Instruction Manual

HAAKE RotoVisco® 1
HAAKE RheoStress® 1

“Translation of the original instruction manual”  version 2.3
Konformitätserklärung /
Declaration of Conformity

Produktbezeichnung / Product name
HAAKE RotoVisco 1
HAAKE RheoStress 1

Identifikation / Identification
376-0010, 376-0020, 376-0030, 376-0040, 376-0050,
376-0060
379-0010, 379-0020, 379-0030, 379-0040, 379-0050, 379-
0060, 379-0080

Hersteller / Manufacturer
Thermo Electron (Karlsruhe)
GmbH
Dieselstraße 4
D – 76227 Karlsruhe
Germany

Dokumentationsbevollmächtigte Person
Authrised person for technical file
Henry Eisenlohr
Thermo Electron (Karlsruhe) GmbH

Richtlinie / Directive
2006/42/EG | Maschinenrichtlinie / Machinery directive

Konform zu weiteren Richtlinien / Conform to other directives
2004/108/EG | Richtlinie für elektromagnetische Verträglichkeit
Electromagnetic Compatibility Directive

2006/95/EG | Niederspannungsrichtlinie
Low voltage directive

Folgende harmonisierte Normen wurden angewandt:
Following harmonized standards are used:

<table>
<thead>
<tr>
<th>Normennummer</th>
<th>Titel der Normen</th>
</tr>
</thead>
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<tr>
<td>EN 61326-1: 2006</td>
<td>Elektrische Mess-, Steuer-, Regel- und Laborgeräte - EMV-Anforderungen, Teil 1 Allgemeine Anforderungen Electrical equipment for measurement, control and laboratory use EMC-requirements, Part 1 general requirements</td>
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<tr>
<td>EN 61010-1: 2001</td>
<td>Sicherheitsbestimmungen für elektrische Mess-, Steuer-, Regel-, und Laborgeräte - allgemeine Anforderungen Safety requirements for electrical equipment for measurement, control and laboratory use - general requirements</td>
</tr>
<tr>
<td>EN 61010-2-010: 2003</td>
<td>Besondere Anforderungen an Laborgeräte für das Erhitzen von Stoffen Particular requirements for laboratory equipment for the heating of materials</td>
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</tbody>
</table>

Wir erklären in unserer ausschließlichen Verantwortung, dass das Produkt, auf das sich diese Erklärung bezieht, mit den oben genannten Normen, normativen Dokumenten und den Bestimmungen der genannten Richtlinien übereinstimmt. Die Prüfprotokolle werden bei Thermo Electron (Karlsruhe) 10 Jahre aufbewahrt.

We declare under our sole responsibility, that this product to which this declaration relates is in conformity with the a.m. standards or other normative documents and is following the provisions of the a.m. directives.
All test certificates will be kept by Thermo Electron (Karlsruhe) for 10 years.

Unterschrift / Signature

Datum / Date
21.03.2006

Thermo Electron (Karlsruhe) GmbH
Dieselstr. 4 * 76227 Karlsruhe
Tel. + 49-721-4094-444, Fax + 49-721-4094-418

Unterschrift / Signature

Datum / Date

Hersteller / Manufacturer

PCM0904_F05 Konformitätserklärung EMV-NSR-MR LI 2009.doc
Erstellt: H. Eisenlohr 07.12.09, genehmigt: K. Nitscher, gültig ab: 29.12.09
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1. Key to Symbols

1.1 Symbols used in this manual

! Warns the user of possible damage to the unit, draws attention to the risk of injury or contains safety notes and warnings.

👉 Denotes an important remark.

▌ Indicates the next operating step to be carried out and ...

⇒ ... what happens as a result thereof.

👉 Draws attention to the risk of injury.

1.2 Symbols used on the unit

⚠️ Caution: Read the instruction manual!

⚠️ Caution: danger of injury your hands

⚠️ Caution: Unit becomes hot

🌡️ Connection for cooling air support

➢➢➢ Display operationa

➢➢➢ Display heating
1.3 Information concerning the CE sign

Thermo Scientific electrical equipment for measurement, control and laboratory use bears the CE marking.

The CE marking attests the compliance of the product with the EC-Directives which are necessary to apply and confirms that the apparatus meets all relevant essential requirements of the directive, the defined relevant protection requirements.

The conformity assessment procedures were performed following a defined methodology according to each applicable directive.

The council decision 93/465/EEC shall be authoritative concerning the modules of the various phases of the conformity assessment procedures and the rules for the affixing and use of the CE marking, which are intended to be used in the technical harmonization directives.

To confirm compliance with the EC-Directive 2004/108/EC Electromagnetic Compatibility (EMC) our product was tested according to the EMC requirements for emission and immunity for electrical equipment for measurement, control and laboratory use.

Compliance with the protection requirements areas (domestic establishments and establishments directly connected to a low voltage power supply network which supplies buildings used for domestic purposes) and industrial areas is ensured.

Our strict standards regarding operating quality and resulting considerable amount of time and money spent on development and testing reflect our commitment to guarantee the high level of quality of our products even under extreme electromagnetic conditions.

Practice however also shows that even electrical equipment which bears the CE marking such as monitors or analytical instruments can be affected if their manufacturers accept an interference (e.g. the flickering of a monitor) as the minimum operating quality under electromagnetic compatibility phenomena. For this reason we recommend you to observe a minimum distance of approx. 1 m from such equipment.
1.4 WEEE Compliance

This product is required to comply with the European Union’s Waste Electrical & Electronic Equipment (WEEE) Directive 2002/96/EC. It is marked with the following symbol:

![WEEE symbol]

Thermo Fisher Scientific has contracted with one or more recycling/disposal companies in each EU Member State, and this product should be disposed of or recycled through them. Further information on Thermo Fisher Scientific compliance with these Directives, the recyclers in your country, and information on Thermo Fisher Scientific products which may assist the detection of substances subject to the RoHS Directive are available at www.thermo.com/WEEERoHS
2. Quality Assurance

Dear customer,
Thermo Fisher Scientific implements a Quality Management System certified according to ISO 9001:2008. This guarantees the presence of organizational structures which are necessary to ensure that our products are developed, manufactured and managed according to our customers' expectations. Internal and external audits are carried out on a regular basis to ensure that our QMS is fully functional. We also check our products during the manufacturing process to certify that they are produced according to the specifications as well as to monitor correct functioning and to confirm that they are safe. The results are recorded for future reference.

The “Final Test” label on the product is a sign that this unit has fulfilled all requirements at the time of final manufacturing. Please inform us if, despite our precautionary measures, you should find any product defects. You can thus help us to avoid such faults in future.

3. Your Contacts at Thermo Fisher Scientific

Please get in contact with us or the authorized agent who supplied you with the unit if you have any further questions.

International / Germany

Thermo Fisher Scientific
Dieselstraße 4
D-76227 Karlsruhe, Germany
Tel. +49(0)721 4094-444
Fax +49(0)721 4094-300

support.mc.de@thermofisher.com
www.thermoscientific.com/mc

The following specifications should be given when product enquiries are made:

Unit name printed on the front of the unit and specified on the name plate.
Typ: Order No. (e.g.: 557–3001)
Ser.: Nr.:

- - - - - - - - - - - - - - - -
- - - - - - - - - - - - - - - -
Manufacturing order no.: (1–9)
Manufacturing year (e.g. 09)
Production order no.: (000001 – 99999)
Serial-number

Mains voltage in V / power input:
e.g. 115 V / 50 Hz / 2 A
4.  **Warranty**

For the warranty and any potential additional warranty, the user shall have to ensure that the devices are serviced by an expert at the following intervals:

The maintenance is required after approx. 2000 operating hours, at the latest, however, twelve months after the initial operation or the last maintenance, respectively.

Two thousand operating hours are achieved:

- at an operating period of eight hours daily (five days a week) about once a year
- at an operating period of more than eight to sixteen hours daily about every six months
- at an operating period of more than sixteen hours daily about every three months

We recommend to have the maintenance carried out by Thermo Fisher Scientific or by staff authorised by Thermo Fisher Scientific as special knowledge and tools are required.

The maintenance and calibration work carried out has to be recorded by certificates in conformity with ISO 9000 ff.
5. Safety Notes and Warnings

The Rheometer corresponds to the relevant safety regulations. However you are solely responsible for the correct handling and proper usage of the instrument.

This instrument exclusively determines the rheological behavior of fluid and half-solid materials. These materials may not be tested if people can be hurt or devices be damaged.

! Do not lift or move the unit at the ends of the glass pane.

! Do not measure / temperature control any materials that may give off dangerous vapours or may be inflammable within the working temperature range of the rheometer.

! The device may not be operated if there are any doubts regarding a safe operation due to the outer appearance (e.g. damages).

! A safe operation of the instrument cannot be guaranteed if the user does not comply with this instruction manual.

! Ensure that this instruction manual is made readily available to every operator.

! Do not bend connection and/or mains cable, do not subject cables to stress or high temperatures (higher than 70 °C).

! Check cables visually at regular intervals.

! The operator must have an uninterrupted view of the machine and its surroundings.

! The rheometer must be fully visible from the PC control stand.

! This unit should only be used for the applications it was designed for.

! The rheometer is designed for use with a rotor. All existing safety devices are based on the correct installation of the rotor. Is the lift (of the measuring table) used without a rotor installed injuries may occur when reaching in the lift area.

! Make sure that the unit has been switched off before you connect or disconnect the cables. This is to avoid electrostatic charging resulting in a defect of the electronic circuit boards.
Safety Notes and Warnings

- Once the probe attains appropriate viscosity, cylindrical tube (Order no. 222-1394) protectors that prevent probe's radial exit must be used when measuring. An operational error when using the measuring device can lead to the probe's radial exit from the measuring gap; it is therefore recommended to wear protective goggles.

- Do not operate the unit with wet or oily hands.

- Do not immerse the unit in water or expose it to spray water.

- Do not clean the unit using solvents (fire danger!) - a damp cloth applied with a household cleaning substance is often sufficient.

- Complete separation from the mains is required when repairs or maintenance work is about to be carried out.

- Suitable personal protective gear, consisting of lab coat, protective eyewear and safety gloves, must be worn at all times when working with the instrument.

- Repairs, alterations or any work involving opening up the unit should only be carried out by specialist personnel. Considerable damage can be caused by incorrect repair work. The Thermo Fisher Scientific service department is at your disposal for any repairs you may require.

- Have the unit serviced by specialists at regular intervals.

- RheoStress1: The pressure of the air supply for the air bearing must not exceed 4 bar. Higher pressure will damage the air bearing permanently!

- For applications at elevated temperatures above 250°C it is a must to switch the fan for the air bearing cooling on stage 2 (on the rear) and use ceramic shafts only. Furthermore use the cone heater TC1 as thermal shield to prevent the heating up of the air bearing housing!

Severe skin burns can be caused by contact with hot unit parts!

The rheometer can reach temperatures up to 350 °C, depending on the temperature control unit installed. This can result in parts of the rheometer heating up to such an extent, even when taking the cooling and insulation into account, that serious burns can result if they come into contact with the skin.

Thermo Fisher Scientific recommends shielding the rheometer when operating at high temperatures and handling it only with high temperature proof gloves and safety glasses.

A danger symbol on the glass plate warns the user of possible danger (burn injury).
Safety Notes and Warnings

We do not know which substances you intend to test using this unit. Many substances are...

- inflammable, easily ignited, explosive
- hazardous to health
- environmentally unsafe

i.e.: dangerous

You alone are responsible for your handling of these substances!

Our advice:

- If in doubt, consult a safety specialist
- Read the product manufacturer’s or supplier’s “EU SAFETY DATA SHEET”
- Read the REGULATIONS CONCERNING DANGEROUS MATERIALS
- Observe the “Guidelines for Laboratories”
6. Unpacking / Ambient conditions

6.1 Transportation damage?
- Notify carrier (forwarding merchant, railroad, post office) etc,
- Compile a damage report.

**Before return delivery:**
- Inform dealer or manufacturer (Small problems can often be dealt with on the spot).

! Do not lift or move the unit at the ends of the glass pane.

! Use the transport handles provided for the instrument when unpacking.

! The instrument must be carried by two persons.

! Unpacking the instrument and putting it into operation is part of the installation and is carried out by trained personnel from Thermo Scientific.

6.2 Contents of Delivery

6.2.1 Standard Delivery Rheometer

The Rheometer is delivered in a recyclable package with the following accessories:

<table>
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<th>HAAKE RotoVisco 1</th>
<th>Part.No.</th>
<th>TCO</th>
<th>TCL/Z</th>
<th>TCL/P</th>
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Unpacking / Ambient conditions

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<th>TCE/P</th>
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<td>1</td>
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<tr>
<td>Fuses 230V/T1.6A</td>
<td>087–0532</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Fuses 230V/T3.15A</td>
<td>087–0533</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Fuses 100/115V/T3.15A</td>
<td>087–0533</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Fuses 100/115V/T5A</td>
<td>087–3353</td>
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<td></td>
<td></td>
<td></td>
<td>2</td>
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<tr>
<td>Leveling indicator</td>
<td>002–4696</td>
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<td></td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
6.2.2 Sensor Systems

Various sensor systems are available for the Rheometer which differ also in their temperature control specifications.

6.2.3 Accessories for the Temperature Control Units

The temp. control units for liquid temp. control may be operated with different hoses:

For the temperature control units, the open-bath circulators and heating circulators the necessary tubing hoses are not part of the standard accessories. They have to be ordered separately.

**Temperature range up to 150°C:**

- Viton-hoses with quick coupling 222-0610
- Hose nozzle set 222-1492

**Temperature range of 100 up to 350°C:**

- Metal hoses (150 cm each) 333-0294
- Hose nozzle set 222-1492

! Secure all hose connections using hose clamps!

6.2.4 Application software

HAAKE RheoWin ® Rheometer software for Windows XP

<table>
<thead>
<tr>
<th>Software RheoWin ®</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>for HAAKE RotoVisco1</td>
<td>098-5003</td>
</tr>
<tr>
<td>for HAAKE RheoStress1</td>
<td>098-5004</td>
</tr>
</tbody>
</table>
6.3 Space Requirements

Good working conditions for a complete installation require an area of about 1 \times 0.6 meters. The two benches should be rigid with a level surface and easy to clean. The circulator used for temperature control should be located below the rheometer on a separate bench to avoid backflow of thermal fluid and possible mechanical oscillation.

! A suitable laboratory bench must be provided for the installation.

! The circulator has to be located below the level of the rheometer, otherwise the thermal fluid flows back in the cup holder and flushes the instrument.

6.4 Mains supply

! Only attach the units to mains sockets with a grounded earth. Compare the local mains voltage with the specifications written on the name plates of the measuring instrument and the control unit. Voltage deviations of \( \pm 10\% \) are permissible.

Mains cable and unit fuses:

1. Use the mains cable according to your local mains voltage (see chapter "Contents of delivery").

2. Insert the fuses according to your local mains voltage below the mains connection 6.

3. For TCO, SHRP, TCL/Z, TCL/P:
   - 230 V: 2 x T1.6 A
   - 100/115 V: 2 x T3.15 A

For TCE/P, TCE/P, TCE/PC, TCP/P:
   - 230 V: 2 x T3.15 A
   - 100/115 V: 2 x T5 A

4. Insertion of the fuses:
   - Pull out the fuse holder from the mains socket and insert the fuses. Reinsert according to the marked voltage.

6.5 Cooling air for the measuring head (HAAKE RotoVisco 1)

- Compressed air is connected at nozzle 9 to avoid overheating under extreme load (high torque, high temperature (200–350 °C)) and at use of the measuring instrument at temperatures > 100 °C in the continuous operation respectively.
- Maximum conduction pressure 0.5 bar.
- (RheoStress are cooled by the outgoing air of the air bearing.)
6.6 Requirements for the air supply
HAAKE RheoStress RS1 / RW1F

- Pure air pressure is connected at nozzle for the air bearing with a pressure by 2.5 bar (ideal way).
- The air supply must have the following conditions:
  - max. 4 bar,
  - consumption approx. 10 dm³/minute
    (1 dm³ = 1 thousandth of a cubic meter),
  - no synthetic oil in the line,
  - max. oil contents → 3 mg/m³ air,
  - dry air with a residual moisture < 40 %

Use the filter unit (order no. 222-1211) or the HAAKE compressor (order no. 222-1434 for 230 V and 222-1435 for 115 V).

! HAAKE RheoStress1: The pressure of the air supply for the air bearing must not exceed 4 bar. Higher pressure will damage the air bearing permanently!

The air bearing reacts highly sensitive to dirt like particles (dust an lint) or liquids (oil or water which condenses at high humidity levels). It is therefore recommended to have new air compressors run for a longer period of time (0,5 hrs.) without actually connecting it to the Rheometer. In the case of internal supply systems polluted air might have collected near the connection nozzle when the line has not been used for some time. Therefore, we also recommend to "flush" this line for a period of approx. 0.5 hrs.

6.7 Pipes in the building

Oil is generally applied to air pipes in the buildings of material-processing plants in order to prevent rusting in the workshops. By means of complex filters the oil content may be reduced by rarely so much that the air bearing does not suffer damage. Thermo Fisher Scientific air bearings must not be used in plants in which oil is added.

6.8 Air compressors

There are "oil-free" and "lubricated" versions of air compressors. Only oil-free compressors (e.g. the HAAKE compressor) are admissible for Thermo Fisher Scientific air bearings.

- If the hose length is larger then 5 m (between compressor and measurement unit), it must be separately attached pressure controller located next to the measurement unit (see instruction manual Air compressor Carat).

6.9 Ambient conditions according to EN 61010

It is recommended to run tests in an air-conditioned room, (T = approx. 23°C):
- indoors, max. 2000 meters above sea level,
- ambient temperature 15 ... 40°C,
- relative humidity max. 80%/31°C (→ 50%/40°C)
- excess voltage category II, contamination level 2
7. Unit Description

Introduction
The viscoelastic behavior of a fluid or a soft solid can be characterized in two ways; either the fluid is deformed and the resulting stress is measured (CR mode), or the stress is applied and the deformation monitored (CS mode). The principle benefits of the CS mode are:

Software
Software control and evaluation with HAAKE RheoWin® or OS1 to program the display unit for production laboratories.

Measurements and evaluation
The Rheometers is controlled either by the HAAKE RheoWin® Software or with one of 10 pre-programmable measuring procedures by the display unit. The results are available for further processing on a PC with the HAAKE RheoWin® Software. Alternatively up to 50 measurements can be stored internally and be evaluated, displayed or printed out for documentation purposes.

Sensors
For HAAKE RotoVisco1 and HAAKE RheoStress1 plates, cones, coaxial cylinders and immersion systems are available.
7.1 HAAKE RotoVisco1

Thixotropy and flow curve
The determination of the flow behavior of a test substance requires a speed ramp up, a holding time and a return curve for the determination of the thixotropy. This hysteresis method can like all other measuring procedures be PC controlled or can be loaded as procedure in the display and control unit.

Time curve
Is the viscosity of a test substance changing with time this can be monitored objectively with the HAAKE RotoVisco1. This is especially important for substances which are curing (adhesives, building materials), change their viscosity with storage time or show considerable changes of viscosity after shearing during the production process (cosmetics, paint, food).

Temperature programs
Temperature programs are very time consuming when the rheometer has to be operated and supervised. With the RotoVisco1 these tasks can be taken over by the PC which controls the rheometer as well as the temperature control units – everything without intervention of the operator.

Determination of the yield point
As soon as substances are strained beyond the Hookean range they start to flow. This can be defined as yield point and is an important characteristic value in quality control. With the HAAKE RotoVisco1 this value can be established relevant to practical applications, fast and easily by applying a small deformation through extremely low speed values.

CD Mode
In the CD mode (speeds lower than 0.1 min⁻¹) it is only measured at constant speeds. When ramps or steps are preset, the following speed table is run:

<table>
<thead>
<tr>
<th>Speed (min⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0125</td>
</tr>
<tr>
<td>0.0250</td>
</tr>
<tr>
<td>0.0375</td>
</tr>
<tr>
<td>0.0500</td>
</tr>
<tr>
<td>0.0630</td>
</tr>
<tr>
<td>0.0750</td>
</tr>
<tr>
<td>0.0875</td>
</tr>
<tr>
<td>0.1000</td>
</tr>
</tbody>
</table>
7.2 HAAKE RheoStress1

Flow curves
in CR and CS mode can be recorded as ramp or steps (steady state).

Time curves
for reactions (e.g. curing) at constant temperature, shear rate, shear stress or frequency.

Temperature programs
are software controlled to determine the temperature dependence with controlled shear stress, shear rate or frequency.

Yield points
can be determined with creep/recovery tests or with stress controlled ramps.

Viscoelasticity
of a fluid can be quantified by a creep/recovery test or by dynamic measurements in CD (Controlled Deformation) or CS (Controlled Stress) mode.

Multiwave
even allows the determination of the frequency spectra as a function of time or temperature by overlay within shortest time.
7.3 Temperature control:

For applications at elevated temperatures above 250°C it is a must to switch the fan for the air bearing cooling on stage 2 (on the rear) and use ceramic shafts only. Furthermore use the cone heater TC1 as thermal shield to prevent the heating up of the air bearing housing!

TCO Glass plate with a Pt100 temperature sensor (not temperature controlled).

TCL/Z Liquid temperature controlled receptacle for cylinder measuring systems with direct contact of the thermal fluid from -40 up to 200°C.

TCL/P Liquid temperature controlled measuring plate for parallel plate or cone & plate measurements (with external circulator from -20 up to 300°C).

TCP/P Measuring plate with Peltier temperature control for parallel plate or cone & plate measurements from -40 up to 180°C (external heat transfer required).

TCP/PE

TCE/P Electrically temperature controlled measuring plate for parallel plate or cone & plate measurements from -20°C up to 350°C.

TCE/PC Electrically temperature controlled measuring plate for parallel plate or cone & plate measurements with electrical cone heating from -40°C up to 350°C.

SHRP Special temperature controlled system utilizing thermal liquid as standardized for asphalts and bitumen. Temperature range: 0°C (-25°C)... +90°C (for HAAKE RheoStress 1)
7.4 Main features of the HAAKE rheometers:

- Quick fitting sensor with a high precision even if not perfectly clean.
- Remote and manually controlled lift with variable speed to preserve the fluid's structure and ensure reproducible test conditions.
- Microprocessor controlled positioning of the sensor to ensure the highest accuracy for routine tests.
- Standard temperature range of -40 to 250 °C using a heating circulator; utilizing electrical cone heating extends this up to 350 °C.
- Controlled rate mode for characterizing rheologically complicated fluids (HAAKE RotoVisco 1 and HAAKE RheoStress 1).
- Controlled stress mode for characterizing sensitive substances (HAAKE RheoStress1).
- Forced oscillation tests at very low frequencies and very low strains allow destruction free measurements (HAAKE RheoStress 1).
- Sophisticated application software packages with userfriendly window menus and an on-line help key.
8. Installation

8.1 Setting up the Rheometer

Lift the Rheometer out of the package and place onto a stable, level table. Do not lift the unit at the glass pane or at the measuring head! For sensible measurements a plane table is recommended.

In the base of the measuring instrument, there are four feet which can be screwed in or out for levelling the unit. Upon completion of the preliminary visual levelling, exact precision levelling can be carried out using the spirit level supplied.

1. The spirit level:
   - is put on the measuring plate at temperature control unit TCL/P; TCE/P; TCE/PC and TCP/P.
   - is put into connection with a vessel at temperature control unit TCL/Z.
   - is put on the measuring plate in the vessel at temperature control unit SHRP.
   - is not used at temperature control unit TCO.

2. Adjust the feet so that the air bubbles remain in the center of the spirit level.

This adjustment process should be repeated at least once a week.
Installation

8.2 Connecting up

! Make sure that the unit has been switched off before you connect or disconnect the cables.

The cable connections between the sensor system, the control unit, the PC and the printer have to be established (see chapter Pin Wiring).

8.2.1 PT100 connection

PT100 (input) socket for external PT100 sensor only when using TCO

PT100 (output) socket for PT100 sensor only when using TCL/Z and TCL/P

The connections are described in chapter “Pin Wiring”.
8.3 Hose connections

8.3.1 Temperature control unit (with liquid):

- The temperature control unit with liquid temperature control is connected with hoses to a heating bath and circulator.

! While fastening the hose connections at the connecting nozzles (14) of the temperature control unit the connecting nozzles must be held up by wrenches.

! Direction of flow of the liquid

Temperature range up to 150° C:

Viton hoses
Hoes nozzle -Set 222-1492

Temperature range of 100° C up to 350° C:

Metal hoses 333-0294
Hoes nozzle -Set 222-1492

Liquid temperature control:

Temperature range up to 100° C:

Thermal liquid in the temperature range between -50° C and 30° C: water with anti-freeze.
Temperature range from 5° C to 90° C: distilled water.

Distilled water

Normal mains water causes cable deposits and frequently requires the unit to be descaled.

In principle, water up to 95° C can be used. However, above 80° C, so much water evaporates that it requires frequent topping-up.

Water with anti-freeze

If you intend working at temperatures below 5° C, anti-freeze must be added to the water. The added amount of anti-freeze should be sufficient for a temperature that is about 10°C lower than the intended working temperature. This prevents the freezing of water on the evaporator coil of the cooling circuit, the surface of which is always much colder than the
Installation

working temperature. However, too much anti-freeze worsens the temperature constancy due to its high viscosity.

**Temperature range from 100° C to 200° C:**
Silicone oils or other suitable liquids are used as thermal liquid.

**8.3.2 Air bearing (measuring unit)**
- The air bearings of the measuring units HAAKE RheoStress1 require cooling air at port 9 (see “Requirements for the air supply”).
9. **Functional Elements**

9.1 **Temperature control units**

<table>
<thead>
<tr>
<th>Rheometer</th>
<th>TCO</th>
<th>TCL/Z</th>
<th>TCL/P</th>
<th>TCE/P</th>
<th>TCP/P</th>
<th>SHRP</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAAKE RotoVisco1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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</tr>
<tr>
<td>HAAKE RheoStress1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
9.2 External filter

An external filter is part of the standard range of items supplied with the temperature control units for Series 1 TCP/P (Peltier-Temperature control system), TCE/P (electrical temperature control unit), TCL/PO (liquid temperature control unit for HAAKE RheoScope) and the UTCP/P (Peltier-Temperature control system for HAAKE RSXXX units). It consists of the filter itself, a plastic cone contained inside it, and clamps.

Using this filter enables the interior of the relevant temperature control unit to be protected against any impurities carried in by the temperature liquid. The external filter represents an additional protection. On the standard model a sieve is built in to the intake of each temperature control unit.

As shown in Fig. X, the filter is installed in the intake hose leading into the temperature control unit between the thermostat and the measurement instrument. The intake and outlet directions must be noted (IN and OUT on the filter). It is fastened with the clamps that are supplied with it. Hoses with a diameter of 8 mm can be installed and fastened with the clamps supplied. The plastic cone on the inside of the filter serves as a direction of flow indicator, and its movements show the through-flow of the tempering liquid. If there are impurities in the filter it can be taken out, cleaned, and used again. The use of the external filter is recommended because any impurities can be recognised and removed more readily than with the sieve that is built in to the temperature control unit. The screw-in sieve (internal) must of course be checked for impurities from time to time in order to ensure the functional capability of the temperature control unit.

Order numbers:

003-5266 Screw-in sieve (internal) for TCL/P, TCP/P, TCE/P, TCL/Z

222-1667 External filter for TCP/P, TCE/P, TCL/PO
9.3 Measuring Instrument with no temperature control unit.

Front

1. Measuring unit
2. Quick cut-off switch
3. Green LED display: operational
A. Caution: Read the instruction manual
6. Mains switch with mains socket and fuses
7. RS 232 interface (PC)
8. Connection for printer
9. Connection for cooling air (RheoStress1 for the air bearing)
10. PT 100 Connection
11. Connection for display unit
12. Reset switch
13. Switch for bootstrap loader
9.4 Measuring Instrument with TCL/Z – temperature control unit.

Front

A. Caution: Read the instruction manual

Glass pane can heat up!
Use safety gloves!

1. Measuring unit
2. Temperature control unit
3. Quick cut-off switch
4. Green LED display: operational
5. Yellow LED display: heating
18. Clamping lever

! When using a circulator for temperature control, this must be located lower than the measuring device, other via the temperature control liquid will flow back in to the measuring beaker location and over the measuring device.
A. Caution: Read the instruction manual
6. Mains switch with mains socket and fuses
7. RS 232 interface (PC)
8. Connection for printer
9. Connection for cooling air (RheoStress1 for the air bearing)
11. Connection for display unit
12. Reset switch
13. Switch for bootstrap loader
14. Liquid cooling for temperature control unit
20. Connection for PT100 (output)
9.5 Measuring Instrument with TCL/P / TCE/P / TCP/P / TCP/PE - temperature control unit.

A. Caution: Read the instruction manual
Glass pane can heat up!
Use safety gloves!

1. Measuring unit
2. Temperature control unit
3. Quick cut-off switch
4. Green LED display: operational
5. Yellow LED display: heating
19. Measuring plate
A. Caution: Read the instruction manual
6. Mains switch with mains socket and fuses
7. RS 232 interface (PC)
8. Connection for printer
9. Connection for cooling air (RheoStress1 for the air bearing)
11. Connection for display unit
12. Reset switch
13. Switch for bootstrap loader
14. Liquid cooling for temperature control unit
20. Connection for PT100 (output) **only at TCL/P**
9.6 Measuring unit with TCE/PC-temperature stabilisation unit and cone heater TC1

Front side

A. Caution: Read the operating instructions! 
Unit parts can get hot! 
Wear protective gloves!

1. Measuring unit
2. Temperature stabilisation unit
3. Emergency OFF switch
4. Green LED: Ready for operation
5. Yellow LED: Heating
19. Measuring plate
21. Cone heater TC1
A. Caution: Read the operating instructions!
6. Mains switch with mains socket and fuses
7. RS 232 interface (PC)
8. Connection for printer (Centronics)
9. Connection for cooling air (RheoStress1 for the air bearing)
11. Connection for display unit
12. Reset switch
13. Switch for bootstrap loader
14. Fluid cooling for temperature control unit
20. Connection for PT100 (output)
22. Fuse T1.25A
23. Fuse T8.0A
24. Fuse T3.15A
25. Connection for cooling air (for TC1)
9.7 Measuring Instrument with SHRP – temperature control unit.

Front

A. Caution: Read the instruction manual
   Glass pane can heat up!
   Use safety gloves!

1. Measuring unit
2. Temperature control unit
3. Quick cut-off switch
4. Green LED display: operational
5. Yellow LED display: heating
17. Influx control

! When using a circulator for temperature control, this must be located lower than the measuring device, other via the temperature control liquid will flow back in to the measuring beaker location and over the measuring device.
Functional Elements

Rear

A. Caution: Read the instruction manual
6. Mains switch with mains socket and fuses
7. RS 232 interface (PC)
8. Connection for printer
9. Connection for cooling air
   (RheoStress1 for the air bearing)
11. Connection for display unit
12. Reset switch
13. Switch for bootstrap loader
14. Liquid cooling for temperature control unit
16. Overflow port
9.8 Display unit (optional)
(Order no. 222–1472)

General display screen splitting

Header gives the display title
see mask number on the right;

Keys 1 to 6 are reserved differently under each display title

Up/Down increase or decrease e.g. number values;
short pressing - small increments,
long pressing - increasingly higher increments;

Enter is the confirmation of an entry or selection;

Menu goes back to an overview display;

Status shows date/time, internal store capacity for measurements, help texts
9.9 Menu tree of the display unit
Operating

10. Operating

10.1 Switching on

When all connections have been established and the supply lines are active, switch-on the mains switch 6:

⇒ The green display 4 on the measuring table of the rheometer indicates the ready state for operation.

The following operation sequence should be used to be able to make the measurements at short notice:

- Instrument:
  - Automatic device initialization
  - Raises the lift. Never switch off the unit during lift movement.

! In case of loss of power during the lift movement, the unit has to be initialized again.

- Then the following display appears:

- Operator: Insert sensor if necessary

- Instrument: Lowers the lift for zero point determination.

! Due to the rotation of the pin spots can appear on the measuring plate. This is normal and does not constitute any damage to the unit.

Then move the lift again to cleaning position (i.e. up), the instrument immediately shows the MENU selection window (A) for defining, if necessary, the operator, sample name etc.

10.2 Working with the display unit

In MENU activate CONFIGURATION by pressing the key.

Pressing the key leads directly into the submenu.
Diagnosis

FULL-DIAGNOSIS:
- The complete device diagnosis contains all internal tests which are possible at present;

HARDCOPY:
- Sends a diagnosis report to the printer.

Date / Time

Display

Pressing each key leads directly into the respective sub-menu:

CONTRAST
Contrast number: xx increase or decrease

UNITS
Switch over facility for
  Temperature: °C or °F
  Viscosity: Pas or mPas

COUNTRY SETTINGS
Choice of one of two available date formats.

ON-LINE-VALUES
ONE predefined display mask with 6 fields (3x large fields on left and 3x small fields on right, respectively assigned to the keys) appears. On pressing a key at the respective field, this field is activated and any desired physical parameter can be assigned to it.

Fields with no parameter assigned to them do not appear during the measurement.

ON-LINE-GRAPHICS
Two y-axes and one x-axis can here be assigned to any desired respective physical parameters.

Data memory
Language

Measure
The measurement sequence as a whole is described under "Measuring sequence".

Lift
LIFT activation takes place in MENU by pressing the key.

Pressing the key leads directly into the submenu:

OPEN
- The lift raises to the top position and stops there (cleaning position).

CONTACT
- The lift moves down to the contact point (zero point)
- and then up again to the cleaning position with status message reporting successful zero point determination.

TOGETHER
- The lift runs max. (if STOP is not actuated before) to the contact point and stops there.

STOP
- Stops the lift immediately.

MEASURING POSITION
- Runs from the current position (usually the cleaning position) to the measuring position.
### Operator

In MENU activate OPERATOR by pressing the key.

Pressing the key leads directly into the submenu:
- The list of OPERATORs is defined in RheoWin and downloaded from there.

### Sample name

In MENU activate SAMPLE NAME by pressing the key.

Pressing the key leads directly into the submenu:
- The list of SAMPLE NAMEs is defined in RheoWin and downloaded from there.
### Operating

**Batch ID**
In MENU activate BATCH ID by pressing the key.

Pressing the key leads directly into the submenu:
- Batch ID must be entered on the display unit.

**Measuring sequence**
In MENU activate MEASURE by pressing the key.

Pressing the key leads directly into the submenu:
- (The names of the jobs are defined by the user in the RheoWin-Software.)
  "Snap-Shot Test" and "Manual measurement" are permanently assigned.

Pressing a key leads directly to the "Measurement definition screen".
- If all specifications are correct, the operator can press "START TEST".
After the operator has started the measurement, the job starts and the display shows the predefined online form.
- The operator waits until the job is completed or discontinues the job or the current element (jumps to the next element).

On completion or discontinuation of the job, the following display appears:

The operator sees the results of the job on the display and has 3 options for continuing:

1. Insert new sample: Press LIFT (lower lift), display No. 110 appears, replace old sample with new one and then continue.

2. Next measurement (same job) with same sample but possibly other parameters: Press START NEW MEASUREMENT. Any existing parameter place holders of this job are shown again for editing.

3. General continuation of operation of the instrument via MENU.
10.3 Starting the software

1. Switch on the PC and load MS Windows.

2. In the Windows Program Manager double-click the RheoWin Job Manager icon.
   ⇒ RheoWin is started.

3. Click the Device Manager icon in the menu bar.

4. Select the connected unit in the Device Manager and check the connection with "Test".

For extensive operation please read the instruction manual of your software.
10.4 The "Upload Mode" for the Display Unit
(RheoWin 2.6 or higher)

The rheometers can be operated by the software RheoWin in "direct mode" or it can be loaded by special functions measuring programs in the store of the measuring device. By that, the measuring device gets independent of the PC and it is only connected for programming or data transfer. The measuring programs ("JOBs") are started after the corresponding programming with the display unit.

For programming or data transfer the Rheometer must be connected to the PC via RS232 cable as usual and Thermo Fisher Scientific Haake software RheoWin must be loaded.

After installing the rheometer two versions per model can be found in the device manager. The device e.g. RotoVisco1 is running in the software direct mode as usual. Model RV1 (Upload mode) has already been pre-defined as independent device.

The characteristic "Upload Mode" is transferred to the device driver on the following card which can be found under "Edit". So you can give the device driver the characteristic "Upload" or "Software" mode. For practical reason it is advisable to define a new device for each operation.
Other options on the device record card are:

**Torque Compensation**

When the torque compensation is activated, the present value of the torque display is set on zero "0" right before the measurement so that possible faults (offset faults) can be reduced. This is always advisable when samples without "yield point" are to be measured. In case of doubt it is measured first without "Torque Compensation" and after that it is decided whether the function can be used.

**Inertia of Masses Correction Ramp**

If fast speed ramps (< 180 s) are driven, the dampening set at the sensors (usually 30%) and also the inertia of the masses of the measuring device (motor and rotor) enter the result. Fast ramp speeds make up a hysteresis curve which does not come from the sample but from the test conditions and the measuring device. The influence can be seen qualitatively in the following diagram. It is recommended to drive measurements with ramp times of less than 120s without correction only in special cases. With correction, the influences of the inertia of masses are compensated. This can be tested individually at examples relating to practice.
Communication Record

This function has been installed for service use. If this function is activated, all commands between the measuring device and the PC are recorded in a file named Driver.log (RV1.log, RS1.log,) and are managed in the directory \rheo-win\driver.

Upload

Under "Upload" you can find the present data for user, sample and sensor. These data are entered with RheoWin and are read out. In the display unit these exact terms can be selected. If you are connected to the measuring device at the running time the present level of the store is read out with "READ" and is displayed. Changes can be made. They are transferred to the measuring device while leaving the menu and are available now. If the device has not been programmed yet (state at delivery) all lists are empty.

Now the three record cards can be filled with information. With the mouse and the cursor the first position is clicked and e.g. a name is entered. After that the second line can be clicked and other entries can be made.
When all names of possible users are entered, the names of the samples which are to be measured can be entered. Only these names can be recalled from a selection list.

In principle the same is valid for the sensors of the rheometer. It is recommended to enter only the sensors which are really in existence from the list of all variants to keep the display clearly organized.
The sensors of the right window are transferred to the measuring device if you leave the menu with <OK> . With Cancel the existing adjustments are kept. If the factors are changed, e.g. after a calibration, the values of the sensors can be renewed with <READ> after the reading of the store.

**Drawing up JOBS for Uploading**

JOBs or measuring and evaluation procedures are drawn up with the RheoWin Job manager. The distinction takes place **before** the drawing up of a JOB at the selection of the measuring device. If existing JOBs are changed afterwards unexpected reactions can take place. The following proceeding is recommended:

First the measuring device is selected. After that the procedure is drawn up.
After the selection of the measuring device, the sensor and a temperature control unit are selected. If no temperature control unit is selected, no temperature control can take place. No selection (---) also means that the temperature control unit is switched off.

The measuring process is now composed according to the requirements of the application or of the user just as in the PC mode. There are some restrictions of the length of names and the selection of elements. These restrictions are visible only at editing.

After the drawing up of a JOB it can directly be started for a test or it can be uploaded to the measuring device. On this
Operating

occasion a list gets visible that shows an empty list or already existing JOBs. The order or position of the list corresponds to the reservation in the measuring device. So you can make an allocation indirectly. Empty positions have to be avoided, because otherwise the following entries would be ignored.

Uploaded JOBs can be called in via the display unit and can be carried out directly.

Reading back uploaded JOBs from the measuring device

JOB’s can be read back from the measuring device with the RheoWin function /File/Open Job of Measuring Device/. This function corresponds to the reading of the hard disk.

If this function is selected, all installed unit drivers are called in and it is tested if a connection can be made. Drivers that are not installed correctly cause error messages and should be cancelled from the device list (device manager). If a measuring device with the possibility of managing JOBs responds it is selected and displayed immediately.
In the white area the existing JOBs are listed for selection.

Measuring result

The measuring result is a chart with measuring and preset values according to the measuring definition. It can be transferred, if defined in the JOB, directly to a printer. The result is then shown as selected. Segments can be printed or ignored. The selection of the column contents takes place via the list menus.

Importing the measuring result in RheoWin

The last measuring result can also be imported directly to the RheoWin software (measuring device connected to PC and RheoWin active). For this the file in the DATA manager is opened.
From the following list the device of your choice is selected for reading out the data. This is necessary because the software RheoWin can drive and read several units by multitasking.

After the selection the data are transferred via RS232 interface from the measuring device to the PC/RheoWin software. The data are treated like comparable values of the local hard disc or of the network.
10.5 Quick Cut-off

The switch (3) at the top of the right column switches off the measuring drive, heating and lift.
Internal measuring jobs are interrupted.
11. Temperature control units

11.1 Temperature control unit TCO

The sample is in the measuring gap of the sensor system. The rotator is driven by a preset speed \( (n) \). Due to its viscosity, the sample is resistant against the rotation. This resistance gets active as (braking) torque \( (Md) \) at the measuring shaft of RV1. The torque is measured.

From the values of speed, torque and measuring system geometry (system factor) the installed PC calculates the measuring values for

If a temperature sensor is connected, the temperature \( T \) (in °C) is also calculated.

The results are shown on the display (operating panel) and can be passed on to a computer (PC) or printer via interface connection RS232.
11.2 Temperature control unit TCL/Z

Place the beaker into the temperature control unit and fix it with the clamping lever.

The sensor system and the temperature control unit require cooling according to load and temperature during the measurement.

Connect the rheometer to a Thermo Fisher Scientific Haake circulator with optional hoses (⌀ 8 mm).

⚠️ While fastening the hose connections at the connecting nozzles (14) of the temperature control unit:
- ensure the correct flow direction (IN/OUT)
- the connecting nozzles must be held secured using a wrench.

maximum conduction pressure 0.5 bar (water circulation).

For the TCL/Z sensor system and the open-bath and heating circulators the necessary tubing hoses are not part of the standard accessories. They have to be ordered separately.

When the measuring beaker is inserted in the temperature control unit, a valve is automatically opened as it is pressed in and temperature control liquid flushes the beaker. The valve is closed again when the beaker is removed.

The displacement path of the valve means that the beaker must be moved 3mm. If the seal is missing or an incorrect closing screw has been fitted, the valve can remain closed and the temperature control function is inoperative.

Remedy: Fit a new seal, a correct closing screw or a spacer.

⚠️ The circulator must be located lower than the measuring device, other via the temperature control liquid will flow back in to the measuring beaker location and over the measuring device.

For the TCL/Z measuring unit and the open-bath and heating circulators the necessary tubing hoses are not part of the standard accessories. They have to be ordered separately.

The lever (222–1639) for cylinders is an accessory for the RheoStress 1 and RotoVisco 1 rheometer models, which are equipped with a liquid temperature control unit (TCL/Z) for coaxial cylinder measuring geometries.

The lever enables the removal of the measuring cup, e.g. for cleaning at the end of a measurement.
Temperature Control Units

The following procedure is recommended:

1. Switch the circulator off, in order to reduce the low pressure of the temperature liquid.
2. Position the lever as illustrated in Fig. and move the lever upwards till the measuring cup is free to move.
3. The measuring cup can be now easily removed by hand.

Handling of the lever
11.3 Temperature control unit TCL/P

The temperature control unit has a holding for the measuring plate. The measuring plate is put on the thermal liquid heated temperature control unit and is fastened.

Cones and measuring plates should have the same diameter e.g. as cone C60/1 and the measuring plate MP60 or plate PP35 and measuring plate MP35. If not, huge measuring faults are the consequence!

For measurements at temperatures higher than 70°C it is recommendable to use at least the sample protection shield (222-0608) to reduce the loss of heat. In any case, the application of measuring cones and measuring plates with a ceramic shaft that do carry off less heat is recommendable.

The sensor system and the temperature control unit need cooling that is dependent on the load and the temperatures during the measurement.

⚠️ While fastening the hose connections at the connecting nozzles(14) of the temperature control unit:
- ensure the correct flow direction (IN/OUT)
- the connecting nozzles must be held secured using a wrench.

For the cooling of the temperature control unit hoses (with Ø 8mm) can be connected to a liquid circulator.

maximum conduction pressure 0.5bar (water circulation).
11.4 Temperature control unit TCE/P

The temperature control unit has holding a for the measuring plate. The measuring plate is put on the thermal liquid heated temperature control unit and is fastened.

Cones and measuring plates should have the same diameter e.g. as cone C60/1 and the measuring plate MPC60 or plate PP35 and measuring plate MPC35. If not, huge measuring faults are the consequence!

For measurements at temperatures higher than 80°C it is recommendable to use at least the sample protection shield (222-0608) to reduce the loss of heat. In any case, the application of measuring cones and measuring plates with a ceramic shaft that do carry off less heat is recommendable.

The temperature control unit is connected to a liquid circulator via hoses (Ø 8mm).

For the TCE/P measuring unit and the open-bath and heating circulators the necessary tubing hoses are not part of the standard accessories. They have to be ordered separately.

The cooling (liquid or gas) is controlled directly in the measuring device via the built-in solenoid valve according to the requirements. It is important that the cooling medium used is selected in the RheoWin software, as the control parameters (PID) are thus selected.

The switching condition of the valve is „open“.

Utilizing the optional electrical cone heating extends the temperature range up to 350°C.
11.5 Temperature control unit TCP/P and TCP/PE

The temperature control unit has a measuring plate ∅ 60, which is at the same time the location for other measuring plates. The measuring plate is put on the Peltier temperature control unit and fastened. The additional plates MPC are only necessary if the same cone-plate diameter is used for measuring.

Temperature control is carried out electrically via a Peltier element within a temperature range of -40° to 180°C.

The Peltier process

The temperature control system is based on a component which uses the Peltier effect. This effect which is the reverse of the thermoelectric effect (e.g. used by thermocouples), was discovered in 1834 by the French physicist Jean Peltier.

Peltier elements consist of two semiconductor bridges of differing doping (p- and n-type). Stimulated by a (regulated direct-)current flow, the electrons transport heat from one connection point to the next.

The heat flow direction is dependent on the current flow direction. Peltier temperature control systems can thus be used for both heating and cooling depending on the current flow direction.

The heating or cooling capacity i.e. the transported heat quantity is proportional to the current strength depending on the semiconductor material used and the number of Peltier elements electrically connected in series within the Peltier module.
Peltier modules transport heat from one side of the module to the other and thus can be understood as the thermoelectric system of a solid state heat pump. Heat itself is scarcely absorbed during this process. The heat side is in any case exposed to the dissipated energy in addition to the transported Peltier heat which has the result of causing the heating and cooling measuring curves not to be identical. The maximum heating rate is therefore higher than the maximum cooling rate.

Operation

In the temperature control unit a cooling coil (with hose connections for liquid cooling) is built in to cool the Peltier element.

⚠ The connector nozzles of the heat exchanger may not be closed during operation. A high overpressure may exist during the heating up.

The temperature control plate is set in a plastic part (TEKAPEEK).

⚠ Recommended cooling liquids are water or mixtures of water / alcohol as well as water / glycol.

⚠ The maximum for the temperature of the cooling liquid is 100° C.

Cooling and Heating

Since the Peltier temperature control unit is cooled by circulating water the temperatures as well as the heating and cooling rates (times to reach those temperatures) depend on the temperature and of the flow through rate of the coolant.

By variation of the flow-through temperature and the flow-through volume optimum conditions can be reached for every working range desired.

In general, the following applies:

• During heating the temperature control unit will reach a max. temperature difference of abt. 100°C between temperature control plate and the temperature of the coolant under optimum conditions.

• During cooling the temperature control unit will reach a max. temperature difference of abt. 20–40°C between temperature control plate and the temperature of the coolant under optimum conditions.
In general, the following applies for the heating:

- Increasing the temperature of the coolant will result in higher final temperatures and higher heating rates (the final temperature will be reached faster).

- Decreasing the flow through volume will result in higher final temperatures and higher heating rates.

Example:

With a preset temperature of 20°C the Thermo Fisher Scientific Haake circulator DC50-K20 will reach max. heating rates up to 1 K/s and a final temperature of about 100°C after about 10 minutes.
Temperature Control Units

Cooling

In general, the following applies for the cooling:

- Decreasing the temperature of the coolant will result in lower final temperatures and higher cooling rates (the final temperature will be reached faster).
- Increasing the flow through volume will result in lower final temperatures and higher cooling rates.

Example:

With a preset temperature of 20°C at the Thermo Fisher Scientific Haake circulator DC50-K20, the Peltier system will reach max. cooling rates up to 1 K/s and a final temperature of 0°C. Starting at +20°C the final temperature of 0°C will be reached after about 6 minutes.

- For a given ambient or room temperature there is a lowest temperature which can be reached. This is usually about 0°C.
- Lower temperature values can be realized if the loss of cooling capacity is reduced by insulation.
Explanation for the cooling

The cooling rate is limited especially for a value when cooling below the ambient temperature. Therefore, the settings of the software have to be adapted in order to reach the temperature desired:

1. For the measuring definition of temperature ramps downwards the "rising" will be tested – for cooling negatively. That means that it has to be calculated according to the set values for start and end temperature as well as the duration using a formula to find out whether the cooling rate can be achieved. If it is not possible an error message shows the possible cooling rate.

2. At the beginning of a segment cooling down to the set starting temperature can be necessary. This cooling-down time will be calculated. In case the time being higher that 10 s the band width will be set from 0.0 to 0.1 to reach the desired start temperature. In this case a message window appears as always whenever the band width for the start temperature is unequal 0.0. The system waits until the band width of 0.1 has been reached.

   **Attention:** An abortion using the F7 key would also abort the cooling process. Then the segment would be measured with the temperature reached until then.

3. For temperature segments the waiting time set by the user might be too short to hold the possible cooling rate. In case the time being more than 10 s too short it will be set to the required value.

The sensor system and the temperature control unit require cooling that is dependent on the load and the temperatures during the measurement.
Temperature Control Units

For the cooling of the temperature control unit hoses (with \( \mathcal{O} 8\text{mm} \)) can be connected to a liquid circulator.

\textbf{!} While fastening the hose connections at the connecting nozzles(14) of the temperature control unit::
- ensure the correct flow direction (IN/OUT)
- the connecting nozzles must be held secured using a wrench.

maximum conduction pressure 0.5bar (water circulation).

For the TCP/P measuring unit and the open-bath and heating circulators the required tubing hoses are not part of the standard accessories. They have to be ordered separately.
11.6 Temperature stabilisation unit TCE/P with cone heater TC1

The temperature stabilisation unit has a holder for the measuring plate. The measuring plate is placed and secured onto the electrically heated temperature stabilisation unit. The wedge and measuring plates should have the same diameter, for example like the taper C60/1 with the measuring plate attachment MPC60 and the plate PP35 with the measuring plate attachment MPC35. Otherwise unavoidable measuring errors arise!

11.7 Cone heater TC1

The high temperature system TC1 was developed for the measuring units with a TCE/P temperature stabilisation unit for rheological measurements at temperatures of > 0°C to 350°C with and without external cooling. Inert gas should be used for cooling.

A PID controller is used to control the temperature, with the upper and lower heating elements being regulated separately and independently of each other. Each of the two systems has individual control parameters and its own control sensor. This enables the lower part to also be used separately for temperature control in order to improve the handling (albeit at the expense of the temperature stability) and so that the behaviour of the flowing sample material can be observed better. When the measuring element body is fitted, only tapers and plates with ceramic shafts can be used.

We generally recommend in the case of measurements over +60°C that these special measuring geometries be used in order to minimise unwanted heat dissipation via the shaft.

11.7.1 Correct application of the ceramic rotors

We recommend the use of the tools supplied at the same time in order to ensure that the ceramic rotors are properly screwed in. Insert the Allen key supplied into the ceramic shaft opening above the cone heating and fasten the rotor. Tighten the union nut by hand.

For applications at elevated temperatures above 250°C it is a must to switch the fan for the air bearing cooling on stage 2 (on the rear) and use ceramic shafts only. Furthermore use the cone heater TC1 as thermal shield to prevent the heating up of the air bearing housing!
11.7.2 Operation
The temperature stabilisation system TC1 is operated exclusively via the application software of the HAAKE rheometer being used.

⚠️ As long as the system is hot, do not touch either the upper chamber or another hot part without wearing suitable protective gloves.

Parking position top or
Measuring position bottom

From the parking position to the measuring position:
Swivel both halves outwards as far as possible and then lower them down. Fold together the TC1 and lower it down onto the measuring plate.

From the measuring position into the parking position:
Lift the TC1 approx. 2 cm in one movement without letting go TC1, swivel it out as far as possible, lift it up as far as it will go and fold together until both halves lie on the engaging pins.

The measuring unit and the temperature stabilisation unit require cooling, depending on the utilisation level and the temperatures during the measurement.

⚠️ When attaching the hose connections to the connection glands (14) of the temperature stabilisation unit:
- pay attention to the flow direction (IN/OUT)
- use an open-ended spanner to hold the connection glands in position.

The TC1 can be cooled by compressed air or inert gas.
11.7.3 Compressed air distributor for TC1

The design of the compressed air distributor depends on the availability of a compressed air supply inside the building. If such a building connection is not available and if a HAAKE compressor is used instead, no adapter is required.

Using a compressed air supply inside the building

Using a compressor for the compressed air supply

In both cases, the valves are actuated via the software.
11.8 Temperature control unit SHRP

Rheometer like HAAKE RheoStress with parallel plate sensor systems are suitable for the rheological testing of viscous and elastic behavior of bitumen and asphalt blends which are used as surfacing at road building. The rheological tests are usually used for more or less solid bitumen samples in the temperature range from about 5°C to 85°C. The samples are most of the time tested in the dynamic mode which subjects disk-like specimens placed into the gap between parallel plates – alternatively a gap between an upper cone and a lower plate is possible, but rarely used for bitumen – to a sinusoidal stress. The resulting response of the sample – a sinusoidal deformation – is measured in the form of the complex modulus G* related to the resistance of the mass against a sinusoidal deformation and the phase shift angle \( \delta \) which appears between the applied stress and the resulting strain. Making use of the angle \( \delta \) the complex modulus G* can be broken up into the components G' – the storage modulus defining the elastic component – and G'' – the loss modulus defining the viscous component in the rheological behavior of a sample subjected to such a dynamic test. The phase angle \( \delta \) defines the ratio of the two moduli.

From the dynamic measurements with special sensor system for SHRP tests which are described in detail below tests of the viscosity of bitumen melts at temperatures of 120°C to 180°C have to be distinguished. For these measurements sensor systems with a measuring gap between coaxial cylinders for the HAAKE rheometers named above are used. At these melt tests the shear stress in proportion to the viscosity of the sample is measured at given shear rate.

Bitumen and asphalt compounds are very sensitive to temperature variations in their rheological behavior, i.e. in their viscoelastic response to applied loads and stresses. When subjecting them in a DSR-rheometer to dynamic or to creep and recovery tests this testing should be carried out in a wide temperature range that relates to summer/winter road pavement conditions. According to the American SHRP specifications measurements at temperatures of 0°C to 85°C are desirable.

At low temperatures the materials are tested for the likelihood of cracks as the result of a short and hard deformation of the more or less hard and brittle material. Under these conditions the road material may just split/crack unless it is sufficiently elastic to absorb temporarily sudden loads. At low temperatures the bitumen may also creep – flow very slowly – even as the result of much lower but longer lasting stresses such as caused by the pressure of car tires when the automobiles have to stop e.g. in front of red traffic lights. It is important to test such samples also at temperatures up
Temperature Control Units

to 85°C as they can occur on the surface of the road pavement in summer. In such cases the tires of trucks often leave lasting deformations.

Under the "Strategic Highway Research Program" in the USA parallel-plate sensor systems of commercial, internationally available DSR-rheometers were surveyed for their suitability for the testing of the rheological behavior of bitumen in the given temperature range. It was found that most sensor systems for these rheometers with electrically heated upper and lower plates provided a temperature control accuracy of considerably more than \( \pm 0.1 \) °C, while for these tests an accuracy better than \( \pm 0.1 \) °C was considered essential. This caused Thermo Fisher Scientific to develop a special thermal liquid heated sensor system "SHRP" with parallel plate measuring geometry for the HAAKE rheometers of series RV and RS. This sensor system meets the requirements set in the "Standard Method for the Determination of Rheological Properties of Asphalt using a Dynamic Shear Rheometer (DSR) (AASHTO Designation: TP5)".

The SHRP sensor system consists of an interchangeable upper and a fixed lower measuring plate. A cup-shaped vessel that encloses the two plates is part of the housing that bears the lower plate. During the rheological bitumen measurement the thermal liquid - normally just water - flows permanently through this cup vessel. By that the two measuring plates and the sample enclosed between the plates can be heated constantly on each set temperature within the temperature range with an accuracy better than \( \pm 0.1 \) °C. For this an external bath and circulator equipped with a built-in cooling unit and a highly accurate electronic temperature control accuracy of better than \( \pm 0.05 \) °C is required. This circulator is connected to the sensor system and pumps the temperature controlled liquid in the cup vessel. During the measurement the liquid level in the cup vessel ascends over the upper measuring plate up to the upper circular ring of bore holes in the cup vessel. Through these bore holes the bath liquid is led to an overflow. Through the overflow the bath liquid is led back again to the bath and circulator via the second connecting hose. This highly precise thermal liquid temperature control by means of circulated water is acceptable for sample materials such as bitumen and their compounds which are not affected or dissolved/leached by water during the duration of such a test.
Temperature Control Units

Installation

The temperature control unit is connected to the bath and circulator placed at disposal (not shown in the picture). The circulator should be equipped with a pressure and suction pump. Connection OUT/IN 14

- While fastening the hose connections at the connecting nozzles (14) of the temperature control unit:
  - ensure the correct flow direction (IN/OUT)
  - the connecting nozzles must be held secured using a wrench.

For the cooling of the temperature control unit hoses (with Ø 8mm) can be connected to a liquid circulator.

maximum conduction pressure 0.5bar (water circulation).

For the SHRP sensor system and the bath and circulator the required hoses are no standard accessories. They must be ordered separately.

The ball valve (accessories) is placed at the outlet port of the bath and circulator. The valve setting is done by means of a screwdriver to regulate the rate of flow of the bath liquid so that the liquid level in cup vessel 6 can ascend to the upper circular ring but not above. When connecting the circulator first time to the SHRP unit the ball valve must be in the "closed position" to prevent a sudden overflow in cup vessel 6. The ball valve should be gradually opened to adjust the proper flow rate. In this phase of the installation valve 8 is maintained in the open-valve position. For placing new sample disks into the gap between the parallel plates and for the removal of these samples at the end of a test, the liquid level in the cup vessel 6 can be lowered by closing the valve 8: the liquid in 6 is sucked back to the circulator via hose 11 and cup vessel 6 is emptied. The inflow and flowing off of the bath liquid is only controlled by valve 8.

Liquids that flow over the cup vessel during the measurement are collected in the underside of the housing and are led back to the bath and circulator via overflow 16 (for hose Ø 8mm).
Temperature Control Units

- In case of extreme load (high torque, high operating temperature of about 200–350°C) cooling air for the motor is needed.

Devices with air bearing:

- For measurements at temperatures of 200–350°C cooling for the measuring head is needed. For this the compressed air connection 9 on the underside of the temperature control unit is used.

Description of HAAKE SHRP sensor system - Fig. 1:

3 lower measuring plate with a diameter of 8 mm (optional) or 25 mm
4 inlet tubing for the bath liquid
5 overflow tubing allowing the return of the bath liquid back to the bath and circulator
6 cup vessel with circular ring of overflow holes through which the level of the bath liquid in the vessel is controlled
The temperature of the liquid surrounding the parallel plates and equally the sample being tested is measured by means of a temperature sensor placed into the lower measuring plate from underneath – not shown in Fig. 1 –. The measured temperature is displayed on the computer screen during the measurement and has an accuracy of $\pm 0.1^\circ C$. According to this actual temperature value of the sensor system the set value must be corrected at the bath and circulator until the actual value of the temperature sensor is conform to the required measuring temperature.

The accuracy of the rheological test data depends heavily on the temperature accuracy of the thermal liquid provided by the bath and circulator. In order to maintain a preset temperature level in the tested bitumen specimen of $\pm 0.1^\circ C$ as required by the SHRP standard, the bath and circulator must guarantee a temperature tolerance of better than or equal to $\pm 0.05^\circ C$. The actual temperature of the thermal liquid surrounding the parallel plates and thus the specimen should be counter checked by means of a calibrated external thermometer graded with a $\pm 0.05^\circ C$ scaling.

Bitumen being characterized by its low thermal conductivity normally requires some 5 min. to reach any test temperature. Operators may check the actual time requirement for reaching a temperature equilibrium by running dynamic tests in the "time mode", i.e. check how long it takes after having raised the liquid level above the parallel plates to reach a time-constant value of i.e. G*.

The specimens placed into the gap between the parallel plates must be preshaped in a separate work step into suitable disks of the right diameter and height prior to their installation in the gap:

a) diameter of 25 mm and 1 mm thick test disks for tests at higher test temperatures and for the measuring plate with a diameter of 25 mm

b) diameter of 8 mm and 2 mm thick disks for tests at lower test temperatures – 5°C – used in combination with the 8 mm plate.

The tests can be run at different constant test temperatures.

a.) with programmed variable shear stresses in "Controlled Stress (CS)" mode of the rheometer or

b.) alternatively with programmed variable frequency in "Controlled Strain (CR)" mode of the rheometer.

If tests are to be run according to the SHRP standard the required standards have to be kept. Please see the added copy of these standards.
Tests at constant shear stress or frequency as function of programmed variable measuring temperatures are also usual: see example in Fig. 2.

The upper measuring plates for the SHRP sensor system has shafts with a ceramic segment to minimize heat losses up or downwards. Attention: these ceramic shafts can break! These special measuring plates with ceramic shaft segments are longer than the standard measuring plates of the HAAKE rheometers. This overlength necessitates the use of an elongation (standard accessories) of the micrometer shaft - at least while using former rheometer models. For this the end piece of the shaft is screwed off, the elongation piece is screwed in and after that the end piece is put on again.

The SHRP sensor system must be adjusted to a gap width of h=0 before starting a test series. This should be done at measuring temperature which means it should be done while the the bath liquid already floats the two measuring plates adjusted to set temperature.
Temperature Control Units

The cup vessel 6 can be moved up and down by turning it at the brim. By that it is moved in a thread opposite to the housing. The bottom of cup vessel 6 that is cut out in a circular shape slides close to the outer rim of the lower measuring plate when the cup vessel is moved. In the upper position the hole in the bottom of the cup vessel makes up a good centering for the disk-like bitumen sample. So the sample can be positioned precisely on the lower measuring plate. Before starting the actual test, the cup vessel must be moved down until its bottom is clearly under the surface of the lower measuring plate and the sample disk cannot be touched by the bottom of the cup vessel. After ending the test or at the end of a working day cup vessel 6 can be removed by screwing it off to be cleaned inside and outside from dirt particles that can possibly be floated from the circulator to the sensor system.

For the SHRP sensor system and the bath and circulator the required hoses are no standard accessories. They must be ordered separately.
Temperature Control Units

measuring plate
12. Sensor Systems

Make sure that the unit has been switched off before you connect or disconnect the cables. This is to avoid electrostatic charging resulting in a defect of the electronic circuit boards.

When unscrewing the rotor from the measuring shaft it should be ensured that the rotor is removed from the cone with small rotational motions.

Not use and store the plate and cone measuring geometry with ceramic shaft in steel execution in the proximity of a magnetic field, since these can be magnetized. The results of measurement are incorrect in this case.

The measurement sensors are the core of a Rheometer and determine the quality of the measuring results.

The appropriate literature mentions a variety of sensor systems which can be classified as follows:

a. Cylinder Sensor Systems
   - Immersion Disc ISO 2555
   - Immersion Cylinder ISO 2555
   - Coaxial Cylinders according to DIN 53018
   - Coaxial Cylinders according to DIN 54453
   - Coaxial Cylinders according to DIN 53019/ISO 3219

b. Cone-Plate / Plate-Plate Sensor Systems
   - Cone-Plate with various opening angles and radii
   - Plate-Plate with various radii and gap widths

Out of these numerous possibilities, Thermo Fisher Scientific supplies the following systems:

- Cylinder systems according to ISO 2555 (optional)
- Cylinder systems according to DIN 53019/ISO 3219
- Cylinder systems according to DIN 54453
- Cylinder systems according to DIN 53018
- Cone-Plate combinations
- Plate-Plate combinations
- Vane (star-shaped) rotors for special measurements
- Optically transparent sensors (cylinder, cone-plate and plate-plate)

These sensors cover the majority of desired applications whereby special sensor systems are developed and made available in close cooperation with customers requiring such special sensor systems.
Calculation Factors

In the case of a rotational rheometer the viscosity of a liquid is calculated in accordance with the Newtonian conditional equation for viscosity:

\[
\eta = \frac{\tau}{\dot{\gamma}}
\]

at defined ambient conditions regarding measuring time, temperature and pressure.

In rheometers, operating in accordance with the CR-principle a speed (angular velocity) is preset which in the sensor system filled with a sample causes a shear rate. The torque required for achieving and maintaining the desired shear rate is the viscosity-proportional parameter.

**CS-rheometers** are designed to operate according to the reversed principle. Here a torque (shear stress) is preset and the resulting movement (deformation) i.e. the resulting angular velocity (shear rate) is measured. The measurement with rotational rheometers can be summed up to the predefinition of a force and from the measurement of the resulting movement a suitable geometry can be derived. This will also define the conditional equations:

The shear stress \( \tau \) is proportional to the torque 'Md' and to a characteristic geometry factor, which at Thermo Fisher Scientific is identified as 'A' (shear stress factor).

\[
\tau = Md \cdot A
\]

A high torque means also a high shear stress. Large values of 'A' stand for small sensors.

The shear rate \( \dot{\gamma} \) is proportional to the rotational movement (angular velocity) and proportional to the geometry factor 'M':

\[
\dot{\gamma} = \Omega \cdot M
\]

A high angular velocity \( \Omega \) means also a high shear stress \( \dot{\gamma} \). High 'M' values stand for very small gaps.

The angular velocity \( \Omega \) results from the following equation where the rotor speed is \( n \) in [1/min] and \( \Omega \) is measured in units of [1/s].

\[
\Omega = 2 \cdot \pi \cdot \frac{n}{60}
\]
Sensor Systems

Measuring Ranges

The different specifications of the models HAAKE RotoVisco 1 and HAAKE RheoStress 1 effect the measuring ranges.

For the values of measuring ranges please see chapter “Technical Specifications”.

The measuring range can be illustrated in a diagram where \( \tau = f (\dot{\gamma}) \) and \( \eta = f (\dot{\gamma}) \).

\( \tau \) - Range

The shear stress measuring range results from the measurement geometry and the presetting range of the torque Md. Now it is quite simple to estimate the smallest and largest shear stress value for a sensor system by using the following calculations:

\[
\begin{align*}
\tau_{\text{min}} &= M_d(\text{min}) \cdot A \\
\tau_{\text{max}} &= M_d(\text{max}) \cdot A
\end{align*}
\]

The limit values of the diagrams differ according to the model specific torque values from the above table.

\( \dot{\gamma} \) - Range

Similar to the shear stress range there is also a meaningful measuring range for the shear rate \( \dot{\gamma} \). The following correlations can be derived:

\[
\begin{align*}
\dot{\gamma}_{\text{min}} &= \Omega(\text{min}) \cdot M \\
\dot{\gamma}_{\text{max}} &= \Omega(\text{max}) \cdot M
\end{align*}
\]

The limit values of the diagrams differ according to the model specific torque values from the above table.
**Sensor Systems**

\( \eta - \text{Range} \)

The viscosity measuring range is derived from the \( \tau \) - and \( \dot{\gamma} \)-range in accordance with the Newtonian conditional equation.

\[
\eta = \frac{\tau}{\dot{\gamma}}
\]

The four fundamental values in the diagram can be calculated as follows:

- Smallest viscosity at max. shear rate
  \[ \eta_{\text{min}} = \frac{\tau_{\text{min}}}{\gamma_{\text{max}}} \]

- Largest viscosity at min. shear rate
  \[ \eta_{\text{max}} = \frac{\tau_{\text{max}}}{\gamma_{\text{min}}} \]

With these four fundamentals, the viscosity range is defined. It is easily comprehensible that the measurement fault in the extreme ranges is very large. It gets smaller as the torque increases and the angular velocity decreases.
12.1 Cylinder Sensor Systems

From the theoretical possibilities of a measurement geometry for cylinder sensor systems Thermo Fisher Scientific selected the following concepts:

12.2 Cylinder Sensor Systems Z-DIN

Application

These sensor systems were introduced for polymer dispersions. Meanwhile they became a standard in Europe as they...

- render comparable measurement results with different rheometers too;
- are easy to clean;
- are quite suitable for temperature programs.

Sensor Systems Z DIN

The sensor system Z DIN comprises one rotor and one beaker each in accordance with the standard DIN 53019/ISO 3219. They are characterized by their rotor diameter.

<table>
<thead>
<tr>
<th>Rotor Diameter</th>
<th>Code Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z34 DIN</td>
<td>222-1499</td>
</tr>
<tr>
<td>Z20 DIN</td>
<td>222-1458</td>
</tr>
<tr>
<td>Z10 DIN</td>
<td>222-0621</td>
</tr>
</tbody>
</table>

Sealing set for Z43DIN Order no. 222-1290
Sealing set for Z20DIN Order no. 222-1291
Sealing set for Z10DIN Order no. 222-1292
**Sensor Systems**

**Geometry:**

Sensor systems according to the standards mentioned have the following peculiarity in that all measurements are relative to the radius of the rotor. In DIN 53019 the following values are defined which are confined and partly extended in ISO 3219.

\[
\begin{align*}
\frac{R_a}{R_i} &= 1.0847 \\
\frac{R_s}{R_i} &= 0.3 \\
\frac{L}{R_i} &= 3 \\
\frac{L'}{R_i} &= 1 \\
\alpha &= 120^\circ \text{ (2.094 rad)}
\end{align*}
\]

The expressions have the following meaning:

- \( \delta = \frac{R_a}{R_i} \) (radius ratio)
- \( L = \text{Length of Cylinder} \)
- \( R_i = \text{Radius interior cylinder (Outside } \emptyset \text{ of the rotor/2)} \)
- \( R_a = \text{Radius outside cylinder (Interior } \emptyset \text{ of the beaker/2)} \)
- \( R_s = \text{Radius of the rotor shaft} \)
- \( a = \text{Distance} \)
- \( \alpha = \text{Angle of the cone} \)
- \( L' = \text{Distance of the rotor} \)
Calculation Equations to DIN 53019/ISO 3219

Shear Stress $\tau$:
The shear stress $\tau$ is proportional to the torque 'Md' and the stress factor 'A'.

$$\tau = A \cdot Md$$

The factor 'A' can be calculated as follows:

$$A = \frac{1}{2 \cdot \pi \cdot L \cdot R_i^2 \cdot C_L} \cdot \frac{1 + \delta^2}{2\delta^2}$$

with $R_i$ = Radius of 'Rotor'
$L$ = Length of Rotor
$C_L$ = Resistance Coefficient ($C_L = 1.1$ according DIN 53019)

It has the unit of an inverse volume.

$\delta = $ Radius ratio $R_a/R_i$
$(A) = L^{-3}$

Shear Rate $\dot{\gamma}$:
The shear rate $\dot{\gamma}$ is proportionally linked to the angular velocity and thus also to the speed and shear factor $M$.

$$\dot{\gamma} = M \cdot \Omega$$

The angular velocity $\Omega$ is calculated according to $\frac{2\pi}{60} \cdot n$

The factor $M$ is calculated:

$$M = \frac{1 + \delta^2}{\delta^2 - 1} \quad \delta^2 = $ Radii Relationship $R_a/R_i$
$$\delta^2 = 1.0847$ (DIN 53019)

Deformation $\gamma$:
The deformation $\gamma$ is linearly linked to the angular deflection and the geometry of a sensor system.

$$\gamma = M \cdot \varphi \quad \text{with } \varphi = \text{Torsion angle [rad]}$$
$$\gamma \text{ is a dimensionless number}$$

Filling Volume:
The standard lists the equation for the calculation of the filling volume as follows:

$$V = 8.17 \cdot R_i^3 \text{ (cm}^3)$$
### Cylinder Sensor System according to DIN 53019/ISO 3219

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Z10DIN</th>
<th>Z20DIN</th>
<th>Z34DIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotor order No.</td>
<td>222-0621</td>
<td>222-1458</td>
<td>222-1499</td>
</tr>
<tr>
<td>Mass m (g)</td>
<td>37.4</td>
<td>62.0</td>
<td>87.3</td>
</tr>
<tr>
<td>Material: Titan DIN No.</td>
<td>3.7035</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inertia I (kg m² E-6)</td>
<td>0.4</td>
<td>1.60</td>
<td>15.39</td>
</tr>
<tr>
<td>Radius Ri (mm)</td>
<td>5.000</td>
<td>10.000</td>
<td>17.000</td>
</tr>
<tr>
<td>± delta Ri (mm)</td>
<td>0.0015</td>
<td>0.002</td>
<td>0.004</td>
</tr>
<tr>
<td>Length l (mm)</td>
<td>15</td>
<td>30</td>
<td>51</td>
</tr>
<tr>
<td>± delta l (mm)</td>
<td>0.015</td>
<td>0.03</td>
<td>0.06</td>
</tr>
<tr>
<td>Clearance to bottom (mm)</td>
<td>2.1</td>
<td>4.2</td>
<td>7.2</td>
</tr>
<tr>
<td>Cup</td>
<td>222-1497</td>
<td>222-1487</td>
<td>222-1498</td>
</tr>
<tr>
<td>Radius Ra (mm)</td>
<td>5.425</td>
<td>10.850</td>
<td>18.44</td>
</tr>
<tr>
<td>± delta Ra (mm)</td>
<td>0.002</td>
<td>0.00295</td>
<td>0.004</td>
</tr>
<tr>
<td>Material: Steel DIN No.</td>
<td>1.4305</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gasket (200 °C) Order No.</td>
<td>222-1292</td>
<td>222-1291</td>
<td>222-1290</td>
</tr>
<tr>
<td>Ratio of Radii Ra/Ri</td>
<td>1.0847</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gap (mm)</td>
<td>0.425</td>
<td>0.85</td>
<td>1.44</td>
</tr>
<tr>
<td>Sample volume (cm³)</td>
<td>1.0</td>
<td>8.2</td>
<td>40.1</td>
</tr>
<tr>
<td>perm.temperature max. (°C)</td>
<td>200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calculation factors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A (Pa/Nm)</td>
<td>356800</td>
<td>44600</td>
<td>9080</td>
</tr>
<tr>
<td>± delta A (%)</td>
<td>0.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M (s⁻¹/rad s⁻¹)</td>
<td>12.29</td>
<td></td>
<td></td>
</tr>
<tr>
<td>± delta M (%)</td>
<td>0.8</td>
<td>0.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>
HAAKE Rheometer  Measuring Range of Sensor

Shear rate (1/s) vs. Shear stress (Pa) and Viscosity (mPas) for different Sensor types:
- RS1-Z10DIN
- RS1-Z20DIN
- RS1-Z40DIN

The charts illustrate the measuring range of Sensor Systems provided by HAAKE Rheometer.
12.3 Cylinder Sensor System Z

Application

This sensor system is preferred for medium viscous liquids when a comparability of the measurements in accordance with DIN 53018 is requested. These sensors have an extremely small front surface influence and are therefore intended for exact measurements. Temperature programs are not recommended as the volume of the trapped air bubble will change its volume with the temperature. This also has an effect on the front surface influence.

Sensor System Z

The sensor system Z comprises a collapsible beaker Z43 and 3 rotors with different radii.

Sealing set for Z40 Order no. 222-1290
### Geometry

The geometry of this sensor system corresponds to DIN 53018.

#### Calculation Equations:

**Shear Stress** $\tau$:

The shear stress $\tau$ is proportional to the torque 'Md' and to a geometric factor i.e. stress factor 'A'.

$$\tau = A \cdot Md$$  \hspace{1cm} \text{(Stress Factor $\times$ Torque)}

The factor 'A' can be calculated as described by the following equation:

$$A = \frac{1}{2 \cdot \pi \cdot R_i^2 \cdot L}$$

\[A\] = \frac{1}{m^3}

It has the unit of an inverse volume.

**Shear Rate** $\dot{\gamma}$:

The shear rate $\dot{\gamma}$ is proportionally linked to the angular velocity or speed and the shear factor 'M'.

$$\dot{\gamma} = M \cdot \Omega$$

The angular velocity $\Omega$ is calculated according to $\frac{2\pi}{60} \cdot n$ from the speed $n$. The factor M is calculated:

$$M = \frac{2 \cdot R_a^2}{R_a^2 \cdot R_i^2}$$

**Deformation** $\gamma$:

The deformation $\gamma$ is linearly linked to the angular deflection and the geometry of a sensor system.

$$\gamma = M \cdot \varphi$$  \hspace{1cm} \text{with $\varphi$ = Torsion angle rad}

$\gamma$ is a dimensionless number
## Cylinder Sensor System Z

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Z31</th>
<th>Z38</th>
<th>Z41</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotor order No.</td>
<td>222-1461</td>
<td>222-1460</td>
<td>222-1459</td>
</tr>
<tr>
<td>Inertia I (kg m(^2))</td>
<td>11</td>
<td>21.00</td>
<td>28.0</td>
</tr>
<tr>
<td>Material: Titan DIN No.</td>
<td>3.7035</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radius R(_i) (mm)</td>
<td>15.720</td>
<td>19.010</td>
<td>20.710</td>
</tr>
<tr>
<td>± delta R(_i) (mm)</td>
<td>0.0020</td>
<td>0.004</td>
<td>0.004</td>
</tr>
<tr>
<td>Length l (mm)</td>
<td>55</td>
<td></td>
<td></td>
</tr>
<tr>
<td>± delta l (mm)</td>
<td>0.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clearance to bottom (mm)</td>
<td>8.1</td>
<td>8.1</td>
<td>3</td>
</tr>
<tr>
<td>Cup</td>
<td>222-1488</td>
<td>222-1488</td>
<td>222-1488</td>
</tr>
<tr>
<td>Radius R(_a) (mm)</td>
<td>21.700</td>
<td>21.700</td>
<td>21.700</td>
</tr>
<tr>
<td>± delta R(_a) (mm)</td>
<td>0.004</td>
<td>0.004</td>
<td>0.004</td>
</tr>
<tr>
<td>Material: Steel DIN No.</td>
<td>1.4305</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gasket (200 °C) Order No.</td>
<td>222-1290</td>
<td>222-1290</td>
<td>222-1290</td>
</tr>
<tr>
<td>Ratio of Radii R(_a)/R(_i)</td>
<td>1.3804</td>
<td>1.1415</td>
<td>1.0478</td>
</tr>
<tr>
<td>Gap (mm)</td>
<td>5.98</td>
<td>2.69</td>
<td>0.99</td>
</tr>
<tr>
<td>Sample volume (cm(^3))</td>
<td>52.0</td>
<td>33.0</td>
<td>14.0</td>
</tr>
<tr>
<td>perm.temperature max. (°C)</td>
<td>200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calculation factors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A (Pa/Nm)</td>
<td>11710</td>
<td>8010</td>
<td>6750</td>
</tr>
<tr>
<td>± delta A (%)</td>
<td></td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>M (s(^{-1})/rad s(^{-1}))</td>
<td>4.21</td>
<td>8.60</td>
<td>22.40</td>
</tr>
<tr>
<td>± delta M (%)</td>
<td></td>
<td>0.5</td>
<td></td>
</tr>
</tbody>
</table>
Sensor Systems
12.4 Double Gap Cylinder Sensor DG43 according to DIN 53544

Application

This sensor system is preferred for low viscous liquids ($<1000 \text{ mPa} \cdot \text{s}$) or for small sample volumes. The double shearing surfaces of this particular system result in a higher shear stress than what is customary for comparable DIN sensors. It is standardized as DIN 53544 for measurements with low viscous glues.

Sensor System DG43

The sensor system DG43 is made up of a dismountable beaker and either the bell-shaped rotor.

The temperature vessel should not be employed for temperatures above $200^\circ\text{C}$. There must be a sufficiently long heating period so that the inner part of the beaker, which is not temperature controlled, can adopt the desired temperature. Heating times of 5 to 20 minutes, depending on the viscosity and liquid, are quite common.
Geometry

The geometry of the sensor system is designed so that radii relationship of the shear surfaces is almost equal so that identical shearing conditions in both gaps can be expected.

\[ \frac{R_2}{R_1} = \frac{R_4}{R_3} \]

- \( R_1 = \) Radius Beaker (Inside)
- \( R_4 = \) Radius Beaker (Outside)
- \( R_3 = \) Radius Rotor (Outside)
- \( R_2 = \) Radius Rotor (Inside)
- \( L = \) Length of Shear Surface
- \( a = \) Distance

Calculation Equations:

Shear Stress \( \tau \):

The shear stress \( \tau \) is proportional to the torque 'Md' and to a stress factor i.e. stress factor 'A'.

\[ \tau = A \cdot Md \]

The factor 'A' can be calculated as described by the following equation:

\[ A = \frac{1}{2 \cdot \pi \cdot L \cdot (R_2^2 + R_3^2)} \quad [A] = \frac{1}{m^3} \]

Shear Rate \( \gamma \):

The shear rate \( \gamma \) is proportionally linked to the angular velocity and thus speed and the shear factor 'M'.

\[ \dot{\gamma} = M \cdot \Omega \]

The angular velocity \( \Omega \) is calculated according to \( \frac{2\pi}{60} \cdot n \) from the speed \( n \). The factor \( M \) is calculated as follows:

\[ M = \frac{2 \cdot R_2^2}{Ra \cdot R_i^2} \quad Ra = R_4, R_2 \quad Ri = R_3, R_1 \]

Deformation \( \gamma \):

The deformation \( \gamma \) is linearly linked to the angular deflection and the geometry of a sensor system.

\[ \gamma = M \cdot \varphi \quad \text{with } \varphi = \text{Torsion angle rad} \]

\( \gamma \) is a dimensionless number
### Double Gap Cylinder Sensor System DG43 according to DIN 53544

<table>
<thead>
<tr>
<th>Sensor</th>
<th>DG43</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotor order No.</td>
<td>222-1559</td>
</tr>
<tr>
<td>Radius R₁ (mm)</td>
<td>17.75</td>
</tr>
<tr>
<td>± delta R₁ (mm)</td>
<td>0.004</td>
</tr>
<tr>
<td>Radius R₂ (mm)</td>
<td>18.35</td>
</tr>
<tr>
<td>± delta R₂ (mm)</td>
<td>0.004</td>
</tr>
<tr>
<td>Radius R₃ (mm)</td>
<td>20.99</td>
</tr>
<tr>
<td>± delta R₃ (mm)</td>
<td>0.004</td>
</tr>
<tr>
<td>Length l (mm)</td>
<td>55</td>
</tr>
<tr>
<td>± delta l (mm)</td>
<td>0.06</td>
</tr>
<tr>
<td>Clearance to bottom (mm)</td>
<td>5.1</td>
</tr>
<tr>
<td>Inertia I (kg m²)</td>
<td>35.1</td>
</tr>
<tr>
<td>Mass m (g)</td>
<td>117.0</td>
</tr>
<tr>
<td>Cup</td>
<td>222-1489</td>
</tr>
<tr>
<td>Radius Ra (mm)</td>
<td>21.7</td>
</tr>
<tr>
<td>± delta Ra (mm)</td>
<td>0.004</td>
</tr>
<tr>
<td>Material: Steel DIN No.</td>
<td>1.4305</td>
</tr>
<tr>
<td>Gasket (200 °C) Order No.</td>
<td>222-1293</td>
</tr>
<tr>
<td>Ratio of Radii Ra/R₁</td>
<td>1.0338</td>
</tr>
<tr>
<td>Gap R₄-R₃ (mm)</td>
<td>0.71</td>
</tr>
<tr>
<td>Gap R₂-R₁ (mm)</td>
<td>0.6</td>
</tr>
<tr>
<td>Sample volume (cm³)</td>
<td>11.5</td>
</tr>
<tr>
<td>perm.temperature max. (°C)</td>
<td>200</td>
</tr>
</tbody>
</table>

**Calculation factors**

| A (Pa/Nm) | 3701 |
| ± delta A (%) | 0.1 |
| M (s⁻¹/rad s⁻¹) | 31.08 |
| ± delta M (%) | 6 |
12.5 Solvent trap for Z10, Z20, Z31, Z34, Z38, Z41 und DG43 (222-1509)
12.6 Solvent trap for Z43
(222-1593)
12.7 Cone-Plate and Plate-Plate Sensor Systems

Application

This sensor system is predominantly used for measurements with highly viscous liquids and for difficult to clean samples with due to need for only a small sample volume. Their application is limited when the sample contains coarse particles and fiber strings.

Cone-Plate sensors call for a higher precision, both in manufacturing and in handling in order to achieve true measurement results. The sensor systems differ only in the cone/plate radius and in the cone angle.

12.8 Cone-Plate Sensor Systems

The cone radius and the cone angle are the typical characteristics of the cone-plate sensor system.
All sensor cones are individually calibrated by Thermo Fisher Scientific and the results entered in an accompanying certificate as shown in the example below.

**Calculation Equations - Cone/Plate**

### Shear Stress \( \tau \)

The shear stress \( \tau \) is proportional to the torque 'Md' and to the stress factor 'A'.

\[
\tau = A \cdot Md
\]

The factor 'A' is calculated as described in the following equation:

\[
A = \frac{3}{2 \cdot \pi \cdot R_K^3}
\]

with \( R_K = \) Cone Radius

\[ [A] = \frac{1}{m^3} \]

It has the unit of an inverse volume.

### Shear Rate \( \dot{\gamma} \)

The shear rate \( \dot{\gamma} \) is proportionally linked to the angular velocity and thus speed and the shear factor 'M'.

\[
\dot{\gamma} = M \cdot \Omega
\]
The angular velocity $\Omega$ is calculated according to $\frac{2\pi}{60} \cdot n$ from the speed $n$.

The factor 'M' is calculated as follows:

$$M = \frac{1}{\alpha} \quad \text{with} \quad \alpha = \text{Cone Angle}$$

The following conversion equation should be applied:

1 rad = 57.296 deg. or 1 deg. = 0.0174 rad

**Deformation $\gamma$**

The deformation $\gamma$ is linearly linked to the angular deflection and the shear factor $M$.

$$\gamma = M \cdot \varphi \quad \text{with} \quad \varphi = \text{Torsion Angle rad}$$

$\gamma$ is a dimensionless number

It is very important to use the exact cone angle for accurate measurements. Therefore all Thermo Fisher Scientific cones are supplied with a certificate listing the respective individual calculation factors.

**Cone/plate measuring errors**

Significant measuring errors can result when using cone/plate sensor systems if ...

- the correct gap between the cone and plate is not observed,
- filling is not carried out correctly.

Both errors can be estimated quantitatively:
1. Cone/plate gap error

The measuring cones are equipped with a truncated tip which corresponds to a fictive gap. If this gap is not observed measuring errors will occur, since the assumptions made when determining the calculation factors no longer hold true.

If the "ideal" gap distance "a" is increased, the viscosity calculation deviates as detailed below:

\[
\text{Measuring uncertainty} = x \cdot (\alpha \cdot 0.0174) / R / 1000
\]

\( \alpha = \) cone angle  
\( R = \) cone radius in (mm)

2. Cone/plate reduced effective radius error

If a cone/plate sensor system is insufficiently filled or the gap empties itself during a measurement, significant measurement errors can result. This condition of insufficient filling can be referred to as a reduced effective radius error and is characterized by a reduction in the effective radius.

The measurement error can be estimated using the following equation:

\[
\text{viscosity measuring error} = 1 - \frac{R^3}{(R - \Delta R)^3}
\]

\( R = \) plate radius  
\( R_{\text{eff}} = \) effective radius  
\( \Delta R = \) reduced effective radius
## Cone-Plate Sensor System with 0.5° Angle

<table>
<thead>
<tr>
<th>Sensor</th>
<th>C20/0.5</th>
<th>C35/0.5</th>
<th>C60/0.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Temp. Cone Order No.</td>
<td>222-1259</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inertia I (kg m²) E-6</td>
<td>0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass m (g)</td>
<td>24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material: Steel DIN No.</td>
<td>1.4112</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cone Order No.</td>
<td>-</td>
<td>222-1267</td>
<td>222-1272</td>
</tr>
<tr>
<td>Inertia I (kg m²) E-6</td>
<td>-</td>
<td>1.5</td>
<td>15</td>
</tr>
<tr>
<td>Material: Titan DIN No.</td>
<td>3.7035</td>
<td>3.7035</td>
<td></td>
</tr>
<tr>
<td>Radius R₁ (mm) *</td>
<td>10.0</td>
<td>17.5</td>
<td>30.0</td>
</tr>
<tr>
<td>± delta R₁ (mm)</td>
<td>0.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cone angle (°) *</td>
<td>0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance a (mm)</td>
<td>0.026</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measuring plate location</td>
<td>222-1503</td>
<td>222-1504</td>
<td>222-1505</td>
</tr>
<tr>
<td>Radius Rₐ (mm)</td>
<td>10.5</td>
<td>18.0</td>
<td>30.5</td>
</tr>
<tr>
<td>± delta Rₐ (mm)</td>
<td>0.025</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sample volume (cm³)</td>
<td>0.02</td>
<td>0.1</td>
<td>0.5</td>
</tr>
<tr>
<td>perm.Temperature max. (°C)</td>
<td></td>
<td></td>
<td>350</td>
</tr>
<tr>
<td>Calculation factors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A (Pa/Nm) *</td>
<td>477500</td>
<td>89090</td>
<td>17680</td>
</tr>
<tr>
<td>± delta A (%)</td>
<td>0.6</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>M (s⁻¹/rad s⁻¹) *</td>
<td>114.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>± delta M (%)</td>
<td>3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* The exact values are specified on the individual certificate.
Sensor Systems
Sensor Systems

HAAKE Rheometer Measuring Range of Sensor

RV1-C20/0,5
RV1-C35/0,5
RV1-C60/0,5
## Cone-Plate Sensor System with 1° Angle

<table>
<thead>
<tr>
<th>Sensor</th>
<th>C20/1</th>
<th>C35/1</th>
<th>C60/1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cone Order No.</td>
<td>222-0589</td>
<td>222-1268</td>
<td>222-1273</td>
</tr>
<tr>
<td>Inertia I (kg m²) E-6</td>
<td>0.3</td>
<td>1.8</td>
<td>17</td>
</tr>
<tr>
<td>Material: Titan DIN No.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radius Rᵢ (mm) *</td>
<td>10.0</td>
<td>17.5</td>
<td>30.0</td>
</tr>
<tr>
<td>± delta Rᵢ (mm)</td>
<td></td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Cone angle (Deg) *</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Distance a (mm)</td>
<td></td>
<td></td>
<td>0.052</td>
</tr>
<tr>
<td>Measuring plate steel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measuring plate location</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radius Rₐ (mm)</td>
<td>10.5</td>
<td>18.0</td>
<td>30.5</td>
</tr>
<tr>
<td>± delta Rₐ (mm)</td>
<td></td>
<td>0.025</td>
<td></td>
</tr>
<tr>
<td>Sample volume (cm³)</td>
<td>0.02</td>
<td>0.20</td>
<td>1.00</td>
</tr>
<tr>
<td>perm.temperature max. (°C)</td>
<td></td>
<td></td>
<td>350</td>
</tr>
<tr>
<td>Calculation factors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A (Pa/Nm) *</td>
<td>477500</td>
<td>89090</td>
<td>17680</td>
</tr>
<tr>
<td>± delta A (%)</td>
<td>0.9</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>M (s⁻¹/rad s⁻¹) *</td>
<td></td>
<td>57.3</td>
<td></td>
</tr>
<tr>
<td>± delta M (%)</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

* The exact values are specified on the individual certificate.
Sensor Systems

HAAKE Rheometer Measuring Range of Sensor

![Graph showing shear stress vs. shear rate for different sensors (RS1-C20/1, RS1-C35/1, RS1-C60/1).](image)
Sensor Systems
Cone-Plate Sensor System with 2° Angle

<table>
<thead>
<tr>
<th>Sensor</th>
<th>C20/2</th>
<th>C35/2</th>
<th>C60/2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cone Order No.</td>
<td>222-1254</td>
<td>222-1269</td>
<td>222-1274</td>
</tr>
<tr>
<td>Inertia I (kg m²) E-6</td>
<td>-</td>
<td>1.5</td>
<td>15</td>
</tr>
<tr>
<td>Material: Titan DIN No.</td>
<td>3.7035</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radius (Ri mm) *</td>
<td>10.0</td>
<td>17.5</td>
<td>30.0</td>
</tr>
<tr>
<td>± delta Ri (mm)</td>
<td>0.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cone angle (Deg) *</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance a (mm)</td>
<td>0.104</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measuring plate steel</td>
<td>Standard ø 60 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measuring plate location</td>
<td>222-1503</td>
<td>222-1504</td>
<td>222-1505</td>
</tr>
<tr>
<td>Radius Ra (mm)</td>
<td>10.5</td>
<td>18.0</td>
<td>30.5</td>
</tr>
<tr>
<td>± delta Ra (mm)</td>
<td>0.025</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sample volume (cm³)</td>
<td>0.05</td>
<td>1.50</td>
<td>2.00</td>
</tr>
<tr>
<td>perm.Temperature max. (°C)</td>
<td>350</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calculation factors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A (Pa/Nm) *</td>
<td>477500</td>
<td>89090</td>
<td>17680</td>
</tr>
<tr>
<td>± delta A (%)</td>
<td>0.6</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>M (s⁻¹/rad s⁻¹) *</td>
<td>28.65</td>
<td></td>
<td></td>
</tr>
<tr>
<td>± delta M (%)</td>
<td>3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* The exact values are specified on the individual certificate.
HAAKE Rheometer Measuring Range of Sensor

Sensor Systems
Sensor Systems
# Sensor Systems

## Cone-Plate Sensor System with 4° Angle

<table>
<thead>
<tr>
<th>Sensor</th>
<th>C20/4</th>
<th>C35/4</th>
<th>C60/4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cone Order No.</td>
<td>222-0590</td>
<td>222-1270</td>
<td>222-1275</td>
</tr>
<tr>
<td>Inertia I (kg m²) E-6</td>
<td>0.3</td>
<td>1.8</td>
<td>17</td>
</tr>
<tr>
<td>Material: Titan DIN No.</td>
<td>3.7035</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radius Ri (mm) *</td>
<td>10.0</td>
<td>17.5</td>
<td>30.0</td>
</tr>
<tr>
<td>± delta Ri (mm)</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Cone angle (Deg) *</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance a (mm)</td>
<td>0.14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Truncation diam (mm)</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measuring plate steel</td>
<td>Standard ⊙ 60 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measuring plate location</td>
<td>222-1503</td>
<td>222-1504</td>
<td>222-1505</td>
</tr>
<tr>
<td>Radius Ra (mm)</td>
<td>10.5</td>
<td>18.0</td>
<td>30.5</td>
</tr>
<tr>
<td>± delta Ra (mm)</td>
<td>0.025</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sample volume (cm³)</td>
<td>0.1</td>
<td>0.8</td>
<td>4.0</td>
</tr>
<tr>
<td>Perm.temperature max. (°C)</td>
<td>350</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calculation factors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A (Pa/Nm) *</td>
<td>477500</td>
<td>89090</td>
<td>17680</td>
</tr>
<tr>
<td>± delta A (%)</td>
<td>0.3</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>M (s⁻¹/rad s⁻¹) *</td>
<td>14.32</td>
<td></td>
<td></td>
</tr>
<tr>
<td>± delta M (%)</td>
<td>0.8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* The exact values are specified on the individual certificate.
HAAKE Rheometer Measuring Range of Sensor

RV1-C20/4

RV1-C35/4

RV1-C60/4
12.9 Plate-Plate Sensor Systems

The plate-plate sensor system is determined by the plate radius and the variable distance between the stationary and the movable plate. This distance should not be smaller than 0.5 mm and not larger than 3 mm as other measurement errors, depending on the substance, could be experienced.

Geometry:

The distance of the plate should be at least three times larger than the largest particle contained in the substance. The plate-plate sensor system must be very carefully filled in order to minimize measurement errors. Both, too low a filling and too high a filling will cause measurement errors.

\[ R = \text{Plate Radius} \]
\[ h = \text{Distance} \]

\[ R_{\text{eff}} = \text{effective Radius} \]
Calculation Equations

Shear Stress $\tau$

The shear stress $\tau$ is proportional to the torque 'Md' and to the stress factor 'A'.

$$\tau = A \cdot Md$$

The factor 'A' is calculated as described in the following equation. It has the unit of an inverse volume:

$$A = \frac{2}{\pi \cdot R^3}$$

with $R$ = Plate Radius

Shear Rate $\dot{\gamma}$

The shear rate $\dot{\gamma}$ is proportionally linked to the angular velocity or speed and the shear factor M.

$$\dot{\gamma} = M \cdot \Omega$$

The angular velocity $\Omega$ is calculated according to $\frac{2\pi}{60} \cdot n$ from the speed $n$.

The factor 'M' is calculated as follows:

$$M = \frac{R}{h}$$

with $R$ = Plate Radius

$h$ = set distance

Deformation $\gamma$

The deformation $\gamma$ is linearly linked to the angular deflection and the shear factor M.

$$\gamma = M \cdot \varphi$$

with $\varphi$ = Torsion Angle rad

The following conversion equation should be applied:

$$1 \text{ rad} = 57.296 \text{ deg.} \quad \text{or} \quad 1 \text{ deg.} = 0.0174 \text{ rad}$$
Note!

The shear rate $\gamma$ in this sensor system alters with the radius; it is equal to $= 0$ (R = 0) in the center and has a maximum value (R = R) at the edge. The values specified in the table refer to $R = R_R$, i.e. at the edge of the plate. For non-Newtonian samples the shear stress linked to this value has to be calculated in order to achieve correct viscosity results.

The following equation applies:

$$\tau = Md \cdot \frac{3 + n}{4} \left( \frac{2}{\pi \cdot R^2} \right)$$

- $A$ = Shear factor
- $Md$ = Torque
- $R$ = Plate Radius
- $n$ = Structural Exponent of the Ostwald flow law

$$n = \frac{\Delta \cdot \log Md}{\Delta \cdot \log \omega^2_R}$$

or

$$\tau \text{ (non-Newtonian)} = \tau \text{ (Newtonian)} \cdot (3 + n) / 4$$

$$\tau \text{ (non-Newtonian)} = Md \cdot A \cdot (3 + n) / 4$$

Graphical determination of the structural exponent 'n'.
Plate/plate measuring errors

Significant measuring errors can result when using plate/plate sensor systems if ...

- the correct gap between the plates is not observed,
- filling is not carried out correctly.

Both errors can be estimated quantitatively:

1. Plate/plate gap error

If the desired gap $h$ which is set at the rheometer is not observed, the following measuring uncertainty results:

$\text{Measuring uncertainty} = \frac{\Delta h}{h}$

2. Plate/plate reduced effective radius error

If a plate/plate sensor system is insufficiently filled or the gap empties itself during a measurement, significant measurement errors can result. This condition of insufficient filling can be referred to as a reduced effective radius error and is characterized by a reduction in the effective radius.

$R = \text{plate radius}$

$h = \text{gap}$

$Reff = \text{effective radius}$

$Reff = R_{\text{plate}} - \text{reduced effective radius } x$

Viscosity measuring uncertainty

$\frac{\eta_{\text{korrekt}} - \eta_{\text{Fehler}}}{\eta_{\text{korrekt}}} = 1 - \frac{R^4}{(R - x)^4}$
Plate-Plate Sensor System with variable distance

<table>
<thead>
<tr>
<th>Sensor</th>
<th>PP20</th>
<th>PP35</th>
<th>PP60</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light weight Cone Order No.</td>
<td>222-0586</td>
<td>222-1266</td>
<td>222-1271</td>
</tr>
<tr>
<td>Inertia I (kg m²) E-6</td>
<td>0.3</td>
<td>1.7</td>
<td>17</td>
</tr>
<tr>
<td>Material: Titan DIN No.</td>
<td>3.7035</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radius Rᵢ (mm)</td>
<td>10</td>
<td>17.5</td>
<td>30</td>
</tr>
<tr>
<td>± delta Rᵢ (mm)</td>
<td>0.002</td>
<td>0.0035</td>
<td>0.006</td>
</tr>
<tr>
<td>Gap (mm)</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measuring plate steel</td>
<td>Standard</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measuring plate location</td>
<td>222-1503</td>
<td>222-1504</td>
<td>222-1505</td>
</tr>
<tr>
<td>Radius Rₐ (mm)</td>
<td>10.5</td>
<td>18.0</td>
<td>30.5</td>
</tr>
<tr>
<td>± delta Rₐ (mm)</td>
<td>0.025</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sample volume (cm³)</td>
<td>0.4</td>
<td>1.0</td>
<td>4.0</td>
</tr>
<tr>
<td>perm.temperature max. (°C)</td>
<td></td>
<td></td>
<td>350</td>
</tr>
<tr>
<td>Calculation factors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A (Pa/Nm)</td>
<td>636600</td>
<td>118800</td>
<td>23580</td>
</tr>
<tr>
<td>± delta A (%)</td>
<td>0.3</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>M (s⁻¹/rad s⁻¹)</td>
<td>10</td>
<td>17.5</td>
<td>30</td>
</tr>
</tbody>
</table>

12.10 Platter-platter measuring equipment with profiled surface.

Platter/platter measurement geometries are also available with profiled surface. These special geometries give relative measurement results and are particularly suited to tests which show wall slip. Pre-defined A and M measurement geometry factors are stored in the HAAKE RheoWin Software. Because of the profiling, the measurement gap approached through the software is smaller than the actual one, which results in a too low a value being measured for the viscosity. The M factor in the RheoWin-Software needs to be altered for this reason, using a Newtonian fluid with a known viscosity.
Sensor Systems

HAAKE Rheometer Measuring Range of Sensor

RS1-PP20

RS1-PP35

RS1-PP60

Shear stress (Pa)

Viscosity (mPas)

Shear rate (1/s)
12.11 High Shear Cylinder Sensor System HS

Application:

The sensor system HS is primarily used for viscosity measurements at high shear rates e.g. for coating materials, PVC-plastisols, oils etc. It can, furthermore, be used to determine the shear stability of emulsions which tend to split or slip "on the rotor" or "in the gap". The coaxial cylinder sensor system consists of a beaker with a temperature jacket and two rotors covering different measuring ranges. The temperature vessel is not required in this case.

The beaker is hooked up to the measuring system. The rotors are inserted from below. A double universal joint achieves self-centering of the rotor in the cup.

The test substance is injected by means of a syringe until it appears at the upper rim of the annual gap. Highly viscous substances are loaded by means of a small grease gun.

If the test substance is non-thixotropic, a rotational speed with small jis applied while injecting the substance. This will support charging and rotor centering.

Measurements at high speeds will cause considerable amounts of heat in the annular gap. It is, therefore, important that a circulator with a high pumping capacity and short connecting hoses is selected. In most cases this enables measurements without temperature drift due to frictional heating. Should this not be possible, it is recommended to conduct a step-by-step or a rapid automatic flow curve measurement.
## Sensor Systems

<table>
<thead>
<tr>
<th>Sensor</th>
<th>HS25</th>
<th>HS100</th>
<th>HS400</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardan</td>
<td>222-1361</td>
<td>222-1362</td>
<td>222-1430</td>
</tr>
<tr>
<td>Inertia I (kg m²) E-6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material: Steel DIN No.</td>
<td></td>
<td>1.4112</td>
<td></td>
</tr>
<tr>
<td>Radius Ri (mm)</td>
<td>10.975</td>
<td>10.900</td>
<td>10.600</td>
</tr>
<tr>
<td>± delta Ri (mm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length l (mm)</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>± delta l (mm)</td>
<td>0.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clearance to bottom (mm)</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cup for HS</td>
<td>222-1496</td>
<td>222-1496</td>
<td>222-1496</td>
</tr>
<tr>
<td>Radius Ra (mm)</td>
<td>11.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>± delta Ra (mm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material: Steel DIN No.</td>
<td></td>
<td>1.4112</td>
<td></td>
</tr>
<tr>
<td>Ratio of Radii Ra/Ri</td>
<td>1.0023</td>
<td>1.0092</td>
<td>1.0377</td>
</tr>
<tr>
<td>Gap (mm)</td>
<td>0.025</td>
<td>0.1</td>
<td>0.4</td>
</tr>
<tr>
<td>Sample volume (cm³)</td>
<td>4.5</td>
<td>4.6</td>
<td>4.8</td>
</tr>
<tr>
<td>perm.temperature max. (°C)</td>
<td>200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calculation factors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A (Pa/Nm)</td>
<td>80900</td>
<td>89305</td>
<td>94432</td>
</tr>
<tr>
<td>± delta A (%)</td>
<td>0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M (s⁻¹/rad s⁻¹)</td>
<td>440.50</td>
<td>112.00</td>
<td>28.40</td>
</tr>
<tr>
<td>± delta M (%)</td>
<td>0.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Sensor Systems

HAAKE Rheometer  Measuring Range of Sensor

RS1-HS100

RS1-HS25

RS1-HS400

Shear stress (Pa)

Shear rate (1/s)

Viscosity (mPas)
### 12.12 SHRP Plate-Platte Sensor System PP 1 mm

<table>
<thead>
<tr>
<th>Sensor</th>
<th>PP8</th>
<th>PP20</th>
<th>PP25</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Temp. Rotor Order No.</td>
<td>222-1356</td>
<td>222-0595</td>
<td>222-1355</td>
</tr>
<tr>
<td>Inertia I (kg m²) E-6</td>
<td>0.19</td>
<td>0.43</td>
<td>0.85</td>
</tr>
<tr>
<td>Material: Steel DIN No.</td>
<td></td>
<td></td>
<td>1.4112</td>
</tr>
<tr>
<td>Radius Rᵢ (mm)</td>
<td>4</td>
<td>10</td>
<td>12.5</td>
</tr>
<tr>
<td>± delta Rᵢ (mm)</td>
<td>0.0008</td>
<td>0.002</td>
<td>0.0025</td>
</tr>
<tr>
<td>Gap (mm)</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Measuring plate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radius Rₐ (mm)</td>
<td>10.5</td>
<td>18.0</td>
<td>30.5</td>
</tr>
<tr>
<td>± delta Rₐ (mm)</td>
<td></td>
<td>0.025</td>
<td></td>
</tr>
<tr>
<td>Sample volume (cm³)</td>
<td>0.1</td>
<td>0.4</td>
<td>0.5</td>
</tr>
<tr>
<td>perm.temperature max. (°C)</td>
<td></td>
<td></td>
<td>200</td>
</tr>
<tr>
<td>Calculation factors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A (Pa/Nm)</td>
<td>9.95E+06</td>
<td>6.37E+05</td>
<td>3.26E+05</td>
</tr>
<tr>
<td>± delta A (%)</td>
<td>0.3</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>M (s⁻¹/ rad s⁻¹)</td>
<td>4</td>
<td>10</td>
<td>12.5</td>
</tr>
<tr>
<td>± delta M (%)</td>
<td></td>
<td></td>
<td>0.1</td>
</tr>
</tbody>
</table>
Sensor Systems
Application:

**12.13 Immersion Sensor System FL**

Star shaped rotors (3 types) - they can be successfully employed to measure cremes, gels etc. which are often highly thixotropic losing their structure even before the test just by forcing them into small annular gaps. Cutting into the sample with the star-shaped rotor will leave the structure of the sample undamaged.

Yield points are determined from the peaks of a $\tau$/time-curve: When the yield point is surpassed, the rotor "cuts a hole" into the sample and the test is finished. The curve progression from this point onward should not be evaluated.

<table>
<thead>
<tr>
<th>Sensor</th>
<th>FL16</th>
<th>FL22</th>
<th>FL40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel Rotor order No.</td>
<td>222-1326</td>
<td>222-1325</td>
<td>222-1324</td>
</tr>
<tr>
<td>Inertia $I$ (kg m$^2$) E-6</td>
<td>1.0</td>
<td>1.0</td>
<td>30.0</td>
</tr>
<tr>
<td>Material: Steel DIN No.</td>
<td></td>
<td></td>
<td>1.4112</td>
</tr>
<tr>
<td>Radius $R_i$ (mm)</td>
<td>8.000</td>
<td>11.000</td>
<td>20.000</td>
</tr>
<tr>
<td>$\pm$ delta $R_i$ (mm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length $l$ (mm)</td>
<td>8.8</td>
<td>16</td>
<td>55</td>
</tr>
<tr>
<td>$\pm$ delta $l$ (mm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clearance to bottom (mm)</td>
<td></td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>perm.temperature max. (°C)</td>
<td></td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Calculation factors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$A$ (Pa/Nm)</td>
<td>175000</td>
<td>56370</td>
<td>5823</td>
</tr>
<tr>
<td>$\pm$ delta $A$ (%)</td>
<td></td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>$M$ (s$^{-1}$/rad s$^{-1}$)</td>
<td></td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>$\pm$ delta $M$ (%)</td>
<td></td>
<td>0.5</td>
<td></td>
</tr>
</tbody>
</table>
Sensor Systems

**HAAKE Rheometer Measuring Range of Sensor**

- **RS1-FL16**
- **RS1-FL22**
- **RS1-FL40**
Sensor Systems

HAAKE Rheometer Measuring Range of Sensor

- RV1-FL16
- RV1-FL22
- RV1-FL40
### 13. Optional sensor systems

<table>
<thead>
<tr>
<th>Sensor</th>
<th>HAAKE RotoVisco1</th>
<th>HAAKE RheoStress1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z10DIN</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Z20DIN</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Z34DIN</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>DG41</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Z31</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Z38</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Z41</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>HS25</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>HS100</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>HS400</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>C20/0.5</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>C35/0.5</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>C60/0.5</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>C20/1</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>C35/1</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>C60/1</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>C20/2</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>C35/2</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>C60/2</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>C20/4</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>C35/4</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>C60/4</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>PP20</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>PP35</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>PP60</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>PP25</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>PP8</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>PP35</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>PP60</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>FL16</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>FL22</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>FL40</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
14. Hints on Measurement

14.1 Temperature programs with Series 1 units

When temperature programs are run with rheometers of Series 1 the thermal expansion of unit plus sensor of about 1 micro meter per Kelvin have to be taken into consideration.

E.g. with cone C60/1°, which has a gap of 52 micron as standard value. If a temperature program is run from 20°C to 80°C, probably from a temperature of 72°C on the cone will touch the measuring plate and then drill a „hole”.

The problem is avoided when plate-plate measuring sensors with gaps of 0.7 to 1.5 mm are used instead of cones or the function „ThermoGap” in the software is activated.
14.2 Range Limits in Oscillation
(RheoStress 1)
Hints on Measurement

14.3 Correction of Dynamic Measurement (RheoStress 1)

Description of the problem

There are two important influences:

Mechanical influence:

- additional frequency dependent phase shift caused by inertia $I$ of the rotor (as well as by the damping $D$ and the spring constant $K$ of the measuring system).

Electro-magnetic interactions:

- frequency dependent phase shift $\kappa$ between the current in the motor coil and the torque acting on the axis.
- reduced motor torque ($M_d(\omega)<M_0$) due to frequency (and current) dependent induction effects in the coil.

Consequently, we have to correct two quantities in the rheological equations:

- phase angle $\delta$
  $\kappa$ corrects for electromagnetic effects,
  mechanical influences on the phase shift can be corrected by taking into account $I$, $(D)$, $(K)$.
- acting torque on the axis $M_d$
  $\mu$ corrects for electromagnetic influences on the torque amplitude.

Quantities we assume to be well-known or measured exactly:

- inertia $I$ (determined by a creep experiment without sample),
- damping constant $D$ and spring constant $K$ of the systems (both have only a negligible influence),
- A- and M-factors of the measuring system (sensor),
- rotation angle $\phi$ measured with the optical encoder.

Indices used:

- exp $\rightarrow$ original measuring data
- me $\rightarrow$ quantities corrected for electromagnetic but not for mechanical (inertia) influences
- (without) $\rightarrow$ corrected data
Equations of Moduli, Viscosity and Loss Tangent:

Basic equations including corrected quantities:

\[ G' = \frac{T}{\gamma} \cos \delta \quad G'' = \frac{T}{\gamma} \sin \delta \]  
(1)

\[ \eta = \eta_o = |\eta^*| = \frac{|G'|}{\omega} = \sqrt{G'^2 + G''^2} \]  
(2)

\[ \tan \delta = \frac{G''}{G'} \]  
(3)

Equations for the original experimental data and the corresponding corrections:

\[ \frac{T}{\gamma} = \left( \frac{T}{\gamma} \right)_{\text{exp}} - \frac{\mu A}{\gamma_{\text{exp}}} = f(\omega) \]  
(4)

corrected amplitude ratio

\[ \delta_{\text{me}} = \delta_{\text{exp}} - \kappa = f(\omega) \]  
(5)

original phase angle corrected for electromagnetic effects but not for mechanical influences

\[ G' = \frac{A}{M} \left| \frac{M}{A} \cdot \frac{T}{\gamma} \cos \delta_{\text{me}} + I\omega^2 + K \right| \]  
(6)

\[ G'' = \frac{A}{M} \left| \frac{M}{A} \cdot \frac{T}{\gamma} \sin \delta_{\text{me}} - D\omega \right| \]

\[ \eta = \eta_o = |\eta^*| = \frac{|G'|}{\omega} = \sqrt{G'^2 + G''^2} \]  
(7)

\[ \tan \delta = \frac{G''}{G'} \]  
(8)
14.4 Determination of the mass moment of inertia (RheoStress1)

Oscillation measurements are influenced very much by the mass moment of inertia of the sensor system at higher frequencies. This is why an exact determination of this value is very important.

Because the measurement of the mass moment of inertia by the jump-answer-method is not precise enough, another method was developed which is described here briefly.

If the mechanical system motor-sensor-Newtonian-oil is excited periodically by Torque $M_{d,0}$ with frequency $f$, the following formula results for the angle amplitude $\Phi_0$:

$$\Phi_0 = \frac{M_{d,0}}{I} \cdot \frac{1}{\omega \sqrt{\omega^2 + \left(\frac{\eta}{G} \cdot \frac{1}{I}\right)}}$$

in which $I$ represents the mass moment of inertia, $\eta$ the viscosity of the Newtonian-oil, $G = \frac{A_{\text{Sensor}}}{M_{\text{Sensor}}}$ and $\omega = 2\pi \cdot f$. At the oscillation in air, $\eta \rightarrow 0$ is valid. This means that at frequencies that are high enough the second term under the root in (1) can be neglected towards the first term. Equation (1) can be changed to:

$$\Phi_0 = \frac{M_{d,0}}{\omega^2 \cdot I}$$

If you now measure the resulting angle amplitudes at different torque amplitudes (OSC-Stress-Sweep) and the measuring results are described as $\Phi_0 = f(M_{d,0})$, from the ascending gradient

$$\frac{d\Phi_0}{dM_{d,0}}$$

of this function the mass moment of inertia $I$ can be determined.

$$\frac{d\Phi_0}{dM_{d,0}} = \frac{1}{\omega^2 I} \quad \text{(3)} \quad \text{or} \quad I = \frac{1}{4\pi^2 \cdot f^3 \left(\frac{d\Phi_0}{dM_{d,0}}\right)^2} \quad \text{(4)}$$

This processing is implemented in the Thermo Fisher Scientific rheometer software. For increasing the accuracy it is recommended to repeat the determination of the mass moment of inertia for each rotor (once) five times and to enter the average value of the determined values of the mass moment of inertia manually into the sensor file.
15. Maintenance

The Rheometer is a robust but also sensitive measuring instrument. It does not require any special care if the following points are observed:

- avoid bumps or knocks

- take care not to kink mains or other connection cables. Do not expose cables to tensile load or temperatures above 70 °C. It is strongly recommended that the power cable be inspected regularly (VDE (the German Association for Electrical & Information Technologies), ground terminal test, insulation resistance).

- when dirty: do not use cleaning solvents! Unit components can be damaged and/or combustible fumes can result.
15.1 Maintenance Instructions HAAKE RheoStress1

The system check on the HAAKE RheoStress1 must be carried out once yearly.

1. Check the lifting device with drive and guideway cover. *
2. Clean and lubricate screw.*
3. Check safety device and final cut-off lift.*
4. Check air-cushion bearing monitoring function.*
5. Test and adjust surface plate and plate carrier mechanically.*
6. Update devices to newest operating software.
7. Test measurement with test liquid in CS/CR mode.
8. General function test.*
9. Check all sensors for smooth running and damage.
10. Check temperature stabiliser (if applicable):*

**Liquid tempering:**
Check hose connections, sensors, update operating software.

**TCE/P electric tempering:**
Check heating elements, sensors, tempering.

**TCP/P and TCP/PE Peltier tempering:**
Check tempering, safety circuit, tempering.

* Check by official Thermo Fisher Scientific service.

Points 7 and 9 are recommended every 3 months.
15.2 Maintenance Instructions HAAKE Rotovisco1

The system check on the HAAKE Rotovisco1 must be carried out once yearly.

1. Check the lifting device with drive and guideway cover. *
2. Clean and lubricate screw.*
3. Check safety device and final cut-off lift.*
4. Test and adjust surface plate and plate carrier mechanically.*
5. Update devices to newest operating software.
6. Check speed step with digital speed measurement device.*
7. Calibrate torque measurement with thread measuring instrument and box of weights, check linearity of torque indication.*
8. Test measurement with normal liquid in CR mode.
9. General function test.*
10. Check all sensors for smooth running and damage.
11. Check temperature stabiliser (if applicable):*

   Liquid tempering:
   Check hose connections, sensors, update operating software.

   TCE/P electric tempering:
   Check heating elements, sensors, tempering.

   TCP/P and TCP/PE Peltier tempering:
   Check tempering, safety circuit, tempering.

* Check by official Thermo Fisher Scientific service.

Points 8 and 10 are recommended every 3 months.
15.3 Filter unit (order no. 222-1211)

The filter unit is connected to an oilfree air supply (e.g. the HAAKE compressor (order no. 222-1434 for 230 V and 222-1435 for 115 V).

The filters for the air bearings should be changed:
- every half-year at pressure of 2.5 bars or
- every 500 operating hours.

Replacement of the filters

1. Separate the filter unit from the air supply.
2. Screw out the filter housings (order no. 222-1475 and 222-1476) from the unit. Take care of the sealing rings.
3. Replace the filters 222-1214 and 222-1213. Clean the oil filter.
4. Insert the sealing rings into the housings. Screw the housings into the filter unit.
5. Connect the filter unit to the air supply.
15.4 Flat sieve

To keep dirt out of the tempering unit there is a flat sieve (003-5266) inserted in the suction side 14 (IN). This sieve has to be changed or at least cleaned at the following intervals:

- every six months, or
- as soon as the through-flow is too small.

Changing the flat sieve:

1. Switch the unit off.
2. Separate the hose from the hose connectors (IN)
3. When loosening the hose connections at the tempering unit, hold the connectors with an open-jaw spanner
4. Loosen and remove the hose connections from the tempering unit
5. Unscrew the flat sieve from the connector with a wrench.
6. Clean the flat sieve or replace it with a new one.
7. Insert the flat sieve and fasten it to the hose connections together again
8. Reconnect the hoses

! Tighten all the hose connections with hose clamps.
15.5 Repairs

Due to the modular design of the rheometer, damaged or faulty components can be easily exchanged for replacement parts. Repairs should only be carried out by specially equipped and trained personnel.

\!
ON NO ACCOUNT should you attempt to open up the unit. This warning applies especially to the powers supply unit:

Tampering can have FATAL consequences!

Please contact the Thermo Fisher Scientific-SERVICE department in case of repairs.

You can help us and yourself if you specify the complete type no. printed on the name plate when reporting the damage.

Thermo Fisher Scientific Service department address

Thermo Fisher Scientific
SERVICE
Dieselstraße 4
D-76227 Karlsruhe

Telephone ++49/721/4094-444
Telefax ++49/721/4094-360
E-Mail:Support.mc.de@thermofisher.com
16. Pin Wiring

RS232 interface connection to computer (7)

<table>
<thead>
<tr>
<th>Pin</th>
<th>Signal type</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>RXD</td>
</tr>
<tr>
<td>3</td>
<td>TXD</td>
</tr>
<tr>
<td>4</td>
<td>CTS</td>
</tr>
<tr>
<td>5</td>
<td>RTS</td>
</tr>
<tr>
<td>6</td>
<td>DSR</td>
</tr>
<tr>
<td>7</td>
<td>Signal ground</td>
</tr>
<tr>
<td>8</td>
<td>NC</td>
</tr>
<tr>
<td>9</td>
<td>+5 V</td>
</tr>
</tbody>
</table>

Centronics-Connection (8)

<table>
<thead>
<tr>
<th>Pin</th>
<th>Signal type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>STROBE</td>
</tr>
<tr>
<td>2</td>
<td>DØ</td>
</tr>
<tr>
<td>3</td>
<td>D1</td>
</tr>
<tr>
<td>4</td>
<td>D2</td>
</tr>
<tr>
<td>5</td>
<td>D3</td>
</tr>
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<td>6</td>
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<td>15</td>
<td>ERROR</td>
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<tr>
<td>16</td>
<td>NC</td>
</tr>
<tr>
<td>17</td>
<td>NC</td>
</tr>
<tr>
<td>18-25</td>
<td>GND Signal ground</td>
</tr>
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</table>
**Display unit connection (11)**

<table>
<thead>
<tr>
<th>Pin</th>
<th>Signal type:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Power supply display unit</td>
</tr>
<tr>
<td></td>
<td>(+ 10 V, 0.5 A)</td>
</tr>
<tr>
<td>2</td>
<td>NC</td>
</tr>
<tr>
<td>3</td>
<td>RxD</td>
</tr>
<tr>
<td>4</td>
<td>Code</td>
</tr>
<tr>
<td>5, 9</td>
<td>Ground</td>
</tr>
<tr>
<td>6</td>
<td>NC</td>
</tr>
<tr>
<td>7</td>
<td>TxD</td>
</tr>
<tr>
<td>8</td>
<td>SLLK</td>
</tr>
</tbody>
</table>

**PT100 (input) (10) only at TCO**

<table>
<thead>
<tr>
<th>Pin</th>
<th>Signal type:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pt100 (+I)</td>
</tr>
<tr>
<td>2</td>
<td>Pt100 (+U)</td>
</tr>
<tr>
<td>3</td>
<td>Pt100 (-U)</td>
</tr>
<tr>
<td>4</td>
<td>Pt100 (-I)</td>
</tr>
</tbody>
</table>

**PT100 (output) (20) only at TCL/P and TCL/Z**

<table>
<thead>
<tr>
<th>Pin</th>
<th>Signal type:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pt100 (+I)</td>
</tr>
<tr>
<td>2</td>
<td>Pt100 (+U)</td>
</tr>
<tr>
<td>3</td>
<td>Pt100 (-U)</td>
</tr>
<tr>
<td>4</td>
<td>Pt100 (-I)</td>
</tr>
</tbody>
</table>
17. External Connections

Shielded Cables

In order to keep the electromagnetic noise in the instrument within the tolerable limits it is indispensable to use only shielded cables and high quality plug connections. The complete contact of the shielding within the plugs is of special importance. Insufficient contact may lead to noise penetration and result in performance errors.

External PT100 sensor

A sensor in four wire technology is necessary. Only sensors with shielded wires can be used to fulfill the EMC requirements. The shielding must be connected with the housing of the plug and the sensor shaft. This sensor has to be connected according to the wiring diagram.

Pin assignment:
Pin 1 = current I +
Pin 2 = voltage U +
Pin 3 = voltage U -
Pin 4 = current I -
18. Technical Specifications

The technical specifications with the allowable deviations are

<table>
<thead>
<tr>
<th>Modell</th>
<th>HAAKE RV1</th>
<th>HAAKE RS1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Break torque</td>
<td>mNm</td>
<td>0.1</td>
</tr>
<tr>
<td>Torque max.</td>
<td>mNm</td>
<td>50*)</td>
</tr>
<tr>
<td>min. speed</td>
<td>min⁻¹</td>
<td>0.0125</td>
</tr>
<tr>
<td>max. speed</td>
<td>min⁻¹</td>
<td>1000</td>
</tr>
<tr>
<td>min. frequency</td>
<td>Hz</td>
<td>-</td>
</tr>
<tr>
<td>max. frequency</td>
<td>Hz</td>
<td>-</td>
</tr>
<tr>
<td>Number of impulses</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Strain resolution</td>
<td>rad</td>
<td>0.3·10⁻⁶</td>
</tr>
<tr>
<td>MultiWave</td>
<td>Hz</td>
<td>0.01-10</td>
</tr>
<tr>
<td>Measuring distance</td>
<td></td>
<td>&gt; 2π</td>
</tr>
<tr>
<td>Bearing</td>
<td>mec. bearing</td>
<td>Air bearing</td>
</tr>
<tr>
<td>Motor</td>
<td>Stepper</td>
<td>Drag cup</td>
</tr>
</tbody>
</table>

*) depending on speed

Torque-Speed Characteristic Curve HAAKE RV1

![Torque-Speed Characteristic Curve HAAKE RV1](image)
## Technical Specifications

<table>
<thead>
<tr>
<th></th>
<th>TCO</th>
<th>SHRP</th>
<th>TCL/Z</th>
<th>TCL/P</th>
<th>TCE/P</th>
<th>TCE/PC</th>
<th>TCP/P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions: H</td>
<td>mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W</td>
<td>mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight: (depending on equipment)</td>
<td>kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mains voltage:</td>
<td>V</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mains frequency:</td>
<td>Hz</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuses: 230V</td>
<td>A</td>
<td>2 x T1.6</td>
<td>2 x T3.15</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>115V</td>
<td>A</td>
<td>2 x T3.15</td>
<td>2 x T5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*HAAKE RV1; HAAKE RS1 with TCO, SHRP, TCL/Z, TCL/P, TCE/P, TCE/PC, TCP/P*

Dimensions: H 660 mm, W 385 mm, D 420 mm

Weight: (depending on equipment) 40 - 50 kg

Mains voltage: 230 - 115 V

Mains frequency: 50 - 60 Hz

Fuses: 230V 2 x T1.6, 2 x T3.15

115V 2 x T3.15, 2 x T5

Subject to alterations

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Order no. 003-5213h
19. Terms of Rheological Measurements

**Rheometrical measuring modes:**

Categorized into *preset values*:

- **CD:** Controlled Deformation
  Measuring mode for the direct determination of the yield point in the quality control; the reaction of the substance on a micro-step controlled deformation is evaluated.
  (HAAKE ViscoTester550/RotoVisco1)

- **CR:** Controlled Rate
  Measuring mode, e.g. for the recording of flow curves and the analysis of thixotropy; here the shear stress reaction of the substance on a preset shear rate ramp is evaluated.
  (HAAKE ViscoTester / RotoVisco / RheoStress)

- **CS:** Controlled Stress
  Measuring mode e.g. for the examination of a sample’s structure or for the recording of flow curves in the very low shear rate range; here the deformation reaction of the substance on a preset shear stress ramp is evaluated.
  (HAAKE RheoStress)

Categorized into *signal forms*:

- **Steady Rotation:**
  - **Creep/Recovery**
    CS measuring mode to determine the viscous and elastic properties of a material, e.g. for the determination of the zero-viscosity or as a criterion of shelf life.
    (HAAKE RheoStress)

- **Stress Growth/Decay**
  CR measuring mode to determine the time behavior and steady state flow curves.
  (HAAKE ViscoTester / RotoVisco / RheoStress)

- **Steady Rotation with ramps**:
  Measuring mode where the stress changes over the time e.g. to determine a yield point or a dynamic flow curve (thixotropy loop).
  (HAAKE ViscoTester / RotoVisco / RheoStress)
Oscillating Movement:

**OSC:** Oscillation

Measuring mode for the non-destructive determination of elastic and viscous material properties.

Here e.g. the influence of the frequency by forced oscillating stress on the storage and loss modules (G' and G'') can be investigated.

The measuring data gained in the linear visco-elastic range allow conclusions on other physical quantities (e.g. molecular quantities for polymers)

(HAAKE RheoStress)

---

Flow Properties regarding Viscosity Behaviors:

**Newtonian:** Property of substances where the viscosity will not change under shear rate and shear stress.

(HAAKE Falling Ball Viscometer, System Höppler)

**Pseudoplastic:** Property of substances where the viscosity will decrease under shear rate and shear stress.

(Most common material behavior)

**Dilatant:** Property of substances where the viscosity will increase under shear rate and shear stress.

**Thixotropic:** Non-Newtonian substances where the viscosity decreases under shear (structure break-down). The substances will eventually regain their viscosity after the shearing has stopped.

**Rheopectic:** Non-Newtonian substances where the viscosity increases under shear (structure build-up). The substances will eventually regain their viscosity after the shearing has stopped.

(Rare phenomenon)

**Plastic:** Property of non-Newtonian substances which only start flowing after being subject to a certain force (shear stress), i.e. after a certain yield point. The yield point strongly depends on external parameters like temperature and change rate of the acting force. Therefore, a "practical" yield point is determined taking in account the environmental conditions specific for the application.

(Measuring modes: CD, CS)

(HAAKE ViscoTester 550 / RotoVisco1 / RheoStress)
Terms of Rheological Measurements

Typical Quantities of Rheometry and Rheology:

**Instrument quantities:**

\[ M_d \quad - \text{torque} \]
\[ \Omega \quad - \text{angular velocity} \]
\[ \phi \quad - \text{rotation angle} \]
\[ \omega \quad - \text{angular velocity} (2\pi f) \]
\[ F_N \quad - \text{normal force} \]
\[ R, h, ... \quad - \text{dimensions of sensor} \]
\[ - \text{etc.} \]

**Measuring parameter:**

\[ T \quad - \text{temperature} \]
\[ p \quad - \text{pressure} \]
\[ t \quad - \text{time} \]
\[ - \text{etc.} \]

**Rheometrical quantities:**

\[ \tau \quad - \text{shear stress} \]
\[ \dot{\gamma} \quad - \text{shear rate} \]
\[ \gamma \quad - \text{deformation} \]
\[ N_1, N_2 \quad - \text{normal stress differences} \]
\[ - \text{etc.} \]

**Rheological quantities:**

**Material functions:**

\[ \eta, \eta^*, \eta^+ \quad \eta^- \quad - \text{viscosities} \]
\[ \Psi_1, \Psi_2 \quad - \text{normal stress functions} \]
\[ G \quad - \text{shearing modulus} \]
\[ G^*, G' \quad G'' \quad - \text{dynamic shear moduli} \]
\[ J \quad - \text{compliance} \]
\[ J^*, J' \quad J'' \quad - \text{dynamic compliances} \]
\[ - \text{etc.} \]

**Material parameters:**

\[ \eta_0 \quad - \text{zero viscosity} \]
\[ \tau_y \quad - \text{yield point} \]
\[ \Psi_{10} \quad - \text{1st normal stress coefficient} \]
\[ - \text{etc.} \]
Bitte wenden Sie sich bei Servicefragen an uns, unsere Partnerfirmen oder an die für Sie zuständige Generalvertretung, die Ihnen das Gerät geliefert hat.

Please get in contact with us or the authorized agent who supplied you with the unit if you have any services questions.

Veuillez vous adresser pour tout renseignement à votre fournisseur ou directement à :

**Thermo Fisher Scientific**

**International / Germany**

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Fax +49(0)721 4094-300
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Fax: +86(21) 64457830
info.china@thermofisher.com

www.thermoscientific.com/mc
# RMA (Return Materials Authorization) Formular / RMA Form

Die Annahme Ihres Gerätes/Ihrer Komponenten in unserem Hause kann nur erfolgen, wenn eine korrekt und vollständig ausgefüllte Erklärung mit einer gültigen RMA-Nr. vorliegt. Ist das nicht der Fall, kommt es leider zu Verzögerungen bzw. muss die Ware zurückgewiesen werden. Bitte nehmen Sie dazu unter support.mc.de@thermofisher.com Kontakt mit unserem Technischen Kunden Support auf.

The acceptance of incoming equipment will only be carried out if a correctly completed declaration with a valid RMA no. has been submitted. Non-completion will cause a delay and the return of the equipment cannot be accepted. Please contact our Technical Support Center under support.mc.de@thermofisher.com.

Diese Erklärung darf nur von autorisiertem Fachpersonal ausgefüllt und unterschrieben werden.

This declaration can only be completed and signed by authorized and qualified staff:

<table>
<thead>
<tr>
<th>1. Art der Geräte / Description of equipment</th>
<th>2. Grund der Einsendung / Reason for return</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gerätytyp: ..................................................</td>
<td>..................................................</td>
</tr>
<tr>
<td>Typ-Nr. ..................................................</td>
<td>..................................................</td>
</tr>
<tr>
<td>BOM no. ..................................................</td>
<td>..................................................</td>
</tr>
<tr>
<td>Serien-Nr. .................................................</td>
<td>..................................................</td>
</tr>
<tr>
<td>Serial no. ................................................</td>
<td>..................................................</td>
</tr>
<tr>
<td>RMA-Nr. ..................................................</td>
<td>..................................................</td>
</tr>
<tr>
<td>RMA no. ..................................................</td>
<td>..................................................</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3. Gerätezustand / Equipment condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waren die Geräte in Betrieb? / Has the equipment been used?</td>
</tr>
<tr>
<td>☐ Ja/Yes: ☐ Nein/No:</td>
</tr>
<tr>
<td>Sind die Geräte frei von gesundheitsgefährdenden Schadstoffen? / Is the equipment free of potentially harmful substances?</td>
</tr>
<tr>
<td>☐ Ja/Yes: ☐ Nein/No: (weiter Absatz 4/go to section 4)</td>
</tr>
</tbody>
</table>

*) Mikrobiologisch, explosiv und/oder radioaktiv kontaminierte Geräte und Komponenten werden nur bei Nachweis einer vorschriftsmäßigen Reinigung entgegengenommen!

We will not accept the return of any equipment that has been radioactively, explosively and/or microbiologically contaminated without written evidence of decontamination.

Art der Schadstoffe oder prozessbedingte, gefährliche Reaktionsprodukte, mit denen die Geräte und Komponenten in Kontakt kamen:

Please list all substances, gases and by-products which may have come into contact with the equipment:

<table>
<thead>
<tr>
<th>Handelsname/Tradename</th>
<th>Chem. Bezeichnung/chemical name</th>
<th>Gefahrenklasse/hazard classification</th>
<th>Maßnahmen bei Freiwerden der Schadstoffe/ precautions associated with substance</th>
<th>Erste Hilfe bei Unfällen/containment/first aid measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Produktnname/product name</td>
<td>Chem.Formel/chem. symbol</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hersteller/manufacturer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| 1. | 2. | 3. |

Rechtsverbindliche Erklärung / Legally binding declaration


I hereby declare that the information supplied on this form is complete and accurate. The dispatch of equipment will be in accordance with the appropriate regulations covering packaging, transportation and labeling of dangerous substances.

Firma/company name: .................................................. 
Adresse/address: .................................................. 
Telefon/phone: .................................................. Fax: .................................................. 
Ansprechpartner/contact person: .................................................. E-Mail: .................................................. 
Datum/Date: .................................................. Firmenstempel/company stamp: ..................................................

Rechtsverbindliche Unterschrift/legally binding signature: ..................................................