HAAKE MARS
Modular Advanced Rheometer System

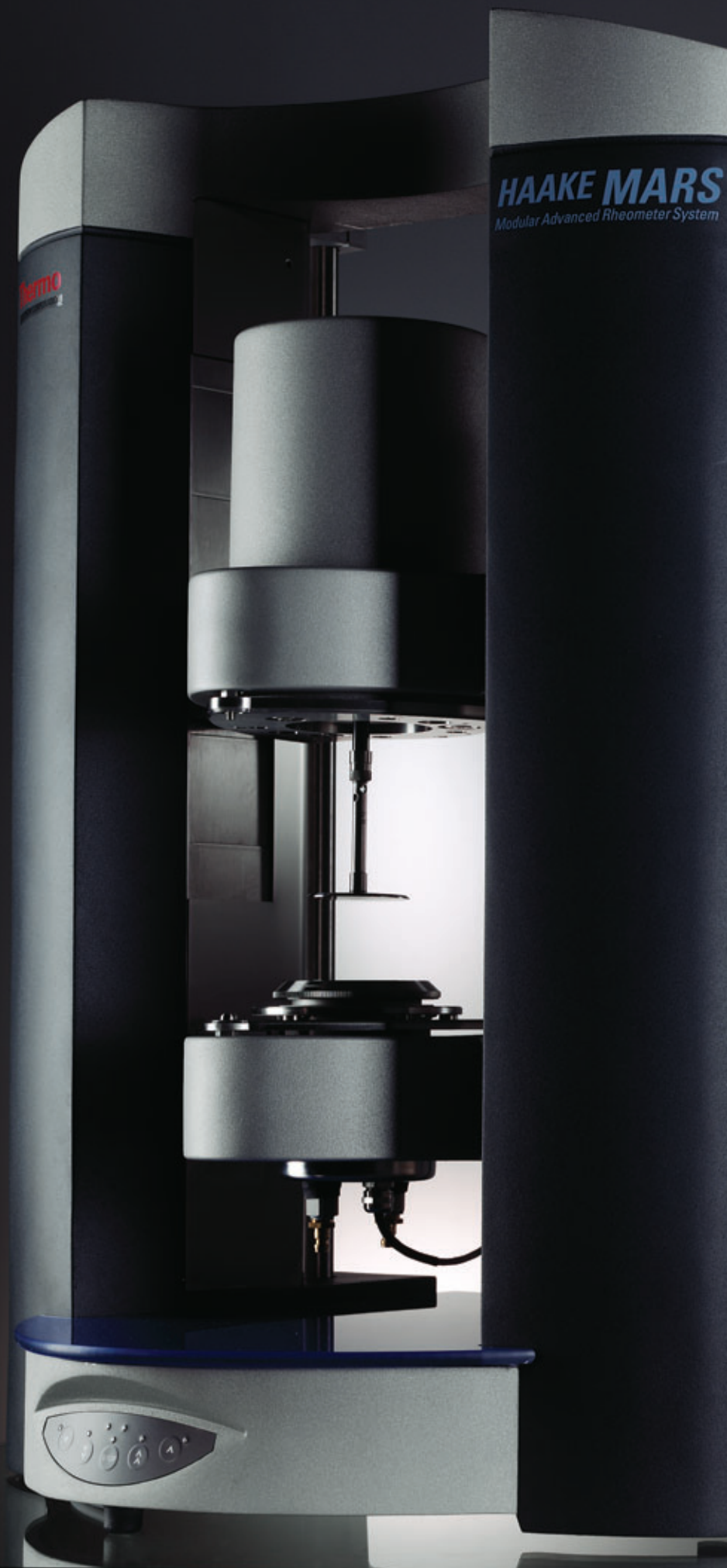
Analyze • Detect • Measure • Control™

Thermo
ELECTRON CORPORATION

As a pioneer in the field of rheology, Thermo Electron Corporation is well-known for its leading HAAKE rheometer lines. These instruments precisely analyze a material's processability and temperature-related mechanical changes as well as rheological properties – no matter whether the sample is solid or liquid.

The innovative HAAKE MARS (Modular Advanced Rheometer System) platform, was designed for flexibility – now and into the future – to maximize your instrument investment. The new platform meets the most demanding requirements in R&D with an architecture that permits custom modules to be integrated into the system.

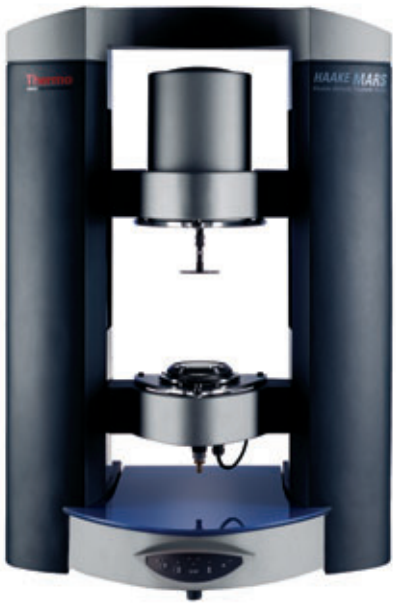
You can be assured this platform will meet your future requirements.



INVEST
INTO THE FUTURE

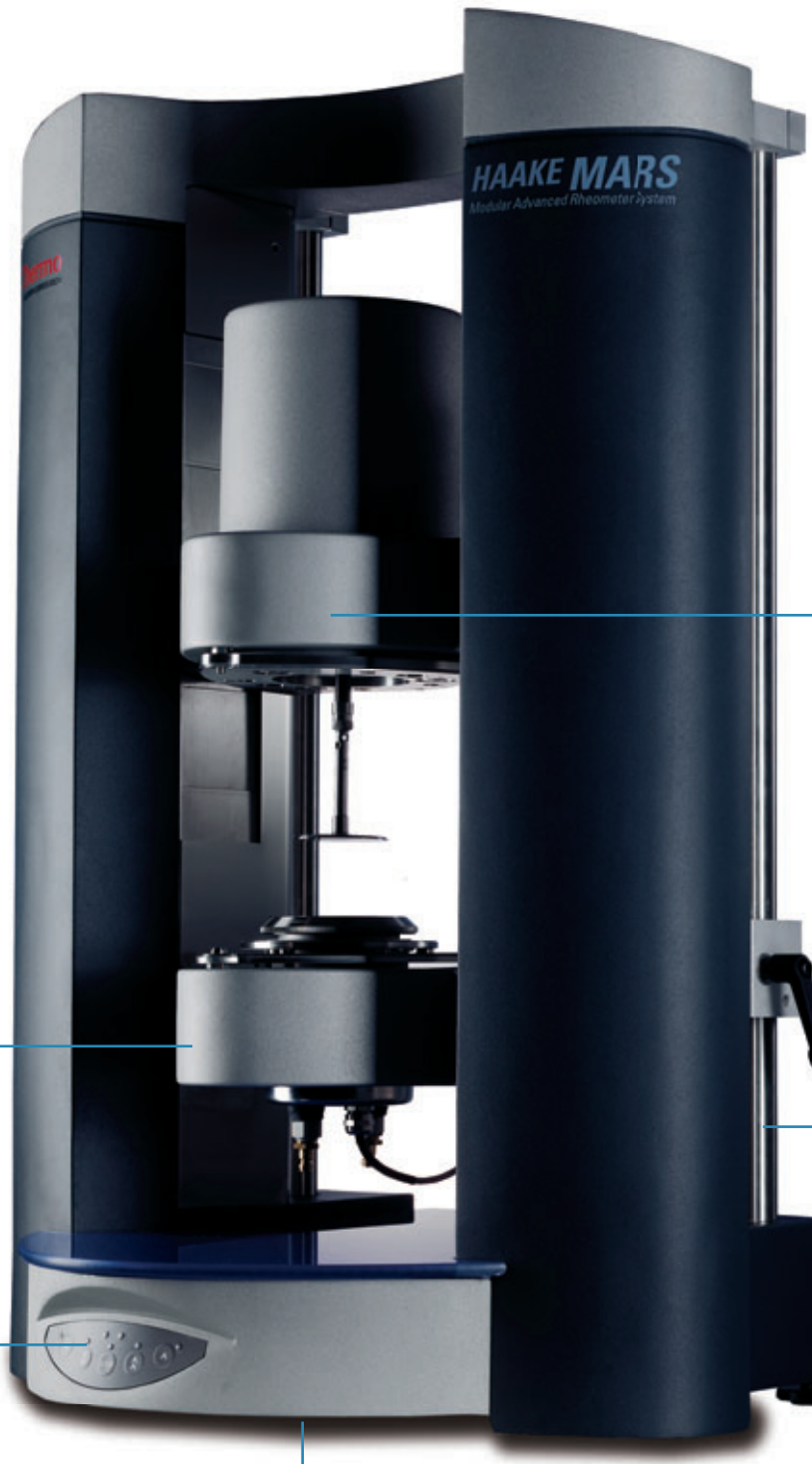
Thermo's HAAKE MARS platform is the most modular rheometer in its class. It fully meets all R&D rheological requirements – now and tomorrow. We will base future technical innovations on this new platform well into the future.

The HAAKE MARS platform also allows you to capitalize on past investments. The wide range of accessories from the HAAKE RheoStress series (HAAKE RheoStress 600, 300, 150, 100, 50, etc.) including temperature control units, measuring geometries and special measurement equipment, can still be used. Compatibility is assured.



MODULAR DESIGN

A one-piece, aluminum-cast H-shaped frame offers unmatched stability and optimizes force distribution



Measuring head with the upper mount lifts to accommodate samples

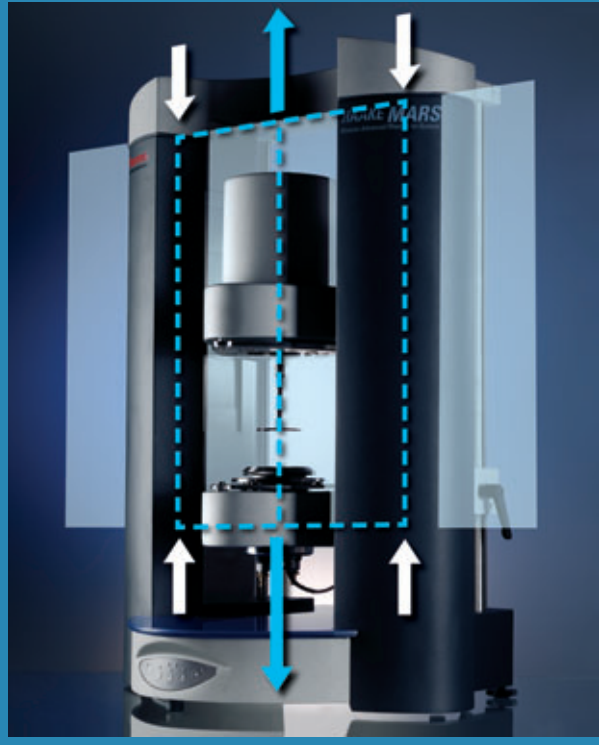
Mounting rods (optional) for temperature-controlled test chamber and other special modules

Fixed lower mount attaches temperature control and other specialty modules securely

Manual control panel for lift with LED status indicators for operator convenience

Additional access below measuring geometry for individual measuring options

The active forces from the sample and the reactive forces in the frame operate in the same plane in the HAAKE MARS' "H-shaped" frame. This effectively prevents the gap from widening as a result of high normal forces that occur in a standard "C-shaped" frame.



RHEOMETER WITH "PLUG AND PLAY" COMPONENTS

All application-relevant components, including measuring geometries, temperature control modules, instrument electronics, and even the measuring head, are easily exchangeable.

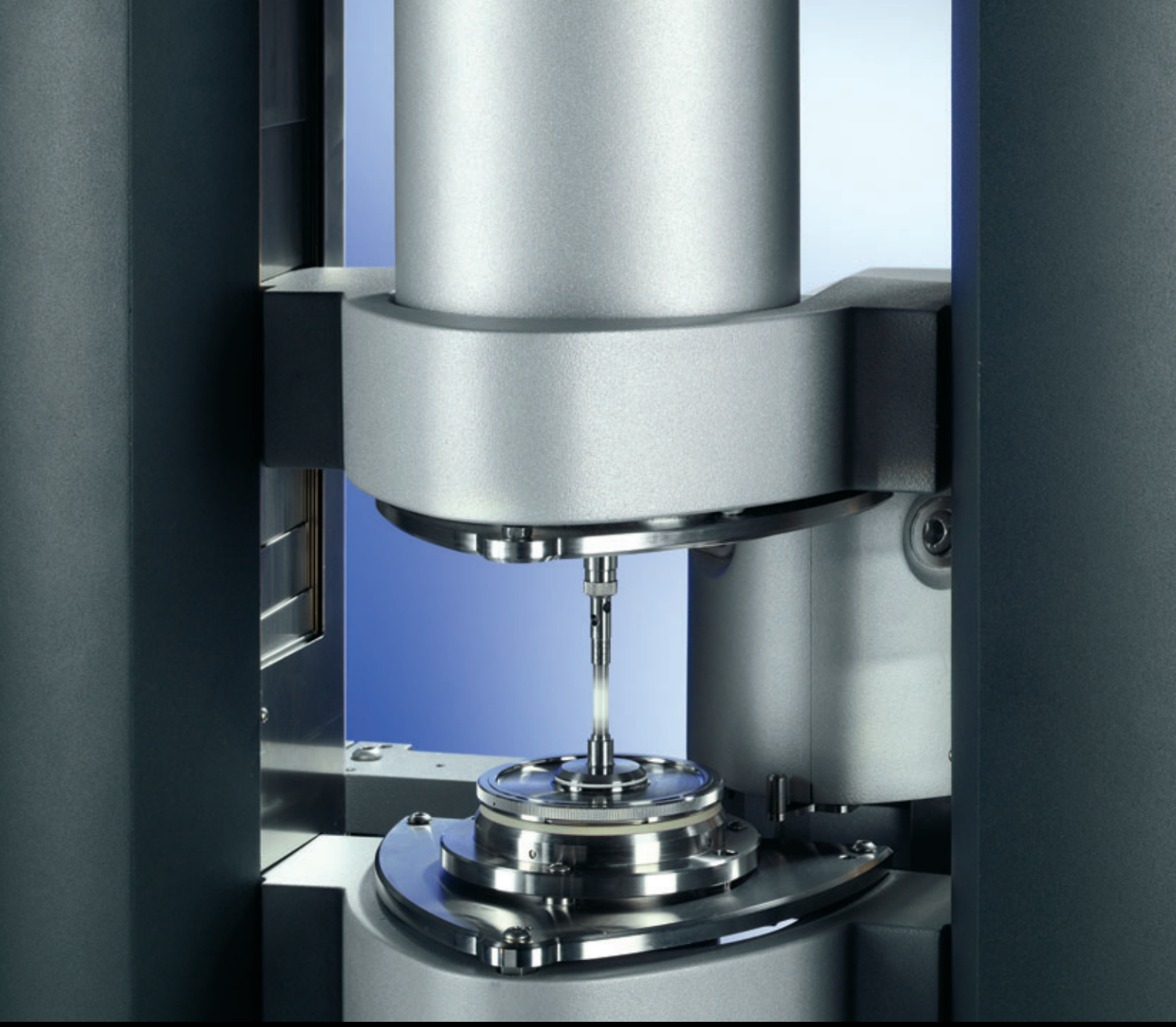
CONTROL AND POWER ELECTRONICS

The main control and power electronics are separated from the instrument itself, thereby preventing thermal and mechanical interference from heat sources, fans, etc. By removing the secondary control electronics for the upper mount lift from the rheometer frame, an opening in the base of the frame can be used to access the measuring geometry from below. This is ideal for optical methods which require more space. The ability to remove the electronic components from the instrument altogether makes the HAAKE MARS perfectly suited for use in radioactive "hot-cells" or in biohazard environments.

TCP/IP ETHERNET INTERFACE

Using the TCP/IP Ethernet data communication interface between the rheometer and the RheoWin PC software allows data points to be acquired and displayed every 2 ms in real time. This is important for measuring samples with fast changing properties, e.g. UV-curing materials. Since each HAAKE MARS rheometer has its own specific IP-address, each rheometer can be connected to the internet or a company network and controlled individually. The HAAKE MARS rheometer is equipped with an integrated web server that offers remote status checks for measurements, service information, and limited remote control.

Integrated web-server for monitoring data online, e.g. via PDA.



DRAG CUP MOTOR | The drag cup motor applies a stationary or oscillatory torque to the sample.

The main advantages of a drag cup motor over other motor types are its extremely smooth operation and its very low moment of inertia. At 10^{-5} µNms, the inertia of the HAAKE MARS drag cup motor is the lowest available! The integrated memory chip contains all relevant calibration data and therefore allows a quick exchange without time-consuming calibration.

AIR BEARING | The patented 4th generation air bearing* in the HAAKE MARS is the result of more then 25 years of experience with the design and manufacturing of porous carbon air bearings. The air bearing consists of three individual air bearings:

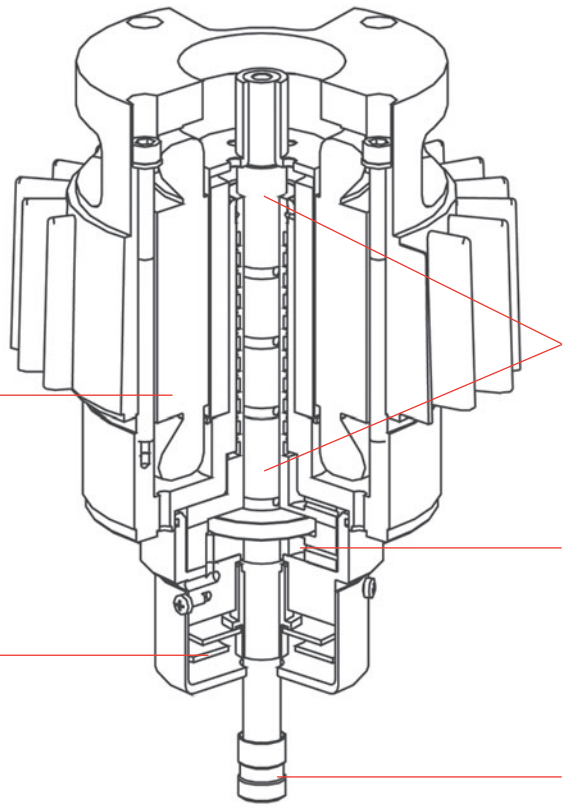
- **One axial air bearing that supports the motor shaft in the vertical (axial) direction and is responsible for excellent axial stiffness.**
- **Two widely spaced radial air bearings that support the motor shaft in the radial direction and prevent the shaft from tilting.**

*** DE10247783 A1 patent pending; US020040069050 A1 patent pending**

OPTICAL ANGLE ENCODER | **The HAAKE MARS' optical angle decoder is mounted to the bottom of the measuring head to minimize the influence of the inevitable compliance of the motor shaft. This is important when measuring semi-solids. The optical angle encoder has a very high resolution of 12 nanorad, which is important when measuring delicate samples within the linear visco-elastic regime at very low amplitudes in oscillation as well as the determination of the zero-shear viscosity at very low shear rates (10^{-6} s^{-1}).**

NORMAL FORCE SENSOR | **The newly developed normal force sensor is based on temperature-compensated strain-gauge technology and offers a measurement range of 0,01 to 50 N in both positive and negative direction. The new normal force sensor enables the HAAKE MARS system to perform sensitive normal force measurements even on samples with low viscoelasticity. In addition, the system controls the normal force in the sample to compensate for sample shrinkage and expansion when measuring semi-solids. In combination with the controlled axial movement (lift) of the entire measuring unit, the HAAKE MARS system can also detect the "tackiness" of a sample.**

HAAKE MARS MEASURING HEAD - DETAILS



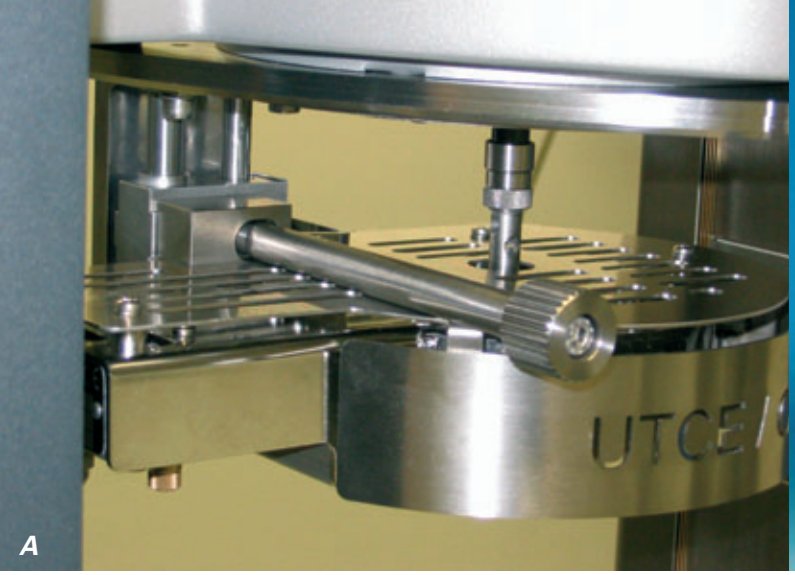
TEMPERATURE CONTROL UNITS

A variety of temperature control units is available to reliably and accurately handle temperatures ranging from -150°C up to 600°C. Choose from a Closed Temperature Chamber (CTC), or Peltier, electrical or liquid temperature control units for coaxial cylinders and cone and plate measuring geometries. All temperature control units from previous rheometer models can be used with the HAAKE MARS platform.

Overview Temperature Control Units	Temp. min. °C	Temp. max. °C	Heating rate	Cooling rate
Liquid temperature-controlled cylinder unit	-40*	200	2*	1*
Liquid temperature-controlled cone & plate unit	-80*	350	3*	2*
Electrically heated cylinder unit	30	300**	8*	1*
Electrically heated cone & plate unit	-80*	500	15*	2*
Peltier controlled cone & plate unit	-60*	185	40*	40*
Closed temperature chamber CTC	-150	600	40*	40*

* Depending on the temperature control unit used.

** Using suitable measuring geometries.



Comprehensive portfolio of temperature control units: *A electrically heated cone & plate unit with active cone heater*
B liquid temperature-controlled unit for coaxial cylinders

UNIVERSAL TEMPERATURE CONTROL UNIT (UTC)

The UTC consists of a universal controller box to regulate different temperature control units for cone and plate measuring geometries – Peltier as well as electrical. A Peltier unit with a temperature range from -60°C up to 185°C has the advantage of responding quickly and accurately to temperature changes. The electrical temperature control unit, comprising a lower and an upper heater, can be converted to a measuring chamber with a tempered glass ring. This enables measurements up to 500°C under visual control and inert gas.

LIQUID TEMPERATURE-CONTROLLED UNITS

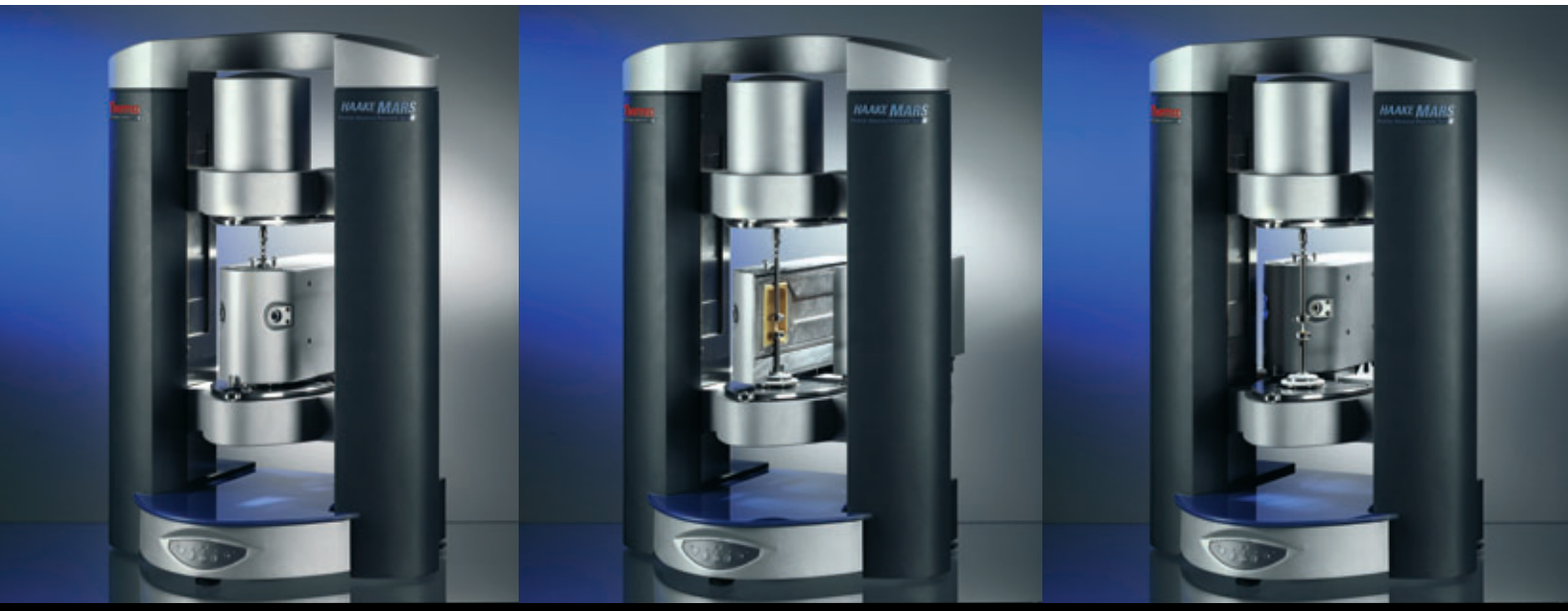
Choose from a temperature control unit for cone & plate measurement geometries and two units with different coaxial cylinder diameters. Liquid temperature-controlled units require either a circulator or cryostat and a bath liquid specific to the application. Thermo Electron offers a wide product portfolio and many years of experience in temperature control to ensure a fit with your requirements.

Powerful HAAKE Phoenix II temperature control unit to be used for liquid temperature-controlled units.

CONTROLLED TEST CHAMBER (CTC)

Developed specifically for the HAAKE MARS platform, the new Controlled Temperature Chamber (CTC) moves smoothly on guide rails. The CTC consists of two halves that allow convenient handling and optimal access to the sample. They can be moved independently backwards and sidewards, and can be opened and closed easily by hand. No special tools are needed. The two halves automatically center themselves around the sample automatically when closed. Each chamber half is equipped with a window to observe the sample during measurement.

A unique feature is the "parking" position, which allows another temperature control unit to be attached without removing the CTC. While in the "parking" position, the CTC measuring temperature can be set, and the sensors can be cleaned or the next sample can be prepared. No time is wasted waiting for the CTC to reach its set temperature.



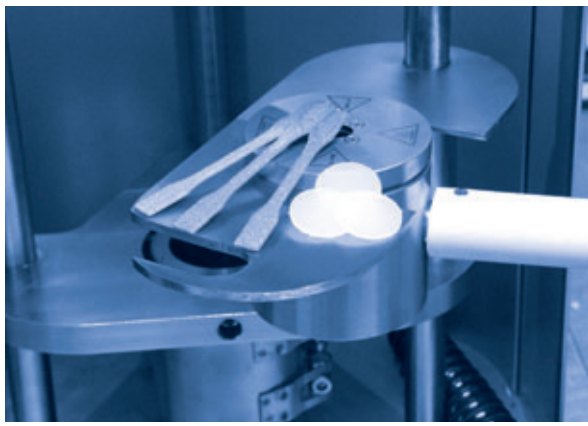
BENEFIT | **The HAAKE MARS can be equipped easily and quickly with any other temperature control unit without removing the temperature chamber. A combination of convection and radiant heating guarantees an even temperature distribution within the CTC (patent DE 10 2004 050 751 A1). The temperature range spans from 30 °C to 600 °C and can be expanded to -150 °C with the low temperature option. With this optional device, liquid nitrogen can be evaporated to achieve cooling rates of 20 K/min. Since the siphon and the flexible premium hoses have a double-walled vacuum insulation, ice formation on the outer surfaces is negligible even at extremely low temperatures. The flexible connections of the premium hoses ensure that the free chamber halves move freely. Special sensors have been developed for the CTC.**

CTC MEASURING GEOMETRIES OVERVIEW

Patented clamps for solid samples for measurements according to DIN/ISO 7621-1. These clamps are self-centering and self-adjusting to allow for physical changes of the sample (e.g. expansion or contraction due to temperature changes).

Exchangeable plates and cones of various sizes and various materials (e.g. steel or aluminum).

SAMPLE PREPARATION | **In order to achieve highly reproducible measurements on polymers, suitable sample preparation is of utmost importance.**



Using the HAAKE MiniJet injection molding system, specimen can be prepared with the same diameter as the measuring geometry, (e.g. disks for plate/plate measuring geometries or rectangular specimens for solid clamps).

Disposable tool for cone & plate measuring geometry ensures gaps are filled when measuring pellets.

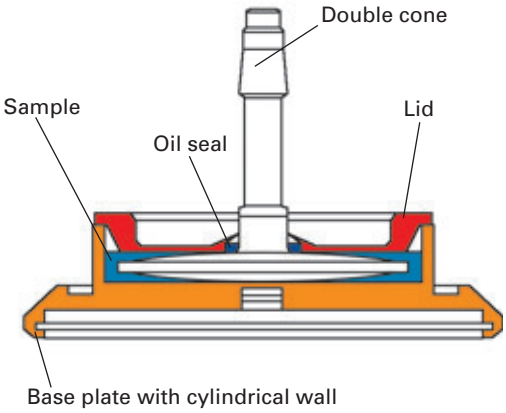
MEASURING GEOMETRIES

Disposable coaxial cylinders, plate/plate and cone/plate measuring geometries, custom-tailored dimensions, and a variety of different materials are all part of the product portfolio. Standard titanium measuring geometries have a low mass and therefore a low inertia. For measurements at higher temperatures, geometries with a ceramic shaft are available. The geometries are characterized by a reduced heat transfer to the measuring head and a limited temperature gradient within the sample. To avoid sedimentation or slippage, measuring geometries with serrated or sand-blasted surfaces are available.

Description	Type	Shear rate (s^{-1}) standard	Shear rate (s^{-1}) high shear option	Recommended viscosity range (mPas)**
Double gap cylinder system	DG41	0.007 - 11 415	34 245	0.5 - 10 000
Cylinder Ø 40 mm ISO 3219	Z40 DIN	0.001 - 1 931	5 793	5 - 100 000
Cylinder Ø 20 mm ISO 3219	Z20 DIN	0.001 - 1 931	5 793	50 - 1 000 000
Cylinder Ø 10 mm ISO 3219	Z10 DIN	0.001 - 1 931	5 793	500 - 10 000 000
Cylinder Ø 41 mm DIN 53018	Z41	0.002 - 3 500	10 500	10 - 100 000
Cylinder Ø 38 mm DIN 53018	Z38	0.001 - 1 400	4 200	30 - 500 000
Cylinder Ø 31 mm DIN 53018	Z31	0.0005 - 660	1 980	50 - 1 000 000
Profiled cylinder Ø 38 mm DIN 53018	Z38/S	0.001 - 1 500	4500	50 - 100 000
Disposable cylinder Ø 41 mm ISO 3219	Z41DIN/E	0.001 - 1 931	5793	10 - 100 000
Disposable cylinder Ø 25 mm ISO 3219	Z25DIN/E	0.001 - 1 931	5793	50 - 1 000 000
High shear cylinder 25 µm gap	HS25	0.1 - 69 200	207 600	5 - 100
High shear cylinder 100 µm gap	HS100	0.1 - 15 000	45 000	5 - 100
Double cone Ø 60 mm, 1° angle	DC60/1	0.006 - 9 000	27 000	1 - 50 000
Cone Ø 60 mm, 1° angle*	C60/1	0.006 - 9 000	27 000	2 - 100 000
Cone Ø 35 mm, 1° angle*	C35/1	0.006 - 9 000	27 000	100 - 1 000 000
Cone Ø 20 mm, 1° angle*	C20/1	0.006 - 9 000	27 000	1 000 - 1.0 E+08
Plate Ø 60 mm	PP60	0.003 - 4 700	14 100	2 - 100 000
Plate Ø 35 mm	PP35	0.002 - 2 700	8 100	100 - 1 000 000
Plate Ø 20 mm	PP20	0.001 - 1 570	4 710	1 000 - 1.0 E+08
Plate Ø 35 mm serratetd	PP35/S	0.002 - 2 700	8 100	100 - 1 000 000
Plate Ø 20 mm serratetd	PP20/S	0.001 - 1 570	4 710	1 000 - 1.0 E+08

* Cones with angles of 0.5° and 2.0° are available as well.
** Theoretical minimum viscosity value at lowest torque and highest shear rate.
Theoretical maximum viscosity value at highest torque and lowest shear rate.

SELECTION OF HAAKE MARS MEASURING GEOMETRIES



Double-cone geometries for measurements on low viscosity samples

High-temperature geometries with ceramic shaft at different diameters

Titanium geometries with measuring plate cover with same diameter for optimized gap filling; sample cover with integrated solvent trap

Selection of special measuring geometries with serrated surfaces to prevent slippage, with helical groovings to prevent sedimentation, vane rotors and rotors with glass covers

Coaxial cylinders according to DIN 53019 in different sizes

ACCESSORIES

Thanks to its modularity, the HAAKE MARS rheometer can be adapted easily and quickly to new requirements. Apart from special measuring cells, customized solutions can be achieved to meet even the most complex demands.

Individual rheometer configuration

SPECIAL MEASURING UNITS

Insulated coaxial cylinders and plate/plate measuring geometries are suitable for electro-rheological measurements up to 10 kV. Different versions of pressure cells for pressures up to 400 bar and temperatures up to 300°C are available. A Hastelloy® version can be used with corrosive samples. For tests on UV-hardening materials, Thermo Electron offers a standard version of a UV cell and an individual measuring unit with freely configurable distances for optical components such as light guides, condensers and glass plates.

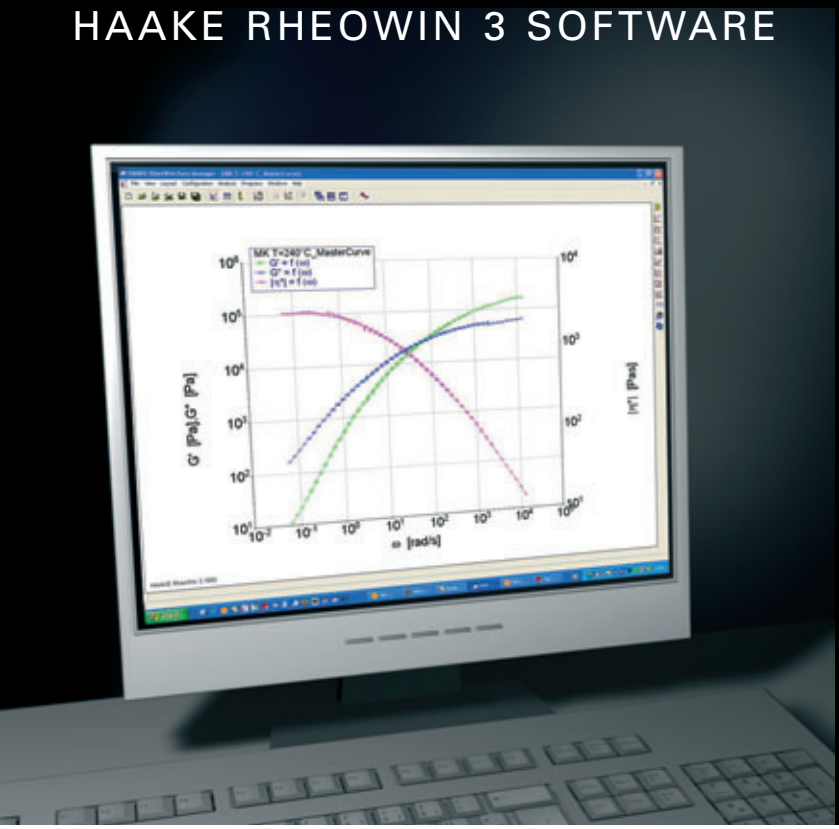
RHEOSCOPE MODULE

A RheoScope Module was developed for the HAAKE MARS system that combines high resolution microscopy and advanced rheometry technology. With this module the connection between a sample's microscopic structures and rheological properties can be monitored simultaneously, and the rheological and optical data can be saved in the same file. Visible textures and structures in solutions, suspensions, emulsions, gels and foams can be investigated for rheological phenomena including shear thinning, dilatancy, thixotropy, emulsification, coalescense, aggregation, gelification, dissolution, and flocculation. Together with the user-friendly HAAKE RheoWin 3 measuring and evaluation software, all functions of the microscope and camera can be controlled in addition to the rheometer. The rheological and optical data can be monitored online during the measurement as well as saved and exported in different formats for further analysis.

SPECIFICATIONS

Microscope	**Servo motor-driven, focus and position adjustment controlled via software**
Lenses	**Magnification: 5x, 10x, 20x and 50x**
Light source	**150 W, 12 V, wave length range: 380 – 750 nm**
Resolution	**1 µm (20x lenses)**
Field depth	**5 µm (20x lenses)**
Contrast improvement	**Polarizer servo motor-driven**
Data acquisition and storage	**Maximum 15 images/second with standard image format (e.g. TIFF) or video acquisitions with user-definable data compression**
Image analysis software	**Option for the determination of the particle size and its distribution**
Measuring geometries	**Polished plates and cones with different diameters**

HAAKE RHEOWIN 3 SOFTWARE



Thermo Electron works closely with its customers to provide the most user-friendly software for rheological instruments. HAAKE RheoWin software is continuously aligned to customer needs and requirements. RheoWin software is comprehensive and can be used for all HAAKE viscometers and rheometers. The software is customized to offer convenient operation with default settings for beginners and full access to all relevant measuring parameters for advanced rheologists.

COMPONENTS

- **RheoWin JobManager for manual instrument control, automated measuring routines ("jobs") and report printout or export**
- **RheoWin DataManager for interactive evaluation of measured data as well as sophisticated tools for creating reports and generating templates for graphs, tables and screen views**
- **RheoWin UserManager for comprehensive user management regarding user access control and assignment of specific access rights**

FUNCTIONALITY

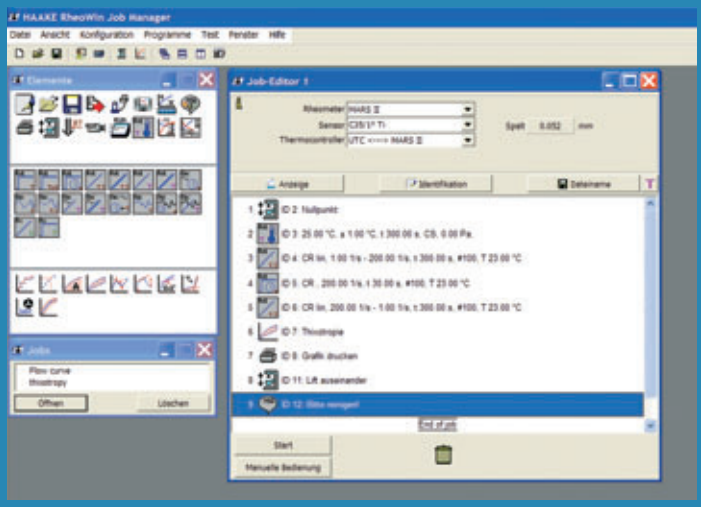
- **Manual control for preliminary testing, for displaying selected parameters and for saving manually acquired data**
- **Convenient creation and customization of measuring jobs using predefined measuring and evaluation elements via "drag and drop" techniques**
- **Fully automated measuring, data evaluation and documentation within a job**
- **Real multitasking – simultaneous measurements using several instruments and data evaluation**
- **Freely configurable data export (ASCII, Excel, etc.)**
- **Filing graphs in various formats (pdf, etc.)**
- **Numerous algorithms for data analysis (e.g. interpolation, regression and automated quality control)**
- **Automated backup file generation for retrieval of configuration data**
- **Availability of saving the raw data and numerical values for quality control purposes**

CUSTOMIZATION

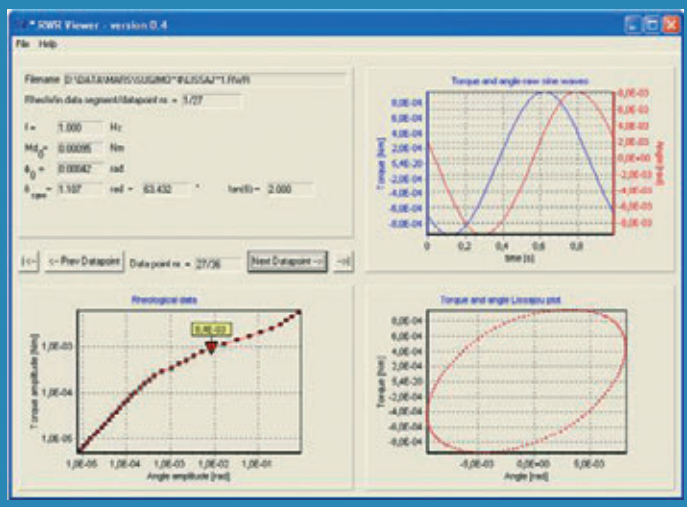
- **User-defined definitions of paths and subdirectories for data filing**
- **Push-button selection of one out of 12 languages**
- **Modular generation of a file name and automated filing in a predefined subdirectory**
- **Selectable units and arbitrary labeling of axes**
- **Links to data bases (SAP, LIMS, etc.)**
- **Online display of all corrections to improve measuring data (Micro Stress Control)**
- **Snapshot for quick characterization of an unknown sample**
- **RheoWizard help feature for expert knowledge to set up a measuring job**
- **Customizable report templates to permit the use of custom logos and text**

OPTIONAL TOOLS

- **Efficient tool to make RheoWin compliant with FDA 21 CFR Part 11**
- **TTS (Time Temperature Superposition) to generate master curves**



Definition of a measuring and evaluation procedure



Data evaluation using Lissajous plots

The latest version of the HAAKE RheoWin software is provided free-of-charge to Thermo's customers on our website.

BENEFITS

M MODULAR

- Quick and easy interchange of temperature control units
- Application-oriented measuring systems: Pressure cells up to 400 bar / 300°C, Electro-Rheology, UV-curing cell and scope
- Spacious frame with optional mounting rods and opening in the base plate for the adaptation of custom modules for special applications

A ADVANCED

- Integrated web server for remote monitoring, lift control and service information
- Ethernet TCP/IP interface to HAAKE RheoWin Software for fast data acquisition (0.5 kHz)
- HAAKE RheoWin 3 Software with optional modules: 21 CFR Part 11 tools, TTS (Time Temperature Superposition)

R RHEOMETER

- CR-, CS-, CD-mode in rotation and CS- and CD-mode in oscillation
- Axial force measurement during rotation as well as during axial movement in tension and compression
- Innovative, spacious and extremely rigid frame
- Adaptable to wide range of applications – now and in the future

S SYSTEM

- Easily interchangeable parts including the measuring head and the control electronics
- Pre-calibrated components for fast on-site change-outs
- Compatible with previews-generation HAAKE RheoStress rheometers (temperature units and sensors)

SPECIFICATIONS HAAKE MARS

Min. torque rotation CS	µNm	0.05
Min. torque rotation CR	µNm	0.05
Min. torque oscillation CS	µNm	0.05
Min. torque oscillation CD	µNm	0.05
Max. torque	mNm	200
Torque resolution	nNm	0.5 [a]
Motor inertia	µNms	10
Angular resolution	nrad	12 [b]
Min. angular velocity CS	min^{-1}	10^{-7}
Min. angular velocity CR	min^{-1}	10^{-4}
Max. angular velocity	min^{-1}	1500, 4500 [c]
Min. oscillation frequency	Hz	10^{-5}
Max. oscillation frequency	Hz	100
Min. Normal force	N	0.01
Max. Normal force	N	50 [d]
Normal force resolution	N	0.001
Min. lift speed	µm/s	0.02
Max. lift speed	mm/s	20
Lift positioning accuracy	µm	0.5
Temperature range	°C	-150 to +600 [e]
Dimensions (W x D x H)	mm	600 x 600 x 870
Weight	kg	55

(a) at the lowest torque
(b) internal resolution
(c) high shear option
(d) in both positive and negative direction
(e) depending on temperature control unit

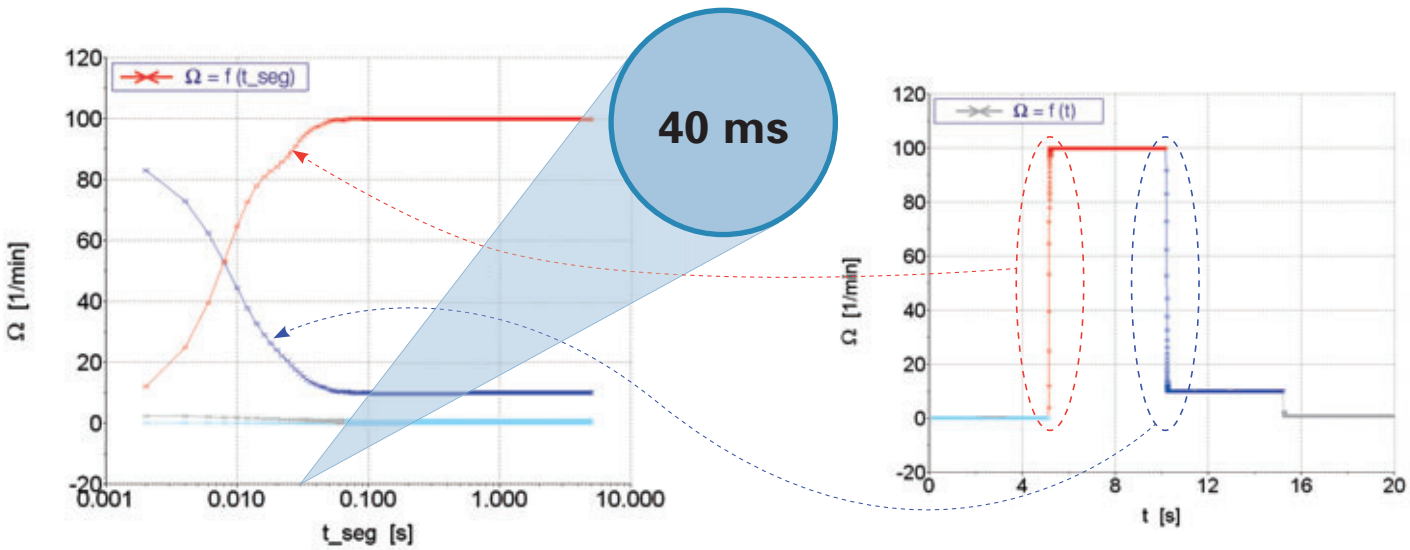
SELECTED MEASUREMENTS

Rheological measurements in the CR-, CS-, CD mode in rotation and oscillation as well as combinations, e.g. creep recovery and stress relaxation, are covered by the HAAKE MARS. In addition to that, normal forces and "tackiness" can be measured.

CR (CONTROLLED RATE) – MODE

Target parameters can only be reached quickly if the system has a very low inertia. The HAAKE MARS' optimized speed control loop and its very low motor inertia (I = 10^{-5} µNms) allow for speed steps to be conducted in less than 100 ms without significant overshoot.

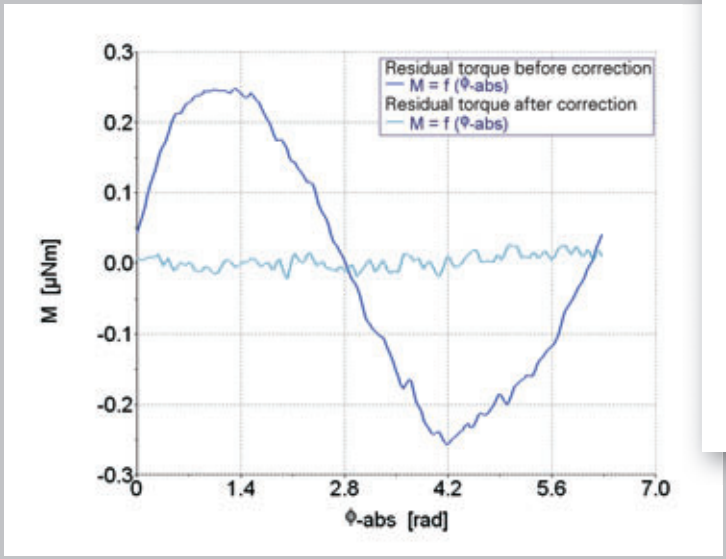
CR-Mode: Speed Steps



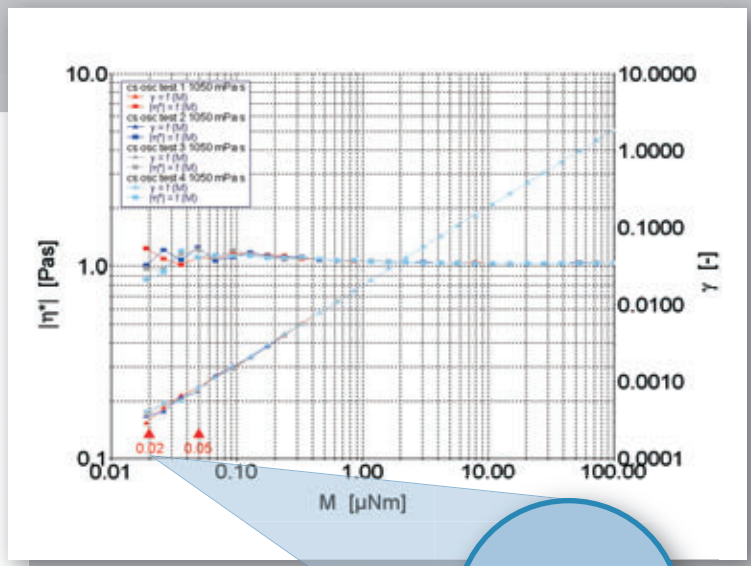
Graph with logarithmic time-scale

Same graph with linear time-scale

CS (CONTROLLED STRESS) – MODE | **Thermo's 4th generation diffusion air-bearing is the result of 25 years of development and manufacturing experience. Our latest advances in air-bearing technology plus accurate residual torque correction (MSC = Micro Stress Control), allow for measurements down to 0.02 µNm.**



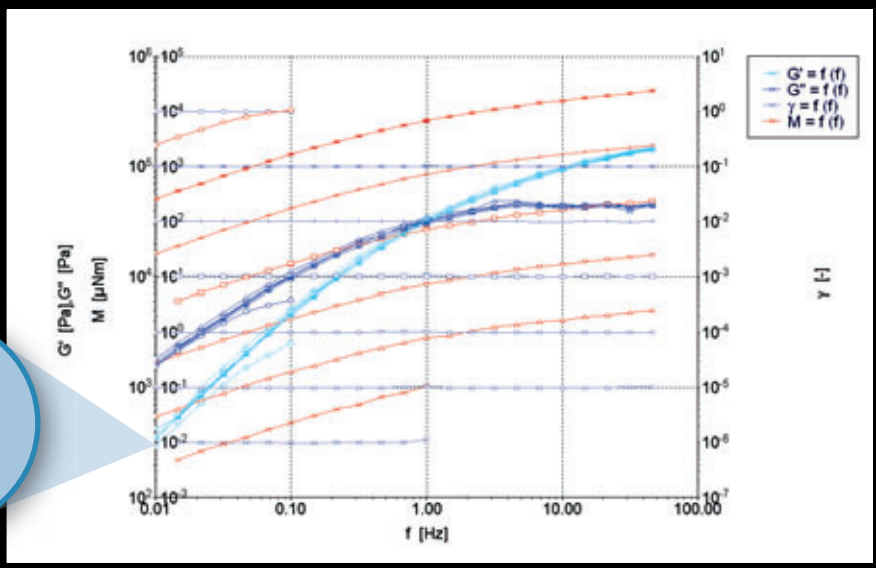
HAAKE MARS – Air-bearing performance



CS-Mode: Amplitude Sweeps
Sample: 1 Pas Oil

0.02 µNm

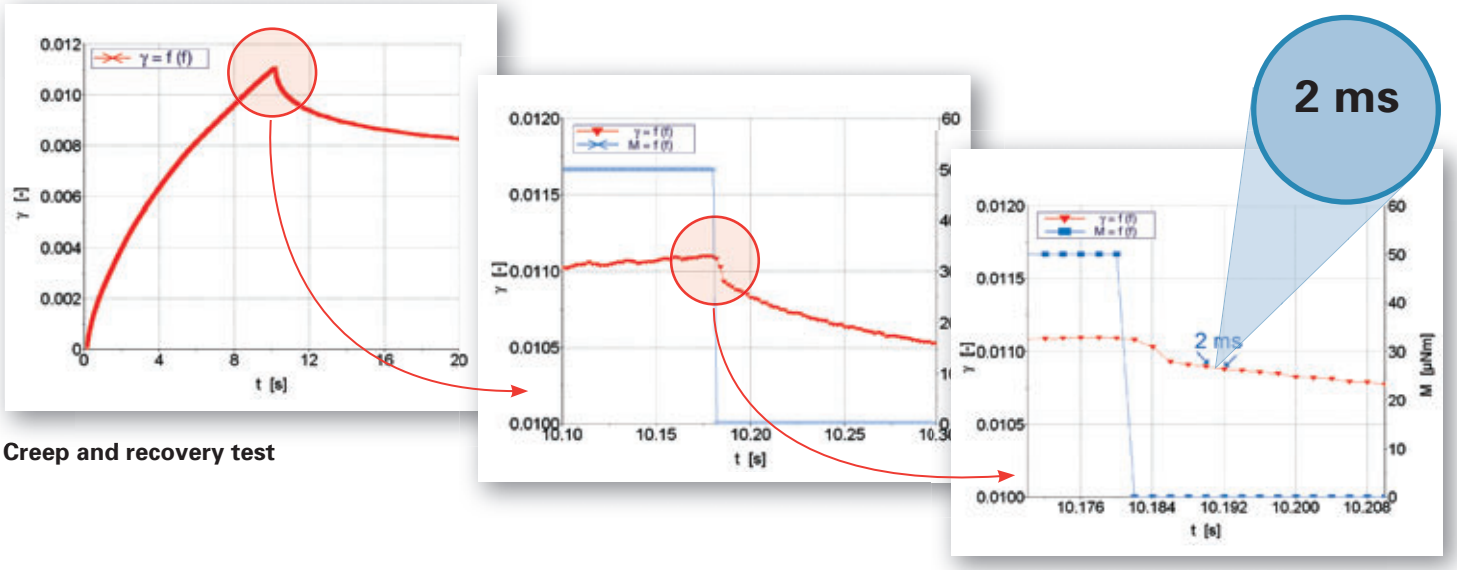
CD (CONTROLLED DEFORMATION) – MODE | **The newly developed self-learning deformation control loop is based on neural network technology. This control mode enables the fast adaptation of the parameters to changes in rheological behavior (e.g. curing) and the extension of the measuring range to low torques (down to 0.01 µNm). The ethernet TCP/IP communications protocol allows for fast data acquisition and high-speed data transfer rates (up to 0.5 kHz). This capability is important when measuring sample behavior under different conditions (stress, deformation, or when a sample's properties are changing quickly).**



5 nNm

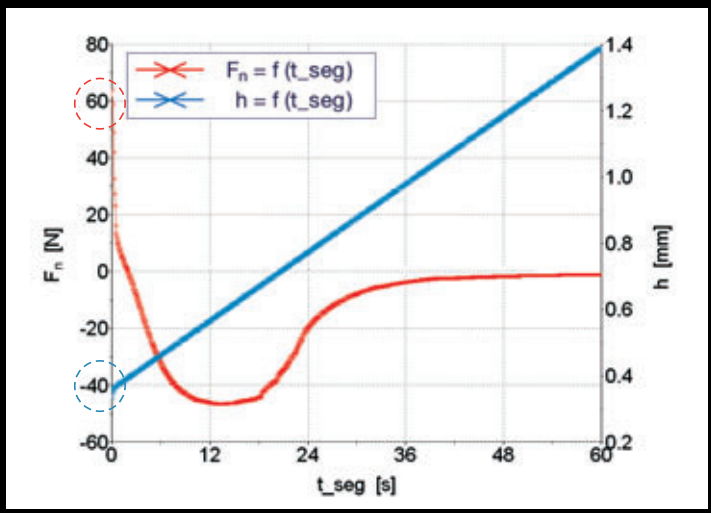
CD-Mode: Frequency Sweeps ($\gamma = 1 - 10^{-6}$)
Sample: PDMS

FAST DATA ACQUISITION | **By using an ethernet TCP/IP communications protocol, high-speed data transfer rates up to 0.5 kHz are possible. A fast data acquisition is needed to measure a sample's behavior when changing in between different strains (stress, deformation, deformation rate) or when a sample's properties are quickly changing.**

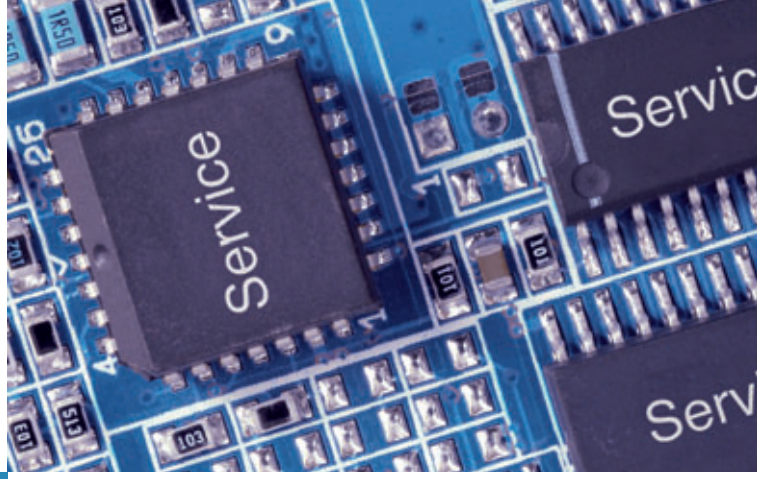


Creep and recovery test

NORMAL FORCE AND TACK MEASUREMENTS | **The HAAKE MARS is equipped with a new normal force sensor based on robust and very sensitive strain gauges with integrated temperature compensation and a measuring range from 0.01 N to 50 N in positive and negative directions. This sensor measures normal force differences in shear experiments and compensates for changes in sample volume. An axial force can be applied so that the HAAKE MARS can be used as a very precise "tack" instrument.**



Measuring Tack:
Sample: Double-sided tape



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