NETZSCH

Analyzing & Testing

Thermal Insulation Materials

Material Characterization, Phase Changes, Thermal Conductivity

Leading Thermal Analysis

Thermal Insulation Materials

Common Types of Insulation Materials

Thermal insulation materials are specifically designed to reduce the heat flow by limiting heat conduction, convection, radiation or all three while performing one or more of the following functions:

- Conserving energy by reducing heat loss or gain
- Controlling surface temperatures for personnel protection and comfort
- Facilitating vapor flow and water condensation of a process
- Increasing operating efficiency of heating/ventilating/cooling, plumbing, steam, process and power systems found in commercial and industrial installations
- Assisting mechanical systems in meeting standard criteria in food and cosmetic plants

There are three general material types into which thermal insulation materials can be categorized.

Fibrous Insulations

Fibrous insulations are composed of small diameter fibers which finely divide the air space. The fibers may be perpendicular or parallel to the surface being insulated, and they may or may not be bonded together.
Silica, glass, rock wool, slag wool and alumina silica fibers are used. The most widely used insulations of this type are glass fiber and mineral wool.

Cellular Insulations

Cellular insulations contain small individual cells separated from each other. The cellular material may be glass or foamed plastic such as polystyrene (closed cell), polyurethane, polyisocyanurate, polyolefin, or elastomer.

Granular Insulations

Granular insulations have small nodules which contain voids or hollows. These are not considered true cellular materials since gas can be transferred between the individual spaces. This type may be produced as a loose or pourable material, or combined with a binder and fibers to make a rigid insulation.

Examples of these insulations are calcium silicate, expanded vermiculite, perlite, cellulose, diatomaceous earth and expanded polystyrene.

Main Modes of Heat Transfer

Heat transfer is the transition of thermal energy, or simply heat, from a hotter object to a cooler object. There are three main modes of heat transfer:

Convection

Convection is usually the dominant form of heat transfer in liquids and gases. Convection comprises the combined effects of conduction and fluid flow. In convection, enthalpy transfer occurs by the movement of hot or cold portions of the fluid/gas together with heat transfer by conduction.

Radiation

Radiation is the only form of heat transfer that can occur in the absence of any form of medium (i.e., in a vacuum). Thermal radiation is based on the emission of electromagnetic radiation, which carries energy away from the surface. At the same time, the surface is constantly bombarded by radiation from the surroundings, resulting in the transfer of energy to the surface.

Conduction

Conduction is the most significant means of heat transfer in a solid. On a microscopic scale, conduction occurs as hot, rapidly moving or vibrating atoms and molecules interact with neighboring atoms and molecules, transferring some of their energy (heat) to these neighboring atoms. The free movement of electrons also contributes to conductive heat transfer. To quantify the ease with which a particular medium conducts, the thermal conductivity, also known as the conduction coefficient, λ, has been employed. The thermal conductivity λ is defined as the quantity of heat, Q, transmitted in time (t) through a thickness (x), in a direction normal to a surface of area (A), due to a temperature difference (ΔT).

A quantitative expression relating the rate of heat transfer, the temperature gradient and the nature of the conducting medium is attributed to Fourier (1822; Fourier's Law, 1-dim.):

$$\dot{Q} = -\lambda A \frac{T_2-T_1}{\Delta x} \; ; \; \dot{q} = -\lambda \frac{\Delta T}{\Delta x}$$

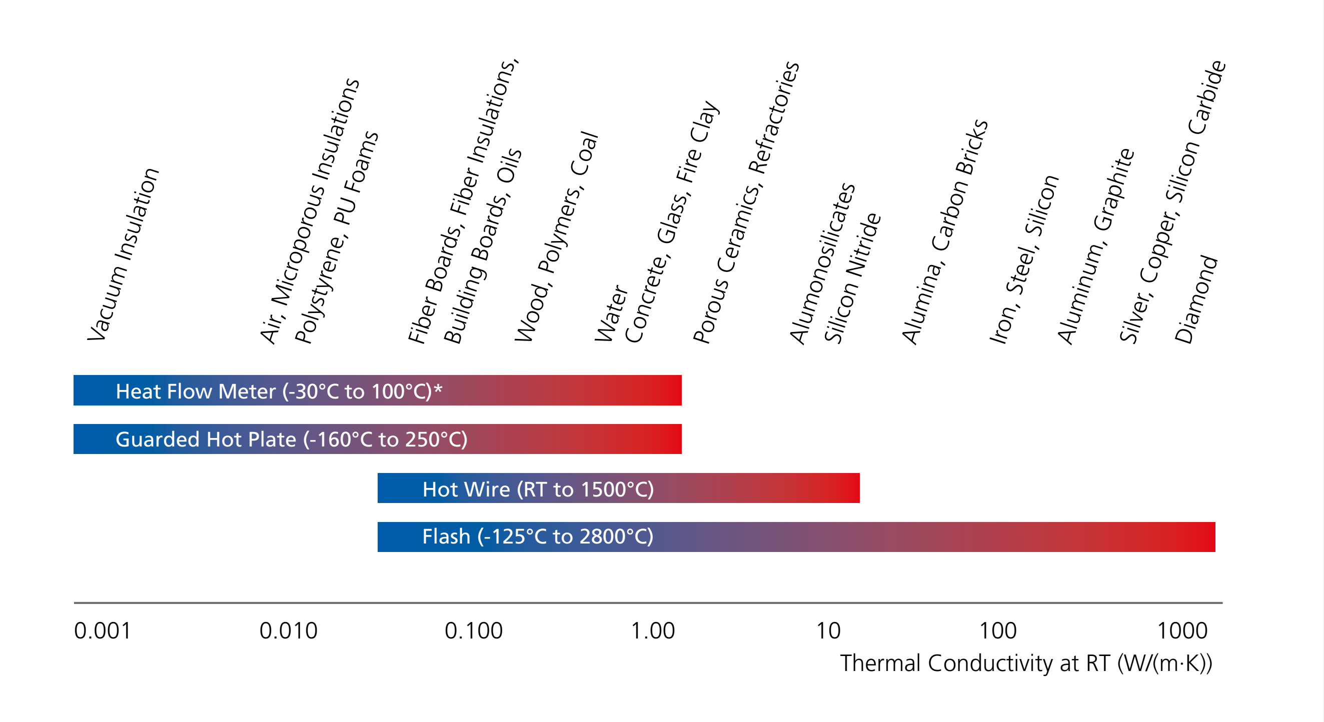
Testing Insulation Materials

During development and quality control, the extent to which thermal insulation materials fulfill their performance expectations is continuously scrutinized. Some of the questions which arise include:

- How is a particular insulation material performing?
- How can I insulate cryo tanks in the best possible way?
- What is the optimum insulation for furnaces operating under different temperature, gas or pressure conditions?
- What is the heating/cooling load of a building?
- How does this change with the weather, and how can I improve it?
- How can I improve the heat transfer from an electronic component?
- How do I design a heat exchanger system to achieve the required efficiency, and what are the best materials to use?

To answer questions like these, material properties such as **thermal diffusivity and thermal conductivity** must be known. To analyze insulations with respect to their heat transfer behavior, a heat flow meter (HFM) or guarded hot plate (GHP) is usually used.

For highly conductive ceramics, metals or diamond composites, the Laser Flash method (LFA) is often employed. The thermal conductivity of refractory materials is determined on large samples with hot wire systems.
In addition, further thermophysical properties such as specific heat (c_p) can be analyzed with high-temperature differential scanning calorimeters (DSC), while density and length changes can be investigated with dilatometers.



* plate temperature

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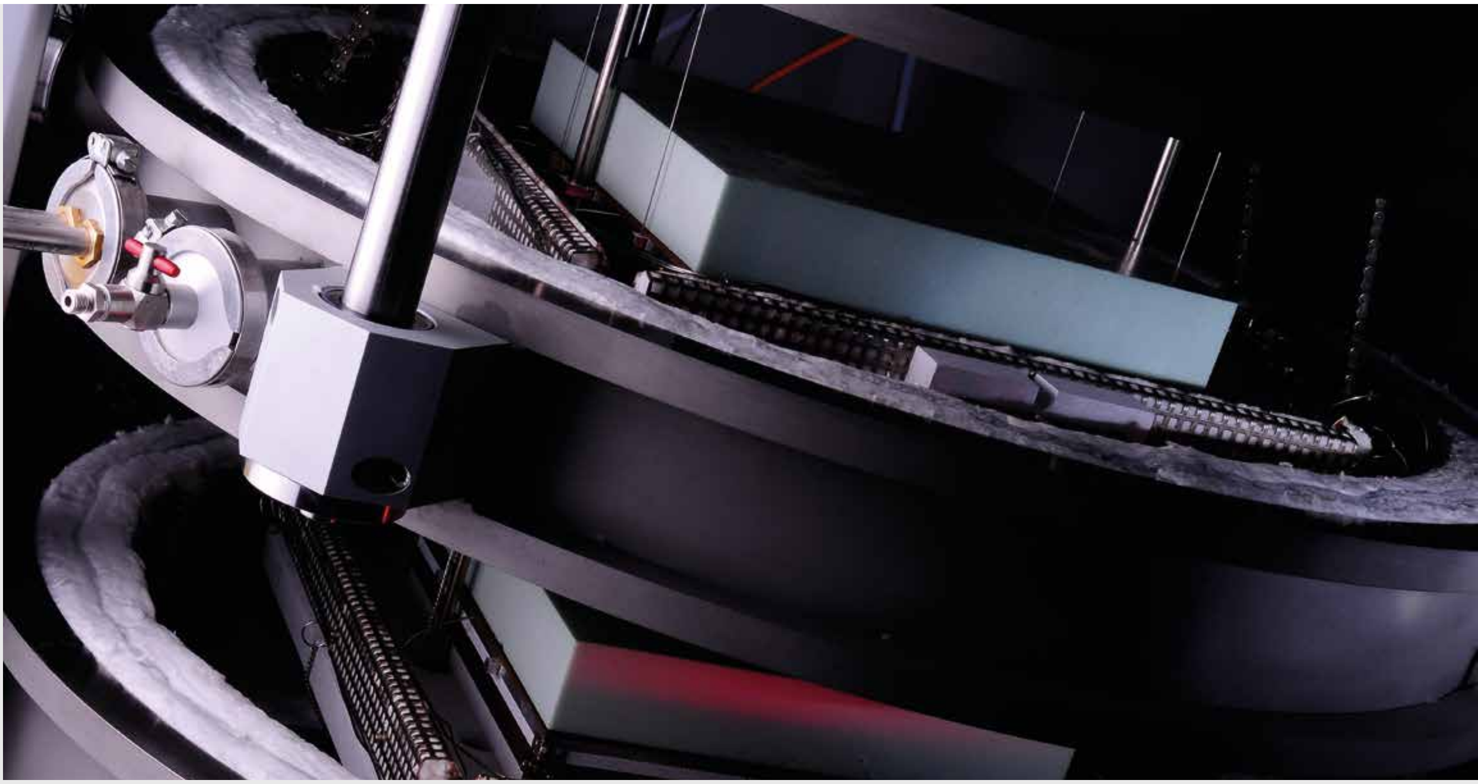
Standards for Testing of Insulation Materials

The guarded hot plate and heat flow meter methods are standardized test techniques. The "insulation materials" application has many standards associated with it. The NETZSCH GHP 456 and HFM 436 series instruments are confirmed for compliance with all of these. Examples for hot wire standards are listed as well.

International Standards	
ASTM C177	Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus
ASTM C335 - 05ae1	Standard Test Method for Steady-State Heat Transfer Properties of Pipe Insulation
ASTM C518	Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus
ASTM C1363 - 05	Standard Test Method for Thermal Performance of Building Materials and Envelope Assemblies by Means of a Hot Box Apparatus
ASTM D5470 - 06	Standard Test Method for Thermal Transmission Properties of Thermally Conductive Electrical Insulation Materials
ASTM E1225 - 04	Standard Test Method for Thermal Conductivity of Solids by Means of the Guarded-Comparative-Longitudinal Heat Flow Technique
ASTM E1530 - 06	Standard Test Method for Evaluating the Resistance to Thermal Transmission of Materials by the Guarded Heat Flow Meter Technique
ASTM F433 - 02(2009)	Standard Practice for Evaluating Thermal Conductivity of Gasket Materials
DIN EN 12667/12939	European Standard for Measurements of Insulating Materials Using the Heat Flow Meter Method or the Guarded Hot Plate Technique
DIN EN 13163	European Standard for Characterization of Foam Insulations for Building Applications Using the Heat Flow Meter Method or the Guarded Hot Plate Technique
ISO 8301/8302	Standard Test Technique for Measurements of Insulating Materials Using the Heat Flow Meter/Guarded Hot Plate Method
ISO 8894-1 (EN 993-14)	Determination of Thermal Conductivity; Hot-Wire Method (cross array; $\lambda \leq 1.5$ W/mK)
ISO 8894-2 (EN 993-15)	Determination of Thermal Conductivity; Hot-Wire Method (cross array; $\lambda \leq 25$ W/mK)

Determination of Thermal Conductivity – Instruments



NETZSCH GHP 456 *Titan*®

Thermal Conductivity

Thermal Conductivity λ is a thermophysical property that determines the ability of a material to transfer heat. The value of the thermal conductivity is characterized by the quantity of heat passing per unit of time per unit area at a temperature drop of 1°C per unit length. It depends on the medium's phase, temperature, density, molecular bonding, humidity and pressure.

The R value is a measure of thermal resistance used in the building and construction industry. The higher the number, the better the effectiveness of the building insulation. R value is the reciprocal of U value.

$$R = \frac{d}{\lambda} = \textit{thermal resistance}$$

$$(\Delta T = R\,\dot{q})$$

Often in heat transfer the concept of controlling resistance is used to determine how to either increase or decrease heat transfer. Heat transfer coefficients represent how much heat is able to transfer through a defined region of a heat transfer area. The inverse of these coefficients are the resistances of those areas. The heat transfer coefficient k or U value is defined as:

$$k = \frac{\lambda}{d} = U\ \textit{value}\ \ (k\ \textit{value})$$

Thermal Conductivity Tester TCT 426

Principle of Operation

The TCT 426 operates according to the hot wire technique. A linear heat source (hot wire) is placed between two test pieces which form the sample. The hot wire is loaded with a constant heating power. The temperature increase at the hot wire, or parallel to it, is measured versus time. Measurements can be carried out from room temperature to 1450°C by placing the sample setup in a stable homogenous furnace.

Measurement Techniques

Depending on the thermal conductivity of the material, various measurement techniques are available. The cross-wire technique can be used to measure thermal conductivities below 2 W/(mK). The parallel-wire technique can be used for thermal conductivities below 20 W/(mK). In the T(R) technique, the hot wire itself is used for the measurement of the temperature rise by measuring the temperature-dependent resistance of the platinum wire. This method can be employed for thermal conductivities below 15 W/(mK).

The TCT 426 thermal conductivity tester allows for the use of any of the three methods described in easily interchangeable, pre-wired measuring frames.

NETZSCH Thermal Conductivity Tester 426

Additional Information

visit www.netzsch.com/n22123

Determination of Thermal Conductivity – Instruments

Heat Flow Meters HFM 436 *Lambda* Series – Quality Control Assured

Heat flow meters are accurate, fast and easy-to-operate instruments for measuring the thermal conductivity of low-conductivity materials such as insulations. The heat flow meter is a calibrated instrument which tests according to various standards (see standards on page 5). The HFM 436 *Lambda* series owes its speed of measurement and precision to patented temperature control (three temperature sensors in each plate) and heat flux measurement technology.

Instruments Characteristics

The instrument is stable within 0.10% to 0.25% over the course of several days, providing excellent repeatability. This is valuable for conducting aging studies or examining the long-term consistency of a product. Steady-state stability criteria can often be met in approx. 15 minutes, resulting in greater laboratory throughput and productivity gains. The HFM 436 comes with an integrated µm-resolution LVDT system, allowing automatic determination of the sample's actual thickness. In addition, an optional feature unique to the HFM 436 allows the user to apply a precise load on the specimen, enabling control of the thickness, and thus density, of compressible materials.

HFM 436 *Lambda*

Thanks to a carefully designed test chamber, loading heavy and thick specimens is made easy.

Additional Information

visit www.netzsch.com/n12511

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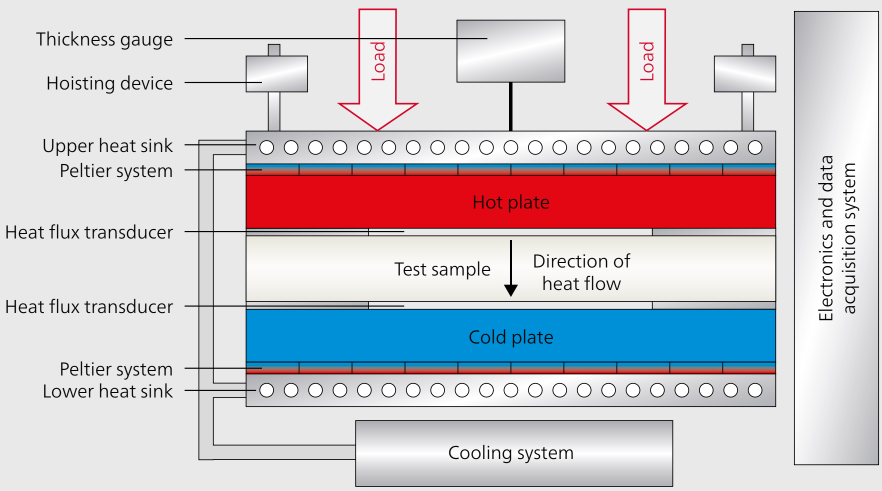


Schematic design of the NETZSCH HFM 436/3/1 *Lambda* (plate temperatures between 0°C and 100°C)

Principle of Operation

The sample is placed between two heated plates set at different temperatures. The heat flow through the sample is measured by heat flux transducers. After reaching thermal equilibrium, the test is carried out. Only the sample center is used for analysis. The heat flux transducer output is calibrated with a NIST certified reference standard.

Technical Key Specifications of the Various HFM 436 *Lambda* Models

	HFM 436/3/0	HFM 436/3/1	HFM 436/3/1E	HFM 436/6/1
Plate Temperature Ranges	Fixed, 0°C to 40°C	Variable, 0°C to 100°C	Variable, -30°C to 90°C	Variable, -20°C to 70°C
Cooling System	Forced Air	Forced Air	External Chiller	External Chiller
Plate Temperature Control	Peltier System	Peltier System	Peltier System	Peltier System
Thermocouple Precision	± 0.01°C	± 0.01°C	± 0.01°C	± 0.01°C
Number of Programmable Temperatures	1	10	10	10
Specimen Size (L x W x H) mm	305 x 305 x 100	305 x 305 x 100	305 x 305 x 100	610 x 610 x 200
Thermal Resistance Range	0.05 to 8.0 $m^2 \cdot K/W$	0.05 to 8.0 $m^2 \cdot K/W$	0.05 to 8.0 $m^2 \cdot K/W$	0.1 to 8.0 $m^2 \cdot K/W$
Thermal Conductivity Range	0.002 to 2.0 W/(m·K)	0.002 to 2.0 W/(m·K)	0.002 to 2.0 W/(m·K)	0.002 to 1.0 W/(m·K)
Repeatability	0.25 %	0.25 %	0.25 %	0.25 %
Accuracy	± 1 to 3 %	± 1 to 3 %	± 1 to 3 %	± 1 to 3 %
Dimensions (L x W x H) mm	480 x 630 x 510	480 x 630 x 510	480 x 630 x 510	800 x 950 x 800
Variable Load	up to 21 kPa	up to 21 kPa	up to 21 kPa	N/A
Instrumentation Kit	Available	Available	Available	N/A

Determination of Thermal Conductivity – Instruments

GHP 456 *Titan®* – An Absolute Technique for Research

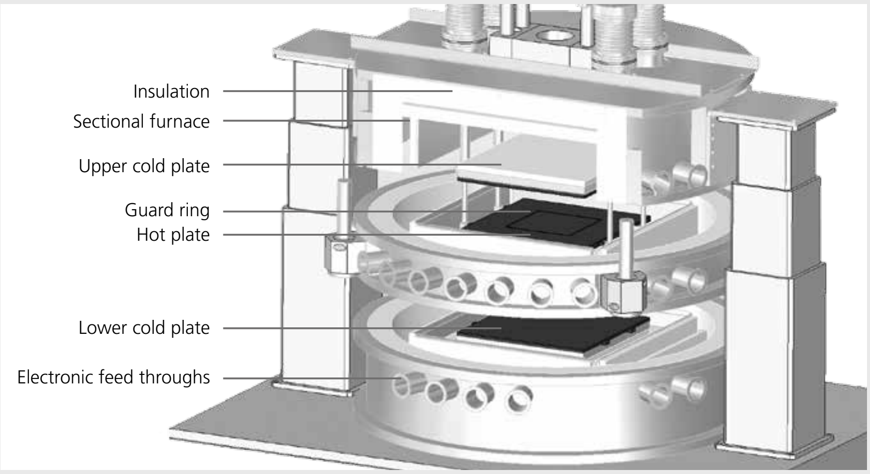
The GHP 456 *Titan®* is the ideal tool for researchers and scientists in the field of insulation testing. Based on the well-known, standardized guarded hot plate technique (see page 5), the system features unrivaled performance. Aluminum plates are used to cover a temperature range from -160°C to 250°C. The GHP principle is based on an absolute measurement method and therefore requires no calibration standards.

The instrument works with sheeted, individually calibrated PT100 resistance temperature sensors (resolution 1 mK, accuracy in the range of 100 mK). The plate stack is placed in a vacuum-tight housing. Depending on the pump employed (rotary or turbo pump systems), measurements can be carried out under vacuum down to 10^{-4} mbar (0.01 Pa) as well as under very pure atmospheres (oxidizing or inert) or defined pressure levels. The system is fully symmetrical and requires two samples for each test. This arrangement ensures the maximum possible accuracy of better than 2%. Each plate, the guard ring and the furnace are connected to a separate control system and a stabilized power supply. The fully-digital five-stage PID control system ensures that plate temperatures are reached quickly and that perfect stability is achieved.

Unique Features

- Motorized hoist for the vacuum housing and plates
- Artificial environment (sectional furnace) for reduced lateral heat loss
- High-resolution temperature measurement (1 mK) using separately calibrated temperature sensors
- Guaranteed mechanical stability of the plates even at minimum or maximum service temperature
- Elimination of radial heat flow via wiring (sensors, power supply)
- Newly developed computerized temperature control system for increased test speed

NETZSCH GHP 456 *Titan®*



Principle of Operation

The hot plate and the guard ring are sandwiched between two samples of the same material and about the same thickness.
Auxiliary heaters (cold plates) are placed above and below the samples. The cold plates are heated such that a well-defined, user-selectable temperature difference is established between the hot and the cold plates (over the sample thickness). The power input in the hot plate with area A is then measured as soon as thermal equilibrium is reached. Using the measured sample thicknesses, temperatures and power inputs, the thermal conductivity can be calculated using the steady-state heat transfer equation:

$$\dot{Q} = -\lambda 2A \frac{\Delta T}{\Delta x}; \quad \lambda_{eff} = -0.5(IU)\frac{1}{A}\frac{\Delta x}{\Delta T}$$

Technical Key Specification of the GHP 456 *Titan*®	
Test configuration	symmetrical (2 samples)
Temperature range	-160°C to 250°C
Thermal conductivity range	0 to 2 W/(m·K)
Atmospheres	inert, oxidizing or vacuum
Sample thickness	up to 100 mm
Plate dimensions	300 x 300 mm (standard version)
Vacuum-tight	by design: down to 10^{-4} mbar
Cooling devices	forced air: minimum 40°C refrigerated bath circulator: min. 0°C liquid nitrogen cooling system: -160°C
Separately calibrated, sheeted Pt-100 temperature sensors (29) for optimum temperature measurement	

Determination of Specific Heat – Enthalpies – Mass Change – Composition

Thermal Analysis (DSC, STA)

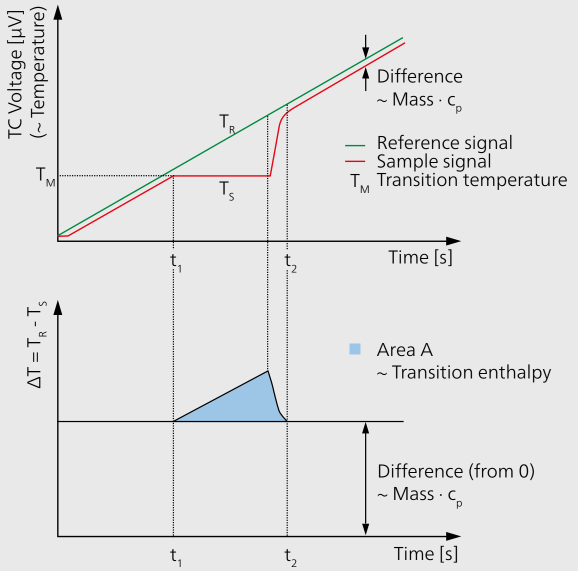
To environmentally and economically develop insulation materials, it is essential to have knowledge and control over their thermal conductivities. Other thermal properties are of equal importance, including specific heat, length change and density. These properties can vary with temperature, pressure, and composition, affecting the transfer and storage of heat.

Differential Scanning Calorimetry

Differential Scanning Calorimetry (DSC) is one of the most frequently employed Thermal Analysis methods. It can be used to analyze nearly any energetic effect occurring in a solid or liquid during thermal treatment. The design of the DSC 404 ***F1*** *Pegasus*® allows testing between -150°C and 2000°C. The vacuum-tight construction (down to 10^{-4} mbar) guarantees precise control of the atmosphere. The specific heat of high-performance materials can be determined between -150°C and 1400°C.

Simultaneous Thermal Analysis

Simultaneous Thermal Analysis (STA) generally refers to the simultaneous application of Thermogravimetry (TG) and DSC to one and the same sample in a single instrument. The test conditions are perfectly identical for the TGA and DSC signals (same atmosphere, gas flow rate, vapor pressure of the sample, heating rate, thermal contact to the sample crucible and sensor, radiation effect, etc.). Furthermore, it improves sample throughput as more information is gathered from each test run.
The DSC and STA systems all meet nearly all respective instrument and application standards for DSC and TGA systems.



Signal generation in a heat flux DSC

DSC Analysis Possibilities

- Specific heat
- Melting/crystallization behavior
- Solid-solid transitions
- Polymorphism
- Degree of crystallinity
- Glass transitions
- Cross-linking reactions
- Oxidative stability
- Purity determination
- Thermokinetics

TG Analysis Possibilities

- Mass changes
- Temperature stability
- Oxidation
- Reduction behavior
- Decomposition
- Corrosion studies
- Compositional analysis
- Thermokinetics

Complete System Solutions

Important hardware extensions, like automatic sample changers (ASC), and software features make the DSC 404 ***F1*** *Pegasus*® and STA 449 ***F1*** *Jupiter*® the most versatile DSC and STA systems for research & development, quality assurance, failure analysis and process optimization. For evolved gas analysis, the systems can be coupled to a QMS and/or FT-IR system, even if equipped with an automatic sample changer.

Additional Information

visit www.netzsch.com/n24271

STA 449 ***F1*** *Jupiter*® coupled with QMS 403 D *Aëolos*® and FT-IR Tensor 27 from Bruker Optics

Determination of Thermal Expansion – Analysis of Resins in Fiber Insulation

Dilatometry (DIL)

For highly precise measurement of dimension changes to solids, melts, powders and pastes at a programmed temperature change and with negligible sample strain, dilatometry (DIL) is the method of choice. Dilatometers have a wide range of applications, such as in the fabrication of metallic alloys, compressed and sintered refractory compounds, insulation materials, glasses, ceramic products, composite materials, plastics, etc.

NETZSCH offers a broad variety of pushrod dilatometers. All DIL instruments fulfill the respective instrument and applications standards for dilatometry and thermo-mechanical analysis.

DIL Analysis Possibilities

- Thermal expansion
- Coefficient of thermal expansion
- Expansivity
- Volumetric expansion
- Density change
- Sintering temperature
- Shrinkage steps
- Glass transition temperatures
- Softening points
- Phase transitions
- Influence of additives
- Optimizing of firing processes
- Rate-controlled sintering
- Kinetic studies

Additional Information

visit www.netzsch.com/n20034

NETZSCH Dilatometer 402 C

DIL Model	Temperature Range	Atmosphere	Δl Resolution
DIL 402 PC	RT to 1600°C	inert, oxidizing	8 nm
DIL 402 C	-180°C to 2000°C	inert, oxidizing, reducing, vacuum	0.125 / 1.25 nm
DIL 402 E	RT to 2800°C	inert, oxidizing, reducing, vacuum	0.125 / 1.25 nm
DIL 402 CD	-180°C to 2000°C	inert, oxidizing, reducing, vacuum	0.125 / 1.25 nm

Dielectric Analysis (DEA)

For investigation of the curing behavior of thermosetting resin systems, composite materials, paints and adhesives in insulation materials, Dielectric Analysis (DEA) has stood the test of time. The great advantage of DEA is that it can be employed not only on a laboratory scale, but also in the production process. One application example is characterizing resins used in fiber insulation panels.

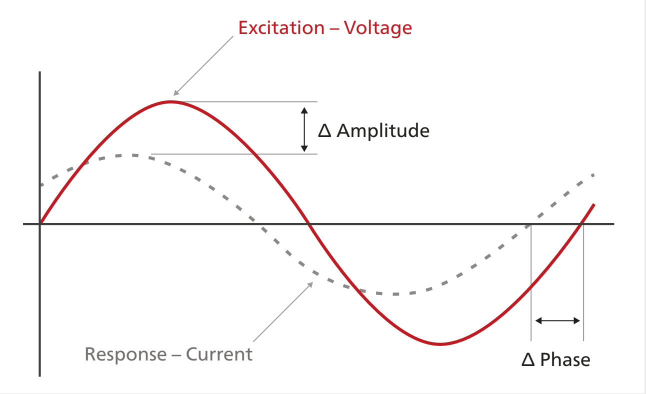
Principle of Operation

A low voltage AC signal (**input**) is applied at one electrode. The response signal detected at the other electrode (**output**) is attenuated and phase shifted.

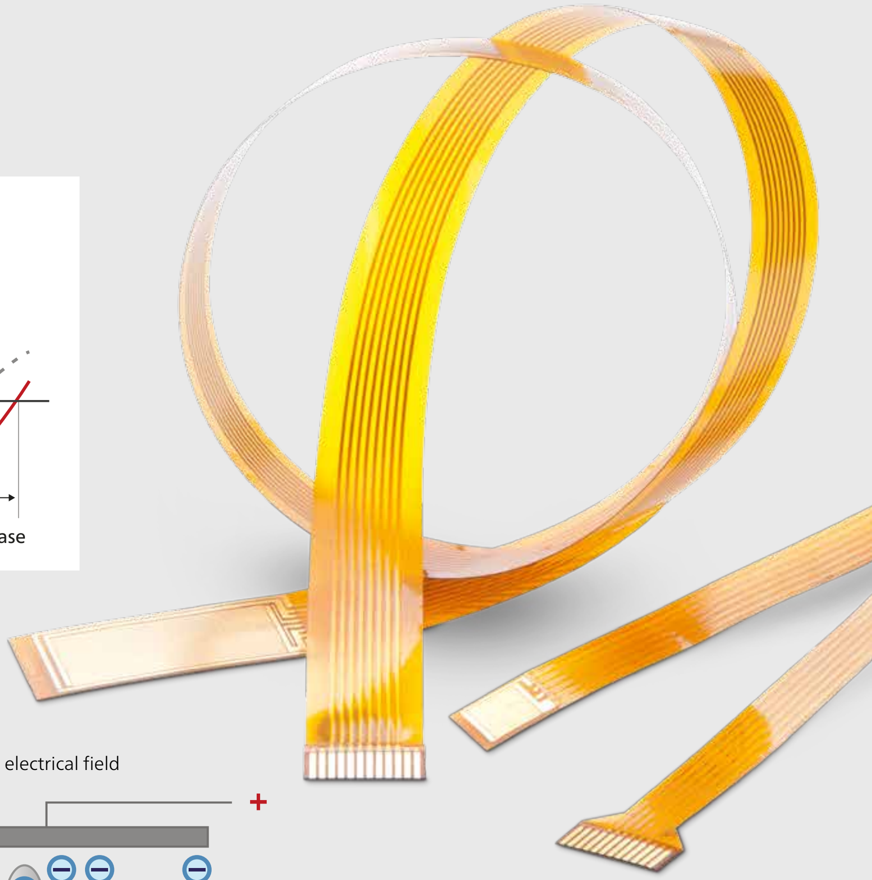
The dielectric sensor monitors the alignment of dipoles and the mobility of ions.

Additional Information

visit www.netzsch.com/n21213

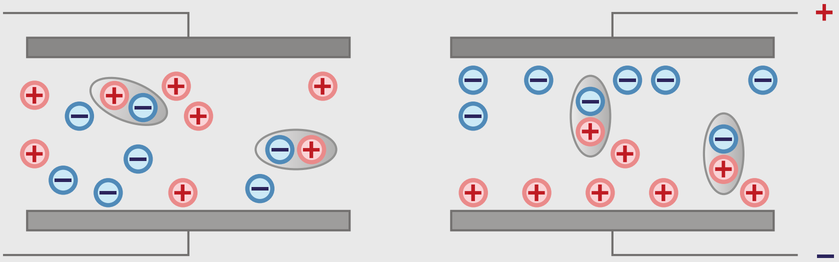


DEA – Measurement principle



Without external electrical field

With external electrical field



Behavior of ions and dipoles inside an external electrical field

Applications – Foam Insulations

Rigid Plastic Foam Insulations

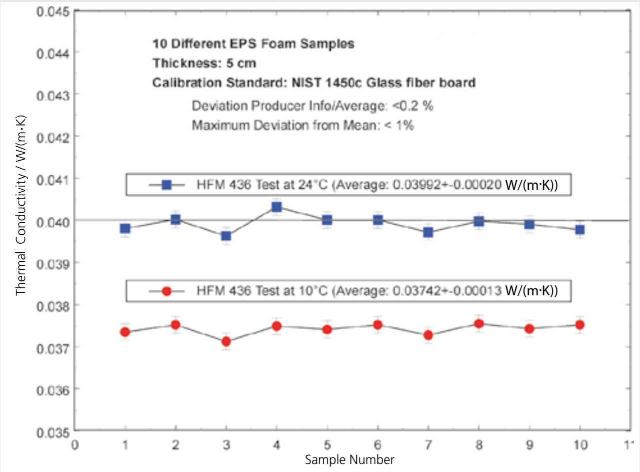
There are four major rigid plastic foam insulations commonly used for residential, commercial and industrial insulation: expanded polystyrene (EPS), extruded polystyrene (XPS), polyurethane (PUR), and polyisocyanurate (PIR).

One of the most popular materials for the thermal insulation of buildings is expanded polystyrene (EPS). The rigid cellular structure provides thermal and acoustical insulation, strength with low weight, and coverage with few heat loss paths. Unlike the other common form of polystyrene, extruded polystyrene, EPS is not made using chlorofluorocarbons (CFCs), which are harmful to the environment. In the case of EPS, the expansion agent is pentane. The most important mechanical property of EPS insulation and building products is their resistance to compressive stresses which increase as the density becomes higher.

The thermal conductivity of such materials is generally within 0.02 and 0.045 W/(mK).

Expanded Polystyrene (EPS)

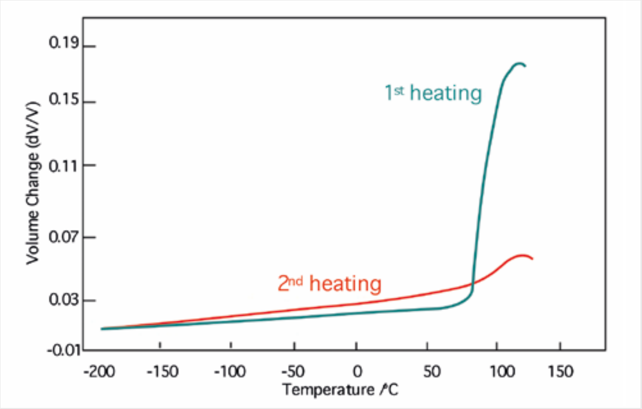
The HFM 436 *Lambda* series instruments carry out measurements with outstanding repeatability and reproducibility. This example shows a quality control run on a commercially available expanded polystyrene material (EPS 040). Ten samples of the same batch were tested at 24°C and again in accordance with DIN EN 13163, at 10°C. Deviation between the different samples is less than 1%. The determined thermal conductivity λ 90/90 value according to DIN 13163 was 0.03808 W/(mK).



Quality control of an EPS 040 batch with the HFM 436

Polystyrene (PS)

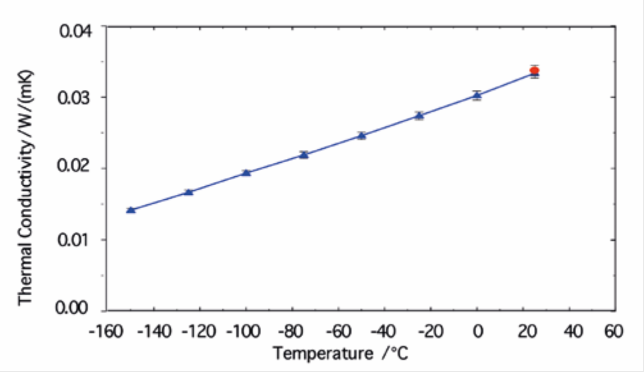
The specific volume of polystyrene can be measured with a dilatometer using a special cylinder as a sample holder. Before the 1st heating, the sample was aged below glass transition temperature (Tg); the 2nd heating was conducted on the same sample after controlled cooling. The volume relaxation for the 1st heating is clearly visible at the Tg, as is the change in slope at the Tg for the 2nd heating.



Volume change of polystyrene between -180°C and 140°C measured with the DIL 402 C

Extruded Polystyrene Foam (XPS)

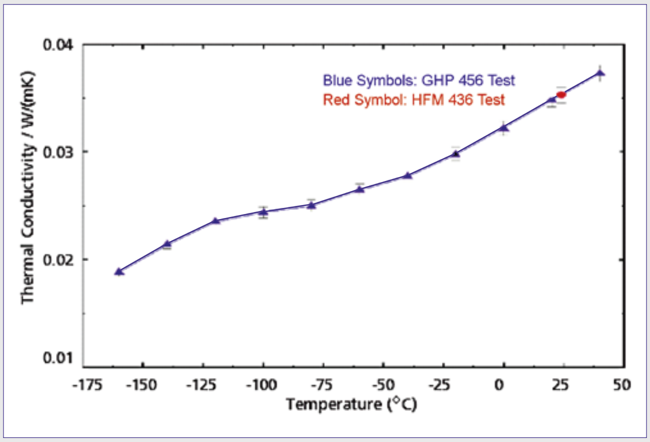
This material has air inclusions, which gives it moderate flexibility, a low density, and a low thermal conductivity. XPS has a well established reputation for long-term reliability and superior resistance to the elemental forces of nature. A 50 mm Styrodur® C board was measured between -150°C and 20°C with the GHP 456 *Titan*®. Good agreement with literature values was observed at RT.



Low-temperature measurement on *Styrodur*® C with the GHP 456 *Titan*®

PUR Foam Measurements

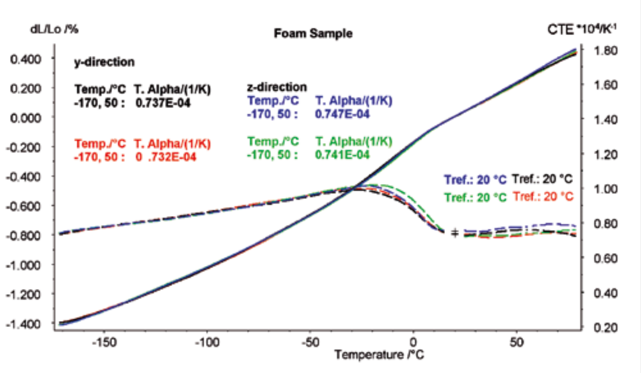
In addition to low thermal conductivity, PUR foams also offer high mechanical stability. This makes them useful as insulation material in roofs, cryo-tanks or even ships. The plot shows a comparison of a test with an HFM 436 *Lambda* at room temperature and a GHP 456 *Titan*® test down to -160°C. The two results are in perfect agreement. Additionally, the GHP result shows the impact of cell-gas condensation between -50°C and -125°C.



Comparison of PUR foam measurements with the HFM 436 and GHP 456 *Titan*®

Thermal Expansion of PUR Foams

PUR foam exhibits an insignificant level of anisotropic behavior which is shown by the dilatometer measurement. The CTE values are nearly the same in the y- and z-directions between -160°C and 100°C. An additional measurement was performed in each direction; the results also demonstrate the excellent reproducibility of the dilatometer DIL 402 C.



Thermal expansion and CTE values of PUR foam

Applications – Aerogels and Fiber Insulations

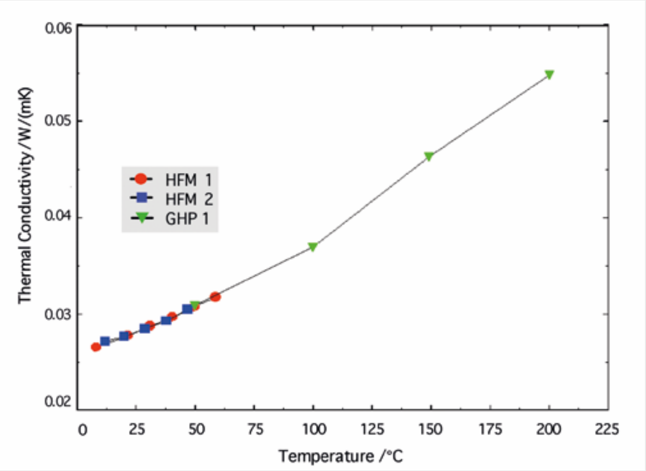
Aerogels

Aerogels are good thermal insulators because they reduce gas conduction by virtue of extremely low pore sizes. They are produced by extracting the liquid component of a gel via super-critical drying. This allows the liquid to be slowly drawn off without causing the solid matrix in the gel to collapse from capillary action, as would happen with conventional evaporation.

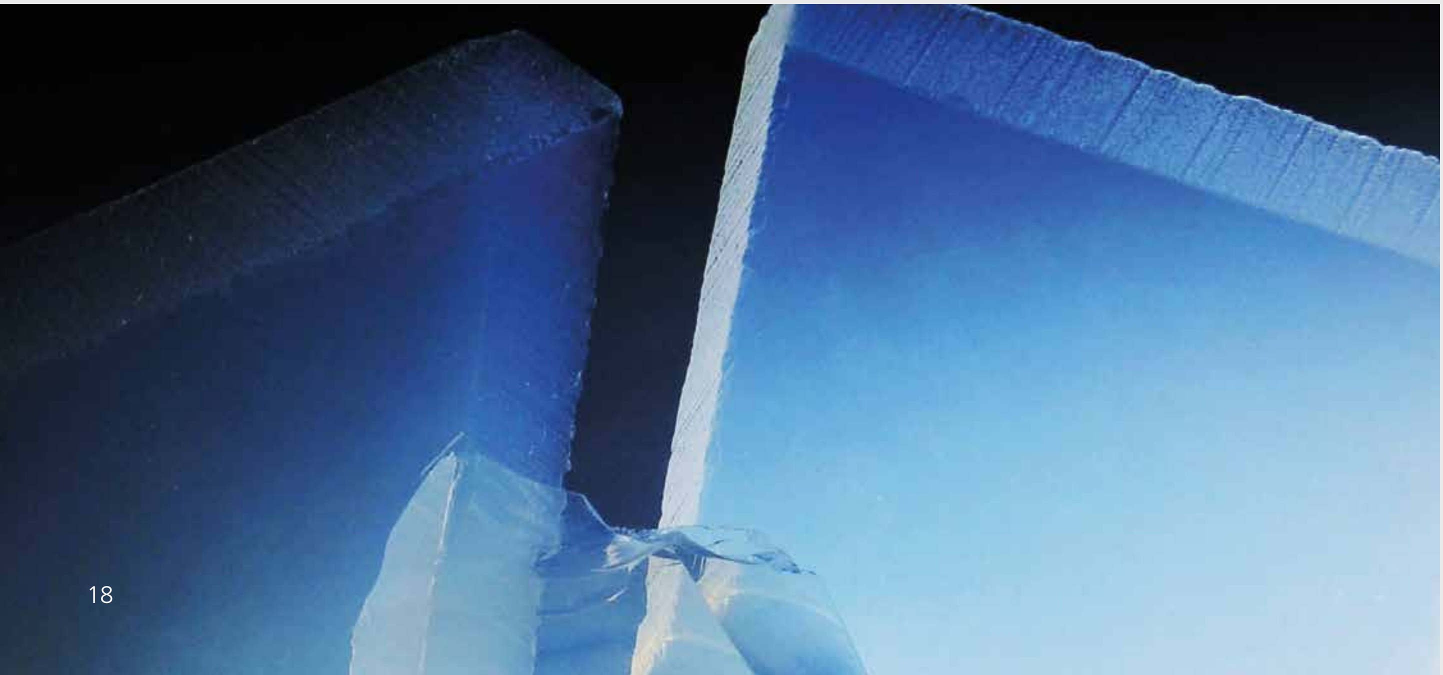
Aerogels can exhibit the lowest known density of any solid. They are nick-named frozen smoke, solid smoke or blue smoke due to their translucent nature and the way light scatters in the material; however, they feel like expanded polystyrene (Styrofoam) to the touch.

Thermal Conductivity Measurement

As part of a Round Robin Test, a nanoporous aerogel board was measured with various NETZSCH heat flow meters as well as with the NETZSCH guarded hot plate system (absolute measurement technique). The results obtained by the three different instruments are in good agreement in the overlapping temperature range.



Thermal conductivity of an aerogel measured with different heat flow meters and the guarded hot plate



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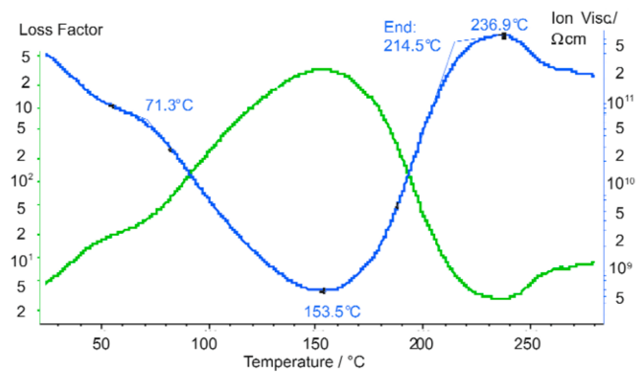
Rock Mineral Wool

Rock mineral wool has excellent thermal, acoustic and fire insulation properties. It has the flexibility to be used in a variety of unique applications ranging from traditional building to high-yield horticultural functions. Its high melting temperatures (>1000°C) make it ideal for fire protection and retardation.

High-tech production techniques are based on spinning molten rock on high-speed spinning wheels. For insulations, the fibers are typically bonded together with a resin, reducing dust and allowing the formation of a more or less well-defined block of material.

DEA Measurement

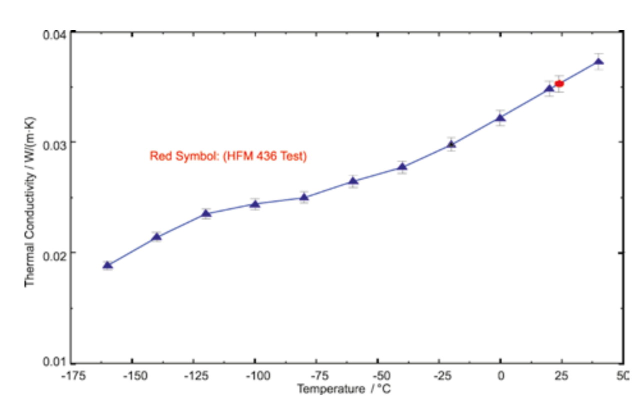
For the DEA measurement, a mineral wool infiltrated with the uncured resin was analyzed. Presented is the logarithm of the ion viscosity and loss factor of the polyester resin on the wool versus temperature. During heating, the ion viscosity decreases above approx. 70°C and the loss factor increases in the same temperature range. This is due to the softening of the dried resin. Above 153°C, the ion viscosity increases up to approx. 237°C. This indicates a decrease in the ion mobility and therefore represents the curing process of the resin. The curing process is finished at this temperature.



Curing process of mineral wool infiltrated with an uncured resin

Application: PUR foam

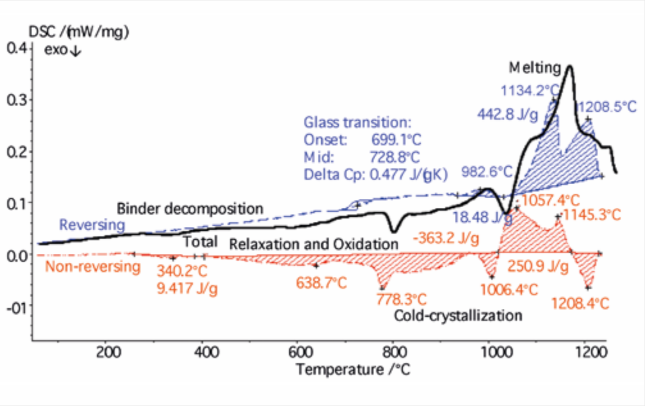
Insulation of modern house roofs, cryo-tanks or even ships requires materials featuring both low thermal conductivity and high mechanical stability. Polyurethane (PUR) foams offer these properties. Presented here is a comparison of a test with an HFM at room temperature and a GHP test down to -160°C. Both results agree perfectly. Additionally, the GHP result shows the impact of cell-gas condensation between -50°C and -125°C.



Applications – Fiber Insulations

Temperature-Modulated DSC

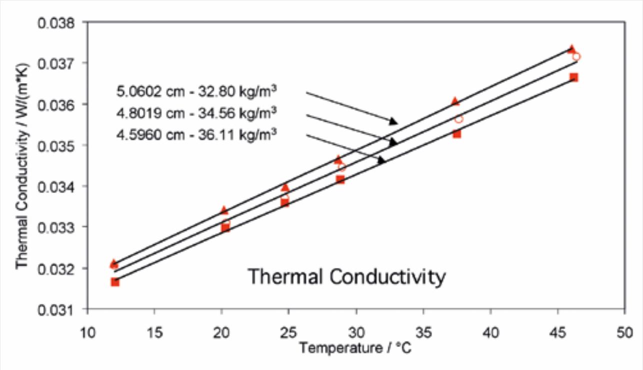
Temperature-modulated DSC (TM-DSC) is a tool generally employed for low-temperature applications on polymers. The STA 449 ***F1** Jupiter*® and DSC 404 ***F1** Pegasus*® are the first instruments capable of doing temperature modulation at high temperatures. Presented here are measurement results for mineral fiber insulation. In the total DSC curve, relaxation, oxidation and glass transition are overlapped. The glass transition can only be analyzed accurately in the reversing part of the DSC curve.



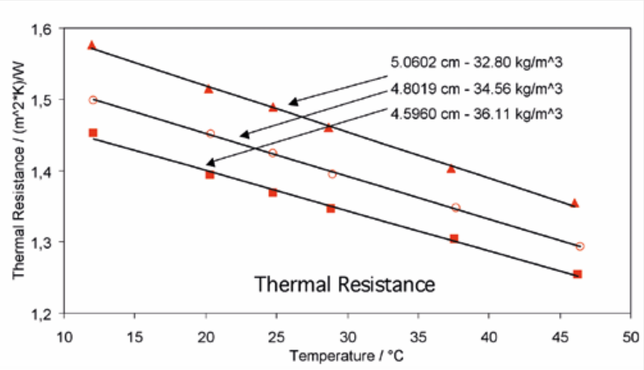
Temperature-modulated DSC measurement of a mineral fiber insulation

Glass Fiber Insulation

Glass fiber insulation is a fibrous product manufactured from silicate sand and bonded together with specially formulated resins. Glass is one of the most widely used insulations. It offers flexibility, resiliency and superior thermal values. Application temperatures vary from -40°C to 535°C. The same glass fiber sample was measured at different loads in the HFM 436, resulting in a different thickness and therefore different density. Due to a reduced radiative/convective heat transfer, the effective thermal conductivity decreases with higher density. However, due to the lower thickness, the thermal resistance decreases as well.



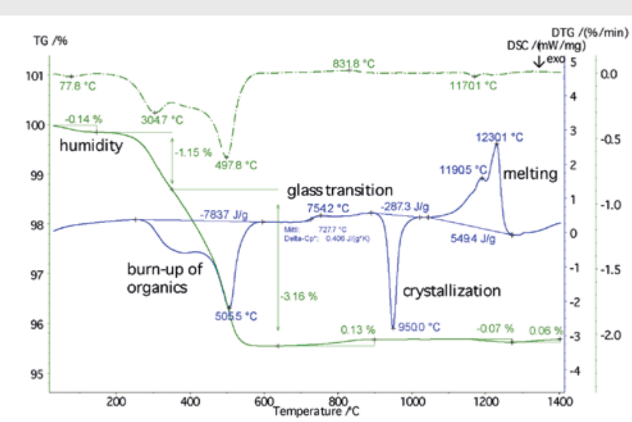
Thermal conductivity of the glass fiber insulation at different loads



Thermal resistance of the glass fiber insulation at different loads

Glass Wool

Glass wool is a form of fiberglass where very thin strands of glass are arranged into a spongy texture similar to steel wool. The cohesion and mechanical strength of the product is achieved by the presence of a binder that cements the fibers together. Due to its intertwined flexible fibers, glass wool offers excellent fire-resistant properties as a thermal insulation material and is also widely used as an absorbent material in acoustic treatments.



STA measurement of a glass wool sample

STA Measurement

The STA measurement (TGA-DSC) of glass wool (approx. 50 mg) was carried out between RT and 1400°C under an air atmosphere. The three massloss steps occurring up to 600°C are due to the evaporation of humidity and the exothermic burn-up of the organic binder. The step in the DSC signal at 727°C is due to the glass transition. The exothermic DSC peak at 950°C (ΔH -287 J/g) is due to crystallization; the endothermic effects between approx. 1050°C and 1250°C with an entire enthalpy of 549 J/g are due to melting. It is likely that the slight mass changes above 700°C are due to oxidation and evaporation of impurities.

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