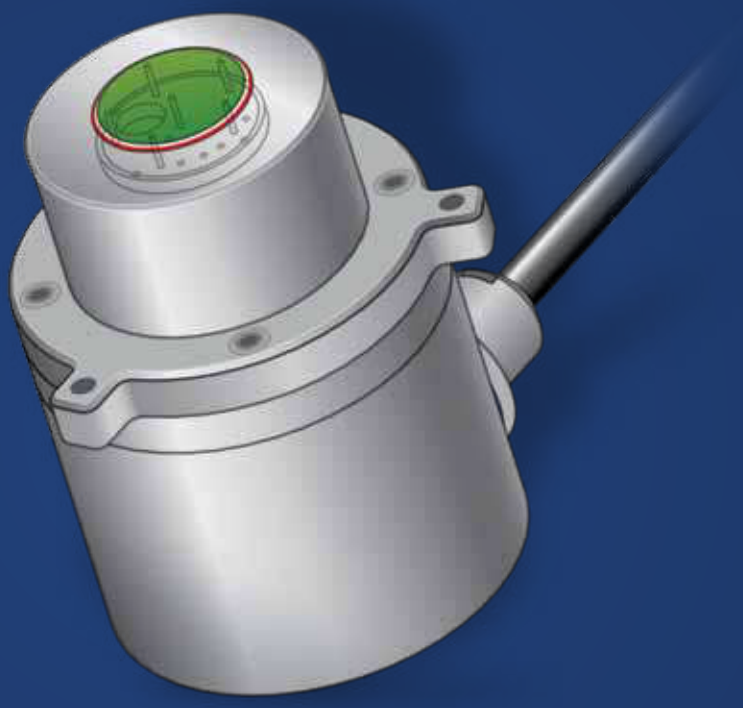
## SIMPLIFYING

# Thermal Conductivity (*k*)



### FAST, ACCURATE TESTING
0 to 500 W/mK in seconds

### WIDE TEMPERATURE RANGE
-50˚ to 200˚C

### NO SAMPLE PREPARATION
Unlimited sample size

### NON-DESTRUCTIVE
Leaves sample intact

### EASY-TO-USE
No user-calibration required

### HIGHLY VERSATILE
Tests solids, liquids, powders and pastes

### MODULAR
Configurable to meet a range of needs and budget
Option to pair with new dilatometer

C-THERM TCi™
Thermal Conductivity Analyzer

**ALSO PROVIDES: EFFUSIVITY | DIFFUSIVITY | HEAT CAPACITY | DENSITY**

SIMPLIFYING

# THERMAL CONDUCTIVITY

The latest generation of C-Therm's patented technology expands the capabilities of this rapid, non-destructive thermal conductivity and effusivity testing instrument to a whole new level. Designed to provide simple, highly accurate thermal characterization for lab, quality control and production environments, the C-Therm TCi Thermal Conductivity Analyzer requires no user-calibration or sample preparation. The system has broad testing capabilities (0 to 500W/mK) across a wide range of temperatures (-50ºC to 200ºC).

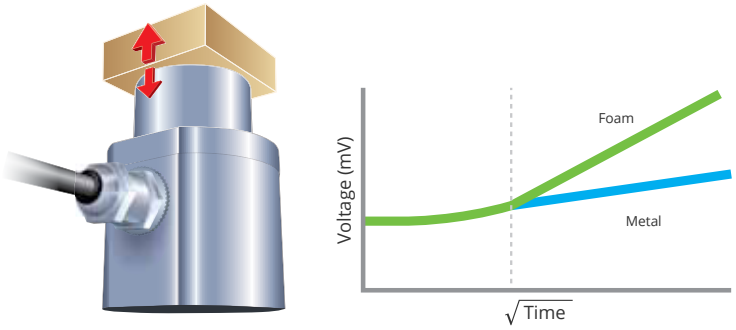

The TCi can be equipped with one or two sensors for increased capacity, and provides accurate thermal analysis of solids, liquids, powders and pastes in less time than any other instrument - less than 5 seconds! And because the procedure is non-destructive, samples remain intact, undisturbed and reusable after testing. The sensors offer users exceptional versatility in being able to operate in various environments, including thermal chambers, high pressure vessels and glove boxes.

## Principles of Operation

The C-Therm TCi is based on the Modified Transient Plane Source (MTPS) technique. It employs a one-sided, interfacial heat reflectance sensor that applies a momentary constant heat source to the sample. Thermal conductivity and effusivity are measured directly, providing a detailed overview of the thermal characteristics of the sample.

## How It Works

A known current is applied to the sensor's spiral heating element, providing a small amount of heat. This results in a rise in temperature at the interface between sensor and sample, which 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. The thermo-physical properties are inversely proportional to the rate of increase in the sensor voltage. The voltage rise will be steeper for more thermally insulative materials (foam). Results are displayed on the system's software in real-time.




The TCi is factory-calibrated for directly measuring both thermal conductivity (k) & thermal effusivity:

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

*Where:*
*k = thermal conductivity (W/m • K)*
$\rho$ = *density (kg/m$^3$)*
$c_p$ = *heat capacity (J/kg • K)*

VERSATILE

# EASILY TEST SOLIDS, LIQUIDS, POWDERS AND PASTES

## APPLICATIONS

- Thermal Interface Materials
- Heat Transfer Fluids
- Explosives
- Batteries
- Textiles
- Geological
- Thermoelectric
- Thin Films
- Rubber and Polymers
- Nanomaterials
- Concrete and Asphalt
- Insulation

### Solids: Taking Ceramics to New Heights

C-Therm has provided a breakthrough in the characterization of critical performance attributes of ceramics used for aerospace applications. The main advantage for solids applications is the simplicity of the sample format. The C-Therm TCi eliminates technician time required for sample preparation. The sample size flexibility allows the evaluation of actual product formats - avoiding the need to mock-up samples.

### Powders: From Explosives to Ink Toners

The C-Therm TCi is being used to safely test the stability, degradation, and shelf life of explosives because it is the only instrument engineered for evaluating the thermal conductivity of powders safely. Sample volumes are as small as 1.85ml. This is also critical to a rapidly growing client base in metal hydrides, where materials are expensive and available in low quantities. The technology is also migratable to manufacturing environments as a cost-effective way to monitor powder processes for moisture and homogeneity.

### Pastes: Keeping the Hottest Electronics Cool

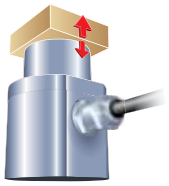
The faster and smaller microprocessors become, the more heat they generate. C-Therm technology is providing vital insights into the development of all materials that contribute to the overall thermal budget, including thermal interface pastes and compounds. By altering the calibration timing parameters the C-Therm TCi allows testing with different amounts of heat penetration. This feature results in a variable scale of scrutiny to probe the material to ensure the homogeneous distribution of vital filler components.

### Liquids: Fluids That Take the Heat Off

The C-Therm TCi is helping manufacturers improve the heat transfer properties of advanced nano-filled liquids. For engineered liquids, the wide range of operating temperatures make the TCi an attractive solution. The low amount of heat introduced during testing and small sample volume requirements negate the convective errors typical in liquid testing with traditional techniques.

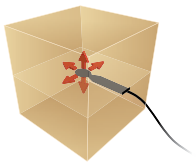
## COMPARISON OF METHODS

# FASTER, EASIER, MORE VERSATILE

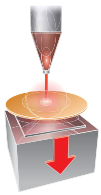


C-Therm TCi
(Modified Transient Plane Source)

Traditional Guarded Hot Plate



Transient Plane Source



LaserFlash Diffusivity

| | | | | |
|---|---|---|---|---|
| **SPEED & FLEXIBILITY** | | | | |
| Sample Preparation | None Required | Extensive | Some | Extensive |
| Testing Time | Seconds | Hours | Minutes | Hours* |
| Training Time | Minimal | Moderate | Significant** | Extensive |
| Non-Destructive | Yes | No | No | No |
| Method Development |  |  |  |  |
| **RANGE** | | | | |
| k-Range (W/mK) | 0 – 500 | 0 – 2 | 0 – 100<br>(100 – 500 requires $C_p$) | 0 – 500<br>(requires density & $C_p$) |
| Temperature Range (°F)<br>(°C) | -58° to 392°F<br>-50° to 200°C | -148° to 2552°F<br>-100° to 1400°C | -148° to 1292°F<br>-100° to 700°C | -238° to 5072°F<br>-150° to 2800°C |
| **SAMPLE CONFIGURATION** | | | | |
| Minimum | 0.67" diameter<br>(17mm) | 6" x 6"<br>(150 x 150mm) | Two Identical Samples<br>1" x 1" (25 x 25mm) | 0.5" diameter (12.4mm)<br>0.004" thick (1mm) |
| Maximum | Unlimited | 24" x 24"<br>(600 x 600mm) | Two Identical Samples<br>Unlimited | 0.5" diameter (12.4mm)<br>0.004" thick (1mm) |
| Material Testing Capabilities | Solids, Liquids,<br>Powders, Pastes | Solids | Solids, Liquids | Solids |
| **PRICING** | **$** | $ $ | $ $ | $ $ $ |

1 Based on publicly available information and feedback from users.
* Calculation of thermal conductivity from Laser Flash Diffusivity Measurement requires the additional following material properties: heat capacity ($C_p$) density, and coefficient of thermal expansion.
** Traditional Transient Plane Source requires iterative testing to obtain the correct experimental parameters in terms of power flux, test time, and sizing of sensor necessary to obtain accurate results.

MODULAR

# SCALABLE SOLUTIONS

## ACCESSORIES

### Compression Test Accessory (CTA)

Compression of sample material increases the density and impacts the effective thermal conductivity of the material. C-Therm's Compression Test Accessory (CTA) enables researchers testing such materials to precisely control the densification in providing highly reproducible results that better reflect the effective thermal conductivity of the sample material. The CTA is particularly recommended to users testing textiles/fabrics, insulation batting, thermal interface materials, and powders.

### High Pressure Cell (HPC)

The High Pressure Cell safely provides researchers the capability to characterize the thermal conductivity of samples under controlled pressure environments up to 2,000 PSI (~138 bar). The HPC is popular with researchers in the energy field, particularly in the characterization of gas hydrates.

### Tenney Jr. Thermal Chamber

The TPS Tenney Jr. Thermal Chamber is recommended to users who wish to measure the thermal conductivity at non-ambient temperatures, from -50ºC to 200ºC. C-Therm's TCi 3.0 release software now enables direct control of the thermal chamber, bypassing manual operation and allowing users to pre-program their desired temperature cycles and walk away!

### Small-Volume Test Kit (SVTK)

The Small-Volume Test Kit was originally developed with the US Navy specifically for testing energetic materials. The effectiveness of the accessory in reducing the volume requirements for testing samples make it ideal for characterizing the thermal conductivity of liquid samples. The SVTK is commonly applied in testing nano and heat transfer fluids, as well as emulsions.

## DILATOMETRY MODULE

Dilatometry provides key expansion and shrinkage properties of materials under defined temperatures.

| | |
|---|---|
| TEMPERATURE RANGE | Room Temperature to 1600°C |
| TEMP. RESOLUTION | 0.1°C |
| MAX DISPLACEMENT | 4mm |
| ΔI RESOLUTION | 1.25nm/digit |
| ATMOSPHERE | Air, Vacuum, Inert Gas |
| SAMPLE DIMENSIONS | 10 to 50mm long x max ϕ12mm |
| SAMPLE HOLDER | Fused Silica, Alumina |
| CONFIGURATIONS | Single or Dual LVDT System<br>1200°C or 1600°C furnace |
| HEATING ELEMENT | FeCrNi, SiCr |
| RATE OF INCREASE (ºC) | 1ºC/min to 50ºC/min |


C-Therm's latest generation TCi offers an innovative new option to pair the controller with an optional dilatometer. This offers researchers significant savings in leveraging commonalities of the TCi control electronics, while expanding the platform's capabilities to dilatometry.

THERMAL EXPANSION • PHASE TRANSITION
SHRINKAGE • SINTERING

# PROVEN

For over a decade, C-Therm's innovative sensor technology has been pioneering the way many of the world's most prominent manufacturers, research facilities, and academic institutions test and measure thermal properties of materials.

R&D 100 WINNER

The technology behind the C-Therm TCi represents a paradigm shift in thermal conductivity measurement and earned the inventor behind the technology the Manning Innovation Principle Award and an R&D 100 Award. These coveted awards are given to the top global innovators, and place C-Therm in the distinguished company of other winners, including developers of the ATM, Polaroid film, and anti-lock brakes.

Since its launch, C-Therm's unique technology has evolved to new levels of accuracy, speed, and flexibility. Today, it is being used around the globe for R&D, quality control, and on-line production monitoring in a wide range of industries.

| C-THERM TCI SPECIFICATIONS | |
|---|---|
| Thermal Conductivity Range | 0 to 500 W/mK |
| Test Time | 0.8 to 2.5 seconds |
| Minimum Sample Testing Size | 17mm (0.67") diameter |
| Maximum Sample Testing Size | Unlimited |
| Minimum Thickness | Nominally 0.02" (0.5mm), dependent on thermal conductivity of material |
| Maximum Thickness | Unlimited |
| Temperature Range | -50° to 200°C (-58° to 392°F) |
| Precision | Typically better than 1% |
| Accuracy | Better than 5% |
| Extra Hook-Ups Required | None |
| Software | Intuitive Windows®-based software interface. Easy export to Microsoft Excel®. Additional functionality offers indirect, user-input capabilities for a number of other thermo-physical properties including:<br>• Thermal Diffusivity<br>• Heat Capacity<br>• Density |
| Input Power | 110-230 VAC 50-60 Hz |
| Certifications | FCC, CE, CSA |


For more information, contact:

C-THERM TECHNOLOGIES Ltd.

North America: 1-877-827-7623
Worldwide: 1-506-462-7201
info@ctherm.com | www.ctherm.com


## COMPANIES AND ORGANIZATIONS USING C-THERM'S PATENTED TECHNOLOGY:

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