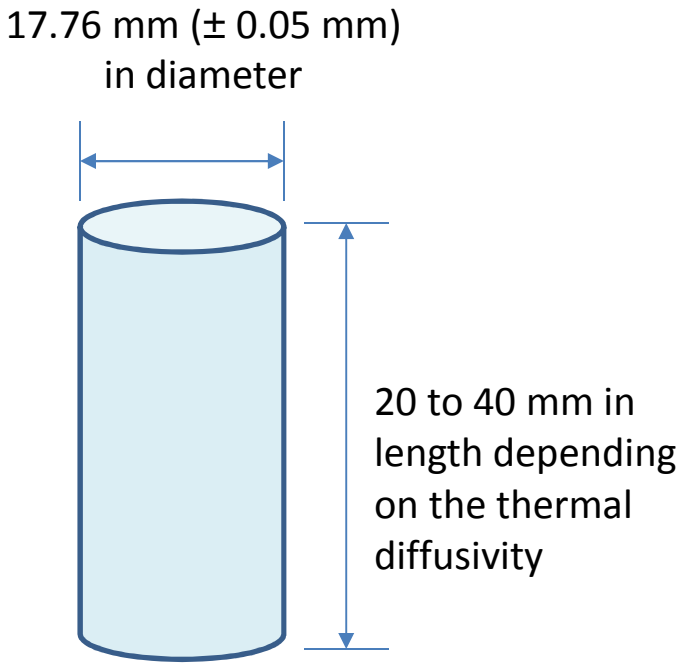
C-THERM TECHNOLOGIES

NOTICE: For High Thermal Conductivity Samples

Those high thermal conductivity samples (> 87W/mK) should be machined to the dimensions given below:



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