NETZSCH
Proven Excellence.

Guarded Hot Plate
GHP 456 *Titan*® and GHP 456 *HT Titan*®

Method, Instrumentation, Applications

Analyzing & Testing

GHP 456 *Titan*®

Guarded Hot Plate

The Absolute Method for Testing Insulation Materials

Insulation materials are growing in significance in a number of applications, including the insulation of buildings. Improved insulation reduces energy use and consequently heating costs for each individual household or industrial operation.

- How is a particular insulation material performing?
- How can cryo tanks be insulated in the best possible way?
- Does cryogenic insulation reliably prevent heat exchange?
- What is the optimum insulation for furnaces operating under different temperature, gas or pressure conditions?
- Is the thermal conductivity low enough to prevent thermal bridges?

In order to answer questions like these, a versatile and reliable, easy-to-operate thermal conductivity tester for insulating materials is required.

The NETZSCH GHP 456 *Titan*® is the ideal tool for researchers and scientists in the field of insulation testing. Based on the well-known, standardized guarded hot plate technique (e.g., ISO 8302, ASTM C177 or DIN EN 12667), the system features unrivaled performance over an unmatched temperature range.

The GHP principle is based on an absolute measurement method and therefore requires no calibration standards. Combining cutting-edge technology with the highest quality standards, NETZSCH has designed a robust and easy-to-operate instrument, featuring unparalleled reliability and optimum accuracy over a wide temperature range.

Principle of Operation

The hot plate and the guard ring are sandwiched between two samples of the same material and approximately the same thickness, *d*.

Cold plates are placed above and below the samples. All plate temperatures are controlled such that a well-defined, user-selectable temperature difference, ΔT, is established between the hot and the cold plates – and thus across the sample thickness. The guard ring is maintained exactly at hot plate temperature in order to minimize lateral heat losses.

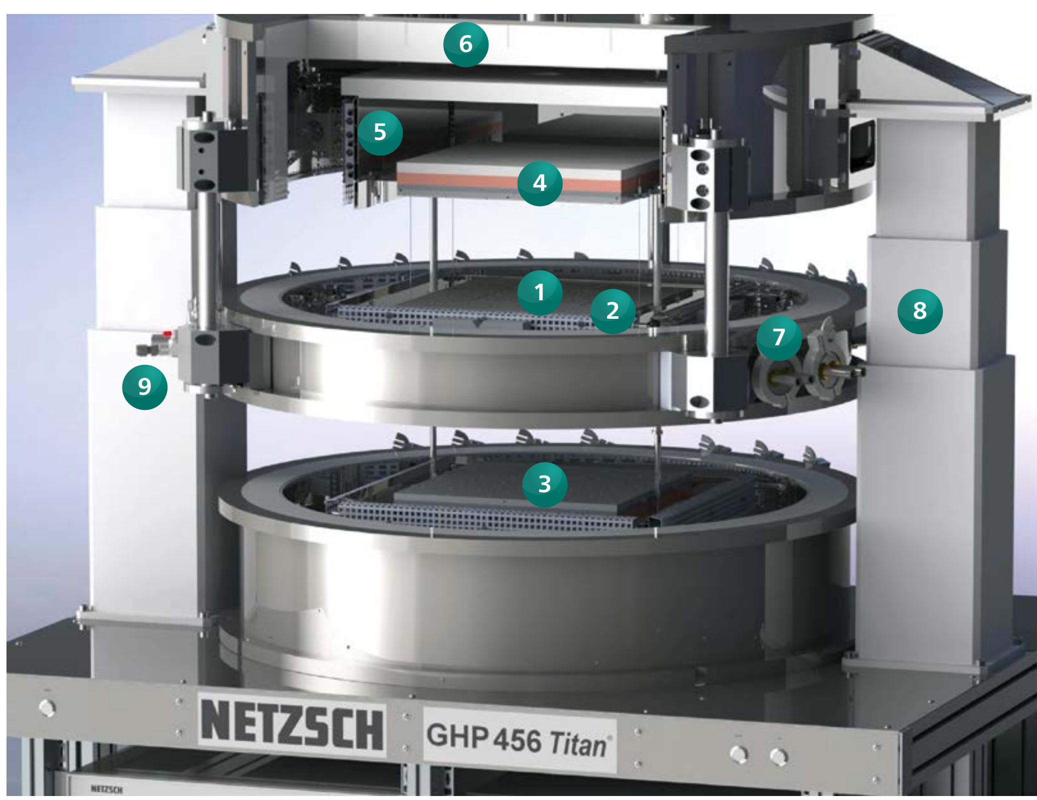
The Absolute Method

The great advantage of the GHP method is that it is an absolute method; i.e., no calibration or correction is required at all. The thermal conductivity values result in the stationary state simply from the:

- precisely measured total power input into the hot plate, $\dot{Q}$,
- average sample thickness, *d*,
- measurement area, *A*, and
- mean temperature difference, ΔT, along the sample or the two samples, as the case may be (the factor 2 results for two samples):

$$\lambda = \frac{\dot{Q} \cdot d}{2A \cdot \Delta T}$$

The Guarded Hot Plate is an **absolute method.**



GHP 456 *Titan*® in open position. The samples are placed between the hot plate (1) with guard ring (2) and the lower (3) and upper cold plates (4), respectively. Additionally shown are the three-part sectional furnace (5), insulation (6), feed-throughs (7), hoisting device (8), and gas connection (9).

GHP 456 *Titan®* – Technology

Ingenious & Smart

Innovative plate materials for higher operating temperatures

The Right Version for Every Application

Two versions of the GHP 456 *Titan®* exist for the investigation of insulating materials, e.g., cryogenic insulation or insulation of high-temperature-furnaces. The instruments cover an extremely broad temperature range; however, the actual minimum achievable working temperature depends on the cooling system used.

Low-temperature version: -160°C to 250°C

High-temperature version (GHP 456 HT *Titan®*): -160°C to 600°C

Controlled and Adaptive Cooling Devices

Various cooling options are available for the system including pressurized air which allows for measurements at temperatures as low as 50°C and a chiller which permits 20°C. The liquid nitrogen (LN_2) system enables measurements down to -160°C (minimal mean sample temperature each).

The cooling strength is automatically minimized for best accuracy and reproducibility. This makes the instrument to the ideal tool for researchers and quality control engineers across a broad field of high-performance insulation materials.

Innovative Plate Materials Minimize the Risk of Thermally Induced Deformation

Plates made of aluminum and tungsten alloy are used to cover a temperature range of up to 250°C and 600°C, respectively.

Each plate, the guard ring and the furnace are connected to a separate control system and stabilized power supply, ensuring fast attainment of programmed plate temperatures and perfect stability.

In equilibrium, differences between the programmed and actual plate temperatures are ≤ 0.01 K for the hot plate and the guard ring.

Two Specimens for Best Accuracy

The system is fully symmetrical. Usually, the measurement is carried out with two identical specimens for best accuracy. However, it is also possible to perform measurements with only one specimen.

According to the relevant standards, this arrangement ensures the maximum possible accuracy of better than 2% at room temperature for most materials.

Defined Environment

A defined environment surrounds the entire plate stack. This sectional furnace (see also schematic on page 3) creates a temperature profile around the plate stack similar to what is generated by the plate stack itself. This nearly eliminates radial heat losses.

Furthermore, all wiring to the plates is connected to the defined environment. Therefore, wire heat loss is negligible.

The vacuum-tight GHP 456 Titan® combines the latest developments in material science and electronics with state-of-the-art design and technology.

Conformity to Standards

From ISO to ASTM

The setup and usage of a GHP instrument are described in international standards such as ISO 8302 or ASTM C177. For the high-temperature range, the technical specification DIN CNT/TS 15548-1 exists. The setup, dimensions and temperature sensors of the GHP 456 *Titan*® are based on these standards.

Widest Temperature Range

Your Application: Covered

The GHP 456 *Titan*® allows for measurements between -160°C and 600°C. The entire temperature range is available – even for a single measurement run.

Measurement Accuracy

Correct Results

The system fulfills the accuracy requirements of ±2% at room temperature and ±5% across the entire temperature range, as stipulated by standard ISO 8302. There are certified standard materials such as IRMM 440 as well as SilCal1100* in order to check the accuracy of the GHP.

Ease-of-Use

Automatic, from Opening the Instrument to Generating Reports

In line with its simple measuring principle, operation of the GHP 456 *Titan*® is also very easy: The apparatus is opened and closed by means of an electronic hoisting device; the operator inserts the specimen(s) from the front. Measurement and the generation of a complete report is all handled by the software (see page 12 ff).

Temperature Measurement

Individually Calibrated Sensors

In the low-temperature version, temperature measurement in the plates, the guard ring and the furnace is accomplished using 31 individually calibrated PT100 temperature sensors. In the high-temperature version, 31 sheeted thermocouples of the same batch are used – one of which is calibrated.

Robustness

Solid for High Reproducibility

The GHP 456 *Titan*® features robust mechanics and temperature stability – prerequisites for good reproducibility of the measurements. Maintenance requirements are relatively low.

Unique Safety

Completely Automatic

Operation of the system is fully automated. Unexpected events are recognized and handled by the software, preventing damage to the device. Even in the case of complete PC software failure, the specially-designed watch-dog system stops the power supply to all plates and therefore also halts any uncontrolled system behavior.

*Including works certificate by NETZSCH

BENEFITS THAT MAKE FOR A GOOD GHP

METHODS
VACUUM-TIGHTNESS
WIZARDS
STABILITY CRITERIA MANAGEMENT
IDLE MODE
ABSOLUTE METHOD
ADAPTIVE COOLING
WIDE TEMPERATURE RANGE
DEFINED ATMOSPHERES
LARGE SPECIMENS
REPORT GENERATOR
ROBUSTNESS
SMARTMODE
STANDARD UNCERTAINTY (GUM)
HIGH ACCURACY

Testing Insulation Materials at Low and High Temperatures

Flexible in the Choice of Test Conditions – From Vacuum to Defined Atmospheres

Porous or Fibrous Insulation

The vacuum-tight design of the GHP 456 *Titan*® is a must for defined atmospheres at the specimen's site: It allows for the application of normal conditions, dry air, or inert, oxygen-free purge gas.

The instrument also allows for measurement in a vacuum under pressures of down to $5 \cdot 10^{-4}$ mbar (0.05 Pa).

All of these possibilities are of particular interest for porous or fibrous insulations since in these cases, the thermal conductivity of the atmosphere in the specimen's free volume represents a significant portion of the specimen's total effective thermal conductivity.

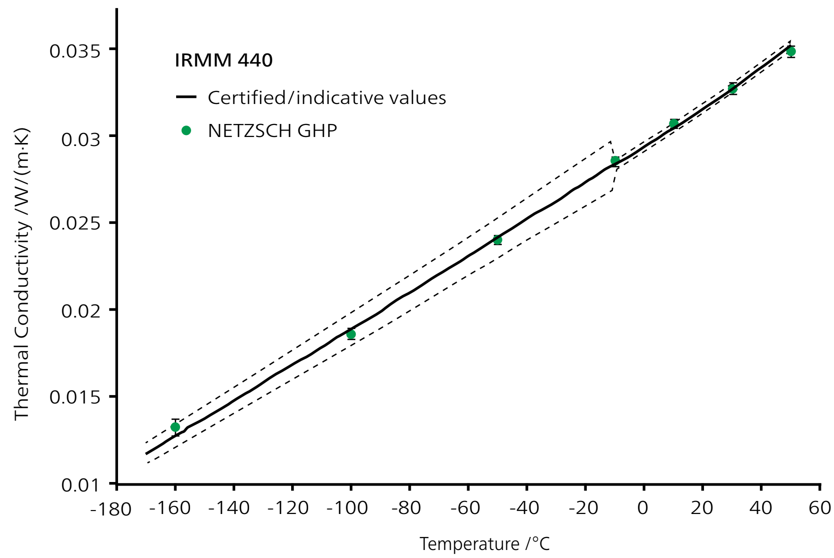
PROVEN ACCURACY

Correct Results

Are the measured thermal conductivity values within the tolerances required by the standards? This important question can only be answered by comparing the measured data with those in literature. Various certified reference materials exist for this purpose, e.g., NIST* SRM 1450D for the temperature range from 7°C to 67°C and IRMM** 440 for the temperature range from -170°C to 50°C.

The plot shows a measurement on IRMM 440 between -160°C and 50°C. The test results are compared with certified values by IRMM (indicative values below -10°C).

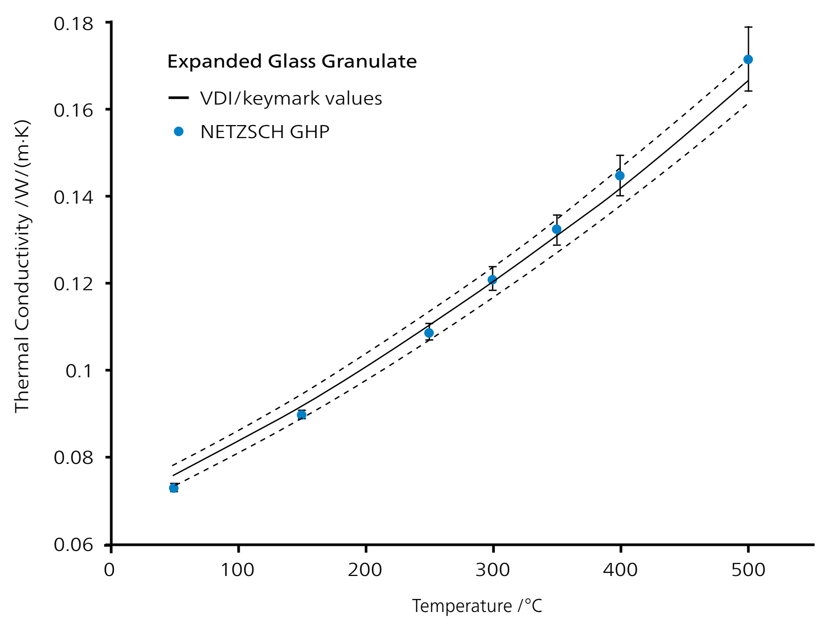
* NIST, National Institute of Standards, USA
** IRMM 440, Institute of Reference Materials and Measurement, Belgium



Thermal conductivity of IRMM 440 in comparison with the values certified by IRMM (solid line; indicative values below -10°C). The dotted lines represent the extended uncertainty budget of the IRMM values (±5% below -10°C, ±1% above -10°C), while the error bars reflect the combined standard measurement uncertainties.

Insulating Materials with Sufficiently Accurate Published Data

Above 67°C, there are no appropriate certified materials. This plot exhibits a comparison between the well-known VDI/Keymark values for an expanded glass granulate (Liaver GmbH & Co. KG) and the measured values obtained by means of the GHP 456 *Titan*®. The agreement in the range from 50°C to 500°C is better than 3%.

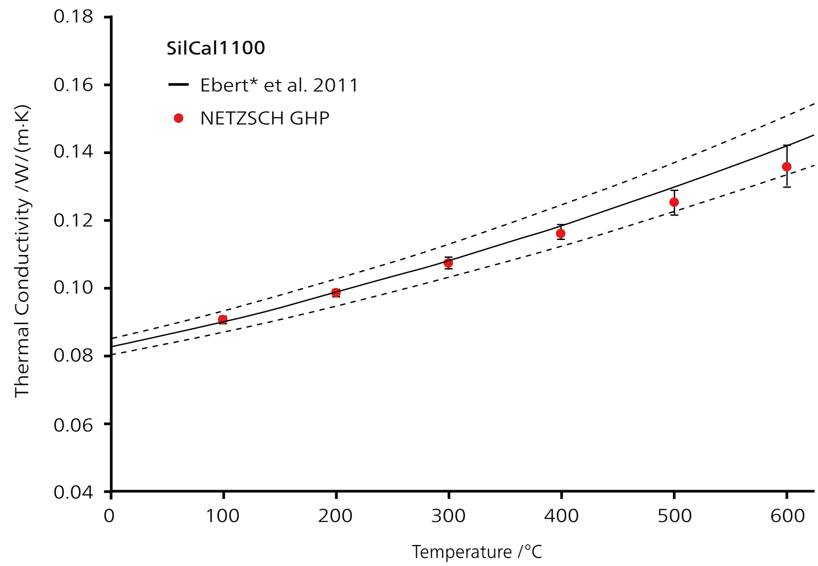


Thermal conductivity of an expanded glass granulate in comparison with the published VDI/Keymark values (solid line). The dotted lines represent the standard uncertainty of the VDI/Keymark values (±3%) while the error bars reflect the combined standard measurement uncertainties.

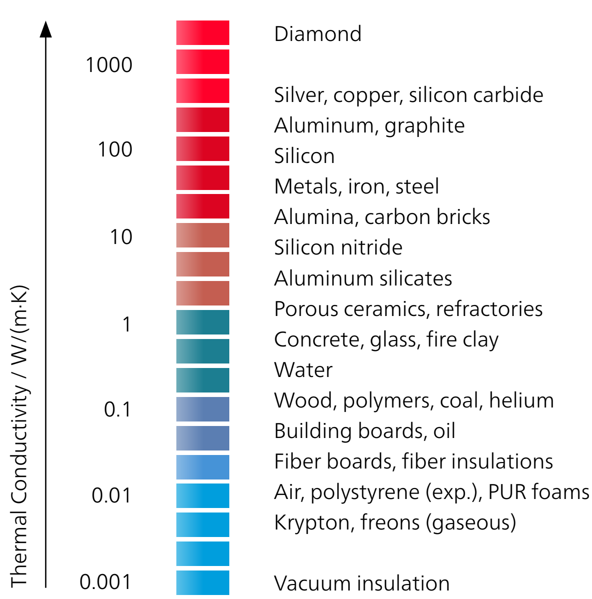
Calcium Silicate – Round-Robin Test Results

Porous calcium silicate SilCal1100 (from CALSITHERM Silikatbaus-toffe GmbH) was tested in a round-robin experiment. Agreement with the round-robin values is approx. 1% to 2% at 100°C and approx. 5% at 600°C.

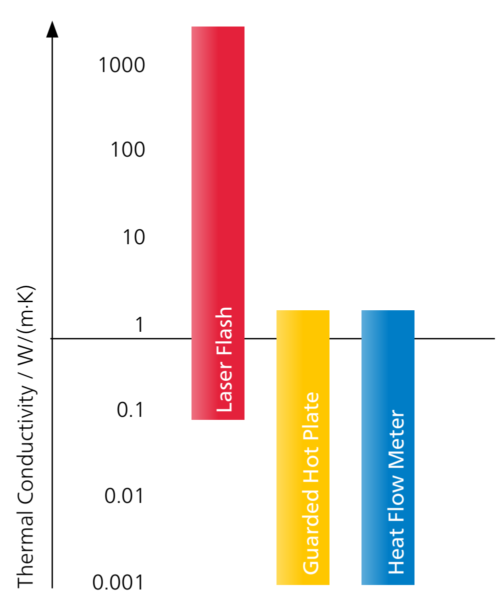
* Hans-Peter Ebert, Frank Hemberger; Bavarian Center of Applied Energy Research, Intern. J. of Thermal Sciences (6/2011)



Thermal conductivity of SilCal1100 in comparison with the published round-robin values (solid line). The dotted lines represent the standard uncertainties of the round-robin values (±3% increasing to ±7%) while the error bars reflect the combined standard measurement uncertainties.



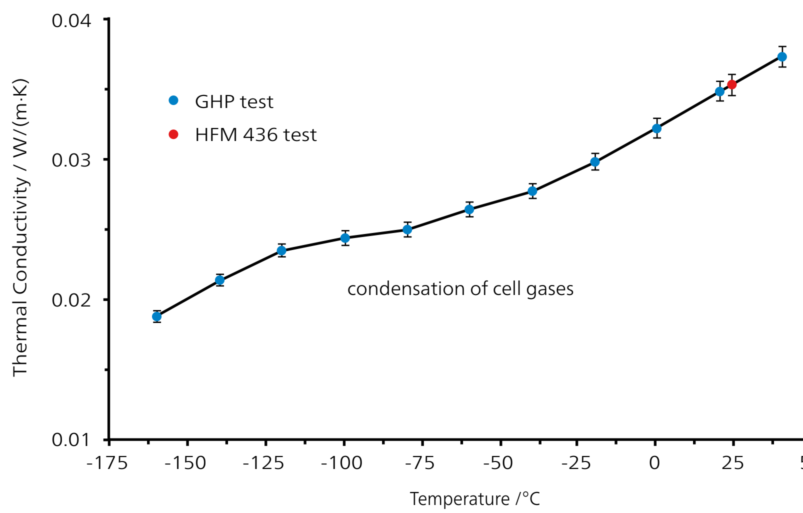
Thermal Conductivity at RT



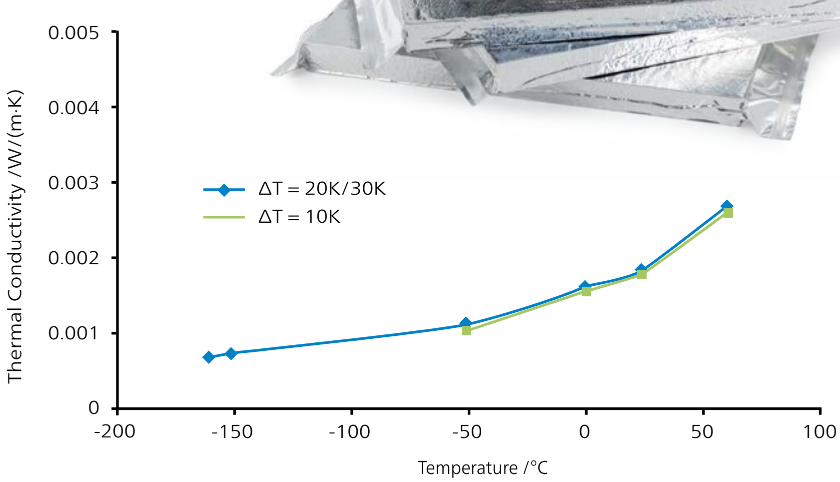
Aged PUR Foam

Insulation of modern house roofs, cryo-tanks or even ships requires materials featuring both low thermal conductivity and high mechanical stability. Polyurethane (PUR) foams offer these properties.

This plot presents a comparison of a test with a heat flow meter (HFM) at room temperature and a GHP test down to -160°C. The two sets of results agree perfectly. Additionally, the GHP result shows the impact of cell-gas condensation between -50°C and -125°C.



GHP measurement compared to a heat flow meter (HFM) test (red measurement point) at 25°C; specimen thickness 25 mm

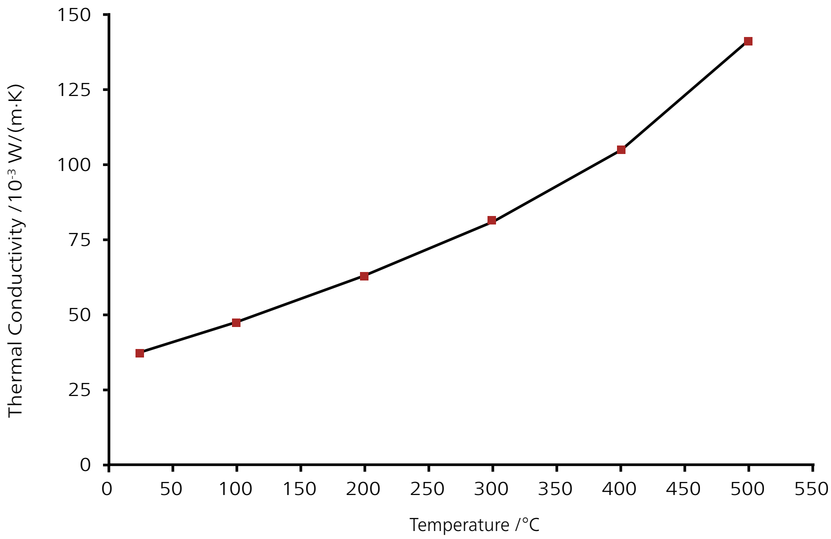


VIP tested at *ΔT* 20/30 K and 10 K between -160°C and 70°C

Ultra-Low-Conductance Insulation Material – VIP

This measurement on a vacuum insulation panel (VIP) shows the thermal conductivity increase with increasing temperature. At room temperature, the thermal conductivity is as low as 1.85 mW/(m·K). In the low-temperature range, even values < 1 mW/(m·K) are measured. The results at different temperature differences, *ΔT*, are in good agreement with each other. This demonstrates the high performance of the GHP 456 *Titan*® – specifically for tests on very low-conductance materials.

High-Temperature Fiberglass Insulation

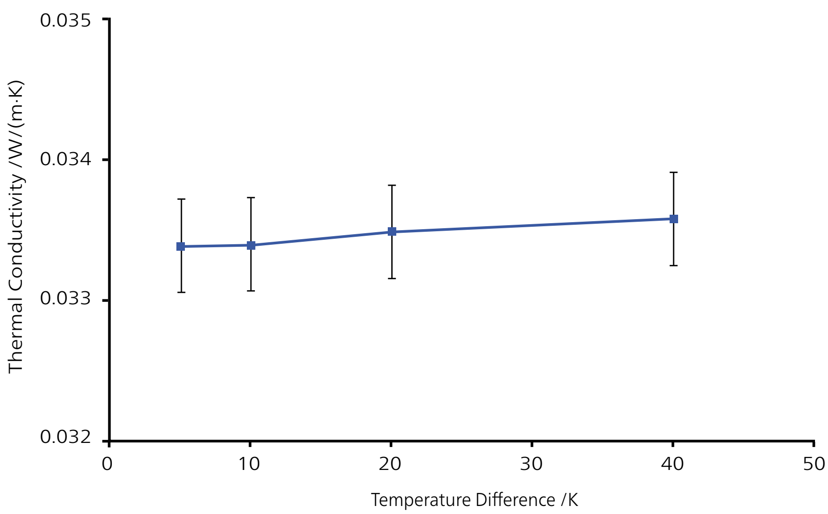


GHP measurement on a glass fiber insulation material

This plot shows a GHP measurement on the most common type of insulation made of molten glass spun into microfibers. Fiberglass is commonly used in different types of insulation: blanket (batts and rolls) and loose-fill and is also available as rigid boards and duct insulation.

Thermal conductivity as a function of temperature is determined using the GHP *HT Titan*® between room temperature and 500°C.

APPLICATION EXAMPLES



GHP measurement on 50-mm-thick Styrodur C in a nitrogen atmosphere at RT

Impact of Temperature Difference

If there is any imbalance in the system (inhomogeneities in the plate temperatures, imperfect gap control or relevant radial heat losses), then different temperature differences, ΔT, cause deviations in the results. This measurement shows that changes in the temperature difference over the specimens from 5 to 40 K have only a slight impact on the measurement results in this GHP system (typically < 0.5% at room temperature).

This clearly demonstrates the near-perfection of the GHP system design.

THE HIGHLIGHT OF *PROTEUS*® SOFTWARE:

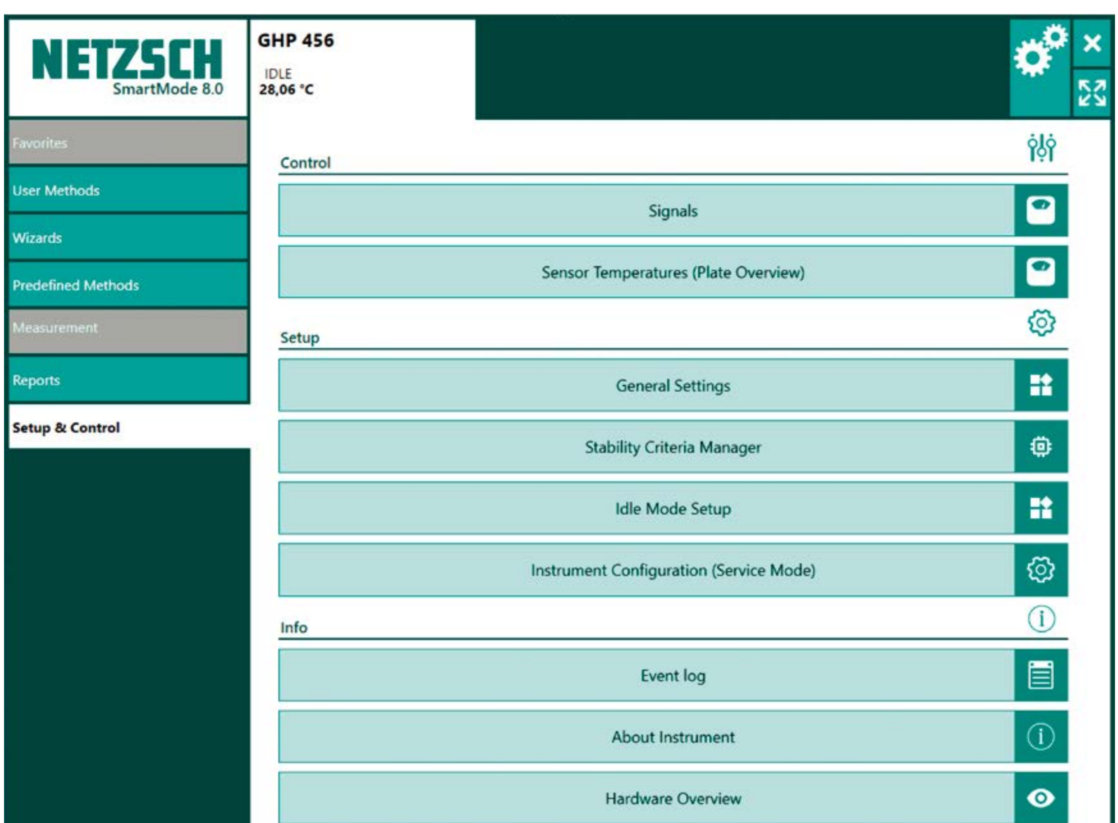
SmartMode

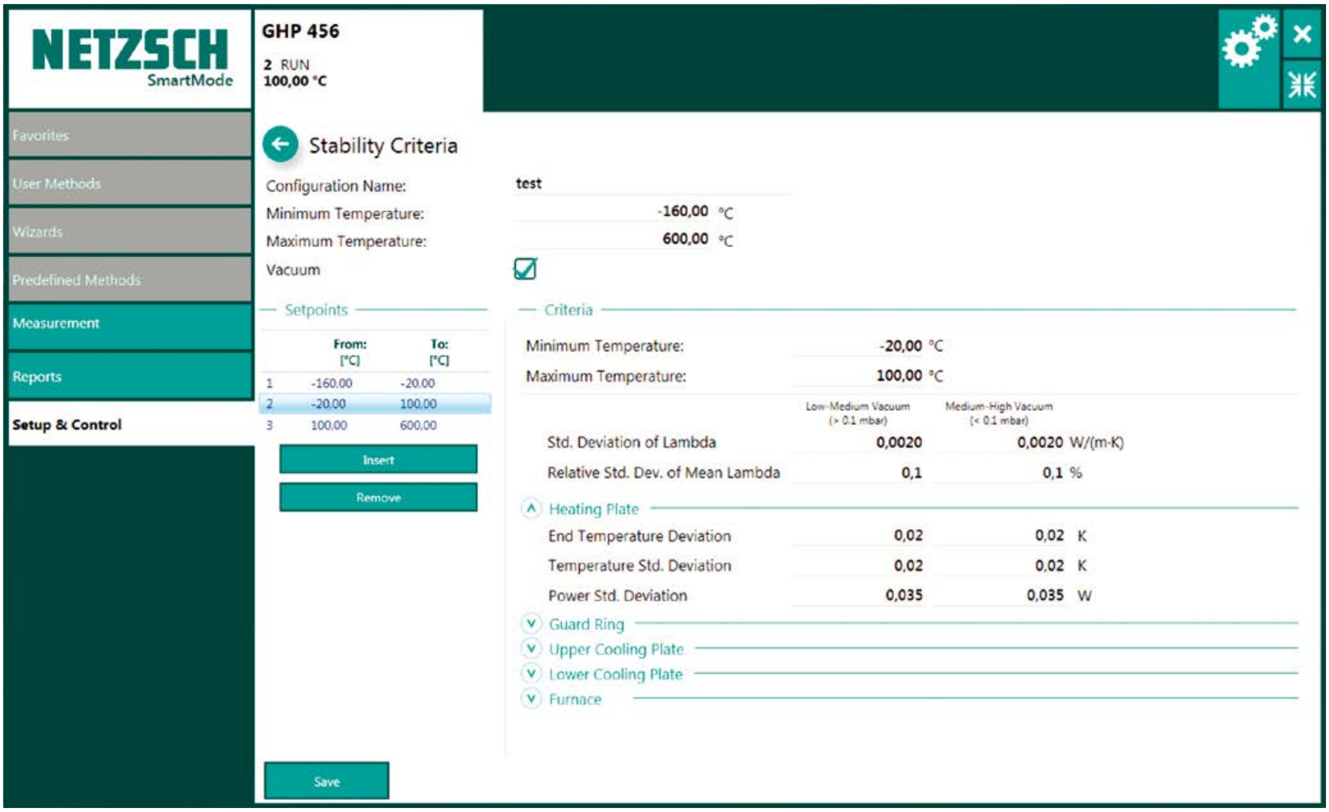
Operating Systems – Windows Professional, Ultimate Pro and Enterprise

The GHP software comes with a 32-/64-bit Windows operating system and allows for connection to a touch screen, keyboard and mouse and the use of a toolbar with shortcut buttons.

SmartMode – Popular with Beginners and Respected by Professionals

The convenient *SmartMode* allows for the prompt start of a measurement via Wizard, via methods which were defined by the user beforehand (known as User Methods), or via Predefined Methods supplied for the NIST 1450D, IRMM 440 and SilCal1100 standard reference materials.





Integrated Stability Criteria Management

When should the measurement points be recorded? The Stability Criteria Manager within the Setup & Control section of *SmartMode* allows conditions to be defined before a measurement starts and even while it is in progress.

The stability criteria ensure optimum reliability and reproducibility for the test results. Of course, the default stability criteria of the instrument work well for most specimens.

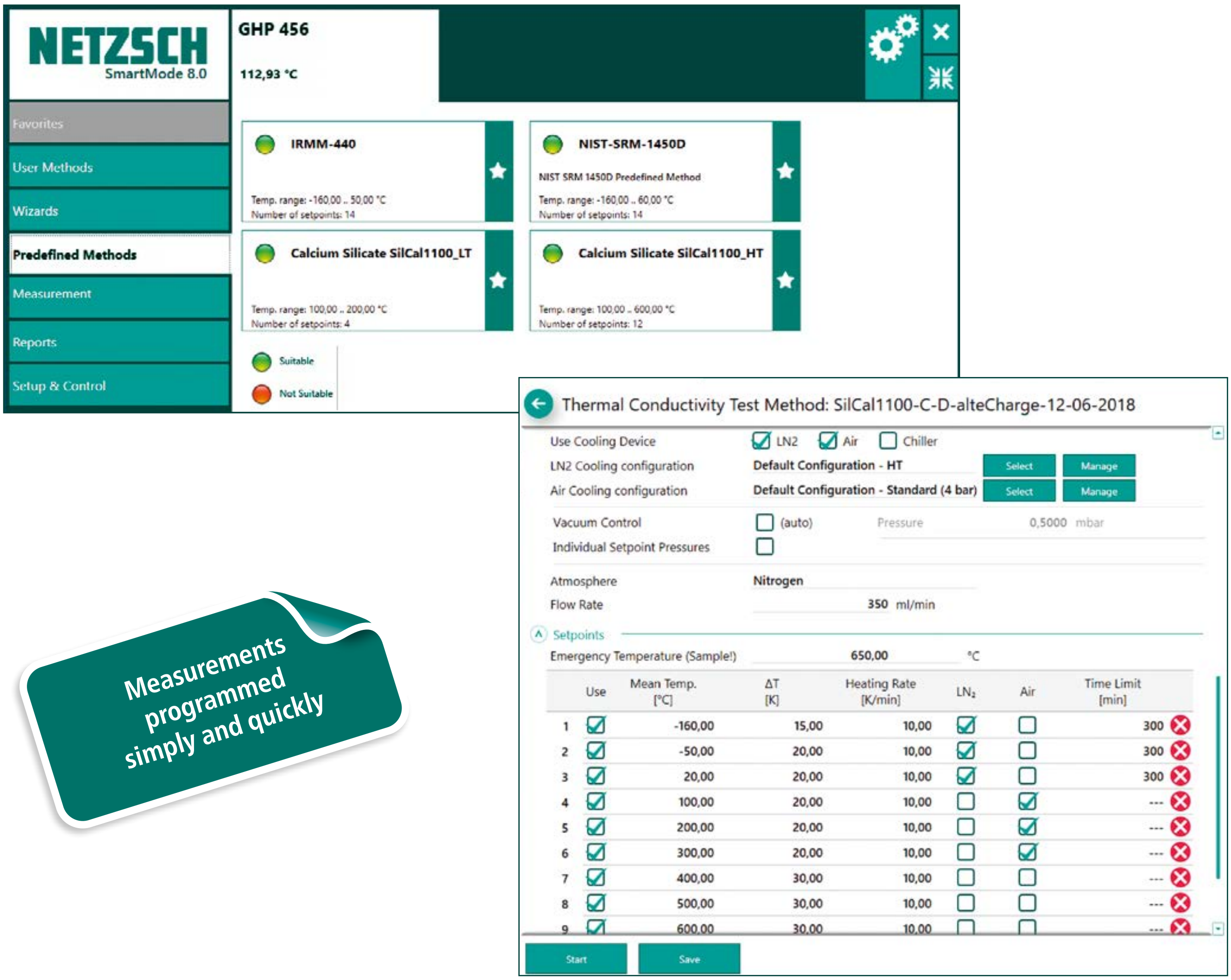
Idle Mode – Control Your Instrument When No Test Is Running

In the Idle Mode Setup, you can control the temperature of the plates and the chiller as well as the vacuum level of the instrument (additional equipment required).

SmartMode – Everything at a Glance!

- Favorites
- User Methods or Predefined Methods
- Measurement
- Reports
- Setup & Control

Being Smart Isn't Hard



User and Predefined Methods

The instrument comes with pre-defined methods for the NIST SRM 1450D, IRMM 440 and SilCal1100 reference materials. For each method, the temperature program and all other measurement parameters are already defined.

In addition, operators can define their own methods, which are available under the User Methods menu.

Languages

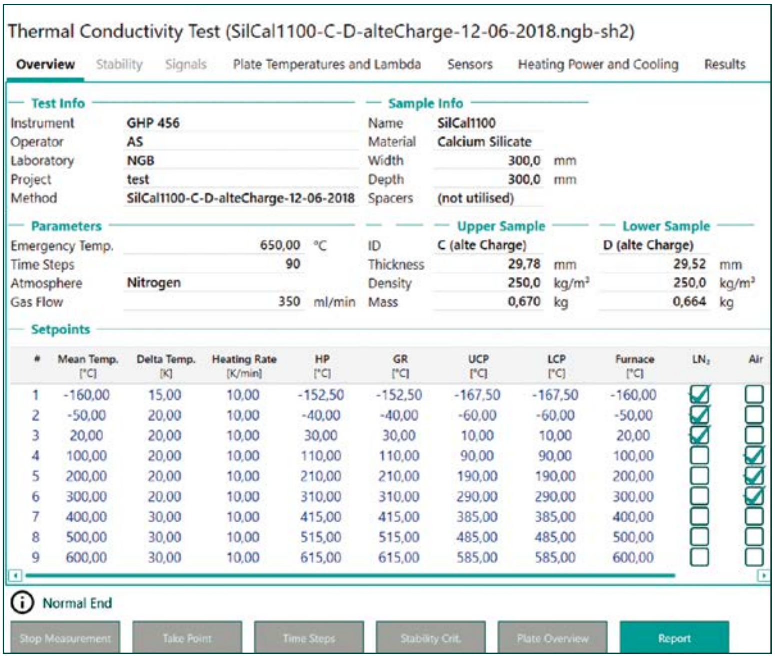
The software can optionally be operated in the German, English, French, Russian*, Chinese* or Japanese* language.

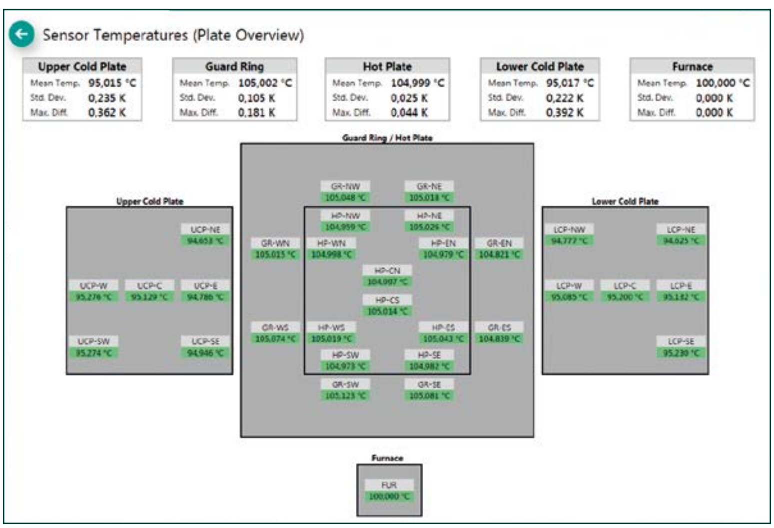
* Russian, Chinese and Japanese languages can only be used if the necessary fonts are installed.

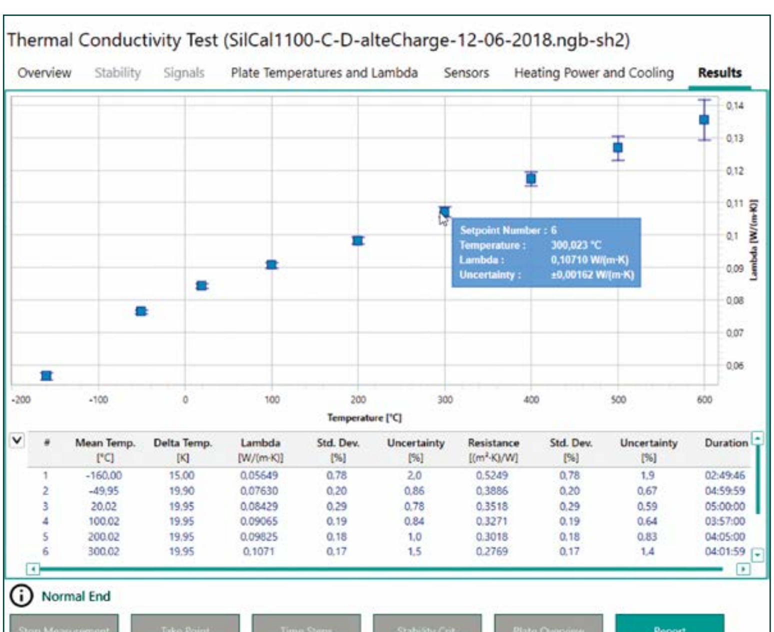
Sophisticated Wizards Guide You Through the Programming

The wizards provide a measurement framework which considerably simplifies any additional definition of a measurement. Cooling devices, controlled vacuum, setpoint temperatures and time limits can all be programmed, depending on your measurement task.

At a Glance – The Measurement Window







Overview

The Measurement Overview shows you all test parameters including sample information, setup, temperature program, etc.

Stability

The Measurement window also includes a stability check and allows for stability criteria to be modified before and during a running measurement.

Plate Temperatures and Lambda

From the charts, users can observe the furnace and all current plate temperatures in addition to the transient lambda curves.

Sensors

The progress of a measurement, including the status of individual sensor temperatures (as a function of time or as a plate overview), can also be seen in *SmartMode*.

Heating Power and Cooling

During a measurement run, controlled heating and cooling is monitored. The entire temperature range of the GHP 456 *Titan*® can be accessed – even in a single measurement – by using liquid nitrogen and compressed air cooling.

Results

The results are presented in the form of a graph and a table. The table shows comprehensive lists of data and includes precision and combined uncertainty for each Lambda (λ) and thermal resistance (R) value.

SmartMode Simply Includes Everything

Report Generator

SmartMode offers convenient, easily accessible report generation in accordance with GHP standards. It allows users to select between either a quick overview of the measurement results, including combined standard uncertainties (GUM), or a full report including comprehensive diagnostic information on the instrument and the measurement parameters.

Of course, the reports can be adapted to one's own corporate identity (CI).

Basic Information

Instrument	GHP 456	Start	12.06.2018 16:53:56
Serial Number		End	14.06.2018 05:21:50
Laboratory	NGB		
Project	test		
Operator	AS		

Test Sample Information

Sample Name	SilCal1100		
Material	Calcium Silicate		
Width × Depth	300,0 mm × 300,0 mm		
Upper Id	C (alte Charge)	Lower Id	D (alte Charge)
Upper Thickness	29,78 mm	Lower Thickness	29,52 mm
Upper Density	250,0 kg/m^3	Lower Density	250,0 kg/m^3
Upper Mass	0,6701 kg	Lower Mass	0,6642 kg

Run Parameters

Use LN2 Cooling	Yes
Cold Plate LN2 cooling configuration	Default Configuration - HT
Use Air Cooling	Yes
Air cooling configuration	Default Configuration - Standard (4 bar)
Use Chiller	No
Use Vacuum	No
Atmosphere	Nitrogen
Gas Flow Rate	350 ml/min
Emergency Temperature	650,00 °C

Setpoints

	Mean Temperature °C	Delta Temperature K	Heating Rate K/min	Time Limit min	Use Cooling	Heating Plate °C	Guard Ring °C	Upper Cold Plate °C	Lower Cold Plate °C	Furnace °C
1	-160,00	15,00	10,00	300	LN2	-152,50	-152,50	-167,50	-167,50	-160,00
2	-50,00	20,00	10,00	300	LN2	-40,00	-40,00	-60,00	-60,00	-50,00
3	20,00	20,00	10,00	300	LN2	30,00	30,00	10,00	10,00	20,00
4	100,00	20,00	10,00	0	Air	110,00	110,00	90,00	90,00	100,00
5	200,00	20,00	10,00	0	Air	210,00	210,00	190,00	190,00	200,00
6	300,00	20,00	10,00	0	Air	310,00	310,00	290,00	290,00	300,00
7	400,00	30,00	10,00	0		415,00	415,00	385,00	385,00	400,00
8	500,00	30,00	10,00	0		515,00	515,00	485,00	485,00	500,00
9	600,00	30,00	10,00	0		615,00	615,00	585,00	585,00	600,00

Stability Parameters

Stability Configuration Name	Default Configuration - SHT
Time Steps	90
Individual Setpoint Time Limits	Yes

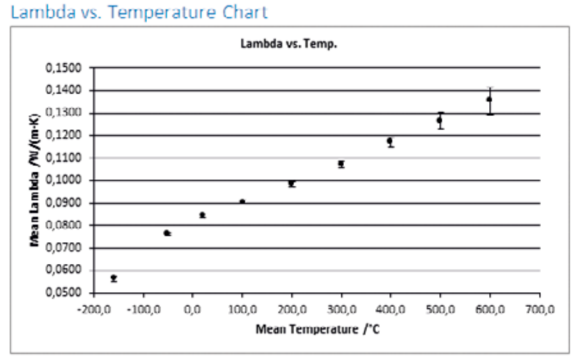
Advanced Parameters

Individual Furnace Offsets	No
Furnace Offset	0,00 °C
Use Custom Offsets	No
Control Configuration Name	Default Configuration - SHT

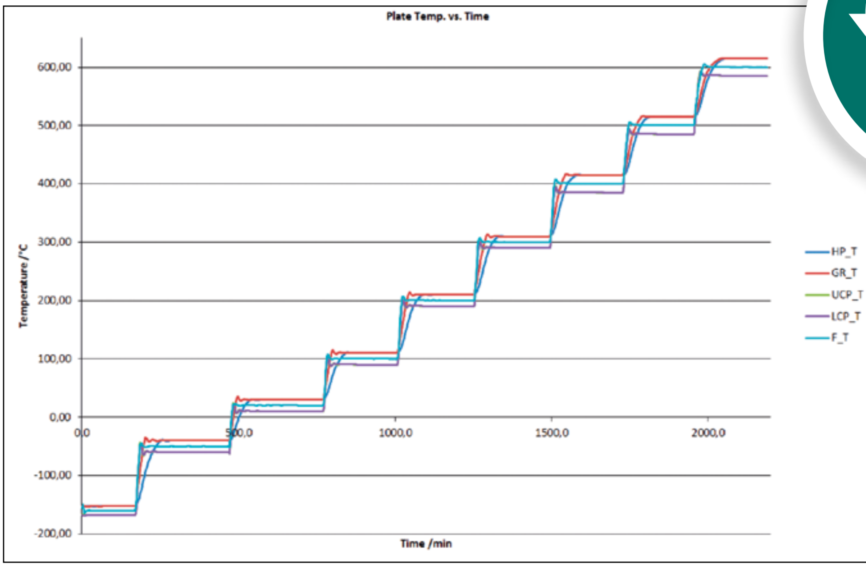
Measurement Results

	Mean Temperature °C	Delta Temperature K	Thermal Conductivity W/(m·K)	Standard deviation %	Comb. Std. uncertainty %	Thermal Resistance (m^2·K)/W	Standard deviation %	Comb. Std. uncertainty %	Duration
1	-160,00	15,003	0,05649	0,78	2,0	0,5249	0,78	1,9	02:49:47
2	-49,95	19,895	0,07630	0,20	0,86	0,3886	0,20	0,67	04:59:59
3	20,02	19,953	0,08429	0,29	0,78	0,3518	0,29	0,59	05:00:01
4	100,02	19,951	0,09065	0,19	0,84	0,3271	0,19	0,64	03:57:00
5	200,02	19,950	0,09825	0,18	1,0	0,3018	0,18	0,85	04:05:00
6	300,02	19,952	0,1071	0,17	1,5	0,2769	0,17	1,4	04:02:00
7	400,02	29,949	0,1172	0,21	1,8	0,2529	0,21	1,7	03:52:59
8	500,02	29,951	0,1267	0,22	2,9	0,2340	0,22	2,8	03:47:00
9	600,02	29,964	0,1353	0,40	4,6	0,2191	0,40	4,5	03:54:00

Lambda vs. Temperature Chart

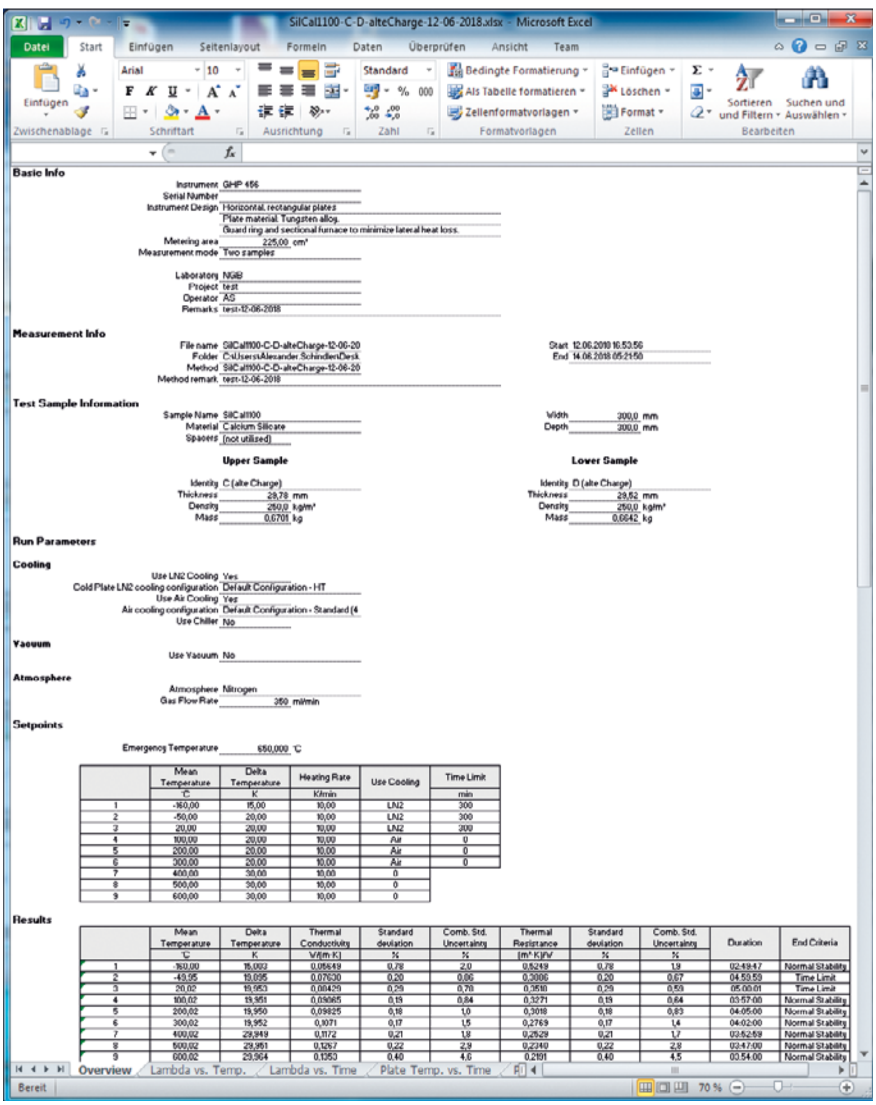


A report generator that meets all your needs.



Plattentemperaturen gegen die Zeit

Examples of charts which the Report Generator can create, according to your requirements.



Reports can be created in different file formats: Excel, Word, cvs, txt

Key Technical Data

	GHP 456 *Titan*®
Technique/Design	▪ Absolute method (no calibration or reference materials required) ▪ Symmetrical arrangement ▪ Fully automated operation
Standards	Based on standards such as ISO 8302, ASTM C177, DIN/EN 12667, DIN/EN 12939, etc.
Mean specimen temperature range	▪ Low-temperature version: -160°C to 250°C ▪ High-temperature version: -160°C to 600°C Both versions require LN_2 cooling for the sub-ambient temperature range
Cooling systems	▪ Liquid nitrogen (LN_2): -160°C to 250°C ▪ Compressed air: 50°C to 300°C ▪ Chiller: 20°C to 85°C → No active cooling from 300°C to 600°C
Plate dimensions	▪ 300 mm x 300 mm ▪ Motorized plate hoist
Plate material	▪ Low-temperature version: Aluminum alloy ▪ High-temperature version: Tungsten alloy
Plate temperature range	▪ Standard version: -180°C to 270°C ▪ High-temperature version: -180°C to 620°C
Vacuum-tightness	By design, 5×10^{-4} mbar (0.05Pa)
Defined pressure levels	Controlled between 0.1 mbar and 100 mbar
Specimen thickness	▪ Up to 100 mm (typically 10 ... 50 mm) ▪ Max. difference in thickness for the two specimens to be measured: 2%
Atmosphere/ pressure level	▪ Oxidizing up to 300°C ▪ Inert ▪ Vacuum ▪ Defined pressure levels
Thermal conductivity range	0.003 to 2 W/(m·K)*
Minimum measurable thermal resistance	0.02 m^2·K/W*
Accuracy	Typically 2%*
Reproducibility	Typically < 1%*
Software specialties	*SmartMode*, including: ▪ Method-based, easy operation (e.g., user and predefined methods) ▪ Support of controlled, adaptive cooling ▪ Report generator ▪ Results including combined standard uncertainties according to GUM**

* Depending on the measurement conditions and specimen properties
** GUM = Guide to the Expression of Uncertainty in Measurement

All over the world, the name NETZSCH stands for comprehensive support and expert, reliable service, both before and after sale. Our qualified personnel from the technical service and application departments are always available for consultation. In special training programs tailored for you and your employees, you will learn to tap the full potential of your instrument.

To maintain and protect your investment, you will be accompanied by our experienced service team over the entire life span of your instrument.

Expertise in SERVICE

TECHNICAL SERVICE

- Maintenance and Repair
- Software Updates
- Exchange Service
- IQ/OQ Documents
- Calibration Service
- Spare Part Assistance
- Moving Service

TRAINING

- Training
- Comprehensive Instrument and Method Training

LABORATORY

- Application Service and Contract Testing

The NETZSCH Group is an owner-managed, international technology company with headquarters in Germany. The Business Units Analyzing & Testing, Grinding & Dispersing and Pumps & Systems represent customized solutions at the highest level. More than 3,800 employees in 36 countries and a worldwide sales and service network ensure customer proximity and competent service.

Our performance standards are high. We promise our customers Proven Excellence – exceptional performance in everything we do, proven time and again since 1873.

When it comes to Thermal Analysis, Calorimetry (adiabatic & reaction) and the determination of Thermophysical Properties, NETZSCH has it covered. Our 50 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.

NETZSCH-Gerätebau GmbH
Wittelsbacherstraße 42
95100 Selb
Germany
Tel.: +49 9287 881-0
Fax: +49 9287 881 505
at@netzsch.com

NETZSCH®

www.netzsch.com

NGB · GHP 456 *Titan*® and GHP 456 *HT Titan*® · EN · 0221 · NWS · Technical specifications are subject to change.