HAAKE

Viscometers

Instruction Manual
RheoStress® RS100

Table of Contents

This instruction manual is part of several information brochures and instruction manuals which together form the documentation for the Rheometer RS100

1. **Book "A Practical Approach to Rheology and Rheometry"**
   Measuring technique and data interpretation
   (Available from HAAKE under Order No. 222-1347)

2. **Instruction Manual for the RS100 Rheometer**
   Description of the function elements and
   measuring ranges of the RheoStress measuring instrument

3. **Instruction Manual for the CS/CR-Software**
   Description of the Functions and Menus

4. **Instruction Manual for the OSC-Software**
   Description of the Functions and Menus

This manual is valid for the following unit versions

RS100 / 1 Ncm Order No. 360-0001
and RS100 / 5 Ncm Order No. 360-0501

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General Remarks

!

This instrument may only be operated with close adherence to the following instructions!

This instruction manual describes exactly how this instrument is to be used.
The following should especially be kept in mind:

- **!** The instrument should only be used by trained personnel in conjunction with the instruction manual.
- **!** Only personnel with the particular know how should be allowed to carry out repairs.
- **!** Only original parts and accessories should be used, when repairs are carried out.
- **!** The instrument may not employed in medical surroundings and/or in the vicinity of patients. (IEC 601-1)

The symbols used in this manual and their meaning:

!	Warns that damages to the instrument and injuries to the user are possible.
☞	Denotes an important remark.
[1]	Indicates the next operating step to be carried out and . . .
⇒	. . . what happens as a result thereof.

Any questions?

Whenever you wish to make any inquiries concerning this instrument you should mention the type printed on the front side of the instrument (e. g. HAAKE ”RS100”) and also the information on the name plate.

1. Contents of Delivery - Measurement System RS100

1.1 Standard Delivery

The Measurement System RS100 is delivered in a recyclable package with the following accessories:

002-3200	RS100 Measuring Unit
002-3842	RS100 Control Unit
002-3206	Connection cable Measuring Unit → Control Unit
002-3458	Spare Light Bulb
002-2099	Extension for distance dial
001-8448	Set of hexagon socket keys
002-3203	Operating Instructions (English)
002-0724	Connection cable 220 V
002-4696	Leveling indicator
002-3092	Connection cable Incremental Sensor → Control Unit 12-pins
002-2557	Cover plate for stand
222-0626	Temperature control cable (analog) 4-pins
091-1620	Monitor software for the RS100/5

1.2 Optional Accessories

In order to enable measurement with the RS100, additional accessories are required which can be composed individually by the user.

1.2.1 Air Supply - Air Bearing

222-1211	Filter Unit with activated carbon insert
222-1213	Filter Element with activated carbon (Replacement)
222-1214	Filter Element for fine filter (Replacement)
222-1212	Air Pressure Distribution with regulator
222-1215	Air Pressure Diaphragm Compressor 230 V / 50 Hz
222-1215	Air Pressure Diaphragm Compressor 115 V / 60 Hz
082-1667	Air hose 10 m

1.2.2 Sensor Systems

Various sensor systems are available for the RS100 which differ also in their temperature control specifications.

Cylinder Sensor Systems:

222-0615 Temp. Control Unit for cylinders ∅ 40 mm with liquid temp. control up to 200/350°C
222-0628 Temp. Contr. Unit for cylinders ∅ 10/20 mm with liquid temp. control up to 200/350°C
222-0626 Temp. Control Cable (analog) 4-pins

Various rotors ∅ 40, 20, 10 mm with the corresponding cups are available for the temperature control units.

Cone/Plate Sensor Systems:

222-0609 Temp. Control Unit for cone/plate and plate/plate with liquid temp. control up to 200/350°C
222-0614 Electrical Temp. Control Unit with accessories and the TC500 temp. control unit

Various cones and plate together with the corresponding senor plates are available for combination with the temp. control units. For measurements above 60°C it is recommended to use ceramic shaft rotors as this minimizes the heat dissipation.

Accessories for the Sensor Systems:

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

Temperatures up to 150°C:

222-0610 1 Set VITON hoses (2) with quick coupling up to 150°C

Temperatures up to 350°C:

333-0294 Metal Hoses (insulated) 150 cm long (2 are required)
002-3424 Adapter M14x1 (2 are required)

For minimizing solvent losses and temperature dissipation two further options are available:

222-0608 Cover, jacketed glass, for sample compartment
222-0607 Solvent trap, glass with N_2-connection and metal slide ring

1.2.3 Software

The Rheometer RS100 cannot be operated without software and is supplied with the monitor software.

091-1620	Software RS-CRT Monitor Software

Optional software

091-1520	Software RS-CSS Controlled Stress Software
091-1020	Software RS-CRS Controlled Rate Software
091-1120	Software RS-OSC Oscillations-Software

The connection to the computer is made via cable:

222-0563	RS232 Connection Cable 25-pins (supplied as standard)

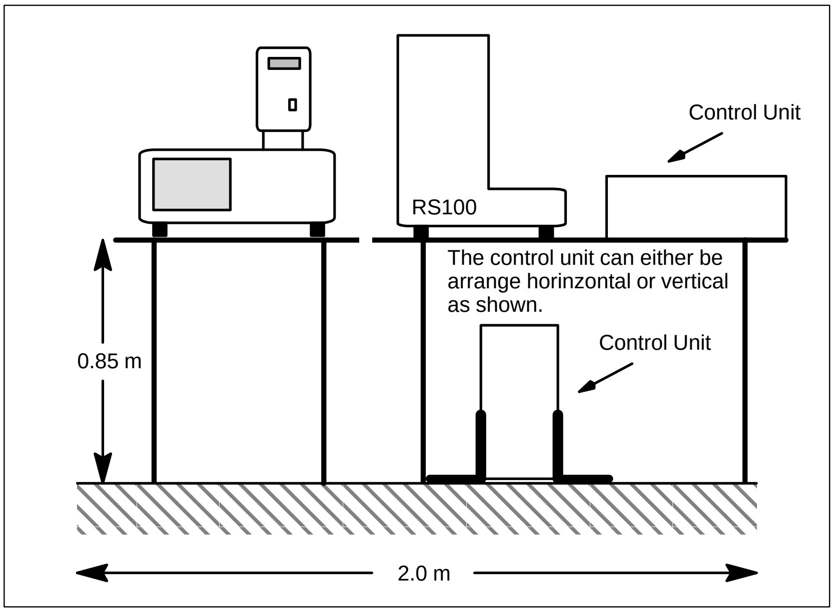
2. Damages en Route

If, when the goods are delivered, it is obvious that there are damages as, for instance, damaged packaging, this has to be brought to the attention of the freight agent making the delivery. Also, the manufacturer or, when the delivery was made outside from Germany, the general representative should be informed.

It is recommended to clearly document such damages (Photos, Sketches, Witnesses etc.) and to prepare a protocol.

3. Space Requirements

Good working conditions for a complete installation require an area of about 2 x 0.6 meters. The bench should be rigid with a level surface and easy to clean. The circulator used for the temperature control of the measuring system RS100 should be located on a separate bench to avoid possible mechanical oscillation when the highest accuracy is set on the instrument.



We usually recommend that the measuring system RS100 is situated on a balance table so that external influences on measurements can be ruled out.

If an extremely high degree of accuracy is required, it is recommended to run tests in an air-conditioned room.

4. Getting Started

After unpacking and setting up the instrument on the bench or balance table, it should be checked if any items are missing. Keep the packaging material for some time due to documentation reasons so that transportation damages coming to light afterwards can be investigated. Later on, the packaging material can be returned to the supplier if desired.

! **Only connect the RS100 to the voltage specified on the nameplate !**

The instrument is either rated at:

230V (+10% / –20%) = (184V – 253V); 50 – 60 Hz

→ Use Order No.: 360-0001 or *360-0501*

or

115V (+15% / –25%) = (86V – 130V); 50 – 60 Hz

→ Use Order No.: 360-0002 or *360-0502*

The RS100 Rheometer cannot be modified at the site of the customer.

The cable connections between the sensor system, the control unit, the computer and the printer have to be established.

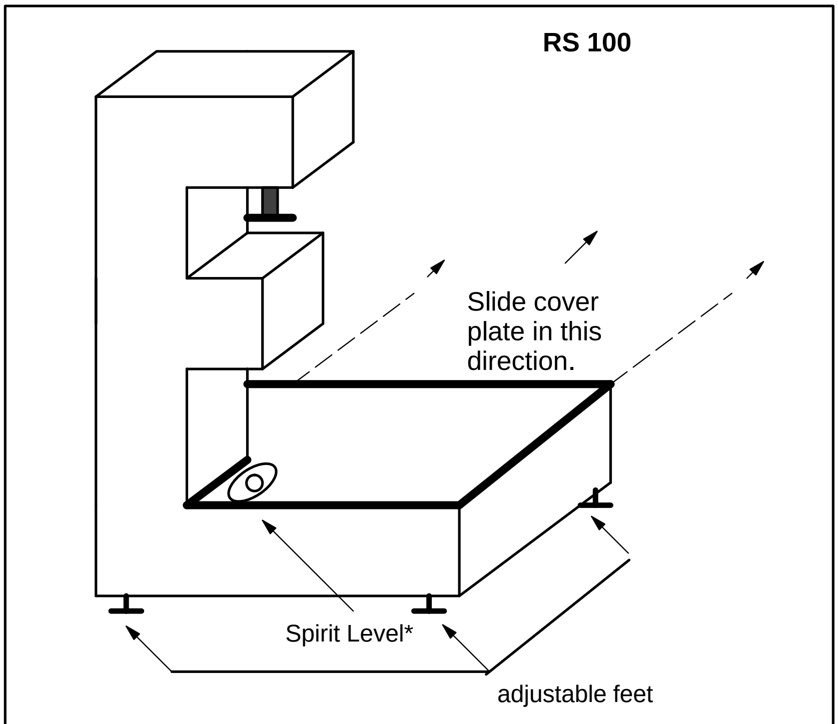
The measuring system has to be supplied with clean air (= free from oil and water). During measurements below 200°C only the proper supply of the air at a minimum pressure of 2.5 bar is required.

Measurements above 200 – 500°C additional compressed air is required for cooling purposes at the measurement table and also for the electric temperature unit.

4.1 Set up of Measuring Unit RS100

Lift measuring unit RS100 out of the package and place onto a stable, level table. For sensible measurements a plane table is recommended.

In the base of the measuring instrument, there is a spirit level with which the unit can be preliminarily levelled by screwing the feet in or out.



* becomes visisble when the cover plate is removed.

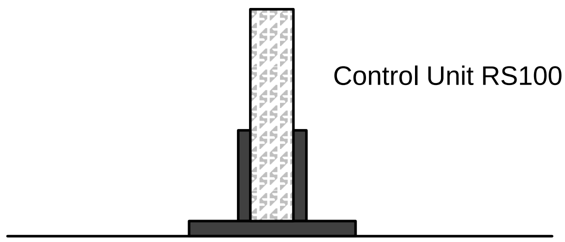
Upon completion of the preliminary levelling, slide the cover plate back onto the instrument until small guide trunnions become seated in their corresponding holes, thus safeguarding the plate against becoming dislocated.

4.2 Setting up the Control Unit for the RS100

The control unit for the RS100 is taken from its package and can now either be placed ***horizontally*** on a table or ***vertically*** under the table or some other convenient location.

Nothing should be placed onto the control unit (sensitive display units like monitors or a external memory units) as the built-in transformer is not shielded. Other peripheral equipment like printers or plotters are not influenced.

In order to place the unit in a upright position under or adjacent to the table, it is recommended to use the supports as they are supplied for setting up computer towers.



The unit is adjusted at HAAKE to be operated at a certain voltage the value of which can be learned from the nameplate located at the rear of the unit.

4.3 Computer

The RS100 asks for certain minimum requirements on the part of the computer and peripheral equipment in order to function properly. The options supported are listed below.

Minimum Requirements

- DOS Computer with at least one diskette drive and a hard disk of $\geq$ 40 MB
- Main memory => 640 kByte
- Graphic Adapter VGA
- Printer with Centronics interface
  e.g.
  Epson FX, LQ, FX800
  Hewlett-Packard PaintJet, LaserJet III, DeskJet 500
- Operating system DOS 5.0 or higher version
- Serial interface (RS232C) for Rheometer

Options

- Coprocessor (8087, 80X87), if available
- RS232C Plotter
- Microsoft® Mouse or PS2®/Mouse (choice)

Incompatibilities

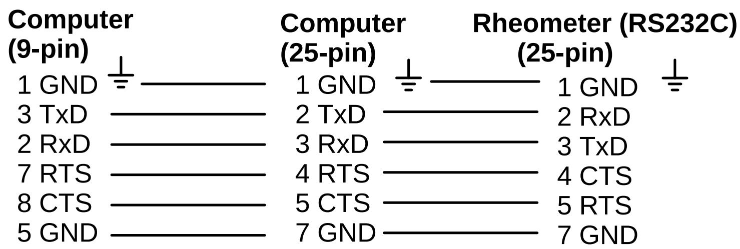
A few incompatibilities are known. They are causing uncontrolled difficulties:

- All memory-resident programs may cause these difficulties except for the HAAKE programs WINDOWS.COM, TTALK.COM and the HAAKE hardcopy routines.
- Printer Spooler in connection with RS232 interfaces are often causing difficulties.
- SIDEKICK causes malfunctions during ONLINE-operation of the viscometer.
- All HP-compatible plotters are **not** supported when they do **not** answer to the ”OI” command in the HP-syntax.

- Some Epson-compatible printers do not work properly.
- RS232 mouse-adapters are supported only under the condition that their interrupt vectors do not interfere with the RS232 interfaces.
- RS232 printers are supported only to a limited extent.
- IBM HR graphic-adapters are not supported.
- Hercules and Hercules-compatible graphic-boards can not be supported.

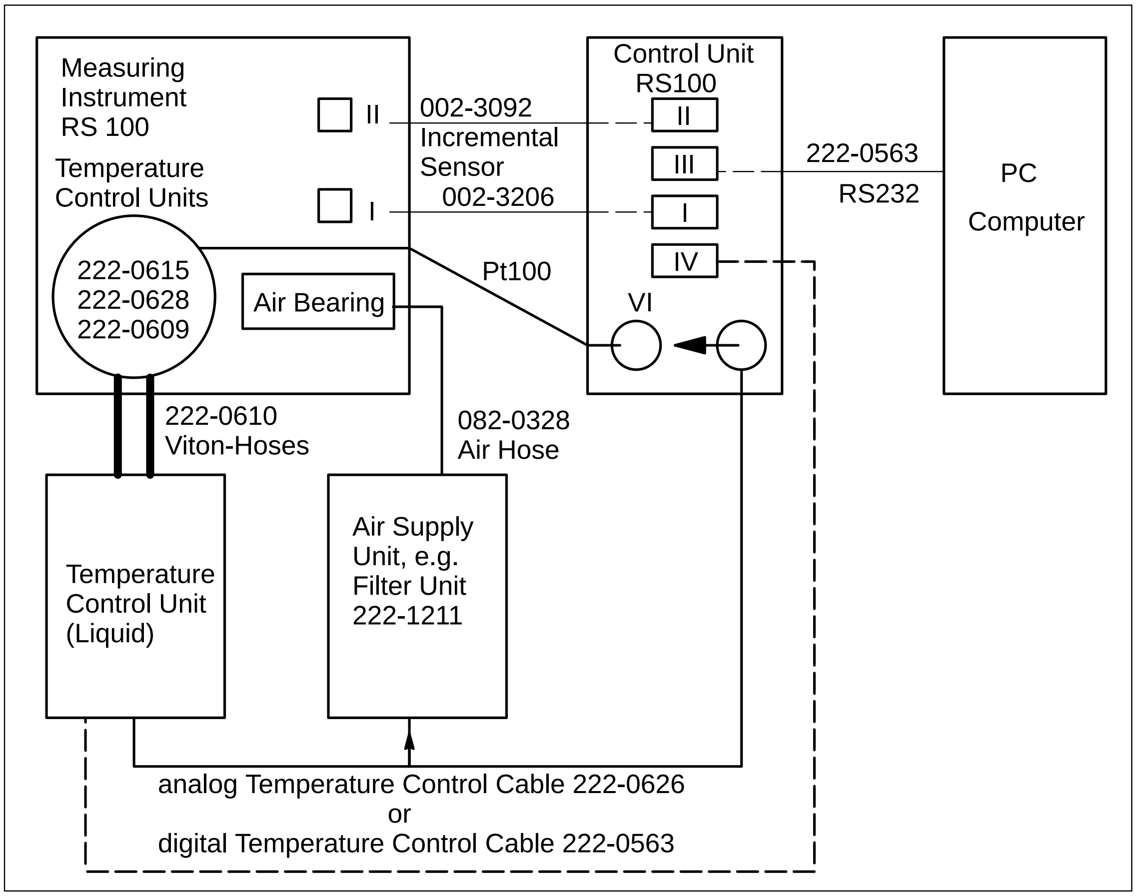
Connection Cables

RS232C cables between Computer and Rheometer (Order-No.: 222-0563)



Some computers (IBM AT, Compaq) are provided with a 9-pin RS232C socket. In this case the wiring of the RS232C cables has to be changed or an adapter (Order No. 222-9322) used.

4.4 Connections



The control unit may only be connected to the mains, when all connections are made **and** verified.

4.5 Supply Services and Ambient Conditions

The RS100 Rheometer is restricted to ambient temperatures of +15 to+40°C at a max. allowable humidity of approx. 80%. It is recommended to install the measuring unit in an air-conditioned room. If the unit is used outside the conditions just stipulated, it should be expected that the lifting functions and some other specifications can no longer be fully maintained.

The following supply services are required:

Mains → 230 V / 50-60 Hz for:

Mains Connection I:

- Control unit RS100 (2 Ampere)
- High temperature control unit TC500

Mains Connection II:

- Temperature control unit
- Computer
- Monitor
- Printer
- Plotter

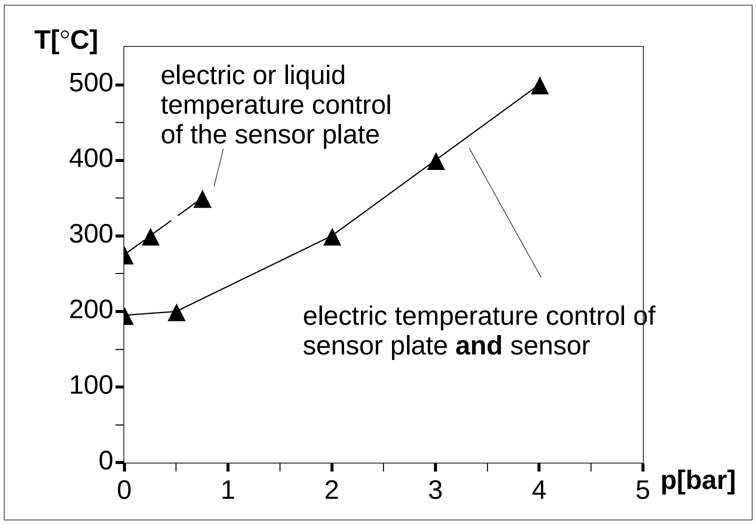
Mains Connection III:

- Air compressor

It is recommended to distribute the units to three independent mains circuits as otherwise switching pulses could show in the measurement results.

Also required

- Pure air pressure with 2.5 bar and approx. 10 dm^3/minute for the air bearing
- Air pressure with approx. 0,5 bar and approx. 30 dm^3/minute for cooling the base during high temperature tests
- Air pressure with 30 dm^3/minute for cooling the high temperature sensor system TC500



Hints/Tips

When all electrical and mechanical connections are made, there are some items which should be checked p r i o r to switching the unit to 'ON'.

1. The air bearing of the RS100 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.) **w i t h o u t** actually connecting it to the RS100. 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.
2. The RS100 measures the deflection under torque conditions of a substance and their regeneration when it is no longer subjected to this force. In doing this measurement, the position of the measuring unit has considerable influence on the measurement results. Therefore a careful levelling is very important. It is recommended to select a firmly positioned flat surface and to use the spirit level supplied in connection with the adjustable feet to level the instrument. This setting should be checked at least once weekly. It is understood that any relocation of the unit or change of the temperature control unit requires a new and careful leveling again.
3. The supply pressure of the unit's air bearing also determines the properties of the unit:

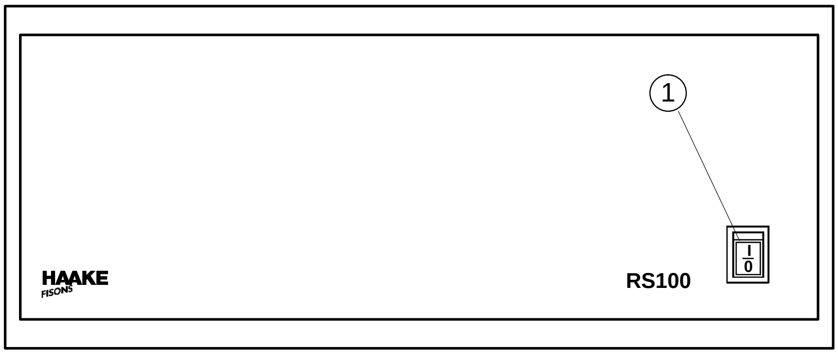
   high air pressure (> 2,5 bar)
   → high stability for highly viscous products, however, there is a higher internal friction of the air bearing

   recommended air pressure (≈ 2,5 bar)
   → sufficient stability for measurements in the stipulated range

   low air pressure (< 2,5 bar)
   → reduced weight bearing capacity and the possibility of normal force deflection
4. The air supply must have the following conditions:
   - no synthetic oil in the line
   - max. oil contents
     → 3 mg/m^3 air
   - dry air with a residual moisture < 40%
   - (air) consumption approx. 10 dm^3/minute
     (**Note!** 1 dm^3 = 1 thousandth of a cubic meter)

4.6 Starting

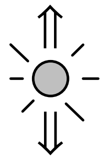
When all connections are made and the supply line are active, the measuring unit may be switched on via the control unit:



1 On- and Off-switch of the RS100 control unit in combination with the measuring system RS100

If the green light in the measuring head is on, the RS100 is ready for operation.

Measuring Head of the RS100



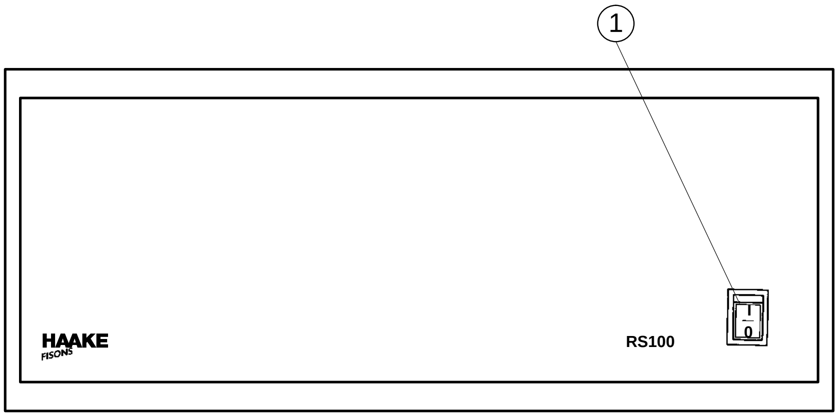
← green light indicates that the unit is operational

If both arrows are on permanently → the RS100 is not operational as the air supply is not active. (Pressure of 2,5 bar must be set!)

If both arrows are flashing → this could indicate that the ambient conditions have not yet been achieved. The instrument could still be too cold (if set up in a cold room) or too warm (if set up adjacent to a radiator or subjected to sun light). Experience shows that the RS100 will adjust to room temperature within one hour and is then operational.

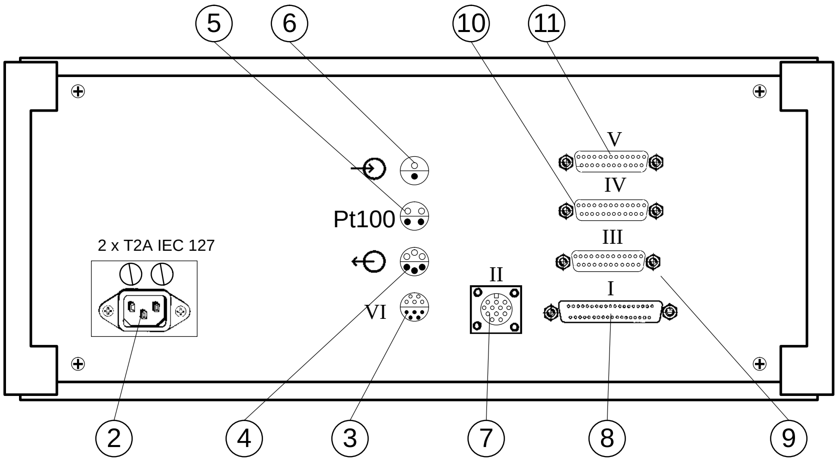
5. Measuring System - Functional and Operational Elements

5.1 Control Box RS100 – Front



1 RS100 On / Off Switch

5.2 Control Box RS100 – Rear



2 Mains connection with built-in fuses
(2 x T2A / 250V IEC 127)

3 (VI) – Control socket for liquid temperature control – Connection via socket VI for the cable of the temperature sensor.

4 External analog control connection for the circulator
In the liquid temperature control of sensor systems quite often a computer controlled temperature program for the test temperature is demanded. This socket is used to establish a connection via cable No. 222–0626 for controlling an external circulator which can then be used to maintain a value fixed with an analog setting or for receiving a measurement signal of the actual value at the measuring plate in order to enable a follow-up control of the circulator.

⑤ Additional external temperature sensor connection – Pt100.

⑥ External voltage input for analog signals of 0 - 10V for measurement signals of external device e.g. pressure, temperature, high voltage or the pH value.

⑦ (II) – Connection for cable II from the RS100.
For transferring the measurement signal from the drive shaft of the RS100 measuring system: torque angle and angular velocity.

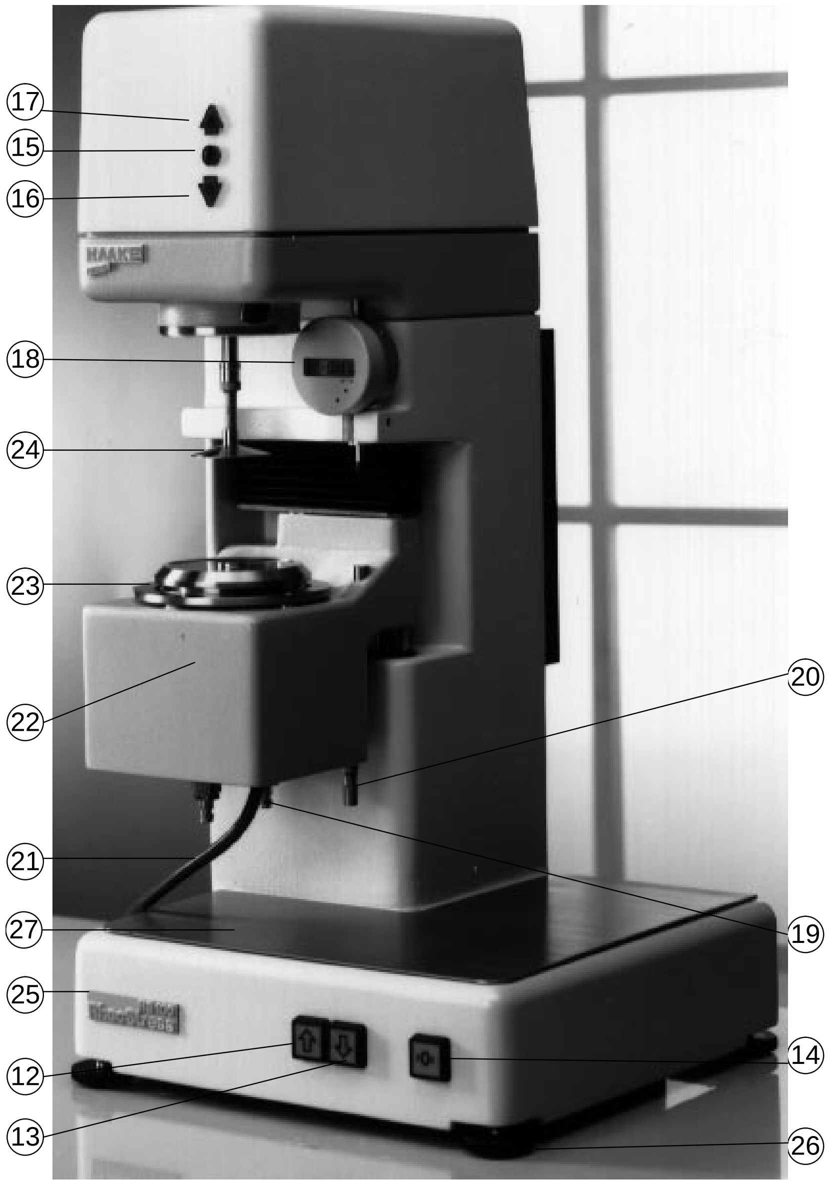
⑧ (I) – Socket for the main connection cable (I) to the Measuring instrument RS100.

⑨ (III) – RS232 interface connection to computer via cable No. 222–0563.

⑩ (IV) – Additional RS232 interface connection for additional external device such as e.g. the high temperature measuring device TC500.

⑪ (V) – RS232 interface connection (control) e.g. for connecting a serial printer with RS232C interface.
Connection cable: Order No. 222-0563.

5.3 Measuring System RS100 – Front



⑫ ⇧ pushbutton for raising the measuring platform via the electric lift
The measuring platform is raised until the distance between the sensor and the plate is zero or the set value reached.
Reference: Automatic Gap Setting

⑬ ⇩ pushbutton for lowering the measuring platform.
The measuring platform is lowered and stops approx. 2.5 cm above the end position. From this point on it can only be moved by pressing the pushbuttons ⑬ and ㉕

(safety button on the left side of the RS100) until it finally reaches the position where it can be pivoted to the side for the exchange of sensors.

With this **Safety Feature** the possible risk of injuring the hand of the operator while lowering the platform is prevented.
The lift moves with its highest speed upwards when key ⑫ is pressed or downwards when key ⑬ is pressed.

Pressing both of these keys simultaneously will stop the lifting movement at once.

If, however, these keys (one at the time) are pressed together with key ㉕ «Safety Button» the lift will move up ⑫ + ㉕ or down ⑬ + ㉕ with its lowest speed of approx. 50 micron per sec.

! **The button ㉕ can be pressed at any time to stop the lift when it is outside the safety area!**

⑭ >0< pushbutton for zero point setting
This pushbutton is used for resetting the digital distance display ⑱ to 0.000 mm.

⑮ Green LED display ●
This LED, when on, indicates the operational condition of the RS100; i.e. when the correct operating pressure (2.5 bar) for the air bearing of has been reached. The measuring shaft is held in the correct position without the influence of falsifying forces, both radially and axially, from below or from above.

⑯ Red LED display ⬇ «Safety Display»
This LED, when on, indicates that the measuring shaft is axially deflected downwards. In this case a test cannot be started, and the lift will not move → **automatic electronic self-locking device of the sensor system.** Only when the disturbance or malfunction indicated by the red light is corrected will the platform move again.

⑰ Red LED display ⬆ safety display

The measuring shaft is subjected to an upward axial deflection. The test cannot be started under this condition, and the lift will not move → **automatic electronic self-locking device of the sensor system.**

If both red arrows ⬆ and ⬇ are illuminated, ⑯ and ⑰, the operating pressure is below 2.5 bar, the RS100 is not in an operating state.

☞ If after completing measurement with a sensor cone and plate or parallel plate and the plate has to be separated from the cone or from the plate in order to clean these items, it may happen that the adhesion of the substance requires a separating force so strong that the air bearing might get damaged during the forceful separation.
As to protect the air bearing, the lift for the platform cannot be moved downward. In the case, the measuring plate (measuring cup) and thereafter the Rotor (plate or cone) have to be separated in order to move the measuring plate together with the released cone downward free of tension.
The measuring cone or the upper plate can then be pushed sideways by hand and separated from the measuring plate.

! **Caution!**

If both red arrows, ⬆ and ⬇ ⑯ and ⑰, are flashing, a more serious fault is the cause. The RS100 measuring system should be checked by the HAAKE Service Dept. if this fault repeats itself after a longer warm up time at an ambient temperature of 20 – 23°C.

⑱ Digital distance display
The measuring gap can be set to any desired value with an accuracy of 1/1000 mm.
This digital display is permanently supplied with power from a built-in battery. This advantageous in that a set value (zero point) remains stored even when the instrument is switched off. The battery capacity is sufficient for approx. 14 days. If it is completely discharged, it may take some minutes for the display to become visible after the RS100 is switched on.

Fault display `E --05`

The fault display above is caused by one of the following situations:

1. The spindle lift is moved too quickly.

2. Interference voltage or pulses occur.

3. Moisture has formed inside the LCD display due to extreme temperature fluctuations.

Remedy:

The display can be switched off and on again by pressing a key situated behind the display face (through the hole) with a pointed instrument.
If condition 3. is the cause of the fault, switch the display off for 2 hours.

(19) Temperature control nozzles
They are part of the liquid temperature control unit integrated into the platform.

a) for cone and plate or parallel plate sensor systems

b) for coaxial cylinder sensors

For the connection between circulator and temperature unit two types of hoses are available:

Accessories:

a) 2 x Viton hoses (1.5 m) with metal casing and quick-fit clutch. The max. allowable temperature for these special hoses is 200°C
Order No.: 222-0610 for 1 set of 2 hoses

b) 2 x Metal hoses (1.5) with outside insulation for a max. allowable operating temperature of 350°C
Order No.: 333-0294 for one hose; 2 hoses and adapter 002-3424 required

(20) Nozzle for cooling circuit
For air or water cooling; dia. of nozzle 10 mm. Hoses with a diameter of 8 - 9 mm may be attached. Perbunan hoses with an interior diameter of 8 mm seem to be best suited. They are stretchable enough to be forced over the nozzle, where they resume a perfect fit without becoming disengaged.

(21) Temperature sensor cable Pt100
The red cable is connected to the socket VI of the control box. The temperature control unit of the measuring plate contains a Pt100 double sensor which is pressed against the measuring plate by spring force. This allows optimal recording of the test sample's temperature.

(22) Measuring platform
The measuring platform can accommodate different types of temperature control units.

The following temperature control units (TE) are available:

- TE for standard cone and plate or parallel plate sensors for temperatures up to +350°C (Order No.: 222-0609)
- TE for high temperature cone and plate or parallel plate sensors, electrically heated up to 500°C (Order No.: 222-0614)
- TE for cylinder sensors ∅ 40 mm for temperatures up to +200/350°C (Order No.: 222-0615)
- TE for cylinder sensors ∅ 10/20 mm for temperatures up to +200/350°C (Order No.: 222-0628)

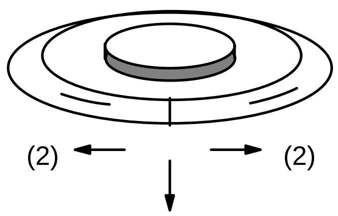
  Further units are currently being developed and are available on request.

When the measuring platform is in its bottom position (lowest limit switch position), it can be pivoted to the right. This feature allows the exchange of temperature control units and also the assembly of extra long measurement cones and plates and last not least, the exchange of high temperature sensor systems is simplified.

! **Please bear in mind! Complete the final phase of lowering only in the two hand control mode.**

On the bottom side of the measuring platform in center position there is a hexagon socket screw safeguarded against falling out. This screw is used to secure the temperature control unit.

The temperature control unit is positively positioned on by two trunnions of different diameters. The temperature control unit has to be fitted onto these pins without using force and should than be seated on three ma-



Adjust plate with its vertical mark to the front and move downward (1) against spring pressure and turn clockwise. Horizontal mark (2) now shows to the front. Plate is properly fixed in place. Turning the plate counter-clockwise will also insure proper seating of the plate.

chined flats of the measuring platform in this position it is secured against becoming disengaged by means of the hexagon screw mentioned above.

In order to be able to remove the temperature control unit from the measuring platform, the hexagon socket screw has to be loosened first. The red Pt100 cable (21) is integral part of the temperature control unit and has to be unplugged from the control unit of the RS100.

(23) Measuring plate (for receiving the test substance)
In its standard version the measuring plate is made from brass which has a high heat distribution ability. An Armoloy coating (ATC) of the brass plate ensures high chemical and mechanical durability. The various plates can be quickly exchanged by means of a bayonet fitting. There are three positions in the exchange of plates. First of all the plate is pressed straight downward against the spring force of the temperature sensor and then turned to either side. Turning the plates by 60° ensures proper seating.

(24) Rotor with shaft and quick-fit coupling

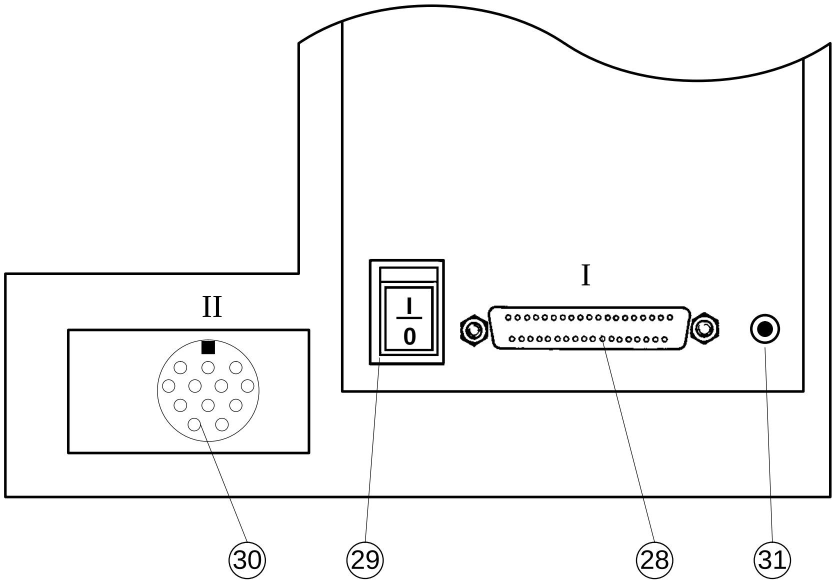
(25) Safety pushbutton – in the bottom portion on the left of the RS100
This pushbutton must be depressed in combination with other keys for certain functions which require special caution i.e. danger of injuries. As both hands are required to effect the movement such danger is excluded.

(26) Adjustable feet
All four adjustable feet (3 rubber feet and 1 metal foot), can be screwed up or down to arrive at complete level conditions.

Precise adjustment can be carried out using the spirit level directly underneath the measuring platform which is used to level the RS100 with the help of the adjustable feet i.e. screws (26).

(27) Base plate
The base plate can easily be removed for cleaning purposes.

5.4 Measuring System RS100 – Rear



(28) Connection I to control unit

(29) On/off switch for measuring gap light

(30) Connection II to control unit

(31) Air connection
The RS100 has to be supplied with clean air (free from moisture of any kind) with a pressure of 2.5 bar. (Special HAAKE Filter Unit No. 222-1211) A compressor for generating this pressure is available as option.

6. Sensor Systems

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

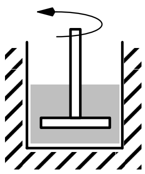
b. Cone - Plate / Plate - Plate Sensor Systems

- Cone - Plate with various opening angles and radii
- Plate - Plate with various radii and gap widths

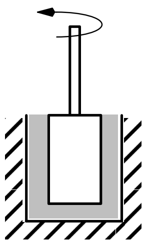
Out of these numerous possibilities, HAAKE supplies the following systems:

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

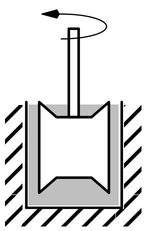
These sensors cover the majority of desired applications whereby special sensor systems are developed and made available in close cooperation with customers requiring such special sensor systems.



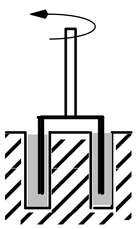
Immersion Disc
ISO 2555



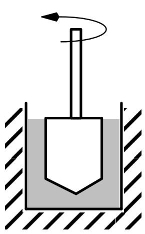
Immersion Cylinder
ISO 2555



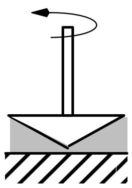
Coaxial Cylinder
DIN 53018



Coaxial Cylinder
DIN 54453



Coaxial Cylinder
DIN 53019



Cone-Plate
Combinations

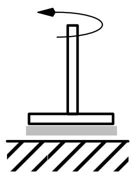


Plate-Plate
Combinations

System Factors

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

$$\text{Viscosity } \eta = \frac{\text{Shear Stress } \tau}{\text{Shear Rate } \dot{\gamma}}$$

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-rheometer 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 predetermination 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 τ is proportional to the torque 'Md' and to a characteristic geometry factor, which at HAAKE is identified as 'A' (shear stress factor).

$$\tau = \text{Md} \cdot \text{A}$$

A high torque or a high 'A'-factor 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 depending on the geometry used which at HAAKE is identified as 'M' (shear rate factor):

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

A high angular velocity Ω or a high value of 'M' means also a high shear rate $\dot{\gamma}$. High 'M' values stand for very small gaps.

If, for instance, highly liquid samples are to be measured one needs sensor systems with a small 'A'-factor (large shearing surface) and large 'M'-value. The most simple method to measure highly viscous products is by employing sensor systems with a small 'M'-factor (large measuring gap) and a large 'A'-factor (small shearing surface).

Measuring Ranges

Once the geometry- and system-factors are determined, the measurement range for each measurement unit can be calculated.

τ - Range

The shear stress measuring range for these sensor systems results from the measurement geometry mentioned and from the presetting range of the torque 'Md' from 1 - 10^5 μNm or 1 - 5 · 10^5 μNm for the RS100 with 5 Ncm. Now it is quite simple to estimate the smallest and largest shear stress value for a sensor system by using the following calculations:

$$\tau_{min} = Md_{(min)} \cdot A$$

$$\tau_{max} = Md_{(max)} \cdot A$$

The values in the diagram are based on the following assumptions:

$$\tau_{min} = 1 \cdot 10^{-6} = 1\ \mu Nm$$

$$\tau_{max} = 500000 \cdot 10^{-6} = 50\ \mu Nm$$

Additional data for the different sensor systems can be taken from the table for the particular sensor systems.

$\dot{\gamma}$- Range

Similar to the shear stress range there is also a meaningful measuring range for the shear rate $\dot{\gamma}$ (in CS measurements $\dot{\gamma}$ is measured and in CR measurements the shear stress τ is measured). Depending on the speed (angular velocity) which can be preset and measured, the following correlations can be derived:

$$\dot{\gamma}_{min} = \Omega_{(min)} \cdot M$$

$$\dot{\gamma}_{max} = \Omega_{(max)} \cdot M$$

The problem now is the fact that in the CS range speed is a calculated parameter π = dδ/dt which is depending on the measuring time and viscosity of the sample. In the CR range only meaningful and feasible values con be preset which, however, often could mean a limitation of the range.

Owing to this fact the basic values of the diagrams are based on the following values:

$n_{(min)}$ – 10^{-2} min^{-1} $\equiv \Omega = 2 \cdot \pi \cdot 10^{-2}/60 = 0{,}01047$ rad/s

$n_{(min)}$ – 500 min^{-1} $\equiv \Omega = 2 \cdot \pi \cdot 500/60 = 52{,}36$ rad/s

In the CS mode the range 10^{-6} to 500 min^{-1} and in the CR mode the range 10^0 min^{-1} to 500 min^{-1} is technically feasible.

η - Range

The viscosity measuring range is derived from the τ - and $\dot{\gamma}$-range in accordance with the Newtonian conditional equation

$$\eta = \tau/\dot{\gamma}$$

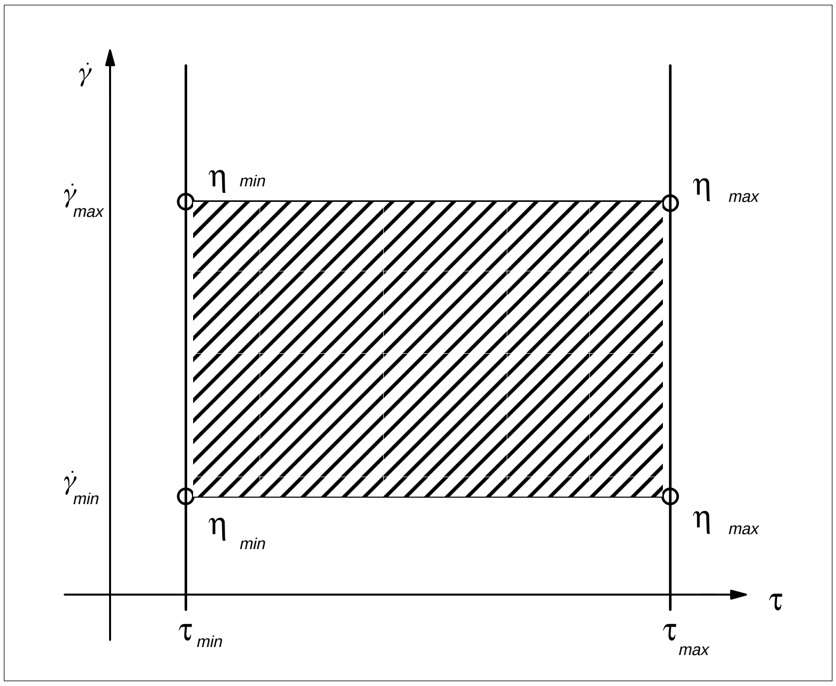
smallest viscosity at max. shear rate
$\rightarrow \eta$ (min) = τ (min) / $\dot{\gamma}$(max)

smallest viscosity at min. shear rate
$\rightarrow \eta$ (min) = τ (min) / $\dot{\gamma}$(min)

largest viscosity at min. shear rate
$\rightarrow \eta$ (max) = τ (max) / $\dot{\gamma}$(min)

largest viscosity at max. shear rate
$\rightarrow \eta$ (max) = τ (max) / $\dot{\gamma}$(max)

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.



6.1 Cylinder Sensor Systems

From the theoretical possibilities of a measurement geometry for cylinder sensor systems HAAKE selected different concepts without, however, excluding other alternatives.

6.1.1 Cylinder Sensor Systems according to DIN 53019 / ISO 3219

Application

These sensor systems were originally introduced for polymer dispersions. However, 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.

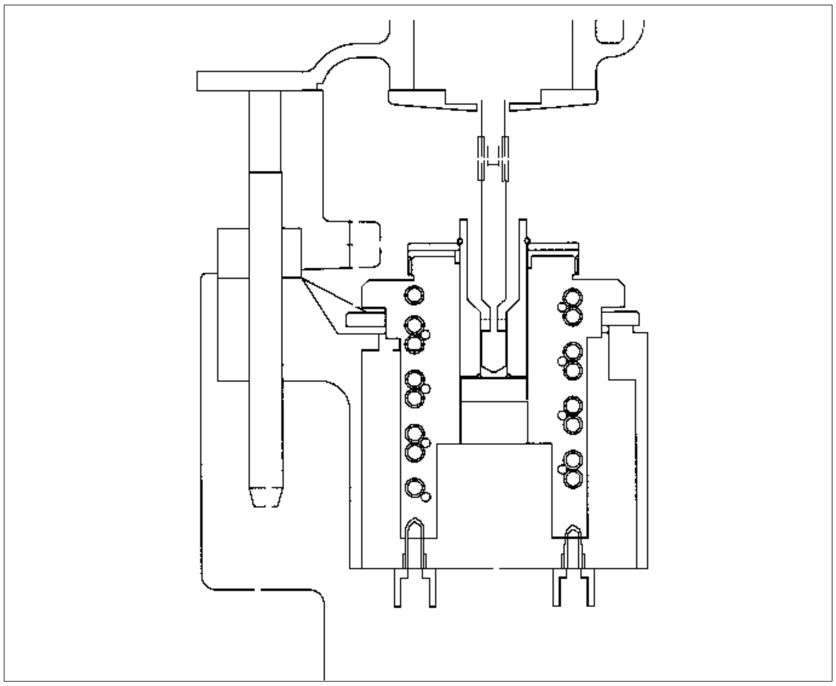
Temperature Control Unit

The sensor system calls for a temperature vessel TEF/Z48 with an interior diameter of ∅ 48 mm for the 40 mm beaker and/or a temperature vessel TEF/Z28 with an interior diameter ∅ 28 mm for the 20 mm and 10 mm beakers. The temperature vessel is inserted from above into the swung out measurement table of the Rheometer and then fixed in place. A calibration is not required as the parts have been adapted in the factory regarding the three calibrated seating points. In order to start the temperature controlling action the inserted vessel (or jacket) is connected with hoses to a heating bath and circulator. The beakers are held in place by means of a clamping ring ∅ 48 mm = 002-4937 and ∅ 28 mm = 002-4936 and a slight screwing movement.

For the **temperature range up to 200°C** Viton hoses (222-0610) with a quick coupling can be employed.
As thermal liquid in the temperature range between -50°C and 30°C usually alcohol or water with a portion of antifreeze is employed. In the temperature range from 5°C to 90°C distilled water can be used and for temperatures above the boiling point of water a suitable thermal oil must be used. (A table of suitable oils can be requested from HAAKE !)

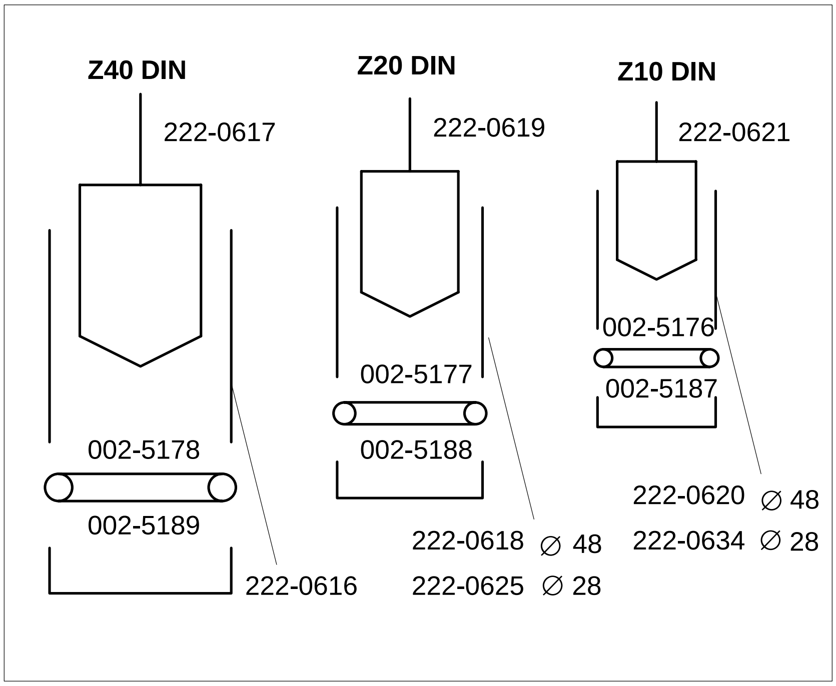
For the temperature range of **100°C up to 350°C** metal hoses (333-0294 → 1 hose = 150 cm) together with the adapters (002-3424) have to be used. Silicone oils or other suitable liquids can be used with them.

Cylinder Sensor System Z10



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 differ only in the rotor diameter as all other parameters are pre-determined by means of proportionality factors or ratios.

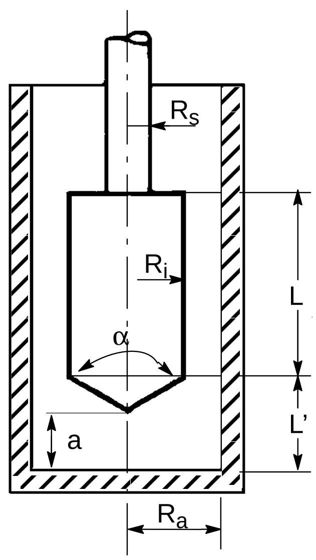


If, for the systems Z20 and Z10, the temperature vessel ∅ 40 (222-0615) is used, the thick-walled beakers Z20/∅ 48 (222-0618) and Z10/∅ 48 (222-0620) can be employed. However, these beakers are only suitable for temperatures near room or ambient temperatures, as, due to the thick walls, only limited temperature control is possible.

Geometry:

Sensor systems according to the standards mentioned have the following peculiarity in that all measurements are relative to the radius of the rotor. With the determination of proportionality factors (ratios) a sensor system can be standardized which means that measuring results achieved with different instruments may be compared. The peculiarity of the standard is the definition radii relationship R_a / R_i (radius of the beaker as compared to the radius of the rotor) and thus of the shearing or deformation of a sample per rotation or movement.
In DIN 53019 the following values are defined which are confined and partly extended in ISO 3219.

The geometry of the sensor systems is defined in proportionality factors as shown below:



DIN 53019 / ISO 3219 A 2

$$\frac{R_a}{R_i} = 1{,}0847$$

$$\frac{R_s}{R_i} = 0{,}3$$

$$\frac{L}{R_i} = 3$$

$$\frac{L'}{R_i} = 1$$

α = 120° (2,094 rad)

The expressions have the following meaning:

δ = R_a/R_i
L = Length of Cylinder
R_i = Radius interior cylinder (Outside ∅ of the rotor/2)
R_a = Radius outside cylinder (Interior ∅ of the beaker/2)
R_s = Radius of the rotor shaft
a = Distance
α = Angle of the cone
L' = Distance of the rotor

Calculation Equations

Once the geometry of a cylinder sensor system is defined, the calculation equations can be developed. If it is assumed that the characteristic measurement parameters are linked via system factors, the following equations can be defined:

Shear Stress τ:

The shear stress τ is proportional to the torque 'Md' and a stress factor 'A'.

$$\boxed{\tau = A \cdot Md}$$ (Stress Factor * Torque)

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

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

with R_i = Radius of 'Rotor'
L = Length of Rotor
C_L = Resistance Coefficient
(C_L = 1,1 according DIN 53019)

Shear Rate $\dot{\gamma}$:

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

$$\boxed{\dot{\gamma} = M \cdot \Omega}$$ (Shear Factor * Angular Velocity)

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

The factor M is calculated:

$$M = \frac{1 + \delta^2}{\delta^2 - 1}$$

δ^2 = Radii Relationship R_a/R_i

δ^2 = 1,0845 (DIN 53019)

Deformation γ:

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

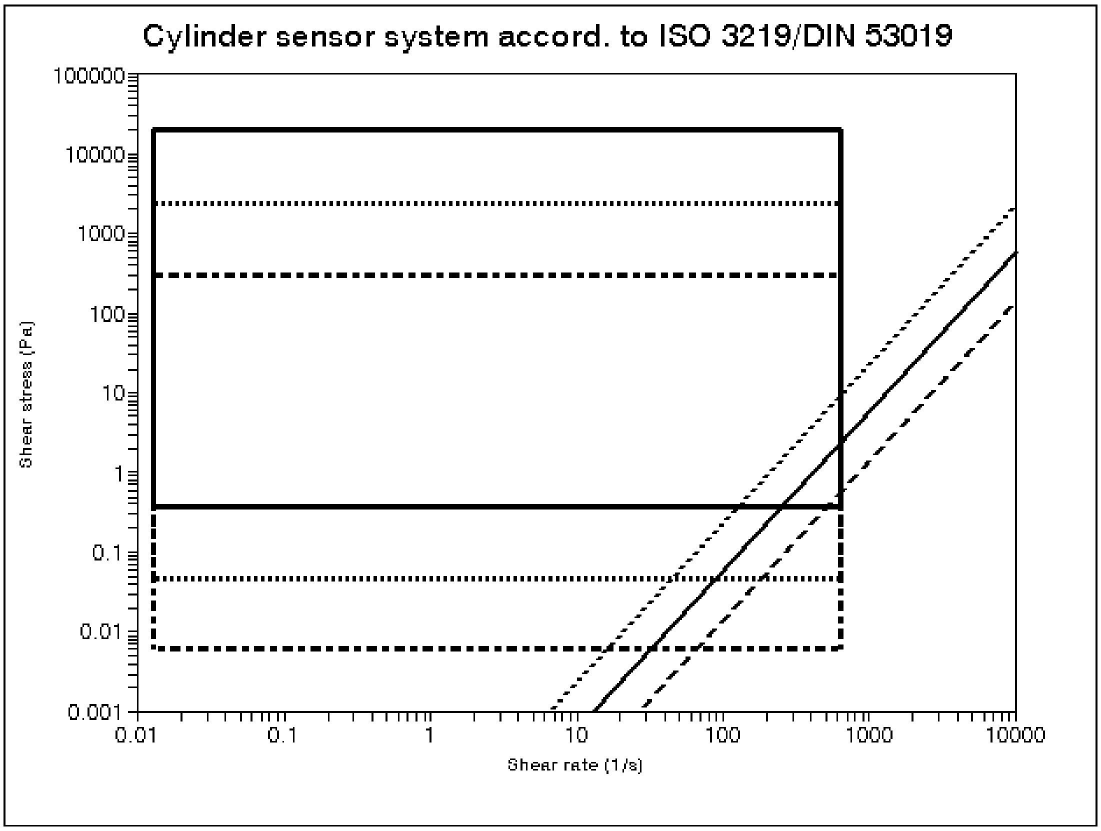
$\gamma = M \cdot \varphi$ with φ = Torsion angle rad

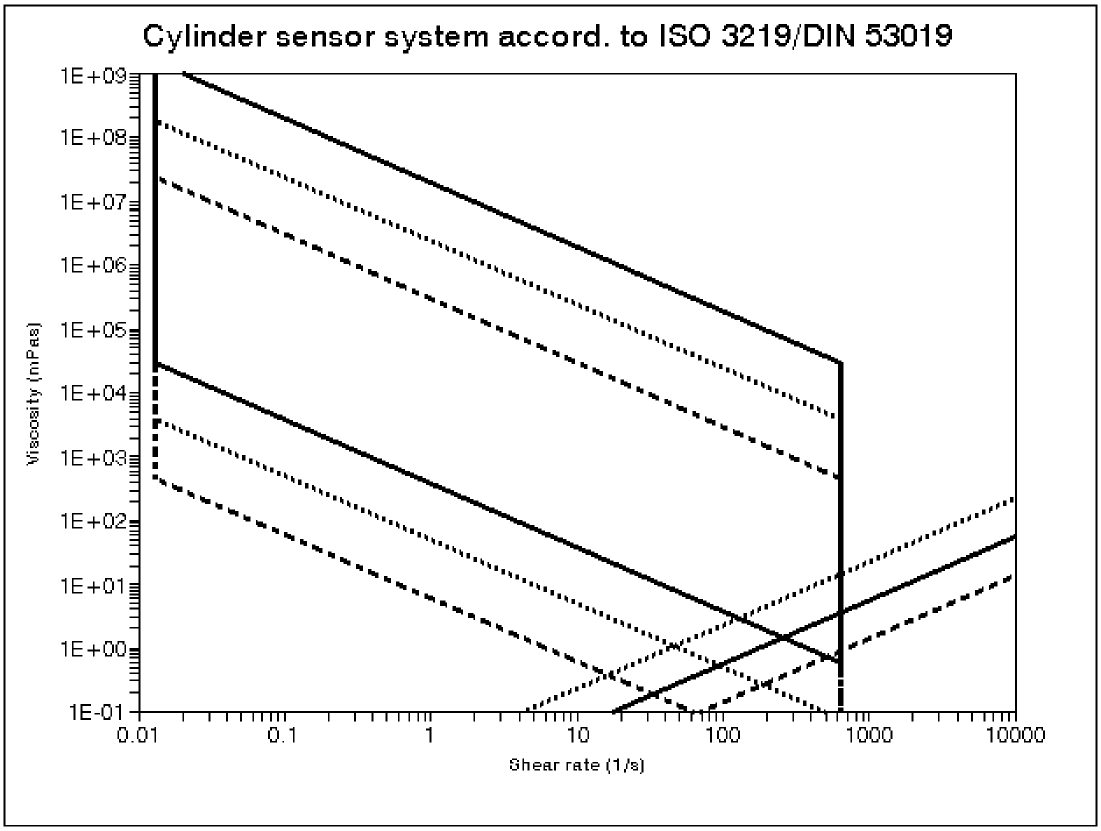
Filling Volume:

The standard lists the equation for the calculation of the filling volume as follows: $V = 8{,}17 \cdot R_i^3$ (cm^3)

Cylinder Sensor System according DIN 53019/ISO 3219

Sensor System	Z10 DIN	Z20 DIN	Z40 DIN
Steel Rotor Order No.:	222-0621	222-0619	222-0617
Inertia I (10^{-6} kg m^2)	0.4	2.9	51.9
Mass m (g)	37.4	62.0	207.0
Material: DIN No.:	1.4112	1.4112	1.4112
Aluminum Rotor Order No.:	———	222-1278	222-1279
Inertia I (10^{-6} kg m^2)	———	1.05	18.0
Mass m (g)	———	29.3	80.0
Material: Aluminum/Armaloy	———	+	+
Radius R_i (mm)	5.0000	10.000	20.000
± Δ R_i (mm)	0.0015	0.002	0.004
Length l (mm)	15	30	60
± Δ l (mm)	0.015	0.03	0.06
Distance a (mm)	2.1	4.2	8.5
Beaker TEF/Z48 222-0615	222-0620	222-0618	222-0616
Beaker TEF/Z28 222-0628	222-0634	222-0635	———
Radius R_a (mm)	5.425	10.850	21.70
± Δ R_a (mm)	0.002	0.0029	0.004
Material: Brass/Armaloy	AlMgSi1	AlMgSi1	AlMgSi1
Gasket 200°C Order No.:	002-5176	002-1291	002-1290
Gasket 350°C Order No.:	002-5187	002-5188	002-5189
Radii Relationship R_a/R_i	1.0847	1.0847	1.0847
Measuring Gap	0.425	0.85	1.7
Sample Volume	1.0	8.2	65.4
Perm. Temperature max. °C	200	200	200
System Factors			
A (Pa/Nm)	385800	48230	6030
± Δ A %	0.2	0.2	0.2
M (s^{-1}/rad s^{-1})	12.29	12.29	12.29
± Δ M %	0.8	0.5	0.4


Cylinder sensor system accord. to ISO 3219/DIN 53019
Shear stress (Pa)
100000
10000
1000
100
10
1
0.1
0.01
0.001
0.01
0.1
1
10
100
1000
10000
Shear rate (1/s)


Cylinder sensor system accord. to ISO 3219/DIN 53019
Viscosity (mPas)
1E+09
1E+08
1E+07
1E+06
1E+05
1E+04
1E+03
1E+02
1E+01
1E+00
1E-01
0.01
0.1
1
10
100
1000
10000
Shear rate (1/s)

6.1.2 Disposable Cylinder Sensor Systems according to DIN 53019 / ISO 3219

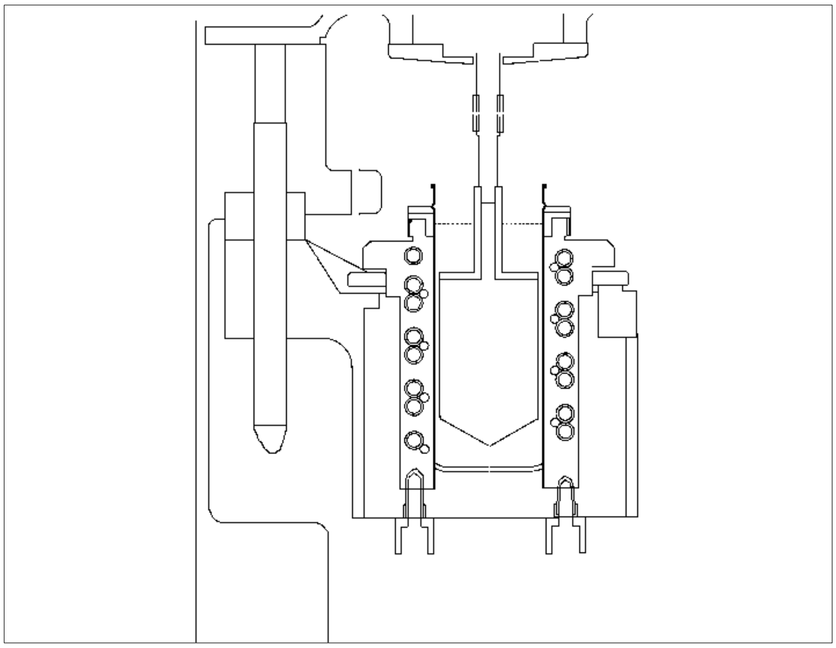
Application

Quite often the cleaning of a sensor system is the most time-consuming part of a measurement; or samples are tested which after a certain length of time cannot be removed from the sensor system. For these applications it is sensible to use beakers which are used for one measurement only. Aluminum beakers are used for this purpose, they don't have the precision as far as the dimensions are concerned and are therefore less expensive.

Temperature Vessel

The sensor system Z-E43 DIN is designed for the temperature vessel ∅ 48 (222-0615) and Z-E25 DIN for the temperature vessel ∅ 28 (222-0628). Due to practical reasons (Handling, Heat Expansion, Temperature Transfer Resistance) these disposable beakers should only be employed for the temperature range 5 to 60°C. Applications at temperatures above this value (up to 200°C) or below (down to -50°C) are possible without facing any safety risks, however, considerable measurement faults and difficult handling might be expected. In the recommended range (5 to 60°C) it is understood that predominantly distilled water is used as thermal liquid.

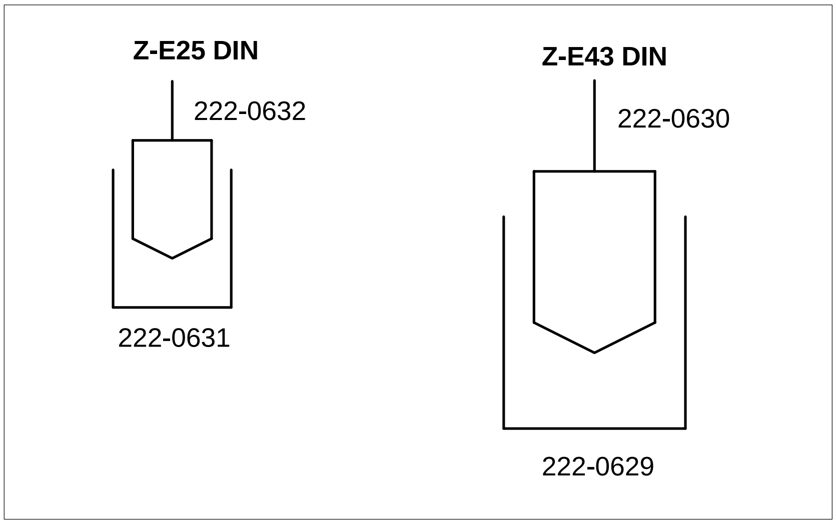
Cylinder Sensor System Z-E43 DIN



Sensor Systems Z-E DIN

The sensor systems Z-E DIN comprise of a rotor and a disposable beaker each in accordance with DIN 53019 / ISO 3219, which is inserted from above and fixed in place with a small screwing movement.

The sensor systems differ in the diameter of their rotors.



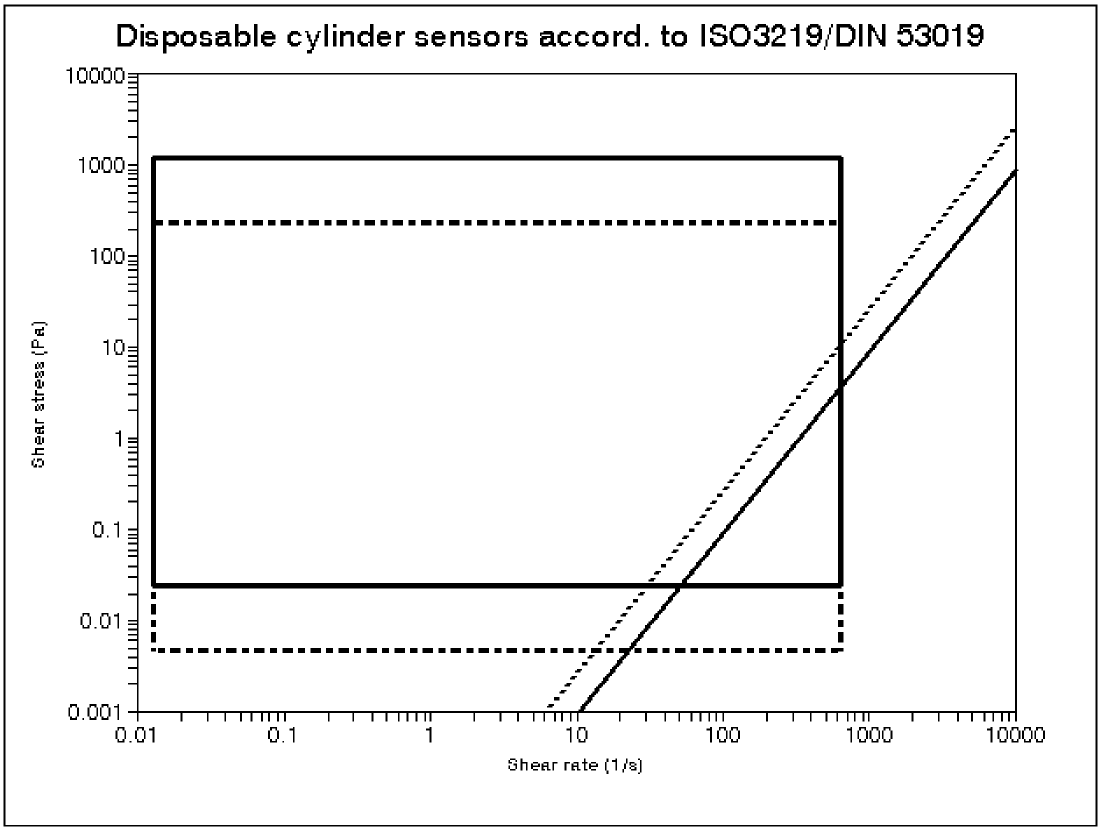
Note!

Geometry → Refer to page 32

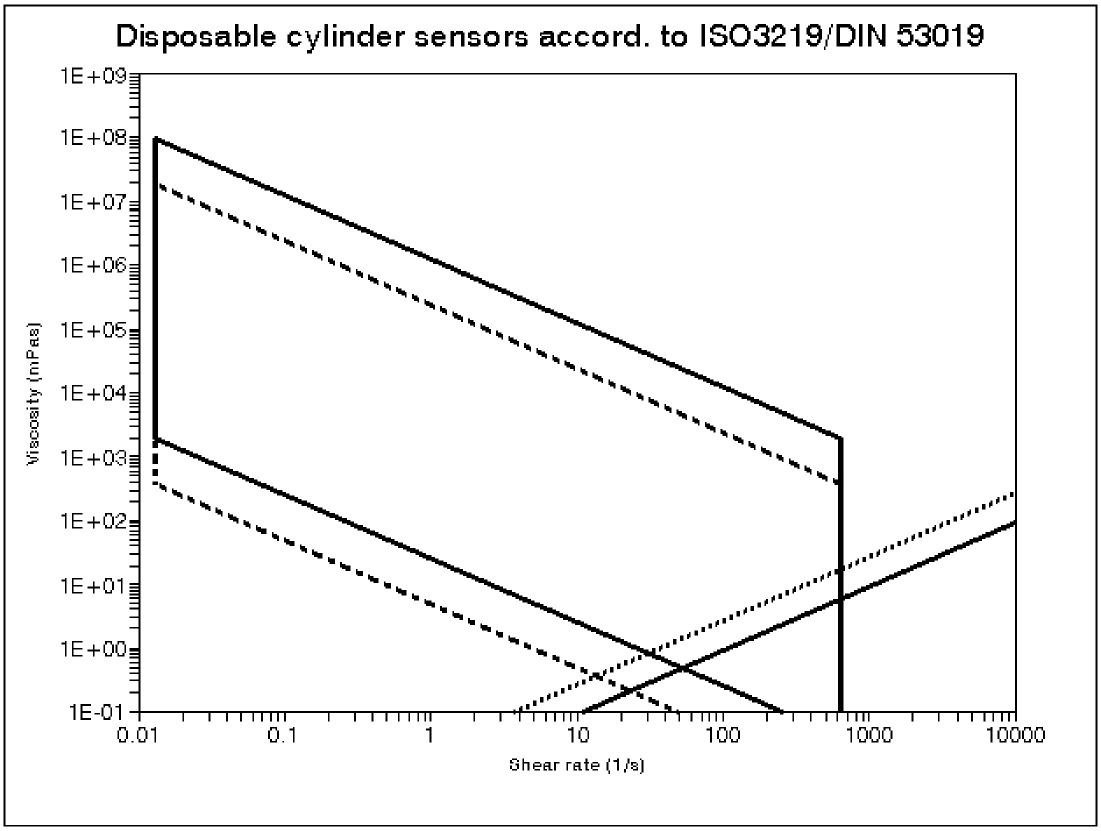
Calculation Equations → Refer to page 33

Disposable Cylinder Sensor System according to DIN 53019/ISO 3219

Sensor System	Z-E25 DIN	Z-E43 DIN
Rotor Order No.:	222-0632	222-0630
Radius R_i (mm)	12.54	21.66
± Δ R_i (mm)	0.002	0.004
Length l (mm)	37.6	65.0
± Δ l (mm)	0.03	0.06
Distance a (mm)	5.3	9.2
± Δ l (mm)	0.0053	0.0092
Inertia I (10^{-6} kg m^2)	8.0	71.7
Mass m (g)	94.0	237.0
Material: Steel No.:	DIN 1.4112	DIN 1.4112
Beaker TEF/Z48 222-0615	________	222-0629
Beaker for TE 28 222-0628	222-0631	________
Radius R_a (mm)	13.6	23.5
± Δ R_a (mm)	0.05	0.05
Material: Aluminum	+	+
Radii Relationship R_a/R_i	1.0847	1.0847
Measuring Gap (mm)	1.06	1.84
Sample Volume (cm^3)	16.1	83.0
Perm. Temperature max. (°C)	200	200
System Factors		
A (Pa/Nm)	24460	4746
± Δ A %	0.2	0.2
M (s^{-1}/rad s^{-1})	12.3	12.3
± Δ M %	5	3



Disposable cylinder sensors accord. to ISO3219/DIN 53019
Shear stress (Pa)
10000
1000
100
10
1
0.1
0.01
0.001
0.01
0.1
1
10
100
1000
10000
Shear rate (1/s)



Disposable cylinder sensors accord. to ISO3219/DIN 53019
Viscosity (mPas)
1E+09
1E+08
1E+07
1E+06
1E+05
1E+04
1E+03
1E+02
1E+01
1E+00
1E-01
0.01
0.1
1
10
100
1000
10000
Shear rate (1/s)

6.1.3 Cylinder Sensor System according to DIN 53018

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 suitable for exact measurements. Temperature programs are not recommended as the air bubble at the bottom will change its volume with the the temperature which in turn might also have an effect on the front surface influence.

Temperature Vessel

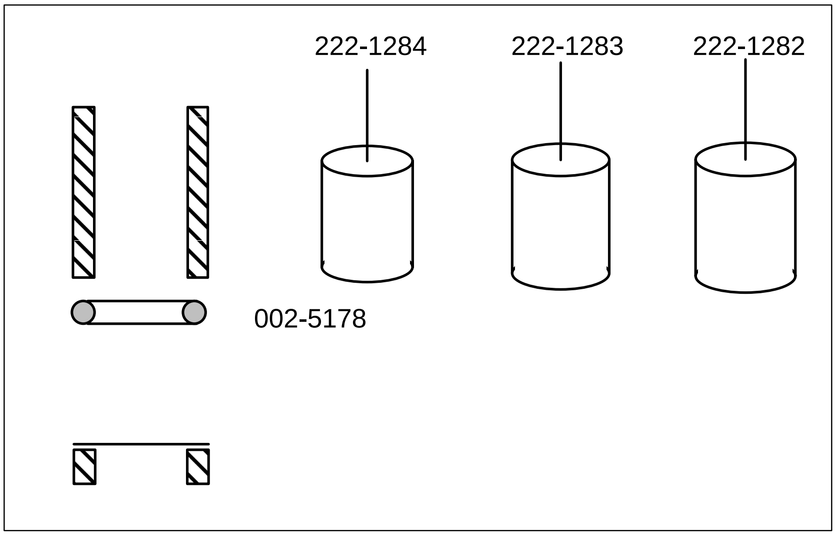
The sensor system requires a temperature vessel TEF/Z48 with an interior diameter of ∅ 48 mm for 40 mm beakers. The temperature vessel is inserted from above into swung out measurement table of the Rheometer and fixed in place. A calibration is not required as the parts have been adapted in the factory regarding the three calibrated seating points. In order to start the temperature controlling action the inserted vessel (or jacket) is connected with hoses to a heating bath and circulator. The beakers are held in place by means of a clamping ring and a slight screwing movement.

For the temperature range up to 200°C Viton hoses (222–0610) with quick coupling can be used.

As thermal liquid in the temperature range between -50°C and 30°C usually alcohol or water with a portion of antifreeze is employed. In the temperature range from 5°C to 90°C distilled water can be used and for temperatures above the boiling point of water a suitable thermal oil must be used. (A table of suitable oils can be requested from HAAKE !)

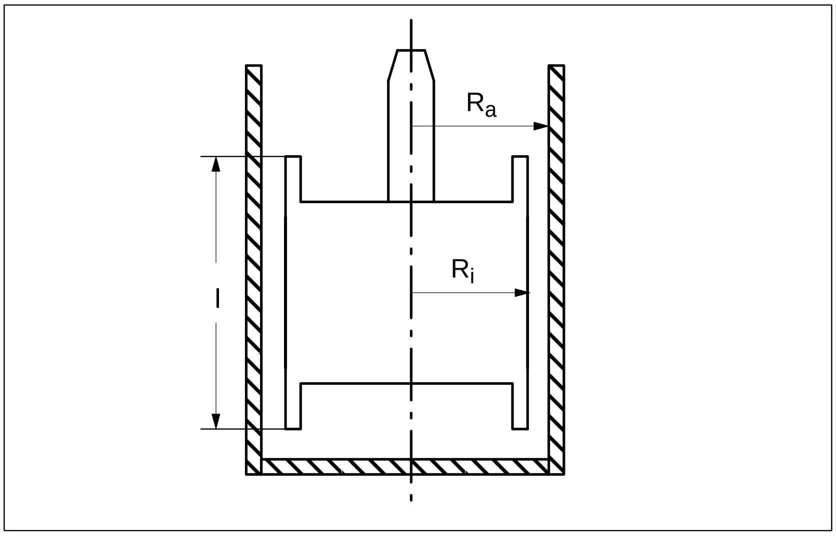
Sensor System Z

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



Geometry

The geometry of this sensor system corresponds to DIN 53018 and has only a small influence on the measurement results with regard to front surface effects.



Calculation Equations:

Once the geometry of a cylinder sensor system is defined, the calculation equations can be developed. If it is assumed that the characteristic measuring parameters are linked via system factors, the following equations can be defined:

Shear Stress τ:

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

$\tau = A \cdot Md$ (Stress Factor * Torque)

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

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

Shear Rate $\dot{\gamma}$:

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

$\dot{\gamma} = M \cdot \Omega$ (Shear Factor * Angular Velocity)

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

The factor 'M' is calculated as follows:

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

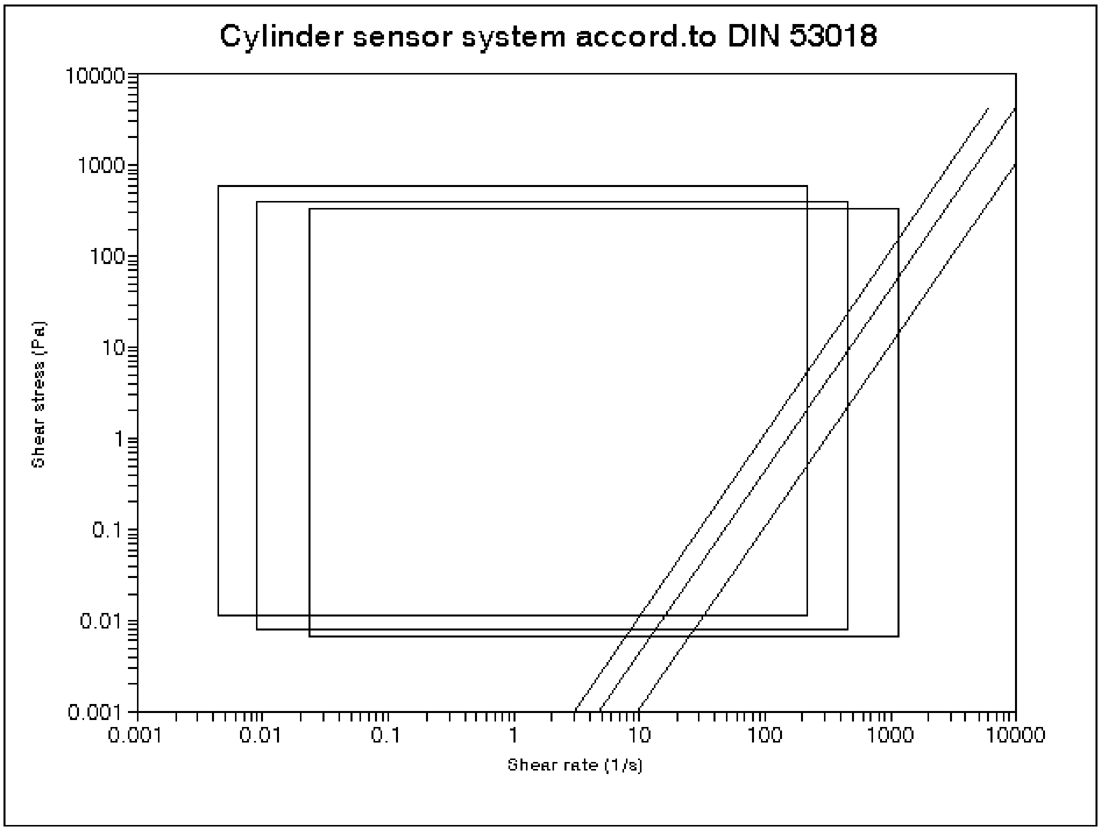
Deformation γ:

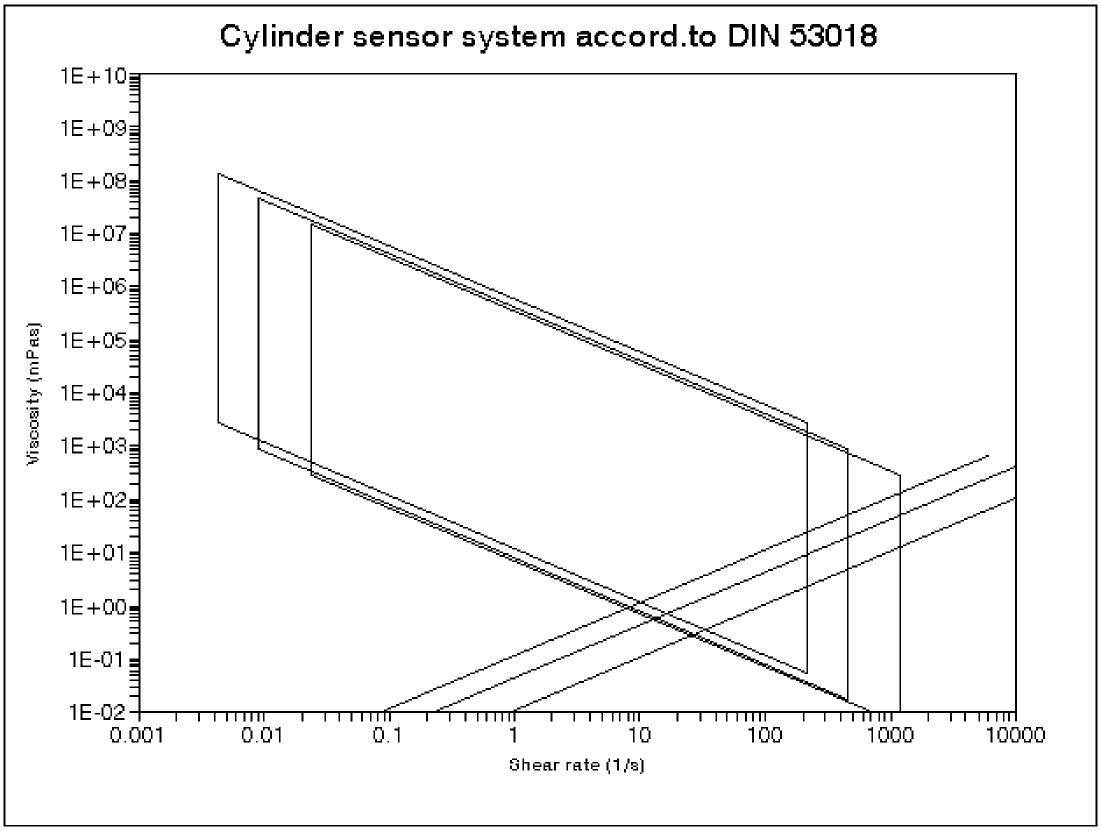
The deformation γ is linearly linked to the angular deflection and the geometry of a sensor system.

$\gamma = M \cdot \varphi$ with φ = Torsion angle rad

Cylinder Sensor System according DIN 53018

Sensor System	Z31	Z38	Z41
Steel Rotor Order No.:	222-1284	222-1283	222-1282
Inertia I (10^{-6} kg m^2)	19.0	38.0	48.0
Mass m (g)	121.0	152.0	169.0
Material: Steel DIN No.:	1.4112	1.4112	1.4112
Alumium Rotor Order No.:	222-1287	222-1286	222-1285
Inertia I (10^{-6} kg m^2)	6.6	12.40	16.4
Mass m (g)	50.0	61.0	67.0
Material: Aluminum/Armaloy	+	+	+
Radius R_i (mm)	15.720	19.010	20.710
± Δ R_i (mm)	0.0020	0.004	0.004
Länge l (mm)	55	55	55
± Δ l (mm)	0.03	0.03	0.03
Distance a (mm)	8.1	8.1	3.0
Beaker f. TEF/Z48 222-0615	222-1288	222-1288	222-1288
Radius R_a (mm)	21.700	21.700	21.700
± Δ R_a (mm)	0.004	0.004	0.004
Material: Brass/Armaloy	+	+	+
Gasket (200°C) Order No.:	002-5178	002-5178	002-5178
Radii Relationship R_a/R_i	1.3804	1.1415	1.0478
Measuring Gap	5.98	2.69	0.99
Sample Volume (cm^3)	52.0	33.0	14.0
Perm. Temperatur max. °C	200	200	200
Calculation Factors			
A (Pa/Nm)	11710	8010	6750
± Δ A (%)	0.5	0.5	0.5
M (s^{-1}/rad s^{-1})	4.21	8.60	22.40
± Δ M (%)	0.5	0.5	0.5


Cylinder sensor system accord.to DIN 53018
Shear stress (Pa)
10000
1000
100
10
1
0.1
0.01
0.001
0.001
0.01
0.1
1
10
100
1000
10000
Shear rate (1/s)


Cylinder sensor system accord.to DIN 53018
Viscosity (mPas)
1E+10
1E+09
1E+08
1E+07
1E+06
1E+05
1E+04
1E+03
1E+02
1E+01
1E+00
1E-01
1E-02
0.001
0.01
0.1
1
10
100
1000
10000
Shear rate (1/s)

6.1.4 Double Gap Cylinder Sensor accord. DIN 54453

Application

This sensor system is preferred for low viscous liquids (<1000 mPa · 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 was standardized as DIN 54453 for measurements with low viscous glues.

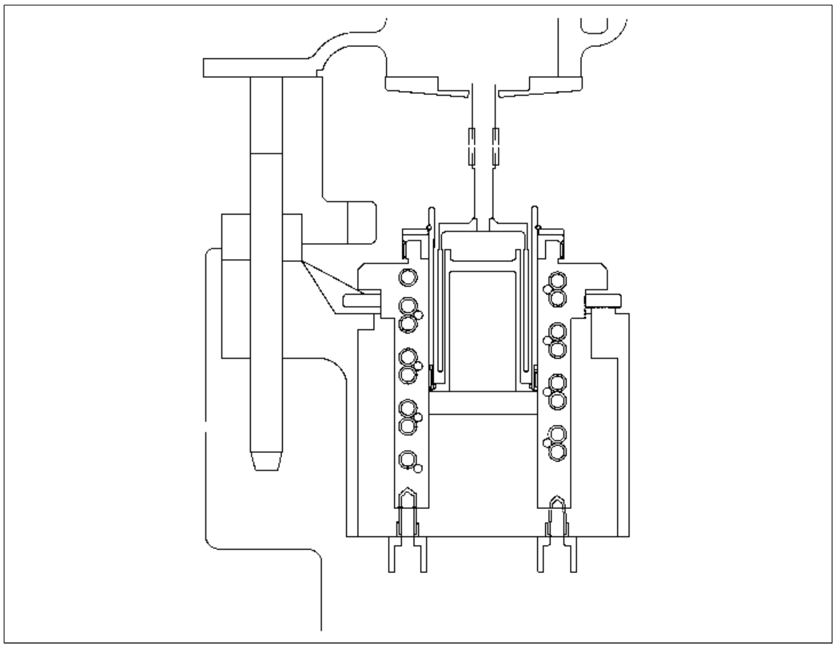
Temperature Vessel

The sensor system requires a temperature vessel TEF/Z48 with an interior diameter of ∅ 48 mm for 40 mm beakers. The temperature vessel is inserted from above into swung out measurement table of the Rheometer and fixed in place. A calibration is not required as the parts have been adapted in the factory regarding the three calibrated seating points. In order to start the temperature controlling action the inserted vessel (or jacket) is connected with hoses to a heating bath and circulator. The beakers are held in place by means of a clamping ring and a slight screwing movement.

For the temperature range up to 200°C Viton hoses (222–0610) with quick coupling can be used.

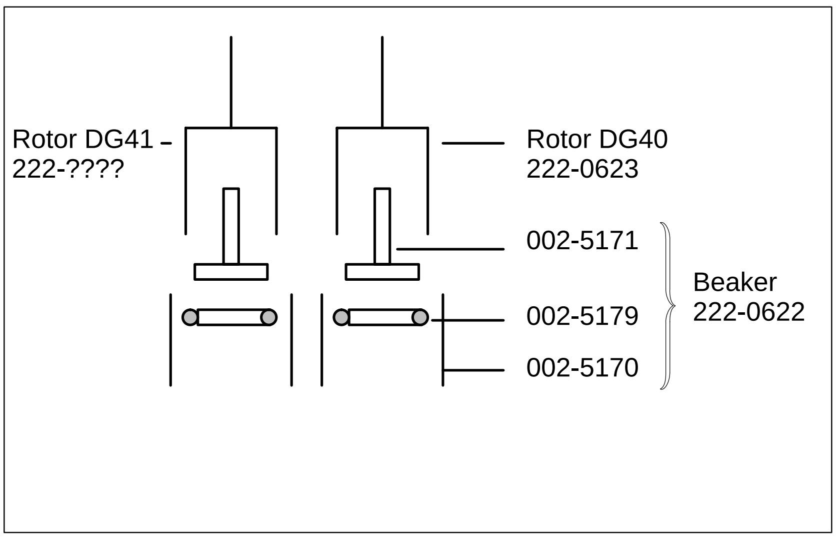
As thermal liquid in the temperature range between -50°C and 30°C usually alcohol or water with a portion of anti-freeze is employed. In the temperature range from 5°C to 90°C distilled water can be used and for temperatures above the boiling point of water a suitable thermal oil must be used. (A table of suitable oils can be requested from HAAKE !)

Cylinder Sensor System DG



Sensor System DG

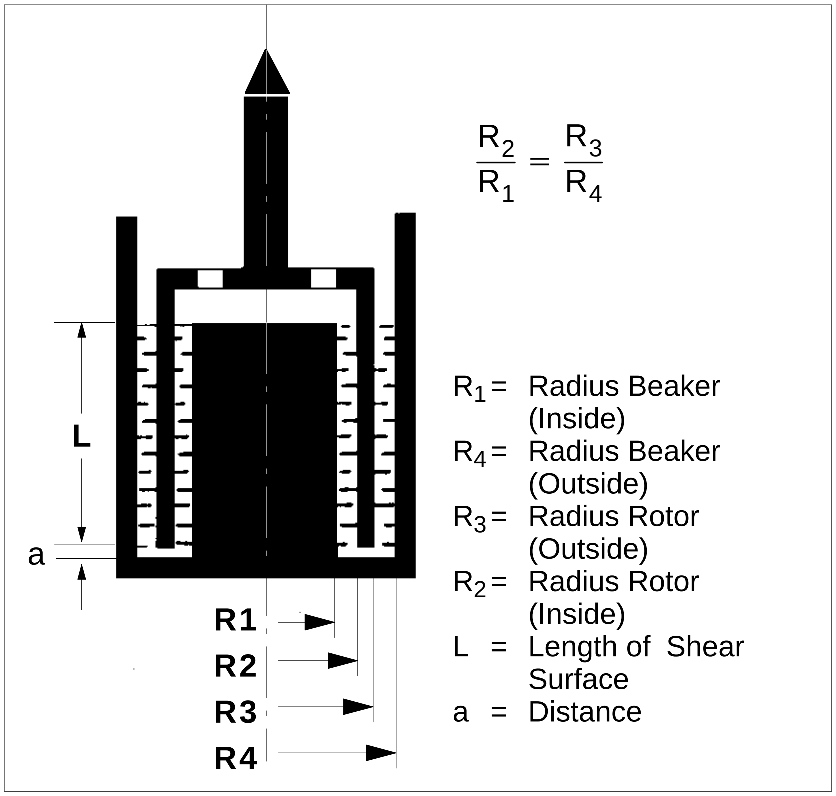
The sensor system DG is made up of a dismountable beaker and either the bell-shaped rotor DG40 or DG41.



The temperature vessel should not be employed for temperatures above 200°C and must have a sufficiently long heating period so that the inner part of the beaker, which is not temperature controlled, can adopt the requested 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 can be expected.



Calculation Equations:

Once the geometry of a cylinder sensor system is defined, the calculation equations can be developed. If it is assumed that the characteristic measuring parameters are linked via system factors, the following equations can be defined:

Shear Stress τ:

The shear stress τ is proportional to the torque 'Md' and to a stress factor i.e. stress factor 'A'.

$$\tau = A \cdot Md$$ (Stress Factor * Torque)

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

$$A = \frac{1}{2 \cdot \pi \cdot L \cdot (R_2^2 + R_3^2)}$$

Shear Rate $\dot{\gamma}$:

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

$$\dot{\gamma} = M \cdot \Omega$$ (Shear Factor * Angular Velocity)

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

The factor 'M' is calculated as follows:

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

Ra = R4, R2

Ri = R3, R1

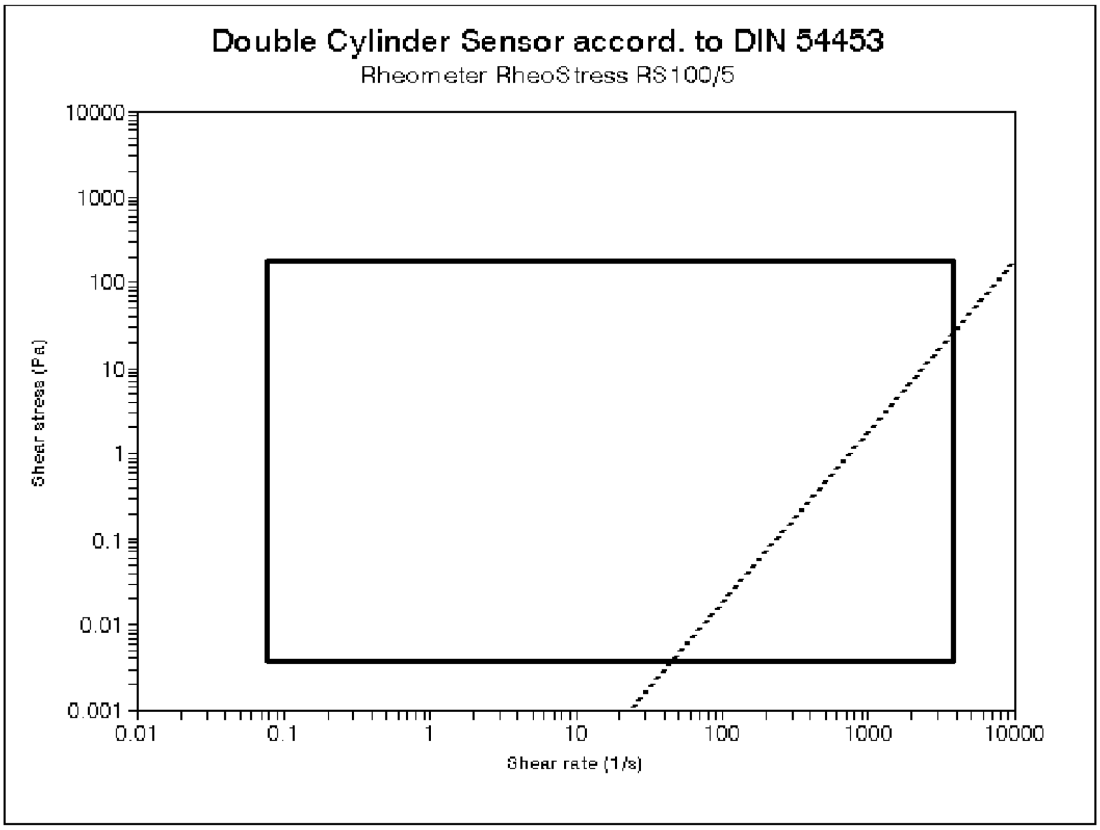
Deformation γ:

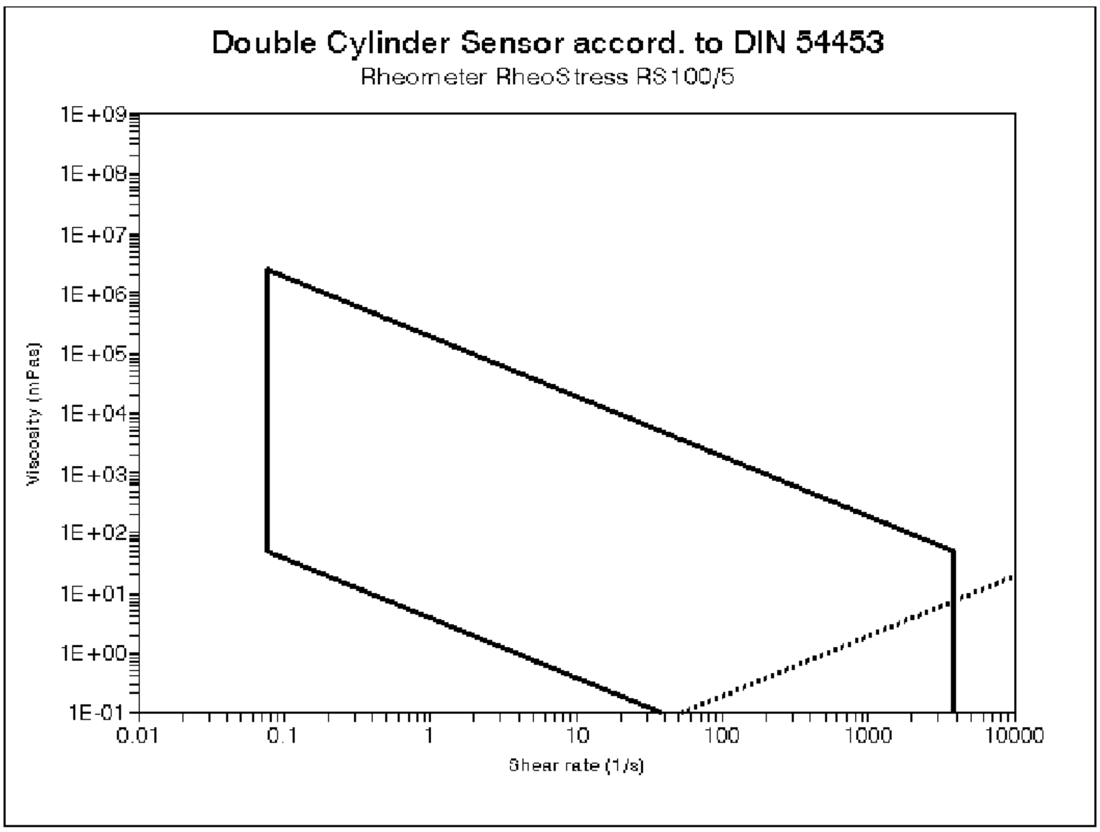
The deformation γ is linearly linked to the angular deflection and the geometry of a sensor system.

$\gamma = M \cdot \varphi$ with φ = Torsion angle rad

Double Gap Cylinder Sensor System according to DIN 54 453

Sensor System	DG40	DG40	DG41
Rotor Order No.:	222-0623	222-1277	222-1309
Radius R_1 (mm)	16.6	16.6	17.75
$\pm \Delta R_1$ (mm)	0.004	0.004	0.004
Radius R_2 (mm)	18	18	18
$\pm \Delta R_2$ (mm)	0.004	0.004	0.004
Radius R_3 (mm)	20	20	21.4
$\pm \Delta R_3$ (mm)	0.004	0.004	0.004
Length l (mm)	55	55	55
$\pm \Delta$ l (mm)	0.006	0.006	0.006
Distance a (mm)	5.1	5.1	0.9
Inertia I (10^{-6} kg m^2)	44.18	15.60	26.56
Mass m (g)	151.0	67.0	67.0
Material:	Steel DIN 1.4112	Aluminum	Aluminium
Beaker f. TEF/Z48 222-0615	222-0622	222-0622	222-1310
Radius R_a (mm)	21.7	21.7	21.7
$\pm \Delta R_a$ (mm)	0.00434	0.00434	0.00434
Material: Alum./Armaloy	+	+	Steel 18/8
Gasket 200°C Order No.:	002-1293	002-1293	222-1293
Radii Relationship R_a/R_i	1.085	1.085	1.014
Meas. Gap R_4-R_3 (mm)	1.7	1.7	10.3
Meas. Gap R_2-R_1 (mm)	1.4	1.4	0.25
Sample Volume (cm^3)	23.7	23.7	4.2
Perm. Temperature max. °C	200	200	200
System Factors			
A (Pa/Nm)	3997	3997	3701
$\pm \Delta$ A %	0.1	0.1	0.1
M (s^{-1}/rad s^{-1})	13.33	13.33	72.67
$\pm \Delta$ M %	1	1	6


Double Cylinder Sensor accord. to DIN 54453
Rheometer RheoStress RS100/5
Shear stress (Pa)
10000
1000
100
10
1
0.1
0.01
0.001
0.01
0.1
1
10
100
1000
10000
Shear rate (1/s)


Double Cylinder Sensor accord. to DIN 54453
Rheometer RheoStress RS100/5
Viscosity (mPas)
1E+09
1E+08
1E+07
1E+06
1E+05
1E+04
1E+03
1E+02
1E+01
1E+00
1E-01
0.01
0.1
1
10
100
1000
10000
Shear rate (1/s)

6.2 Cone-Plate and Plate-Plate Sensor Systems

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.

Application

This sensor systems are predominantly used for measurements with highly viscous liquids and for difficult to clean samples with only a small sample volume. Their application is limited when the sample contains coarse particles and fiber strings, as a particle influence in the narrow gaps might falsify the measurement result.

Temperature Vessel

This sensor system requires the temperature vessel 222-0609 for liquid temperature control or the electrically heated temperature vessel 222-0614 or 222-1228. The temperature vessel is inserted from above into the swung out measurement table of the Rheometer and then fixed in place. A calibration is not required as the parts have been adapted in the factory regarding the three calibrated seating points. In order to start the temperature controlling action the inserted vessel (or jacket) is connected with hoses to a heating bath and circulator.

For the **temperature range up to 200°C** Viton hoses (222-0610) with quick coupling can be employed.

As thermal liquid in the temperature range between -50°C and 30°C usually alcohol or water with a portion of antifreeze is employed. In the temperature range from 5°C to 90°C distilled water can be used and for temperatures above the boiling point of water a suitable thermal oil must be used. (A table of suitable oils can be requested from HAAKE !)

For the **temperature range from 100°C to 350°C**, the electrically heated temperature control device or the standard model with metal hoses (333-0294 → 1 piece = 150 cm) together with the adapters (002-3424) should be used. Silicone oils or other suitable liquids may be employed as thermal liquids.

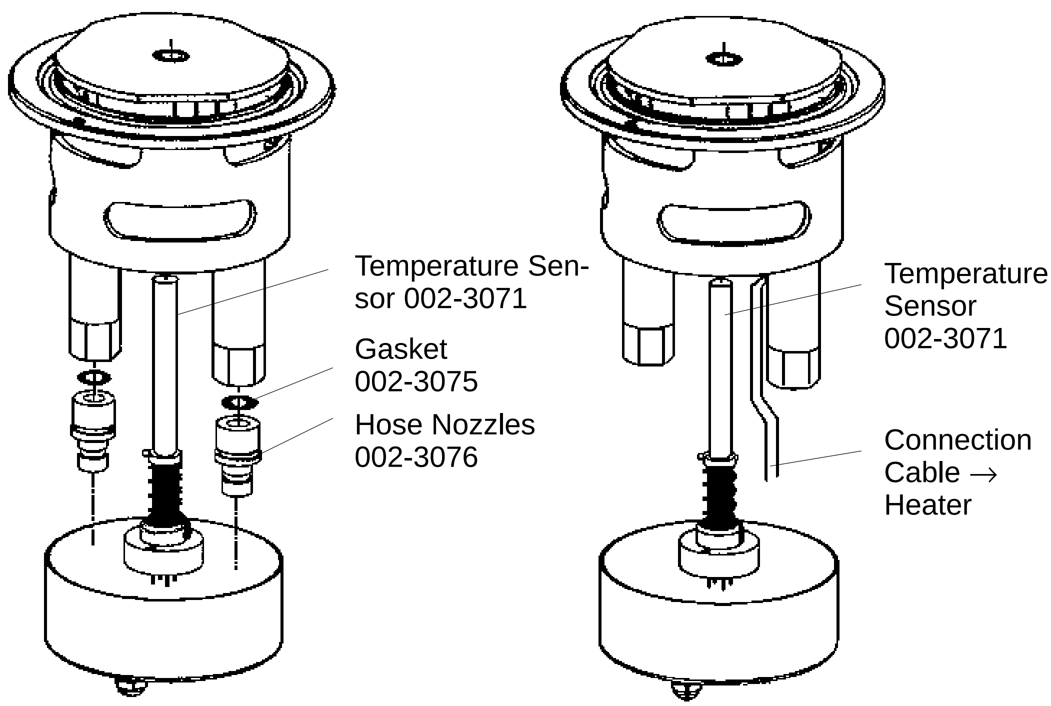
The electrically heated temperature vessel is connected to the control unit TC500 by means of the attached cables. The complete temperature control is handled by the computer in combination with the HAAKE software.

For measurements at temperatures above 80°C it is advisable to use at least the cover for the sample compartment (222-0608) for reducing the heat losses. Better still is the use sensor cones and sensor plates which feature a ceramic shaft with even less heat dissipation. As these special cones have a longer shaft, the extension for the distance gauge must be attached.

In order to minimize problems and mistakes through faulty filling it is strongly recommended to use exclusively sensor systems with identical diameters as for instance the cone C60/1 together with the measuring plate MP60 and the plate PP35 together with the measuring plate MP35.

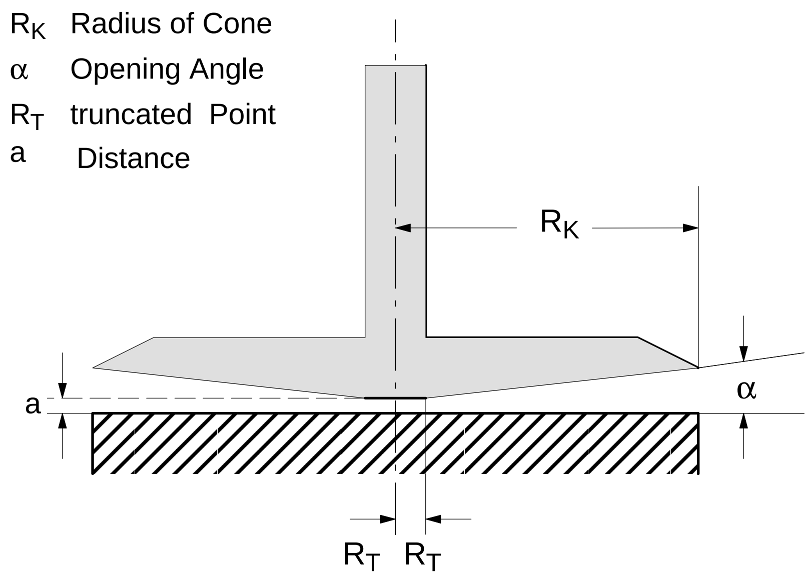
Liquid operated
Temperature Vessel for PK/PP

Electrically heated
Temperature Vessel für PK/PP



6.2.1 Cone-Plate Sensor Systems

The cone-plate sensor system is determined by the cone radius and the cone angles as defined in ISO 3219.



Owing to the fact that the uncertainty of viscosity measurements is strongly influenced by the geometry of the cone, all sensor cones are individually calibrated by HAAKE and the results entered in an accompanying certificate as shown in the example below.

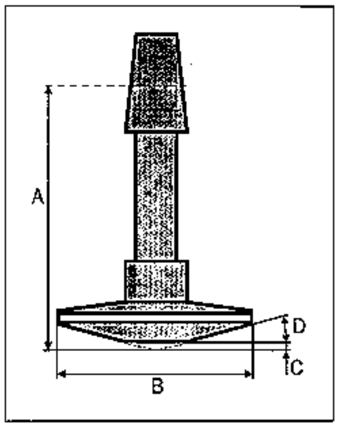
Zertifikat / Certificate HAAKE FISONS

Produkt	Typ	Sachnummer	Seriennummer
Rotor	RS100	222-0589	930001

Specimen

Shaft LengthA: 50
Diameter B: 50
Height of Point D: 2
Cone Angle D: 4

A-Factor: 763580000
M-Factor: 14,325



WUTTGE	04.05.93	Qualitätswesen / Quality control Gebr. HAAKE GmbH * Dieselstraße 4 * 7500 Karlsruhe 41 * Tel. (0721) 40940	
Unterschrift/Signature	Datum	Abteilung/Department	Index

Calculation Equations – Cone/Plate

With a known geometry of a cone-plate sensor system the system or sensor factors can be determined:

Shear Stress τ

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

$$\tau = A \cdot Md$$ (Stress Factor * Torque)

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

Shear Rate $\dot{\gamma}$

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

$$\dot{\gamma} = M \cdot \Omega$$ (Shear Factor * Angular Velocity)

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

The factor 'M' is calculated as follows:

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

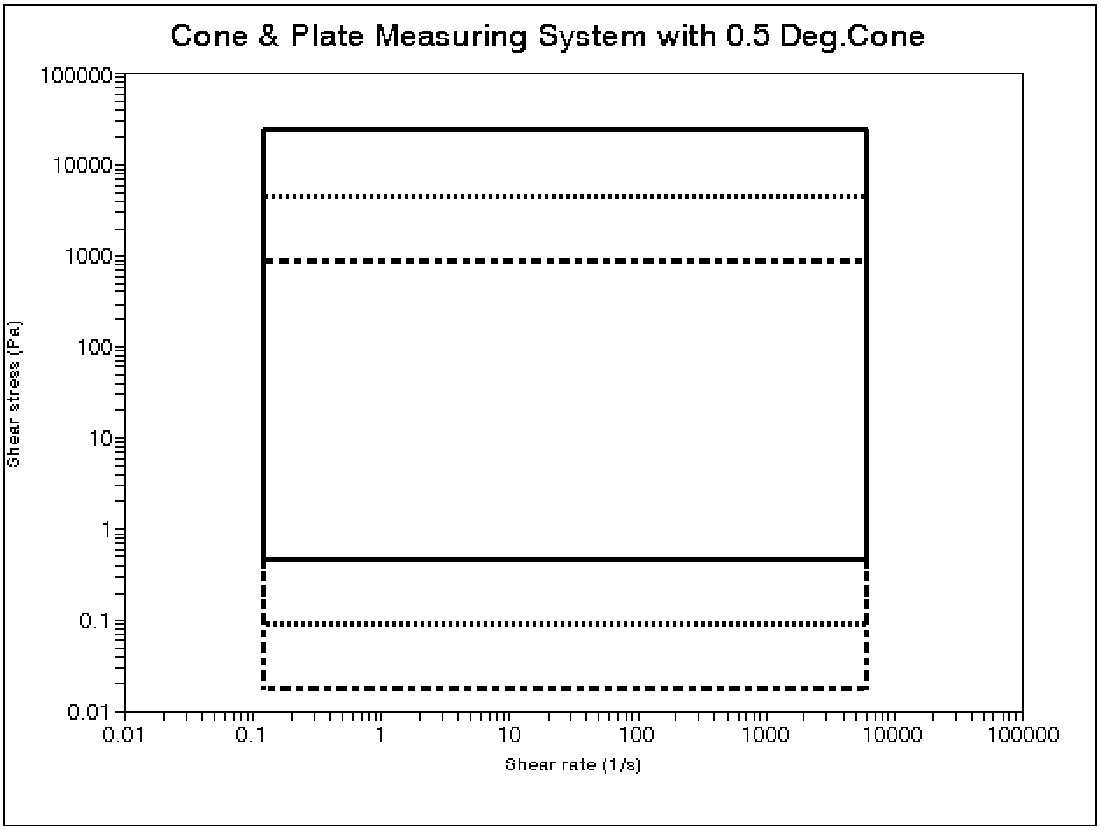
Deformation γ

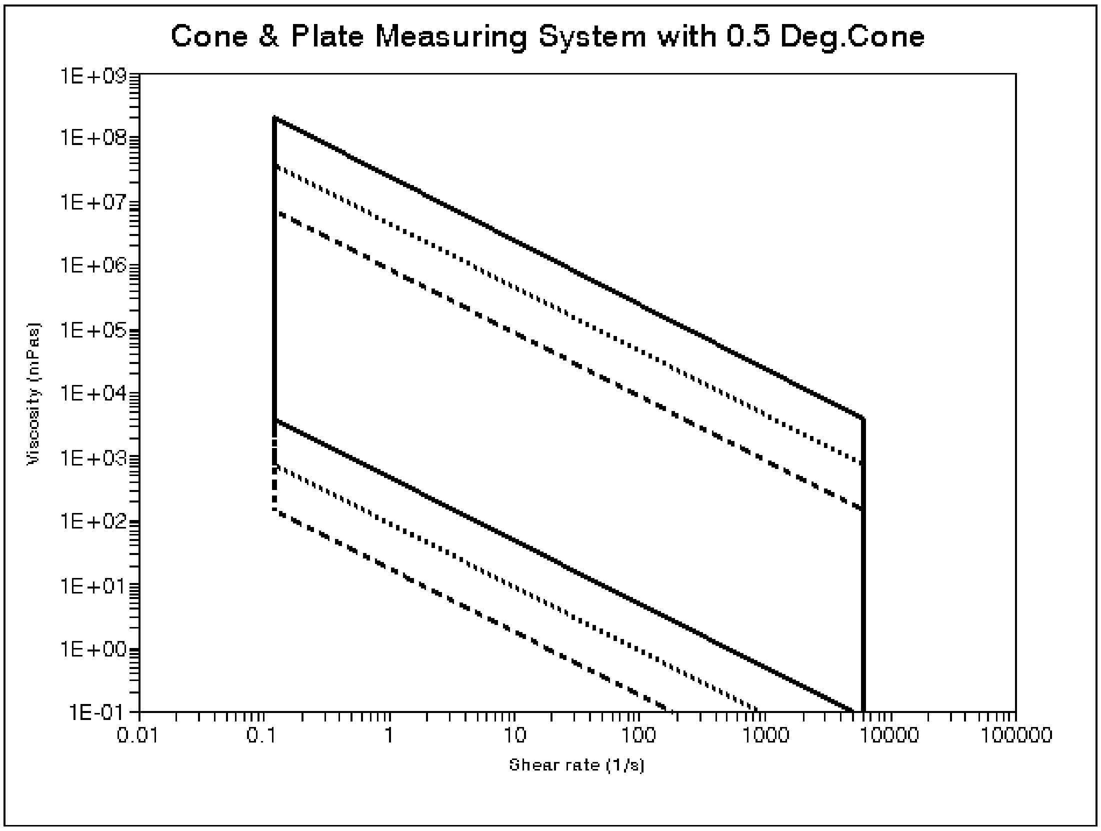
The deformation γ is linearly linked to the angular deflection and the geometry of a sensor system.

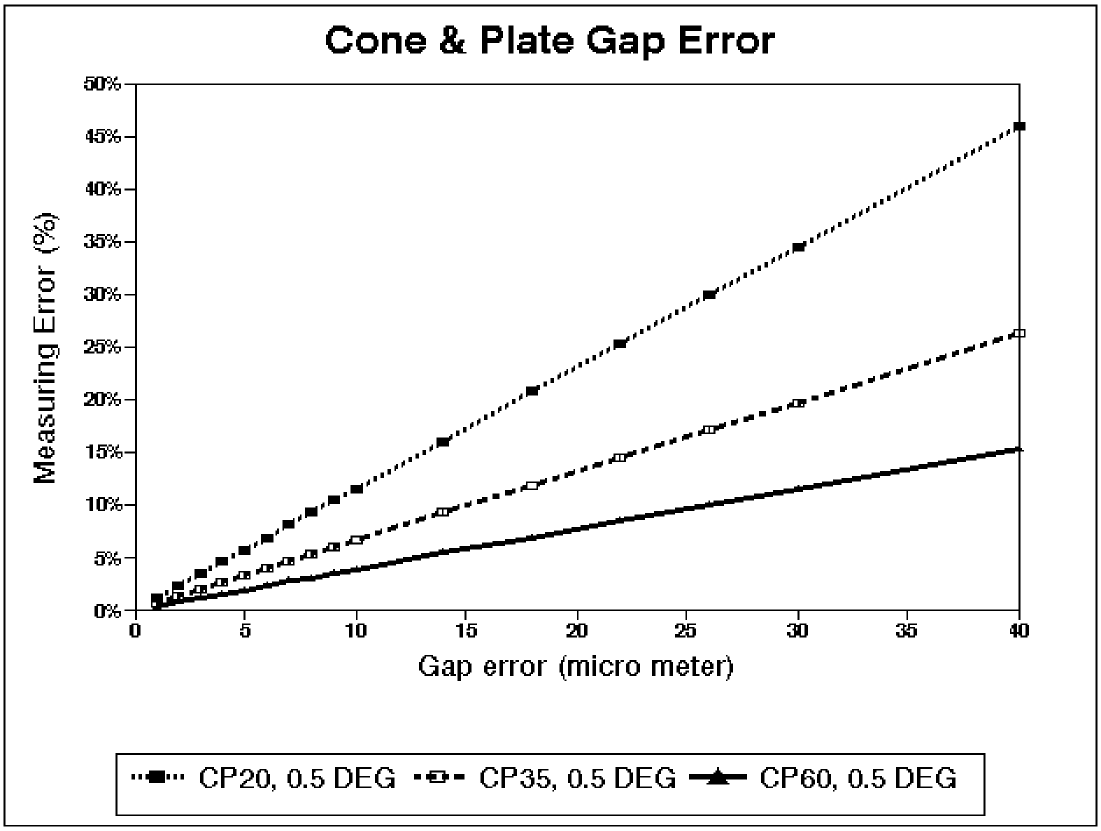
$\gamma = M \cdot \varphi$ with φ = Torsion Angle rad

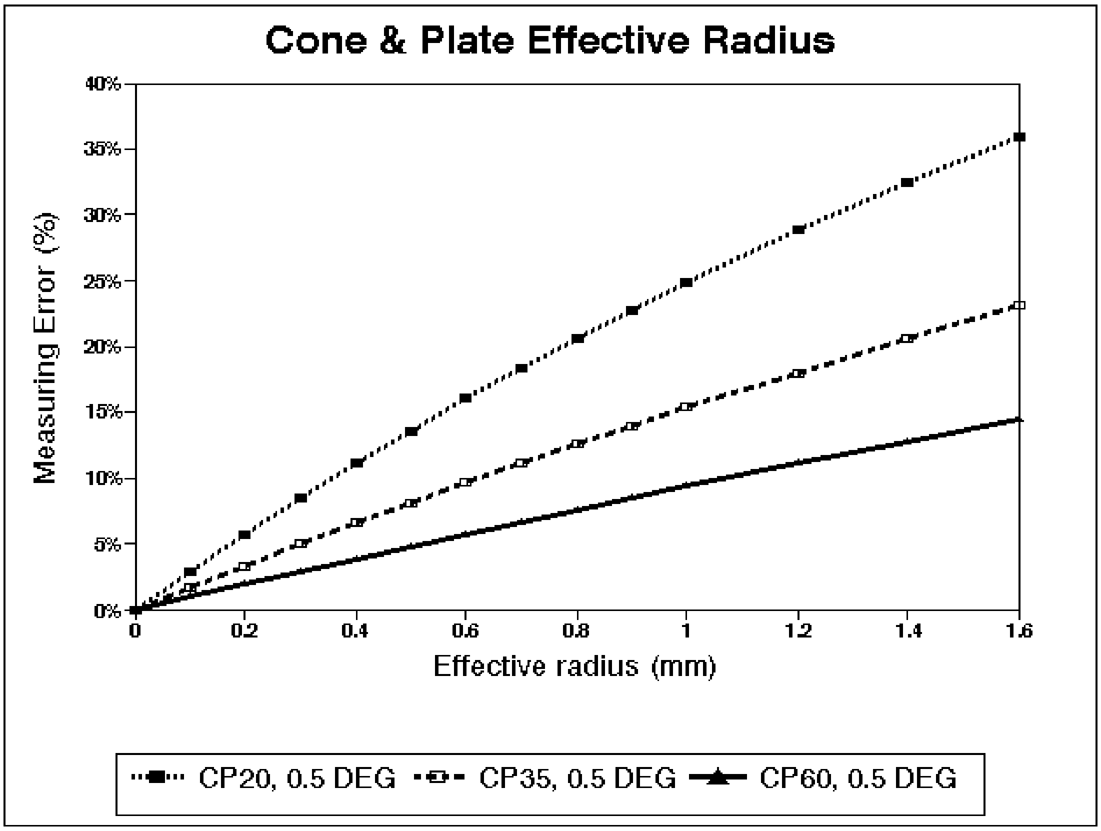
Cone-Plate Sensor System with 0,5° Angle

Sensor System	C20/0,5	C35/0,5	C60/0,5
Standard Cone Order No.:	222-1260	222-1262	222-1263
High Temp. Cone Order No.:	222-1253	222-1255	222-1257
Radius R_i (mm)	10.0	17.5	30.0
$\pm \Delta R_i$ (mm)	0.01	0.01	0.01
Angle DEG	0.5	0.5	0.5
Distance a (mm)			
Inertia I (10^{-6} kg m^2)	0.5	3	26
Mass m (g)	24	38	84
Material: Steel No.	DIN 1.4112	DIN 1.4112	DIN 1.4112
Measuring Plate MP (Brass/Armaloy)	222-0606	222-0605	222-0604
Measuring Plate MP (Steel 18/8)	222-1300	222-1299	222-1298
Radius R_a (mm)	10.05	17.55	30.05
$\pm \Delta R_a$ (mm)	0.025	0.025	0.025
Sample Volume (cm^3)	0.01	0.5	1
Permanent Temperat. max. °C	350/500	350/500	350/500
Calculation Factors			
A (Pa/Nm)	477500	89090	17680
$\pm \Delta A$ (%)	0.6	0.2	0.1
M (s^{-1}/rad s^{-1})	114.6	114.6	114.6
$\pm \Delta M$ (%)	3	3	3


Cone & Plate Measuring System with 0.5 Deg.Cone
Shear stress (Pa)
100000
10000
1000
100
10
1
0.1
0.01
0.01
0.1
1
10
100
1000
10000
100000
Shear rate (1/s)

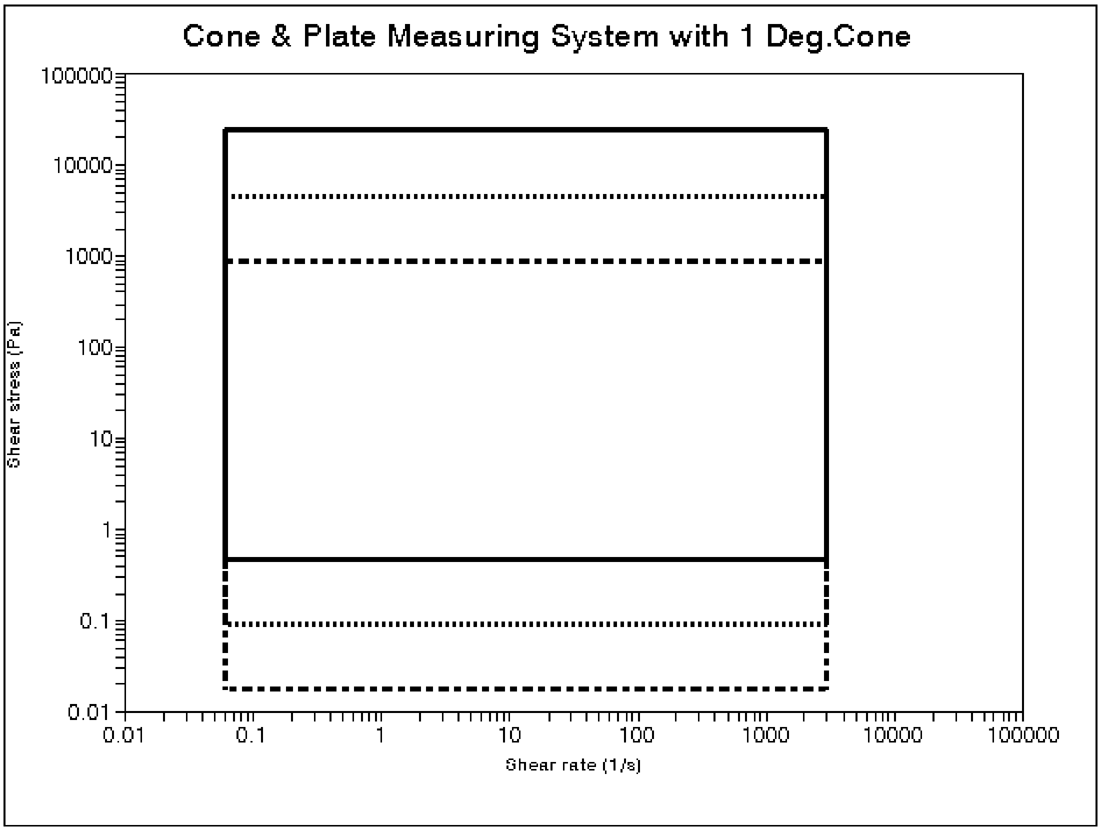

Cone & Plate Measuring System with 0.5 Deg.Cone
Viscosity (mPas)
1E+09
1E+08
1E+07
1E+06
1E+05
1E+04
1E+03
1E+02
1E+01
1E+00
1E-01
0.01
0.1
1
10
100
1000
10000
100000
Shear rate (1/s)

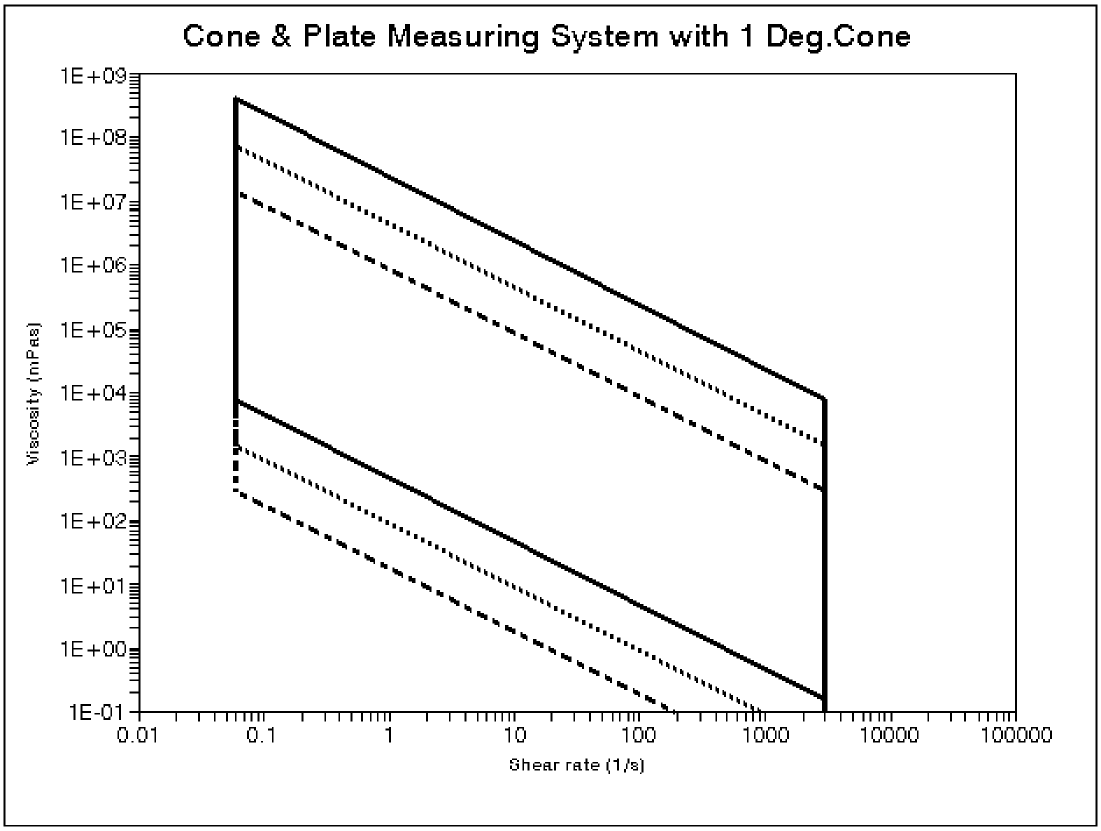

Cone & Plate Gap Error
Measuring Error (%)
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
0
5
10
15
20
25
30
35
40
Gap error (micro meter)
CP20, 0.5 DEG
CP35, 0.5 DEG
CP60, 0.5 DEG

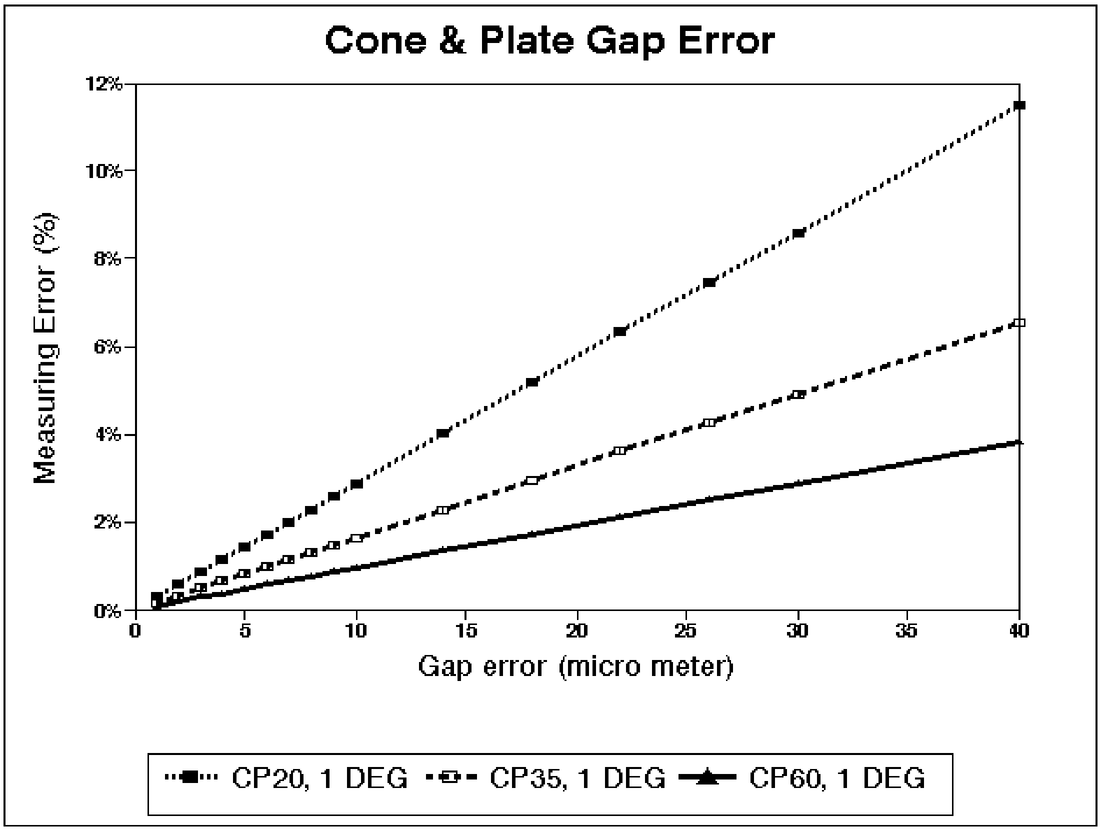

Cone & Plate Effective Radius
Measuring Error (%)
40%
35%
30%
25%
20%
15%
10%
5%
0%
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Effective radius (mm)
CP20, 0.5 DEG
CP35, 0.5 DEG
CP60, 0.5 DEG

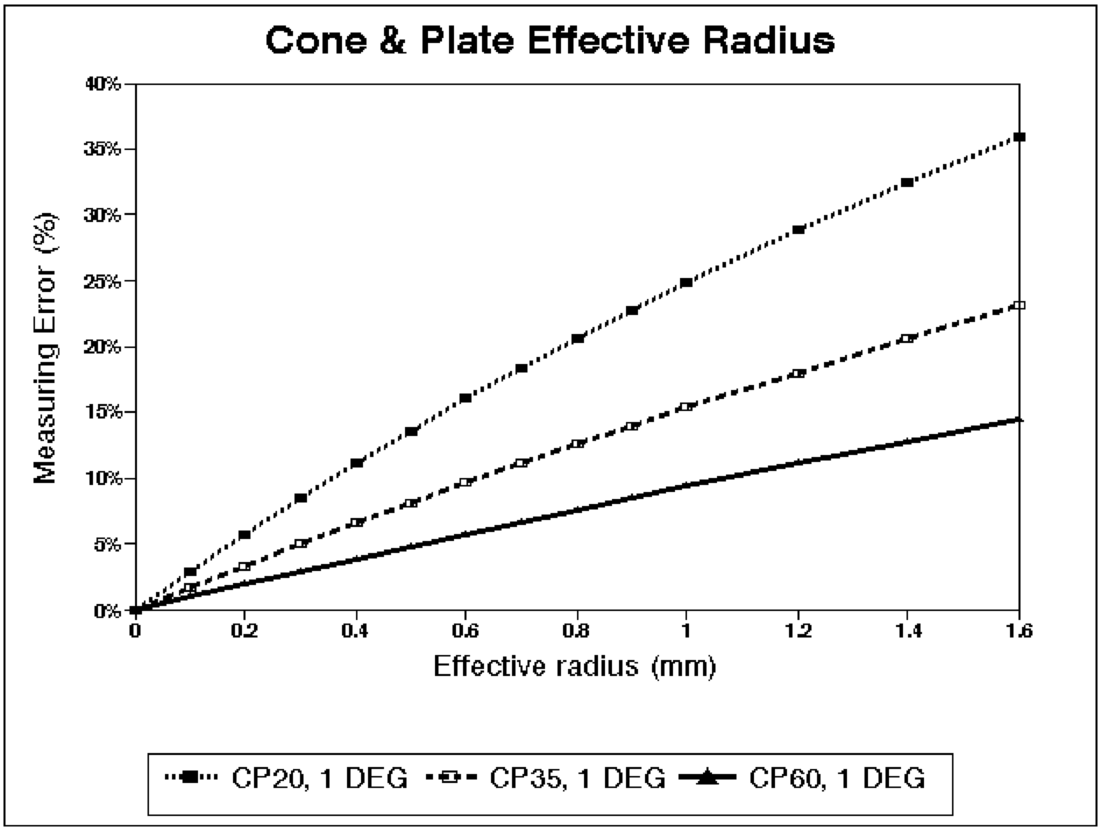
Cone-Plate Sensor System with 1° Angle

Sensor System	C20/1	C35/1	C60/1
Standard Cone Order No.: High Temp. Cone Order No.:	222-0589 222-0598	222-0591 222-0600	222-0593 222-0602
Radius R_i (mm) $\pm \Delta R_i$ (mm) Angle (DEG) Truncation (mm) Inertia I (10^{-6} kg m^2) Mass m (g) Material: Steel No.	10.0 0.01 1 3 0.48 24 DIN 1.4112	17.5 0.01 1 3 2.9 38 DIN 1.4112	30.0 0.01 1 3 26 84 DIN 1.4112
Measuring Plate MP (Brass/Armaloy)	222-0606	222-0605	222-0604
Measuring Plate MP (Steel 18/8)	222-1300	222-1299	222-1298
Radius R_a (mm) $\pm \Delta R_a$ (mm) Sample Volume	10.05 0.025 0.02	17.55 0.0 0.2	30.05 0.025 1
System Factors A (Pa/Nm) $\pm \Delta$ A % M (s^{-1}/rad s^{-1}) $\pm \Delta$ M %	 477500 0.9 57.3 3	 89090 0.2 57.3 3	 17680 0.1 57.3 3


Cone & Plate Measuring System with 1 Deg.Cone
Shear stress (Pa)
100000
10000
1000
100
10
1
0.1
0.01
0.01
0.1
1
10
100
1000
10000
100000
Shear rate (1/s)

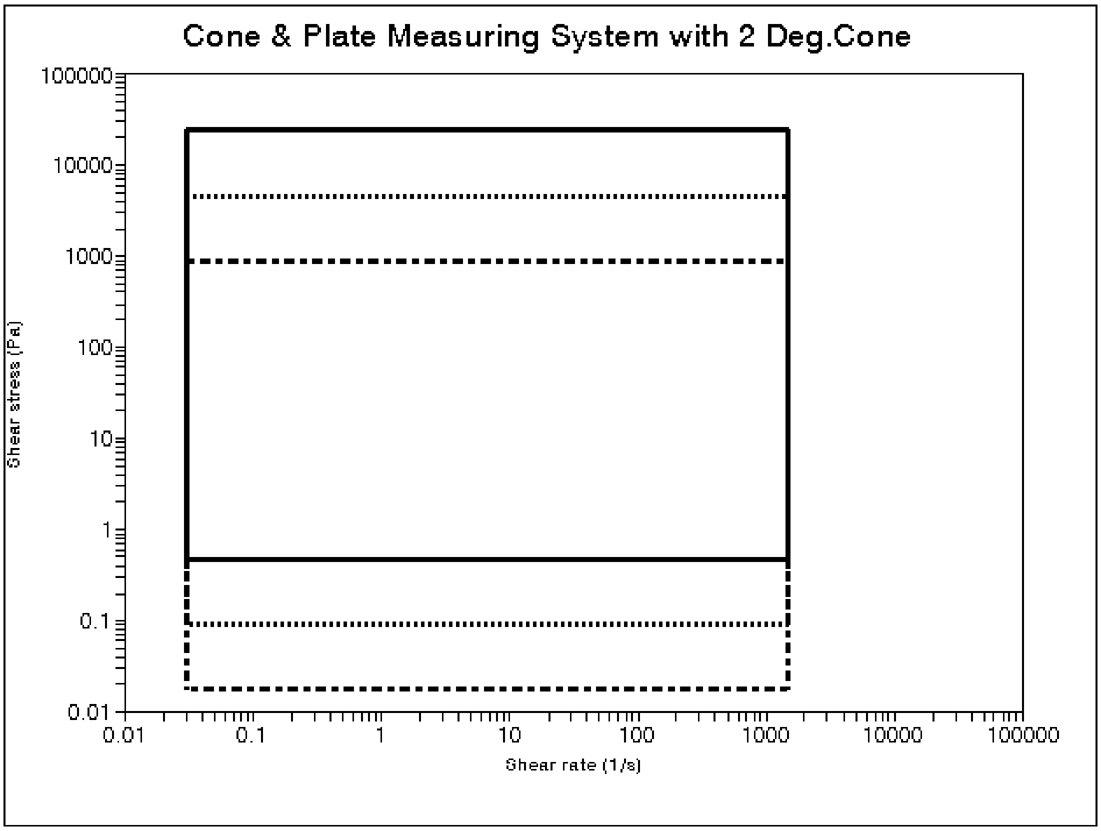

Cone & Plate Measuring System with 1 Deg.Cone
Viscosity (mPas)
1E+09
1E+08
1E+07
1E+06
1E+05
1E+04
1E+03
1E+02
1E+01
1E+00
1E-01
0.01
0.1
1
10
100
1000
10000
100000
Shear rate (1/s)

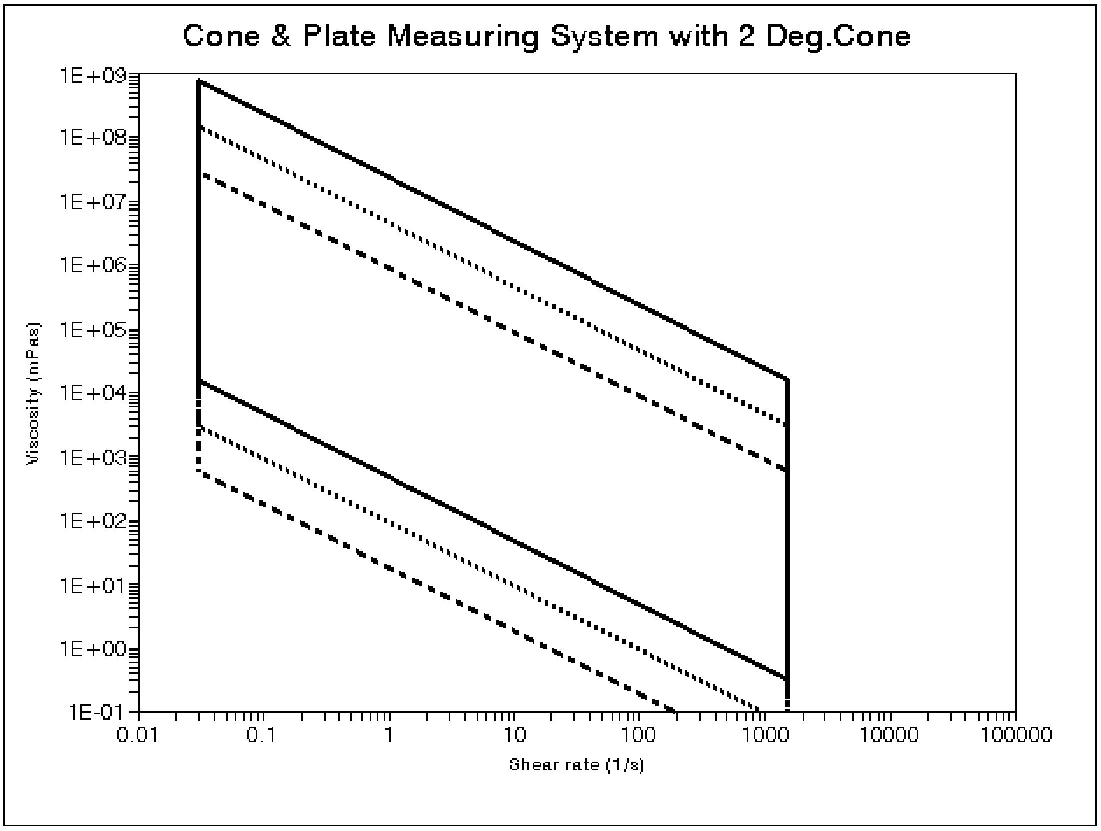

Cone & Plate Gap Error
Measuring Error (%)
12%
10%
8%
6%
4%
2%
0%
0
5
10
15
20
25
30
35
40
Gap error (micro meter)
CP20, 1 DEG
CP35, 1 DEG
CP60, 1 DEG

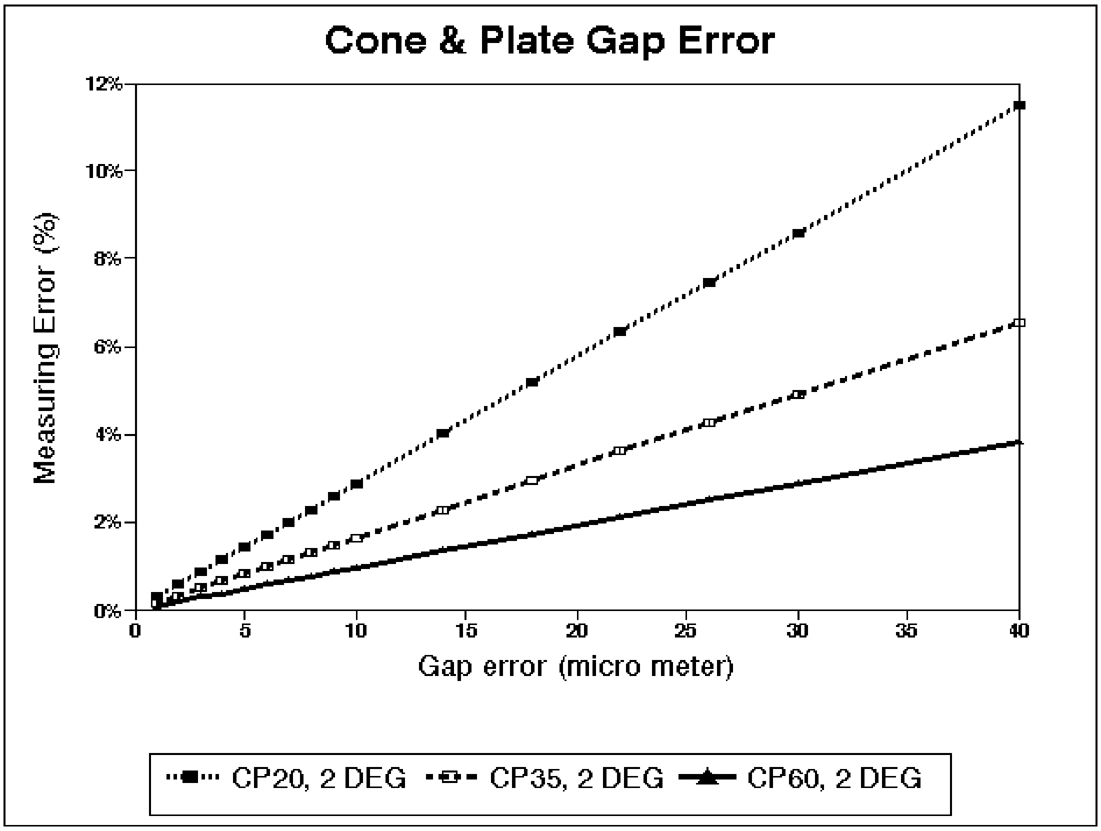

Cone & Plate Effective Radius
Measuring Error (%)
40%
35%
30%
25%
20%
15%
10%
5%
0%
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Effective radius (mm)
CP20, 1 DEG
CP35, 1 DEG
CP60, 1 DEG

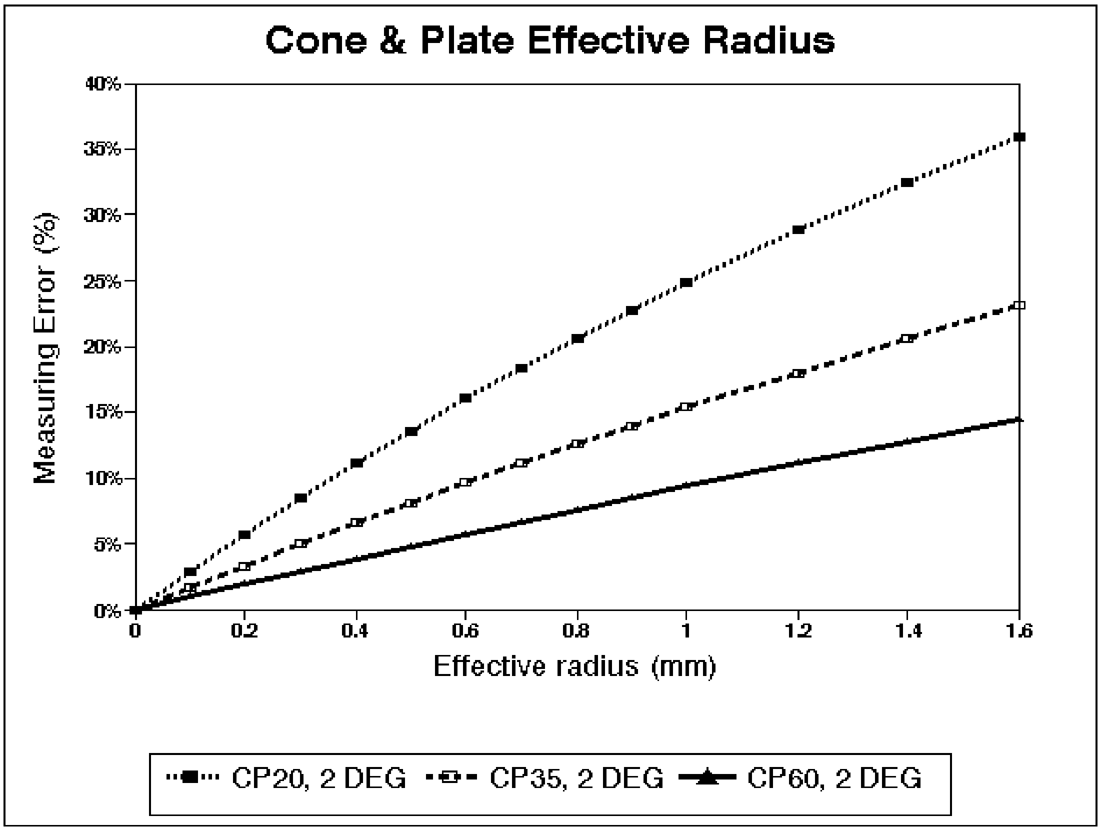
Cone-Plate Sensor System with 2° Angle

Sensor	C20/2	C35/2	C60/2
Standard Cone Order No.:	222-1254	222-1256	222-1258
High Temp. Cone Order No.:	222-1260	222-1262	222-1264
Radius R_i (mm)	10.0	17.5	30.0
$\pm \Delta R_i$ (mm)	0.01	0.01	0.01
Angle (DEG)	2	2	2
Distance a (mm)	0.087	0.087	0.087
Inertia I (10^{-6} kg m^2)	0.5	3	26
Mass m (g)	24	38	84
Material: Steel No.	DIN 1.4112	DIN 1.4112	DIN 1.4112
Measuring Plate MP (Brass/Armaloy)	222-0606	222-0605	222-0604
Measuring Plate MP (Steel 18/8)	222-1300	222-1299	222-1298
Radius R_a (mm)	10.05	17.55	30.05
$\pm \Delta R_a$ (mm)	0.025	0.025	0.025
Sample Volume (cm^3)	0.05	1.5	2
Permanent Temperat. max. °C	350/500	350/500	350/500
Calculation Factors			
A (Pa/Nm)	477500	89090	17680
$\pm \Delta$ A (%)	0.6	0.2	0.1
M (s^{-1}/rad s^{-1})	28.65	28.65	28.65
$\pm \Delta$ M (%)	3	3	3


Cone & Plate Measuring System with 2 Deg.Cone
Shear stress (Pa)
100000
10000
1000
100
10
1
0.1
0.01
0.01
0.1
1
10
100
1000
10000
100000
Shear rate (1/s)

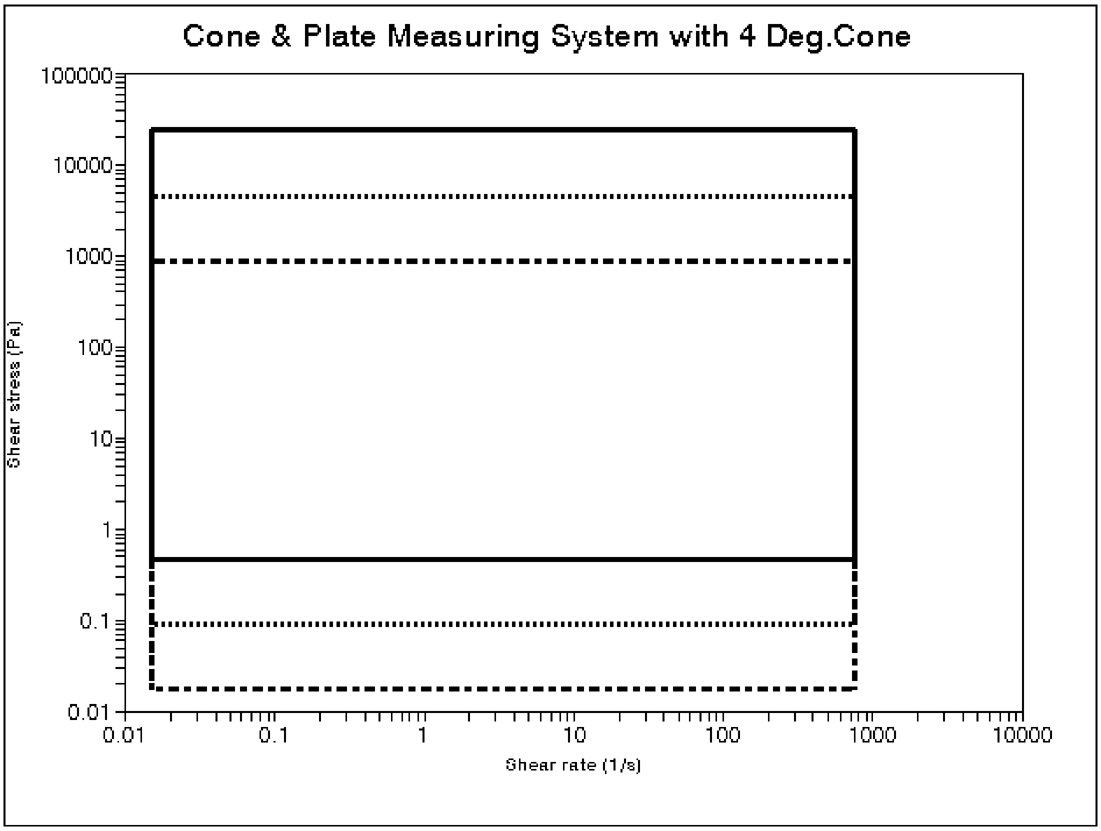

Cone & Plate Measuring System with 2 Deg.Cone
Viscosity (mPas)
1E+09
1E+08
1E+07
1E+06
1E+05
1E+04
1E+03
1E+02
1E+01
1E+00
1E-01
0.01
0.1
1
10
100
1000
10000
100000
Shear rate (1/s)

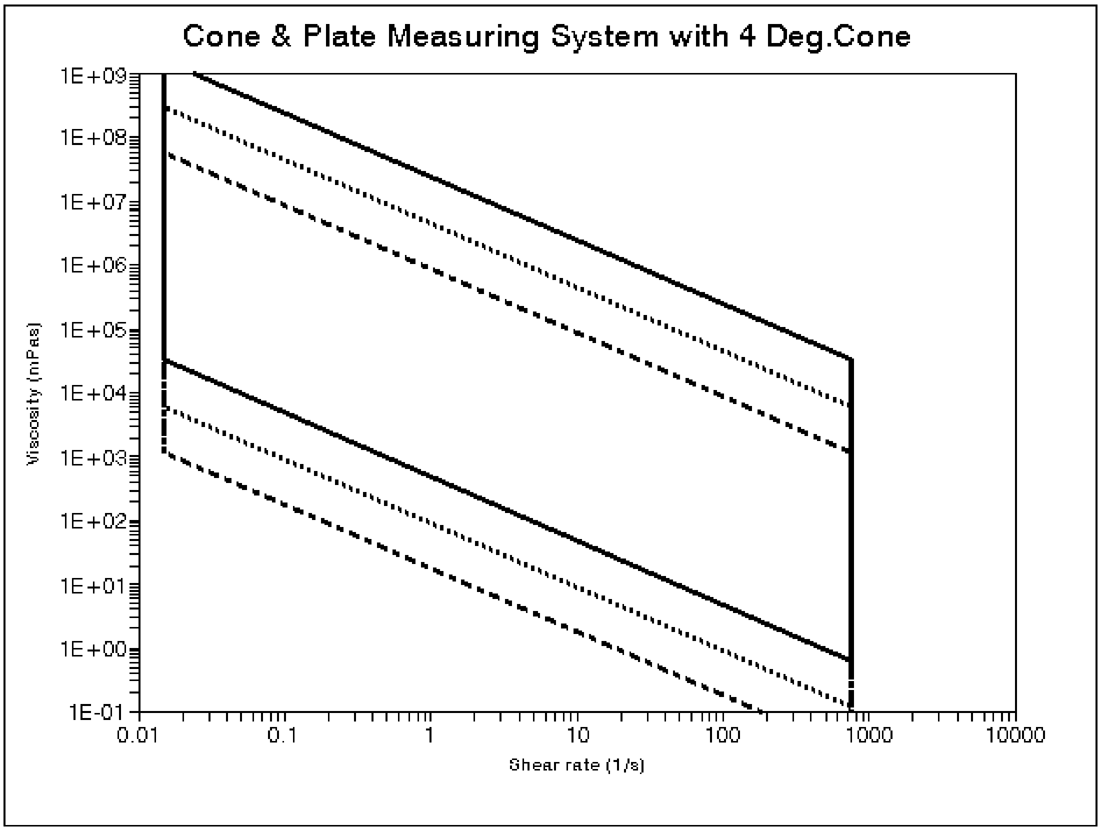

Cone & Plate Gap Error
Measuring Error (%)
12%
10%
8%
6%
4%
2%
0%
0
5
10
15
20
25
30
35
40
Gap error (micro meter)
CP20, 2 DEG
CP35, 2 DEG
CP60, 2 DEG

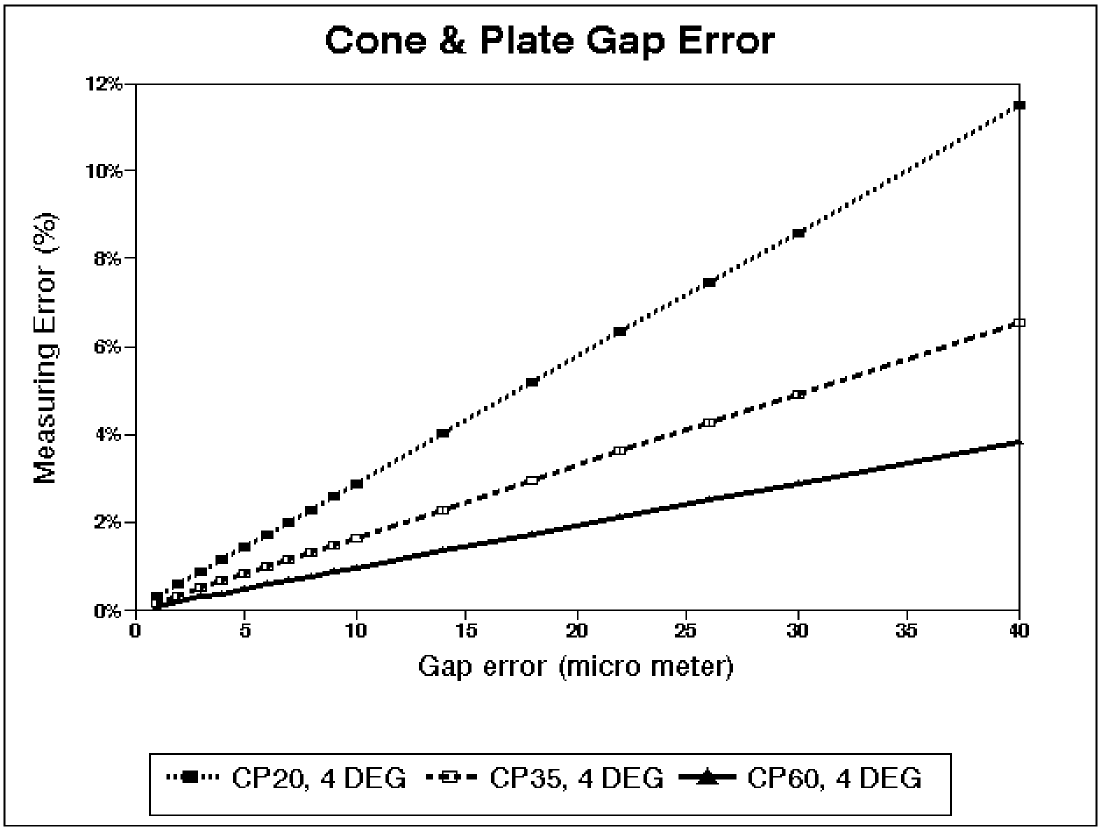

Cone & Plate Effective Radius
Measuring Error (%)
40%
35%
30%
25%
20%
15%
10%
5%
0%
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Effective radius (mm)
CP20, 2 DEG
CP35, 2 DEG
CP60, 2 DEG

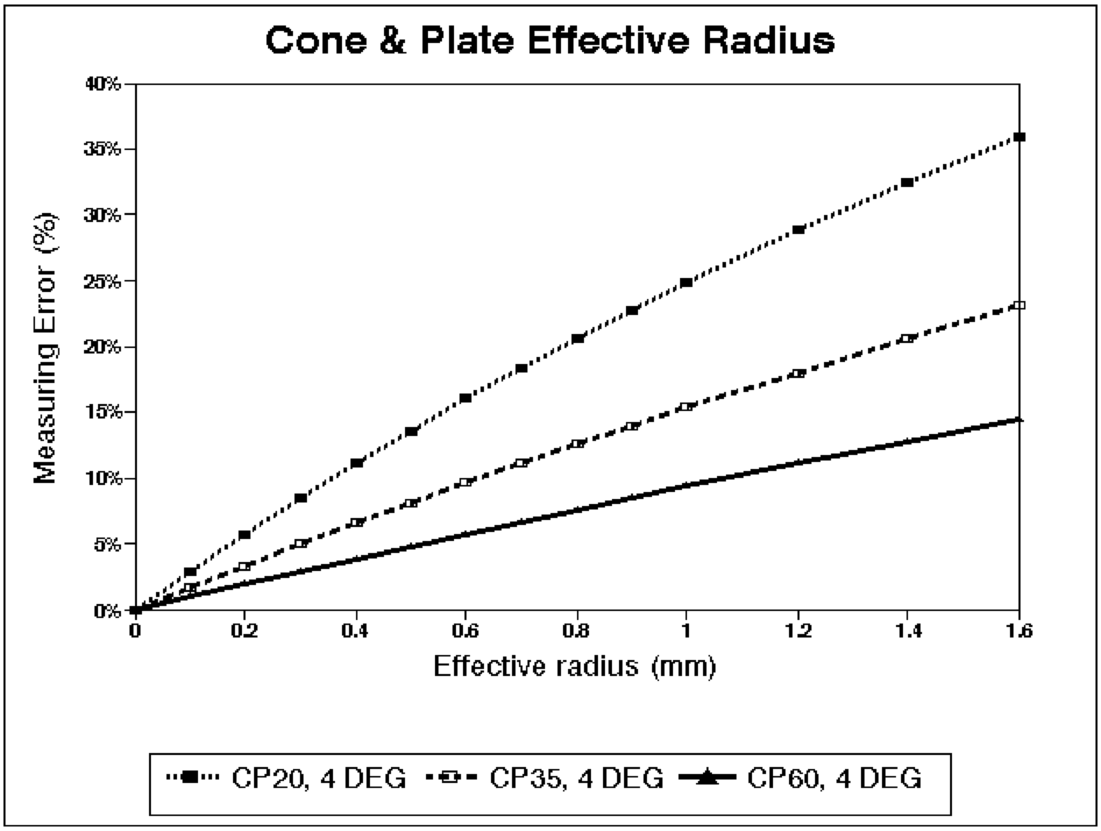
Cone-Plate Sensor System with 4° Angle

Sensor System	C20/4	C35/4	C60/4
Standard Cone Order No.: High Temp. Cone Order No.:	222-0590 222-0599	222-0592 222-0601	222-0594 222-0603
Radius R_i (mm) ± Δ R_i (mm) Angle (DEG) Truncation (mm) Inertia I (10^{-6} kg m^2) Mass m (g) Material: Steel No.	10.0 0.01 4 2 0.49 29.3 DIN 1.4112	17.5 0.01 4 2 3.1 39.1 DIN 1.4112	30.0 0.01 4 2 29 94 DIN 14112
Measuring Plate MP (Brass/Armaloy)	222-0606	222-0605	222-0604
Measuring Plate MP (Steel 18/8)	222-1300	222-1299	222-1298
Radius R_a (mm) ± Δ R_a (mm) Sample Volume Permanent Temp. max. °C	10.05 0.025 0.1 350/500	17.55 0.025 0.8 350/500	30.05 0.025 4 350/500
System Factors A (Pa/Nm) ± Δ A % M (s^{-1}/rad s^{-1}) ± Δ M %	 477500 0.3 14.32 0.8	 89090 0.2 14.32 0.8	 17680 0.1 14.32 0.8


Cone & Plate Measuring System with 4 Deg.Cone
Shear stress (Pa)
100000
10000
1000
100
10
1
0.1
0.01
0.01
0.1
1
10
100
1000
10000
Shear rate (1/s)


Cone & Plate Measuring System with 4 Deg.Cone
Viscosity (mPas)
1E+09
1E+08
1E+07
1E+06
1E+05
1E+04
1E+03
1E+02
1E+01
1E+00
1E-01
0.01
0.1
1
10
100
1000
10000
Shear rate (1/s)

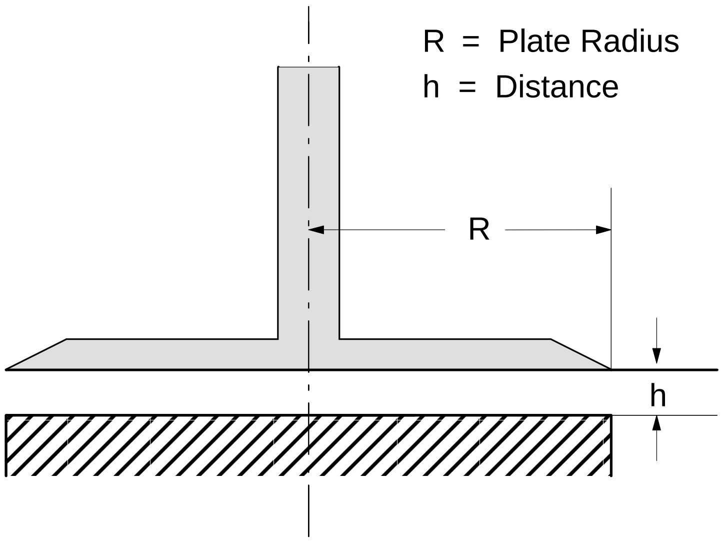

Cone & Plate Gap Error
12%
10%
8%
6%
4%
2%
0%
Measuring Error (%)
0
5
10
15
20
25
30
35
40
Gap error (micro meter)
CP20, 4 DEG
CP35, 4 DEG
CP60, 4 DEG


Cone & Plate Effective Radius
40%
35%
30%
25%
20%
15%
10%
5%
0%
Measuring Error (%)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Effective radius (mm)
CP20, 4 DEG
CP35, 4 DEG
CP60, 4 DEG

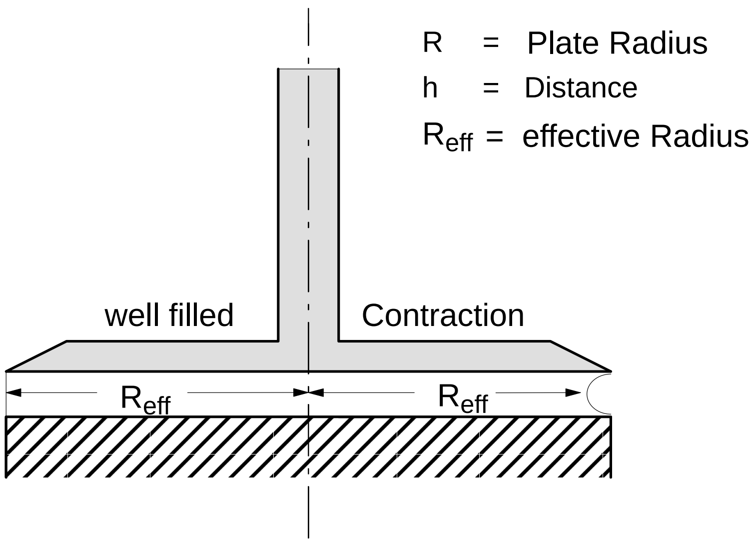
6.2.2 Plate-Plate Sensor Systems

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. Furthermore it is also mandatory that the plate-plate sensor system is very carefully filled in order to minimize measurement errors. Both, too low a filling and too high a filling will cause measurement errors.



Calculation Equations

With a known geometry of a cone-plate sensor system the system or sensor factors can be determined:

Shear Stress τ

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

$$\boxed{\tau = A \cdot Md}$$ (Stress Factor * Torque)

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

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

Shear Rate $\dot{\gamma}$

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

$$\boxed{\dot{\gamma} = M \cdot \Omega}$$ (Shear Factor * Angular Velocity)

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

The factor 'M' is calculated as follows:

$$M = \frac{R}{h}$$ with R = Plate Radius

h = set distance

Deformation γ:

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

$\gamma = M \cdot \varphi$ with φ = Torsion Angle rad

Note!
The shear rate in this sensor system is depending on the radius R ($R = 0 \ldots R_R$). The equation listed refers 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:

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

Md = Torque
R = Plate Radius
n = Structural Exponent

$$\tau = Md \cdot \frac{3+n}{4} \quad (A) \qquad n = \frac{d \cdot \log Md}{d \cdot \log \Omega_R}$$

or

τ (non-Newtonian) = τ (Newtonian) · (3 + n) / 4

τ (non-Newtonian) = Md · A · (3 + n) / 4

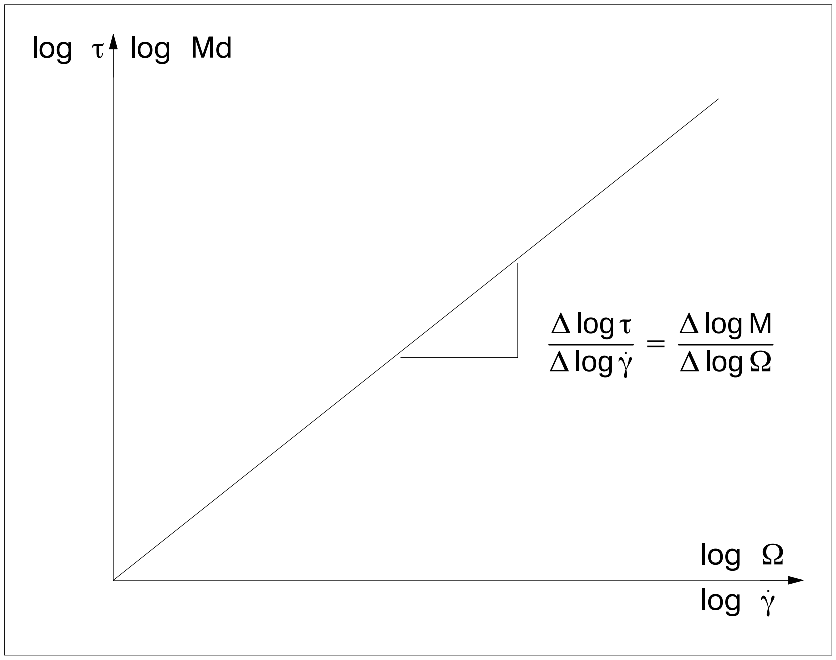
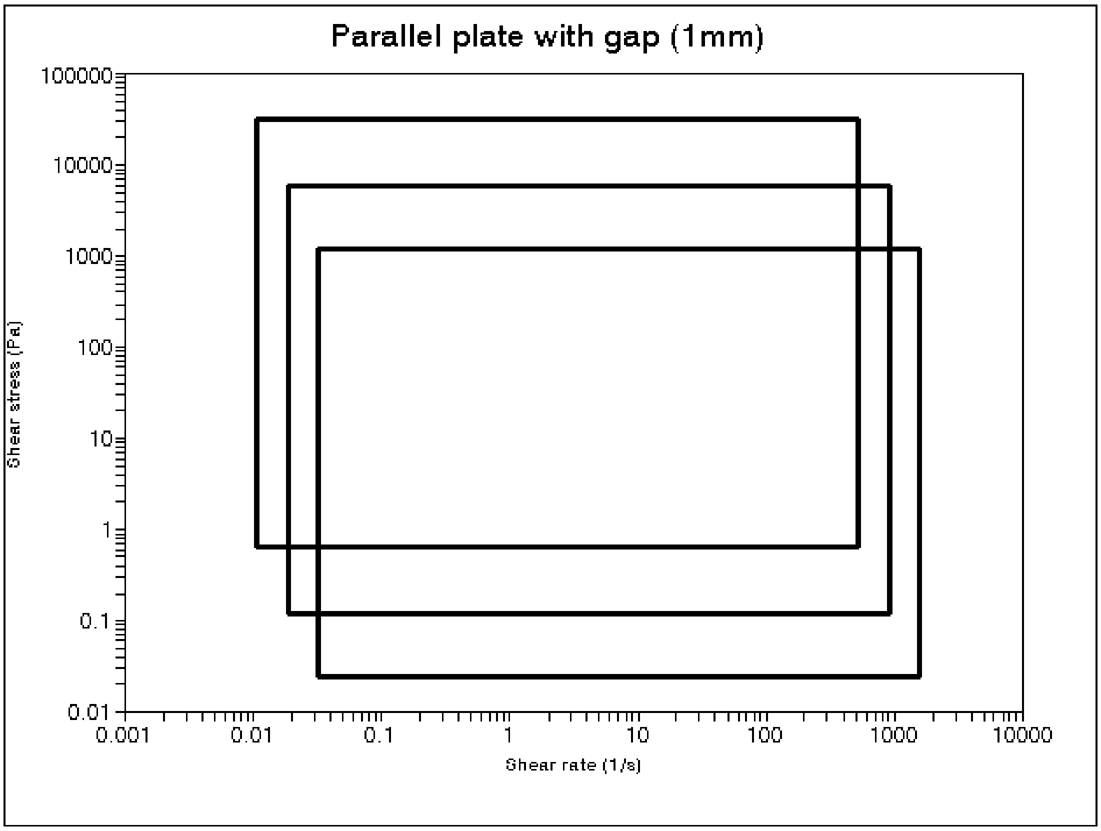
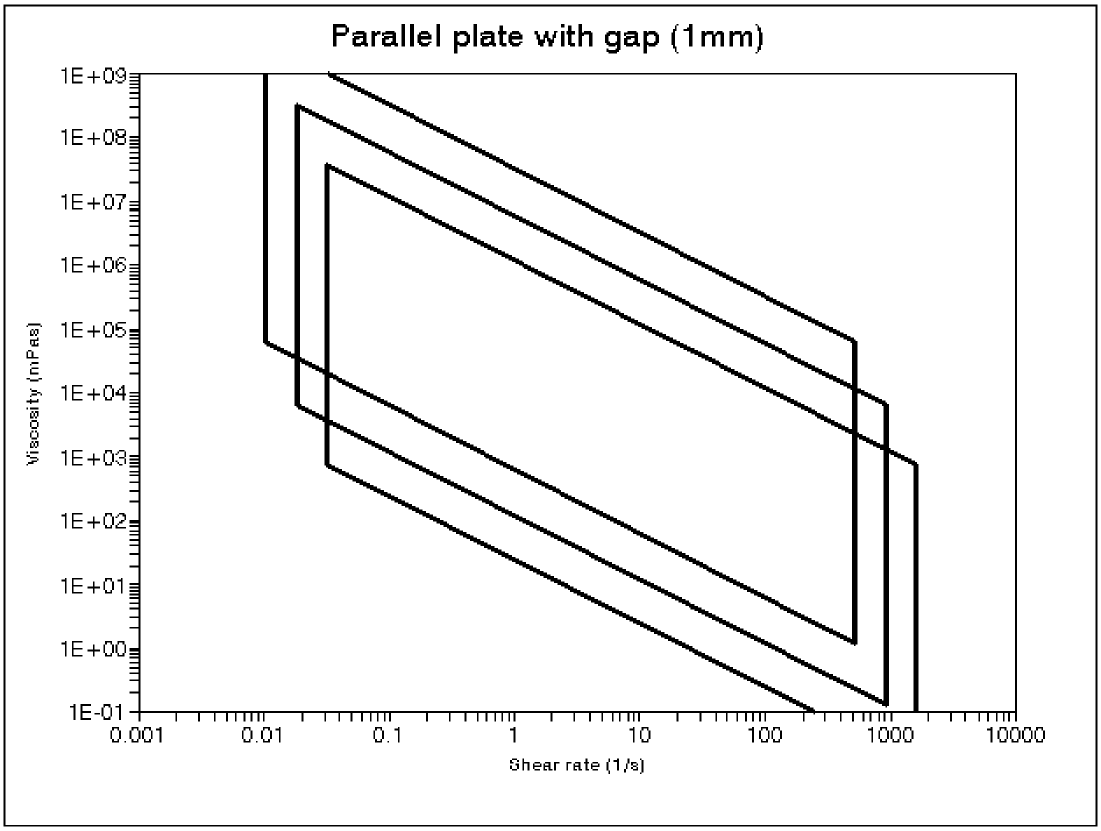
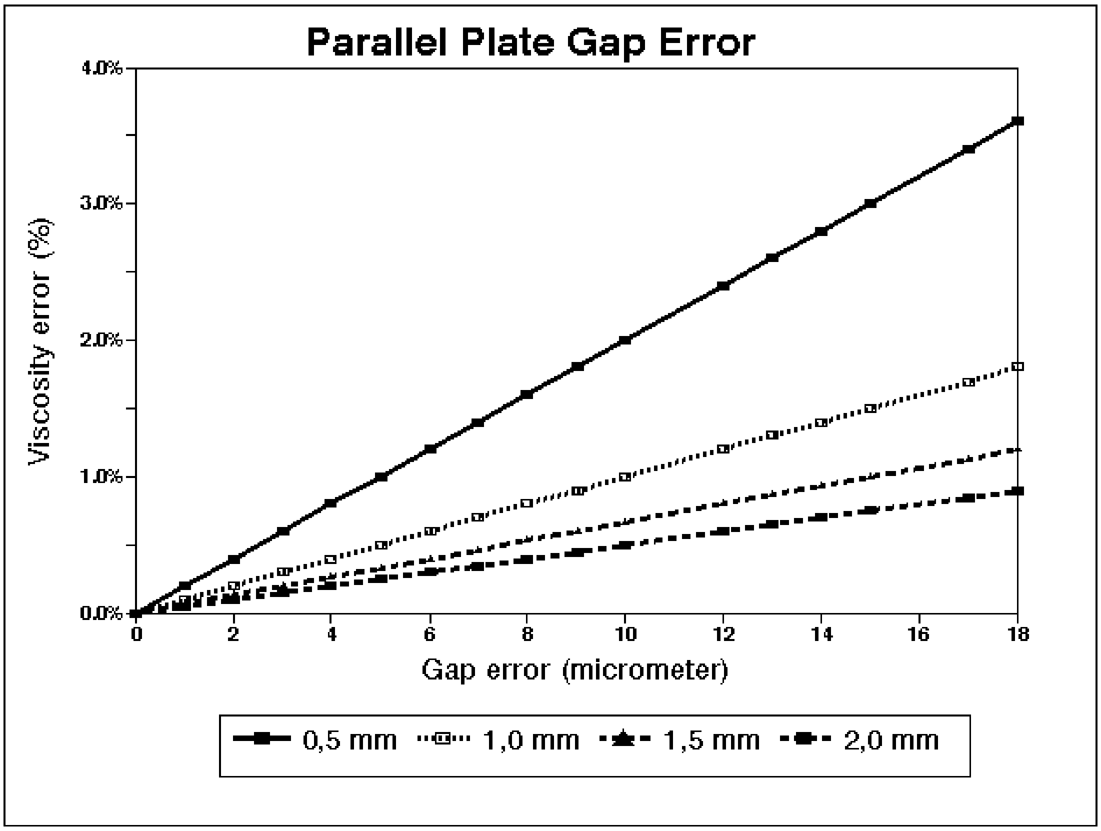


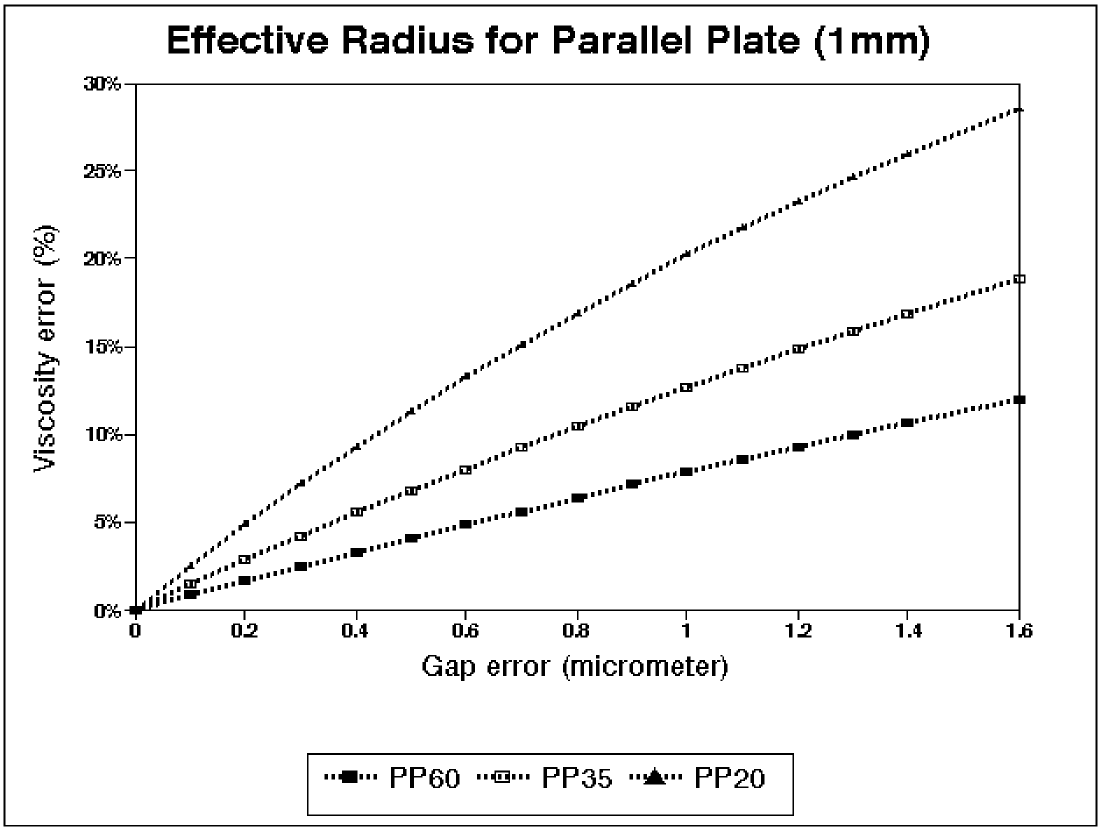
Plate-Plate Sensor System with variable distance (1 mm)

Sensor System	PP20	PP35	PP60
Standard Cone No.:	222-0586	222-0587	222-0588
High Temp. Cone No.:	222-0595	222-0546	222-0597
Radius R_i (mm) $\pm \Delta R_i$ (mm) Distance Inertia I (10^{-6} kg m^2) Mass m (g) Material: Steel No.	10 0.002 1 0.48 24.2 DIN 1.4112	17.5 0.0035 1 2.9 37.5 DIN 1.4112	30 0.006 1 26 83.7 DIN 1.4112
Measuring Plate MP (Brass/Armaloy)	222-0606	222-0605	222-0604
Measuring Plate MP (Steel 18/8)	222-1300	222-1299	222-1298
Radius R_a (mm) $\pm \Delta R_a$ (mm) Sample Volume Permanent Temp. max. °C	10.05 0.025 0.4 350/500	17.55 0.025 1 350/500	30.05 0.025 4 350/500
System Factors A (Pa/Nm) $\pm \Delta$ A % M (s^{-1}/rad s^{-1}) for 1 mm $\pm \Delta$ M %	 636600 0.3 10 0.1	 118800 0.2 17.5 0.1	 23580 0.1 30 0.1


Parallel plate with gap (1mm)
Shear stress (Pa)
100000
10000
1000
100
10
1
0.1
0.01
0.001
0.01
0.1
1
10
100
1000
10000
Shear rate (1/s)


Parallel plate with gap (1mm)
Viscosity (mPas)
1E+09
1E+08
1E+07
1E+06
1E+05
1E+04
1E+03
1E+02
1E+01
1E+00
1E-01
0.001
0.01
0.1
1
10
100
1000
10000
Shear rate (1/s)


Parallel Plate Gap Error
4.0%
3.0%
2.0%
1.0%
0.0%
Viscosity error (%)
0
2
4
6
8
10
12
14
16
18
Gap error (micrometer)
0,5 mm
1,0 mm
1,5 mm
2,0 mm


Effective Radius for Parallel Plate (1mm)
30%
25%
20%
15%
10%
5%
0%
Viscosity error (%)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Gap error (micrometer)
PP60
PP35
PP20

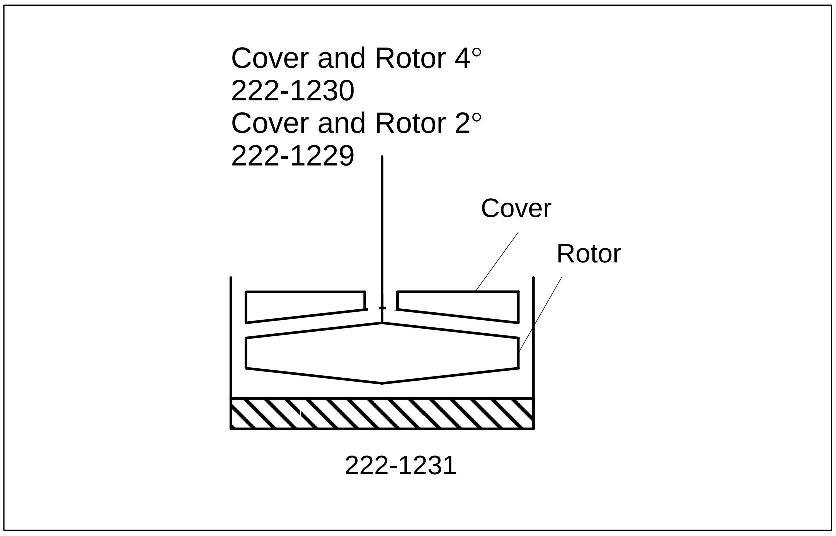
6.2.3 Double Cone Sensors

Application

Double cone sensors are employed for measuring extremely low viscous liquids where the sample volume is limited and where front surface effects are to be expected. The experience with blood and low viscous inks are favorable.

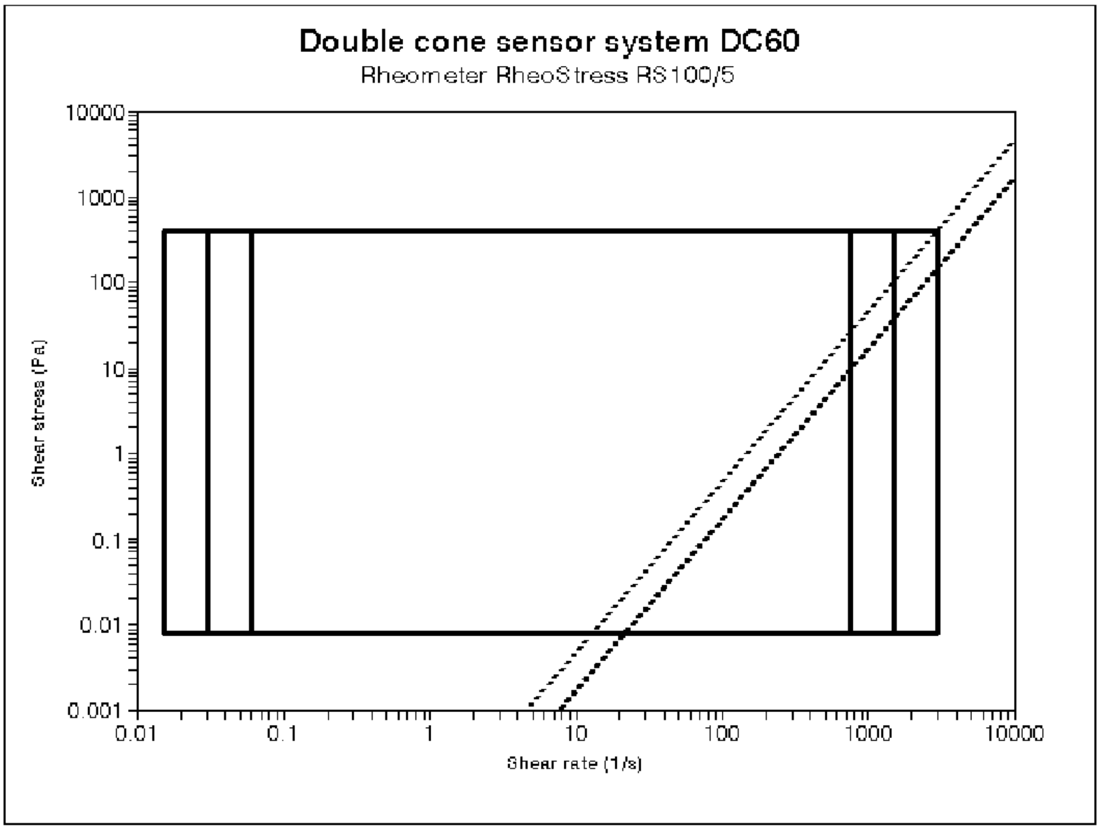
Geometry

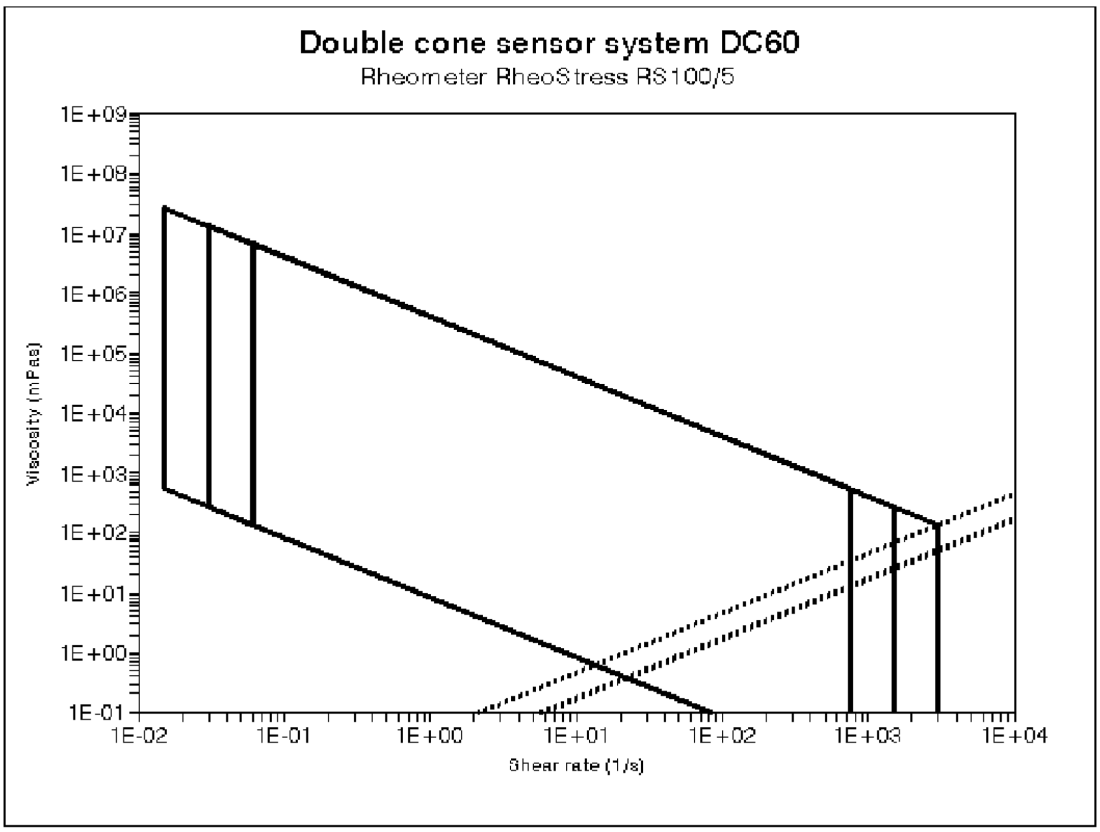
The geometry of the two cone surfaces is designed such that their shear rate is equal. This is also trough for the center of the cylindrical gap which contributes about 10% of the total shear stress. Two different cones, each with fitting covers, are available. The material of the rotors is aluminum in order to keep the resulting inertia low.



Double Cone Sensor System DC60

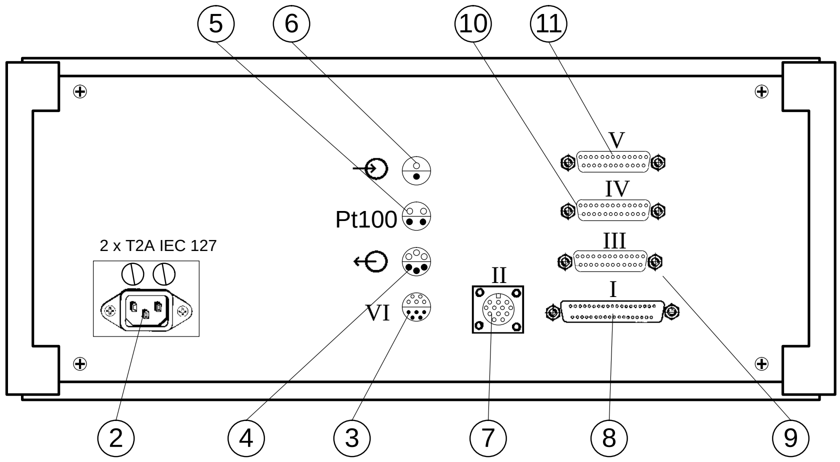
Sensor	DC60/4	DC60/2
Standard Cone Order No.:	222-1230	222-1229
Radius R_1 (mm) $\pm \Delta R_1$ (mm) Cone Angle Distance a (mm) Inertia I (10^{-6} kg m^2) Mass m (g) Material: Alumium/Armaloy	30.0 0.01 4 0.14 9 41 +	30.0 0.01 2 0.087 9 39 +
Measuring Plate MP	222-1231	222-1231
Radius R_a (mm) $\pm \Delta R_a$ (mm) Material: Brass/Armaloy Sample Volume (cm^3) Permanent Temperat. max. °C	32.35 0.025 + 10.8 200	32.35 0.025 + 5.4 200
Calculation Factors A (Pa/Nm) $\pm \Delta$ A (%) M (s^{-1}/rad s^{-1}) $\pm \Delta$ M (%)	 8038 0.5 14.32 3	 8038 0.5 28.65 3

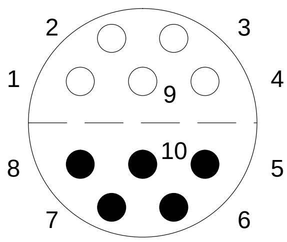

Double cone sensor system DC60
Rheometer RheoStress RS100/5
10000
1000
100
10
1
0.1
0.01
0.001
Shear stress (Pa)
0.01
0.1
1
10
100
1000
10000
Shear rate (1/s)


Double cone sensor system DC60
Rheometer RheoStress RS100/5
1E+09
1E+08
1E+07
1E+06
1E+05
1E+04
1E+03
1E+02
1E+01
1E+00
1E-01
Viscosity (mPas)
1E-02
1E-01
1E+00
1E+01
1E+02
1E+03
1E+04
Shear rate (1/s)

7. Pin Configuration

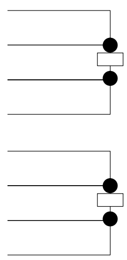
Control Box RS100 – Rear panel





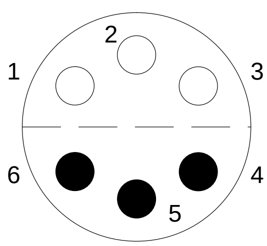
(3) Liquid temperature control socket connection

Pin	Signal type
1	Pt100–1 (+I)
2	Pt100–1 (+U)
3	Pt100–1 (–U)
4	Pt100–1 (–I)
5	Pt100–2 (+I)
6	Pt100–2 (+U)
7	Pt100–2 (–U)
8	Pt100–2 (–I)
9	+ 5 V
10	Coding



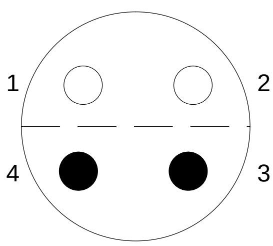
Pt100 Input

Pt100 Input



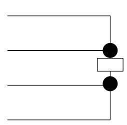
(4) External analog control connection – circulator

Pin	Signal type
1	Pt100–2 (+I)
2	Pt100–2 (+U)
3	Pt100–2 (–U)
4	Pt100–2 (–I)
5	Analog output (–5 U. . . +5 U)
6	0 V ground (+U)

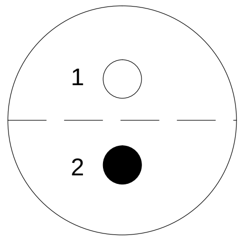


(5) External temperature sensor connection – Pt100

Pin	Signal type
1	Pt100–2 (+I)
2	Pt100–2 (+U)
3	Pt100–2 (–U)
4	Pt100–2 (–I)

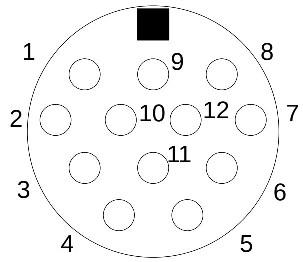


Input



(6) External voltage input 0 – 10V

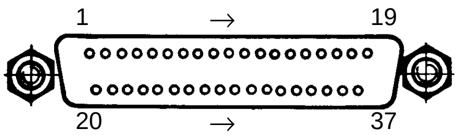
Pin	Signal type
1	0 – 10 V
2	0 V ground



(7) Angle measuring sensor connection

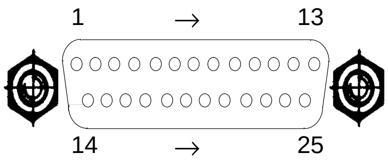
Pin	Signal type
1	Signal 2 inverted
2	Sensor + 5 V
3	Reference pulse
4	Reference pulse inverted
5	Signal 1
6	Signal 1 inverted
7	Fault signal
8	Signal 2
9	Not connected (NC)
10	0 V
11	Sensor 0 V
12	+ 5 V

(8) Measuring instrument connection



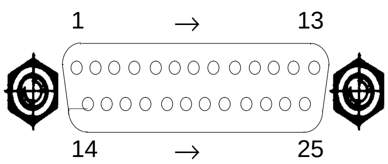
Pin	Signal type
1	+ 24 V
2	+ 24 V
3	– 24 V
4	Output stage ground
5	Output stage ground
6	+ 15 V
7	– 15 V
8	Analog ground
9	+ 5 V
10	Ground
11	
12	RTS measuring unit
13	CTS measuring unit
14	
15	
16	
17	Motor temperature signal
18	Set value motor current L1
19	Set value motor current L3
20	+ 24 V
21	– 24 V
22	– 24 V
23	Output stage ground
24	+ 15 V
25	– 15 V
26	Analog ground
27	+ 5 V
28	Ground
29	
30	Emergency stop signal
31	T x D measuring unit
32	R x D measuring unit
33	
34	
35	
36	Height signal
37	Set value motor current L1

(9) RS232 interface connection to computer



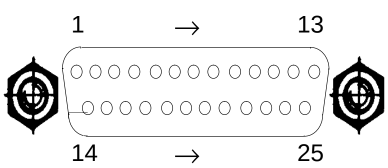
Pin	Signal type
1	Protective ground
2	R x D
3	T x D
4	CTS
5	RTS
6	DSR
7	Ground
8	NC
9	+ 5 V
10 – 25	NC

(10) RS232 interface connection for external control device



Pin	Signal type
1	Protective ground
2	T x D
3	R x D
4	RTS
5	CTS
6	DSR
7	Ground
8	NC
9	+ 5 V
10 – 25	NC

(11) RS232 interface connection for printer



Pin	Signal type
1	Protective ground
2	R x D
3	T x D
4	CTS
5	RTS
6	DSR
7	Ground
8	NC
9	+ 5 V
10 – 25	NC

8. Technical Specifications

The technical specifications with the allowable deviations or resolutions are as follows:

Torque:

Minimum (Standard)	$1 \cdot 10^{-6}$ Nm
Minimum (Optional)	$0.2 \cdot 10^{-6}$ Nm
Maximum	$5 \cdot 10^{-2}$ Nm
Resolution	$2 \cdot 10^{-8}$ Nm
Uncertainty of Presetting	$\pm 2 \cdot 10^{-8}$ Nm

Torque Angle:

Minimum	$6 \cdot 10^{-6}$ rad
Maximum	$10 \cdot 2\pi$
Resolution	$6 \cdot 10^{-6}$ rad
Uncertainty of Presetting	$\pm 6 \cdot 10^{-6}$ rad

Speed:

Minimum (CS)	10^{-6} min^{-1}
Minimum (CR)	0,1 min^{-1}
Maximum	500 min^{-1}
Resolutions	0,001 min^{-1}
Uncertainty of the Speed Measurement	$\pm$ 0,001 min^{-1}