



Thermo Scientific

# HAAKE MARS

## Accessories

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# Accessories

## Temperature modules



Electrical temperature module (TM-EL-P) for plate/cone measuring geometries with active hood (TM-EL-H)



Peltier temperature module for cylinders (TM-PE-C) with adapter for use with plate and cone measuring geometries as well as selection of plate and cylinder geometries



Standardized connections including quick connectors for cooling media and electronics for all temperature modules

### Temperature modules for fast, precise temperature control within a broad temperature range

There is a large selection of temperature modules available for the HAAKE MARS, covering a temperature range from -150 °C to 600 °C. Depending on the application, electrical and liquid controlled temperature modules or Peltier are available. In addition a controlled temperature test chamber is offered.

#### Peltier Plate

for fast temperature changes up to 60 K / min; temperature range: -60 °C\* up to 200 °C

- Easy exchange of lower plates due to new quick bayonet mounting ring
- Fast heat transfer and very good temperature homogeneity due to low thermal masses

#### Electrical Plate

for measurements in a wide temperature range: -40 °C\* up to 400 °C

- Easy exchange of lower plates due to new quick bayonet mounting ring
- In combination with the TM-EL-H active cone heater system a closed chamber with a 360° viewing window is created

#### Liquid Plate

for very precise, constant temperature control; temperature range: -40 °C\* up to 200 °C\*

- Easy exchange of lower plates due to new quick bayonet mounting ring
- Most reasonably priced unit when using an existing circulator

#### Peltier Cylinder

for fast temperature changes up to 60 K / min; temperature range: -40 °C\* up to 200 °C

- Easy exchange of cups due to new quick bayonet mounting ring
- Smaller cups and rotors optimized for fast temperature changes
- Easy switch between cylinder / plate / cone geometry

#### Electrical Cylinder

for very fast temperature changes; temperature range: -20 °C\* up to 200 °C (300 °C using suitable geometries, e.g. for pressure cell)

- For cylinder geometries or application-focused measuring cells such as pressure cells
- Powerful, with heating circuit

#### Liquid Cylinder

for very precise, constant temperature control; temperature range: -20 °C\* up to 180 °C\*

- Larger cups and rotors for low viscosity measurements
- Most reasonably priced unit when using an existing circulator

\* Depending on the cooling medium and circulator

### Benefits of the temperature modules at a glance:

- Plug-and-play modules with new compact design
- Automatic temperature module recognition
- Easy installation in seconds without tools or adjustment
- Standardized connections including quick connects for cooling media and electronics for all modules
- All connections visible from operator position
- No other accessories required, electronics and control valves integrated in HAAKE MARS frame
- Very low thermal mass for fast control response time
- Integrated base so that the dismantled unit can be parked on the lab bench, for example



# Accessories

## Measuring geometries



Plates, cones, cylinders with helical grooving to prevent sedimentation and vane rotors



High-precision production of the lower measuring plate with guide and bayonet ring for simple, plan parallel installation



Titanium rotor with diameter to fit lower plate for optimized gap filling and sample cover (glass or plastic) with integrated solvent trap and inert gas connection

### Comprehensive selection of measuring geometries for a wide variety of applications

We offer concentric cylinders, plate/plate and plate/cone measuring geometries as well as disposable and custom designs:

- in multiple sizes (8 mm - 60 mm)
- of various materials
- with different surfaces (e.g. serrated, sand blasted, polished)

The standard measuring geometries are made of titanium and designed for use with a solvent trap, for preventing the sample from drying out.

For plate and cone rotors lower plates are available with the same

- size
- material
- surface

This ensures ideal measuring conditions, such as optimal sample filling.

### Sample hoods

Sample hoods for preventing heat loss and solvent evaporation as well as minimizing the temperature gradient are available in three different versions:

- Two part POM (Polyoxymethylene) version for temperatures up to 120 °C
- Insolated sample hood TM-IN-H with Ampcoloy® inlet and Teflon® insulation for very fast heat transfer in a temperature range from -40 °C up to 200 °C
- Unique transparent glass cover for observing the sample during the measurement, for temperatures up to 400 °C

### Common features for all hoods

- Integrated inner and outer solvent trap for all geometries!
- Small enclosed volume
- Automatically centered and closed by lower plate
- Inlet for nitrogene gas to create inert atmosphere

# Accessories

## Application-oriented measuring cells



HAAKE MARS with CTC and clamps for measuring solids, SER tool for extensional rheological measurements and RheoScope unit

### Controlled Test Chamber (CTC)

Unique combination of convection and radiation heat transfer for very fast temperature changes and homogeneous temperature distribution from 30 °C to 600 °C, can be extended to -150 °C with the premium low temperature option.

The CTC consists of two independently movable half-shells with the following advantages:

- Good access to sample for easy sample loading, trimming, cleaning.
- Chamber can be closed behind the sample while T is still controlled.
- With the CTC in *Park Position*, other Temperature Control Modules can be used.



Solid clamps

### Solid clamps / DMTA option for Controlled Test Chamber (CTC)

Clamps for solid samples for measurements according to DIN/ISO 6721-1. These clamps are self-centering and self-adjusting to automatically compensate for physical changes of the sample (e.g. expansion or contraction due to temperature changes).

The sample can be 5.0 – 12.7 mm wide, 0.15 – 4.0 mm thick and have a maximum length of 68 mm.

The jaws are easily removable for cleaning. Also jaws with various profiles for different sample types (soft, medium, hard) are available.

Base unit comes with medium samples. Others on request.



Measuring cell for UV assisted thermal curing at elevated temperatures

### UV curing cell for Controlled Test Chamber (CTC)

UV measuring cells as an integrated solution for the controlled test chamber (CTC) to enable the measurement of UV-induced thermal curing.

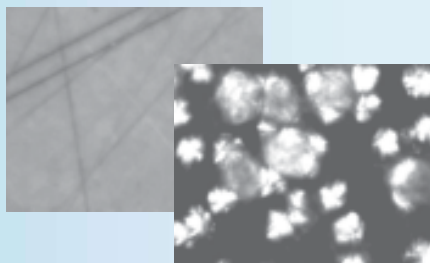
Plate/plate measuring geometries with diameters up to 20 mm and made from various materials (e.g. titanium, stainless steel or aluminium as disposable version) are available.

### SER Tool

The SER (Sentmanat Extension Rheometer) system for the Thermo Scientific rheometers extends a conventional steady rotational rheometer into a robust extensional rheometer for melts and semi-solids.

# Accessories

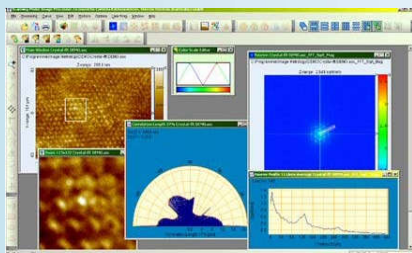
## Combined Methods



Microscopic pictures of the homogeneous molten fat (left) and the same are after crystallization has begun (right)



RheoScope Module



Screenshot SPIP software

Rheology is a “macroscopic” method that provides information on the behavior of a sample under specified conditions. The mechanical properties of a material depend on its structure at the microscopic level. In order to be able to determine the reasons for the rheological properties, rheological measurements must be combined with tests on the microscopic level, using FTIR or microscopy, for example.

### Benefits of combined methods:

- Same sample preparation
- Same measuring conditions
- Shorter test times
- Perfect correlation of results

## RheoScope Module - Microscope Coupling

- Simultaneous rheological measurements and image acquisition
- Fully integrated compact modular unit for the HAAKE MARS
- Visualization of data and images in the same software package
- Analysis of structural changes under shear
- Image analysis software to determine particle sizes, particle size distributions and structural analysis.

### Applications/Examples

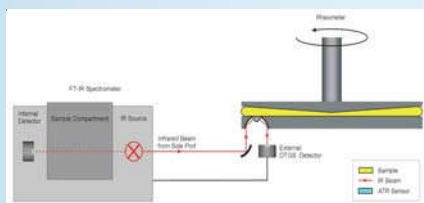
- Food: fat, starch
- Polymer: solution, melt
- Pharma/Cosmetic: creme, lotion
- Paint/Inks: printing paste, thickening agents
- Petrochemical: crude oil, drilling fluid
- Others: medical

### Formulations

- Gels
- Suspensions
- Solutions
- Emulsions/Dispersions
- Foam
- Melts

# Accessories

## Combined Methods



Scheme of the Rheonaut Module



Rheonaut Module manufactured by RESULTEC



Measuring cell for thermal assisted UV curing

## Rheonaut Module - FTIR Coupling

The Rheonaut technology enables a new level of understanding of rheological properties and processes, which depend on changes on the molecular structure. On the one hand, deformations and orientations of molecules as function of shear can be monitored.

On the other hand the insitu-spectroscopy enables the investigation of chemical reactions in the measuring gap such as chemical or thermal curing of polyurethane (PU)- or epoxy-adhesives.

- Simultaneous rheological and FTIR spectra measurements
- Patented technique in a compact module for the HAAKE MARS
- ATR (attenuated total reflection) principle
- Analysis of structural changes on the molecular level under shear/deformation
- Extensive investigation of thermal/UV curing reactions with special measuring cell



# Accessories

## Application-oriented measuring cells



Pressure cell with vane rotor

### Pressure cells

For testing samples at elevated pressures, different pressure cells are available. They are designed as closed systems, which can be filled with the sample and pressurized. Depending on the measuring conditions, which have to be simulated with the pressure cell, different types are available, e.g. made out of titanium for pressures up to 600 bar and temperatures up to 300 °C or made out of Hastelloy® for measurements on chemical aggressive samples.

The pressure can be increased by either increasing the temperature or using an external pressurization, e.g. a pump to compress the sample volume during the filling process.

Depending on the sample different measuring geometries are available: coaxial cylinder geometries, double gap or vane rotors.

### Construction material cell



Construction material cell

A unique special measuring cell with a flexible profile for measurements on building materials is offered. Thanks to the interchangeable profile lamellas the measuring cell can be easily and quickly adapted to new materials. The design avoids slippage layer formation.



# Accessories

## Application-oriented measuring cells



Universal container holder

### Universal holder for individual containers

A universal holder for sample containers has been developed. Thanks to the three individually adjustable clamps, sample containers like glass jars, cans, beakers, cups, etc., can be mounted solidly onto the rheometer. This allows the insertion of a (vane) measuring geometry into the sample without comprising its structure.

Vane rotors with different diameters are available. The universal adapter shaft can be used to adapt any individually designed measuring geometry.



UV-curing cell

### UV-curing cell

For tests on UV-curing materials. UV cells are available as a standard version and as an individual measuring cell with freely configurable distances for optical components such as light guides, condensers and glass plates.



3 point bending tool

### 3 point bending tool

The Thermo Scientific HAAKE MARS is equipped with a highly sensitive normal force sensor and a very precise lift motor which allows applying controlled axial forces to the sample, pushing or pulling the material.

A sample fixture is available to investigate the bending and breaking behaviour of a wide range of materials.

This tool consists of a support plate with two parallel bars with an adjustable distance between 1 cm and 7 cm. An individually designed piston can be lowered onto the sample. The piston is mounted to the Thermo Scientific rheometer using a 6 mm universal adapter. Thanks to this universal adapter any kind of piston design can be attached to the Thermo Scientific rheometer.

# Accessories

## Application oriented-measuring cells



Submersion flow cell

### Submersion flow cell

Submersion flow cell with fluid for testing interactions between creams and salves with human skin or bandage adhesion when subjected to skin secretions



Tribology cell

### Tribology cell

Measuring cell for friction tests to determine the tribological behavior of material combinations with or without lubricants



The BiCone measuring cup (from left to right): cup for BiCone with glass ring insert and securing ring, two piece lid, tool for mounting the securing ring; Insulation sleeve (not included and has to be ordered separately)

### Interfacial rheology

The Du Noüy ring, commonly used for interfacial tension measurements, has been successfully applied to interfacial testing using a Thermo Scientific rheometer.

A new measuring configuration based on a BiCone geometry enables the user to perform temperature controlled interfacial experiments using a HAAKE MARS. This setup can be used for testing the rheological properties of an interfacial film formed between either two liquid phases or a liquid and a gas phase.

## HAAKE MARS related accessories for customized setups



Customized HAAKE MARS set-up

Rheological investigations are very diverse regarding both the measured samples and the measuring methods. As a consequence the ability to configure a special and individually configured test set-up is very important. This is valid for the rheometer control software as well as the rheometer hardware. The exchange of temperature control units and the mounting of application-oriented measuring cells to rheometer must be easy, quick and user-friendly.

The HAAKE MARS is one of the most modular rheometers in its class thanks to its one-piece, spacious, aluminium cast two-columned frame. A circular aperture with a diameter of 125 mm in the base plate of the frame and the possibility to remove the electronics out of the frame allows for access to the sample from all directions. This is useful for integrating special sensing equipment for additional measuring techniques into the rheometer. Optional mounting rods on the rear of the frame can be used for the adaptation and positioning of the Controlled Test Chamber (CTC) or individual accessories.

Due to the fact that all application related components including the measuring head and the control electronics are exchangeable, customized solutions can be realized to meet even the most complex demands. For example, the lower holder - designed to mount a temperature control unit or a special measuring cell - is removable. This space can be used for individual components such as a (huge) individual container (e.g. a 10-liter bucket). It is also possible to mount the measuring head on the lower holder in order to position the sample in a (x-ray) beam. By mounting two measuring heads into the frame a rheometer with co- or counter-rotating measuring geometries can be realized.

# Accessories

## Services and Trainings



### Services to meet individual requirements

We offer a wide range of professional services to a variety of industries to help our customers improve their productivity and decrease costs. Individual solutions to support our customers and maintain their instruments are a standard service. Additional service packages, warranty extensions or premium service packages, which can be bundled, allow our customers to plan and budget for maintenance and service support. All services are provided by skilled and certified service engineers.



### Seminars and training courses

Customers are offered a comprehensive training program and selected courses in our international training center in Karlsruhe, Germany. Basic and advanced rheology seminars and training on special applications are held worldwide. In-house seminars are available on request. For more information visit [www.thermo.com/mc\\_seminar](http://www.thermo.com/mc_seminar).



# Accessories

## Application solution: Polymers



Our equipment covers the entire life cycle of a polymer – from its development to the pilot. Small batches can be compounded using the scale-up method or small quantities of specialized polymers or composites can be processed up to (online) quality control in production.

### Compounding and test specimen production

We provide comprehensive workflow coverage with the Thermo Scientific HAAKE MiniLab micro-compounder together with the Thermo Scientific HAAKE MiniJet mini-injection molding machine. The HAAKE MiniLab combines compounding and viscosity tests for small sample volumes up to 5 g or 7 cm<sup>3</sup>. This unit is based on the proven conical twin-screw technology, with co- or counter rotating screws, and can operate as a separate unit with data export or as a fully software-controlled system. Together with the HAAKE MiniJet, different specimens can easily be produced from the compounded material.

### Rheological measurement

With the Thermo Scientific HAAKE MARS rheometer, the viscoelastic properties of polymer melts or solids can be measured as a function of shear, elongation, time, frequency, temperature, etc. – not only under shear but also under elongation strain.

### Selection of polymer specific accessories

- Micro compounder
- Injection molding machine for the production of test specimens
- Disposable pellet filling aid for optimal gap filling
- CTC controlled temperature test chamber for measurements in the range (-150 °C) 30 °C to 600 °C
- Solid clamp for DMA tests on rodshaped specimens
- SER tool from Xpansion Instruments for extensional rheological measurements
- Interchangeable plate and cone measuring geometries in various sizes and materials
- Measuring cell for UV-curing processes or for thermal assisted UV-curing
- RheoScope module for the measurement of the melting behavior of polymers
- HAAKE RheoWin Software-Module TTS (Time-Temperature Superposition), Spectra and MWD (Molecular Weight Distribution)



HAAKE MARS with controlled test chamber and clamps for measuring solids, SER tool for extensional rheological measurements and RheoScope unit



Mini-injection molding machine with various molds for the production of specimens for rheological tests: disk-shaped, in various diameters, for plate/plate measuring geometries or rectangular for the solid clamp

# Accessories

## Application solution: Petrochemicals



Over 30 billion barrels of crude oil are conveyed and processed annually. Measurements of the viscosity of crude oils of varying compositions at different temperatures and pressures are used to optimize the flow behavior of the crude oil at various depths, while simulating and optimizing extraction and transport. The calculated use of drilling and boring fluids can increase oil field outputs.

Here too we have the entire process covered, from extraction to processing.

### Extraction

For temperature- and pressure-dependent measurements, there is a comprehensive range of measuring cells in various materials (titanium, Hastelloy®, etc.) available, suitable for up to 400 bar and 300 °C. Cylindrical geometries or vane rotors are available as measuring geometries to simulate the starting behavior of pipelines. Isobaric measurements can be done using an automated pressure controller while performing temperature ramps.

### Transport

Simultaneous measurements of rheological properties with the help of microscopic observation of structure formation to study the crystal growth in crude oils ("waxing"), which must be avoided in order to optimize pipeline transport.

### Processing

We offer several application-based measuring cells for petroleum processing and refining, such as for the rheological testing of bitumen or for tribological and rheological testing of oils and lubricants.

### Selection of specific accessories for the petrochemical industry

- Pressure cells: up to 300 °C, up to 600 bar, titanium and Hastelloy® for aggressive liquids, with cylindrical, double gap or vane rotors
- Pump for pressurization
- RheoScope module for studying the waxing behavior of crude oil
- SHRP measuring cells for the rheological characterization of bitumen
- Tribology measuring cell for abrasion tests with greases and lubricants



HAAKE MARS with high pressure measuring cell



Measuring cells for determining the tribological behavior of material combinations with or without lubricants

# Accessories

## Application solution: Pharmaceuticals and cosmetics



Nasal sprays, creams, foams, tablet coatings, shelf life, sprays or active ingredient dosing – no matter what the product or application – rheological tests are essential for the development, optimization or production of suspensions and emulsions in order to reduce product development times and optimize production processes.

While simple viscosity measurements are often sufficient for evaluating raw materials, extensive rheological testing is necessary in order to predict and effectively adjust shelf life, sensitivity or processability. The HAAKE MARS has an extensive range of accessories for pharmaceutical and cosmetic applications.



HAAKE MARS with Du Noüy ring for rheological measurements of interfaces, microtiter plate with liquid temperature control for serial measurements or measurements with small sample volumes

### Selection of accessories for pharmaceutical products and cosmetics

- High-performance Peltier temperature control unit for temperature cycle tests for stability testing
- RheoScope (Microscopy) module for stability testing of multi-phase systems and foams, plus SPIP software determining particle sizes and distribution
- Rheonaut module for analysis of structural changes on the molecular level under shear / deformation e.g. on proteins
- Du Noüy ring and BiCone geometry for interfacial rheology
- Variable holder for measurements in original containers
- Holder for microtiter plates for serial measurements of samples that are only available in small volumes
- Submersion flow cell surrounded by fluid
- Custom solutions for processing pharmaceutical products (hot melt extrusion, continuous granulation)
- Documentation for IQ/OQ and installation with IQ/OQ support
- “21 CFR Part 11” module for the HAAKE RheoWin software to meet FDA requirements



Selection of falling ball and rotational viscometers for fast, reliable viscosity measurement for raw material evaluation or batch testing



# Accessories

## Application solution: Paint, inks and coatings



The requirements and demands placed on paints, inks and coatings are constantly increasing. And in the process, eco-friendly technologies and products are growing in importance: water as a diluting agent, solvent-free powder coatings and UV irradiation as a fast, energy-saving cross-linking method.

The flow behavior of these products is highly complex, but can be controlled when the relevant parameters are known. Suitable rheology additives can be selected depending on the desired formulation, whether they contain solvents or are water-based. For instance, existing coating systems can be reformulated to be in compliance with the law without significant changes to the flow characteristics, or customized photo-initiators that are mixed into the coating as an additive are developed to enable UV cross-linking. The result is a shorter drying times and therefore lower process costs. Our equipment supports you in every phase of your multi-layered process.

### Selection of application-specific accessories for paints, inks and coatings

- Sample covers, including solvent traps to prevent drying out
- Double cone to measure low-viscosity paints without any edge effect
- Ring rotor for measuring powder coatings
- Disposable plate/plate measuring geometry to eliminate time-consuming cleaning
- Measurements with very high shear rates using special cylinders with small measuring gaps (up to 25  $\mu\text{m}$ ) or cones with small cone angles
- UV measuring cells for standard and custom applications such as UV-assisted thermal curing
- Rheometer for measuring extensional properties, such as during spraying or coating
- Rheonaut module for simultaneous rheological and FTIR spectra measurements for extensive investigation of thermal / UV curing reactions



HAAKE MARS with controlled test chamber and measuring cell for UV curing



Thermo Scientific HAAKE CaBER 1, the only commercially available rheometer to measure the extensional properties of fluids, e.g. to optimize a curtain coating or for filling processes



# Accessories

## Application solution: Food



Thermo Scientific HAAKE MARS III



Thermo Scientific HAAKE Viscotester iQ application package for yield point determination on dairy products (e.g. yogurt) and for measurements on samples which are difficult to measure (e.g. due to sedimentation)

Mouthfeel is a crucial property of any food or beverage. To know the visco-elastic properties linked to the mouthfeel is essential for development, production and quality control.

In addition, the rheological properties determine how to run important steps of the production process like pumping, mixing, spraying and filling with best efficiency.

### Selection of application-specific accessories for food

- Adaptable holder for various food containers to accelerate testing
- Special vane rotors for samples containing bigger pieces like fruits or kernels of rice
- Tribology cell e.g. for the taste of chocolate
- 3-point-bending/breaking accessory e.g. for chocolate or cookies
- Pressure cell up to 250 °C and 600 bar to simulate cooking processes
- Viscometer packages with focus on food applications, e.g. HAAKE Viscotester iQ DIN package for measurements on liquids such as chocolate and beverages or package with vane rotor and HAAKE RheoWin software for yield point determination and thixotropy tests

# More information ...

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## Selected product information:

- P48** Universal holder for measurements in original containers
- P46** Temperature controlled interfacial rheology
- P45** The TMP-Helper, a tool for optimized handling of lower measuring plates at higher temperatures
- P44** Dirt and dust protection for Thermo Scientific HAAKE rheometers
- P43** Exchangeable lower plate TMP80 optimized for easy cleaning
- P41** Viscoelastic standard for checking the rheometer functionality
- P38** The Thermo Scientific HAAKE MARS III rheometer frame:  
Improved handling and customization
- P37** New UV module for UV curing measurements
- P36** Double gap geometry for pressure cell D400/300
- P35** New series of sample hoods with integrated solvent trap for plates/cones and cylinders
- P33** Spectroscopical insight into rheology with the Rheonaut module for the Thermo Scientific HAAKE MARS rheometer
- P32** Temperature control unit Peltier cylinder - A new dimension in performance, ease of use and flexibility
- P31** Flexible holder for individual components for Thermo Scientific HAAKE MARS
- P29** Exchangeable lower plates for temperature module
- P27** Rheological investigations on small sample volumes: Liquid temperature control holder for microtiter plate
- P26** Du Noüy ring for interfacial rheology
- P24** Submersion flow cell
- P23** Tribology cell for HAAKE rheometers
- P22** UV curing cell for an individual arrangement of optical components
- P21** Vane rotors for pressure cells for HAAKE MARS and HAAKE RheoStress 6000
- P19** SER - Extensional Rheology System for Thermo Scientific HAAKE MARS
- P18** Universal container holder for HAAKE MARS and HAAKE RheoStress 6000
- P17** New measuring cell for UV assisted thermal curing at elevated temperatures
- P14** Sample fixture for bending and breaking tests for Thermo Scientific rheometer
- P12** Support fixture for the analysis of textile samples
- P10** Disposable plate/plate-measuring geometry for the controlled temperature chamber (CTC)
- P6** New measuring cell for rheology of building materials
- P5** Cone/plate-exchangeable measuring geometries for maximum flexibility
- P4** New solids clamps for measurements on (semi)-solids
- P1** Investigation of the curing behavior with a newly designed ring rotor

## More information ...

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### Selected application notes:

- V265 Image acquisition with the HAAKE RheoScope module
- V263 Tracking Fast UV Curing Reactions in a Rheometer Using the Fast Oscillation Mode
- V261 Characterizing long-chain Branching in Polyethylene with Extensional Rheology
- V258 UV-induced curing reactions investigated by simultaneous rheometry and FT-IR measurements
- V257 Monitoring Emulsions Morphology Under Shear via Simultaneous Rheometry and In-situ FT-IR Spectroscopy
- V254 Curing of an Acrylate Glue – Rheology with Simultaneous FTIR-Spectroscopy
- V248 Well prepared - Good results
- V247 Detailed analysis of curing reactions of polyurethane resins using the Rheonaut technology for simultaneous rheometry and FT-IR
- V246 Measuring fast UV curing materials using oscillatory rheometry
- V242 Determining the flow behaviour of ceramic slurries
- V241 Dynamic Mechanical Thermal Analysis (DMTA) on polymer composites with the HAAKE MARS rheometer
- V240 Waxing of crude oil – An easy approach with rheoptical methods
- V238 Applied food rheology using fast speed control and axial measurements
- V228 What happens when rheological properties change?  
Looking into rheological properties with simultaneous collection of microscopic images



### Brochures for Thermo Scientific viscometer and rheometer

[www.thermoscientific.com/rheology](http://www.thermoscientific.com/rheology)

[www.thermoscientific.com/viscometry](http://www.thermoscientific.com/viscometry)

### Brochures for Thermo Scientific measuring extruders and mixers

[www.thermoscientific.com/polymer\\_testing](http://www.thermoscientific.com/polymer_testing)

### Brochures for pharma solutions

[www.thermoscientific.com/mc\\_pharma](http://www.thermoscientific.com/mc_pharma)

## About Thermo Fisher Scientific

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### Material Characterization

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