NETZSCH

Proven Excellence.

Guarded Heat Flow Meter – TCT 716 *Lambda*

Method, Technique, Applications

Analyzing & Testing

Realizing Precise Determination of Thermal Resistance and Thermal Conductivity

Between Classical Heat Flow Meters and Laser Flash Analyzers

The TCT 716 *Lambda* offers the capability of analyzing specimens with optimum dimensions: smaller than conventional HFM and larger than LFA. This enables investigations on homogeneous and inhomogeneous materials with thermal conductivity values ranging from low to medium, for example polymers, composites, glass, ceramics, some metals, etc.

360°

Unbeatable Features of the TCT 716 *Lambda* – TWO INDEPENDENT TEST STACKS

Based on ASTM E1530

Handling

The robust design of the TCT 716 *Lambda* thermal conductivity tester offers easy, uncomplicated handling of the software and hardware. The guarded heat flow meter (GHFM) is fully software-controlled, including mean temperature and applied force. The software also allows for an unlimited number of steps in test cycles for best performance.

Unique Set-Up – Two Independent Test Stacks

This GHFM has a left and right test stack; which enables tests on a single specimen or simultaneous tests on two specimens.

Each stack is independent of the other in terms of specimen thickness. Both stacks can be operated across the entire temperature range from -10°C to 300°C. This arrangement not only increases sample throughput, but also allows for more data to be collected in less time.

Precise Control and High Resolution

The system provides precise temperature control with a resolution of 0.1°C. It is equipped with multiple high-resolution detectors (RTD), which allow for accurate measurement of the thermal gradient across stack and specimen thickness.

Cost-Effective Cooling

CO_2 is a natural refrigerant that provides sustainable and energy-efficient cooling in everything from warehouses to ice machines – including the TCT 716 *Lambda*!

CO_2 features unique thermophysical properties:

- Very good heat transfer coefficient
- High energy content
- Relatively insensitive to pressure losses
- Very low viscosity

Unlike other GHFMs, this design allows for CO_2 cooling for optimal temperature control. There is no longer any need for an expensive chiller unit. In addition, forced cooling of the instrument is possible and CO_2 consumption above ambient temperature is low.

Realizing Precise Determination of Thermal Resistance and Thermal Conductivity

Knowledge about the thermal conductivity and thermal resistance is important in the case of many metals, polymers, and composites because it helps engineers and scientists design and develop materials and products that can withstand high temperatures and thermal stress.

Thermal resistance is the capability of a material to resist the flow of heat through it, and it is a critical parameter for materials used in applications such as electronics, aerospace, automotive, and energy systems.

In electronics, for example, thermal resistance is a key factor in determining the reliability and performance of electronic devices such as microprocessors, which generate significant amounts of heat. If the thermal resistance of the material used in a device is too high, it can lead to overheating, reduced performance, and ultimately failure of the device. Therefore, materials with low thermal resistance are preferred for electronic applications.

Similarly, in aerospace and automotive applications, materials with high thermal resistance are required, to withstand the high temperatures generated during operation. Materials such as titanium alloys, carbon composites, and ceramic materials are commonly used in these applications due to their high thermal resistance.

Overall, an understanding of the thermal resistance/conductivity is crucial in selecting materials for various applications, ensuring the reliability and performance of products, and optimizing design and manufacturing processes. NETZSCH offers a wide range of testing devices, including laser flash systems, to cover this broad application range.

Thermal conductivity (λ) is the ability of a material to conduct heat. The thermal transmittance, also known as U-value, is the reciprocal of the total thermal resistance (R, see formulas below). The lower the U-value, the better the insulating ability.

$$\lambda = \frac{\dot{Q}}{A}\,\frac{L}{\Delta T}$$

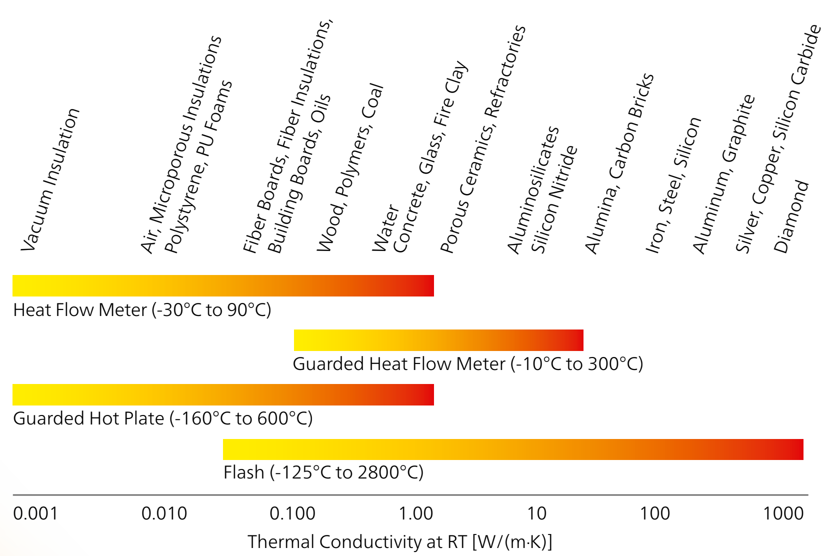
λ in SI unit [W/(m·K)] or British Thermal Units [Btu in/(h·ft²·°F)]

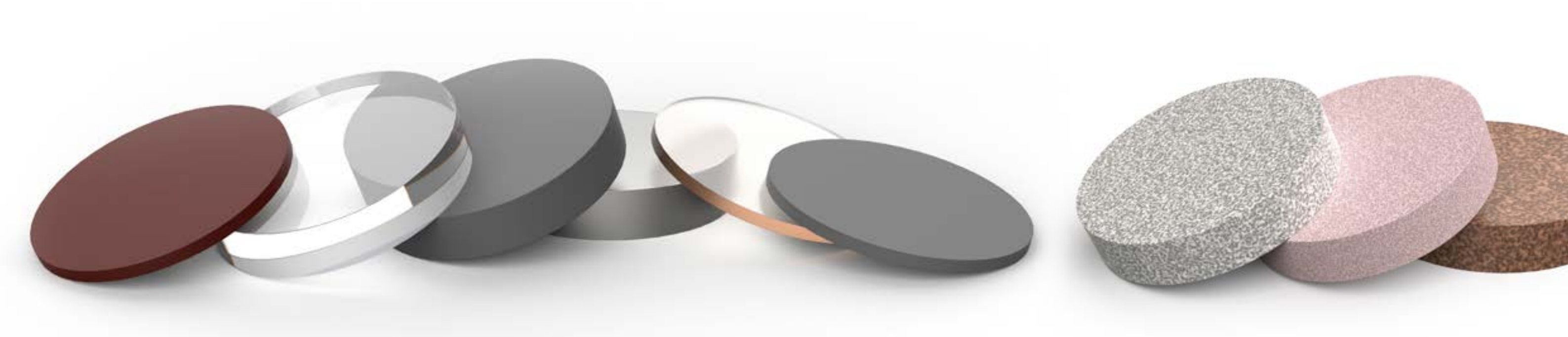
$$R = \frac{L}{\lambda}$$

R in SI unit [(m²·K/W)] or British Thermal Units [(h·ft²·°F)/Btu]

$$U = \frac{1}{R}$$

U in SI unit [W/(m²·K)]





Why a Guard?

With a Guarded Heat Flow Meter, thermal conductivity and thermal resistance can be precisely determined. The heat source and a temperature sensor are surrounded by an active guard (furnace). This prevents lateral heat losses to the environment and increases measurement accuracy.

Automatic Load Control

It is important that thermal contact between the instrument plates and the test sample be reproducible. Thus, the TCT 716 *Lambda* is equipped with reproducible load control.

Measurement

The operator measures the thickness of the test specimen(s), and places them between two heated plates controlled at different temperatures. Temperature sensors (RTD) are mounted just below the plate surfaces for measuring the temperature drop across the specimen. Similar sensors are also embedded in the upper and lower stacks (metering area: 51 mm) to measure the heat flow through the specimen. Once steady-state condition has been achieved, these signals are collected for calculating thermal conductivity. The software indicates thermal equilibrium. After the indication of thermal equilibrium, the measurement is carried out.

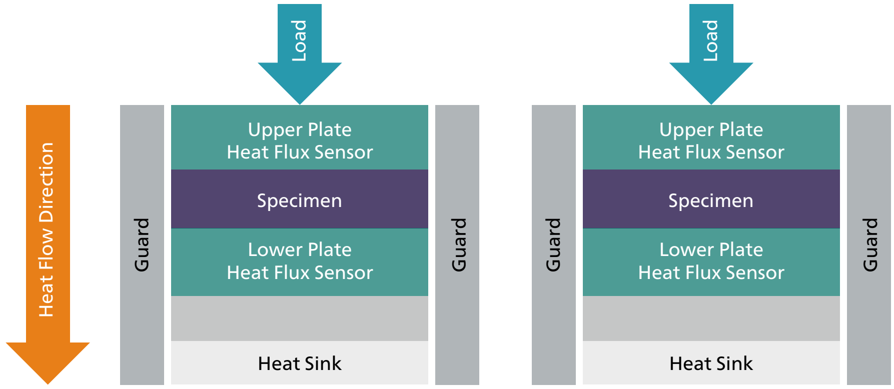
Samples

Typically, the TCT 716 *Lambda* allows for measurements on round solid specimens in the low- and medium-conductive range such as polymers (filled and unfilled) and low-conductive ceramics and metals including porous specimens. An important feature of the instrument is that there are no temperature sensors embedded into the sample. Sample preparation is according to ASTM E1530. For solid specimens, a thermal interface paste is used to improve the thermal contact with the instrument plates.

Advantages of the GHFM

The GHFM provides a reliable and precise method for measuring the thermal conductivity and thermal resistance in a wide variety of solids, thus contributing to materials science research and product development.

- High accuracy: uncertainties typically < 3%
- Non-destructive test: The materials to be tested can be measured as made without destroying or otherwise altering them
- Wide range of materials: metals, polymers, ceramics, composites, etc.
- Specimen dimensions: 51 mm in diameter, up to 31.8-mm thickness – advantageous for inhomogeneous samples
- Easy to use: typically only minimal training required



Schematic diagram of TCT 716 *Lambda* with measurement capability of two specimens

Instrument Calibration

All conditions of calibration, such as management of reference materials, temperature steps and pressure are fully automated with the software. The instrument is calibrated with materials of known thermal resistance. A relationship is established between the known thermal resistance of the calibration material and the related temperature difference and heat flux.

The user can select from among the following reference materials with predefined thermal conductivity values:

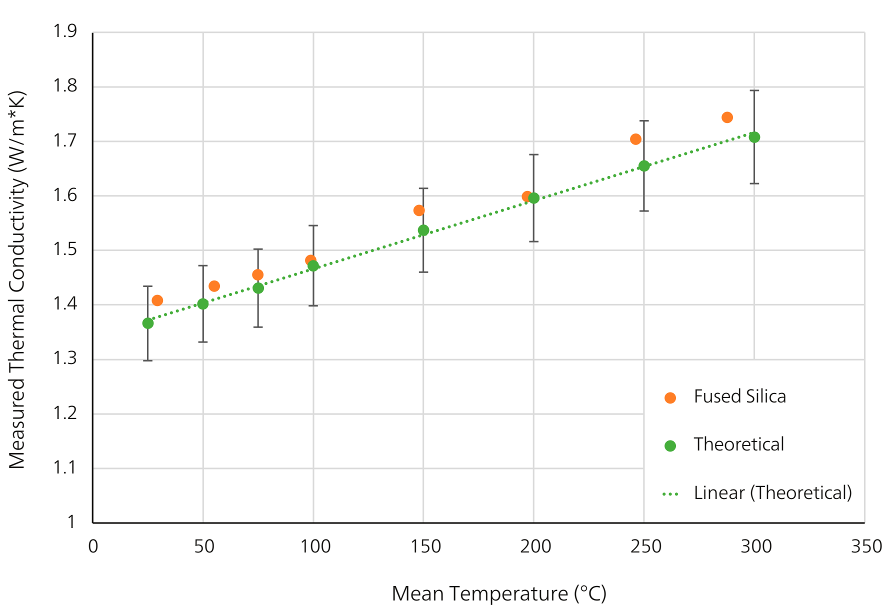
- Fused Silica
- Pyroceram 9606
- Vespel
- 304 Stainless Steel

In addition, operators can enter their own reference materials (in the form of a K vs. T table). An infinite number of points may exist.

Clamping Control

For rigid materials, the plates automatically clamp together for optimum sample contact.

CALIBRATION AND APPLICATION



Thermal Conductivity of Fused Silica

Fused silica is a glass composed of amorphous silica (SiO_2). It is known for its excellent thermal, mechanical, and optical properties. A 12.7-mm-thick specimen was measured on the TCT 716 *Lambda* from room temperature to 300°C. The data are plotted along with reference data for fused silica; error bars are ±5%.

TCT 716 *Lambda*	
General	
Standards	Based on ASTM E1530
Operation	External PC, minimum i5 or equivalent, 500 GB, 2x USB 3.0 (not included)
Automated instrument calibration	Yes; reference materials: fused silica; pyroceram and stainless steel
Testing chamber	Motorized door opening/closing mechanism, interlocked
Measurement data	
Thermal resistance range	0.001 to 0.030 $m^2 \cdot K/W$
Thermal conductivity range	0.1 to approx. 30 W/(m·K) (using proper sample thicknesses)
Thermal conductivity accuracy	±3% deviation from literature value (depending on the accuracy of calibration material)
Thermal conductivity repeatability	±2% (precision; measurement of the same sample in the same device after sample out/in between measurements)
Measurement times for different material types	In general, t < 2 hours/point, depending on thermal conductivity
Number of set points	Free-selectable number of programmable test temperatures; typically full range test includes 5 to 6 test temperatures max.
Number and type of temperature sensors	Premium RTD class A, in protective capsule, 14 total/instrument, resolution: 0.01°C
Metering area of the plates	51 mm, round, full cross section
Sample Dimensions	
Sample shapes	Round
Sample dimensions	ø 51 mm nominal (2 in; +0.005 in, -0.050 in); height up to 31.8 mm (1¼ in)
Sample condition	Solid
Number of samples	Up to 2; independent of type, identical thermal cycles
Contact pressure and load control	
Variable contact pressure	Programmable for incompressible materials; 35/70/175/350 kPa
Load control	Automatic
Temperature	
Temperature	▪ Max. hot plate temperature: 350°C ▪ Sample mean temperature range: -10°C to 300°C
Temperature gradient	Typically 30 K, variable
Cooling system	Liquid CO_2
RTD resolution	±0.05%, class A RTD, approx. ±0.01°C resolution
Locations of temperature measurement	Specific locations along stack, consisting of upper plate/sample/lower plate, heat sink
Instrument Dimensions	
Dimensions and weight	Basic instrument: height 715 mm x width 460 mm x depth 630 mm; 54 kg (basic instrument without CO_2 cylinder)
CO_2 cylinder	mandatory for operation (not included)

Technical Specifications

The owner-managed NETZSCH Group is a leading global technology company specializing in mechanical, plant and instrument engineering.

Under the management of Erich NETZSCH B.V. & Co. Holding KG, the company consists of the three business units Analyzing & Testing, Grinding & Dispersing and Pumps & Systems, which are geared towards specific industries and products. A worldwide sales and service network has guaranteed customer proximity and competent service since 1873.

When it comes to Thermal Analysis, Calorimetry (adiabatic & reaction), the determination of Thermophysical Properties, Rheology and Fire Testing, NETZSCH has it covered. Our 60 years of applications experience, broad state-of-the-art product line and comprehensive service offerings ensure that our solutions will not only meet your every requirement but also exceed your every expectation.

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