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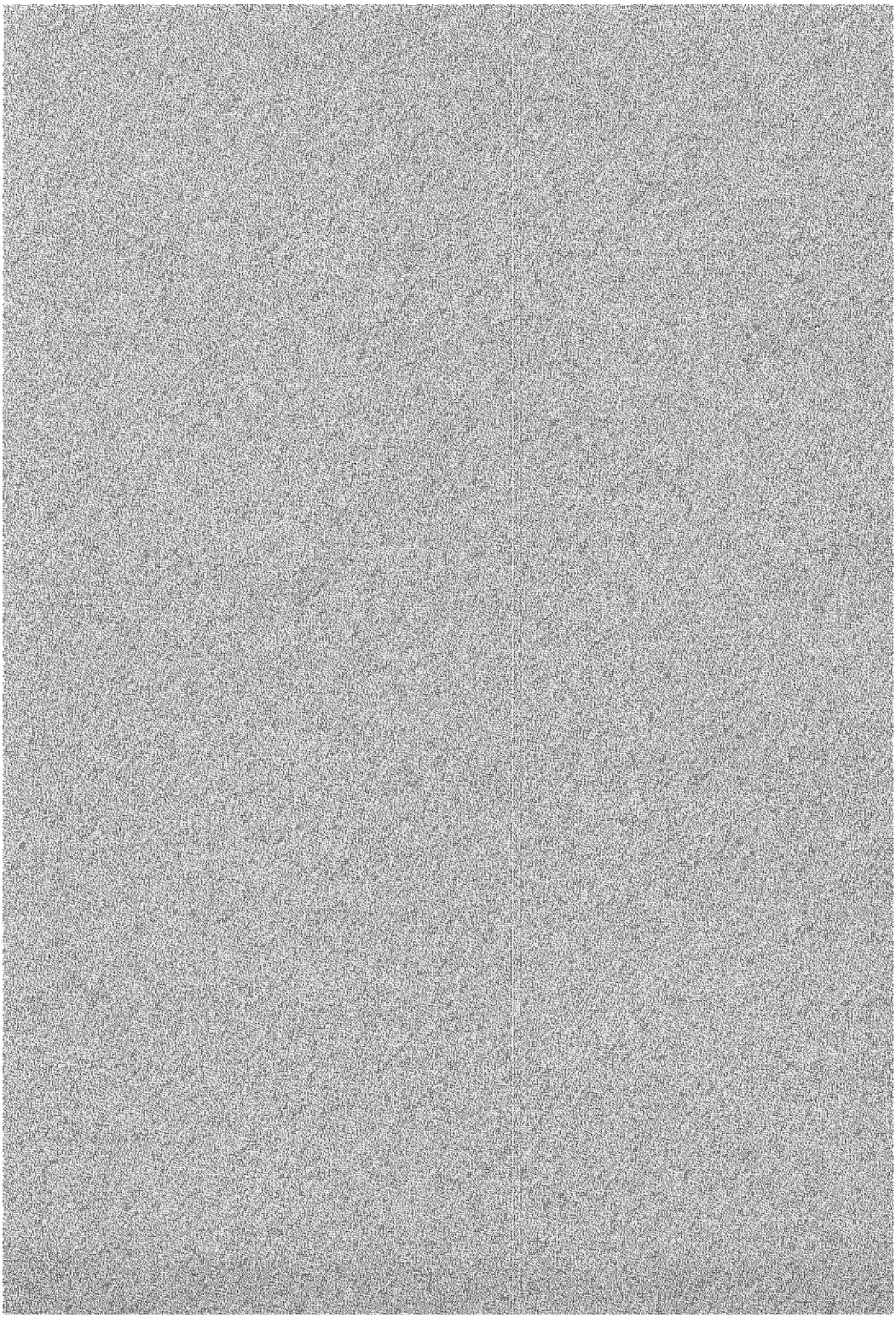
Find the *Thermo / HAAKE RV-20* at our website: ***Click HERE***

HAAKE
Viscometers

Instruction Manual
Rotovisco® RV 20
Measuring System M

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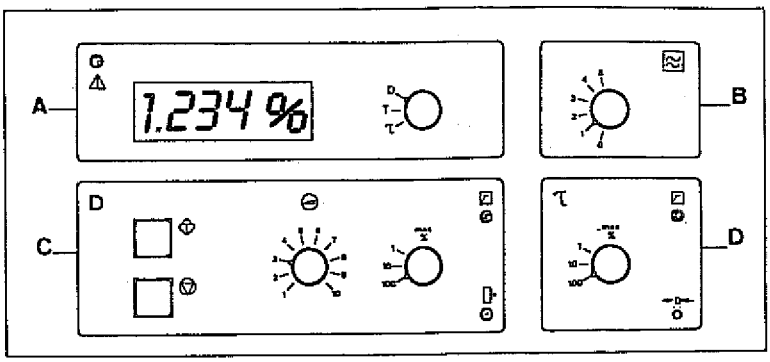
HAAKE

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4.0 ROTOVISCO RV 20 - Operating Controls



The operation panel of the RV 20 comprises four interconnected sections.

A Display Section (Refer to 4.1)

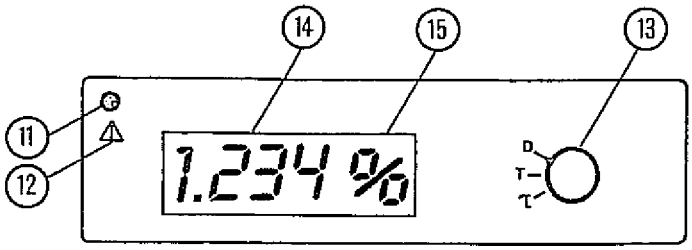
B Signal Filter Section (Refer to 4.2)

C Shear Rate Section (Refer to 4.3)

D Shear Stress Section (Refer to 4.4)

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4.1 Display Section A



(11) The green LED is on when the RV20 is connected to the mains and the main switch (1) at the rear panel of the RV20 is in position "1".

(12) This symbol reminds the user to read this instruction manual before using the instrument.

The display shows the measuring value depending on the position of the display selector (13).

(13) The display selector chooses between 3 display readings:

"D" The value D% shown is the actual preset shear rate in percent of the max. shear rate value depending on the sensor and the measuring system. It also reflects the switch settings of (23) and the D max.% (22) in internal mode or any value externally set at socket (II) by either the speed programmer PG242 or the Rheocontroller RC20.

Display Range: 0.000 to 100.0% (Resolution +/- 1 digit)

Example Measuring system M5 with sensor MV1 in "internal" mode: the display reads "1.67%". The maximum shear rate of the above combination is D = 1170 s^{-1} and the actual value is 1.67% of 1170 = 19.5 s^{-1}.

"τ" The value τ% depends on the sensor, the measuring system and the viscosity of the liquid tested. It reads the signal depending on the measuring system and the sensitivity set with % τmax.(30).

Display Range: 0.000 to 100% (Resolution +/- 1 digit)

Example: Measuring system M5 with sensor MV1 and a display reading of 74.6%. The maximum shear stress of the combination is 322 Pa and the actual value is 74.6% of 322 Pa = 240.2 Pa.

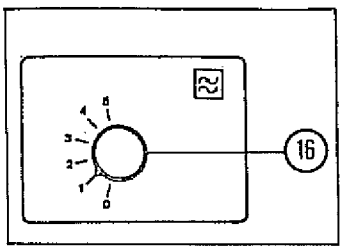
"T" The reading shows the temperature of the Pt100 temperature probe connected at socket (8) in degree centigrade (°C). The display resolution is automatically changed at (199 +/- 2)°C:
Resolution of 0.1°C below 199°C
Resolution of 1°C above 199°C
Display range -199.9°C to 510°C

(14) The display is +/- 1999 with indication (15) of selected dimension:

"%" for τ-display or D-display; "°C" for T-display

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4.2 Signal Filter Section B



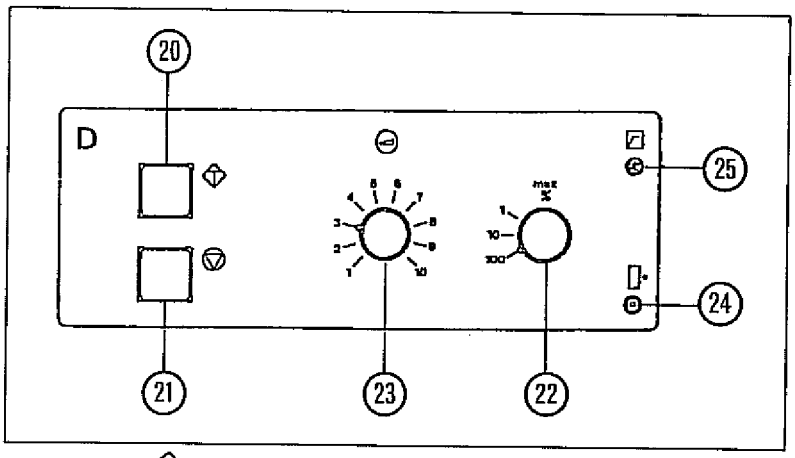
(16) The measuring value shear stress τ can show fluctuations superimposed on the actual signal $\%\tau$ which can be reduced by increasing the filter position from 0 to a value of 1, 2 or higher. This "damping" causes a delayed response for the display and the analog signals used for the recorder or the computer (τ and D)

Standard setting in steady shear mode: 2

Standard setting in dynamic mode: 0

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4.3 Shear Rate Section C



(20) Push-button ◇ to start the test and enable rotation according to the preset values. Green LED of START button is on indicating that START was pressed.

(21) Push-button ▽ to stop or reset the motor speed instantaneous to zero. Red LED of STOP button is on when STOP was pressed.

(22) The max. speed range can be preselected in 3 steps:

100% means that values between 1 and 100% can be set at switch (23)
10% means that values between 0.1 and 10% can be set at switch (23)
1% means that values between 0.01 and 1% can be set at switch (23)

This switch can be understood as a speed reduction with 100% being no reduction, 10% = a reduction of 10 and 1% = a reduction of 100.

NOTE: The position 1% is locked when the Measuring Systems CV 100 or M5-Osc are used.

(23) ⊖ Selector switch to preset the shear rate in 10 steps giving defined rotational speeds depending on:

a) the max. speed of the measuring system:

M5	= 500 rpm	= 100% D
M10	= 1000 rpm	= 100% D
M5-Osc	= 500 rpm	= 100% D
CV100	= 200 rpm	= 100% D

b) the position of switch (22) which reduces the max. speed of the measuring systems by factors of 1, 10, 100

c) speed modul for either linear (optional) or logarithmic steps (standard version) in speed.

Linear steps: 10 equal steps with a step size of 1/10 of the full range

Logarithmic steps: step ratio 1.668 between successive steps

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% D - Table

Step	1	2	3	4	5	6	7	8	9	10
Linear Series	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Logarithmic Series	1%	1.67%	2.78%	4.64%	7.74%	13%	21.5%	36%	60%	100%

The above values can now be further reduced by changing the position of switch Dmax% (22). In position "100" the above values apply, in position "10" the above values are divided by a factor of 10 and in position "1" the above values are divided by a factor of 100.

The resulting % D value incorporating switches (22) and (23) will be displayed when the display selector is set to "D". This is a possibility to check which speed steps are built-in when switch (23) is set to "1" and switch (22) to 100% D:

Display reads "1.0" ⟶ logarithmic series

Display reads "10.0" ⟶ linear series

(24) Signal light ON indicates that the instrument is under external control e.g. with speed programmer PG 242 or Rheocontroller RC 20. In external mode the range switches Dmax% (22) and τmax% (30) as well as the STOP button (21) are still active.
However, the START button (20) and the speed switch (23) are under external control.

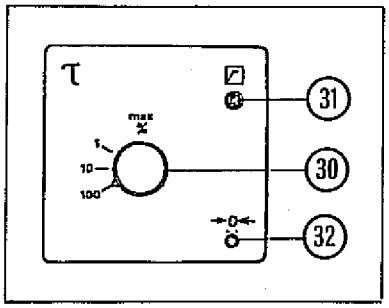
(25) Warning light ERROR is flashing to indicate that illegal speed settings are used or that the measuring system connected is in a dangerous condition e.g. the CV 100 does not receive the required air pressure to support the air-bearing. At the same time the motor speed or the speed program is held but released after setting allowed values.

Maximum and minimum speed settings (logarithmic series):

System	Max.% D	Min. % D (fixed speed)	Min. % D (flow curve mode)
M5	100	0.01	0.01
M10	100	0.01	0.01
M5-Osc	100	0.1	1
CV100	100	0.1	1

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4.4 Shear Stress Section D



The shear stress section defines the condition of the related torque measurement.

(30) The shear stress range switch to set the max. value displayed. The display is in relation to the total torque range and depends on the measuring system. This switch can be regarded as a gain switch with 100% giving the full torque, 10% displaying 10% of the full range and 1% showing only 1% of the full range. This switch floats automatically the decimal point in the display. With the exception of the CV100 the position τmax% = 1 is not allowed because the fluctuations of the measuring signal could be too high.

(31) Warning light OVERLOAD indicates that the measuring system is out of range.
The light is flashing up to 10% overload but changes to permanent lighting when torque is still increasing. At the same time the instrument is reset.

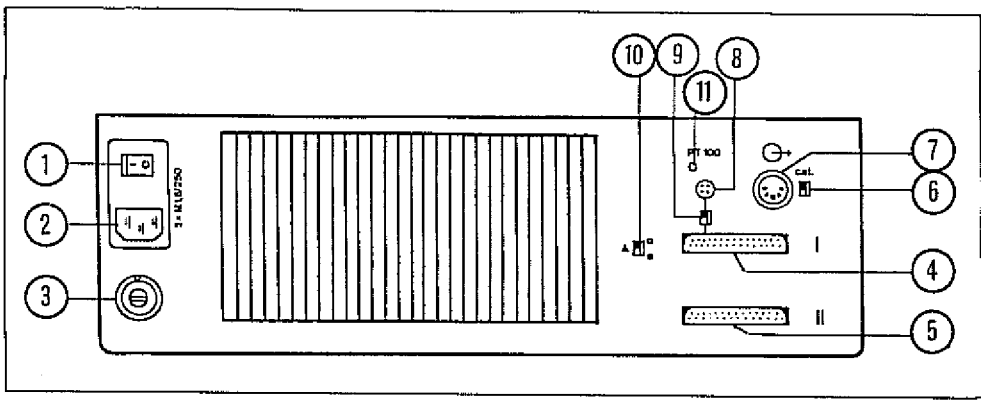
(32) Zero adjustment potentiometer
The zero-point is adjusted before the sensor is filled with test liquid and after the following switch settings have been verified:

Switch	(13)	display selector in "τ"
Switch	(16)	damping in 1
Push-button	(21)	STOP pressed
Switch	(30)	τ max% range at 100

Turning the potentiometer changes the display reading which should be set to 0.0. Then, for better adjustment, the smallest possible range should be choosen in τmax% (10% for the M-system and 1% for CV100) and the adjustment repeated.

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4.5 Rear Panel



(1) Mains switch "I" = ON and "O" = OFF

(2) Socket for mains cable with fuses (2 x M 1.6/250)

(3) Mains voltage selector to set the correct line voltage (50-60 Hz)

According to the local supply:

240 V +/- 10%
220 V +/- 10%
110 V +/- 10%
100 V +/- 10%

INCORRECT SETTINGS WILL DISTURB THE INSTRUMENT !

(4) Socket I to connect the measuring system (female 37-pin subminiature-D-socket)

The socket is internally coded to tell the basic unit which system is connected. The TTL-voltage is measured against pin 6.

System	Pin 11	Pin 29	Pin 10
M5	H	L	L
M10	L	L	H
M5-Osc	H	H	L
CV100	L	H	L

H = High signal; L = Low signal

(5) Socket II for peripheral units like PG 242 or RC 20 (male 37-pin subminiature-D-socket)

This socket delivers a signal output of the measuring conditions such as switch settings τmax%, Dmax%, measured torque, preset speed and measured temperature as well as signal input for the remote control of the ROTOVISCO RV 20 by the Speed Programmer or Rheocontroller.

(6) Calibration
In position "Cal" the signal outlet (7) delivers 10.0 Volt independent of the present reading for adjusting recorder or data acquisition systems. After calibration the switch has to be reset.

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(7) Signal Outlet (DIN 41524 Socket)

This signal outlet gives electric signals to be used for data recording in conjunction with peripheral units like recorders and similar equipment.



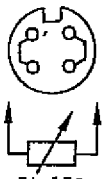
Plug T 3360020(AMT)
or HAAKE 087-0648

Pin	Signal	Range
1	Shear Stress	0 to +/- 10 V
2	Ground	0
3	Shear Rate D	0 to +/- 10 V
4	Not used	-
5	Temperature T	10 mV/°C and 0 V = 0°C

All the signals can be used with a device resistance larger than 10 KΩ

Recorder cable: 222-0543

(8) Temperature sensor socket for Pt100 probes



This socket is used to connect temperature sensors of the type Pt100 from which the signal is displayed at the front panel.

Socket: Fischer No.: S 102 A 053
or HAAKE No.: 078-1673

(9) Temperature probe selector switch

The temperature signal displayed can be from the Pt100 in socket (8) when the switch is in its upper position or from an external probe connected to socket I "measuring system" (4) at pin 4 and pin 23 in which case the switch is in its lower position.

(10) Speed control sensitivity • = ON o = OFF

Because of the large speed range available, an internal gain control system changes the sensitivity at 50% of the speed range which could result in a sudden speed jump giving a small peak on the recorder.
If this peak is not wanted, the switch has to be set to "Off = 0" which slightly reduces the accuracy of the speed control at low rpm.

(11) Potentiometer to adjust the connected Pt100 temperature sensor which is necessary because of the sensor's tolerances. This adjustment has to be done for each sensor only once.

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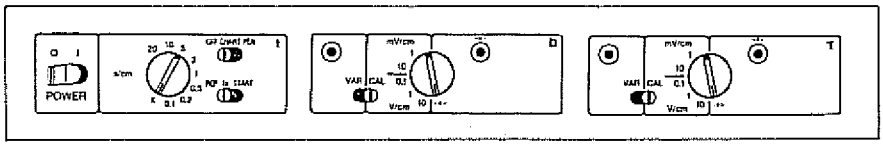
Adjusting the HAAKE xy-t Recorder

Settings RV20:

- Power ON (I) and warm up for 10 min.
- STOP-button (21) pressed
- Display selector (13) set to τ
- Zero point (32) adjusted to 0.000%

Settings Recorder:

- Power ON (I)
- Chart paper placed on table
- Switch VAR/Cal to VAR for τ and D-axis
- Time modul set to "X"
- Coarse Settings τ= 1 V/cm D = 1 V/cm



Note: Do not connect any black plug with ⏚ socket

ZERO Adjustment:

RV20 display shows 0.000%τ and "STOP"-button is pressed. The recorder potentiometers τ-zero and D-zero are used to move the recorder pen exact to the start on the chart paper.

Max. Scale Adjustment:

At the rear panel of RV20 the calibration switch (6) is set to "CAL" which gives a signal of 10.0 V for bothτ and D channels independent of the present display reading.

Turn potentiometers τ-VAR and D-VAR of the recorder to move the pen to the upper right border of the chart paper.

Set calibration switch (6) back to the standard measuring position and if necessary repeat the above procedure.

NOTE: When finished, check calibration switch (6) at rear panel of RV20 and make sure that it is n o t in "CAL" position for measuring.

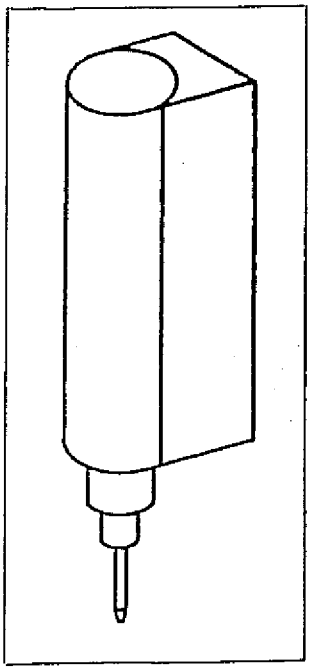
The recorder adjustment should be checked once a day before measuring.

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5.0 Measuring System M

The "Searle"-type measuring system M comprises the motor, tachogenerator, calibrated spring, torque transducer, and pre-amplifier. It is connected to the basic unit by means of a cable to socket I of the rear panel.

The deflection of the spring is proportional to the torque and converted by a transducer into an electric signal. The maximum torque deflects the spring to an angle of approx. 1° or $1.74 \cdot 10^{-2}$ rad. The system is almost friction-free without built-in damping which allows instantaneous response. It might show some fluctuations during a measurement due to an inhomogenous sample, air bubbles or particles in the sample or when the rotor is bent. The fluctuations can be minimized by switching on an electronic filter (switch 16) but this slows down the response time.



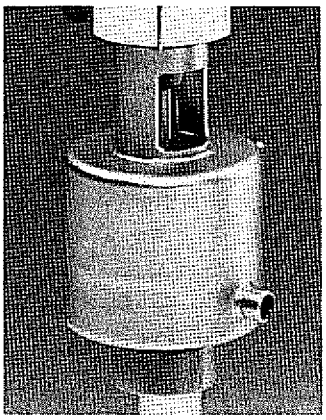
	M5	M5-Osc	M10
Max. Torque 100% τ	4.9 Ncm	4.9 Ncm	9.8 Ncm
Torque/% "a"- value	0.049 Ncm/%τ	0.049 Ncm/%τ	0.098 Ncm/%τ
Max. Speed 100% D	500 rpm	500 rpm	1000 rpm
Min. Speed	0.01%D = 0.05 rpm	0.1%D = 0.5 rpm	0.01%D = 0.1 rpm
Application	Standard Tests	Oscillation	High Shear Tests

Note:

The measuring system M is a precision measuring element of high sensitivity and, thus, always requires careful handling. Take special care to avoid damaging the spindle and in particular do not grasp and lift the unit by the shaft.

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5.1 Temperature Vessel and Stand



The temperature vessel has three functions:

a) it connects the sensor system to the measuring system

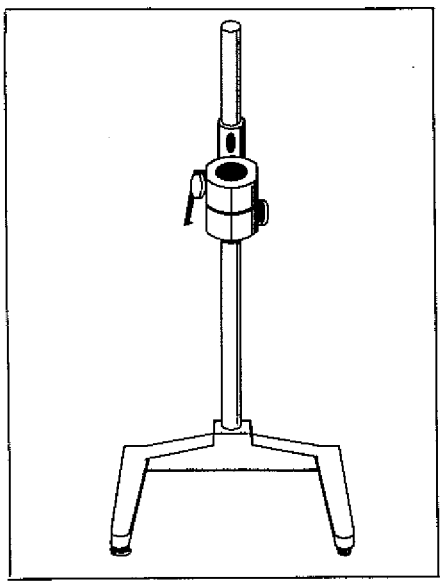
b) it centers the cup

c) it controls the temperature of the test substance (range -30/100°C).

The measuring system is placed into the holder of the stand from the top and the temperature vessel from underneath.

The temperature vessel has two 10 mm metrically threaded fittings for connecting it to a HAAKE circulator. The direction of flow is indicated by arrows on the vessel.

The temperature can be measured using the Pt100 sensor No. 333-0344 which is screwed into the vessel.



It is advisable to wet the outside of the cup with glycerine, light oil etc. to optimize heat transfer from the temperature vessel to the cup.

Insert the chrome-plated rod into the foot of the stand.

A slight twist of the rod will suffice to tighten or loosen the two parts.

The foot of the stand has a levelling screw which helps to balance out any unevenness.

The holder for the measuring system can be tightened on the vertical rod at any desired height.

Assembly: First insert the measuring system M from the top into the stand holder, then insert the temperature vessel from underneath and hold it in place with the longer screw supplied. Slightly tighten the two black knobs to center the combination.

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6.0 Measuring Ranges

A. Measuring Range with System M5

Basic Measuring Range with System M5 and Sensor NV as an example:

This range is achieved with the settings Dmax% = 100 and τmax% = 100 using the steps 1 to 10 and the display reading from 10.0%τ to 100.0%τ. In absolute values of shear rate this provides a range from D = 27 to 2700 1/s and in shear stress a range from 17.8 Pa to 178 Pa.

Total Measuring Range with System M5 and Sensor NV

The total range uses the settings 100%D, 10%D, 1%D and the shear rate steps 1 to 10 and 100%τ and 10%τ with a smallest value of 10% of full scale.

Shear Rate:

Range with speed steps 1 to 10 gives 27 to 2700 1/s (Dmax% = 100)

Range with speed steps 1 to 10 gives 2.7 to 270 1/s (Dmax% = 10)

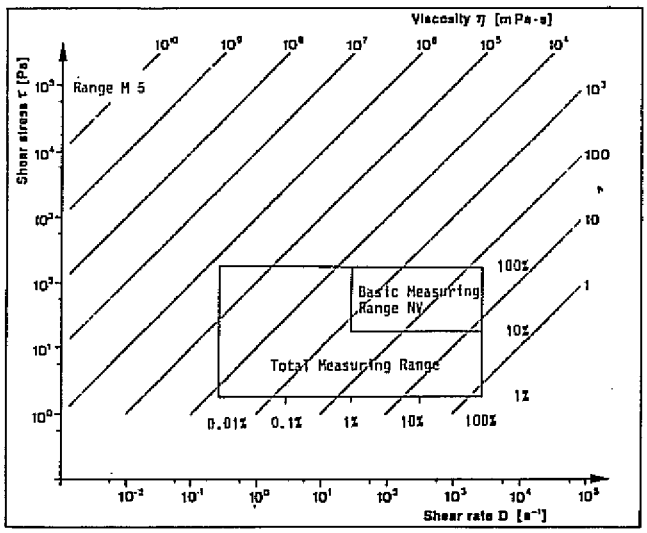
Range with speed steps 1 to 10 gives 0.27 to 27 1/s (Dmax% = 1)

Shear Stress:

Range with readings from 10.0 to 100.0% gives 17.8 to 178 Pa (τmax% = 100)

Range with readings from 1.00 to 10.00% gives 1.78 to 17.8 Pa (τmax% = 10)

This already wide range can be further extended by using other sensors or the measuring system M10 for higher shear stress and shear rate values.



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B. Measuring Range with System M5-Osc and Sensor MV2

The measuring system M5-Osc can be used in rotational (steady shear) or oscillating (dynamic tests) mode controlled by a computer via the Rheocontroller RC20

Rotational mode:

Basic Measuring Range with System M5-Osc and Sensor MV2

This range is achieved with the settings Dmax% 100 and τmax% 100 using the speed steps 1 to 10 and the display reading from 10.0%τ to 100%τ. In absolute values of shear rate and shear stress this provides a range from D = 4.51 to 451 1/s and τ= 37.6 to 376 Pa.

Total Measuring Range with System M5-Osc and Sensor MV2

The total range uses the settings 100%D and 10%D together with the speed steps 1 to 10 and for shear stress 100%τ and 10%τ with a smallest value of 10% of full-scale.

Shear Rate:

Range with speed steps 1 to 10 gives 4.51 to 451 1/s (Dmax% 100)

Range with speed steps 1 to 10 gives 0.451 to 45.1 1/s (Dmax% 10)

Shear Stress:

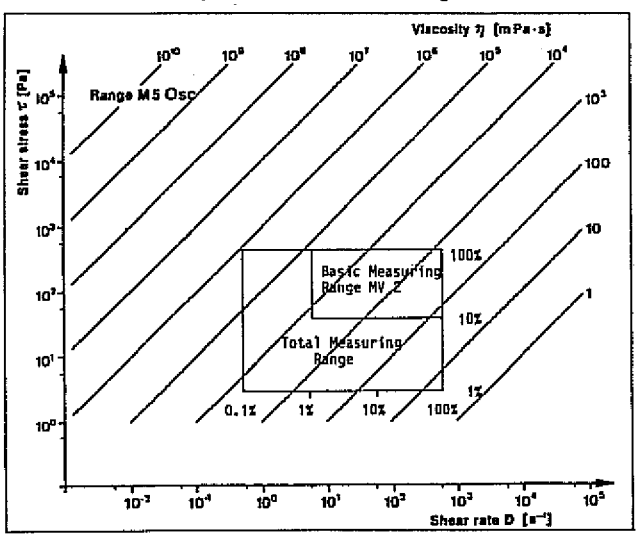
Range with readings from 10.0 to 100.0% gives 37.6 to 376 Pa (τmax% 100)

Range with readings from 1.00 to 10.00% gives 3.76 to 37.6 Pa (τmax% 10)

Oscillation mode:

The system M5-Osc is designed for dynamic tests with a frequency range from 0.05 to 5 Hz. The strain or deformation depends on the deformation angle and the sensor used: γ= 1/30 · M ·φ(rad).

M is the shear rate factor and $\varphi$the deformation angle with recommended values fr 2 to 10°.



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C. Measuring Range with System M10

Basic Measuring Range with System M10 and Sensor HS1 as an example:

This range is achieved in the settings Dmax% 100 and τmax% 100 using the speed steps 1 to 10 and the display reading from 10% τ to 100% τ. In absolute values of shear rate and shear stress this gives a range from D = 400 to 40,000 1/s and τ = 1150 to 11500 Pa

Total Measuring Range with System M10 and Sensor HS1

The total range uses the settings 100%D, 10%D, 1%D and the speed steps 1 to 10 in shear rate and for shear stress 100% τ and 10% τ with a smallest value of 10% of full scale.

Shear Rate:

Range with speed steps 1 to 10 gives 400 to 40000 1/s (Dmax% 100)

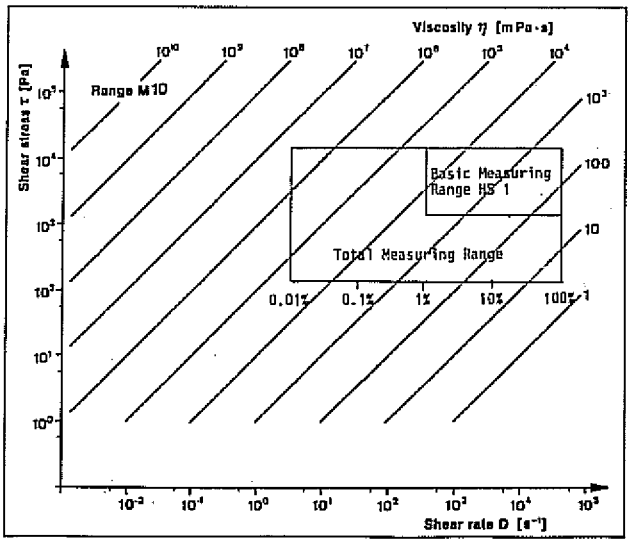
Range with speed steps 1 to 10 gives 40 to 4000 1/s (Dmax% 10)

Range with speed steps 1 to 10 gives 4 to 400 1/s (Dmax% 1)

Shear Stress:

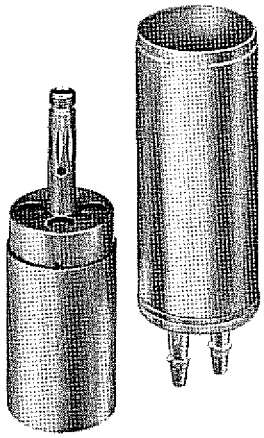
Range with readings from 10.0 to 100.0% gives 1150 to 11500 Pa (τmax% 100)

Range with readings from 1.00 to 10.00% gives 115 to 1150 Pa (τmax% 10)



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6.1 Sensor System NV



Application:

The NV is primarily used for viscosity measurements of low viscous liquids such as oils, diluted solutions, fruit juices etc. working in the medium shear rate range.

The sensor system NV consists of the cup and a bell-shaped rotor. It is classified as a coaxal cylinder sensor system with two gaps for shearing the samples on the inside and on the outside of the rotor.

This sensor system is used with the temperature vessel which is connected to an accurate thermal liquid circulator. The cylindrical insert of the cup can be connected to the circulator to guarantee good temperature control also for the inner gap.

The amount of sample should be adjusted so that during operation the top surface of the inner cylinder is just covered.

The bell-shaped rotor must not be contacted by the liquid sample on its top endface. Excess sample must be removed by a pipette or syringe through any of the four holes in the top face of the rotor.

Low viscous samples require the sealing rings to prevent the liquid sample to leak through the bottom of the cup.
Keep always a sufficient supply of sealing rings in stock as they may deteriorate mechanically or chemically needing to be replaced. (Order No.: 807-0701)

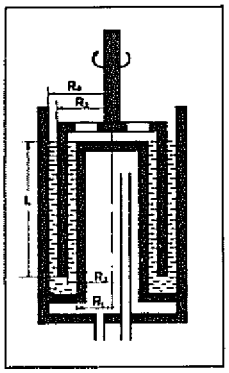
Cleaning:

Remove the cross bar at the bottom of the cup and slide the innér cylindrical insert downwards to simplify cleaning of the cup.

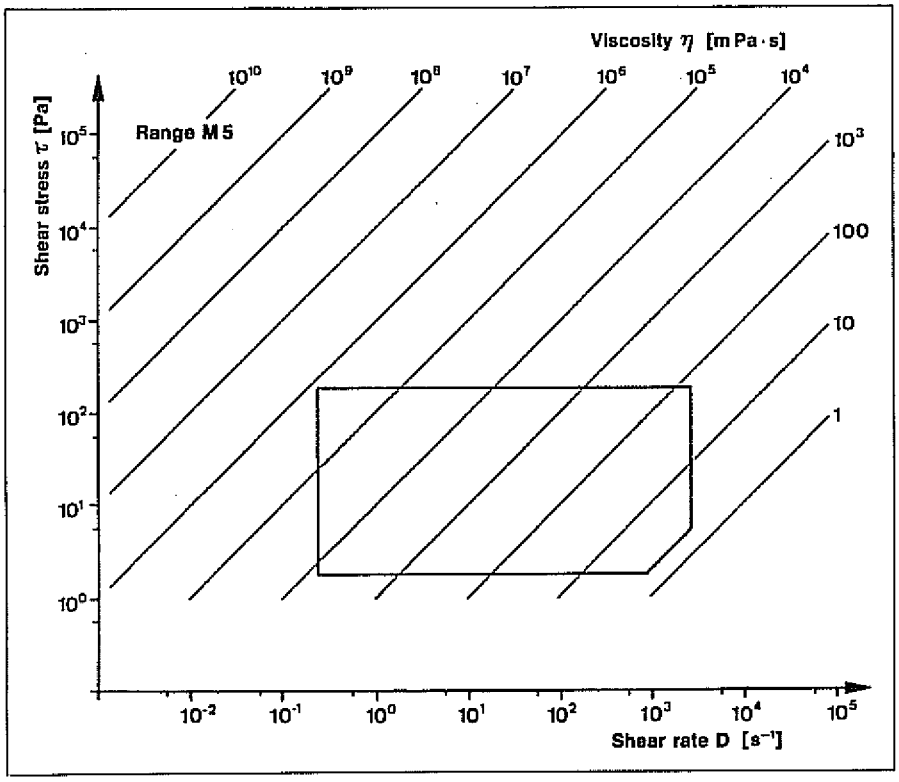
(Order No. for Seal: 807-0701)

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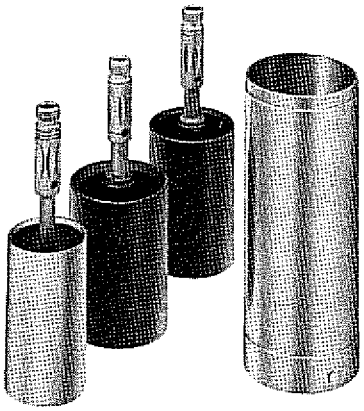


SENSOR NV	NV
INNER CYLINDER (Rotor) radius R_2; R_3 (mm) height L (mm)	 17.85; 20.1 60
OUTER CYLINDER (Cup) radius R_1; R_4 (mm)	 17.5; 20.5
RADII RATIO R_a/R_i SAMPLE VOLUME V (cm^3) TEMPERATURE (°C)	1.02 9 -30/100
FACTORS M5/M5-Osc A (Pa/%τ) M (s^{-1}/%D)	 1.78 27.0
FACTORS M10 A (Pa/%τ) M (s^{-1}/%D)	 3.56 54.1



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6.2 Sensor System MV



Application:

The MV is primarily used for viscosity measurements of medium viscous liquids such as heavy oils, paints, varnishes, resins, emulsions etc. working in the medium shear rate range. Yield points can be determined.

The coaxial cylinder sensor system consists of an MV cup used with three different rotors to provide different viscosity measuring ranges. MV I and MV II are both available in plastic (phenolic thermoset) and in stainless steel 18/8. The plastic rotors are low weight and allow higher rates of rotor acceleration. They are mechanically and chemically safe for temperatures up to 100°C.

This sensor system requires the temperature vessel.

The top and the bottom surfaces of the rotors are recessed to minimize "end effects", i.e. their influence on torque. An air bubble is retained in the bottom recess, while the upper recess accommodates any excess sample.

The required amount of sample depends on the type of rotor used. For reference there are two ring marks on the inside wall of the cup.
The lower mark indicates the approximate sample volume required when the MV1 and the MV2 rotors are used in the MV cup. The upper ring mark applies to the MV3 rotor.

Decreasing the temperature of a sample which just fills the annular gap between cup and rotor to its upper rim will cause the sample volume to shrink. This leads to a just partly filled sensor system, giving reduced torque and erroneous viscosity values below the true viscosity level.

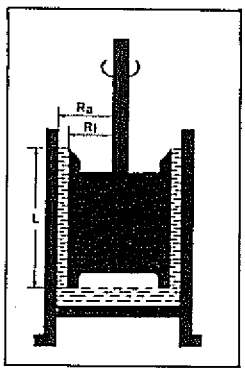
When a sample must be measured at various temperatures, it is advisable to begin at the lowest temperature. When this is not possible, the sensor system MV should be overfilled to such an extent that the sample will be slightly above the rim of the rotor even at the lowest temperature. Alternative rotor: MV DIN

During a test the liquid level of the sample should just overflow into the upper recess of the rotor. The liquid level must not rise above the upper rotor rim for more than 1 to 2 mm. Excess sample may be removed by sucking it back with a suitable syringe.

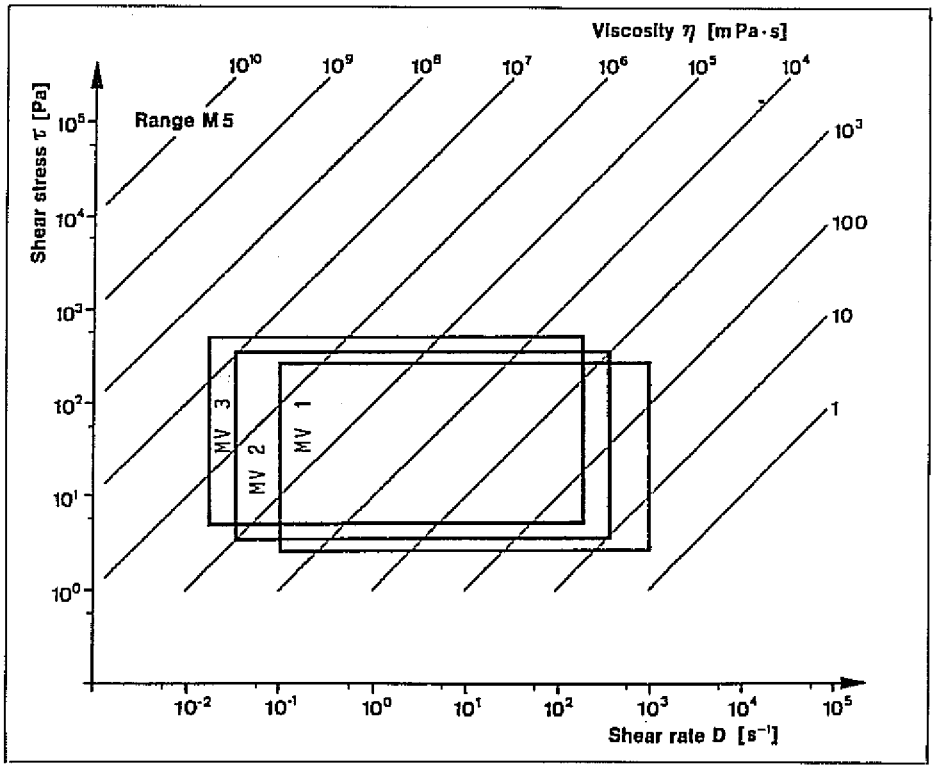
Cleaning: To remove the bottom of the cup, first loosen the knurled screw and take out the cross-bar. (Seal = Order No.: 807-0458)

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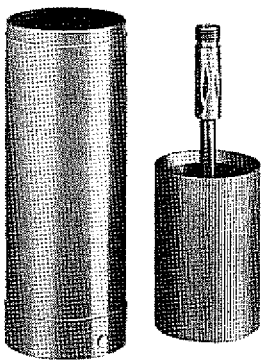


SENSOR MV	MV 1	MV 2	MV 3
INNER CYLINDER (Rotor)			
radius R_i (mm)	20.04	18.4	15.2
height L (mm)	60	60	60
OUTER CYLINDER (Cup)			
radius R_a (mm)	21	21	21
RADII RATIO R_a/R_i	1.05	1.14	1.38
SAMPLE VOLUME V (cm^3)	40	55	70
TEMPERATURE (°C)	-30 / 100		
FACTORS M5/M5-Osc			
A (Pa/%τ)	3.22	3.76	5.44
M (s^{-1}/%D)	11.7	4.51	2.21
FACTORS M10			
A (Pa/%τ)	6.44	7.53	10.9
M (s^{-1}/%D)	23.4	9.0	4.4



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6.3 Sensor System P (profiled)



Application:

These profiled sensor systems are used to test substances which tend to slip on the cup and rotor surfaces, or which are likely to show a phase separation. The materials belonging in this group are: greases, creames, gels, slurries, bentonites etc.

This coaxial cylinder sensor system consists of the cup MVP with the rotors MV1P and MV2P for medium viscous liquids and the cup SVP with the rotor SV2P for higher viscous liquids and requires the temperature vessel.

The top and the bottom surfaces of the rotors are recessed to minimize "end effects", i.e. their influence on torque. An air bubble is retained in the bottom recess, while the upper recess accommodates any excess sample.

The grooves parallel to the axes of both cups and rotors will improve the adhesion between the test substance and surfaces of the sensor system.

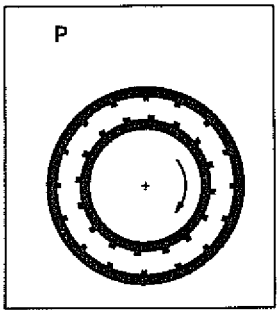
When defining the M and A factors it was assumed that the grooves filled with the test substance would allow calculation with non-grooved cylinder surfaces.

Cleaning:

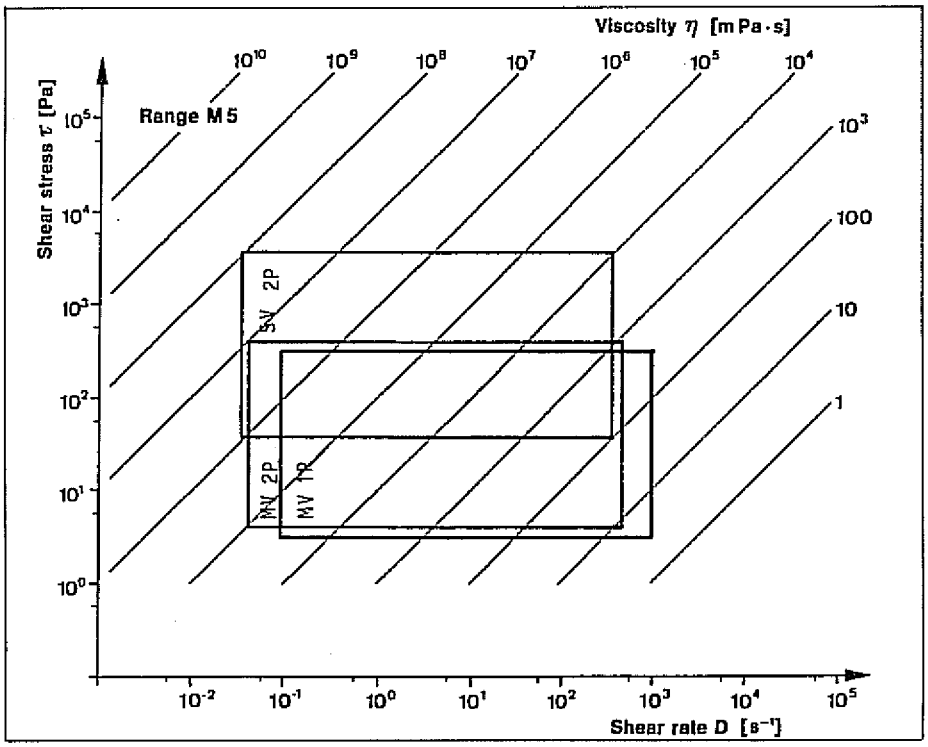
The bottom of the cup can be removed: First loosen the knurled screw and then take out the cross-bar. (Seal = Order No.: 807-0458)

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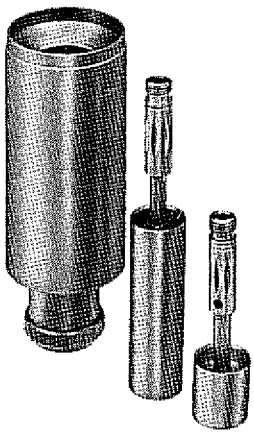


SENSOR MVP	MV IP	MV IIP	SV IIP
INNER CYLINDER (rotor)			
radius R_i (mm)	20.04	18.4	10.1
height L (mm)	60	60	19.6
OUTER CYLINDER (cup)			
radius R_a (mm)	21	21	11.55
RATII RATIO R_a/R_i	1.05	1.14	1.14
SAMPLE VOLUME V (cm^3)	40	55	6
TEMPERATURE (°C)	-30 / 100		
FACTORS M5/M OSC			
A (Pa/%τ)	3.22	3.76	37.6
M (s^{-1}/%D)	10	4.4	3.9
FACTORS M10			
A (Pa/%τ)	6.44	7.53	75.3
M (s^{-1}/%D)	20	8.8	7.8



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6.4 Sensor System SV



Application:

The measuring system SV is primarily used for viscosity measurements of high viscous liquids and pastes such as greases, creames, ointments, plastisols etc. working in the low to medium shear rate range. Yield points are well determined.

This coaxial cylinder sensor system consists of a SV cup with two rotors which provides two different measuring ranges and requires the temperature vessel.

The top and bottom surface of the rotors is recessed to minimize "end effects" i.e. their influence on torque. An air bubble is retained in the bottom recess, while the upper recess accommodates any recess sample.

The amount of sample required depends on the type of rotor used. For reference, there are two ring marks on the inside wall of the cup: the lower mark is a guide for the SV1 rotor, the upper for the SV2 rotor. The SV2 rotor requires less sample when the solid spacer cylinder is placed into the cup.

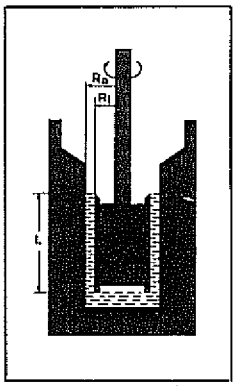
Decreasing the temperature of the sample which just fills the annular gap between the cup and the rotor to the upper rim of the rotor will cause the sample volume to shrink. This will lead to a just partly filled sensor system giving reduced torque and erroneous viscosity values below the true viscosity level.
Rotor alternative: Sensor System SV DIN

When a sample has to be measured at various temperatures, it is advisable to start with the lowest temperature. When this is not possible, the sensor system should be "overfilled" to the extent that the sample will be slightly above the rim of the rotor even at the lowest temperature.

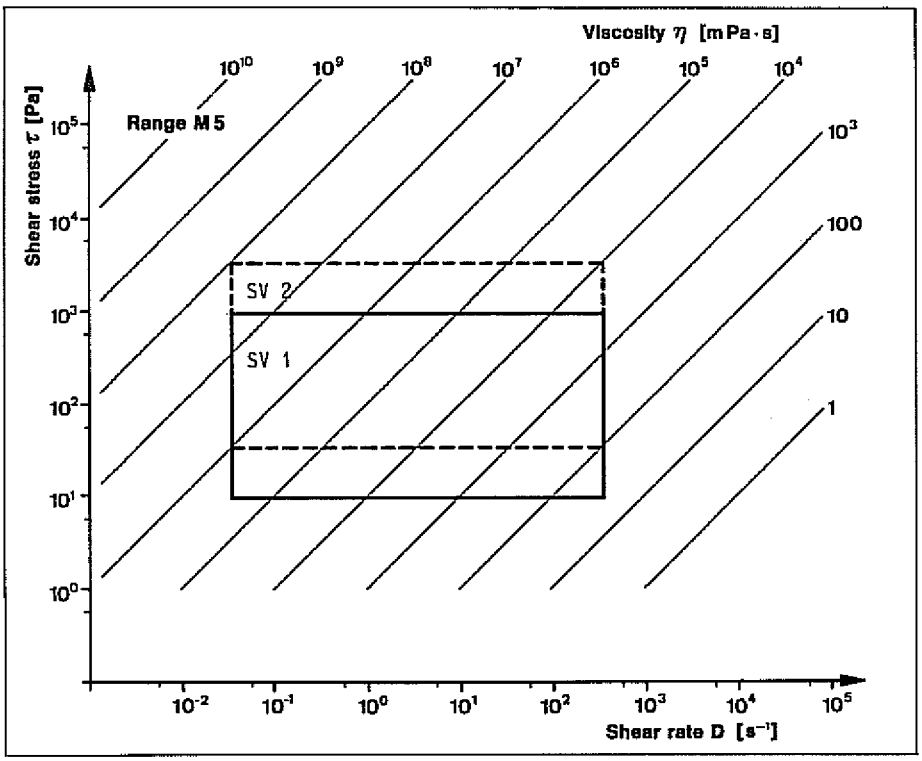
The special rotor SV2FL is designed as a star-shaped rotor and is used with the standard SV cup for the determination of yield points, especially of highly thixotropic samples.

Cleaning: The bottom of the cup can be unscrewed and removed.

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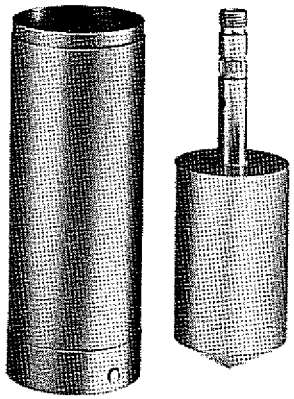


SENSOR SYSTEM SV	SV 1	SV 2	SV 2FL
INNER CYLINDER (Rotor)			
radius R_i (mm)	10.1	10.1	10.1
height L (mm)	61.4	19.6	19.6
OUTER CYLINDER (Cup)			
radius R_a (mm)	11.55	11.55	11.55
RADII RATIO R_a/R_i	1.14	1.14	-
SAMPLE VOLUME V (cm^3)	9	6	10
TEMPERATURE	-30 / 100		
FACTORS M5/M5-Osc			
A (Pa/%τ)	12.4	37.6	28.0
M (s^{-1}/%D)	4.45	4.45	-
FACTORS M10			
A (Pa/%τ)	24.8	75.3	56
M (s^{-1}/%D)	8.9	8.9	-

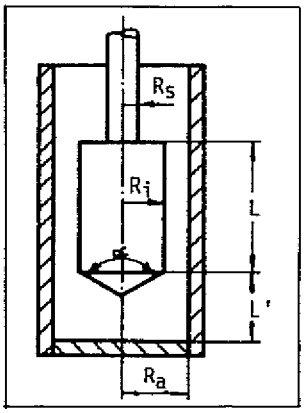


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6.5 Sensor System MV DIN / SV DIN



MV Cup / MV DIN Rotor



Application:

The sensor system has been standardized for the viscosity measurements for water based plastic dispersions (DIN 53 788), and for paints (DIN 53 214).

This coaxial cylinder sensor system consists of the cup MV and the rotor MV DIN or the cup SV and the rotor SV DIN or the cup HV and the rotor HV DIN and requires the temperature vessel.

This sensor system meets the requirements of the German Standard DIN 53 019 for rotational viscometers.

DIN 53019 defines the characteristic geometrical ratios as follows:

$\frac{Ra}{Ri} = 1.0845$ $\quad\quad$ $\frac{Rs}{Ri} \triangleq 0.3$

$\frac{L}{Ri} = 3$ $\quad\quad$ $\frac{L'}{Ri} = 1$

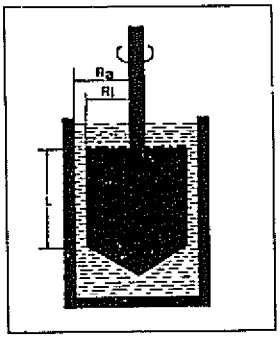
$\alpha = 120^{\circ}$ (2.094 rad)

The sensor system should also be used when samples are subjected to programmed temperature rises and decreases. These temperature changes will only lead to the temperature related change of the sample volume in this sensor system. Its influence on the viscosity measurement will be small unless an unsufficiently overfilled cup leads to an only partly filled anular gap when the temperature is dropped very low.

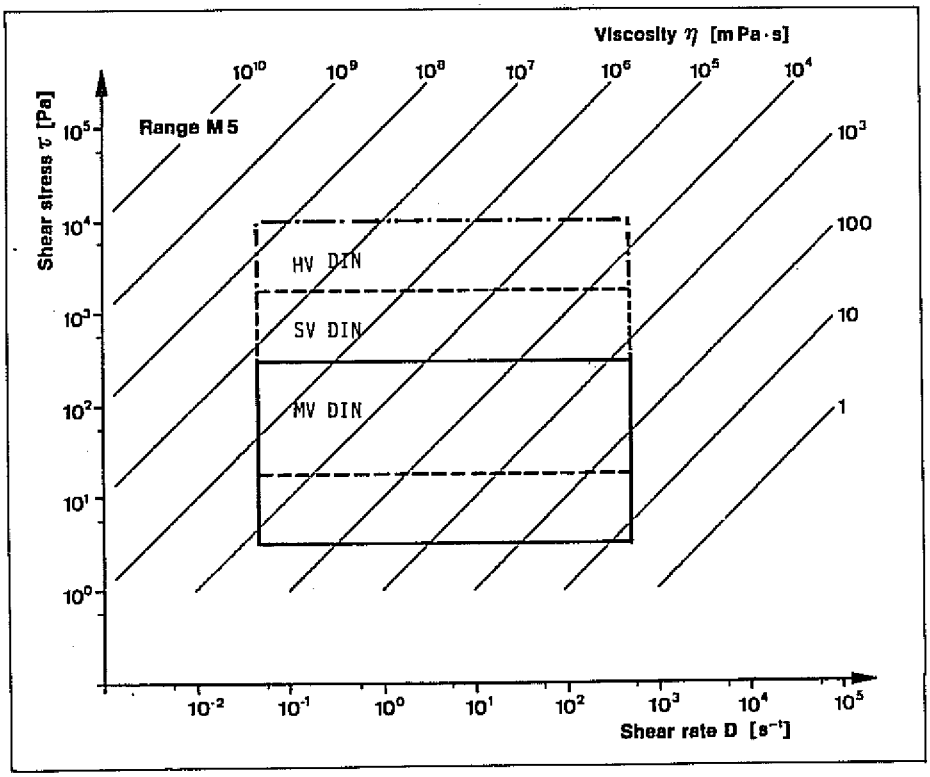
Cleaning: The bottom of the cup can be removed. (Order No. for Seal of MV Beaker = 807-0458)

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SENSOR SYSTEM DIN 53019	MV-DIN	SV-DIN	HV-DIN
INNER CYLINDER (Rotor)			
radius R_i (mm)	19.36	10.65	4.0
height L (mm)	58.08	31.95	11.8
OUTER CYLINDER (Cup)			
radius R_a (mm)	21	11.55	4.388
RADII RATIO R_a/R_i	1.0845	1.0845	1.0845
SAMPLE VOLUME V (cm^3)	50	14	0.7
TEMPERATURE		-30 / 100	
FACTORS M5/M5-Osc			
A (Pa/%τ)	3.01	18.1	345
M (s^{-1}/%D)	6.45	6.45	6.45
FACTORS M10			
A (Pa/%τ)	6.02	36.2	690
M (s^{-1}/%D)	12.9	12.9	12.9



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6.6 Sensor System ME 500

Application: The ME 500 is used for viscosity measurements in the temperature range from 50 to 500°C and, if required, under inert gas. Samples successfully tested were: hot melts, bitumen, pitch, lubricating grease, polymer melts, waxes etc. The ranges of viscosity, shear rate and shear stress covered correspond to those of the standard sensor system MV and SV.

The ME 500 consists of rotors and cups surrounded by a metal block heater which is electronically controlled by the HAAKE temperature regulator (TP) allowing to set the required temperature digitally.

An extension shaft separates the measuring system and the ME 500 to minimize the effect of heat conduction and radiation on the measuring system.

Disposable Sensors:

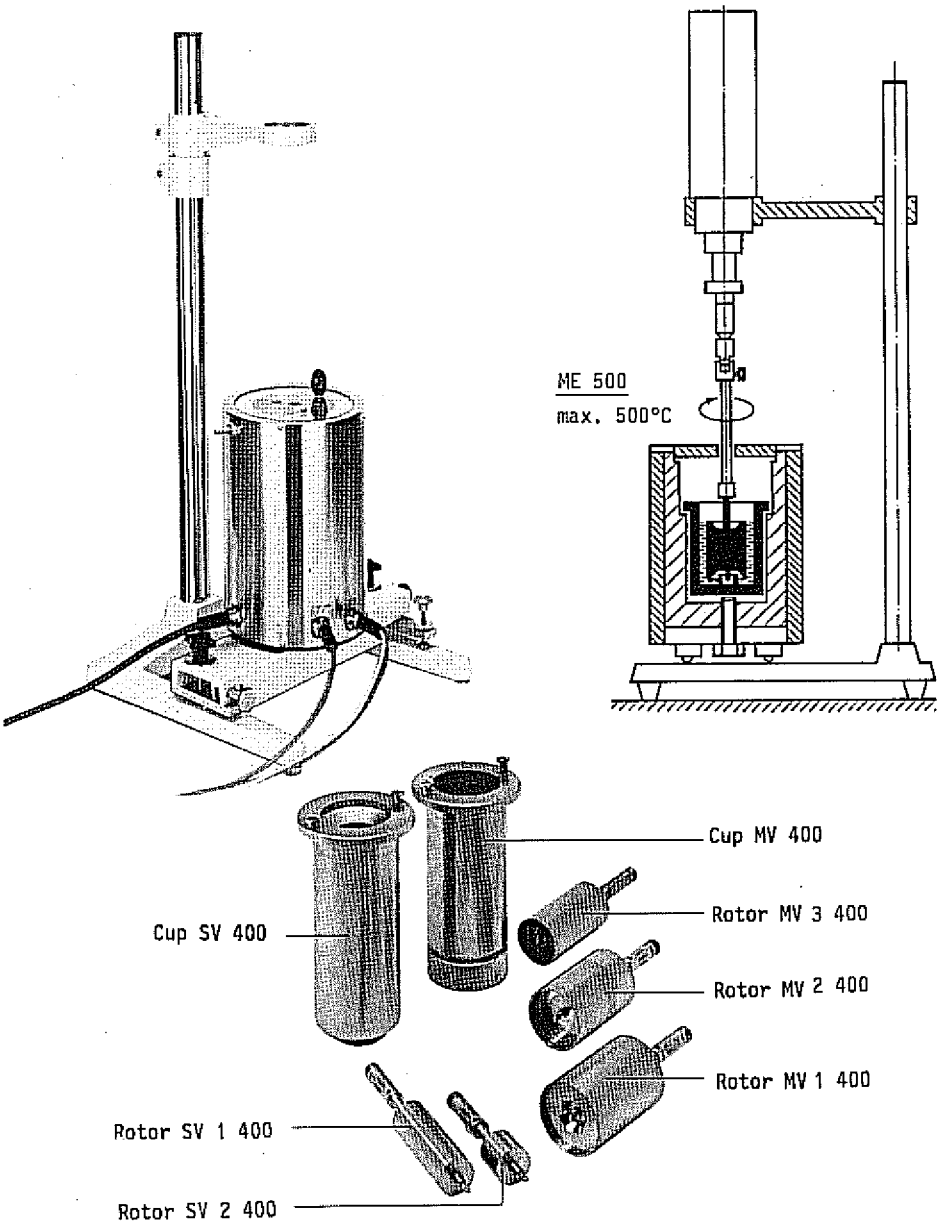
For routine testing of many samples or of samples which are difficult to clean, the disposable sensors are a convenient alternative. The whole package consists of a beaker holder to be put into the ME 500 as well as disposable beakers of aluminum and the standard immersion rotors, e.g. E 30, which are connected to the measuring system via universal joint.

PLEASE NOTE !

Test at temperatures up to 1700°C can be run by making use of special sensor systems. Information will be sent on request.

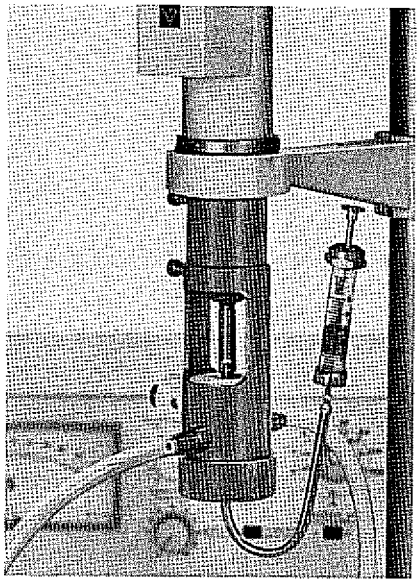
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6.7 Sensor System HS



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 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 press.

If the test substance is non-thixotropic, a rotational speed of 1 to 2% D is applied while injecting the substance. This will support the charging and rotor centering.

The cup is provided with a temperature sensor (Pt 100) which can be connected to the RV 20. The two fittings of the temperature jacket are connected to a circulator.

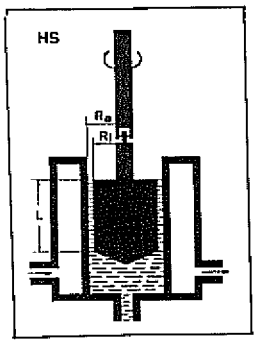
NOTE: Measurements at high speeds will cause considerable amounts of heat in the annular gap. It is, therefore, important that a circulator with a high pumping capacity and short connecting hoses is selected. In most cases this enables measurements without temperature drift due to frictional heating.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

Cleaning:

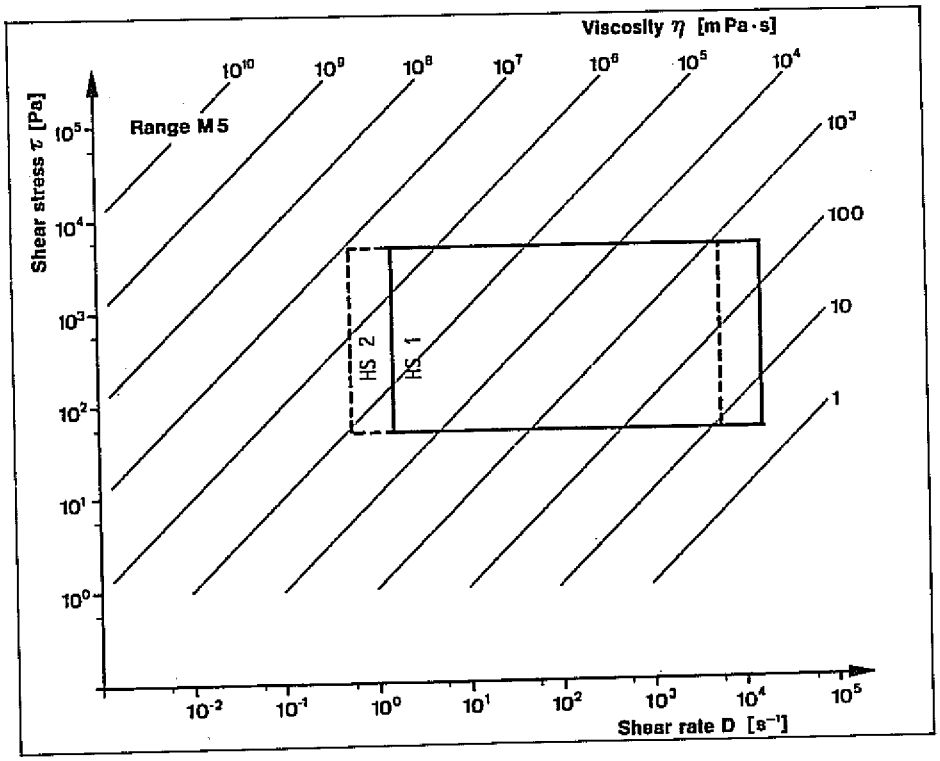
First withdraw the sample with the syringe. Unscrew the bottom lid and remove the rotor. Clean the outer cylinder, the rotor and cover with suitable solvents. sample residues in the syringe can be removed by repeated flushing.

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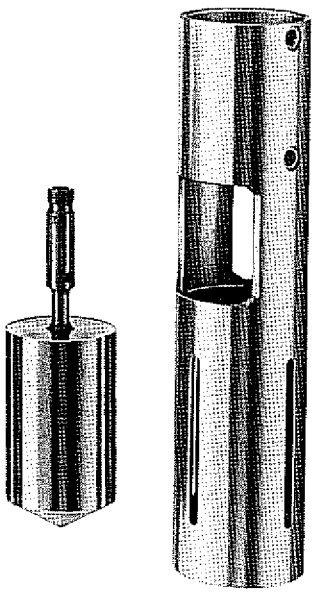


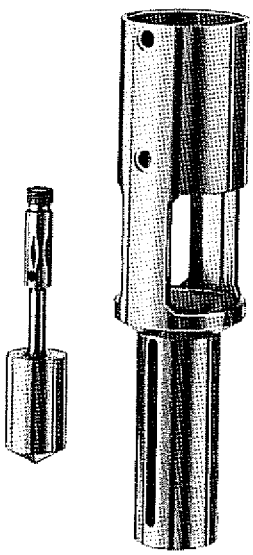
SENSOR SYSTEM HS	HS 1	HS 2
INNER CYLINDER (Rotor) radius R_i (mm) height L (mm)	9.975 15.0	9.90 15.0
OUTER CYLINDER (Cup) radius R_a (mm)	10.00	10.00
RADII RATIO R_a/R_i	1.003	1.01
SAMPLE VOLUME V (cm^3)	5	5
TEMPERATURE	-50 / 100	
FACTORS M5/M5-Osc A (Pa/%τ) M (s^{-1}/%D)	57.4 200	56 50
FACTORS M10 A (Pa/%τ) M (s^{-1}/%D)	115 400	112 100



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6.8 Sensor System T





Application:

The immersion sensor system T is primarily used for the rapid measurement of absolute viscosity of medium viscous samples which are subjected to low and medium shear rates. The sensor system will be simply placed into open vessels or containers.

The sensor system T consists of:

a) immersion tube T/MV and the rotor MV DIN
b) immersion tube T/SV and the rotor SV DIN

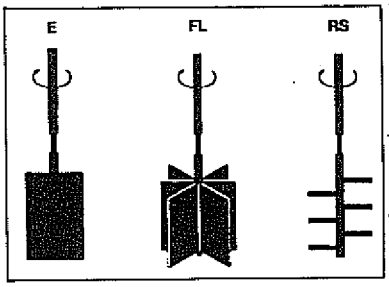
The sensor systems T correspond to the systems MV and SV DIN with regard to the geometrical dimension, the shear rate ranges, the shear stress and the viscosity ranges.

The sample can easily flow into the annular gap between the immersion tube and the rotor either from below or through the slots in the side wall of the tube.

Customers must provide their own temperature control of the sample. The temperature must be noted and specified along with the viscosity data given. Temperature range: 0 - 100°C. Deviations of the sample temperature from a specified temperature can have serious consequences on the viscosity data. As a rule of thumb: 1°C temperature deviation can mean 10% viscosity deviation.

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6.9 Sensor Systems E, FL, RS



Application:

The relative sensors comprise rotors which differ in size and shape and which are suspended into open containers, vessels etc. They are primarily used for simple and rapid measurements of viscous samples which are highly non-homogeneous and contain coarse particles. Test results allow a relative classification of samples with respect to their flow properties.

Please bear in mind! These immersion sensor systems cannot be used to measure absolute values of viscosity for non-Newtonian substances.

To avoid the influence of the walls, the inner diameter of the vessel should be at least 4 times the diameter of the rotors. If the measurements have to be done in smaller vessels, the influence of the walls can be determined by calibrating the rotor/container combination with Newtonian oils.

Rotors are suspended from the shaft of the measuring system by means of a universal coupling. Measurements at high temperatures will call for an optional extended shaft. The temperature of the sample to be tested must be measured and noted along with the viscosity data. Temperature range: - 50 to 100°C.

Immersions Sensor System E

These are cylindrical rotors (5 types). Rotor E 3 is bell-shaped.

Immersion Sensor System FL

These are star-shaped rotors (3 types). They can be successfully used to determine yield points of creams, gels etc. which are often highly thixotropic losing their structure even before the test just by forcing them into narrow 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 τ/time-curve: When the yield point is surpassed, the rotor "cuts a hole" into the sample and the test is finished.

Immersion Sensor System RS

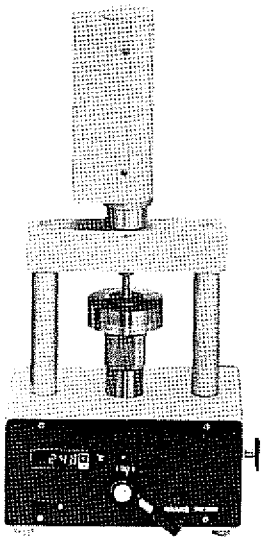
Pin-shaped rotors (2 types). The number of pins and their length may be altered to shift the measuring range or to cope with varying amounts or sizes of particles. A special version of the RS is the sensor system RSS which is positively centered by mechanical means. The universal coupling is not required.

Sensor System:	Diameter/Height (mm):	Measuring Ranges (mPa·s):
E 3	50/116	$20 - 10^3$
E 30	24/50.5	$200 - 10^4$
E 100	16/34.5	$10^3 - 10^5$
E 500	10/18	$10^4 - 10^6$
E 1000	7/17.7	$5 \cdot 10^4 - 2 \cdot 10^6$
FL 10	40/60	$100 - 10^4$
FL 100	22/16	$10^3 - 10^5$
FL 1000	10/8.8	$10^4 - 10^6$
RS	2 sets of 6 pins: 43 and 103 dia.	$10^4 - 10^7$
RSS	2 sets of 6 pins: 43 and 103 dia.	$10^4 - 10^7$

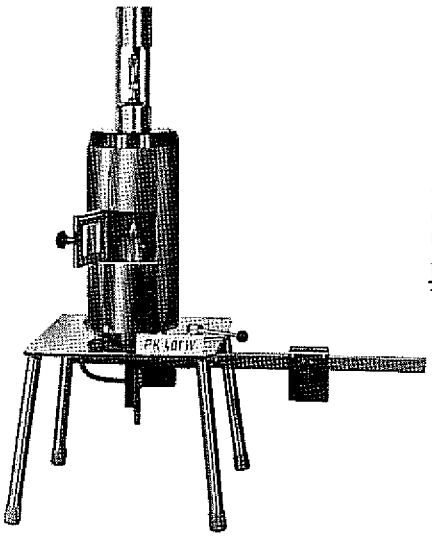
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6.10 Sensor System and 'Cone and Plate'

PK 100



PK 401



Application:

These sensor systems are primarily used when only small sample volumes are available, when testing at high shear rates is required and when cleaning after a test would present tremendous problems in coaxial cylinder sensor systems. Typical samples tested with 'cone and plate' are printing inks, resistor pastes, lipstick base materials, thermosetting polymers etc.

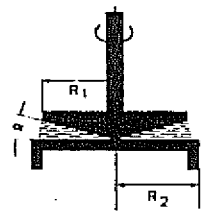
Samples are sheared in the angular gap between the cone and the plate. The design of several cones available ensures that the shear rate is constant from the tip to the outer rim of the cone. Contact between the tip of the cone and the plate is a must for the correct interpretation of the test results. Cones with cone angles of 0.5° and 1.0° are listed. Cones with angles above 4° are rheologically not recommended.

Cones with a wider radius as compared to cones with a smaller radius will allow to test lower viscous samples.

Small sample sizes and the effect of high shear causes the temperature of a sample to rise above the required test temperature due to frictional heat. In cases where this phenomenon becomes dominant, it is advised to check some points on the flow curve for values of high shear rate. Tests are then run at fixed rotor speed for short periods of time only. Time intervals are allowed between different values of speed to allow the temperature of the sample to settle again on the required level.

NOTE: The PK 100 allows to monitor the temperature of the sample during a test. (Optional for the PK 401)

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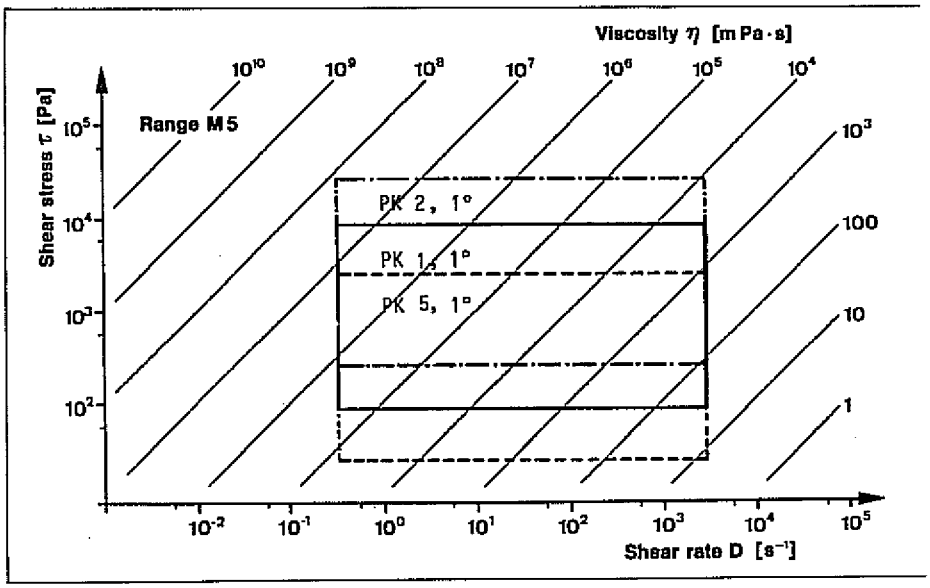


cones for PK 100

cones for PK 401

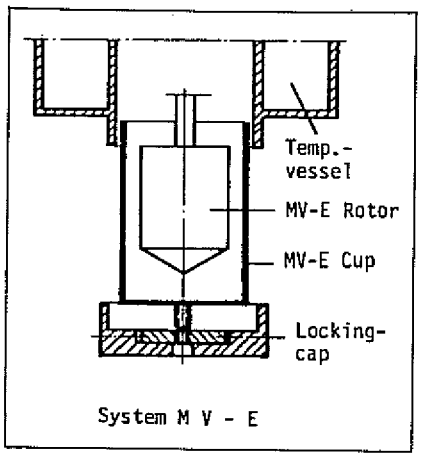
SENSOR SYSTEM PK	PK1, 0.5°	PK1, 1.0°	PK2, 0.5°	PK2, 1.0°	PK5, 0.5°	PK5, 1.0°	PK1* 2.0°	PK5* 2.0°
CONE Radius R_1 (mm) Cone angle (10^{-2}rad)	14 0.873	14 1.74	10 0.873	10 1.74	25 0.873	25 1.74	14 3.49	25 3.49
SAMPLE VOLUME V (cm^3)	0.1	0.2	0.1	0.15	1	1	0.3	1.5
FACTORS M5/M5-Osc A (Pa/%τ) M (s^{-1}/%D)	85.3 60	85.3 30	234 60	234 30	15 60	15 30	85.3 15	15 15
FACTORS M 10 A (Pa/%τ) M (s^{-1}/%D)	170.5 120	170.5 60	468 120	468 60	30 120	30 60	170.5 30	30 30
GAP SETTING (µm)	0	0	0	0	0	0	70	100

* = truncated cones

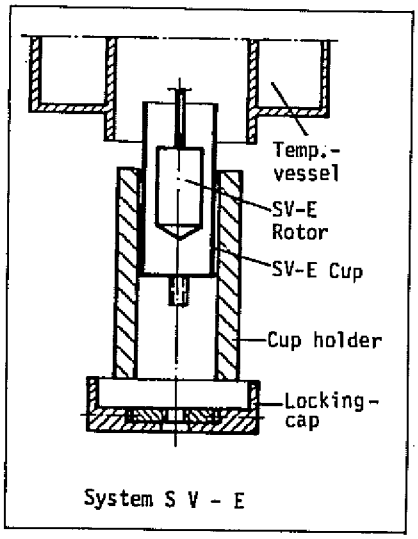


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6.11 Disposable Sensors



System M V - E



System S V - E

Application:

The disposable sensors are recommended when cleaning is a problem or when many tests with various samples have to be run. The disposable part is the measuring cup made of aluminum whereas the rotor remains the same, its shape making cleaning easy.

There are two disposable sensors available for use with the regular temperature vessel. One is the system MV-E DIN consisting of aluminum cups (disposable) and a stainless steel rotor MV-E. While the cups with the sample are discarded at the end of the test, the rotors are cleaned and used anew. The other system is the SV-E DIN system consisting of a stainless steel holder, aluminium cup (disposable) and a stainless steel rotor SV-E. Both systems have similar measuring range factors as the systems MV/SV DIN. A special locking cap is required for holding the cups in the temperature vessel.

Sensor System:	MV - E	SV - E
Inner Cylinder (Rotor)		
Radius R_1 (mm)	20.005	11.15
Height L (mm)	60	33.4
Outer Cylinder (Cup)		
Radius$_a$ (mm)	21.7	12.1
Radii Ratio R_a/R_i	1.0847	1.0847
Sample Volume V (cm³)	65	11
Temperature Range (°C)	0/60	0/100
Factors M5/M5-Osc		
A (Pa/%τ)	2.74	15.78
M (s^{-1}/%D)	6.45	6.45
Factors M10		
A (Pa/%τ)	5.48	31.56
M (s^{-1}/%D)	12.9	12.9

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8.0 Evaluation

The given calculation factors A and M of a sensor system are used to determine shear rate, shear stress and viscosity-values from the recorded curve.

Shear Rate D:

$D = M \cdot \%D \quad [1/s]$

M = Shear rate factor, depending on the sensor system

%D = Preset shear rate value set and displayed at the RV 20

Shear Stress τ:

$\tau = A \cdot \%\tau \quad [Pa]$

A = Shear stress factor, depending on the sensor system

$\%\tau$ = Indicated shear stress value of the display

Viscosity η:

$\eta = \tau/D \quad [Pa \cdot s]$

τ = Shear stress

D = Shear rate

The result is in "Pa·s" units. To get "mPa·s" multiply the value by the factor 1000.

Conversion of data from SI to CGS units:

Viscosity η:	Pascal seconds (Pa·s); 1 Pa·s = 10 Poise; 1 mPa·s = 1 cP (centi Poise)
Shear Stress τ:	Pascal (Pa) 1 Pa = 10 dynes/cm²
Shear Rate D:	Reciprocal second (1/s)

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8.1 Equations for the Evaluation

The designations used are:

M_d	=	torque at the rotor (Ncm)	f	=	shape factor
L	=	height of the rotor (cm)	A	=	shear stress factor
R_i	=	radius of rotor (cm)	a	=	torque-signal factor
R_a	=	radius of cup (cm)	M	=	shear rate factor
n	=	speed of the rotor (min^{-1})	%τ	=	displayed shear stress
α	=	opening angle of the cone (rad)	%D	=	preset shear rate
R_k	=	radius of the cone (cm)			

Shear Stress τ

The shear stress τ is linearly linked to the torque M_d:

$$\tau = f \cdot M_d \qquad (1)$$

The proportionality factor 'f' recognizes the characteristic geometry of the rotor. One might call 'f' the 'shape factor'. The shear stress τ can be calculated easily using the value '% τ' measured:

$$\tau = A \cdot \%\tau \qquad (2)$$

Combining (1) and (2) defines the shear stress factor A:

$$A = f \cdot a \quad \text{with a = torque/\%}\tau\text{reading} \qquad (3)$$

The 'a'-value is a constant correlation factor to correlate the torque applied at the shaft of the measuring system to the reading. The value 'a' depends on the constant of the torsion bar and the electrical specifications of both the basic-unit and the measuring system. The true value of 'a' is given in the list of calculation factors supplied with each measuring system.

The shape factor 'f' can be calculated for the range of sensors offered using the following equations:

Cylinder Sensor Systems:

$$f = \frac{1}{2 \cdot \pi \cdot L \cdot R_i^2} \qquad (4)$$

It is common practice to add a correction factor to the value 'f' which originates from the unavoidable torque caused by the cylinder end faces (end-effects) and which is added to the real torque created by the mass sheared in the coaxial cylinder gap. Thus instead of the real rotor height L a corrected height L* is used in the equation (5).

$$L^* = L + \Delta L \qquad (5)$$

This value ΔL is defined by means of the procedure as stated in the German Standard DIN 53 018, page 2.

Cone-and-Plate Sensor Systems:

$$f = \frac{3}{2 \cdot \pi \cdot R_k^3} \qquad (6)$$

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Shear Rate D:

The shear rate D can be calculated using the value %D.

$$D = M \cdot \%D \qquad (7)$$

The proportionality factor 'M' recognizes the characteristical geometry of the sensor system. It is defined as the shear rate per speed unit. The following equations define this 'M' factor:

Cylinder Sensor Systems:

$$M = \frac{\pi}{15} \cdot \frac{R_a^2}{R_a^2 - R_i^2} \cdot \frac{n\ (max)}{100} \qquad (8)$$

Cone-and-Plate Sensor System:

$$M = \frac{\pi}{30 \cdot \alpha} \cdot \frac{n\ (max)}{100} \qquad (9)$$

NOTE: The new SI-unit of an angle is the "radiant" rad. This correlates to the normally used "degree angle" (°):

$$1° = \frac{\pi}{180}\ rad = 0.0174\ rad$$

Viscosity η:

The equation to calculate the viscosity of Newtonian liquids is:

$$\tau = \eta \cdot D \qquad (10)$$

or

$$\eta = \frac{\tau}{D}\ (Pa \cdot s) \qquad (11)$$

$$\eta = 10^3 \cdot \frac{\tau}{D}\ (mPa \cdot s) \qquad (12)$$

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8.2 Determination of Instrument Constants

Shear rate D, shear stress τ and viscosity η are computed from test results of %D and $\%\tau$ with the sensor factors M (shear rate factor) and A (shear stress factor). These factors are documented in the list of calculation factors delivered with each instrument. The have been established by means of an absolute test of 'weighing torques' or they are, as for instance M and f, calculated by using the geometrical dimensions of the sensor:

Sensor System:	$f \cdot 10^{-4}$ (cm^{-3})	M5 (s^{-1}/%D)	M10 (s^{-1}/%D)
NV	36.3	27.0	54.1
MV 1 / T 1	65.7	11.7	23.4
MV 2 / T 2	76.8	4.51	9.0
MV 3	111.0	2.2	4.4
MV 1 P	65.7	10.0	20.0
MV 2 P	76.8	4.4	8.8
MV SP	87.8	56.0*	112.0*
SV 1	253.0	4.45	8.9
SV 2	768.0	4.45	8.9
SV 2 P	768.0	3.9	7.8
SV 2 FL	572.0	-	-
SV SP	253.0	22.0*	44.0*
MV DIN	61.43	6.45	12.9
SV DIN	369.4	6.45	12.9
HV DIN	7041.0	6.45	12.9
MV-E	55.9	6.45	12.9
SV-E	322.1	6.45	12.9
HS 1	1172.0	200.0*	400.0*
HS 2	1142.0	50.0*	100.0*
PK 5, 2°	305.6	15.0*	30.0*
PK 1, 2°	1740.0	15.0*	30.0*
PK 5, 1°	305.6	30.0*	60.0*
PK 1, 1°	1740.0	30.0*	60.0*
PK 2, 1°	4775.0	30.0*	60.0*
PK 5, 0.5°	305.6	60.0*	120.0*
PK 1, 0.5°	1740.0	60.0*	120.0*
PK 2, 0.5°	4775.0	60.0*	120.0*
PK 5, 0.3°	305.6	100.0*	200.0*
PK 1, 0.3°	1740.0	100.0*	200.0*
PK 2, 0.3°	4775.0	100.0*	200.0*

* Denotes reference values only. See list of calculation factors for exact values.

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9.0 Measurements

1) Preset %τ, % D according to application.

2) Adjust the zero point.

3) Fill the test sample into the sensor system and wait for the required temperature to be reached.

4) Press button "START" to run the test.

Hints for choosing the instrument parameters:

a) τ max% setting

Choose value of τmax% setting so that the highest shear rate level required will result in the highest signal.

Please Note: The values of %τ will increase when sensor systems with smaller values of the calculation factor 'A' are selected.

b) % D

The selection of % D must be based on the requirements of the expected test results: High shear rates which may be required will lead to high values of % D. If yield points must be measured or if the recovery of a thixotropic structure After shearing a sample is of main interest, then small values of % D such as 1% D should be selected.

c) Program times with Speed Programmer PG242:

Selecting t_1:

t_1 is defined as the hold time period which starts by pressing button (10).

The time t_1 for good temperature control depends on:

- the type of sample and its specific heat coefficient
- the temperature difference between ambient and the required test temperature
- the type of sensor system selected: Gap size between inner cylinder and beaker, surface area of the inner cylinder, wall thickness of the beaker etc.
- the type of circulator used to control the temperature (heating and pumping capacity etc.)

Values of t_1 = 3 min. will be acceptable for many water based samples to be tested at or slightly above room temperature. Testing pastes or cremes at temperatures above 30°C may require a t_1 = 4 min. or more.

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Selecting t_2

Apart from selecting the shear rate and the shear stress ranges, the program time t_2 is the most important parameter.

In the τ/D-mode the t_2 value defines the time to ramp up the speed from zero to the maximum set value and back to zero.

Flow curves can be recorded for continuously increasing shear rates (up-curve) and for continuously decreasing shear rates (down-curve). Proper test conditions have been found when for Newtonian liquids such as mineral oils the up- and down-curves are straight and fully superimposed. If the rates of acceleration (small values of t_2 and high values of max. %D) are high for the up- and down-curves then quite often a sizeable hysteresis between both curves will be experienced: the "down-curve" comes back above the "up-curve". This hysteresis, which effects the true measurement, is caused by the time-lag between the imposed shear rate and the resulting shear stress. Especially for samples of higher viscosity it is recommended to increase the value t_2 in order to decrease the hysteresis.

Statistically a t_2 = 3 min. will be suitable for 50% of all viscosity measurements. On samples of high viscosity, however, acceptable values of t_2 might be close to 10 min. Values of t_2 smaller than 1 min. are not recommended.

Selecting t_3

t_3 is defined as the hold time at max. shear rate before the program cycle is reversed and the "down-curve" started.

For non-thixotropic samples a value t_3 = 0.1 min. is suitable. For thixotropic samples which are shear-time dependent, the value of t_3 should be increased to 1, 3 or even 10 minutes.

Please Note:

Expanding a small speed range and using high sensitivity %τ an off-set of the start of the flow curve can occur. This is normal and a result of the unavoidable play in the gear train.

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9.1 Test Example 1

As an example the measurement of a Newtonian liquid (mineral oil) is used to determine the calculation factors of the sensor system.

The instrument combination in this example comprises the ROTOVISCO RV 20 with measuring system M5 and cone and plate sensor system PK 100 with cone PK 1, 1°. For calibration normally "standard liquids" such as mineral oils of known viscosity are measured after having the sample temperature controlled in the sensor system under rotation for at least 20 minutes. The reference temperature, in this case 20.0°C, for the HAAKE standard oil E 6000 has to be kept constant better than +/- 0.1°C

Measurement: Pairs of data $\%\tau$ and %D are take manually with a rest time of some minutes between two measurements to remove frictional heat.

Data Table:

%D	1.67	2.78	4.64	7.74	13	21.5	36
$\%\tau$	7.2	9.4	13.3	19.8	30.2	48.1	75

The above data are plotted in the graph paper and the data points connected to get a straight line. It can be seen that the curve does not go through the origin, which means that the zero-point was not adjusted properly. At high shear rates the data points are below the straight line, which can be explained with a reduction in viscosity and shear stress due to frictional heat. These values are neglected for calculations, only the slope of the straight line is used.

$$\text{Slope: } \frac{\Delta\%\tau}{\Delta\%D} = \frac{\%\tau\,(2) - \%\tau\,(1)}{\%D\,(2) - \%D\,(1)} = \frac{40.9}{19.83}$$

To calculate the instrument factors the shape factor 'f' of the sensor PK 1, 1° has to be taken from section 8.2 and the small 'a' factor of the measuring system from section 5.0:

$$f = 1740 \cdot 10^{-4}\ cm^{-3} \quad \text{and} \quad a = 0.049\ Ncm/\%\tau$$

With the equation "A = f . a" the A-factor can be determined to 85.3 Pa/$\%\tau$.

To calculate the viscosity the following equation applies:

$$\eta\,(Pa \cdot s) = (\%\tau \cdot A)/(\%D \cdot M)$$

In this example the viscosity of the standard is known but the shear rate factor M has to be determined:

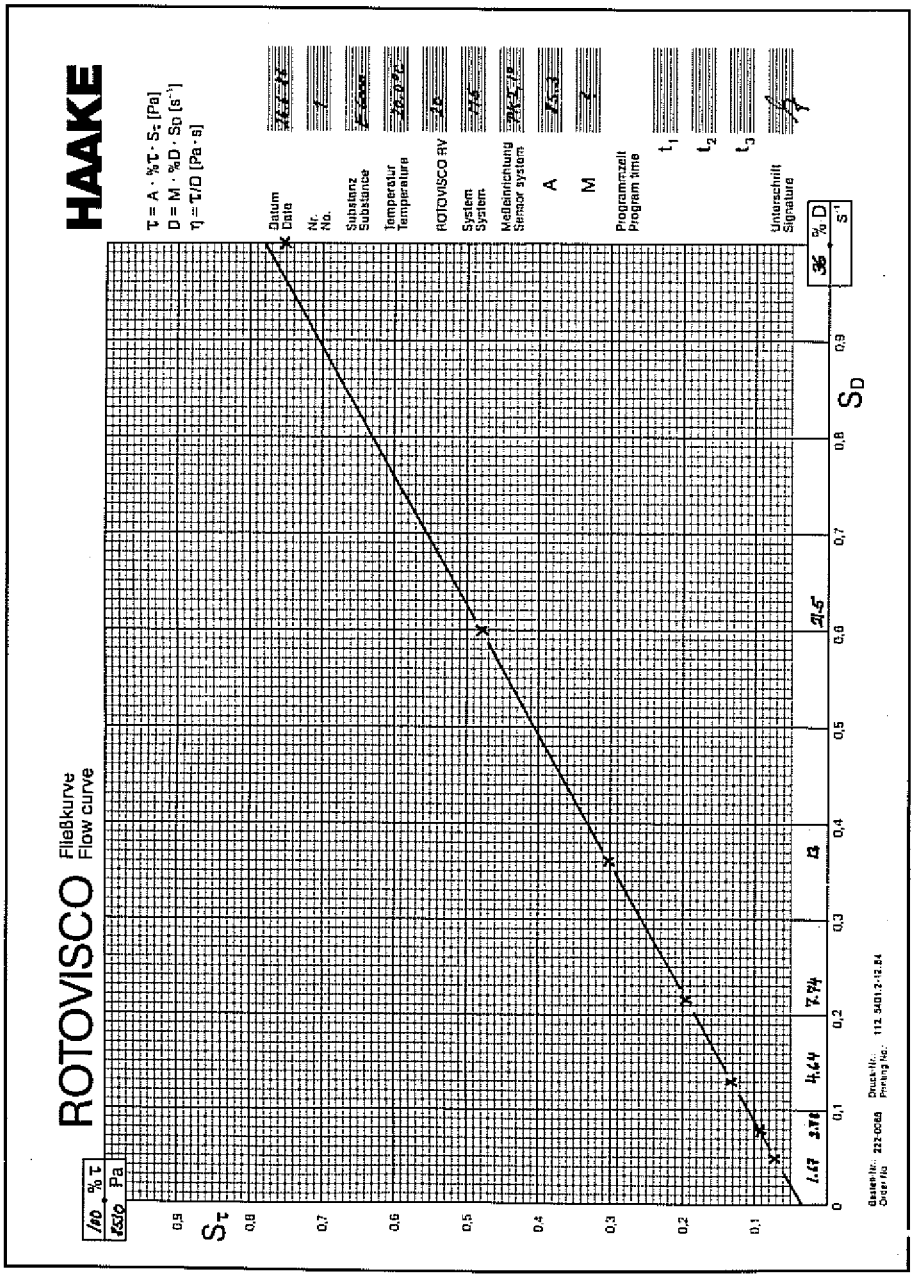
$$M = (\Delta\%\tau\,/\Delta\%D) \cdot A/\eta \text{ (standard)}$$

$$\underline{M} = (40.9/19.83) \cdot 85.3/5.74 = \underline{30.6}$$

With this procedure the calculation factors A and M can be determined which is necessary for sensors like PK, HS, MVSP and SVSP.

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HAAKE



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9.2 Test Example 2

As an example to show the differences between manual operation and programmed flow curve recording, a non-thixotropic paste was measured. Preliminary tests showed slippage using the standard sensor MV2 which led to the use of the grooved sensor MV2P.

a. Manual operation:

Several shear rates were preset and the resulting shear stress read from the display. The data table shows the result:

%D	100	60	36	21.5	13	7.74	4.64	2.78
D=%D·M	440	264	158.4	94.6	57.2	34.1	20.4	12.2
$\%\tau$	81	67	54	46.3	39	35	32	26
$\tau=\%\tau \cdot A$	304.6	252	203	174	147	132	120	98
$\eta=\tau/D$ [Pa.s]	0.692	0.954	1.28	1.84	2.57	3.87	5.88	8.03

The values %D and $\%\tau$ plotted in a graph paper give the flow curve of the sample tested. The flow behaviour looks like plasticity but the yield point cannot be measured. By extrapolating the curve to shear rate '0' a fictive yield point can be determined.

b. Programmed flow curve recording:

The ROTOVISCO RV20 with Programmer PG242 and the HAAKE xy-t Recorder allow the automatic recording of flow curves. For this test, the same sensor and measuring range was choosen to compare the test result.

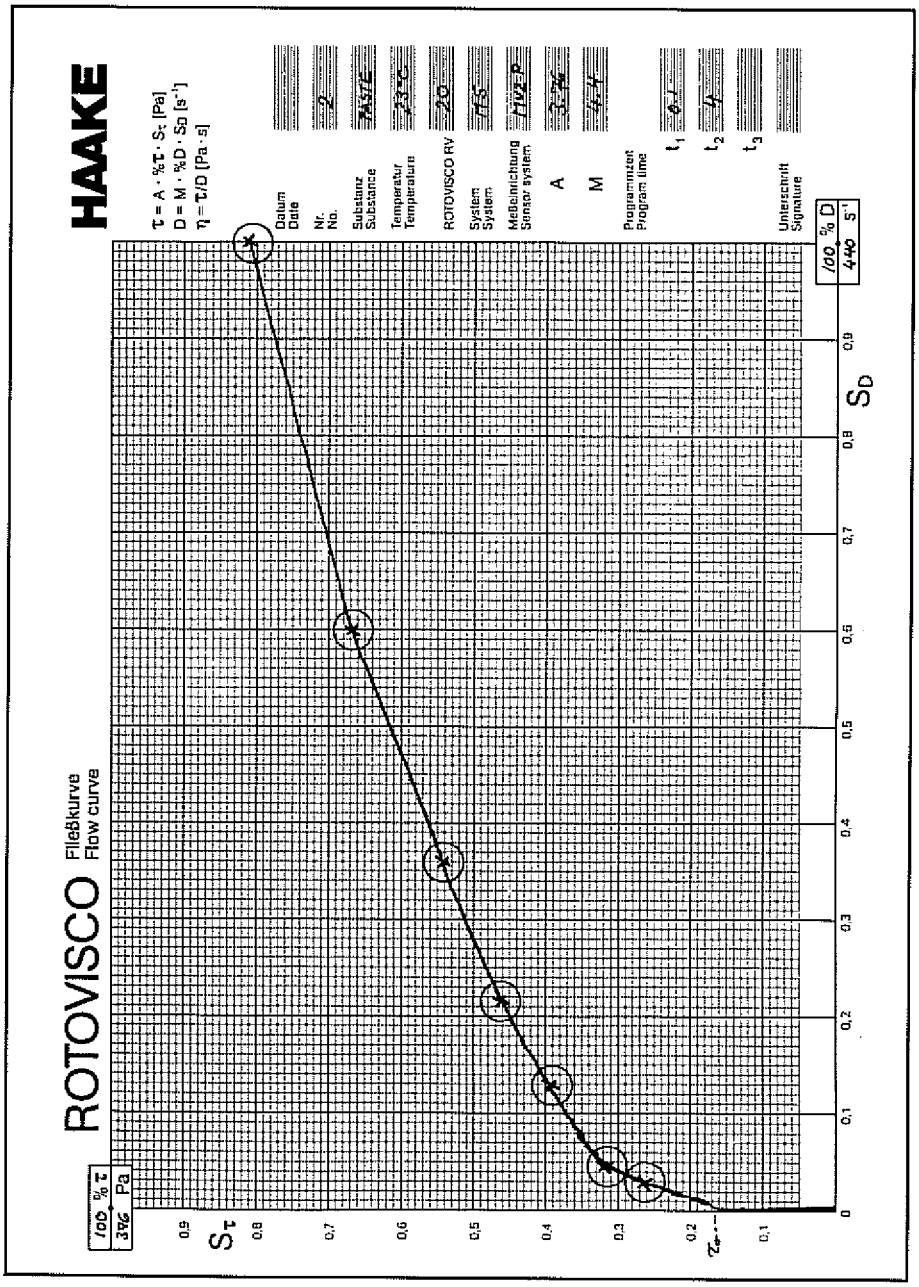
The flow curve shows the same result as in manual operation with the exception of data at shear rates close to zero. Here, the automatically taken curve shows a steep increase in shear stress at the beginning which represents the yield point. The yield point is the shear stress required to make the sample flow and can be observed in the transition from non-flow to flow.

c. Conclusion

Using the programmed flow curve method yield points can be measured which are not seen in manual operation.

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9.3 Test Sample 3

Several procedures are known to characterize a thixotropic sample. One of them, the "hysteresis loop" method is common in research and quality control because of its advantage in speed and reproducibility.

To demonstrate its use, a thixotropic coal slurry was tested with sensor MV2P in the shear rate range from 0 to 200 1/s, using the ROTOVISCO RV20 with measuring system M5 and the Programmer PG242. The flow curve was recorded with the HAAKE xy-t Recorder.

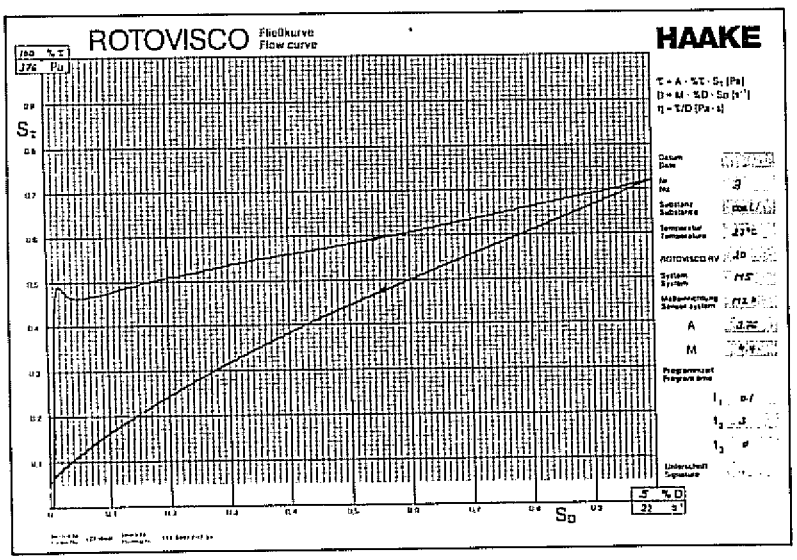
The test result shows a yield point of τ_{01} = 184 Pa and τ_{02} = 22 Pa and a distinct difference between the up and down curve. This hysteresis area shows the amount of thixotropy under the test conditions choosen and are a measure for comparison.

Thixotropy = (Area under up curve) - (Area under down curve)

A further possibility to quantify thixotropy, is to select one shear rate in the curve and to calculate the viscosity of the up and down curve.

Thixotropy = (Viscosity up curve) / (Viscosity down curve)

Using always the same test conditions both procedures give reproducible data to quantify thixotropy.



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11.0 RELAXATION TESTS

a) Application

Relaxation tests are used to determine the elasticity of liquids or paste. This is in principle a simple method but results are based on several assumptions:

- the sample can be described by a certain model (Maxwell-body);
- the viscometer can measure without delay.

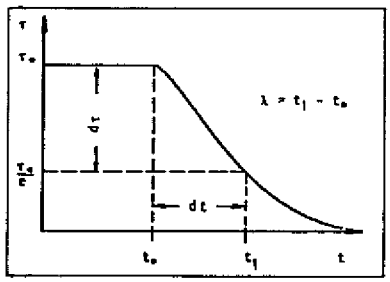
In most cases both assumptions cannot be realized. That is why the results should be used for comparison only.

b) Test method

The test sample is sheared with a constant shear rate until the resulting shear stress is constant. Then the shear rate is instantaneously removed and the delay of the shear stress recorded.

c) Result and Evaluation

The relaxation curve is the result obtained.



The relaxation time λ is the same time which the shear stress τ_0 takes to go down to τ_0/e with e = 2.7183

d) Measurement

Preset shear rates as small as possible (just enough to get a reasonable $\%\tau$ signal) and use the 'D% = 1' range setting if possible. Choose a sensor system with a small shear rate factor M to reduce the applied strain. Record the shear stress signal $\%\tau$ with a fast y-t recorder or the HAAKE xy-t recorder in time mode. Switch the filter (damping) at the RV20 off (position zero).

Press the start-button of the RV20 and wait a few seconds until the shear stress signal reaches a constant level. Then press the STOP-button to remove the shear rate instantaneously and record the decay of the shear stress signal. For evaluation use the method shown in "c".

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12.0 DYNAMIC TESTS - Theory

In this mode the sensor oscillates around a fictive zero-point with the amplitude and frequency controlled by the RHEOCONTROLLER. The preset strain is a cosine according to the following equation:

$$\gamma = \gamma_0 \cdot \cos(\omega t)$$

γ = Strain

γ_0 = Amplitude of strain

The reaction of the substance to the preset strain can be expressed as:

$$\tau = \tau_0 \cdot \cos(\omega t + \delta)$$

τ = Shear stress

τ_0 = Amplitude of shear stress

δ = Phase shift

With these equations all the expressions can be derived:

a) the complex module G* is defined as:

$$G^* = \tau_0 / \gamma_0$$

It can be divided in:

Storage module G' with $G' = G^* \cos\delta$ (elastic part)
Loss module G" with $G'' = G^* \sin\delta$ (viscous part)

b) Dynamic viscosity

The complex viscosity 'η^*' is defined as:

$$\eta^* = G^*/\omega$$

ω = Angular velocity

$\omega = 2\pi \cdot f$

and can be divided in:

dynamic viscosity: η' with $\eta' = \eta^* \cdot \sin\delta$
imaginary part of the complex viscosity: η'' with $\eta'' = \eta^* \cdot \cos\delta$

NOTE:

The dynamic viscosity η' is <u>not identical</u> with the steady shear viscosity η.

c) Further expressions

In the literature, two more values are mentioned:

Loss factor $\tan\delta$ with $\tan\delta = G''/G'$

Relaxation time λ with $\lambda = \eta'/G'$

The dynamic measurements can only be done using the RHEOCONTROLLER RC20 with a computer system and software.
Detailed instructions come with the instruction manual of the software.

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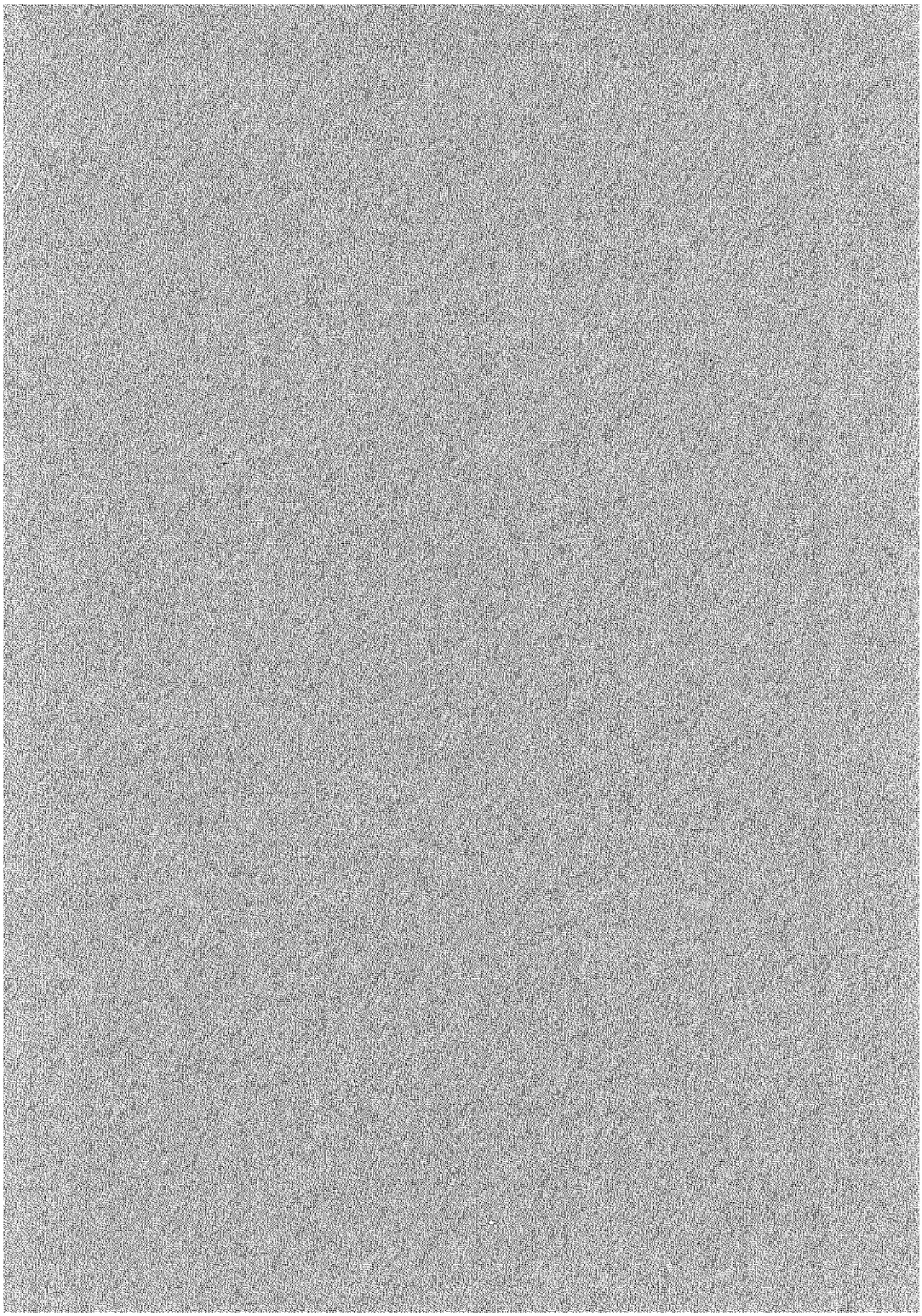
13.0 Spare Parts/Consumables

Order No.:	Description:
222-0187	Chart paper for RV20 (50 sheets)
999-0078	Fiber pens (red); 6 pieces for HAAKE xy-t recorder
333-0344	Pt100 temperature probe for temperature vessel
222-0543	Recorder cable for RV20 xy-t recorder
001-2682	Pen-lift cable for PG242 xy-t recorder
001-3636	Cable from RV20 - PG242/RC20
001-3398	Circuit board - Display/Tau from RV20 Basic Unit
001-3412	Circuit board - Power supply/D from RV20 Basic Unit
000-2074	Fan for M5, M10, M5-Osc
807-0701	Gasket for NV beaker
807-0458	Gasket for MV/MVP beaker
001-0006	Gasket for MV/Pt100 beaker (Viton)
001-0081	Gasket for MV/Pt100 beaker (Perbunan)
333-0269	Pt100 probe for MV/Pt 100 beaker
807-1270	Gasket for MV400 beaker
807-1239	Gasket for SV400 beaker

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