Proven Excellence.

HFM 706 *Lambda* Series – Heat Flow Meter for Testing Insulation Materials

Based on ASTM C518, ISO 8301, JIS A1412, DIN EN 12664, and DIN EN 12667 Method and Technique for the Characterization of Insulation Materials

Analyzing & Testing

A Key Parameter for Improved Energy Efficiency

THERMAL CONDUCTIVITY

The HFM is an exact, fast and easy-to-use instrument for measuring the low thermal conductivity, λ, of insulation materials.

The Heat Flow Meter (HFM) is a widely used tool for measuring the thermal conductivity (λ) of insulation materials.

Typical applications are:

- Characterization of insulation materials such as foams, mineral wool, aerogels
- Calculation of the energy efficiency of building and insulation materials
- Temperature protection against heat and cold provided by packaging materials

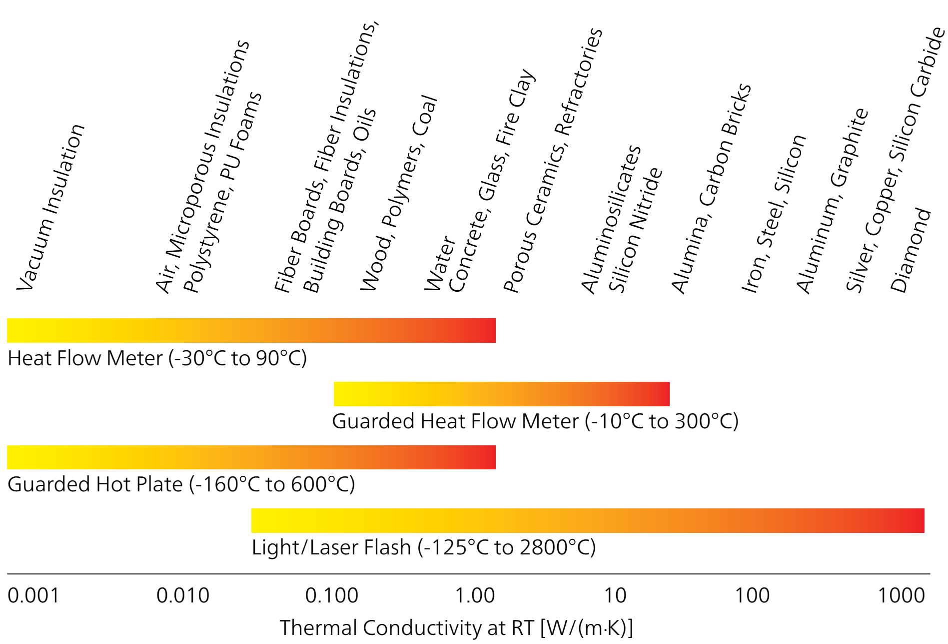
Areas where the heat flow method is used are:

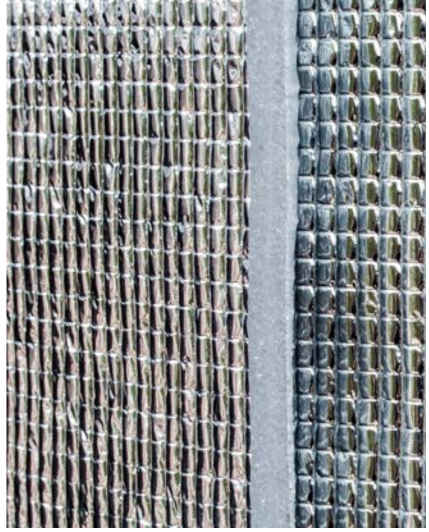
- Quality control alongside production to ensure that materials meet the required specifications
- Development of new materials with optimized thermal properties in research and development
- Improvement of energy savings in energy management and building engineering

For the analysis of low-conductivity materials such as fiber insulations or vacuum insulation panels, NETZSCH stands out with various types of heat flow meters (HFMs) for diverse sample dimensions and temperature ranges.

The HFM 706 *Lambda* series is based on various relevant standards, e.g., ASTM C518, ISO 8301, JIS A1412, DIN EN 12664* and DIN EN 12667.

* excluding HFM 706 *Lambda Large*





In a heat flow meter (HFM), the test specimen is placed between two heated plates controlled to a user-defined mean sample temperature and temperature gradient to measure heat flowing through the specimen. The specimen thickness, L, is measured by an internal thickness gauge. Alternatively, the user can enter and drive to the desired thickness, which is of particular interest for compressible samples.

Since the Heat Flow Method is a relative method, the instrument must be calibrated against a reference material. For the calculation of the thermal conductivity, λ, and the thermal resistance, R, the average heat flux, $\dot{Q}/A$, the sample thickness, L, and the temperature gradient, ΔT, are used, in accordance with Fourier's Law (see formulas on the right). The thermal transmittance, also known as U-value, is the reciprocal of the total thermal resistance. The lower the U-value, the better the insulating ability.

The heat flow, $\dot{Q}$, through the sample is measured by two calibrated heat flux transducers covering a large area of both sides of the specimen. After reaching thermal equilibrium, the test is done.

Thermal Conductivity

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

λ in SI unit [W/(m·K)] or British Thermal Units [Btu in/(h·ft^2·°F)]

Thermal Resistance

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

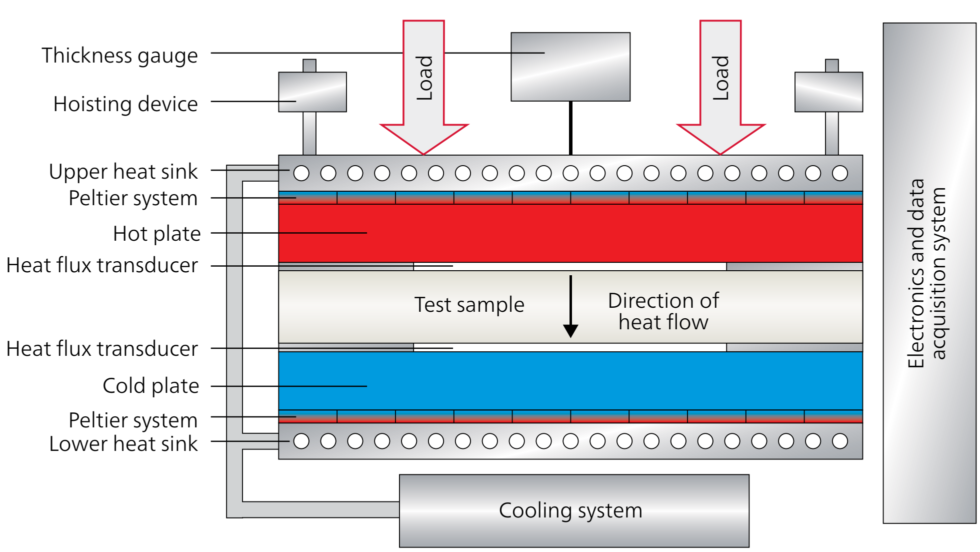
R in SI unit [(m^2·K/W)] or British Thermal Units [(h·ft^2·°F)/Btu]

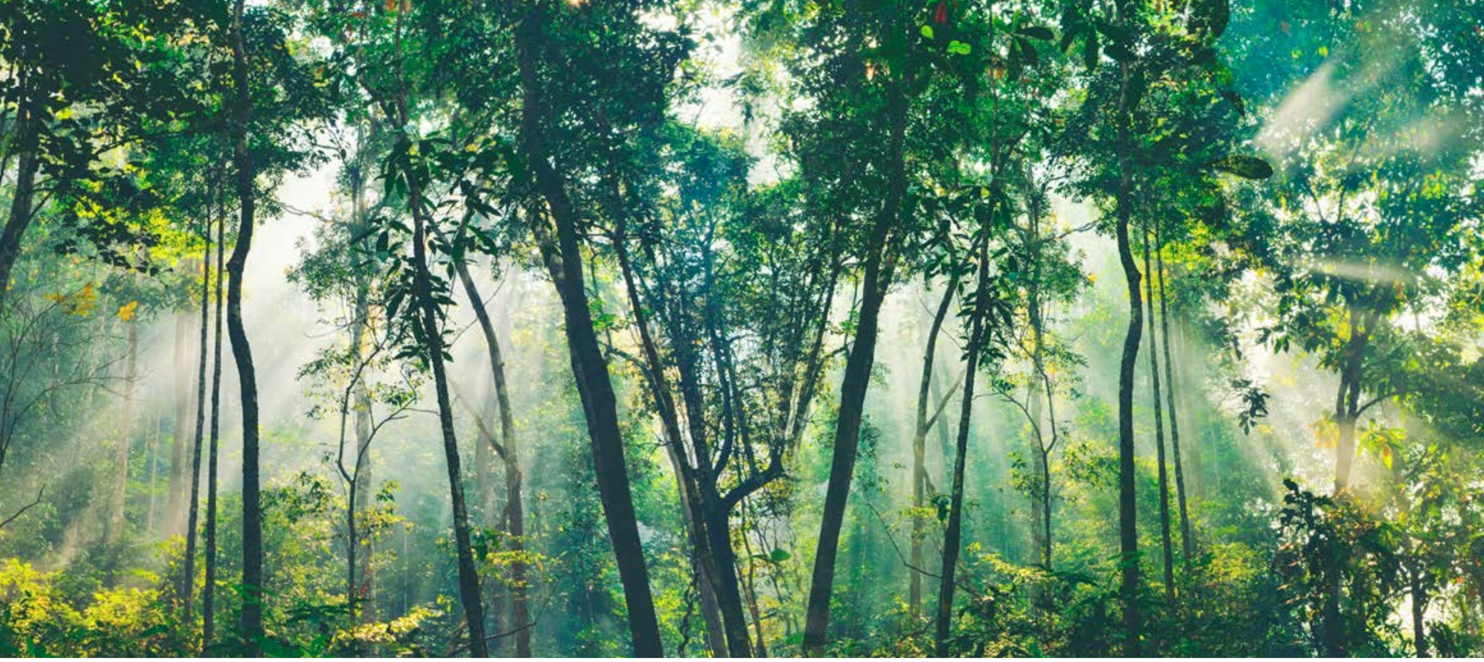
U-Value (Thermal Transmittance)

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

U in SI unit [W/(m^2·K)]

PRINCIPLE OF OPERATION





Thermal Analysis Made More Sustainable

Reduced Energy Consumption and Operating Costs

In standby, the HFM 706 *Lambda* can be switched to the energy-saving Eco Mode or to Idle Mode. The timing for when each mode is active can be adjusted via a scheduler.
The *SmartMode* software offers a user-defined time schedule for activating either Idle or Eco Mode. In Eco Mode, the HFM plate temperature control and chiller are deactivated, resulting in a negligible energy consumption level for the entire system. During periods when no measurement runs, e.g., overnight or during the weekend, energy savings in Eco Mode are significant.

In Idle Mode, the HFM plate temperatures are held at predefined values, allowing for the quick start of a new measurement at those plate temperatures. The chiller is also running during Idle Mode, with a power consumption between 0.5 and 1.0 kW.

Idle/Eco Mode

General | **Schedule**

	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
12:00 AM	ECO	ECO	ECO	ECO	ECO	ECO	ECO
1:00 AM	ECO	ECO	ECO	ECO	ECO	ECO	ECO
2:00 AM	ECO	ECO	ECO	ECO	ECO	ECO	ECO
3:00 AM	ECO	ECO	ECO	ECO	ECO	ECO	ECO
4:00 AM	ECO	ECO	ECO	ECO	ECO	ECO	ECO
5:00 AM	ECO	ECO	ECO	ECO	ECO	ECO	ECO
6:00 AM	ECO	IDLE	IDLE	IDLE	IDLE	IDLE	ECO
7:00 AM	ECO	IDLE	IDLE	IDLE	IDLE	IDLE	ECO
8:00 AM	ECO	IDLE	IDLE	IDLE	IDLE	IDLE	ECO
9:00 AM	ECO	IDLE	IDLE	IDLE	IDLE	IDLE	ECO
10:00 AM	ECO	IDLE	IDLE	IDLE	IDLE	IDLE	ECO
11:00 AM	ECO	IDLE	IDLE	IDLE	IDLE	IDLE	ECO
12:00 PM	ECO	IDLE	IDLE	IDLE	IDLE	IDLE	ECO
1:00 PM	ECO	IDLE	IDLE	IDLE	IDLE	IDLE	ECO
2:00 PM	ECO	IDLE	IDLE	IDLE	IDLE	IDLE	ECO
3:00 PM	ECO	IDLE	IDLE	IDLE	IDLE	IDLE	ECO
4:00 PM	ECO	IDLE	IDLE	IDLE	IDLE	IDLE	ECO
5:00 PM	ECO	IDLE	IDLE	IDLE	IDLE	IDLE	ECO
6:00 PM	ECO	ECO	ECO	ECO	ECO	ECO	ECO
7:00 PM	ECO	ECO	ECO	ECO	ECO	ECO	ECO
8:00 PM	ECO	ECO	ECO	ECO	ECO	ECO	ECO
9:00 PM	ECO	ECO	ECO	ECO	ECO	ECO	ECO
10:00 PM	ECO	ECO	ECO	ECO	ECO	ECO	ECO
11:00 PM	ECO	ECO	ECO	ECO	ECO	ECO	ECO

Time schedule for Idle and Eco modes (software screenshot)

HFM 706 *Lambda* Series

DEDICATED TO SMALL-, MEDIUM- AND LARGE-SIZED SPECIMENS

HFM 706 *Lambda Large*

HFM 706 *Lambda Medium*

HFM 706 *Lambda Small*

Three Instrument Versions – Perfect for Individual Sample Dimensions

The HFM 706 *Lambda* is available in three sizes. Choose from among:

Small	203 mm x 203 mm x up to 51 mm
Medium	305 mm x 305 mm x up to 105 mm
Large	611 mm x 611 mm x up to 200 mm

We understand that finding the right fit is important, so we've made it easy to have an instrument that fits your specimen size. Whether you're working with small laboratory samples or larger industrial materials, we've got you covered.

Heat Flux Transducer – High Sensitivity and Accuracy

The dual heat flux transducers monitor the heat flow to and from the specimen. For calibration of the sensors, a reference material is used with known thermal conductivity. Various calibrations can be combined to increase the accuracy of a measurement.

Best Test Conditions with Reduced Risk of Condensation

The design of the testing chamber of the HFM 706 *Lambda* series minimizes influences from the environment and reduces condensation effects inside the testing chamber and on the plate surfaces. Optionally, the testing chamber can be purged with dry gas.

Determination of Specific Heat Capacity

The HFM 706 *Lambda Small* and *Medium* models are equipped with advanced hardware and software capabilities that facilitate the measurement of thermal conductivity and the determination of specific heat capacity (c_p). These models account for the contribution of thermal mass in the panels, a feature that enhances their functionality.

Perfect for Most Sample Types

Peltier Temperature Control for Hot and Cold Plates

The plate temperatures are individually controlled by bidirectional heating/cooling Peltier systems connected to an external chiller. Thanks to optimized temperature control, the high-output Peltier elements accomplish thermal equilibrium and produce data sets within a short time – a productivity increase for your laboratory.

Fast Sample Change without Affecting the Plate Temperature

The plates of the HFM 706 *Lambda* can be separated just slightly at the end of a test. For the next test, the change of specimens can thus be carried out within seconds. This feature minimizes plate temperature disturbances, enabling the plates to swiftly return to the set point. Consequently, subsequent tests can be initiated faster toward achieving equilibrium. The *Small* and *Medium* versions are equipped with a motorized front door.

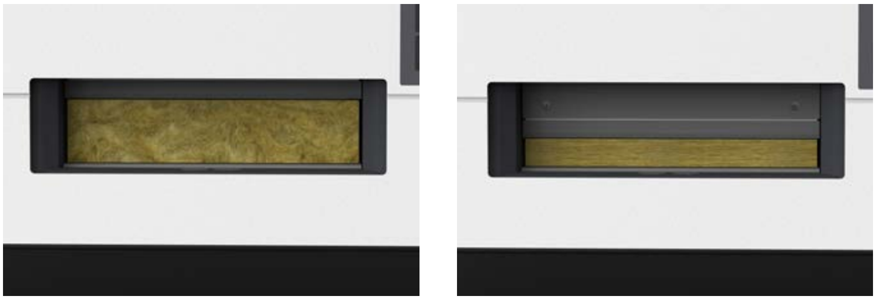
Integrated Thickness Measurement

The HFM 706 *Lambda* series comes with an integrated µm-resolution transducer, allowing measurement of the specimen's actual thickness within a few seconds. On the upper plate, a two-axis inclinometer is integrated. The construction allows for many sample geometries, specifically for inclined and nonparallel specimens, without any stress on the motor shafts.

Variable Load – Control of Thickness and Density of Compressible Samples

The operator can define a contact force of up to 850 N (HFM 706 *Lambda Small*) or 1930 N (HFM 706 *Lambda Medium* and *Large*). This enables control of the thickness, and thus density, of compressible materials.

It also provides for intimate contact between the plates and the specimen across the entire surface in order to produce minimal and uniform contact resistance – two necessary requirements for obtaining reproducible thermal conductivity results.



Precise control regulates thickness and therefore also the density of compressible materials

Measuring the Thermal Conductivity of Compressible or Oversized Specimens at Variable Density

HFM 706 *Lambda Large* for Oversized, Long Samples

The HFM 706 *Lambda Large* has a second opening opposite the front door of the instrument. This makes it possible to insert specimens of different lengths. Insulation panels can be tested with the excess material extending beyond the front and back of the instrument. This is particularly useful for Vacuum Insulation Panels (VIPs), which are often supplied as long panels rather than square samples, and where cutting to size is not possible.

For conventional insulation materials, the "open" version is particularly useful in industrial environments, especially for quality assurance, where maintaining a continuous process is critical and eliminating the need to cut samples saves time.

The HFM 706 *Lambda* for long samples is based on the GB/T 37608-2019 standard.

HFM 706 *Lambda Large* for samples such as long VIP panels

ACCESSORIES
AND MORE

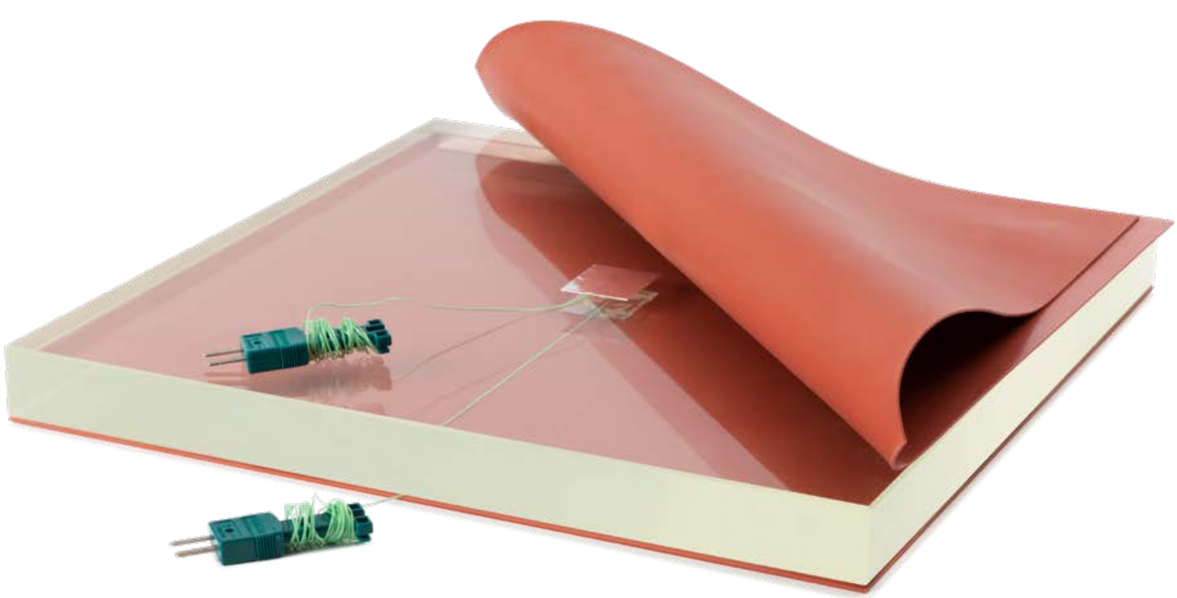
Materials beyond the routine capability of the HFM method can be tested by inserting additional thermocouples and rubber interface pads – eliminating the impact of interface resistance for low thermal resistance and correspondingly higher thermal conductivity materials.

Improved Measurement Precision for Rigid Specimens with Low Thermal Resistances

The HFM 706 *Lambda* series can be equipped with an optional Instrumentation Kit* that expands its range to lower thermal resistances (down to 0.02 $(m^2 \cdot K)/W$) to allow for tests on materials such as concrete, wood products, brick, etc.

The optional kit includes thin, compressible rubber pads for use at both interfaces, and auxiliary thermocouples to be fixed on both surfaces of the specimen. This increases temperature accuracy – especially for applications which require enhanced temperature sensing.

* For HFM 706 *Lambda Large*, on request



Glass specimen with Instrumentation Kit including thermocouples placed in the specimen's center and rubber pads

The instrument is delivered calibrated and a reference specimen is optionally included for verification. Of course, the list of available reference materials can be expanded by the operator.

Pre-Calibrated with Certified Reference Materials

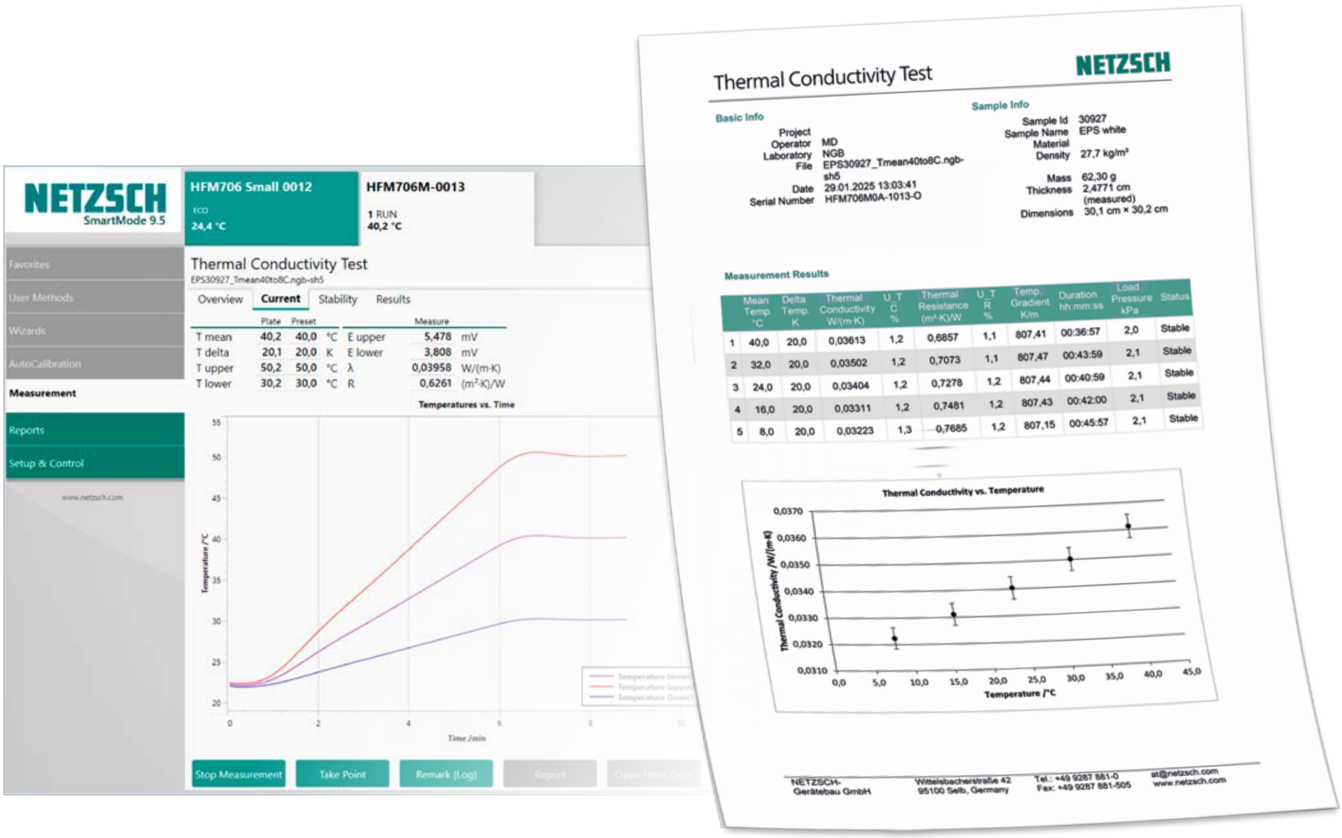
The HFM system is delivered pre-calibrated with international certified reference standards of known thermal conductivity. This establishes precise correlation between the signal output of the transducers and the actual heat flow. Thermal resistance and thermal conductivity are determined once the user-adjustable stability criteria are met. Of course, customers can also use their own reference materials. An accuracy of ± 1% can be easily achieved.

Inserting the reference material;
various reference materials can be used

HFM 706 Lambda Small and Medium are able to measure the specific heat capacity, c_p

Measuring frame for loosely filled material

Software Interface



SmartMode – Easy Measurement, Analysis and Reporting

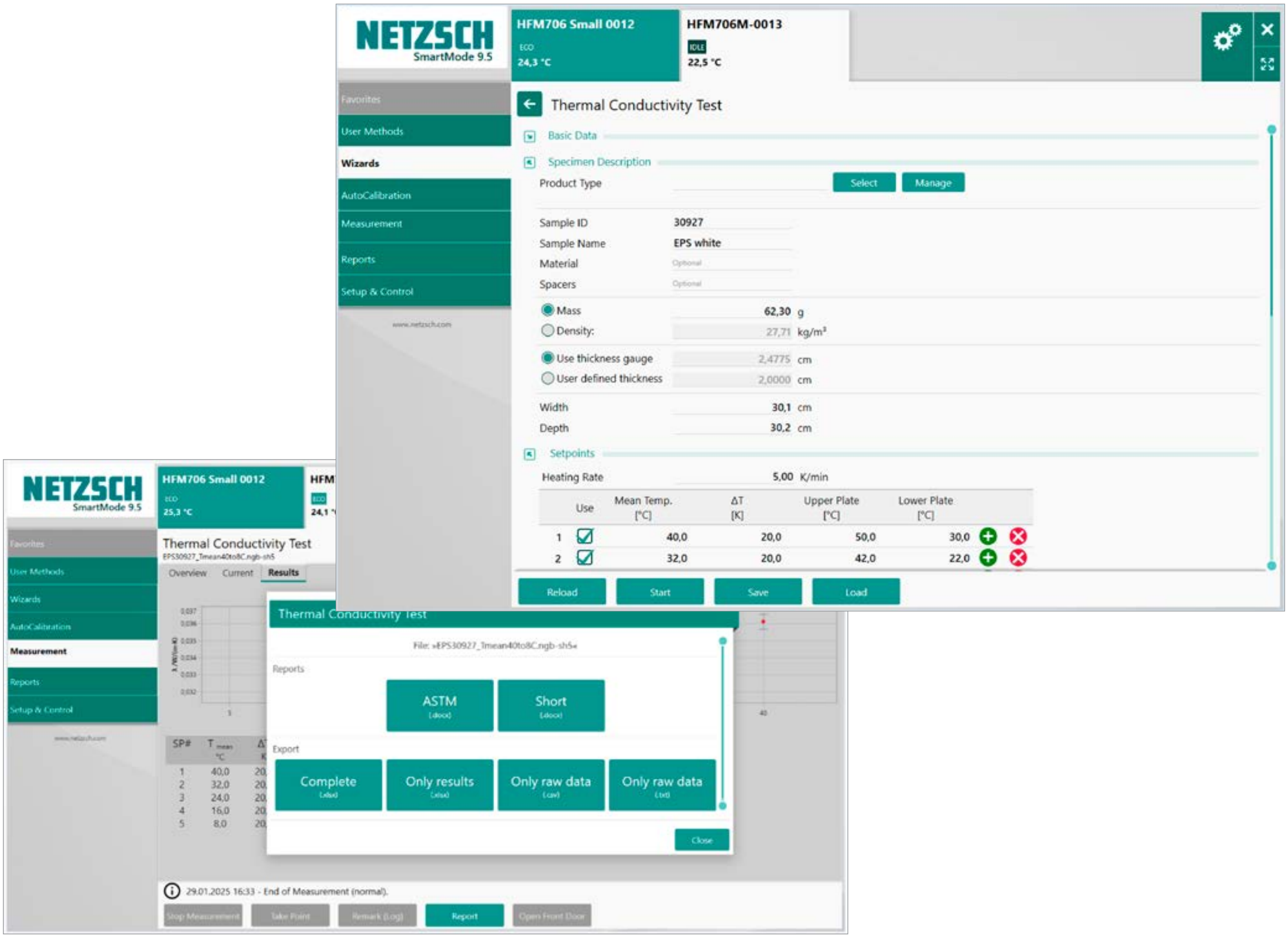
SmartMode is the user-friendly, smoothly running user interface of the HFM *Proteus*® software. It is characterized by a logical structure which quickly gives a clear overview of the current measurement status and provides various report and export possibilities. When the test is complete, all relevant results can be exported to a report when a PC is connected.

Calibration in Next to No Time

For calibration purposes, the thermal conductivity values of the most common certified reference materials, such as NIST SRM 1450d, are already stored in the software. However, *AutoCalibration* also offers the ability to create calibration curves for any user-defined material on the basis of up to 99 freely selectable temperature steps.

Wizards and Methods Guide You to the Results

The "Wizards" button allows for manual parameter input, while the "User Methods" button retrieves parameter sets defined by the user beforehand. Such "User Methods" can also be transferred to "Favorites" for faster access if they are used frequently. Any measurement can be started by using the pre-defined instrument parameters (including number and position of thermocouples, stability criteria, etc.). However, experienced users who wish to apply their own parameter sets can define them under "Setup & Control".



Complete QA Documentation – Just a Click Away

The “Reports” button allows for reports to be quickly and easily generated by granting access to various templates; one of these templates meets all of the requirements stipulated by ASTM C518. Each report can be adapted to the customer’s own corporate identity. In addition, data can easily be exported into either Word or Excel format with just a few mouse clicks. The “Full” export button exports data, graphs and results together into a single file. Measurement data is stored in binary format and is thus fully tamper-proof.

MultiCalibration

The MultiCalibration function can be used to combine several individual calibrations, either of the same type and thickness to reduce measurement uncertainty, or of different types and thicknesses to make measurements on samples of different thicknesses. more flexible and convenient.

Statistics: $\lambda_{90/90}$

The $\lambda_{90/90}$ value is the basis for determination of the declared value for thermal conductivity within the realm of CE declarations of building materials. It is calculated from a measurement series of at least 10 measurements and states which thermal conductivity values, to a probability of 90%, can be achieved for 90% of the output production volume. The integrated report calculates the $\lambda_{90/90}$ value with a click of the mouse. The calculation is based on your measurements; no additional documentation or calculation is required.

Performance & Applications

Performance Checked on EPS Material

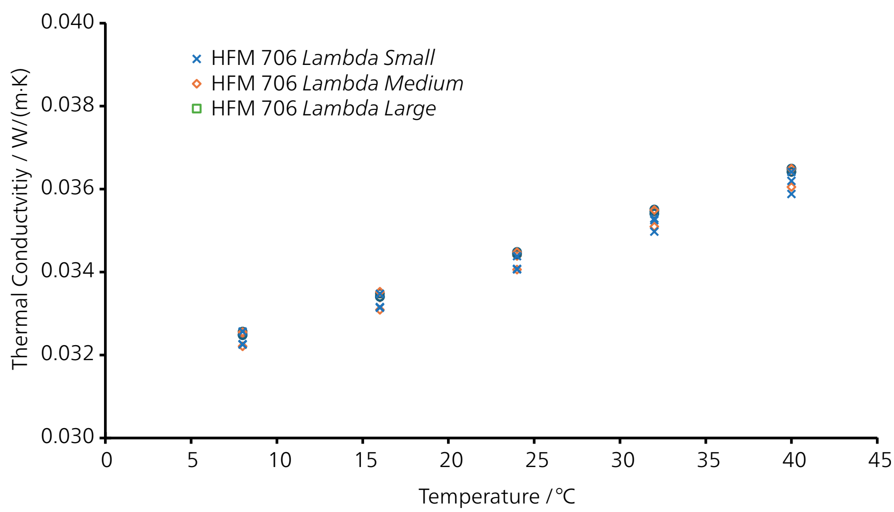


Figure 1: Thermal conductivity of several NETZSCH EPS samples on different HFM 706 *Lambda* instruments versus temperature

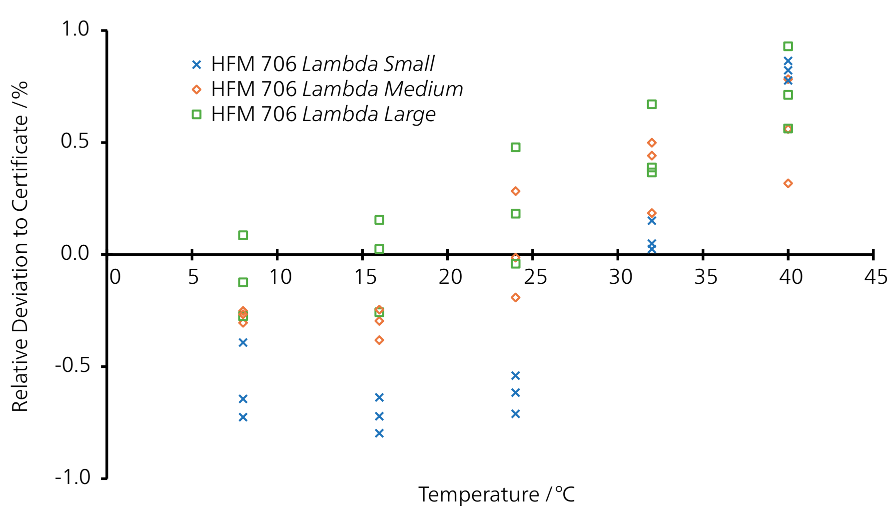


Figure 2: Results from Figure 1 in relation to certified values

In addition to the internationally certified ERM-440 standard, NETZSCH also offers its own factory-certified NETZSCH EPS (expanded polystyrene) standard. This is used for both calibration and validation for all instruments in the HFM 706 *Lambda* series and can be used in the temperature range from 8°C to 40°C.

Figure 1 shows the thermal conductivity of three EPS standards each on the HFM 706 *Lambda Small*, HFM 706 *Lambda Medium* and HFM 706 *Lambda Large* versus temperature with measuring points between 8°C and 40°C.

The instruments were previously calibrated against the international reference material NIST 1450D.

Figure 2 shows the thermal conductivity results of all the measurements from Figure 1 in relation to the certified values as a percentage deviation. It is clear that all measurements have an accuracy of better than ± 1%. The repeatability for each individual instrument is better than ± 0.25%.

Statistics: $\lambda_{90/90}$

The $\lambda_{90/90}$ value is a measure of the thermal conductivity of insulation materials that incorporates statistical safety margins. It provides a reliable basis for the quality assurance and standardized evaluation of insulation materials.
The *SmartMode* software of the HFM series offers the option of outputting this important quality value directly, thus creating added value for the operation of the device and the evaluation of the measurement results.
The example shows measurements on ten different XPS (extruded polystyrene) samples of equal quality at an average sample temperature (T_{mean}) of 10°C (ΔT=20 K). Due to the idle mode, which keeps the plates at a defined temperature after a measurement, the measurement time for each test is a maximum of 30 minutes. The $\lambda_{90/90}$ value shown in Figure 1 is then automatically determined by the *SmartMode* software; see Figure 2.

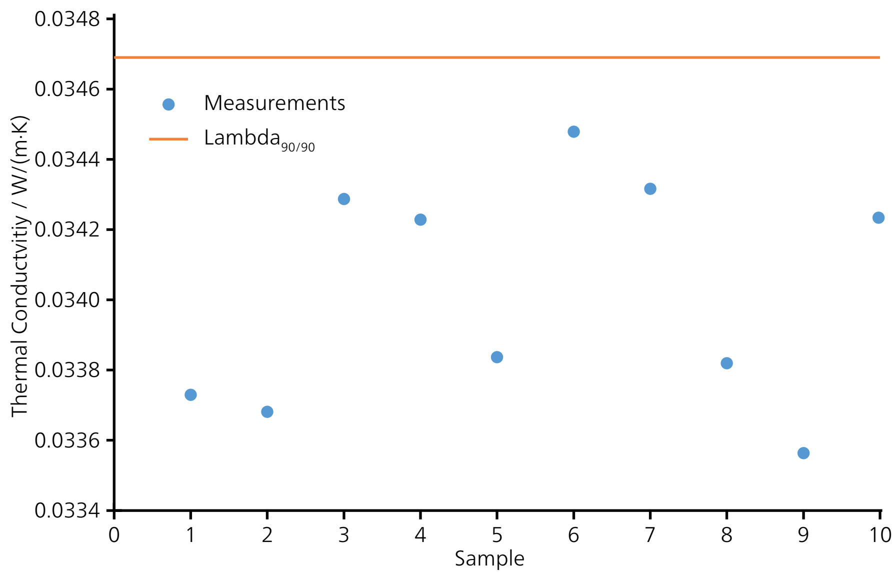


Figure 1: Thermal conductivity of ten XPS samples at T_{mean} = 10°C (ΔT=20K) including $\lambda_{90/90}$ value.

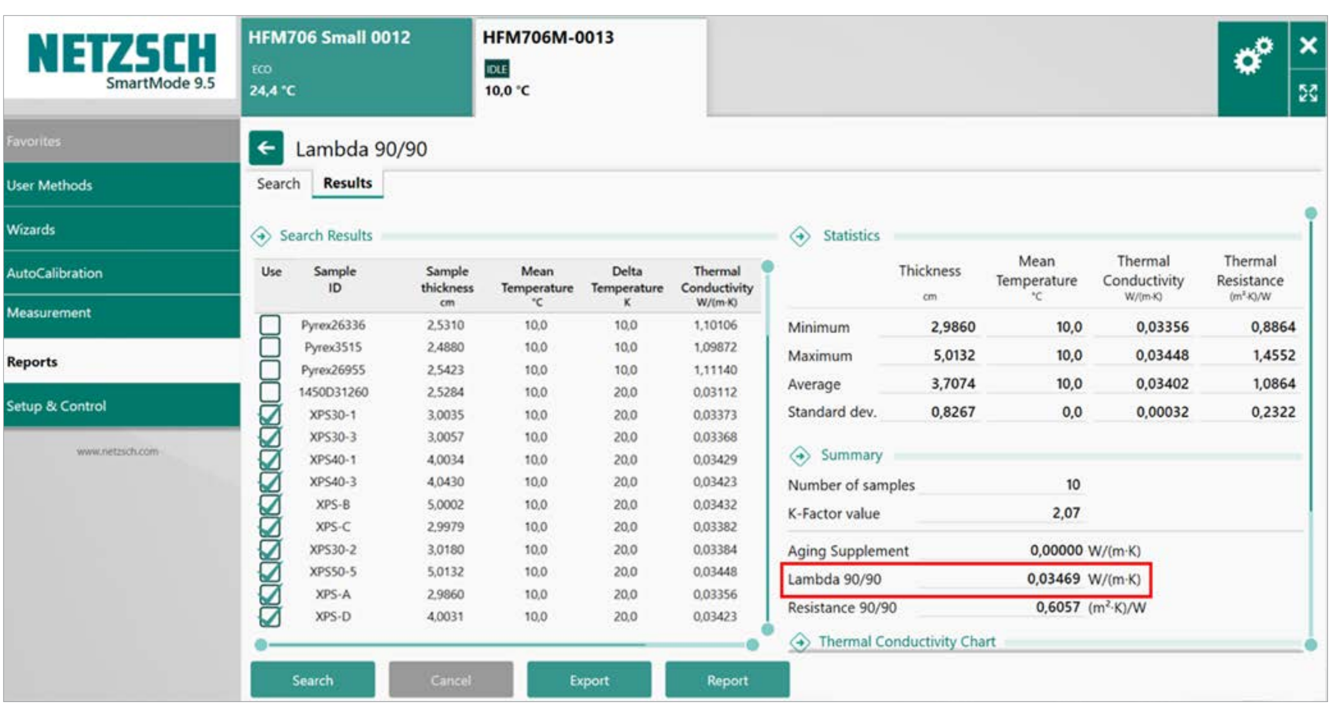


Figure 2: $\lambda_{90/90}$ in *SmartMode* software

Specific Heat Capacity of a Solid Polymer (PVC)

The HFM 706 *Lambda Small* and *Medium* versions measure the specific heat capacity (SI unit J/(g·K)) of solid polymers such as polyamide and PVC (see Figure 1), as well as of insulating materials such as glass wool. Measurements on two PVC sheets (200 mm x 200 mm x 30 mm and 300 mm x 300 mm x 30 mm) were performed at average temperatures of 10°C, 30°C, and 50°C, with a 20 K temperature step between isothermal segments.

The results show that the specific heat capacity increases with temperature and remains within ± 3% of the mean and within the expected range for PVC (0.9 - 1.1 J/(g·K)).

This confirms the ability of the HFM 706 *Lambda* to determine the specific heat capacity of different materials typically used for building and insulation applications.

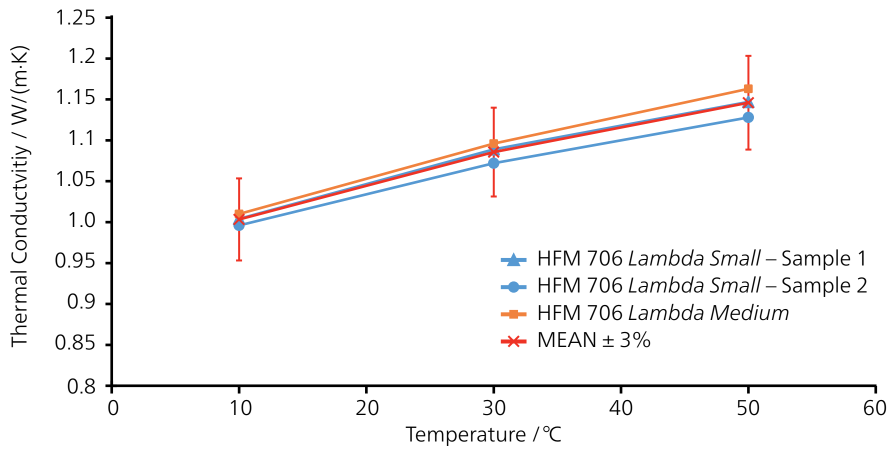
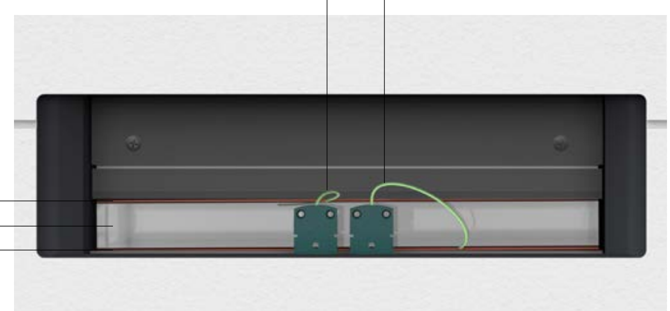


Figure 1: Specific heat capacity of two PVC boards of the same chemical composition



Use and components of the Instrumentation Kit

Low Thermal Resistance

To determine the thermal conductivity of samples with low thermal resistance, it is essential to use the Instrumentation Kit (see page 8). Figure 2 shows the measured thermal conductivity of several borosilicate glass samples (thickness about 25 mm) in different HFM meters as a function of temperature. All measured values are within ± 3% of the literature value [1]. This is only possible due to the use of silicone mats and additional thermocouples. This combination reduces the contact resistance between the low thermal resistance samples and the plates of the HFM, thus allowing for the generation of meaningful results.

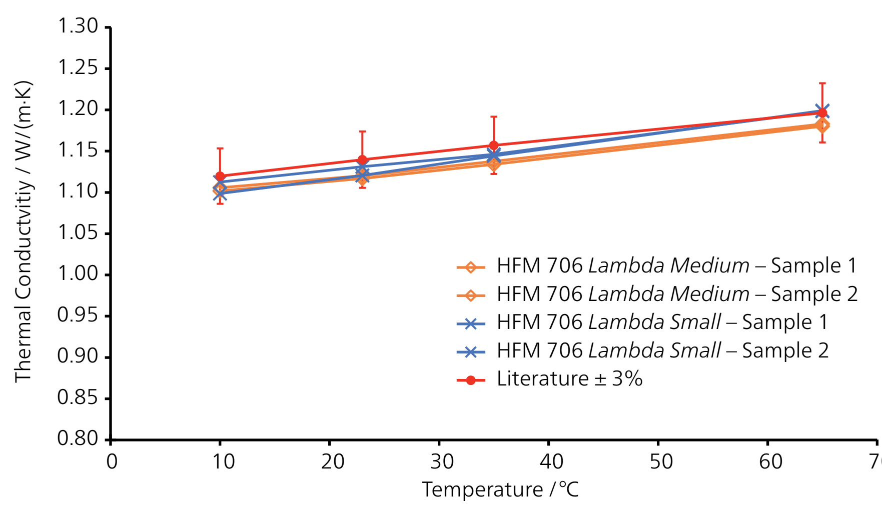


Figure 2: Thermal conductivity of borosilicate glass samples compared to literature values

[1] I. Williams, R. E. Shawyer: Certification report for a pyrex glass reference material for thermal conductivity between -75°C and 195°C; Commission of the European Communities; Luxembourg; 1991

Technical Specifications

HFM 706 *Lambda* Series	
Standards	ASTM C518, ISO 8301, JIS A1412, DIN EN 12667, DIN EN 12664*
Installation	Bench-top device (*Small*, *Medium*) Mobile metal base frame (optional for *Large*)
Thermal conductivity range	▪ *Small*: 0.007 to 2 W/(m·K)** ▪ *Medium*: 0.002 to 2 W/(m·K)** ▪ *Large*: 0.001 to 0.5 W/(m·K)** ▪ Accuracy: ± 1-2% ▪ Repeatability: ± 0.25% ▪ Reproducibility: ± 0.5% → All performance data is verified with NIST SRM 1450 D (thickness:25 mm)
Plate temperature range	-20°C to 90°C, optional for the HFM 706 *Lambda Medium*: -30° to 90°C (ΔT: variable, up to 40 K)
Air-tight system	Sample compartment with the possibility of introducing purge gas
Metering area heat flux transducer	▪ *Small/Medium*: 102 mm x 102 mm ▪ *Large*: 254 mm x 254 mm
Chiller system	External; constant temperature setpoint over plate temperature range
Plate temperature control	Peltier system
Plate motion	Motorized
Plate thermocouples	Three thermocouples on each plate, type K (two extra thermocouples with Instrumentation Kit)
Thermocouple resolution	± 0.01°C
Number of setpoints	Up to 99
Specimen sizes (max.)	▪ *Small*: 203 mm x 203 mm x 51 mm ▪ *Medium*: 305 mm x 305 mm x 105 mm ▪ *Large*: 611 mm x 611 mm x 200 mm
Variable load/ contact force	▪ *Small*: 0 to 854 N (21 kPa on 203 x 203 mm^2) ▪ *Medium*: 0 to 1930 N (21 kPa on 305 x 305 mm^2) ▪ *Large*: 0 to 1900 N (5 kPa on 611 x 611 mm^2) Force-controlled adjustment of the contact force or the desired thickness, and thus density, of compressible materials
Thickness determination	▪ Automatic measurement of mean sample thickness ▪ Four-corner thickness determination via inclinometer ▪ Specimens with a slight wedge shape can be measured
Software features	▪ *SmartMode* (incl. *AutoCalibration*, report generation, data export, wizards, user methods, predefined user definable parameters, user-defined parameters, c_p determination, etc.) ▪ Measurement History Report ▪ Enhanced Export Settings ▪ Storage and restoration of calibration and measurement files ▪ $\lambda_{90/90}$ Report ▪ Plot of plate/mean temperatures and thermal conductivity values ▪ Monitoring of heat flux transducer signal

* not HFM 706 *Lambda Large*

** Please note: In the very low thermal conductivity range, accuracy of Lambda (λ) values can be restricted. *Small* and *Medium*: 2.0 W/(m·K) achievable with optional Instrumentation Kit; recommended for hard materials and those with higher thermal conductivity

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.

Proven Excellence.

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