

BROOKFIELD CAP VISCOMETER

MODEL CAP 2000+

Operating Instructions

Manual No. **M02-313**



SPECIALISTS IN THE
MEASUREMENT AND
CONTROL OF VISCOSITY

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This manual is intended for use with CAP2000+ series Viscometers which have serial numbers beginning with a prefix of “CPN”.

Earlier model CAP Viscometers with a serial number prefix of “CP” require a different manual. Please contact Brookfield or your authorized dealer/representative to obtain this manual.

I. INTRODUCTION

The CAP Series Viscometers utilize Cone and Plate geometry with integrated temperature control of the test sample material. The CAP 2000+ is a variable speed viscometer over the range of 5-1000 RPM. The instrument operates by digital setting and display; rotational speed can be automatically timed to stop. Viscosity measurements are made over various viscosity ranges depending upon the cone spindle and the rotational speed (shear rate). Viscosity is selectively displayed in units of centipoise (cP), poise (P), milliPascal seconds (mPa•s) or Pascal seconds (Pa•s). Temperature control of sample is possible between either 5°C (or 15°C below ambient, whichever is higher) and 75°C, or 50°C and 235°C depending on viscometer model.

The CAP 2000+ Viscometer selectably displays in either the **CGS** or **SI** units (see page 8):

	<u>CGS</u>	<u>SI</u>	<u>Comment</u>
Viscosity:	P or cP	Pa•s or mPa•s	0.1 Pa•s = 1 P (= 100 cP)
Shear Rate:	SEC ⁻¹	SEC ⁻¹	
Speed:	RPM	RPM	
Temperature:	°C	°C	

The CAP 2000+ Viscometer outputs data to a parallel printer in the **CGS** and **SI** units:

	<u>CGS</u>	<u>SI</u>	<u>Comment</u>
Viscosity:	P or cP	Pa•s or mPa•s	0.1 Pa•s = 1 P (= 100 cP)
Full Scale Range (F.S.R.):	%	%	
Shear Stress:	Dynes/cm ²	N/m ²	1.0 N•m = 10 ⁷ dyne•cm
Shear Rate:	SEC ⁻¹	SEC ⁻¹	
Speed:	RPM	RPM	
Run Time:	Seconds	Seconds	
Temperature:	°C	°C	
Cone Spindle Number:	No.	No.	

I.1 Components

The following items are included:

	<u>Part No.</u>
1. CAP 2000+ Viscometer	
2. Cone Spindle(s)	CAP-S-XX (XX will be shown as a number 01-10)
3. Spindle Case	CAP-106Y
4. Solvent Trap	CAP-118
5. Power Cord: 115V	DVP-65
or	220V DVP-66
or	UKDE-8
or	Germany DE-7
6. Operating Instructions Manual	M/02-313

The following optional items may have been included:

	<u>Part No.</u>
7. Viscosity Standard Fluid for calibration	See Table A-1 in Appendix A
8. CAPCALC Software	CAP-225Y

Please check to be sure that you have received all components, and that there is no damage. If you are missing any parts, please notify Brookfield Engineering or your local Brookfield dealer immediately. Any shipping damage must be reported to the carrier. Save the packing container, if possible, for future use when returning the viscometer to Brookfield or an authorized dealer for service.

I.2 Utilities

Input Voltage:	115 VAC or 230 VAC	
Input Frequency:	50/60 Hz	
Power Consumption:	Less than 345 WATTS	
Fuses:	(2) 5x20mm, 4A, 250V, Time-Lag for 125VAC (2) 5x20mm, 2A, 250V, Time-Lag for 250VAC	
Power Cord Color Code:		
	<u>United States</u>	<u>Outside United States</u>
Hot (live)	Black	Brown
Neutral	White	Blue
Ground (earth)	Green	Green/Yellow

I.3 Specifications

Torque Ranges: 1x = 181,000 dyne•cm
22.7x = 7,970 dyne•cm

Speeds: 5-1000 RPM (in increments of 1 RPM)

Temperatures: CAP 2000+L 5°C (or 15°C below ambient, whichever is higher) to 75°C
CAP 2000+H 50°C to 235°C
All models provide 0.1°C increments

Weight: Gross Weight 36 lb 16.3 kg
Net Weight 27 lb 12.3 kg
Carton Volume 4.9 cu ft 0.15 m³
Carton Dimensions 18 in. L x 18 in. W x 26 in. H
48 cm. L x 48 cm. W x 66 cm. H

Materials: CAP cone spindles and temperature plates are made of tungsten carbide.

Operating Environment: CAP 2000+ Viscometers **must** be operated within the following ambient temperatures: **+5°C (41°F) to 40°C (149°F)**
and humidity: **20% to 80% R.H. (non-condensing atmosphere)**

Electrical Certification: Conforms to CE Standards:
BSEN 50081-1: Emission Standard — Light Industrial
BSEN 50082-1: Immunity Standard — Light Industrial
BSEN 61010-1: Safety requirements for electrical equipment, for measurement, control and laboratory use.

I.4 Safety Symbols and Precautions

Safety Symbols

The following explains safety symbols which may be found in this operating manual.



Indicates hazardous voltages may be present.



Caution: HOT surface.



Refer to the manual for specific warning or caution information to avoid personal injury or damage to the instrument.

Safety Overview



If this instrument is used in a manner not specified by the manufacturer, the protection provided by the instrument may be impaired.



This instrument is not intended for use in a potentially hazardous environment.



In case of emergency, turn off the instrument and then disconnect the electrical cord from the wall outlet.

I.5 Installation

Note: DO NOT lift the viscometer by the handle or display panel! LIFT by the base console or column!

- 1) Set the viscometer on a clean level bench surface.
- 2) **Remove shipping spindle blank and foam packing from CAP Viscometer.** Store the spindle blank in the spindle case. Use again only when transporting CAP Viscometer.
- 3) Verify that the viscometer's power requirements match your power source **BEFORE** connecting it to power.



The AC input voltage and frequency must be within the appropriate range as shown on the name plate of the viscometer.

Note: The CAP Viscometer must be earth grounded. Use the three (3) wire power cord! Do not alter!

- 4) Connect the power cord to the viscometer and to the power supply (source).
- 5) If using a printer, connect the printer cable to the printer port and printer.
- 6) If using a computer, connect the RS-232 cable (supplied with Brookfield CAPCALC software) to the serial port and the computer.

Note: Ensure that both the printer and the CAP-2000+ are off when connecting cables.

I.6 Key Functions

Figure I-1 shows the control keys on the face of the viscometer display panel:

NUMERIC 0 - 9

These keys are used for data entry and speed selection.

ENTER

This key accepts entered data.

STOP / ESCAPE

Stops cone spindle rotation at any time. Exits data entry field.

DELETE

This key overwrites entered data.

PRINT

This key sends data to the parallel port.

RUN

This key starts spindle rotation.

RUN TIME

This key selects time entry mode (time of spindle rotation).

HOLD TIME

This key selects time entry mode (wait time before spindle rotates).

SPINDLE

This key selects the cone spindle entry mode which includes the option to perform a cone calibration.

TEMP

This key selects the temperature entry mode.

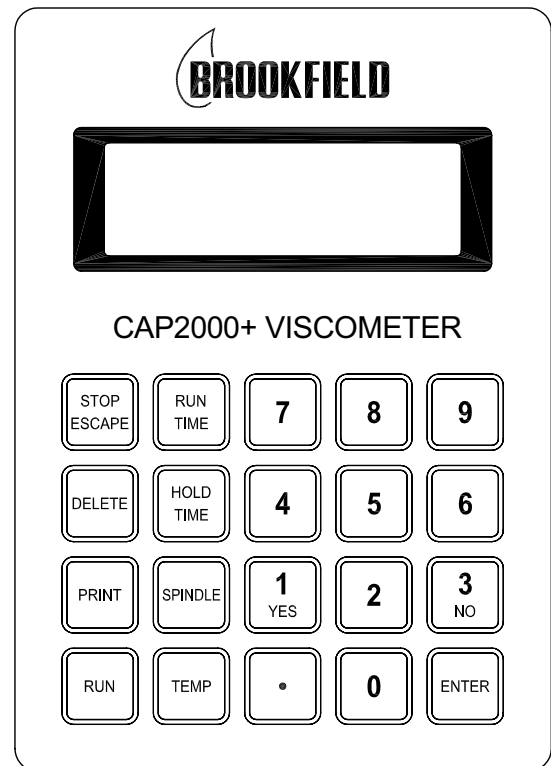


Figure I-1

I.7 Viscosity and Temperature Display

Viscosity is displayed in either **P=Poise** or **cP=Centipoise** (CGS system) or **Pa•s=Pascal seconds** or **mPa•s=milliPascal seconds** (SI system). If the viscosity measurement is over range, “EEEE” will be displayed. Brookfield recommends a minimum reading of 10%. If the torque display value is between 0 and 10%, the display will flash to indicate an out of range condition. If the viscometer settles out with a final “%” reading below zero, negative values will be displayed.

Temperature is displayed in **°C=degrees centigrade**.

I.8 Cleaning

Instrument, Keypad & Painted Surfaces:

Clean with dry, non-abrasive cloth. Do not use solvents or cleaners.

Immersed Components (cone spindle and plate):

All immersed components are made of carbide steel. Clean with non-abrasive cloth and solvent appropriate for sample material that is not aggressive to immersed components.

Note: When cleaning, take care not to apply excessive force which may bend the spindle shaft or otherwise damage the instrument.

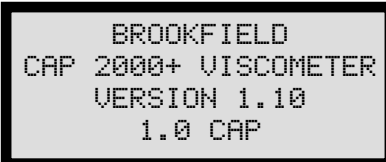
II. GETTING STARTED

II.1 Power ON

Turn the power **ON** using the switch located on the rear of the base console.

The start-up screen will be displayed for four seconds and will indicate the viscometer model, version number and torque range.

START-UP SCREEN

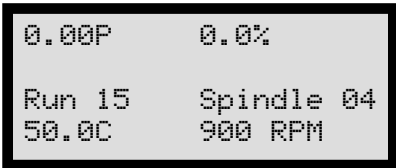


```
BROOKFIELD
CAP 2000+ VISCOMETER
VERSION 1.10
1.0 CAP
```

Figure II-1

After four (4) seconds, the main screen will be displayed (Figure II-2).

MAIN SCREEN



```
0.00P    0.0%
Run 15   Spindle 04
50.0C    900 RPM
```

Figure II-2

The instrument will be set to the default temperature:

CAP L Series Viscometer	25.0°C
CAP H Series Viscometer	50.0°C

Special Functions

Units of measure and speed control may be selected through the **special functions screen**. This screen is accessed by pressing the **STOP** key during instrument power up.

The CAP-2000+ can be configured to control speed by either rotations per minute (RPM) or shear rate (1/SEC). This selection is set by choosing **1=SPEED CONTROL** in the **special functions screen**, then selecting **1=RPM** or **2=1/SEC** and pressing **ENTER**.

The CAP-2000+ can be configured to display viscosity in one of four units: **Poise (P)**, **Centipoise (cP)**, **Pascal Seconds (Pa•s)** or **milliPascal seconds (mPa•s)**. This selection is set by choosing **2=Units of Measure** in the **special functions screen**, selecting **1=P**, **2=cP**, **3=Pa•s**, or **4=mPa•s**, and then pressing **ENTER**.

Once the CAP-2000+ has been configured, the instrument must be turned **OFF**. The configuration will be stored in memory.

Note: When operating the CAP2000+ with shear rate as the method of speed control, the shear rate value entered may be adjusted based on the shear rate multiplier for the spindle. For example: if using cone 4 (shear rate multiplier of 3.33), an entered shear rate of 51 1/SEC will be displayed as 50 1/SEC.

II.2 Cone Spindle Selection and Setting

Raise the viscometer handle to its highest position.

The CAP cones have viscosity ranges as shown in Appendix A. After selecting the appropriate cone for the viscosity range to be utilized, *carefully* attach the cone to the viscometer as shown (Figure II-2).

Note: Spindles 7-10 should only be used in the speed range of 5-400 RPM. At speeds greater than 400 RPM, the test sample will not remain in the gap and measurement results will be unreliable.

Be sure to align the flats on the spindle shaft with the thumb screw.

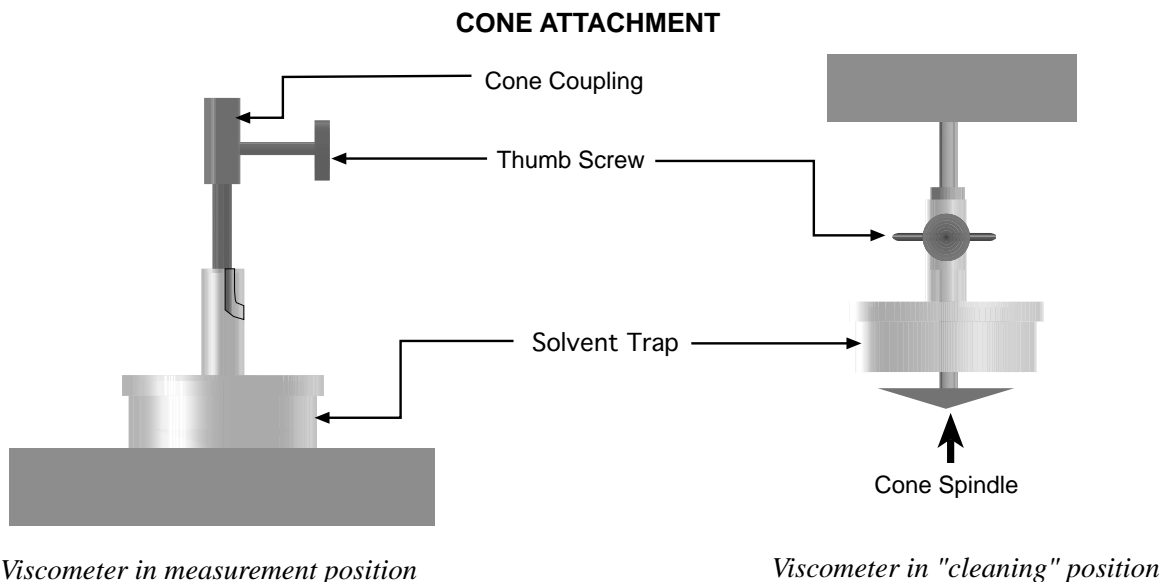


Figure II-2

When using the solvent trap, connect it to the cone coupling by sliding it up, passing the slot by the thumb screw and turning the trap clockwise onto the thumbscrew. Slide the cone up into the adapter as far as it will go and hand lock it in place with the thumb screw. Tighten the thumb screw firmly and securely.

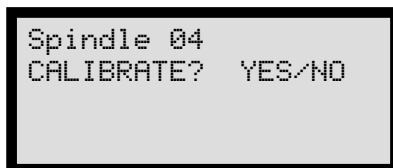
Press the **SPINDLE** key. The display will change to the spindle entry screen. Using the number keys, type in the required spindle number.

Two digits must be entered for the cone number. For cone **01** through **09**, the first number remains as "0".

Note: The default cone setting on power-up will be the last cone entry prior to shutting off the viscometer.

After the correct two (2) digits have been entered, press the **ENTER** key and the cone will be accepted for viscometer calculations.

The screen will display the following message:



```
Spindle 04
CALIBRATE? YES/NO
```

Figure II-3

Normally there is no requirement to perform a cone calibration. Cones supplied at the time of order are calibrated to the viscometer prior to shipment.

- Note:**
1. CAP Viscometers allow for **only one** cone at a time of the **same cone number** to be calibrated to the viscometer. Multiple cones of the same cone number **must each be calibrated** to the viscometer before operation (refer to **Appendix B**).
 2. Cones entered as 11 through 20 must be first calibrated following the directions in **Appendix B**.

If you are not going to calibrate the cone, continue by pressing the **NO** key followed by the **ENTER** key. The viscometer will display the **MAIN SCREEN** (Figure II-1). The instrument is now ready to provide viscosity measurements based on this cone.

If you are going to calibrate the cone, press the **YES** key, refer to **Appendix B**, and follow the calibration instructions under **Cone Calibration**.

II.3 Speed and Shear Rate Setting

The CAP2000+ is a variable speed viscometer. The speed of rotation is shown in the lower right corner of the display. To change the speed of rotation, enter the new speed using the number keys. The new speed will be shown in the lower right hand corner of the display. To accept the new speed, press **ENTER**.

The new speed may be cancelled by pressing **ESCAPE** before pressing **ENTER**.

To begin spindle rotation, press the **RUN** key.

Note: The speed cannot be changed while the motor is running.

Speed control may be configured to either shear rate or rotations per minute (see Special Functions in section II.1). Data entry for speed selection is the same in either configuration.

Data entry must be in whole numbers.

II.4 Temperature Control Setting

Press the **TEMP** key and the current temperature setting will blink. The default temperature on start-up is **25.0°C** on low temperature models and **50°C** on high temperature models.

The temperature ranges are:

Low temperature: 5°C (or 15°C below ambient, whichever is higher) to 75°C
High temperature: 50°C to 235°C

Note: The temperature can be set in increments of **0.1°C**.

Use the number keys to type in the required set point.

Use the **ENTER** key to accept the new set point.

Note: *Thermal equilibrium* of the sample and of the spindle must be considered for best measurement results. Upon powering up the Viscometer or after changing the temperature set point, allow sufficient time for the plate to reach the desired temperature (10 minutes or more is recommended). It is recommended to have the spindle in contact with the plate prior to introducing the sample material to ensure that the spindle is also at the temperature of test. Brookfield recommends using the solvent trap at all times to enhance the temperature control of the sample material. After inserting the sample material onto the plate, lower the spindle and solvent trap and allow sufficient time for thermal equilibrium prior to starting the test.

II.5 Hold Time Settings

Hold time sets the time period between when the **RUN** key is pressed and when the spindle begins to rotate. This time period is normally used to ensure thermal equilibrium of the sample and spindle. The hold time range is 0 to 999 seconds.

Press the **HOLD TIME** key and the current hold time will blink on the default screen. Use the number keys to type in the required hold time and press the **ENTER** key.

Note: When the hold time is set to zero, it is not displayed on the default screen.

II.6 Run Time

Run time sets the the time period of spindle rotation. The run time range is 0 to 999 seconds.

Press the **RUN TIME** key and the current run time will blink on the default screen. Use the number keys to type in the required run time and press the **ENTER** key.

Note: Run time will be shown on the default screen only when hold time is set to zero.

A run time of zero sets the viscometer to infinite run mode. In this mode, the spindle will rotate at the set speed for as long as the **RUN** button is pressed. When the **RUN** key is released, the spindle will stop rotating.

Note: With a run time of zero, the hold time will not be used.

The time required for reading stabilization will depend on the speed of rotation and the nature

of the test sample. Longer runs times are recommended at lower speeds.

Speed of Rotation	Run Time
50-1000 RPM	12 seconds
20-50 RPM	20 seconds
5-20 RPM	30 seconds

II.7 Printing

Pressing the **PRINT** key at any time sends information on test parameters to the printer port. However, viscosity, full scale range and shear stress data will only be printed after it is first displayed during a test run.

To print a heading, press and hold the **STOP/ESCAPE** key and press the **PRINT** key. At the end of a timed speed execution, data will automatically be sent to the printer.

CAP 2000+ PRINT OUTPUT

VISCOSITY (POISE)	F.S.R. (%)	TEMP (Deg C)	S.STRESS (D/CM2)	S.RATE (1/sec)	SPEED (RPM)	TIMER (SEC)	CONE No.
-	-	25.0	-	10000	0750	20	02

A maximum of 999 seconds can be printed when running in manual **TIMER** mode (00). Over 999 seconds will print **EEE**.

Note: The **TIMER (SEC)** column will indicate the accumulated time that the cone has been rotating at the moment the print key is pressed. This time value will not include the hold time.

II.8 Run and Stop Keys

The **RUN** key has three functions:

1. Press **RUN** to execute a timed measurement.
2. Press and hold the **RUN** key for continuous rotation when **00** is the run time setting.
3. Used in executing a cone calibration.

The **STOP** key has three functions:

1. Stops the cone rotation at any time.
2. Pressing and holding the **STOP/ESCAPE** key during power up selects the viscosity display units and speed of rotation.
3. Pressing the **STOP** and **PRINT** keys simultaneously executes the printing of a new heading (Section II.7).

II.9 Parameter Display

The parameter display will appear, as shown in Figure II-1, immediately after the **RUN** key is pressed. All relevant measurement parameters will be shown for 5 seconds including speed,

shear rate, run time, hold time and spindle. The display will return to the default screen after five seconds.

Note: The viscometer will be operating according to the selected parameters while the parameter display screen is shown.



```
Speed      15 RPM
Shear Rate 50 1/sec
Run 20 S   Hold 10S
Spindle 04
```

Figure II-4

III. OPERATION

The CAP 2000+ Viscometer rotates a precisely machined cone spindle over a temperature controlled plate shearing the test sample over a range of speeds from 5 to 1000 RPM. This provides a comprehensive capability to analyze materials for viscosity behavior as a function of both shear rate and temperature. Tests can be run in standalone mode or under PC control. This chapter explains how to use the CAP2000+ toward these objectives.

III.1 Making Viscosity Measurements

The following procedure is recommended for making a single point viscosity measurement in standalone mode.

With the viscometer on a clean level surface, connect it to the proper power supply (Section I.4).

1. Turn the power switch **ON** (Section II.1).

The procedure assumes that the following list has been done:

- a) If the viscometer has been “off” for an extended period (i.e., overnight) a “warm up” period of 30 minutes is suggested. The default temperature (25°C) is used for low temperature instruments (CAP2000+L). The default setting for high temperature instruments is 50°C (CAP2000+H). If a cone calibration is to be done immediately after the warm up period, temperature should be set to 60°C right away (calibration temperature for high temperature instruments) to save some time.
- b) The cone calibration procedure (Appendix B) will be done at Brookfield for all cones which are supplied with the instrument. Cone calibration is required when a new cone (i.e., replacement for lost/damaged cone) is used, or when calibration check fails.
- c) When making measurements with low temperature instruments (CAP2000+L), the solvent trap may not be required (for the containment of solvents and/or prevention of sample “drying”). The trap should be used for all measurements with high temperature instruments (CAP2000+H).
- d) The CAP2000+ will print automatically when a reading is taken if a parallel printer is connected and “on line.”
- e) Select and attach the cone (Section II.2).
Notes:
 1. Lock the cone tightly into the adapter.
 2. When measuring volatile samples such as paints and coatings, and when using either a high temperature CAP 1000+H or CAP 2000+H, the solvent trap must be put in place over the cone to prevent the test sample from drying out during the rotation of the cone.
- f) Set the temperature control (Section II.5).

2. Set the cone number.
3. Set the speed of rotation.
4. Lower the handle placing the cone onto the plate. Lock the handle into its lowest position. Drop the solvent trap over the cone.

Note: Allow ten (10) minutes for the cone to come to equilibrium temperature with the plate.

5. Raise the handle. Place the sample to be measured onto the plate below the cone and solvent trap. Refer to **Appendix A** for recommended sample sizes. Lower the cone and solvent trap.

- Note:*
1. Lower the handle **gently**. **DO NOT FORCE THE CONE ONTO THE PLATE.**
 2. The sample must completely cover the face of the cone and extend beyond the edge of the cone about 1.0 mm (see table A-1 for sample size).
 3. Release the solvent trap placing it onto the plate over the cone so it does not touch the cone shaft.



The user should ensure that the substances placed under test do not release poisonous, toxic or flammable gases at the temperatures to which they are subjected to during the testing.

6. Allow the cone, plate and sample to equilibrate to the temperature control setting.

Note: A minimum of one (1) to three (3) minutes equilibrium time is recommended, depending upon the sample.

7. Set the **Run Time** for rotating the cone (Section II.6) and the **Hold Time**.

Note: The time required for reading stabilization will depend on the speed of rotation and the nature of the test sample. Longer runs times are recommended at lower speeds.

Speed of Rotation	Run Time
50-1000 RPM	12 seconds
20-50 RPM	20 seconds
5-20 RPM	30 seconds

8. Put the printer on-line (optional, Section II.7).
9. Press the **RUN** key and execute the viscosity measurement.

Note: Due to the dynamics of shearing a fluid in the CAP “H” series Viscometers, the temperature display may indicate a deviation from the equilibrium temperature setting as the cone begins rotating at high shear rates. The temperature display may indicate the temperature of the plate and the momentary changes show the cycling of the temperature control at high temperature. The accuracy of the viscosity measurement is maintained within the limits specified in Table 3.1.

- Note:* The parameter display will be shown for 5 seconds.
10. Read the results of the sample test on the printer or write down the test conditions and viscosity results from the viscometer display.
 11. Relocate the solvent trap onto the coupling and raise the handle.
 12. It is recommended to remove the cone for cleaning. However, with care, the cone can be cleaned in place.
 13. Clean the viscometer plate (refer to Section I.8).

III.2 Computer Control

The CAP2000+ Viscometer can be operated remotely under PC control when using the CAPCALC application software.

When advanced sample analysis is required, Brookfield CAPCALC application software can control the CAP2000+ Viscometer from a PC. CAPCALC for Windows requires Windows 95, 98, ME, NT, or 2000 operating system, a processor of 486 or higher, a minimum of 8 megabytes RAM, VGA color monitor (640x480 resolution minimum), serial and parallel ports, and hard disk. CAPCALC application software displays, prints and stores tabulated data files (Brookfield, Excel).

CAPCALC software has automatic data capture (up to 200 data points per test) and graphical data display (rheograms) to facilitate analysis of test samples. The software also allows temperature control of the sample plate for integrated viscosity/temperature tests between 5°C and 75°C (CAP 2000+L) or 50°C and 200°C (CAP 2000+H) depending on viscometer model. CAPCALC features include on-screen and printed plots of % F.S.R.; viscosity or shear stress vs. cone speed, shear rate, time or temperature. Also available are automatic calculation of Yield Stress (Bingham Plastic or Casson) and Power Law Consistency Index.

Additional information on the communications protocol for CAP2000+ is contained in **Appendix D**.

Contact Brookfield or our authorized agent to obtain the CAPCALC software program.

III.3 Accuracy of Measurement

Table III.1 indicates the accuracy of the viscosity measurement with CAP spindles 01-06. This accuracy depends on both the rotational speed of the cone and the percent of full scale range at which viscosity is measured. The accuracy for viscosity data provided by CAP Viscometers is the indicated percentage of the full scale range. See **Appendix A** for information on how to determine Full Scale Viscosity Range (FSR).

Table III-1 Accuracy of Viscosity Measurement

CAP 2000+L VISCOMETERS				
Cone	FULLSCALE VISCOSITY RANGE ACCURACY			
	≤400 RPM	≤750 RPM	≤900RPM	Over 900 RPM to 1000 RPM
01	—	± 2.0%	±2.0%	Varies depending on the thermal conductivity of the sample being measured
02	—	± 2.0%	±2.0%	
03	—	± 2.0%	±2.0%	
04	—	± 3.0%	±4.0%	
05	—	± 4.0%	±6.0%	
06	—	± 7.0%	±10.0%	
07	≤ ± 2.0%	Cones 07-10 are not recommended for use at these speeds.		
08	≤ ± 2.0%			
09	≤ ± 2.0%			
10	≤ ± 2.0%			

CAP 2000+H VISCOMETERS					
Cone	FULLSCALE VISCOSITY RANGE ACCURACY				
	≤400 RPM	≤750 RPM	≤900RPM		Over 900 RPM to 1000 RPM
	10 to 100%*	10 to 100%*	≤50%*	>50%*	
01	—	± 2.0%	±2.0%	±4.0%	Varies depending on the thermal conductivity of the sample being measured.
02	—	± 2.0%	±2.0%	±4.0%	
03	—	± 2.0%	±2.0%	±4.0%	
04	—	± 3.0%	±3.0%	±6.0%	
05	—	± 4.0%	±4.0%	±8.0%	
06	—	± 5.0%	±5.0%	±10.0%	
07	2%	Cones 07-10 are not recommended for use at these speeds.			
08	2%				
09	2%				
10	2%				
Viscometer		Temperature Control Accuracy			
CAP1000L & H		± 0.2°C			

* = Full Scale Range

III.4 Repeatability

The CAP 2000+ Viscometer is repeatable to $\pm 0.5\%$ of the full scale viscosity range (FSR). Due to shear heating considerations which occur at higher shear rates, the measurement of NIST Viscosity Standard Fluids at rotational speeds above 900 RPM may show a decrease in viscosity with an increase in rotational speed (shear rate).

Normal forces due to the shearing of a viscoelastic fluid (such as paint) are accounted for in the CAP Series Viscometers by weight on the spindle column: 3.6 Newtons (360,000 dynes) on a 1xCAP, 1.2 Newtons (120,000 dynes) on a 22.7xCAP total force. This is done to avoid having the cone lift off the plate, thereby changing the cone plate geometry and producing incorrect viscosity readings. For normal forces greater than 3.4 Newtons (340,000 Dynes) total force, additional externally mounted weights are required. However, more weight means more wear on the cone and plate. Additional weights should only be considered when definitely required and removed when not required.

Contact Brookfield Engineering Laboratories or your Brookfield Dealer/Distributor/Representative for details on the above information.

APPENDIX A - Cone Numbers, Sample Sizes, Viscosity Ranges

CAP 2000+ VISCOMETERS						
Cone Number ¹	Shear Rate (sec ⁻¹)	Sample Size (micro liters)	Calibrating Fluid ² Low Temp Cap at 25°C		Calibrating Fluid ² High Temp Cap at 60°C	
			Part No.	Viscosity*	Part No.	Viscosity*
01	13.33N	67	CAP1L	- 100 cP	CAP1H	- 100 cP
02	13.33N	38	CAP2L	- 170 cP	CAP2H	- 180 cP
03	13.33N	24	CAP3L	- 350 cP	CAP3H	- 350 cP
04	3.33N	124	CAP4L	- 700 cP	CAP4H	- 700 cP
05	3.33N	67	CAP5L	- 1400 cP	CAP5H	- 1400 cP
06	3.33N	32	CAP6L	- 3500 cP	CAP6H	- 3500 cP
07	2N	1700	CAP7L	- 1330 cP	CAP7H	- 1330 cP
08	2N	400	CAP8L	- 5300 cP	CAP8H	- 5300 cP
09	2N	100	CAP9L	- 21,250 cP	CAP9H	- 21,250 cP
10	5N	170	CAP10L	- 240 cP	CAP10H	- 240 cP
	N = RPM		*Approximate Value			

¹Number marked on the cone shaft

²Recommended Speed of calibration: **900 RPM (Cones 1-6)**
100 RPM (Cones 7-10)

Table A-1

Cone Number ¹	CAP 2000+ VISCOSITY RANGES (POISE)			Cone Range Coefficient	Cone Angle (degrees)	Cone Radius (cm)
	400 RPM	750 RPM	900 RPM			
01	0.46 - 4.6	0.25 - 2.5	0.21 - 2.08	1,875	0.45	1.511
02	0.93 - 9.3	0.5 - 5.0	0.42 - 4.17	3,750	0.45	1.200
03	1.87 - 18.7	1.0 - 10.0	0.83 - 8.33	7,500	0.45	0.953
04	3.75 - 37.5	2.0 - 20.0	1.67 - 16.67	15,000	1.8	1.200
05	7.5 - 75	4.0 - 40.0	3.33 - 33.33	30,000	1.8	0.953
06	18.7 - 187	10.0 - 100.0	8.33 - 83.33	75,000	1.8	0.702
07	0.78 - 7.8	Not recommended	Not recommended	3,150	3.0	2.399
08	3.12 - 31.2	Not recommended	Not recommended	12,500	3.0	1.511
09	12.5 - 125.0	Not recommended	Not recommended	50,000	3.0	0.953
10	1.25 - 12.5	Not recommended	Not recommended	5,000	1.2	1.511

¹Number marked on the cone shaft

Table A-2

Note: Spindles 7-10 should only be used in the speed range of 5-400 RPM. At speeds greater than 400 RPM, the test sample will not remain in the gap and measurement results will be unreliable.

SAMPLE SIZE

It is necessary that sufficient sample is placed between the cone and plate to completely cover the surface of the cone when the cone is locked in the RUN position. With sufficient sample, an excess of about 1 mm in width will be seen around the periphery of the cone edge.

For calibration and best reproducibility of results, the sample sizes shown in Table A1 should be used.

CAP 2000+ RANGES FOR CONES 01 THROUGH 10

To determine the full scale viscosity range (FSR) for any cone/speed, divide the Cone Range Coefficient (refer to Table A2) by the rotational speed (RPM).

$$\text{Full Scale Viscosity Range (Poise)} = \frac{\text{Cone Range Coefficient}}{\text{RPM} \times \text{TK}} \quad \text{Equation A1}$$

$$\begin{aligned} \text{TK} &= 1 \text{ for 1.0 CAP} \\ \text{TK} &= 22.7 \text{ for 22.7 CAP} \end{aligned}$$

CAP 2000+ RANGES FOR CONES 11 THROUGH 20

Spindle Multiplier Constant (SMC):

SMC = (supplied by the manufacturer)

Shear Rate Constant (SRC):

SRC = (supplied by the manufacturer)

$$\text{Viscosity (poise)} = \frac{\text{Shear Stress (dynes/cm}^2\text{)}}{\text{Shear Rate (sec}^{-1}\text{)}} \quad \text{Equation A2}$$

$$\text{Shear Stress (dynes/cm}^2\text{)} = \text{Viscosity (poise)} \times \text{Shear Rate (sec}^{-1}\text{)} \quad \text{Equation A3}$$

$$\text{Shear Rate} = \frac{\omega}{\sin \theta} \quad \text{Equation A4}$$

$$\omega = \text{Cone Speed (rad/sec)} = \left(\frac{2\pi}{60} \right) \times N$$

$$N = \text{RPM}$$

$$\theta = \text{Cone Angle (degrees)}$$

$$r = \text{radius of cone spindle}$$

$$\text{Viscosity (poise)} = \frac{\text{Full Scale Viscosity Range} \times (\% \text{ FSR})}{100} \quad \text{Equation A5}$$

EXAMPLE: CAP 2000+L Viscometer; Cone (02); running at 750 RPM; temperature 25.0°C; % FSR = 73.8. Determine the viscosity (poise), shear stress (dynes/cm²), shear rate (sec⁻¹).

Using **Equation A2**, determine the full scale viscosity range at 750 RPM:

$$\text{Full Scale Viscosity Range (poise)} = \frac{3,750}{750} = 5.00 \text{ poise}$$

Using **Equation A5**, determine the viscosity at 73.8% of full scale range:

$$\text{Viscosity (poise)} = 5.00 \text{ (poise)} \times \frac{73.8}{100} = 3.69 \text{ poise}$$

Using **Equation A4**, determine the shear rate:

$$\text{Shear Rate (sec}^{-1}\text{)} = \frac{(2)(3.1416)(750)}{(60)(\text{sine } 0.45)} = 10,000 \text{ sec}^{-1}$$

Using **Equation A2**, determine the shear stress:

$$\text{Shear Stress (dynes/cm}^2\text{)} = (3.69)(10,000) = 36,900 \text{ dynes/cm}^2$$

APPENDIX B - Calibration Procedures

Normally there is no requirement to perform a cone calibration. Cones supplied at the time of order are calibrated to the viscometer prior to shipment.

Verification of Calibration

At selected intervals, depending upon usage and number of operators, the CAP Viscometer calibration should be verified using NIST Fluids. Referring to Appendix A (Table A-1), find the appropriate NIST Fluid(s) for the cone(s) being used.

With the viscometer set up, perform viscosity measurements following the outline of Section III. Prior to pressing the **RUN** key to initiate a cone calibration, we recommend a period of thermal equilibrium of approximately 30 minutes for the fluid, cone and plate. This period should begin immediately after entering the calibration temperature and associated viscosity value (in cP). Execute viscosity measurement and record results.

Verify the result to have an accuracy according to the information in Section III (Table III-1).

If the calibration is outside the accuracy limits, proceed with the following *Cone Calibration*.

Interpretation of Calibration Test Results:

When verifying the calibration of the **CAP 2000+**, the instrument and viscosity standard fluid error must be combined to calculate the total allowable error.

The **CAP 2000+** accuracy is defined in **Section III.1** as a function of spindle number 03.

Brookfield Viscosity Standards Fluids are accurate to (+/-) 1% of their stated value.

Example: Calculate the acceptable range of viscosity using **CAP 2000+** with Spindle 03 at 900 RPM when measuring Brookfield Standard Fluid CAP-3L with a viscosity of 350 cP at 25°C:

1) Calculate full scale viscosity range using the equation:

$$\text{Full Scale Viscosity Range [P]} = \frac{\text{Range Coefficient}}{\text{RPM}}$$

Where:

Range Coefficient = 7500 from **Table A2**

$$\text{Full Scale Viscosity Range} \frac{7500}{900} = 8.33 \text{ P (833 cP)}$$

The viscometer is accurate to (+/-) 16.7 cP (which is 2% of 833)

2) The viscosity standard fluid is 350 cP. Its accuracy is (+/-)1% of 350 or (+/-)3.5 cP.

3) Total allowable error is (16.7 + 3.5) cP = (+/-) 20.2 cP (0.2 P).

- 4) Therefore, any viscosity reading between 329.8 and 370.2 **cP** indicates that the viscometer is operating correctly. Any reading outside these limits may indicate a viscometer problem. If the reading falls outside the acceptable range, perform a cone calibration (**Appendix B**). If the calibration is outside the accuracy limits, proceed with the following *Cone Calibration*.

Cone Calibration

A special feature of the **CAP Series** Viscometers allows the user to perform a cone calibration using Viscosity Standard Fluids. This field calibration will accommodate any wear on the tip of the cone which may result from contact with the plate.

Note: A cone calibration should be performed when: 1) using a new cone for the first time, 2) switching between two cones of the same number and 3) verification of calibration provides data outside of the acceptable range.

Refer to Appendix A (Table A1) and choose the calibration fluid for the spindle being calibrated. These fluids are for the recommended calibration speed (900 RPM for cones 1-6, 100 RPM for cones 7-10). You may choose a different speed of calibration. The calibration fluid should be selected to be approximately 42% of full scale range (see **Equation A1**).

Example: If you choose to calibrate Cone 01 at a speed of 500 RPM:

- Calculate full scale viscosity range at 500 RPM:

$$A1: \text{FSR} = \frac{1875}{500 \times 1} = 3.75 \text{ Poise}$$

- Determine 42% of FSR (full scale range)

$$3.75\text{P} \times 0.42 = 1.575 \text{ Poise}$$

- Select a calibration fluid in the range of 1.575 Poise

1. Turn on the CAP2000+ Viscometer.
2. Attach solvent trap to coupling shaft.
3. Attach spindle.
4. Place appropriate amount of sample (Refer to Appendix A (Table A1)) onto the center of the Viscometer plate directly below the spindle.
5. Pull down the handle, locking it into the lowest position, placing the spindle in contact with the plate.
6. Lower the solvent trap.

Note: The solvent trap must be utilized when calibrating to ensure proper temperature control.

7. Select the spindle to be calibrated by using the **SPINDLE** key.
8. Select **YES** for **CALIBRATE** and press **ENTER**.
9. Enter the appropriate values for speed (**RPM**), temperature (**°C**) and viscosity (**cP**) prompted by the screen.

Brookfield recommends calibration speed of 900 RPM for cones 1-6 and 100 RPM for cones 7-10. Other speeds of rotation may be selected. Brookfield does not recommend speeds greater than 400 for spindles 7-10 since the fluid may not stay in the gap.

Note: Viscosity values are always entered in units of **CENTIPOISE (cP)** regardless of what units have been selected as unit of measure for normal operation.

$$100 \text{ cP} = 1\text{P}; 1\text{cP} = 1\text{mPa}\cdot\text{s}; 1000 \text{ cP} = 1\text{Pa}\cdot\text{s}$$

Note: The Viscometer temperature control must be identical to the specified temperature for the viscosity standard when executing the calibration. Normally calibration will be at 25°C for “L” Series CAP Viscometers and 60°C for “H” Series CAP Viscometers.

10. Allow at least 30 minutes for thermal equilibrium of the plate, calibration fluid and spindle.

11. Press the **RUN** key to start the calibration.

Note: The calibration process may be cancelled at any time prior to pressing **RUN** to calibrate, by pressing the **ESCAPE** key.

When calibration is complete, spindle rotation will stop and the “**CALIBRATION COMPLETE**” screen is displayed. Press **ENTER** to continue.

Custom Spindles

The CAP Series Viscometer allows for the use of custom spindles. Please contact Brookfield’s Technical Sales Department for more information.

Custom spindles are calibrated using spindle entry codes 11-20. The calibration of a custom spindle requires the entry of two parameters: **SMC** and **SRC**. The SMC and SRC are required for proper calculation of viscosity.

The SMC and SRC must be entered after entering the spindle number (11-20) and selecting **YES (1)** for calibration. Follow the screen prompts.

Once SMC and SRC are entered, follow the procedure described above for spindles 01-10.

Note: SMC and SRC need to be entered only once for any spindle number 11-20. The CAP Series Viscometer will store these values. SMC and SRC can be overwritten by executing a spindle calibration.

CONE (00) CALIBRATION

VISCOSITY (POISE)	FSR (%)	TEMP (Deg C)	S.STRESS (D/CM ²)	S.RATE (1/sec)	SPEED (RPM)	TIMER (SEC)	CONE No.	SAMPLE No.
----------------------	------------	-----------------	----------------------------------	-------------------	----------------	----------------	-------------	---------------

Operator: _____

Date: _____

Model/Serial#: _____

Fluid: _____

Figure B-1

APPENDIX C - Variables in Viscosity Measurements

As with any instrument measurement, there are variables that can affect a Viscometer measurement. These variables may be related to the instrument (Viscometer), or the test fluid. Variables related to the test fluid deal with the rheological properties of the fluid, while instrument variables would include the Viscometer design and the spindle geometry system utilized.

Rheological Properties

Fluids have different rheological characteristics that can be described by Viscometer measurements. We can then work with these fluids to suit our lab or process conditions.

There are two categories of fluids:

- Newtonian** - These fluids have the same viscosity at different Shear Rates (different RPMs) and are called Newtonian over the Shear Rate range they are measured.
- Non-Newtonian** - These fluids have different viscosities at different shear rates (different RPMs). They fall into two groups:
- 1) Time Independent non-Newtonian
 - 2) Time Dependent non-Newtonian

The time dependency is the time they are held at a given Shear Rate (RPM). They are non-Newtonian, and when you change the Viscometer spindle speed, you get a different viscosity.

Time Independent

- Pseudoplastic** - A pseudoplastic material displays a decrease in viscosity with an increase in shear rate, and is also known as “shear thinning”. If you take Viscometer readings from a low to a high RPM and then back to the low RPM, and the readings fall upon themselves, the material is time independent pseudoplastic and shear thinning.

Time Dependent

- Thixotropic** - A thixotropic material has decreasing viscosity under constant shear rate. If you set a Viscometer at a constant speed, recording **P** values over time, and find that the **P** values decrease with time, the material is thixotropic.

Brookfield publication, “**More Solutions to Sticky Problems**” includes a more detailed discussion of rheological properties and non-Newtonian behavior.

Viscometer Related Variables

- Most fluid viscosities are found to be non-Newtonian. They are dependent on Shear Rate and the spindle geometry conditions. The specifications of the Viscometer cone and plate geometry will affect the viscosity readings. If one reading is taken at 400 rpm, and a second at 1,000 rpm, the two viscosity values produced may be different because the readings were made at different shear rates. The faster the spindle speed, the higher the shear rate.
- The shear rate of a given measurement is determined by the rotational speed and the cone angle.
- A repeatable viscosity test should control or specify the following:
 1. Viscometer model
 2. Cone used
 3. Test temperature
 4. Test speed(s) [or the shear rate(s)]
 5. Length of time to record viscosity
 6. Sample volume sufficient to cover the face of the cone

APPENDIX D — Communications

Printer Output - CAP 2000+

The cable connection on the CAP2000+ Viscometer is a standard 25 pin parallel printer cable connector.

RS 232 Output - CAP 2000+

When connecting the CAP 2000+ to a computer, use Brookfield Computer Cable (Part No. DVP-80). If you are *not using* the Brookfield computer cable, jump (connect) pins 4 and 9 (refer to **Figure E1**) on the CAP 2000 end of the serial cable. The cable connections are:

- Com Port RxD (pin 2 (9 pin) or pin 3 (25 pin) to CAP TxD (pin 3)
- Com Port TxD (pin 3 (9 pin) or pin 2 (25 pin) to CAP RxD (pin 2)
- Com Port ground (pin 7) to CAP Serial Ground (pin 5)

The RS232 protocol is implemented as follows:

- Baud rate: 9600
- Parity None
- Data bits: 8
- Stop bits: 1

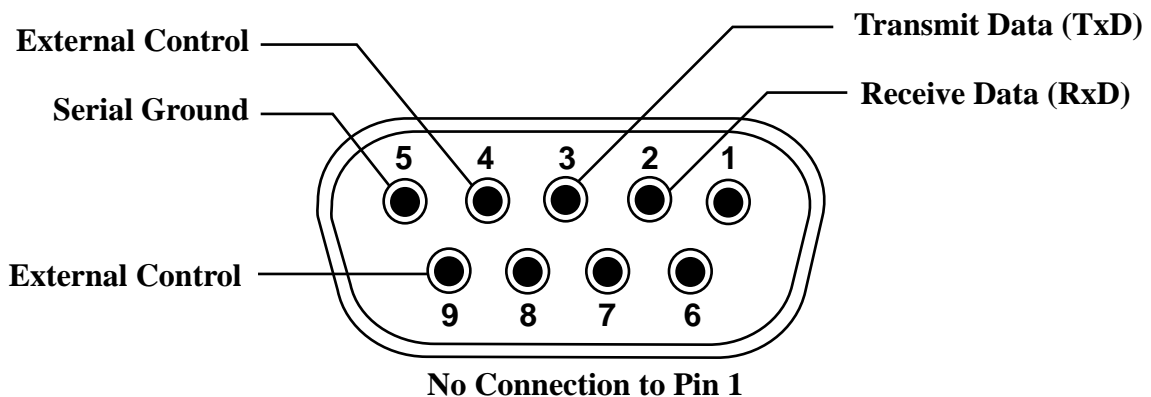


Figure D1

The following pages review the transmit/receive commands between the CAP 2000+ and a computer (Table D2), the byte status interpretation (Table D1) and a sample program for external control of the CAP 2000+ Viscometer.

CAP 2000+ TRANSMIT/RECEIVE COMMANDS FOR COMPUTER COMMUNICATION

Command Received	CAP 2000 Response	Function
Vyyy<CR>	V<ss><CR>	<ul style="list-style-type: none"> • Sets current speed and starts motor. • 000H <= yyy <= 3E8H (5 to 1000 RPM). • Anything between 001H and 005H is interpreted as 5 RPM. • Anything over 3E8H is interpreted as 1000 RPM. • All yyy values shall be padded to 3 characters with leading zeros. • A speed of 000 will stop the motor. • Sets or clears the motor on bit (bit 1) in the status byte accordingly. • Sets illegal value bit in status byte if yyy is outside limits (See Table D2).
Tttt<CR>	T<ss><CR>	<ul style="list-style-type: none"> • Sets current temperature and controls to it. • 032H <= ttt <= 2EEH; CAPLO (5°C to 75 °C). • 000H <= ttt <= 92EH; CAPHI (0°C to 235°C). • Any temperature under the lower limit is interpreted as the lower limit. • Any temperature over the upper limit is interpreted as the upper limit. • The CAP 2000+ must divide all ttt values received by 10 before use. • All ttt values shall be padded to 3 characters with leading zeros. • Sets illegal value bit in status byte if ttt is outside limits (See Table D2).
R<CR>	R<vvvvvvffffrrrrrrttcc> <ss><CR>	<ul style="list-style-type: none"> • Returns a data packet to the host. • vvvvvv : viscosity ,P, (multiplied by 1000 by the CAP 2000+). All vvvvvv values shall be padded to 6 characters with leading zeros. • ffff : FSR ,%, (multiplied by 100 by the CAP 2000+). All ffff values shall be padded to 4 characters with leading zeros. • rrrrrr : shear rate ,1/seconds, (multiplied by 100 by the CAP 2000+). All rrrrrr values shall be padded to 6 characters with leading zeros. • ttt : temperature ,°C, (multiplied by 10 by the CAP 2000+). All ttt values shall be padded to 3 characters with leading zeros. • cc : cone. All cc values shall be padded to 2 characters with leading zeros.
I<CR>	ICAP+<bbxxxdddd> <ss><CR>	<ul style="list-style-type: none"> • Identify the viscometer and firmware in use. • bb: HI or LO : temperature range. • xxx : firmware version (decimal format) multiplied by 100. • ddddd : spring constant, (multiplied by 10,000 by the CAP 2000+). All ddddd values shall be padded to 5 characters with leading zeros.
Scc<CR>	Saaaaaaeeeeeecc<ss><CR>	<ul style="list-style-type: none"> • Selects cone to be used. • cc : cone #: All cc values shall be padded to 2 characters with leading zeros. • 01H<=cc<=14H; Any S command sent with a cone number outside these limits will be ignored. • Cone # outside limits: response values represent the cone the instrument is staying with. • aaaaaa : cone multiplier constant. All aaaaaa values shall be padded to 6 characters with leading zeros. • eeeee : shear rate constant of cone (multiplied by 10000). All eeeee values shall be padded to 6 characters with leading zeros. • Sets illegal value bit in status byte if cc is outside limits (See Table D2).
Kccvvvvveeeee aaaaaayy<CR>	Kccvvvvveeeee aaaaaayy<ss><CR>	<ul style="list-style-type: none"> • Calibrate a new cone. • The response will not be returned to the host until the calibration is complete. • cc : cone #: All cc values shall be padded to 2 characters with leading zeros. • vvvvvv :viscosity of calibration fluid (centipoise). All vvvvvv values shall be padded to 6 characters with leading zeros. • eeeee : shear rate constant of cone. The CAP 2000+ divides all eeeee values by 10000 upon receiving them and multiplies by 10000 before sending them. All eeeee values shall be padded to 6 characters with leading zeros. • aaaaaa : cone multiplier constant. All aaaaaa values shall be padded to 6 characters with leading zeros. • yyy: calibration speed. Subject to same limitations as in V command. • If there is an error, bit 7 of the status byte is set.
Invalid Command	??<CR>	<ul style="list-style-type: none"> • Invalid command received

Table D1

Note: All multiplication and division operations performed on any of the command values should be done while the values in question are in their decimal (base 10) form (i.e. before any conversion to hexadecimal).

LEGEND	
Command	Description
<aaaaaa>	Cone multiplier constant (hexadecimal). All cone multiplier constant values are six characters padded with leading zeroes.
<bb>	{HI / LO} Indicates whether the instrument operates in the high (0°C to 235°C) temperature range or the low (5°C to 75 °C) temperature range.
<cc>	Cone number (hexadecimal); all cone numbers are two characters padded with leading zeroes. All cone values are two characters padded with leading zeroes.
<CR>	Carriage return
<dddd>	Spring Constant (hexadecimal). The Spring Constant must be multiplied by 10,000 before transmission by the CAP 2000+. Use the base Spring Constant for the model, not an adjusted constant after calibration.
<eeeeee>	Shear rate constant of a cone to be calibrated (hexadecimal). The CAP 2000+ must divide shear rate constants by 10000 after they are received, and multiply shear rate constants by 10000 before sending them out. All shear rate constant values are six characters padded with leading zeroes.
<ffff>	% FSR (hexadecimal). % FSR values are multiplied by 100 before transmission from the CAP 2000+. All FSR values are four characters padded with leading zeroes.
<rrrrrr>	Shear rate (1/seconds) values (hexadecimal). Shear rate values are multiplied by 100 before transmission by the CAP 2000+. All shear rate values are six characters padded with leading zeroes.
<ss>	Status byte, returned in hexadecimal format, see Table 2 for complete description. All status bytes are two characters padded with leading zeroes.
<ttt>	Temperature (°C) sent to or from the CAP 2000+ (hexadecimal). The CAP 2000+ must divide all temperature values received by 10, and multiply all temperature values sent by 10. All temperature inputs are three characters padded with leading zeroes.
<vvvvvv>	Viscosity (P) sent to or from the CAP 2000+ (hexadecimal). The CAP 2000+ must divide all viscosity values received by 1000, and multiply all viscosity values sent by 1000; all viscosity values are six characters padded with leading zeroes.
<xxx>	Firmware version number, in decimal format, multiplied by 100 by CAP 2000+ before transmission (i.e. for firmware version 2.15, xxx would be 215).
<yyy>	Speed (RPM) input (hexadecimal). All speeds are three characters padded with leading zeroes.

INTERPRETATION OF BYTE STATUS

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1
Motor Off	x	x	x	x	x	x	0
Motor On	x	x	x	x	x	x	1
Over FSR ($\geq 115.0\%$) ¹	x	x	x	x	x	1	X
Valid FSR ($< 115.0\%$)	x	x	x	x	x	0	x
Value Outside Limits ²	x	x	x	x	1	x	x
Value Within Limits	x	x	x	x	0	x	x
Calibration Error	1 ³	x	x	x	x	x	x

¹ Bit 2 is set in response to an R command (request for information) only.
² If an input is received that is outside the allowable limits for a command, Bit 3 shall be set for the response to that command only. Once the response to the command has been sent to the host, Bit 3 shall be cleared again.
³ This bit is set in response to a calibration command if an error occurred in the respective operation.

Example:

1. The CAP 2000+ has been turned on with the proper cable inserted in the serial port placing the unit in its external mode.

2. The host computer sends an **I**. The CAP2000+ responds with an **ICAPHI2201000000**, indicating a high temperature CAP2000+ with Version 2.20 firmware, a spring constant of 1.00, and a status byte of 0.
3. The host sends a **T190**. The CAP 2000+ begins controlling to 40.0°C and responds with **T100**.
4. The host sends **V1F4**. The CAP 2000+ ramps to 500 rpm and responds with **V02** indicating the motor is running.
5. The host sends a **T9C4**. The request to control temperature to 250.0C is illegal. The CAP 2000+ responds with **T0A** indicating a temperature request outside the limits of the instrument.
6. The host sends an **R**. The CAP 2000+ responds with **R002B1115950A25A83E80102** indicating a viscosity reading of 11.025 Poise, a FSR reading of 55.25%, a shear rate of 6650 1/sec, a sensed temperature of 100.0°C, and a number one cone. Note that Bit 3 of the status byte has been cleared. It is set only in response to the offending command (**T9C4**) and is cleared as soon as the response is issued.

APPENDIX E - Warranty Repair and Service

Warranty

Brookfield Viscometers are guaranteed for one year from date of purchase against defects in materials and workmanship. They are certified against primary viscosity standards traceable to the National Institute of Standards and Technology (NIST). The Viscometer must be returned to **Brookfield Engineering Laboratories, Inc.** or the Brookfield dealer from whom it was purchased for warranty service. Transportation is at the purchaser's expense. Remove the spindle from the viscometer and attach the shipping cap to the pivot cup to prevent shipping damage. The Viscometer should be shipped in its carrying case together with all spindles originally provided with the instrument.

For repair or service in the **United States** return to:

Brookfield Engineering Labs., Inc.
11 Commerce Boulevard
Middleboro, MA 02346 U.S.A.
Telephone: (508) 946-6200
FAX: (508) 946-6262
www.brookfieldengineering.com

For repair or service **outside the United States** consult **Brookfield Engineering Laboratories, Inc.** or the dealer from whom you purchased the instrument.

For repair or service in the **United Kingdom** return to:

Brookfield Viscometers Limited
1 Whitehall Estate
Flex Meadow
Pinnacles West
Harlow, Essex CM19 5TJ, United Kingdom
Telephone: (44) 27/945 1774 FAX: (44) 27/945 1775
www.brookfield.co.uk

For repair or service in **Germany** return to:

Brookfield Engineering Labs. Vertriebs
Hauptstrasse 18
D-73547 Lorch, Germany
Telephone: 7172/927100 FAX: 7172/927105
www.brookfield-gmbh.de