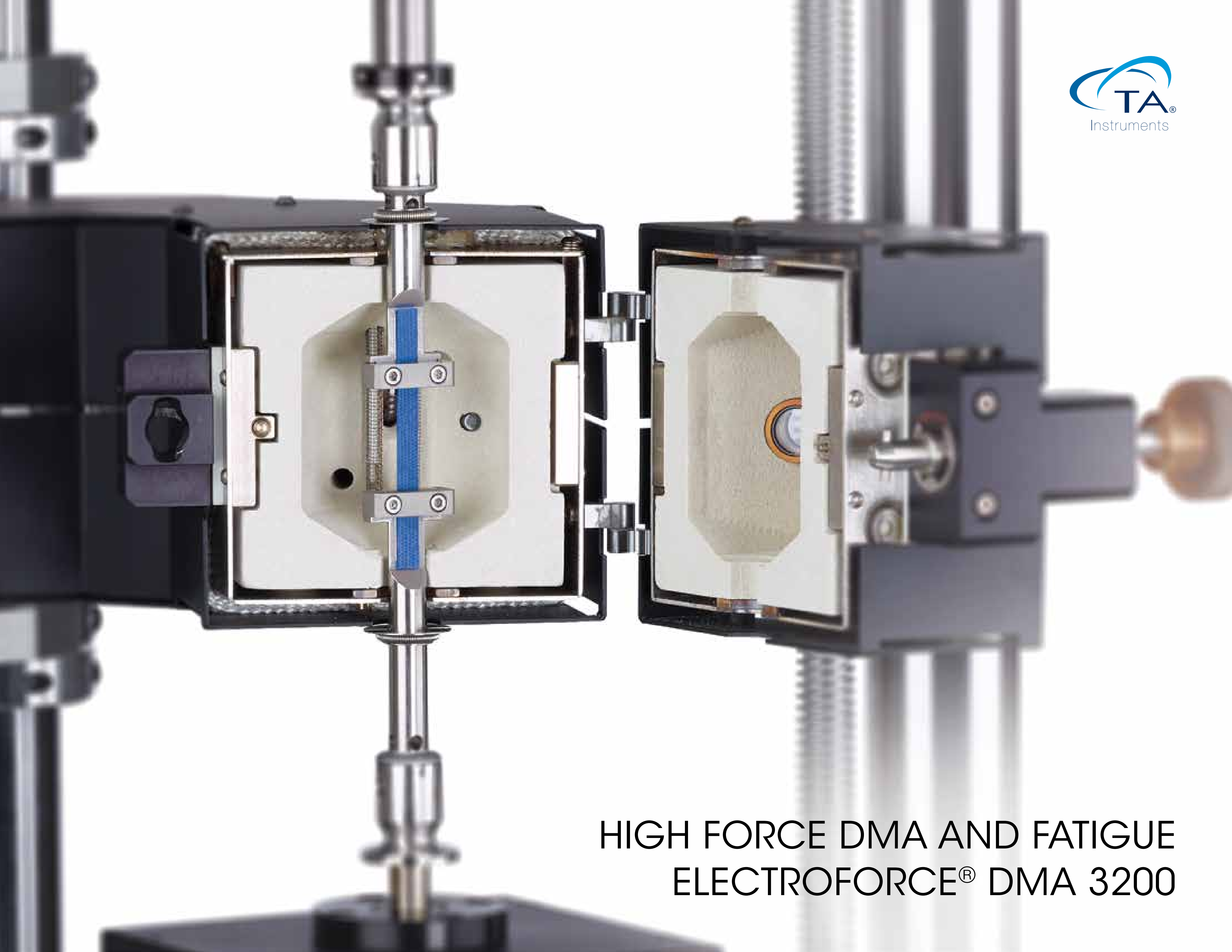
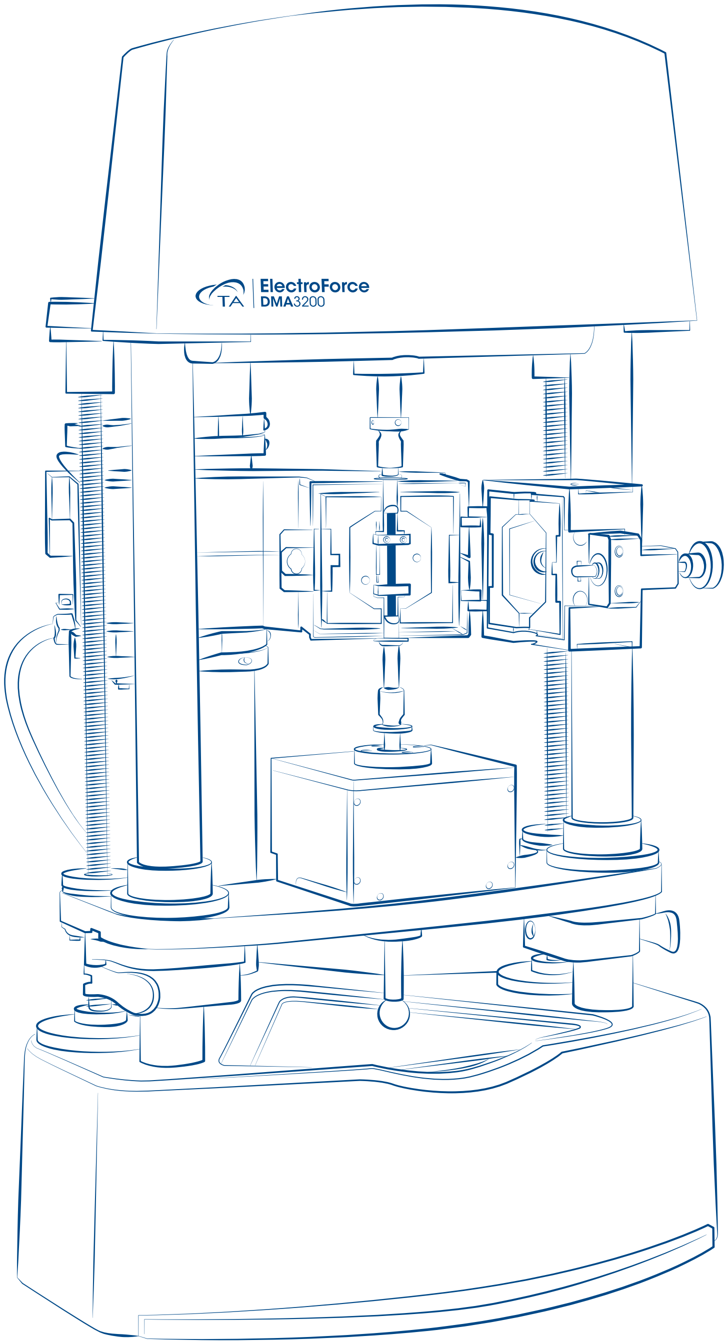


TA Instruments

HIGH FORCE DMA AND FATIGUE
ELECTROFORCE® DMA 3200



Materials encounter a range of mechanical loads and deformations (stresses and strains) over a wide variety of environmental conditions in practical daily use. Therefore, for most applications in nearly every industry, including aerospace, medical devices, asphalt, automotive, electronics, biomaterials, elastomers, composites, food, etc., mechanical properties are often considered the most important of all physical and chemical properties of materials.

The increasing demands for high-quality, high-performing products make it vitally important to understand the complex viscoelastic mechanical properties of these materials to determine and ensure their suitability for reliability, processability and end-use performance. Two instruments that are critical to scientists and researchers for understanding this complex mechanical behavior of solid and soft-solid materials are a Dynamic Mechanical Analyzer, DMA, and a Fatigue Testing System. DMA provides structure-property analysis for a wide variety of material characteristics over the value chain. Fatigue analysis provides insights into strength under repetitive loading, leading to product durability and reliability.

TA Instruments is proud to present the ElectroForce® DMA 3200, a powerful high-performance instrument that delivers excellence in **high force DMA AND fatigue characterization in a single platform**. Only TA could combine patented linear motion technologies with the world's leading DMA capabilities into the most versatile mechanical testing platform for the most demanding applications.

HIGH FORCE DMA & FATIGUE | DMA 3200

The **DMA 3200** combines decades of cutting-edge fatigue and world-leading Dynamic Mechanical Analysis technologies into a unique and highly versatile testing platform. The patented frictionless ElectroForce® motor technology, superior mechanical design, efficient environmental control, and wide variety of clamping systems deliver superior data accuracy for the broadest range of applications.

The ULTIMATE in MECHANICAL TESTING VERSATILITY in a SINGLE INSTRUMENT that delivers INDUSTRY-LEADING DMA and FATIGUE TESTING CAPABILITIES

Features and Benefits:

- Patented, linear motor and high-resolution displacement sensor provide unmatched control over the widest ranges of force, displacement, and frequency, for superior data accuracy
- Ultra-durable, frictionless motor, backed by the industry's only ten-year warranty, provides maintenance- and worry-free operation
- High force of 500 N enables testing of larger samples or final parts under real-world conditions, by achieving higher loading levels in both DMA and fatigue analysis
- Forced Convection Oven (FCO) provides superior control and responsiveness over a temperature range of -150 °C to 600 °C for the highest degree of accuracy and flexibility in experiment thermal profiles
- Large Sample Oven (LSO), with a temperature range of -150 °C to 315 °C, offers spacious interior dimensions to accommodate testing of large samples or components
- Air Chiller Systems (ACS) offer unique gas flow cooling for sub-ambient testing without the use of liquid nitrogen, eliminating potential laboratory hazards while providing an incredible return on investment
- Broad range of fixtures accommodate a wide range of sample sizes and geometries adding to testing versatility
- Extremely rigid test frame and air bearings ensure the most accurate results on samples of very high stiffness
- Multi-color status lights provide clear and visible indication of instrument and test status
- WinTest® and TRIOS Software packages provide powerful and easy-to-use instrument control and data analysis for the ultimate flexibility in experimental design

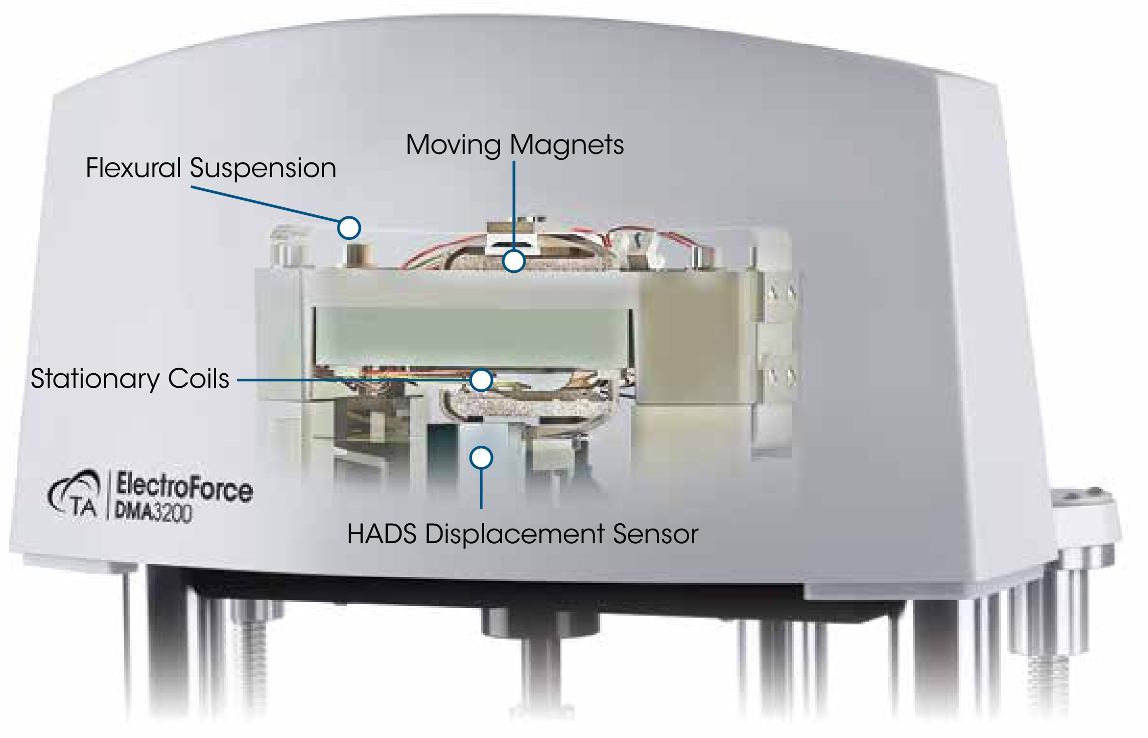
DMA 3200 | TECHNOLOGY

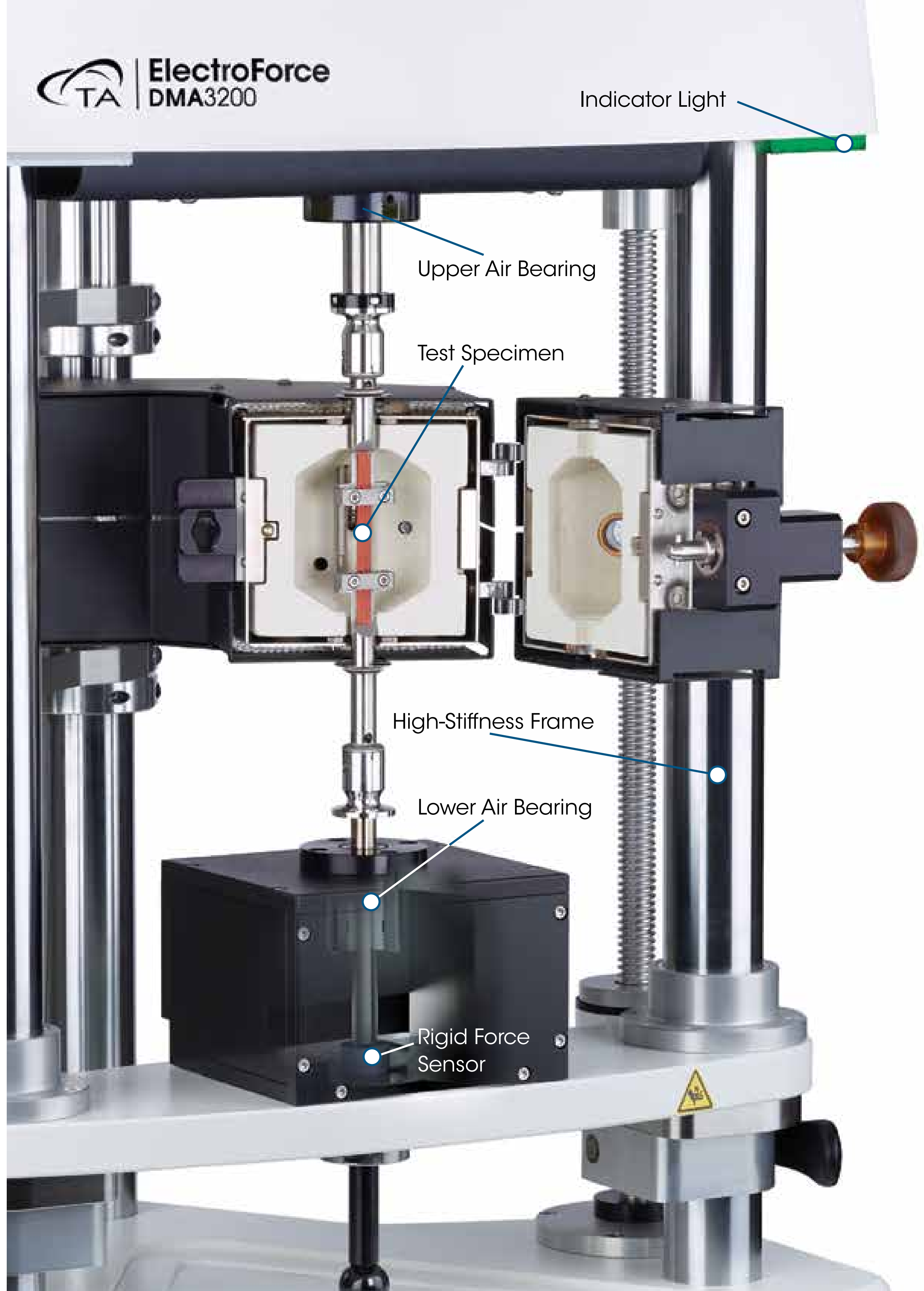
ElectroForce® Linear Motor

The DMA 3200 features patented ElectroForce linear motor technology enabling a single instrument to deliver unequalled performance and data accuracy. This unique motor technology combines powerful rare-earth magnets with a frictionless flexural suspension for the most precise force and displacement control over a wide range of frequencies and amplitudes. The DMA 3200 motor delivers a force output of up to 500 N and controlled displacements ranging from 1 micron to 13 mm. Testing can be conducted in both static and dynamic modes.

In addition, the frictionless moving-magnet design eliminates failure points that exist in other motor designs, such as moving wires and bearing degradation. This ensures the most durable and reliable performance that has been proven over billions of cycles through decades of maintenance-free use in ElectroForce fatigue test instruments. It is the only motor in the industry backed by a ten-year warranty.

This efficient, quiet, and lubrication-free motor technology allows the DMA 3200 to be used virtually anywhere, from lab to production floor, or from the cleanroom to office space.





High Resolution Optical Displacement Sensor

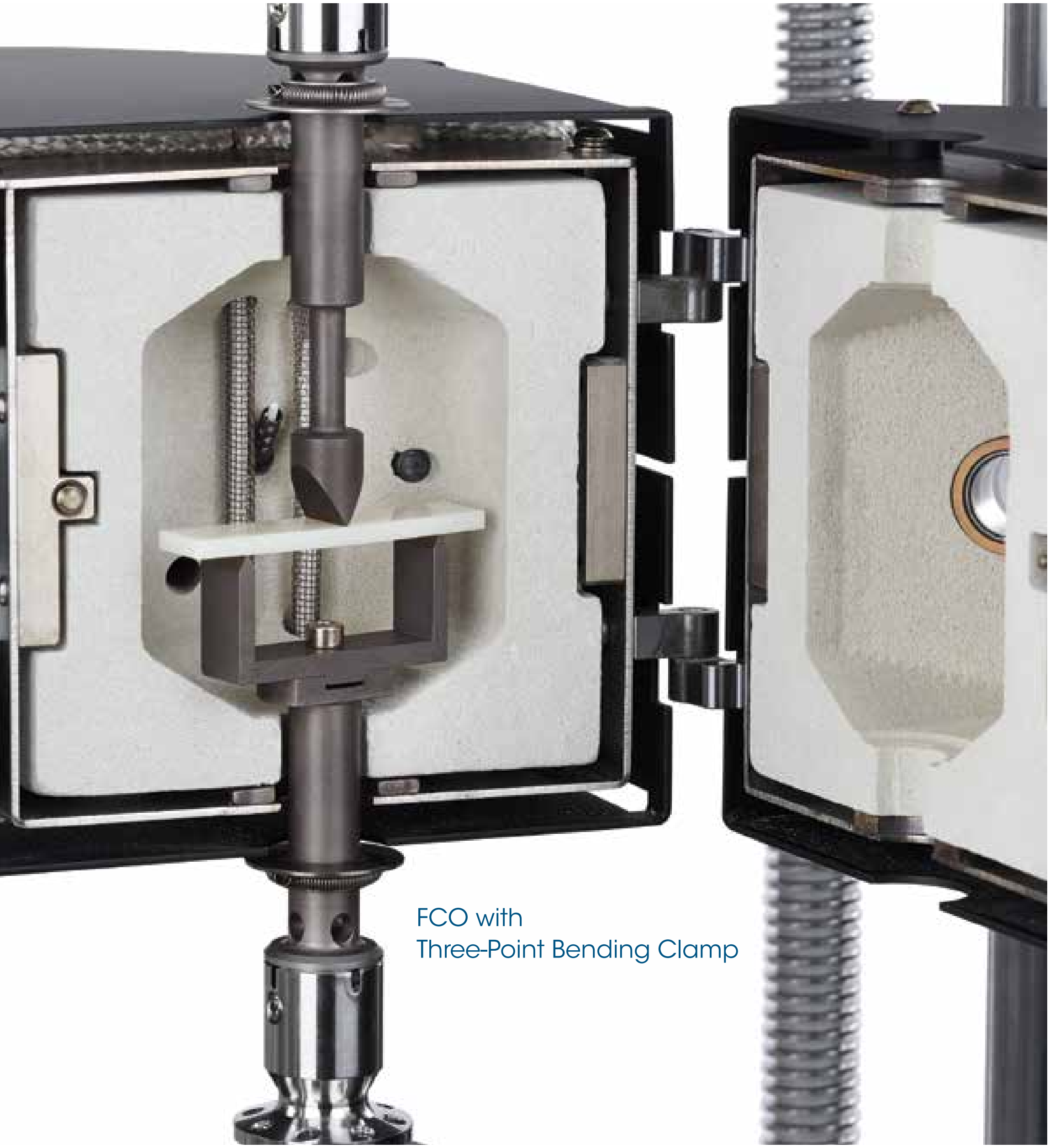
The DMA 3200 features a High Accuracy Displacement Sensor, HADS, for the purest control and measurement of the small and large deformations necessary for DMA and fatigue testing. The HADS is an ultra-performance optical device capable of friction-free, low-noise measurements with nanometer resolution at high speeds. The sensor is placed close to the sample and loading axis to further minimize errors in compliance or thermal expansion.

Interchangeable Force Sensors

High-stiffness and high-bandwidth force sensors are mounted on the base of the rigid frame and are interchangeable for flexibility in test ranges. The instrument comes standard with a 500 N sensor and a 22 N force sensor can be optionally added to improve low-force data for soft-sample tests.

High Mechanical Stiffness Design

In mechanical testing, an instrument design with highly stiff components, such as the frame, connecting components and sample clamps, are critical for measurement accuracy. Minimizing these instrument component deformations, or compliance, reduces displacement measurements that can otherwise appear to be sample deformation. The ultra-stiff design of the 3200 ensures superior data accuracy. It starts with a rigid three-column frame design which maximizes axial and off-axis stiffness, which are further enhanced through the use of air bearings above and below the test specimen. Unlike traditional rolling or plain bearings that introduce noise and friction into the measurement, air bearings have the added benefit of preserving the high-performance attributes of the friction-free ElectroForce® linear motor.



FCO with
Three-Point Bending Clamp

The DMA 3200 can be configured with one of two environmental systems offering the flexibility to meet a wide variety of testing requirements. Both offer a variety of clamping systems, and are compatible with TA's Air Chiller Systems with unique gas flow cooling for sub-ambient testing without the use of liquid nitrogen.

Forced Convection Oven, FCO

The FCO is the premier temperature device for materials testing and is designed to optimize temperature response time, uniformity and stability. This powerful oven can heat at rates up to 60 °C/min. Superior temperature stability is achieved through the use of twin element-resistive gun heaters, which provide counter-rotating air flow into a uniquely shaped oven chamber which optimizes gas mixing for uniformity and stability over the temperature range of -150 °C to 600 °C*. The FCO comes standard with a convenient long-life internal LED light and viewing port. An optional liquid nitrogen cooling system is available for temperature control to -150 °C. Alternatively the FCO can be cooled to as low as -100 °C using LN2-free Air Chilling Systems.

Large Sample Oven, LSO

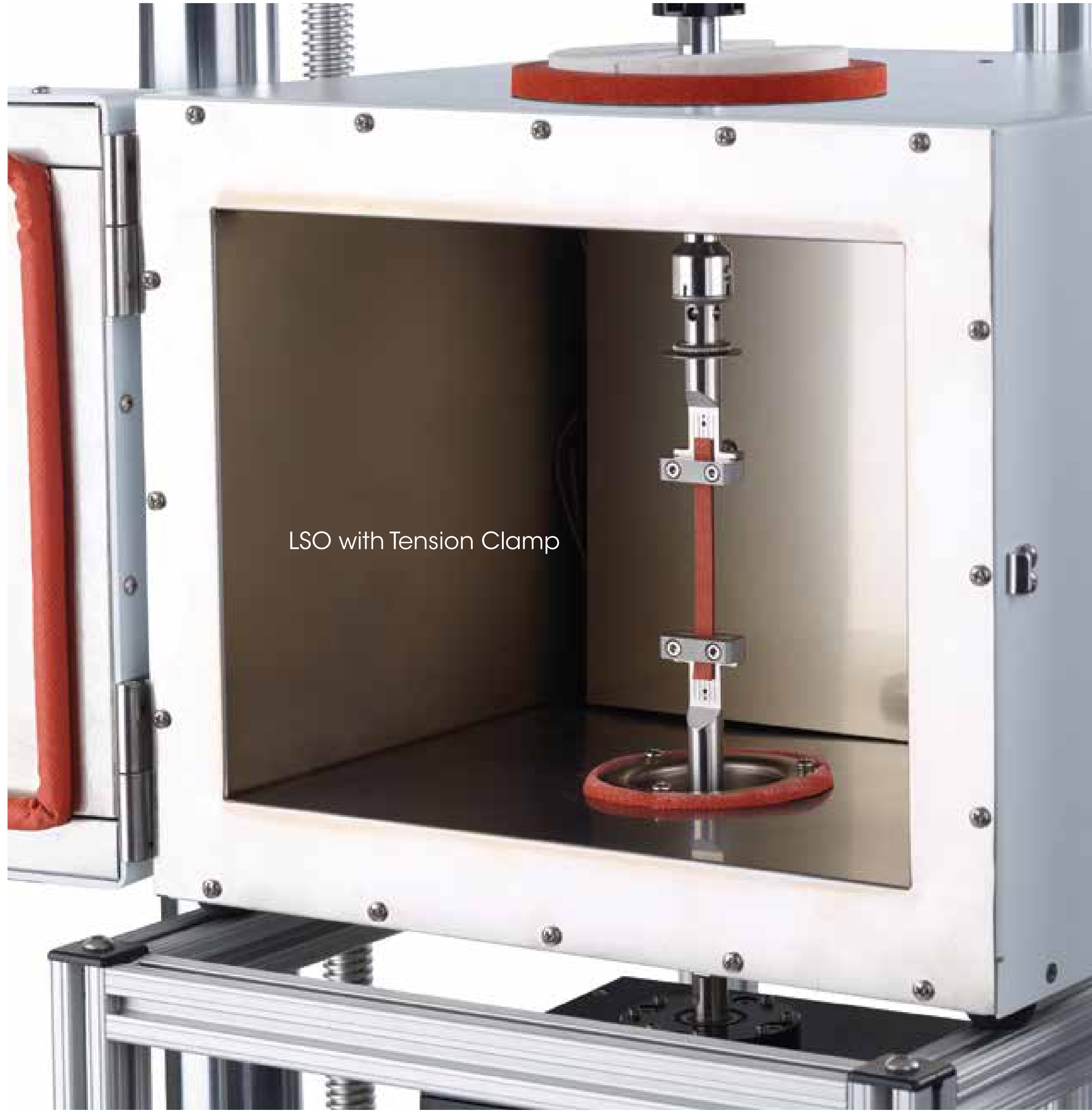
The LSO offers spacious interior dimensions to accommodate larger sample sizes or components. In this design, air is passed over two resistive elements and into the cavity, optimizing uniformity over large volume for temperature control from -150 °C to 315 °C. The LSO comes standard with a large 140 mm x 190 mm viewing window and removable door for convenience. The larger volume of the LSO is ideal for configuring the DMA 3200 with customized clamping solutions for unique applications.

*Testing above 500 °C requires high temperature sample clamps

Air Chiller Systems, ACS

Air Chiller Systems offer unique gas flow cooling that provides for sub-ambient testing without the use of liquid nitrogen. Available in two models, the ACS-2 and ACS-3, the chillers feature a multi-stage cascading compressor design that is capable of utilizing compressed air (7 bar, 200 l/min) as the cooling medium. The ACS-2 and ACS-3 models permit operation of the FCO at temperatures as low as -55 °C and -100 °C respectively. For the LSO, the ACS-2 and ACS-3 models permit operation to -15 °C and -50 °C respectively. The chiller systems can help eliminate or reduce liquid nitrogen usage and associated hazards from any laboratory and offer an incredible return on investment.

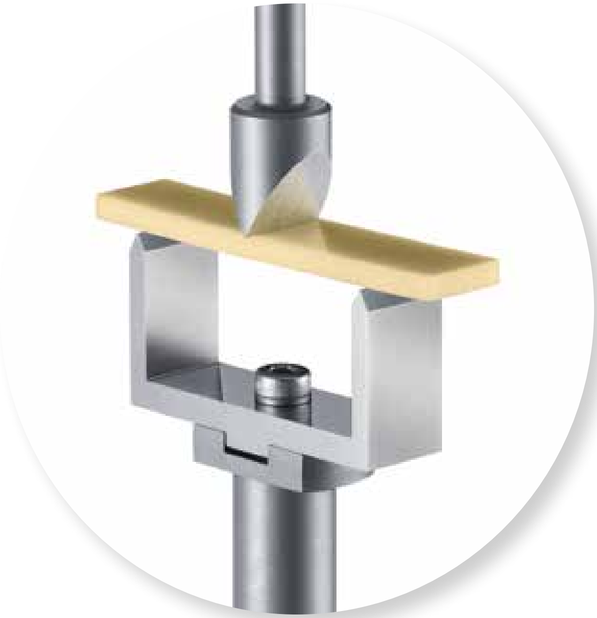
ACS-3 ACS-2



LSO with Tension Clamp

CLAMPING SYSTEMS | TECHNOLOGY

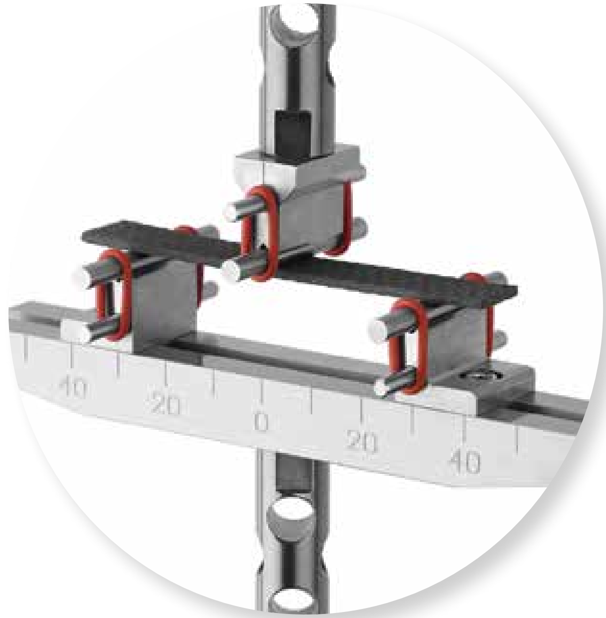
The DMA 3200 features a variety of sample clamping systems that provide multiple modes of deformation to accommodate a wide range of sample stiffness. Standard clamping systems available for use with the FCO include tension, compression, three-point bending, clamped bending, and shear sandwich. Standard FCO clamps, constructed of 17-4 stainless steel, are for use to a maximum temperature of 500 °C, with optional clamps available for extended use to 600 °C. LSO clamping systems, constructed of titanium, can accommodate larger samples and are available in tension, compression and three-point bending modes. All FCO clamps can be used with the LSO.



FCO

Three-Point Bending

In this mode, the sample is deformed around three-point contacts at both ends and its middle. It is considered a "pure" mode of deformation as the sample is freely supported by fulcrums eliminating clamping effects. It is ideal for testing solid bars of stiff materials, such as composites, ceramics, glassy and semi-crystalline polymers, and metals.



LSO

FCO

Tension

In this mode, the sample is clamped at the top and bottom and placed in tension. The tension clamp is for tensile testing of thin films, strips, bars, and individual fibers and fiber bundles.

LSO

FCO

Compression

In this mode, the sample is placed between upper and lower round plates and deformed under various conditions of compression. Compression can be used for testing of many low to moderate modulus materials including foams, elastomers, gels, and other soft solids.

LSO

Dual and Single Cantilever

Cantilever modes are also known as "clamped" or "supported" bending modes because the support and deformation points are mechanically fixed to the sample. In dual cantilever, the sample is clamped at both ends and at the center. The same clamp is used for single cantilever and the sample is clamped between one end and the central clamp. Single cantilever allows for testing of shorter sample lengths. Cantilever is ideal for general-purpose testing of thermoplastics and elastomers and other highly damped materials, as well as measuring transitions of coatings on substrates.

Shear Sandwich

In Shear Sandwich, two equal-size pieces of a material are "sandwiched" between two ends and a central plate. The applied deformation is parallel to the sample thickness and the resultant deformation is simple shear. This mode is sometimes refered to as double-lap shear. Typical samples tested include polymer melts, foams, elastomers, gels, pastes, and other soft solids or high-viscosity liquids.

Clamp Specifications	FCO* Clamp Sample Dimensions	LSO Clamp Sample Dimension
Tension	Up to 35 mm long, 12.5 mm wide, and 2.0 mm thick	Up to 100 mm long, 12.7 mm wide, and 8 mm thick
Compression	8, 15, and 25 mm diameter plates provided; maximum sample thickness is 25 mm	Up to 50 mm diameter, and 100 mm thickness (height)
Three-Point Bend	Spans of 10, 25, and 40 mm. Up to 12.8 mm wide and 5 mm thick	Adjustable Span of 10 to 100 mm. Up to 13 mm wide and 10 mm thick
Cantilever Bend	Up to 38 mm long, 12.5 mm wide, and 1.5 mm thick	N/A
Shear Sandwich	Sample thicknesses of 0.5, 1.0 and 2.0 mm; shearing surface is 15 mm square.	N/A

* Note: All FCO fixtures are compatible with the DMA 3200 LSO Environmental System. Adapters are included.

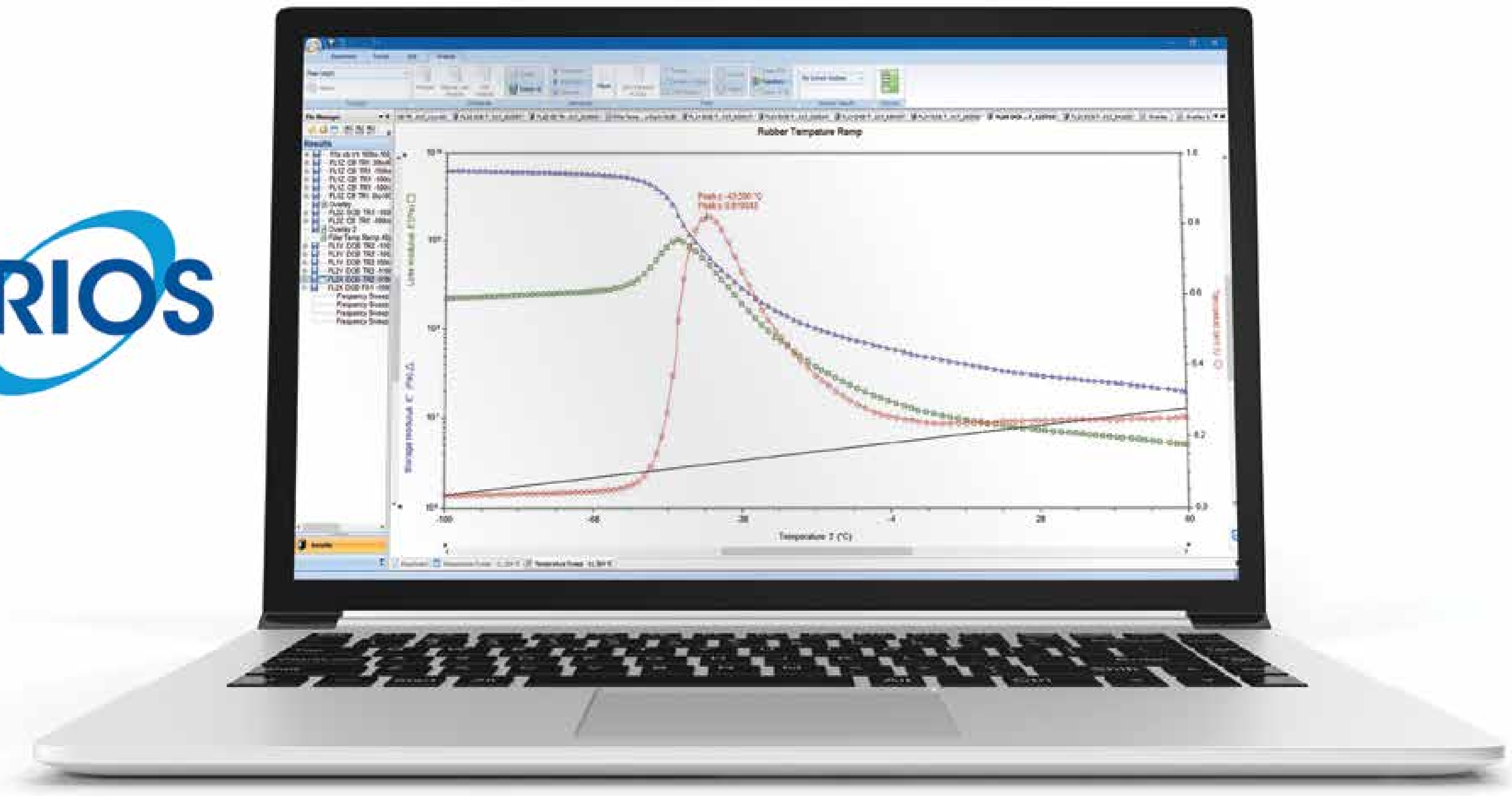
The DMA 3200 is powered by two of the industry's most powerful software packages: WinTest® and TRIOS. These two packages provide advanced algorithms, sophisticated data visualization, and powerful analysis tools for fast and flexible execution and presentation of experiments.

WinTest Advanced Control Software

WinTest is a powerful instrument control and data acquisition software for the DMA 3200. It offers an intuitive environment that provides the flexibility in fatigue and DMA experimental design. DMA experimental methods include temperature ramps, temperature sweeps, strain sweeps, and frequency sweeps. Fatigue and ramp-to-failure tests are easily programmed with a variety of available waveforms including sine, triangle, square, or ramp. In addition, waveforms can be combined, or real-to-life waveforms can be imported. Unique TuneIQ and Controlled Stop help users harness the acceleration and power of ElectroForce® motors by simplifying tuning tasks.

TRIOS for Data Analysis Software

TA Instruments TRIOS software seamlessly transfers DMA data from WinTest, providing experimentalists with the industry's leading tool for analyzing and presenting DMA data. This intuitive software includes a wide variety of plotting tools, some of which include multi-axis plotting, smart default and user-customizable graph settings, drag-and-drop overlay, and user-defined variables. A complete range of DMA analysis models and functions includes Time-temperature superposition (TTS), peak analysis, onset point analysis, peak integration, and continuous and discrete relaxation spectrum. The software can be installed offline on any computer for easy sharing of data with colleagues.



DMA 3200 | APPLICATIONS

Dynamic Mechanical Analysis, DMA

DMA is a technique that applies a sinusoidal deformation, stress or strain, to a sample and measures the viscoelastic response. The frequency and magnitude of the deformation can be held constant or varied (swept) during an experiment. The material response to the deformation can be monitored as a function of temperature, frequency, or time. DMA is used to determine a variety of mechanical properties, i.e., complex modulus, E*, storage and loss moduli (E', & E") and damping (tan δ) of viscoelastic materials, detect molecular motions, and develop structure-property relationships.

Measurable material properties and typical applications of DMA are as follows:

Material Properties:

- Modulus of Elasticity (E)
- Modulus of Rigidity (G)
- Complex Moduli (E*,G*)
- Storage and Loss Moduli (E', E", G', G")
- Damping Properties (tan δ)
- Complex Stiffness (K*)
- Storage and Loss Stiffness (K', K")

Typical Applications:

- Glass Transition Temperature
- Secondary Transitions
- Softening and Melting Temperature
- Time-temperature Superposition
- Linear Viscoelastic Region
- Payne Effect
- Mullins Effect
- Heat Build-up
- Molecular Weight/Cross Linking
- Curing Studies
- Transmissibility
- Hysteresis
- Physical or Chemical Aging
- Orientation Effects
- Effects of Additives
- Impact Strength

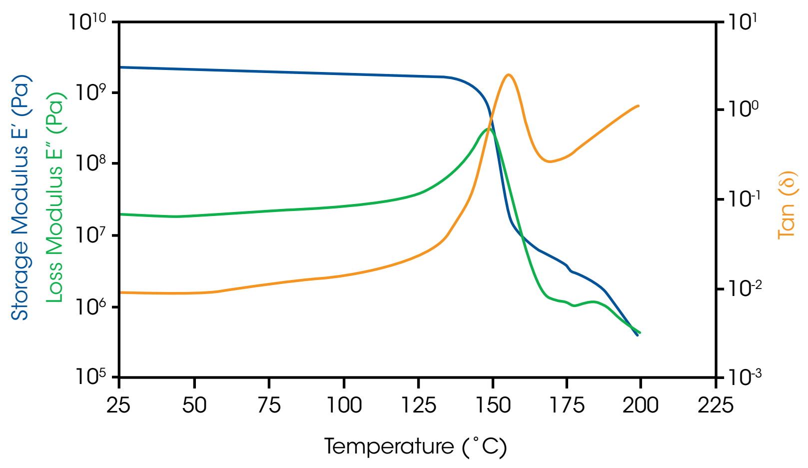
High Force Dynamic Mechanical Analysis, DMA

The high-force capability of the DMA 3200 extends experimental loading regimes and enables testing of larger samples or actual components. Examples of high force DMA capabilities are shown in the figures to the right.

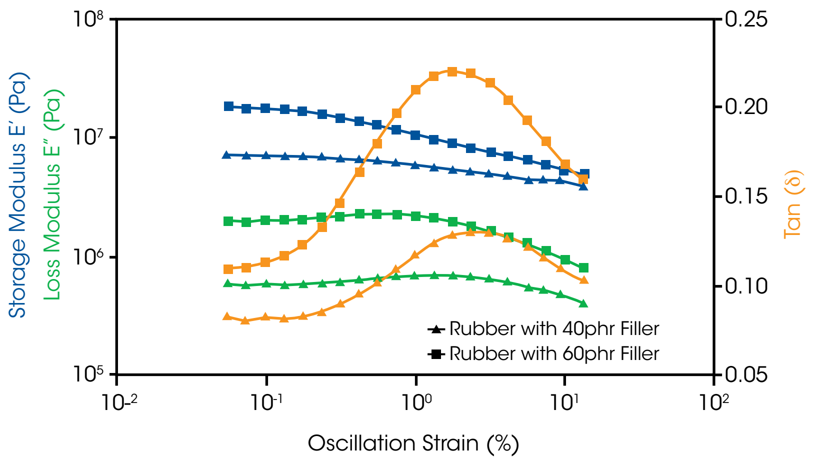
The top figure shows a temperature ramp on a bar of Polycarbonate at a heating rate of 3 °C/min and strain of 0.4%. The dimensions of the sample are 1.6 mm thick, 12.8 mm wide, and 19 mm long. These results demonstrate the capabilities of the DMA 3200 design in several ways. First, the high-force, high-stiffness design of the DMA 3200 enables such a thick sample to be tested in the glassy region, or below the Tg, of the polymer in tension mode. A more traditional lower force DMA instrument design would be both force- and stiffness-limited. Such results would have to be obtained in a bending configuration vs. tension. Second, the friction-free design, which provides excellent low force sensitivity, enables characterizing the glass transition through over three decades of change in modulus.

The bottom figure shows strain sweeps on two cylindrical rubber samples, tested using compression clamps, at a temperature of 30 °C and frequency of 10 Hz. The sample dimensions were a diameter of 10 mm and thickness of 20 mm. These two rubber samples have different amounts of filler content, specifically 40 phr and 60 phr, where phr is a batch unit standing for parts per hundred of rubber. It can be seen that higher filler content results in a higher modulus as well as a more strain-dependent modulus. During this test, forces required to apply 20% strain, which is equivalent to 5 mm, are approaching 60 N. These results highlight both the high force and exceptional displacement control of the DMA 3200.

Polycarbonate Temperature Ramp in Tension



Rubber Strain Sweeps in Tension-Compression



Fatigue and Quasi-Static Testing

Most materials, components, and devices are exposed to repeated loading conditions during their use and this loading causes fatigue of the material. This fatigue can lead to dramatic changes in material behavior, which can impact overall performance, or it can result in complete and catastrophic failure. Mechanical fatigue testing provides insights on how and when materials, components, or devices fail when subjected to oscillating forces, or stresses. These insights into material behavior are used to ensure reliable product performance and prove out lifetime claims.

Monotonic testing, also known as tensile testing, is also useful for evaluating strength and deformation response. In this case, properties are measured during a single load-to-failure test.

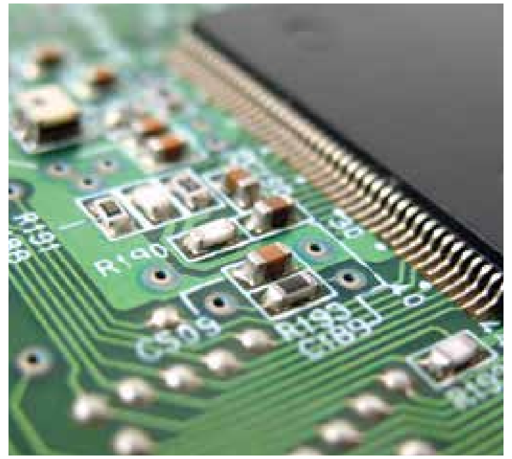
Various material, component or device characteristics can be measured with the DMA 3200, supporting many types of dynamic or static strength studies.

Example Measurements:

- Modulus of Elasticity (E)
- Stiffness (K)
- Yield Strength
- Tensile Strength
- Elongation at Break
- Fatigue Strength

Example Strength Studies:

- Accelerated Life Testing
- SN Curve Determination
- Mechanical Aging
- Creep and Recovery
- Stress Relaxation
- Tensile Testing



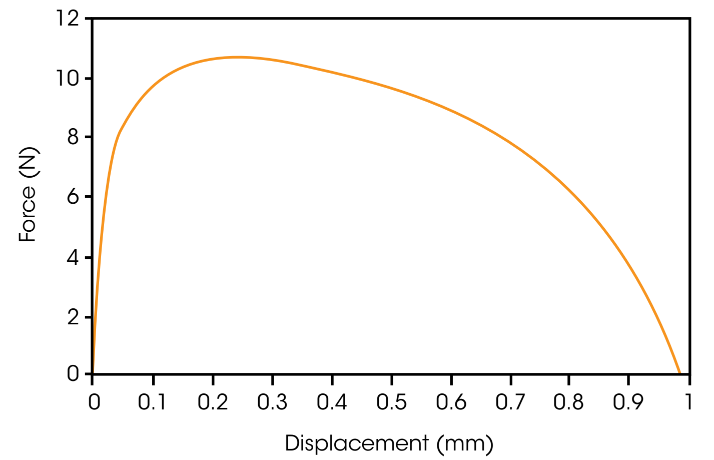
Enabling Fatigue and Quasi-Static Testing

The flexibility, power, and durability of the DMA 3200 enable a variety of tests in addition to DMA. Its wide range of speed and force make it useful for both fatigue and quasi-static testing. Examples of these capabilities are shown in the figures to the right.

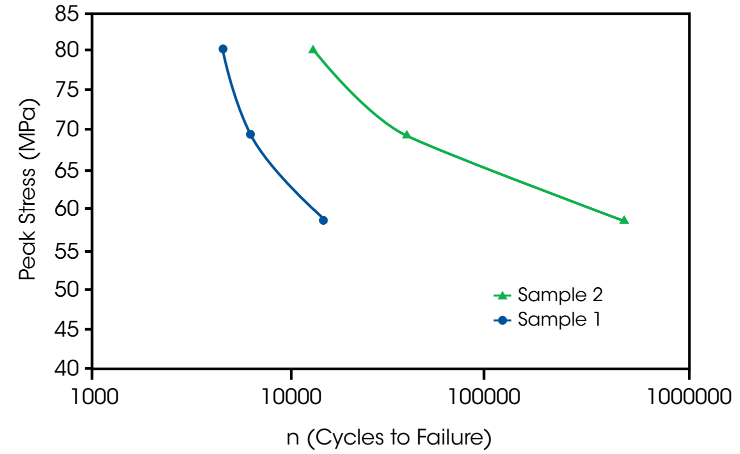
The top figure shows a single pull-to-failure test, aka tensile test, on a small bar of solder. The displacement ramp was controlled at 1 micron per minute and temperature was constant at 25 °C. The dimensions of the sample are 0.5 mm diameter and 2 mm long. This test requires slow and precise control of displacement over a very long time, in this case 14 hours. The sample demonstrates the classic linear region in the beginning of the test in the left of the plot and a very long ductile failure over the middle and right of the plot. This test demonstrates flexibility of the ElectroForce® linear motor. Even though it has very high dynamic capabilities it can also be used for precise and slow testing as well.

The bottom figure shows the results of a fatigue study on thermoplastic elastomers. This curve is often called an "S-N Curve" for Strength versus Number of cycles. It is a common plot to illustrate and characterize the cyclic-loading lifetime of materials or components as a function of the loading level. It can be seen that as the stress is decreased the sample required more cycles to failure. This test demonstrates how the DMA 3200 can be used for a high cycle test, leveraging its high acceleration and durability attributes.

Tensile Fatigue Test on Solder



Fatigue Test comparing two Thermoplastic Elastomers



DMA 3200 | SPECIFICATIONS

Instrument Specification	DMA	Fatigue & Quasi-Static
Maximum Force	500 N	450 N
Minimum Force		
500 N Sensor	0.2 N	0.5 N
Optional 22 N Sensor	0.025 N	0.022 N
Force Resolution		
500 N Sensor	0.006 N	0.015 N
Optional 22 N Sensor	0.00026 N	0.00067 N
Dynamic Displacement Range	±0.0005 to ± 6.5 mm	±0.002 to ± 6.5 mm
Displacement Resolution	1 Nanometer	1 Nanometer
Maximum Acceleration	80 G	80 G
Maximum Displacement at 50 Hz	± 6.5 mm	± 6.5 mm
Maximum Displacement at 100 Hz	± 1.0 mm	± 1.0 mm
Modulus Range	10^3 to $3x10^{12}$ Pa	NA
Modulus Precision	± 1%	NA
Tan δ Sensitivity	0.0001	NA
Tan δ Resolution	0.000015	NA
Frequency Range	0.01 to 100 Hz	0.00001 to 300 Hz

Oven Specifications	FCO	LSO
Maximum Temperature	600 °C*	315 °C
Minimum Temperature with LN2 Cooling	-150 °C	-150 °C
Minimum Temperature with ACS-3	-100 °C	-55 °C
Minimum Temperature with ACS-2	-50 °C	-15 °C
Heating Rate	0.1 to 60 °C/min	0.5 to 10 °C/min
Cooling Rate	0.1 to 60 °C/min	0.5 to 10 °C/min
Isothermal Stability	± 0.1 °C	± 2 °C
Interior Dimensions	70 mm High x 60 mm Dia	191 x 200 x 200 mm

* Note: Standard sample clamps are for use to a maximum temperature of 500 °C. Optional sample clamps are required for testing to 600 °C.

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