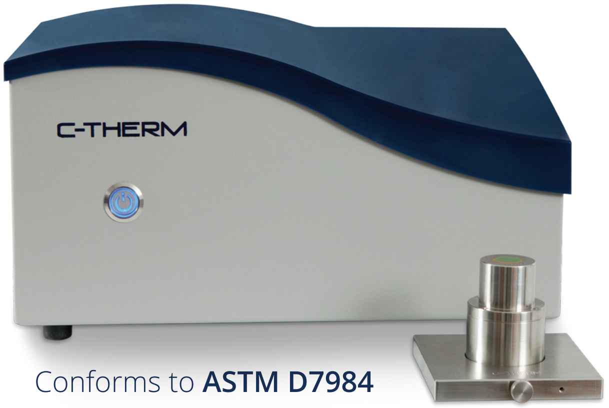
C-THERM TCi™
Thermal Conductivity Analyzer

Thermal Property Characterization of

Fabric, Textile and Apparel



Conforms to **ASTM D7984**

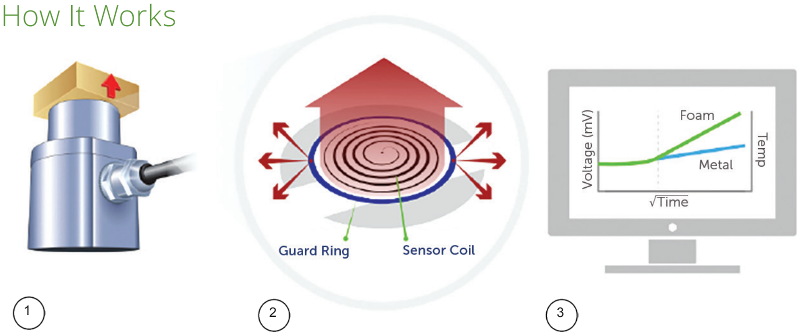
Thermal Conductivity | Thermal Effusivity

Principles of Operation

The C-Therm TCi employs the patented Modified Transient Plane Source (MTPS) technique. The one-sided, interfacial heat reflectance sensor 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.

MTPS GUARD RING TECHNOLOGY

How It Works



1. A known current is applied to the sensor's spiral heating element, providing a small amount of heat.
2. The sensor's guard ring is fired simultaneously supporting a one-dimensional heat exchange between the primary sensor coil and the sample. The current applied to the coil results in a rise in temperature at the interface between the sensor and sample, which induces a change in the voltage drop of the sensor element.
3. The increase in temperature is monitored with the sensor's voltage and is used to determine the thermo-physical properties of the sample. The thermal conductivity is inversely proportional to the rate of increase in the sensor voltage (or temperature increase). The voltage rise will be steeper for lower thermal conductivity materials (e.g. foam) and flatter for higher thermal conductivity materials (e.g.metal).

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

k (Thermal Conductivity) & $\text{Effusivity} = \sqrt{k\rho c_p}$

Where:

k = thermal conductivity (W/m • K)

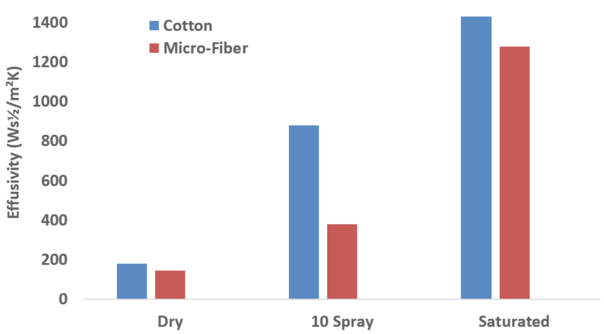
ρ = density (kg/m^3)

c_p = heat capacity (J/kg • K)

Application in Textile, Fabrics & Apparel

The perception of "warm feel" of a textile is a key factor affecting the consumer's overall comfort in the clothing. It is important to understand that the physical sensation of warmth is separate from the absolute temperature of a material. The physical process which governs the touch perception of warmth is the rate of heat transfer. This means that metals (which conduct heat away from the skin very quickly) broadly feel cool to the touch, whereas woods (which do not readily conduct heat) feel warmer, even when both are at the same absolute temperature. The physical property of thermal conductivity (k) might therefore be thought to be correlated with perceived warmth of a material. In reality, the character of heat transfer is more complicated, and has further dependencies upon the mass specific heat capacity (Cp) and the density (ρ). These quantities can be combined into a factor called the thermal effusivity (also described as "thermal inertia"), defined as the square root of the product specific heat capacity, thermal conductivity and the density of the material. With the C-Therm TCi, researchers can characterize directly both the thermal conductivity and thermal effusivity of their samples.

Case 1: Thermal Effusivity vs. Mositure



Left: The C-Therm TCi Thermal Analyzer provides a quantitative means of measuring thermal effusivity. Numerous human test panels have established a correlation ($R^2 \geq 95\%$) between a textile's perceived feeling of "warmth" with the textile's physical property of thermal effusivity. This can be useful to provide a quantitative characterization of human comfort in the textile. Recently, a client was interested in assessing how the feelings of "warmth" changed with increased moisture content. Water has a very high thermal effusivity (~1600 Ws½/m²K) compared with that of dry textiles (100- 200 Ws½/m²K). Notice the thermal effusivity of the cotton textile is twice the effusivity of the micro fibre material when moderately wet with 10 sprays of water. Incidentally, when fully saturated both materials have a effusivity very close to that of water itself. This reinforces that if you fall in a cold lake, the best thing you can do to improve your comfort is remove your clothing upon exiting. However, technical apparels such as this micro-fibre material can provide substantial improvements in comfort under moderate wetting conditions.

Right: Fabrics are typically compressible and it is important to control the compaction of the material in the test method applied for measuring either the thermal conductivity or the thermal effusivity. There is no "universal" level of compression recommended as it is application-dependant. For example, in measuring the insulation quality of a down jacket minimal compression would be applied. Conversely, in measuring a down sleeping bag, considerable compression force would be applied to mimic the "real-world" application conditions. With the C-Therm CTA accessory researchers can reproducibly create such user conditions in testing the performance of the materials.

Case 2: Thermal Conductivity vs. Compression