WHITE PAPER

NETZSCH

Thermal Conductivity of Insulating Materials by Means of HFM Measurements

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1 NETZSCH heat flow meter HFM 446 *Lambda Medium* – closed

2 NETZSCH heat flow meter HFM 446 *Lambda Medium* – open

Introduction

A key parameter for characterizing the poperties of insulating materials is thermal conductivity (λ). It describes the transport of energy – in the form of heat – through a body based upon a temperature gradient. Using the thermal conductivity, the parameters important in structural physics – including the thermal insulation coefficient (Λ), thermal resistance (R, or R-value in the US), thermal transmittance (R_T) and U-value – can be easily derived.

For flat materials with plane surfaces, the thermal insulation coefficient (Λ) is calculated from the ratio of the thermal conductivity (λ) and material thickness (d): $\Lambda = \lambda/d$

Its reciprocal value is the thermal resistance: $R = 1/\Lambda = d/\lambda$

If the thermal resistance is supplemented by the outer (R_{Se}) and inner (R_{Si}) thermal transfer resistances to the adjacent air layer, the thermal transmittance can be obtained: $R_T = R_{Si} + R + R_{Se}$

Its reciprocal value, in turn, is the U-value, also called the overal heat transfer coefficient: $U = 1/R_T$

In quality assurance, the thermal conductivity itself is often used in the form of the statistical mean $\lambda_{90/90}$, which serves as a basis for calculation of the nominal value λ_D:

$$\lambda_{90,90} = \lambda_{Mittel} + k \cdot s_\lambda$$

$\lambda_{90,90}$: indicates the value at which 90% of the tests samples lie within a confidence level of 90%

λ_{Mittel}: mean value of the thermal conductivity of n measurements

s_λ: standard deviation of n measurements

k: confidence factor, tabulated, dependent on the number of data

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Thermal Conductivity on Insulating Materials by Means of HFM Measurements

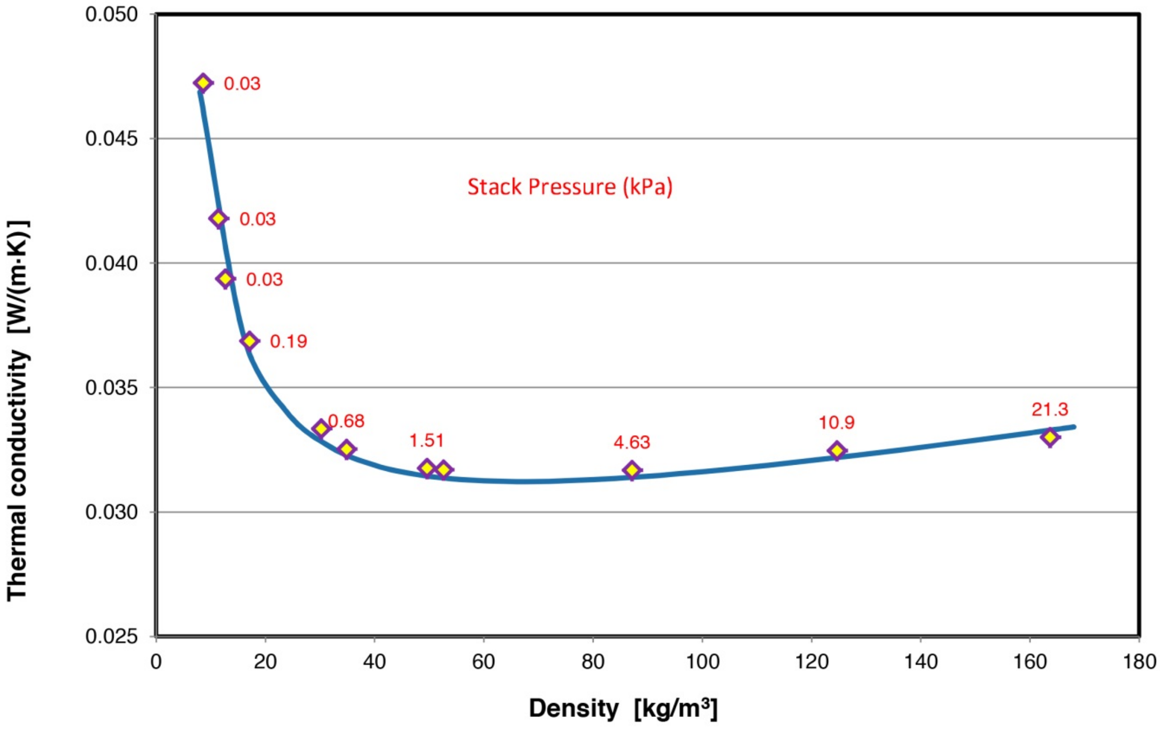
If the insulating materials are compressible plates or mats made of fleece, fiber, wool or foam, their density also plays an important role. Although the thermal conductivity is not a function of thickness as a material property, this only applies if the proportions of the heat transfer mechanisms in the material involved do not change. If, however, compression occurs, there is an increase in heat transfer due to the higher heat conduction via the fibers. This can strongly influence the effective thermal conductivity of the total fiber material. Figure 1 illustrates the described relationship between density and thermal conductivity using a glass-fiber insulation material as an example. Here, the thermal conductivity decreases by more than 30% when the contact pressure is increased from approx. 30 kg/m^3 to approx. 50 kg/m^3.

This means:

Only be means of active control of the thickness, and thereby also of the density, of compressible insulating material is it possible

- to obtain exact information on the thermal conductivity of insulating layers
- to compare fiber materials from different batches or of differing nature under identical conditions

The results of such investigations can yield important information to manufacturers for optimizing the structure, performance and costs of insulating materials – e.g., by reducing the amount of material used.



3 Change in thermal diffusivity of a glass-fiber mat with increasing compression (blue) due to an increase in contact pressure; within the first 3 measurement points, it was possible to compress the sample without increasing the pressure (0.03 kPa).
The measurement was carried out at 25°C with a ΔT of 20 K; the instrument was initially calibrated with an NIST 1450d standard with a thickness of 25 mm.

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NETZSCH HFM 446 *Lambda Medium* – Ideal for the Investigation of Insulating Materials

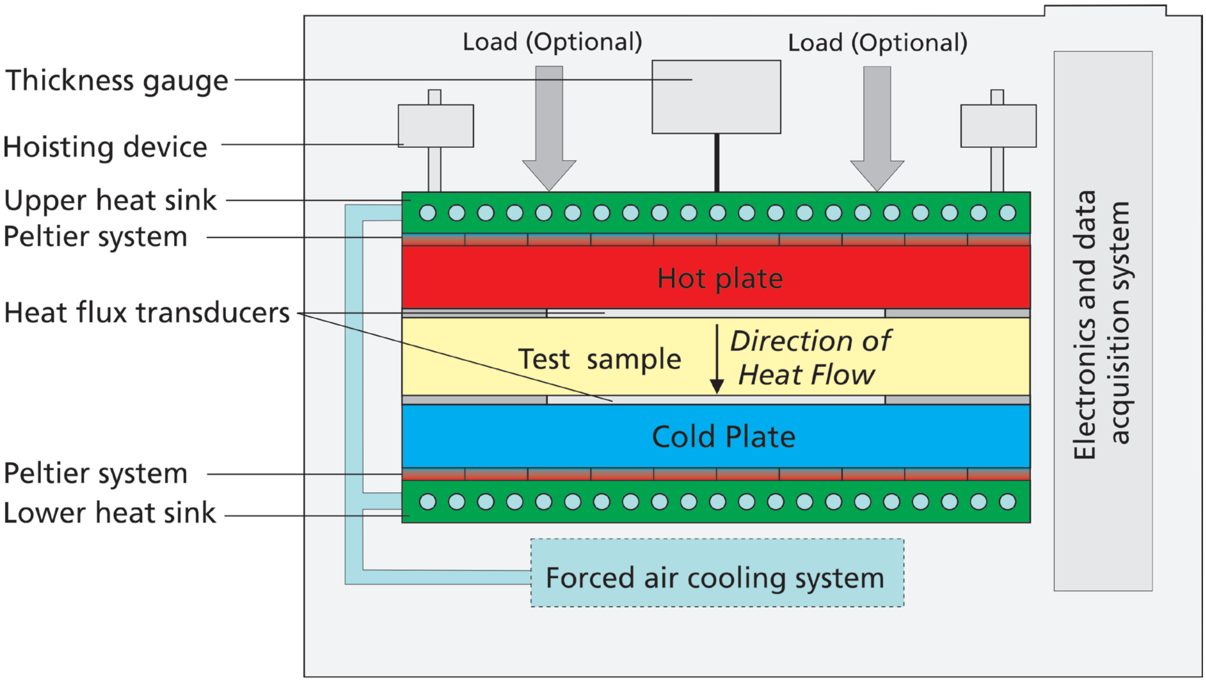
Heat flow meter systems are the first choice for the easy and fast determination of thermal conductivity in insulating materials. This refers to instruments in which a plane, usually square sample is positioned between a hot and a cold plate. The stationary heat transfer through the sample material is measured (see figure 4) by means of heat-flow sensors embedded in the plates.

The robust heat flow meter NETZSCH HFM 446 *Lambda* measuring instrument series can be operated based on relevant industrial standards such as ASTM C518, ISO 8301, JIS A1412 or DIN EN 12667 and is suited for use in both industry and research. The HFM 446 *Lambda Medium* can optionally be operated as a stand-alone system or with an externally connected computer. For stand-alone applications, parameters like measuring temperature or temperature differences between the plates (ΔT) can be inputted by means of an integrated keyboard; an integrated printer serves as an output medium for the results.

The temperature of the hot and cold plates is controlled by Peltier elements which are connected to an external thermostat (which is at a constant temperature, e.g., 20°C). This allows for fast adjustment of the required plate temperatures. In order to be able to also record the dependence of the thermal conductivity on temperature, up to 10 different measuring temperatures can be defined per measurement.

It is very easy to carry out a measurement:
Open the instrument – insert the sample – select the contact pressure – ensure that the upper plate of the HFM is in contact with the sample surfaces – close the instrument – start the measurement.

Pre-selectable contact pressure allows the user to regulate compression for fiber insulations or foams and thus ensure that these are not compressed excessively. The resulting thickness of the sample is automatically determined and documented. If the contact pressure from the previous investigation can be adopted, a new selection is not necessary prior to starting a test. The installed actuator system ensures that the contact pressure of maximum 21 kPa is evenly applied across the entire sample surface, guaranteeing good contact between the sample surface and the hot plate, even for hard, solid samples. Two independent load cells take over the pressure measurement and control.



4 Schematic design of the NETZSCH HFM 446 *Lambda Medium* (HFM: heat flow meter) with patented control of the plate temperature (US Patent No. 5.940.784), dual-sensor arrangement, integrated thickness measurement and adjustable contact pressure on the upper plate

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The test is completed as soon as the thermal conductivity values determined fulfill the predefined stability criterion – which often happens in less than 15 to 20 minutes. These are the best conditions for high sample throughput in processes such as quality assurance carried out during production.

For invesigating building materials with higher thermal conductivities such as concrete, the measuring range of the system can be expanded from 1 W/(mK) to approx. 2 W/(mK).

When operated with an external computer (Windows® operating system), the *SmartMode* software regulates management of the calibration and measurement data. The software features a clear structure and an intuitive, user-friendly interface. Even users without previous experience will be able to define measurements and generate test reports within a very short period of time. Measurement parameters such as plate temperature or the temperature difference between the plates (ΔT) can be monitored at a glance thanks to graphical presentation in separate windows.

Technicata Data of the HFM 446 *Lambda Medium*	
Typical sample sizes /mm^3	200 x 200 and 300 x 300, respectively
Measurable thermal conductivity range	0.002 to 1.0/2.0 W/(mK)
Measurable range of the thermal resistance	0.05/0.1 to 8.0 m^2K/W
Reproducibility	0.25%
Precision	± 1 to 3% (depending on the standard used)
Variable contact pressure	Up to 21 kPa

The Author

Dr. Gabriele Kaiser studied chemistry in Erlangen and started working at NETZSCH-Gerätebau after receiving her doctorate in physical chemistry in September 1991.

As former head of the Training Department, she has been responsible for providing application training and consultation to customers, sales partners and co-workers. In July 2008, she took over the Applications Laboratory at NGB in Selb. Since February 1st, she has been responsible for Technical and Scientific Communication.

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