

NETZSCH

Proven Excellence.



DMA GABO EPLEXOR® Series up to ± 4000 N Ultra-High-Force DMA/DMTA

Dynamic-Mechanical Testing Systems

Analyzing & Testing



MODULAR DESIGN
allowing for a multitude
of configurations

Ultra-High Forces

FOR LARGE AND HIGH-MODULUS SAMPLES

Certain materials and sample geometries require high levels of force for investigating their dynamic-mechanical or static properties, including:

- Very stiff materials such as metals, ceramics and composites
- Specimens of larger dimensions, or even components
- Polymers to be measured in the compression or tension mode below their glass transitions

For all such cases, the ultra-high-force EPLEXOR® series by NETZSCH is the perfect solution. It combines state-of-the-art technology with more than 40 years of experience in developing and manufacturing premium-quality DMA/DMTA testing devices.

The ultra-high-force EPLEXOR® portfolio consists of:

Instrument Type	Max. Static Force	Max. Dynamic Force
EPLEXOR® 2000N	2000 N	± 2000 N
EPLEXOR® 4000N	4000 N	± 4000 N

Dynamic-Mechanical Analysis

Dynamic-mechanical analysis (DMA) or dynamic-mechanical thermal analysis (DMTA) is the best-suited method for determining a material's mechanical properties as well as phase transformations such as glass transitions.

During a DMA test, a mostly sinusoidal force (stress, σ) with a certain frequency is applied to a sample (fig. 1). The result is a sinusoidal deformation (strain, ϵ) as a material response (fig. 2). The deviation between the excitation and response is called phase shift (δ). Theoretically, it exhibits a value of 0° for fully elastic samples and a value of 90° for completely viscous substances. In fact, the phase shift of most materials is somewhere between 0° and 90° , depending on the elastic and viscous proportions.

Mathematical processing of the measured data yields the complex modulus E^* , the storage modulus E' , the loss modulus E'' and the loss factor $\tan\delta$.

The storage modulus E' , which is the real part of the complex modulus E^* , refers to the elastic part of the response and is a measure for a material's stiffness. The loss modulus E'' , the imaginary part, corresponds to the dissipated oscillation energy. The loss factor ($\tan\delta$) which is the ratio between E'' and E' , describes the mechanical damping or internal friction of a visco-elastic system.

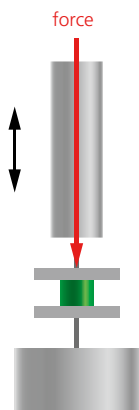


Figure 1: Example of an oscillatory stress on a sample in compression mode

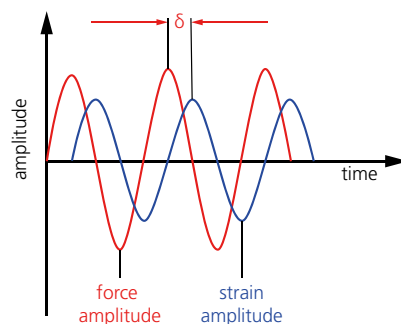


Figure 2: Schematic relationship between the force and strain for a visco-elastic sample; δ stands for the phase shift between the two curves

DMA/DMTA Features

- Dynamic modulus
- Damping factor ($\tan\delta$)
- Young's (static) modulus
- Frequency dependence
- Temperature dependence
- Glass transition
- Secondary transitions
- Master curve
- Hysteresis
- Relaxation and retardation
- Creep testing
- Aging behavior
- Fatigue test
- Predictive testing
- Durability test
- Impact test
- Immersion test
- Tests under UV light
- Tests in humid atmosphere
- Thermal expansion

THE UNIQUE EPLEXOR® MODULAR DESIGN PRINCIPLE

EPLEXOR® Ultra-High-Force

FORWARD-LOOKING SETUP

The EPLEXOR® instrument line is the only DMA/DMTA series on the market with hardware that can easily be upgraded – also as a retrofit – to meet future needs. A factor such as this is important in maintaining the value of the investment.

Quality and Precision
Made in Germany

Unrivaled Temperature Range from -160°C to 1500°C

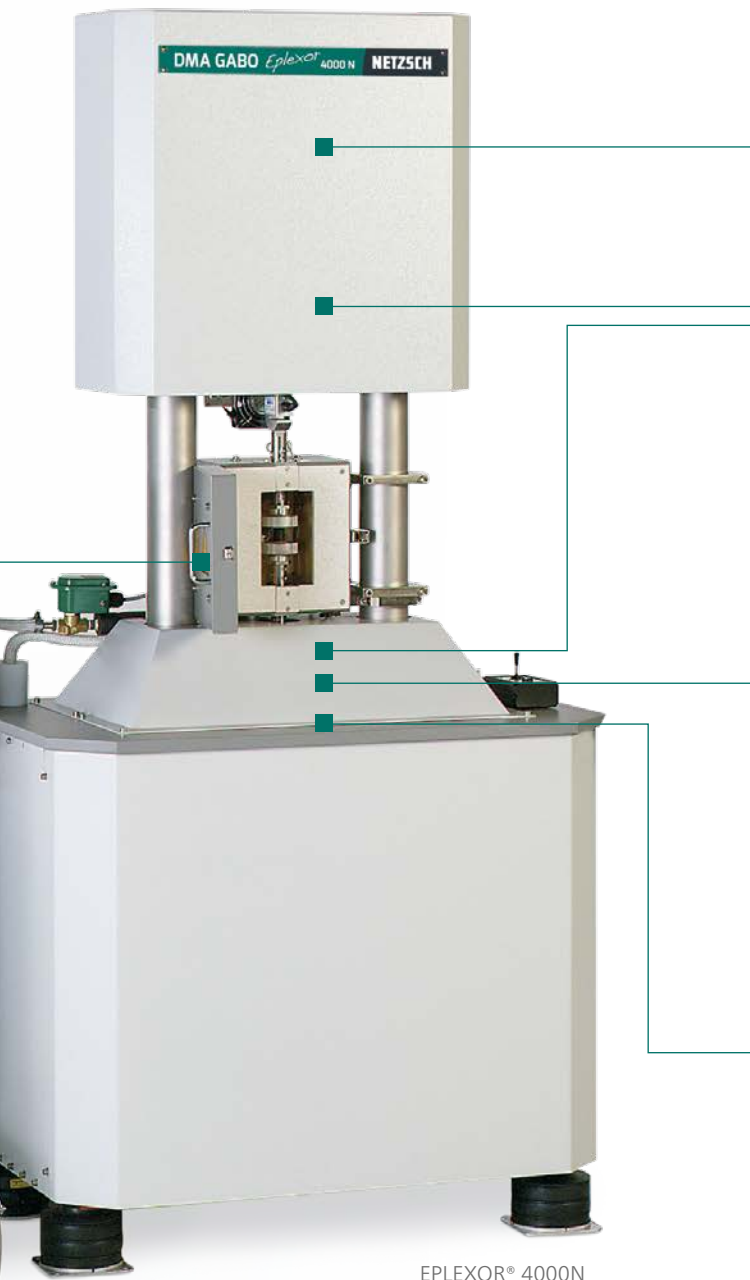
Three different furnaces are available to cover the broadest temperature range for DMA/DMTA testing machines on the market. Shown here is the standard furnace, reaching a maximum temperature of 500°C.

Highly Cost-Effective Cooling Systems

Optimized temperature control in combination with a Dewar (standard: 100 liters) ensures low liquid nitrogen consumption during cooling down to -160°C. Alternatively, an air chiller (minimum temperature: -60°C) can be applied to the standard furnace.



DMA Line – Best in Its Class



EPLEXOR® 4000N

User-Interchangeable Force Sensors for Controlling the Load

In certain measurement modes (compression, tension, bending), the independently applied static force must always be higher than the dynamic force. If necessary, the force range can be extended up to 12000 N, thus allowing measurements on a broad range of materials.

Static Deformation up to 60 mm

Dynamic Strain up to $\pm 10\text{mm}$

Each instrument allows for maximum deformations of up to $\pm 10\text{ mm}$.

Effective Stroke Protection of the Shaker via the Special Blade Spring System

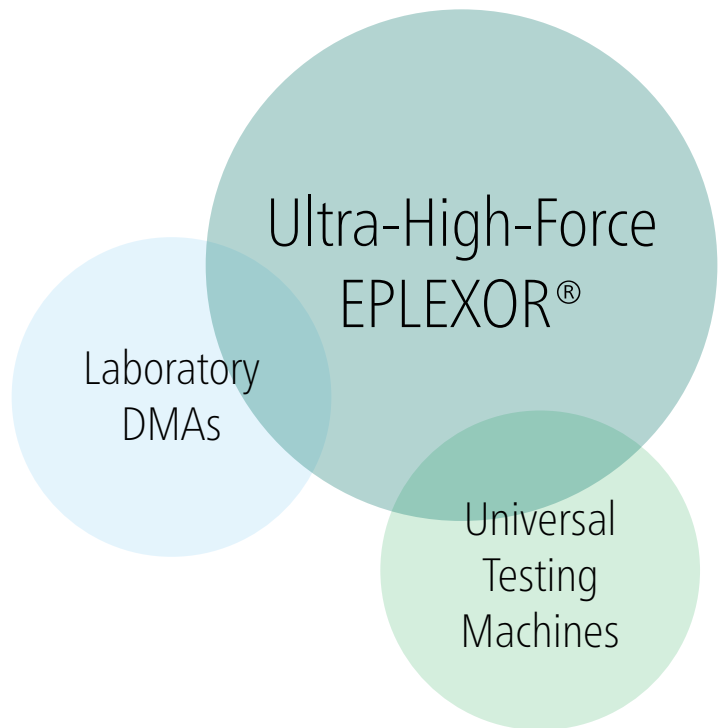
For maximum safety of the shaker system when using ultra-high static forces and/or for destructive measurements, all EPLEXOR® instruments feature an adjustable blade spring system.

The EPLEXOR[®] Line –

The Best of Two Worlds Combined in One Instrument Line

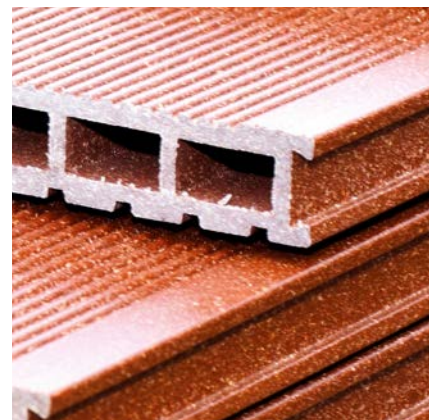
The EPLEXOR[®] series bridges the gap between laboratory DMA instruments offering total forces of just a few Newtons, and powerful universal testing machines covering force ranges up to several thousand Newtons. Ultra-high-force EPLEXOR[®] DMTAs are capable of characterizing both the linear and non-linear visco-elastic behavior of materials.

This instrument line can be used for all kinds of mechanical measurements from the determination of dynamic-mechanical standard parameters ($\tan\delta$, E' , E'' , etc.) to creep, relaxation, fatigue, heat built-up, tensile or rolling resistance tests and more.



Designed to Investigate Metals, Ceramics or Composites

Total force levels of up to 12000 N (static plus dynamic) can be applied to a sample, generating optimal conditions for the study of highly stiff materials.



Unmatched Force Design

2-in-1 Device – Both a DMTA and a Universal Tester

Only EPLEXOR® DMTA instruments have two independent drives for static and dynamic force.

The static force is generated by a servo motor; the dynamic force by an electrodynamic shaker system. The two drives can be used independently, which allows EPLEXOR® instruments to be used either as classical DMTAs or as universal testers. Additionally, two add-ons are available: The Mini Tester, which is based on the static servo drive, and the Micro Tester, which is applied by using the shaker.

Maximum Safety during Fatigue and Tensile Tests

Fatigue or tensile tests at highest force levels are often destructive experiments. In case of unexpected sample destruction the unique blade spring assembly absorbs the mechanical oscillation energy and realizes an inherent self protection for the system.

Lots of Dynamic Signal Shapes at One's Option

The optional Digital Signal Processor (DSP) offers a great variety of different signal forms for DMTA tests such as sine, sine², half-sine, double-sine, triangle, saw-tooth or pulse. Additional application of the "Modify" advanced software allows the operator to create customized wave forms.

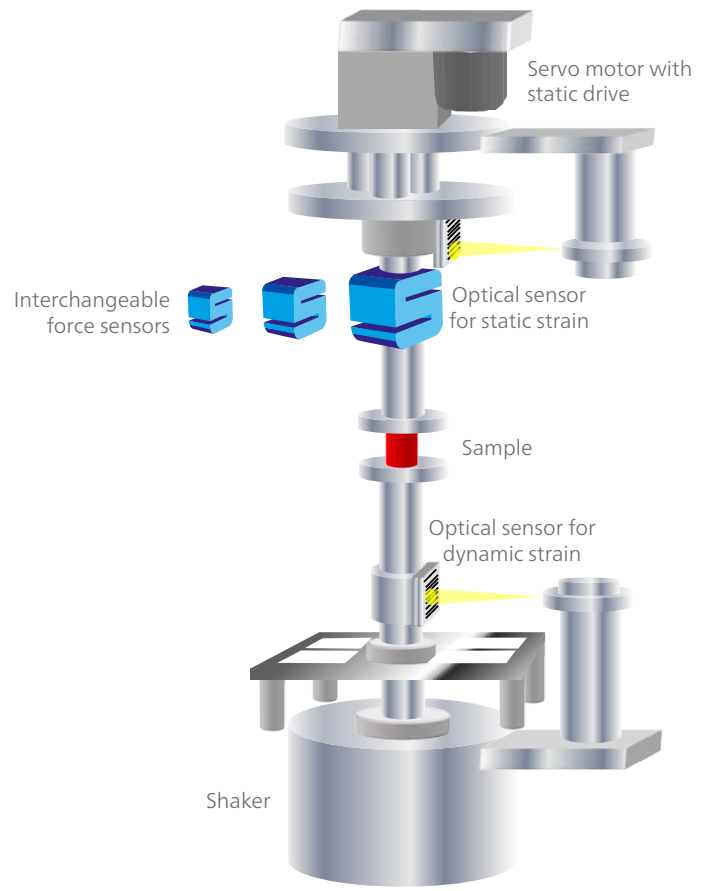
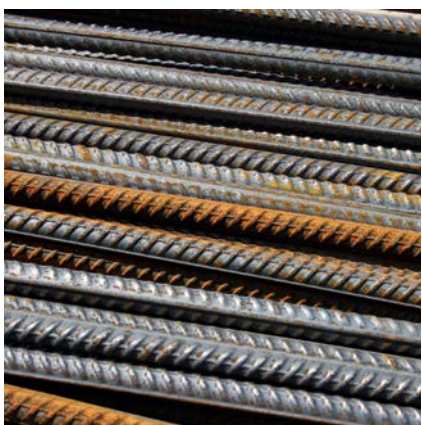


Diagram of the EPLEXOR® line illustrating the functional principle with two independent drives for static and dynamic force



Sample Holders

THE RIGHT DESIGN FOR ANY SCOPE OF WORK

The Modulus Result Depends on the Direction of the Applied Stress

The plots on the right display two temperature sweeps on the same rubber material (filled with carbon black) in the temperature range between -50°C and 80°C, first using the tension geometry, and then using the shear mode. Over the entire curve, the absolute value of the complex elastic modulus $|E^*|$ (red curve) is higher – at about 60/80°C by a factor of approx. 3 – than the absolute value of the complex shear modulus $|G^*|$ (blue curve).

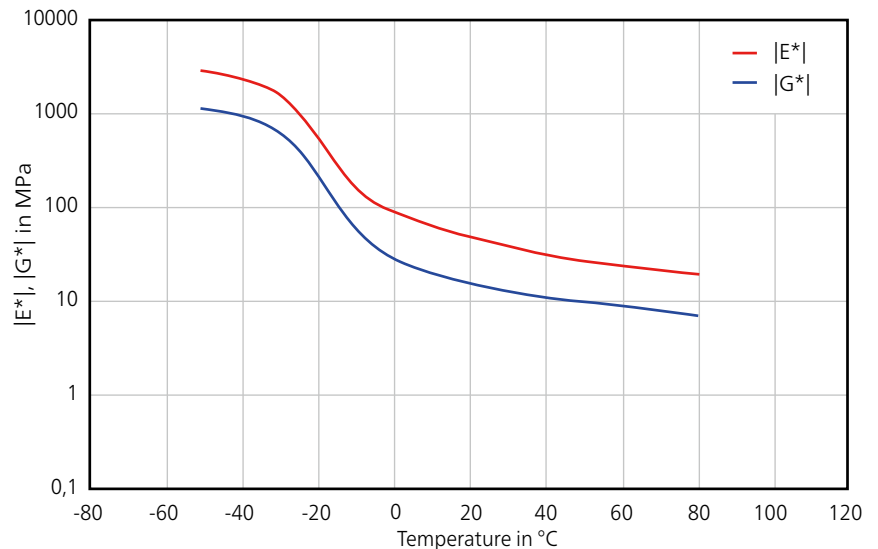
The relationship between the two modulus types is based on Poisson's ratio, ν , which describes a material's change-in-length relative to its change-in-width:

$$E^* = 2G^* (1 + \nu)$$

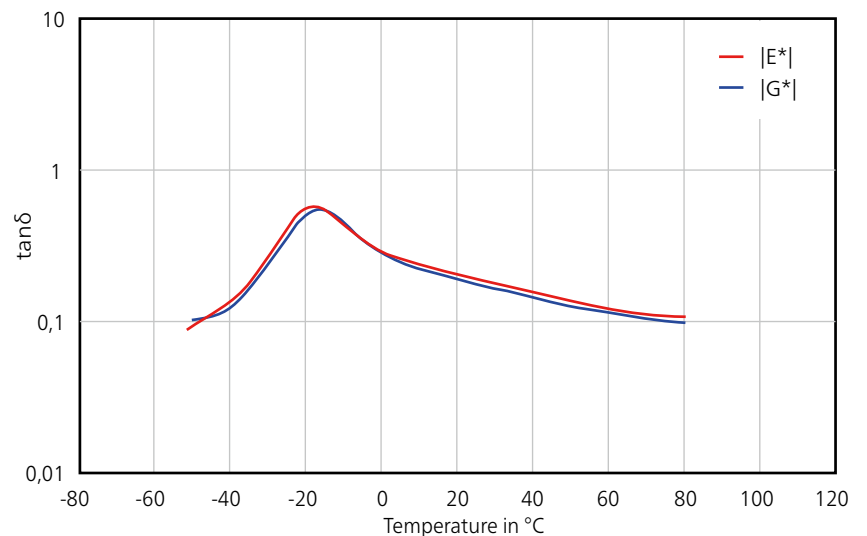
(applicable to linear elastic, isotropic, homogeneous materials)

This equation reveals that the modulus of elasticity must always be higher than the shear modulus.

In contrast, the loss factor, ($\tan\delta$) – sometimes also called the damping factor – exhibits just slight deviations, indicating that this value is not dependent on the load direction and thus also not on the applied sample holder system or on the sample dimensions.



Comparison of the storage modulus (red) and shear modulus (blue) of a rubber sample (two specimens from the same batch), first measured in the tension mode and in a second test, in the shear mode.



Comparison of the loss factor ($\tan\delta$) of a rubber sample, first measured in the tension mode and in a second test in the shear mode; $\tan\delta$ is independent of the test geometry



TENSION



SHEAR

The Right Sample Holder for Every Measurement



Compression for large samples



Tension



3-point bending



Asymmetric bending



Dual cantilever



Double shear



In order to achieve reliable measurement results, appropriate sample holders for the various sample geometries are needed.

The following sample holders are shown here:

- Compression – large and small specimens
- Tension – bars and strips with self-tightening mechanism
- 3-/4-point bending
- Asymmetrical 3-point bending – up to 1500°C
- Single/Dual cantilever
- Double shear
- Hydraulic clamps for tension

Additionally, special sample holders are available for fiber tests (filaments and bundles), for heat build-up tests (see page 13), for measuring of tire cords (T and H tests), and for dynamic-mechanical investigations of parts as well as for user-defined test geometries.

Unsurpassed Versatility

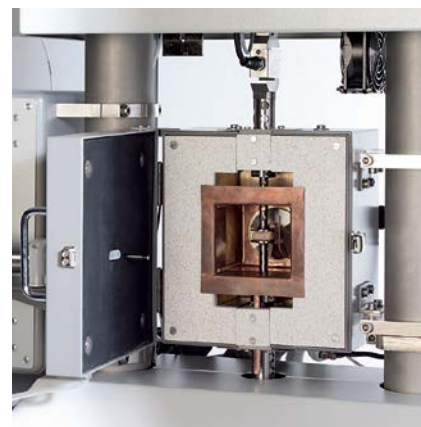
Accessories

Humidity Generator (HYGROMATOR®) for Measurements in Controlled Humid Atmospheres

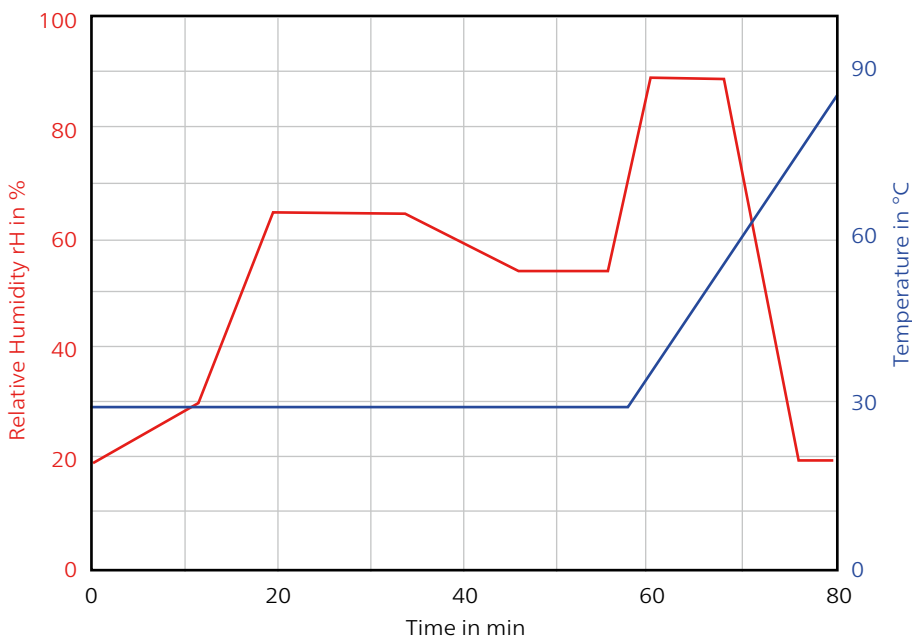
To simulate various climates or to study the influence of moisture on samples, the HYGROMATOR® can be attached to any EPLEXOR® DMTA. This humidity generator works between 20°C and 95°C and provides relative humidity levels from 5% to 95%. It can be used together with a modified standard furnace (see on the right).



Humidity generator connected to the standard furnace



Modified standard furnace for working under humid conditions (humidity device can be exchanged)



Humidity and temperature profiles are freely programmable

Immersion Tests for Studying Materials in Liquid Media

Sample holders for tension, bending and compression can be inserted into a container filled with water or oil to investigate the material's aging or the plasticizer effect of the liquid.



Sample holders for 3-point bending and for tension mode

Unique Combination of DMTA with Dielectric Analysis (DEA)

In dielectric analysis (DEA), charge carriers (ions or dipoles) are stimulated to move within the sample by applying an external alternating electrical field. In combination with DMTA, the resulting alternating current reflects the changing dielectric properties of a material; e.g., of rubbers under high dynamic deformation caused by a spatial variation in the carbon cluster distribution. Depending on the material properties and the desired level of compression strain (up to 60%), forces up to the kN range may be required.

The upper and lower parts of the compression sample holder act as capacitor plates, ideally separated by 1 to 2 mm. The sample between them acts as the dielectric medium. The instrument specifically designed for performing simultaneous DMTA-DEA measurements is called DiPLEXOR and, along with the appropriate sample holder, also includes an impedance spectrometer operating with frequencies of up to 10^7 Hz.



Combined DEA and DMTA sample holder for small samples

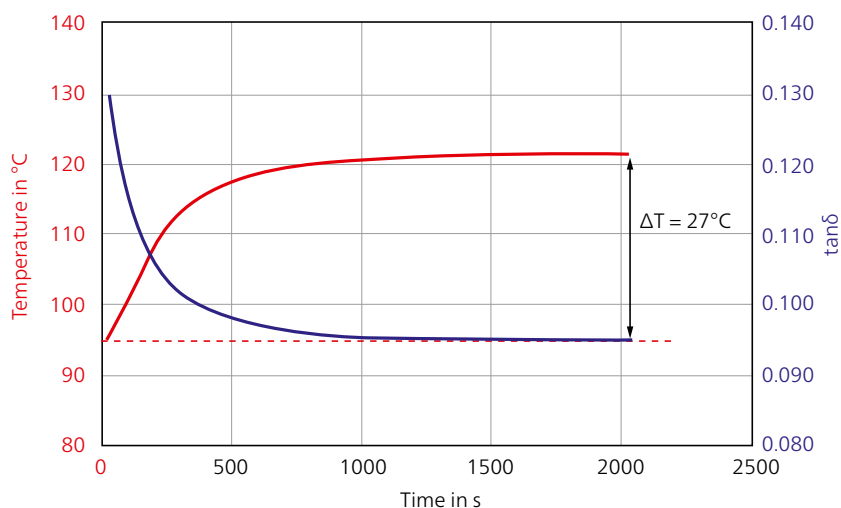
Ideal for Heat Build-Up and Blow-Out Tests

In a conventional Goodrich flexometer, in accordance with ASTM D623, a rubber sample is exposed to a cyclic load in compression mode at a fixed frequency of 30 Hz and the resulting heat generation is detected at the sample surface. The increase in sample temperature is a consequence of the extremely high internal friction during this treatment while the rubber network decomposes. Furthermore, the sample undergoes deformation (thermal set).

As high deformations are required for these tests, ultra-high-force devices such as the 2000N/4000N testing machines by NETZSCH are needed.* They have the capability to measure not only the heat build-up, but simultaneously also the visco-elastic properties of the sample.

Versatile static and dynamic load conditions (as e.g., stress, strain and force-controlled tests) and freely adjustable test frequencies (option) are key features of this modern flexometer and surpass the conventional Goodrich flexometer.

* GABOMETER option



The traditional setup for a heat build-up test consists of a pair of insulated compression sample holders including a contact thermocouple for recording the sample temperature on the surface of the specimen. The result of such a measurement on SBR is depicted on the left. During the heat build-up test, the temperature increase on the sample's surface is 27°C.

Heat build-up measurement on SBR, compression mode, static load:
1 MPa, frequency: 30 Hz, amplitude (peak-to-peak): 4.45 mm



Intelligent Flexometer (GABOMETER) Module as Accessory for EPLEXOR® Systems

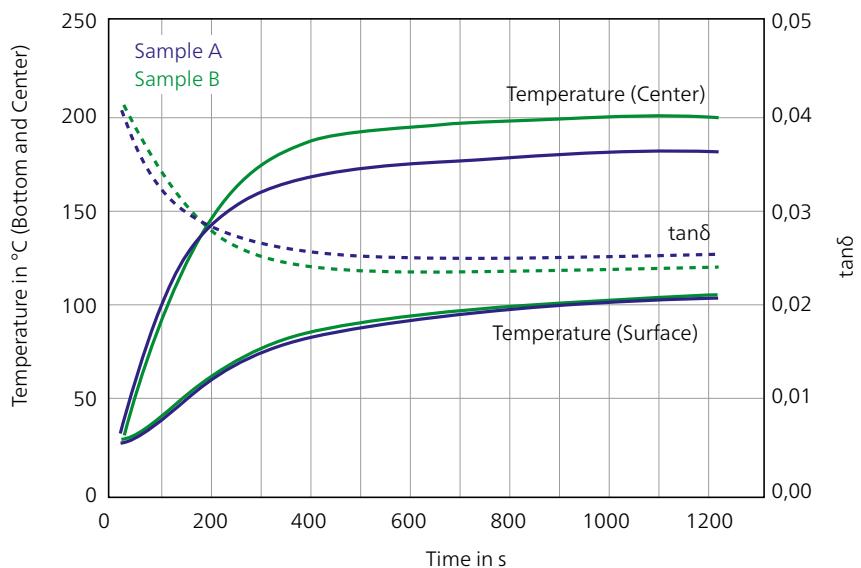
Any ultra-high-force EPLEXOR® instrument can be upgraded to perform heat build-up tests by adding the appropriate flexometer package.

A Needle Thermocouple Measures the Temperature at the Sample's Core

More information about the processes inside a sample can be gathered by using a second temperature sensor in the form of a needle injected into the center of the sample (see image on the left).

Sample arrangement with needle thermocouple (optional)

The graph shows the results for the heat build-up tests on two rubber samples (A and B) consisting of the same base compound but filled with different types of carbon black. There is a significant difference visible between the temperature at the samples' surface and the temperature in the samples' core measured with the needle thermocouple mentioned-above. In the case of sample B, this difference is approx. 100K; the temperature jump in sample A is a bit smaller and exhibits approx. 80 K. The reason for the improved heat transfer of sample A is the higher thermal conductivity of the filler material.

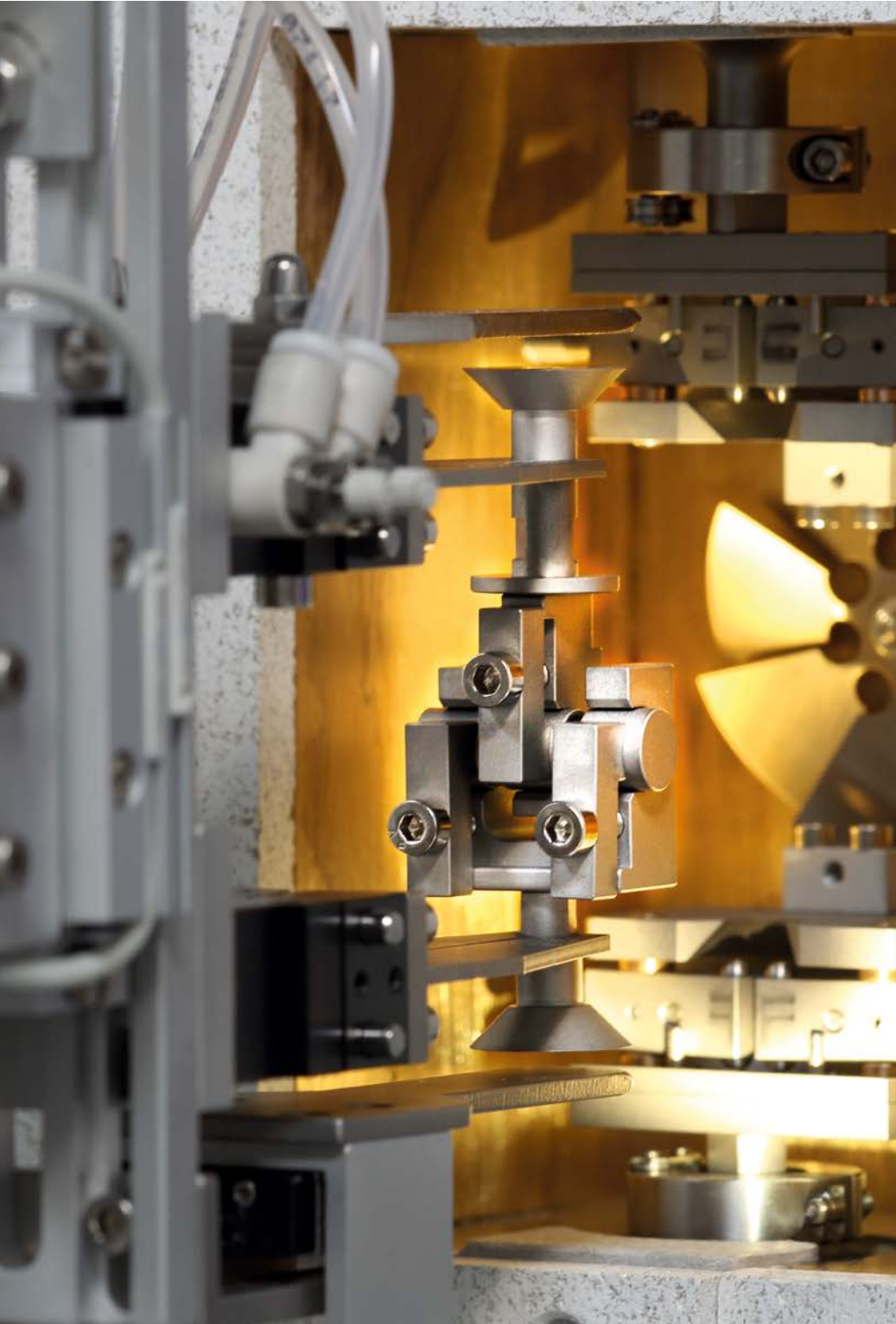


Tests on cylindrical specimens, Height: up to 25 mm, Diameter: up to 40 mm, Static stress: 1 MPa

Fully Automatic Testing System

Non-Stop Operation with the Unmatched Autosamplers

Two automatic sample changers (ASC or MPAS – MPAS stands for multi-purpose automatic sample supply system) are available to convert any EPLEXOR® DMTA into a true hands-off system. While the ASC supports bending, tension and compression modes, MPAS is additionally able to support the shear mode. The MPAS even allows for the insertion of sample holders of various geometries (incl. customized ones) in arbitrary order.



Multi-purpose automatic sample changer (MPAS) with sample gripper in removal holder. The complete sample holder is transferred, along with the specimen.

for up to 150 Samples



Autosampler (ASC) for compression mode; only the specimen is changed out



Tension holder inside of the force axis adapter for MPAS

Exchanging the Entire Sample Holder or Just the Sample

Specimens which are not fixated inside a sample holder, such as samples for the compression or bending modes, can be handled by the ASC individually (see above). For specimens which are fixated to a holder, however, the complete sample holder with implemented sample is changed out. An example showing the tension sample holder can be seen on the left.

A robot arm with two grips takes hold of the given sample holder at both its lower and upper ends, removes it from the magazine (see previous page) and places it into position for measurement inside the furnace.

A complete autosampling system consists of:

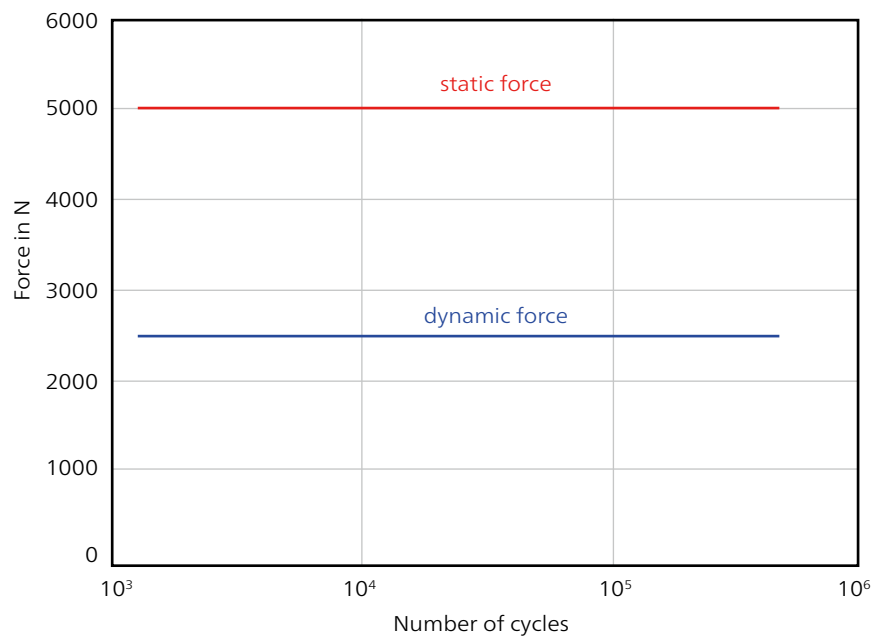
- A storage magazine with vertical pneumatic lift
- A pneumatic gripping arm with gripper(s)
- An automatic mechanism for opening and closing the furnace door

An Intensive Look at Material Properties



Dynamic Fatigue Test on Steel

Ultra-high-force DMTAs are far faster in performing continuous vibration tests on metals than traditional servo-hydraulic systems or universal testing machines because much higher frequencies and therefore many more load cycles can be applied within a certain time interval. The adjacent graph depicts a fatigue test on a steel sample in tension mode applying a static force of 5000 N, a dynamic force of ± 2500 N and a frequency of 100 Hz. Under these conditions, about 1/2 million cycles can be executed within 2 hours. But the sample is so stable that it resists the stress.

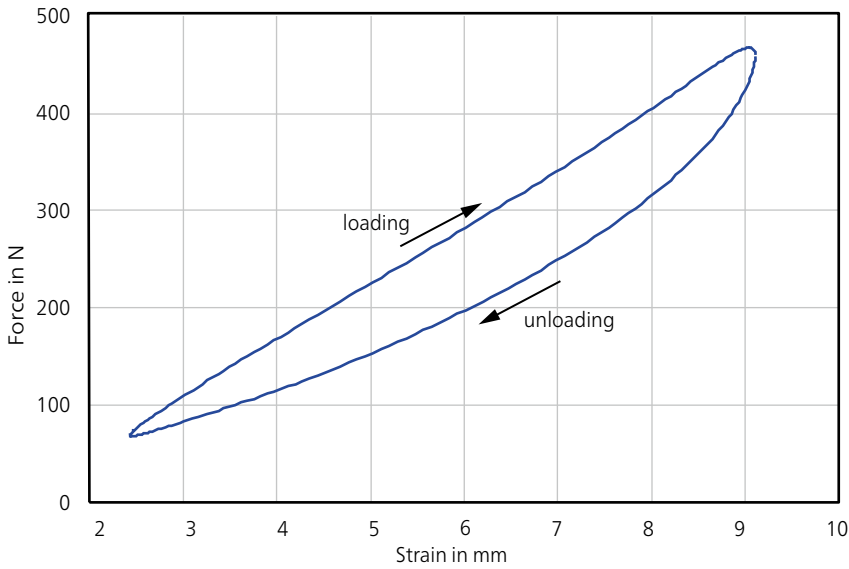


Fatigue test on a steel sample

Please Consider: Compression Mode Requires Higher Force Levels

Due to the high stiffness of steel (E' of about 210000 MPa), for a 30-mm long, 10-mm wide and 1-mm thick sample, a dynamic force of about 2100 N would be necessary to realize a strain

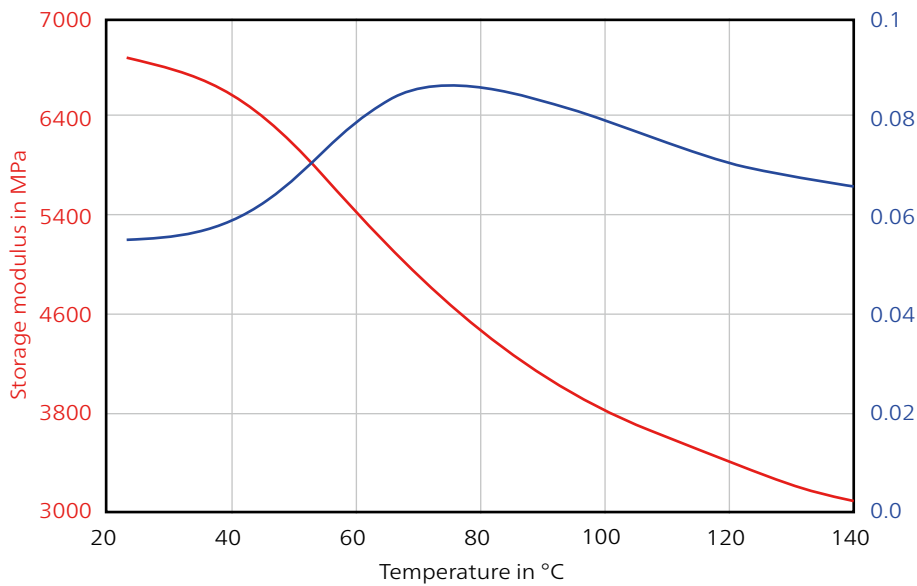
of 0.1% in tension mode. In compression mode, however, a cylindrical steel sample with a diameter of 4 mm would require roughly 2640 N to achieve the same dynamic amplitude.



Dynamic stress-strain diagram (total force levels between 50 N and 450 N; resulting strains between 2.5 mm and approx. 9 mm); cylindrical sample of 30 mm diameter and 30 mm height; compression test at RT

Hysteresis on Micro-Cellular Polyurethane

Ultra-high-force DMTA instruments are able to perform loading/unloading cycles on large polymer specimens. Displayed here is a measurement on PUR conducted using a static preload of 250 N, a superimposed dynamic force of ± 200 N and a frequency of 5 Hz. The area spanned by the resulting hysteresis loop correlates to the amount of energy lost as heat during loading/unloading and is caused by the visco-elastic behavior of the sample material. The larger the area, the greater the amount of energy dissipated. For linear visco-elastic behavior, this curve is an ellipse; the present curve, however, indicates that the material shows already non-linear mechanical behavior.



Measurement of PA6.6-GF30 in tension mode

Temperature Sweep on PA6.6-GF30

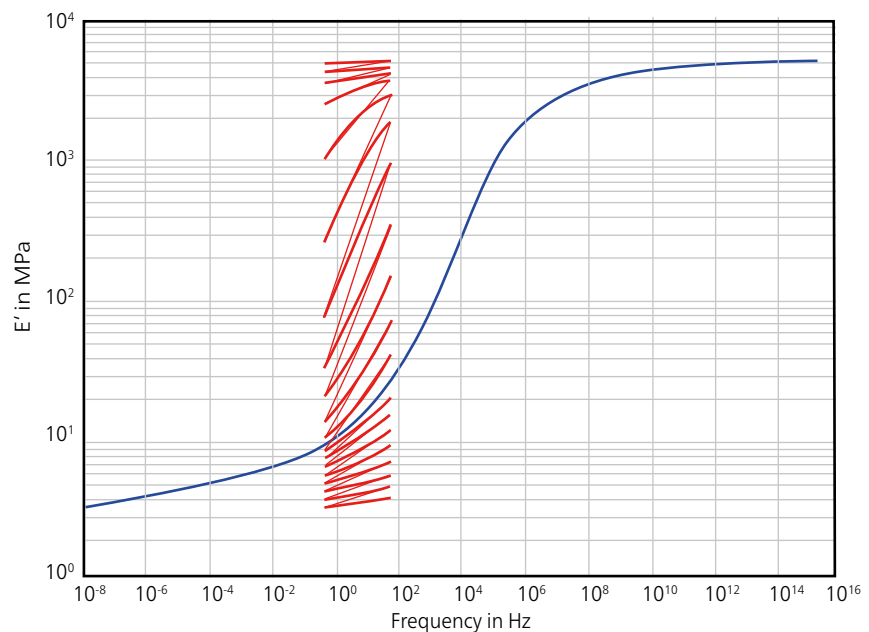
A glass-fiber-reinforced polyamide sample with a thickness of 4 mm and a width of 10 mm was investigated in tension mode under a dynamic force of ± 1000 N at a frequency of 10 Hz using hydraulic sample clamps. Shown here is the glass transition region. The $\tan\delta$ peak of approx. 75°C falls well within the literature value range (T_g for PA 6.6: 65°C to 90°C). Between 20°C and 140°C, the storage modulus drops by more than 50%, from approx. 6500 MPa to 3000 MPa.

Smart Software Solution

Any sophisticated measuring system comes with well-engineered software. The EPLEXOR® software is based on the Windows operating system and offers comprehensive possibilities for defining measuring programs and analyzing data and curves.

Some of the software features in detail:

- Frequency sweep (from 0.001 Hz up to 200 Hz – standard: 0.01 Hz to 100 Hz)
- Time sweep
- Temperature sweep
- Static and dynamic stress or strain sweep
- Temperature and frequency sweep
- Constant stress amplitude mode per ASTM D623 (heat build-up test – optional)
- Universal test, either driven by the servo motor (Mini Tester, optional) or by the shaker (Micro Tester, optional)
- Time-temperature superposition – TTS (WLF, Arrhenius, numeric – optional)
- Evaluation of complex modulus (E^* , G^*), storage modulus (E' , G'), loss modulus (E'' , G''), damping factor ($\tan\delta$) and glass transition temperature
- Testing of creep, relaxation and retardation, fatigue and energy loss (optional)
- Payne/Mullins effect analysis (optional)
- Crack growth testing (optional)
- Hysteresis presentation of results (optional)




Calculation of a master curve (according to the William-Landels-Ferry, or WLF, equation) based on a multi-frequency measurement on a rubber sample (stepwise isothermal temperature profile, frequency scan between 0.5 Hz and 50 Hz, tension mode)

Technical Specifications

EPLEXOR® Series up to ± 4000 N	
Temperature range	-160°C to 500°C alternative: high-temperature versions up to 1000°C or 1500°C
Drives	Two, independent of each other: <ul style="list-style-type: none"> ▪ Servo motor for static force ▪ Electrodynamic shaker for dynamic force
Static force	<ul style="list-style-type: none"> ▪ EPLEXOR® 2000N: up to ± 2000 N ▪ EPLEXOR® 4000N: up to ± 4000 N
Dynamic force	<ul style="list-style-type: none"> ▪ EPLEXOR® 2000N: up to ± 2000 N ▪ EPLEXOR® 4000N: up to ± 4000 N
Force measurement	User-exchangeable force sensors (various load ranges up to ± 12000 N)
Static strain (static deformation)	Up to 60 mm
Dynamic strain (amplitude)	<ul style="list-style-type: none"> ▪ EPLEXOR® 2000N: up to ± 10 mm ▪ EPLEXOR® 4000N: up to ± 10 mm
Frequency range	<ul style="list-style-type: none"> ▪ 0.01 Hz to 100 Hz ▪ 0.01 Hz to 200 Hz (option 1) ▪ 0.0001Hz to 100 Hz (option 2)
Wave forms	Sine (standard); triangle, sin ² , half-sine, double-sine, saw-tooth, user-defined wave forms, pulses (optional)
Main measurement types	<ul style="list-style-type: none"> ▪ Time sweep ▪ Temperature sweep ▪ Frequency sweep ▪ Temperature/frequency sweep ▪ Static-dynamic sweep ▪ Creep, relaxation/retardation ▪ Humidity sweep ▪ Flexometer test ▪ Fatigue tests ▪ Heat built-up/blow-out tests ▪ Universal testing
Automatic sample length/thickness determination	Yes, for tension, compression and bending geometry
Optional instrumentation	<ul style="list-style-type: none"> ▪ Humidity generator (HYGROMATOR®) ▪ UV extension for furnace ▪ Automatic sample changer: type ASC or MPAS ▪ Combined DMTA-DEA sample holder plus impedance spectrometer (DiPLEXOR)

The EPLEXOR® instrument series is in line with the following standards:

DIN 53513, ISO 6721-1, ISO 6721-4, ISO 6721-5, ISO 6721-6, ISO 4664,
ISO 4666-3, ISO 4666-4, ASTM D4065, ASTM D4473, ASTM D623



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), the determination of Thermophysical Properties, Rheology and Fire Testing, 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. ■

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