

BROOKFIELD CAP VISCOMETERS

MODELS CAP 1000 and CAP 2000

Operating Instructions, version 1.20

Manual No. **M/94-310-F699**



SPECIALISTS IN THE
MEASUREMENT AND
CONTROL OF VISCOSITY

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I. INTRODUCTION

The CAP Series Viscometers are Cone and Plate geometry high shear rate instruments with integrated temperature control of the test sample material. The CAP 2000 has variable shear rate capability over the speed range from 50 - 2000 RPM. The CAP 1000 is a fixed shear rate viscometer rotating at 750 RPM on 50 Hz and 900 RPM on 60 Hz power supply. The instruments operate by digital setting and display; rotational speed can be automatically timed to stop. High shear rate viscosity measurements are made over various viscosity ranges depending upon the model of the viscometer (CAP 1000 or CAP 2000), the cone spindle and the rotational speed (shear rate). Viscosity is selectively displayed in either poise (P) or Pascal seconds (Pa•s). Temperature control of sample is possible between either 5°C and 75°C or 50°C and 200°C depending on viscometer model.

The CAP Series Viscometers selectably display in either the **CGS** or **SI** units (see page 7):

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

The CAP Series Viscometers output data to a computer or parallel printer in the **CGS** and **SI** units:

	<u>CGS</u>	<u>SI</u>	<u>Comment</u>
Viscosity:	P	Pa•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.	
Sample Number:	No.	No.	

I.1 Components

The following items are included:

	<u>Part No.</u>
1. CAP 1000 or CAP 2000 Viscometer	
2. Cone Spindle(s)	CAP-S-0X (X will be shown as a number 1-6)
3. Spindle Case	CAP-106Y
4. Thumb Screw Wrench	RK-24
5. Solvent Trap	CAP-118
6. Power Cord: 115V	DVP-65
220V	DVP-66
UK	DE-8
Germany	DE-7
7. Operating Instructions Manual	M/94-310

The following optional items may have been included:

	<u>Part No.</u>
8. CAPCALC Software and PC Cable (CAP 2000): DOS	CAP-114Y
	Windows CAP-225Y
9. Printer (CAP 1000 and 2000) PRINTER 115/PRINTER 230
10. Viscosity Standard Fluid for calibration See Table A1 in Appendix A

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

Voltage and frequency requirements for the CAP viscometer are indicated on the label on the back side of the instrument base. Check to make sure these agree with the power supply available in your laboratory. This information can be found on the name plate.

I.3 Specifications

Speeds:	CAP 1000	750 RPM at 50 Hz 900 RPM at 60 Hz		
	CAP 2000	50 - 2000 RPM (50 Hz or 60 Hz as dedicated; check name plate on the viscometer) 1.0 RPM increments		
Temperatures:	CAP 1000L	5°C to 75°C	CAP 2000L	5°C to 75°C
	CAP 1000H	50°C to 200°C	CAP 2000H	50°C to 200°C
	All models provide 0.1°C increments			
Weight:	Gross Weight	46 lb	21 kg	
	Net Weight	39 lb	17.7 kg	
	Carton Volume	4.7 cu ft	0.13 m ³	
	Carton Dimensions	25.5 in. L x 17.5 in. W x 18.25 in. H 65 cm. L x 44.5 cm. W x 46.4 cm. H		
Materials:	CAP cone spindles and temperature plates are made of tungsten carbide.			
Operating Environment:	CAP 1000 and 2000 Viscometers <i>must</i> be operated within the following ambient temperatures: -5°C (4°F) to 40°C (149°F)			

I.4 Set-Up

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 **CAPCALC** software (CAP 2000), connect the PC cable (Brookfield Part No. DVP-80) to the RS232 port and computer.

1.5 Key Functions

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

RPM

This key selects the speed (RPM) setting mode.

TEMP

This key selects the temperature (°C) setting mode.

SAMPLE

This key selects the sample number mode.

TIMER

This key selects the running time mode.

CONE

This key selects the cone spindle entry mode.

INDEX

This key is used together with the RPM, TEMP, SAMPLE, TIMER and CONE keys to enter (index) digits within each mode.

PRINT

The PRINT key is used to send data to the parallel printer port.

RUN

The RUN key starts the cone spindle rotating.

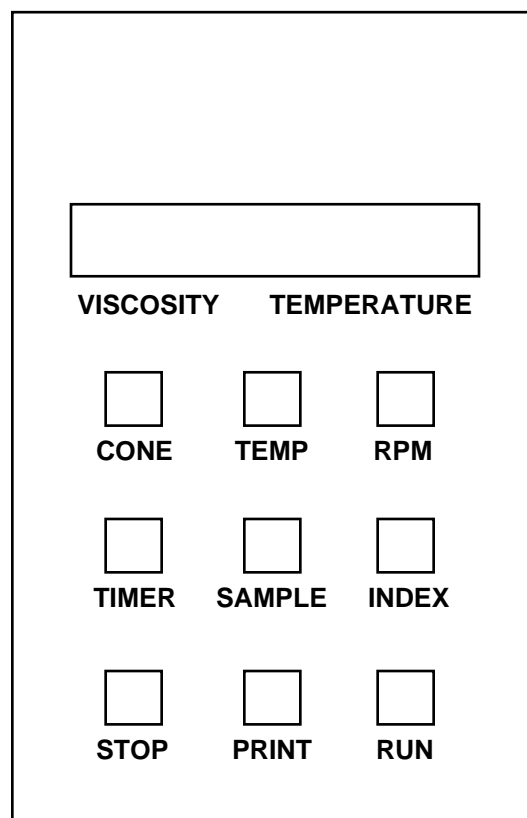


Figure 1

STOP

The STOP key has several functions:

1. Stops the cone spindle rotation at any time. Think of it as an ESCAPE key.
2. Pressing the STOP key during any sequence of RPM, TEMP, SAMPLE, TIMER or CONE entry exits the mode and returns the display to the Main Screen (**Figure 2**).
3. Pressing and holding the STOP and RUN keys simultaneously selects the viscosity display units (CGS or SI) and executes the printing of a new header (Section II.1).
4. Pressing and holding the STOP and PRINT keys simultaneously executes the printing of a new heading (Section II.7).
5. Pressing and holding the STOP and RPM keys simultaneously show “SET RPM”; pressing the RPM key again will show “SHEAR RATE”; pressing the RPM key again will show full scale range.

The CAP series Viscometers use an alternating key press method for selecting and setting the parameters **RPM** (speed), **TEMP** (temperature), **SAMPLE** (number), **TIMER** (run time) and **CONE** (spindle). Each parameter setting is executed using its function key sequentially with the **INDEX** key.

To set a parameter, first press the function key. This will produce a display message with a blinking cursor. Then press the **INDEX** key to select the number wanted in the blinking cursor column. Then press the function key again to move to the next column. Using the **INDEX** key, select the number for that column. This alternating sequence is used until all the columns have been selected. After the last column has been selected, pressing the function key one more time sets the parameter.

I.6 Viscosity and Temperature Display

Viscosity is displayed in either **P=Poise** (CGS system) or **Pa•s=Pascal seconds** (SI system). If the viscosity measurement is over range “EEEE” will be displayed. If the viscometer settles out with a final reading below zero, negative values will be displayed.

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

II. GETTING STARTED

II.1 Power ON

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

The display will sequentially show **BROOKFIELD**, then the MODEL of the viscometer. After about ten seconds, the **MAIN SCREEN** will be displayed, indicating the temperature of the sample plate (**Figure 2**).

DEFAULT TEMPERATURES

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



Figure 2

SELECTING CGS OR SI UNITS

Pressing the **STOP** and the **RUN** keys simultaneously after power **ON** will enable you to select either **CGS** or **SI** units of measurement for the display and printer. A momentary **CGS** or **SI** will be displayed on the **MAIN SCREEN**. If a printer is connected, a new header will be printed showing the change in measurement unit.

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:

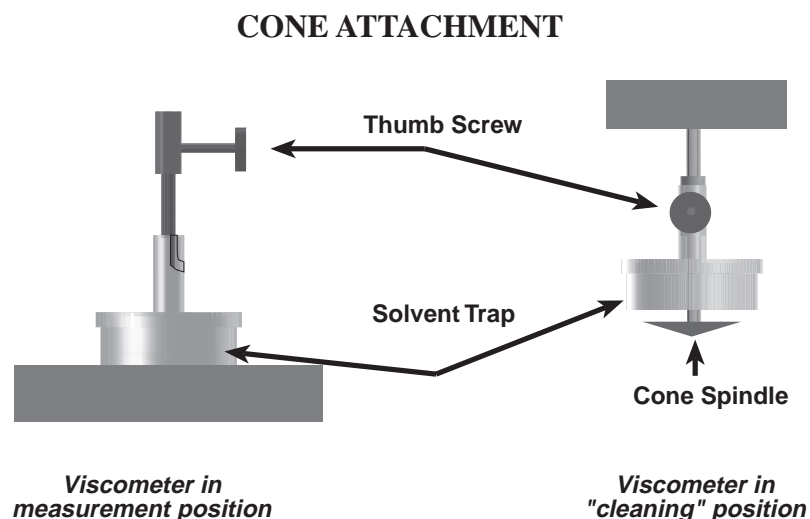


Figure 3

When using the solvent trap, connect it to the cone adapter 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. (An Allen wrench is provided as an *optional method* for tightening the thumb screw.)

Press the **CONE** key. The screen displays as shown in **Figure 4**.



Figure 4

Two digits must be entered for the cone number. For cone **01** through **09**, the first number remains as “0”. Press the **CONE** key again to move to the second column. Using the **INDEX** key, sequence through the digits 0 through 9 selecting the cone to be utilized.

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 **CONE** key a third time and the cone will be accepted for viscometer calculations. The screen will display the following message:



Figure 5

Pressing the **INDEX** key will toggle the words **NO** and **YES**.

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 07 through 99 must be first calibrated following the directions in **Appendix B**, Step 6.

If you are not going to calibrate the cone, continue by pressing the **CONE** key, with the word **NO** displayed. The viscometer will display the **MAIN SCREEN** (**Figure 2**).

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

II.3 Sample Number Setting (optional)

Press the **SAMPLE** key and the screen will be displayed as shown in **Figure 6**.



Figure 6

Four digits of a sample number can be set in the range 0000 to 9999. The number will be printed in the sample number column when a print sequence is executed.

Using the **SAMPLE** key and the **INDEX** key, select the sample number. The same methodology used for setting the cone is used for setting the sample number. The **SAMPLE** key moves the cursor from left to right through the columns. The **INDEX** key selects the digits 0 through 9 for each column. After the fifth press of the **SAMPLE** key, the sequence is completed and the sample number is set. The display will revert to the main display (**Figure 2**).

II.4 Speed Setting

Press the **RPM** key and the screen will be displayed as shown in **Figure 7**.



Figure 7

CAP 1000 Viscometers

This screen will only show 900 RPM for 60 Hz units or 750 RPM for 50 Hz units. The speed cannot be changed.

CAP 2000 Viscometers

On start-up, the screen will display the default speed either **SET RPM 0750** (for 50 Hz instruments) or **SET RPM 0900** (for 60 Hz instruments).

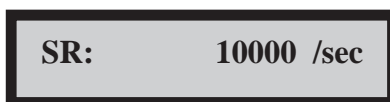
Four digits of speed (RPM) can be set in the range 50 to 2,000 for CAP 2000 Viscometers. Using the **RPM** and **INDEX** keys, select the cone rotational speed to be utilized. After the fourth press of the **RPM** key, the sequence is completed and the cone rotational speed is set.

Shear Rate and Viscosity Display

Example: Cone 01 set to rotate at 750 RPM.

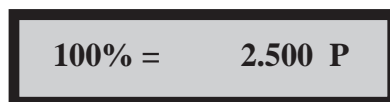
To enter the sequence to display the shear rate and viscosity range for the cone/speed selected, hold the **STOP** key and press the **RPM** key. **SET RPM 0750** will be displayed. Continue by pressing the **RPM** key and the shear rate is shown (**Figure 8**). Press **RPM**

again and the full scale viscosity is shown (**Figure 9**). Press **RPM** once more and the display will revert to the **MAIN SCREEN** (**Figure 2**).



SR: 10000 /sec

Figure 8



100% = 2.500 P

Figure 9

II.5 Temperature Control Setting

Press the **TEMP** key and the screen will display the current temperature setting. The default temperature on start-up is **25.0°C** on low temperature models (**Figure 10**) and **50°C** on high temperature models.



SET TEMP 25.0°C

Figure 10

The temperature ranges are:

Low temperature: 5.0°C to 75.0°C

High temperature: 50.0°C to 200.0°C

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

Using the **TEMP** and **INDEX** keys, enter the temperature for controlling the sample during measurement. After the digit in the tenths column is selected and the **TEMP** key is pressed, the sequence is completed and the control temperature is set. The display will revert to the main display screen and show the viscometer going to the control temperature setting.

II.6 Run Time Setting

Press the **TIMER** key and the screen will be displayed as shown in **Figure 11**.



SET RUN TIME 020

Figure 11

The default time for the run time setting is 15 seconds.

The timer range is 10 to 999 seconds.

Note: Entering 00 sets the **manual** run time mode. Pressing and holding the **RUN** key rotates the cone **continuously**.

Using the **TIMER** and **INDEX** keys, select the run time for rotating the cone. After the second press of the **TIMER** key, the sequence is completed and the run time is set. The display will revert to the **MAIN SCREEN (Figure 2)**.

Note: Run time entries below 10 seconds are not allowed as viscometer/fluid equilibrium, in most cases, will not be established.

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.

At the end of a timed speed execution, data will automatically be sent to the printer port.

To Print a Heading, Press and Hold the STOP key and Press the PRINT key.

CAP 2000 AND 1000 PRINT OUTPUT

VISCOSITY (POISE)	F.S.R. (%)	TEMP (Deg C)	S.STRESS (D/CM2)	S.RATE (1/sec)	SPEED (RPM)	TIMER (SEC)	CONE No.	SAMPLE No.
-	-	25.0	-	10000	0750	20	02	0000

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 of running at the moment the print key is pressed while the cone is rotating.

II.8 Run and Stop Keys

The **RUN** key has four functions:

1. Press **RUN** to execute a timed rotational speed.
2. Press and hold the **RUN** key for continuous rotation when **00** is the timer setting.
3. Used in executing a cone calibration.
4. Used with **STOP** key to select units.

The **STOP** key has several functions:

1. Stops the cone rotation at any time.
2. Pressing the **STOP** key during any sequence of RPM, TEMP, SAMPLE, TIMER or CONE entry exits the mode and returns the display to the Main Screen (Figure 2).
3. Pressing and holding the **STOP** and **RUN** keys simultaneously selects the viscosity display units and executes the printing of a new header (Section II.1).
4. Pressing and holding the **STOP** and **PRINT** keys simultaneously executes the printing of a new heading (Section II.7).

5. Pressing and holding the STOP and RPM keys simultaneously executes the sequence Shear Rate and Viscosity Display (**Section II.4**).

III. OPERATION

The CAP Series Viscometers rotate a very precisely machined conical spindle over a temperature controlled plate shearing the test sample at either a single rotational speed (CAP 1000) or multiple rotational speeds (CAP 2000). The CAP 1000 operates at 750 RPM on 50 Hz power supply and 900 RPM on 60 Hz power supply. The CAP 2000 operates over the speed range from 50 RPM to 2000 RPM (50 Hz or 60 Hz as dedicated) in increments of 1 RPM.

III.1 Accuracy of Measurement

Table 3.1 indicates the accuracy of the viscosity measurement which depends on both the rotational speed of the cone and the percent of full scale range (in Poise) 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).

ACCURACY OF VISCOSITY MEASUREMENT

CAP 1000L AND CAP 2000L VISCOMETERS				
Cone	FULLSCALE VISCOSITY RANGE ACCURACY			
	750 RPM	900RPM		Over 900 RPM to 2000 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	≤ ± 2.0%	≤ ±4.0%		
05	≤ ± 2.0%	≤ ±4.0%		
06	≤ ± 4.0%	≤ ±10.0%		
Cone	FULLSCALE VISCOSITY RANGE ACCURACY			
	750 RPM	900RPM		Over 900 RPM to 2000 RPM
	10 to 100% FSR	≤50% FSR	>50% FSR	FSR = Full Scale Range
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%	
Viscometer		Temperature Control Accuracy		
CAP1000L & H		± 0.2°C		
CAP2000L & H		±0.2°C		

Note: For CAP2000L Viscometers, the accuracy stated at 750 RPM and 900 RPM applies over the speed range 50 RPM to 750 RPM and 50 RPM to 900 RPM.

Table 3.1

III.2 Repeatability

CAP 1000 and CAP 2000 Viscometers are repeatable to $\pm 0.5\%$ of the full scale viscosity range (FSR). Due to shear heating considerations which occur in high shear rate instrumentation, the measurement of NIST Viscosity Standard Fluids at rotational speeds above 900 RPM will show a decrease in viscosity with an increase in rotational speed (shear rate). When using Brookfield CAPCALC software together with CAP 2000 Series Viscometers and knowing the thermal conductivity of the test sample being measured, corrections to the viscosity measurements can be made which compensate for the heat generated. Refer to the CAPCALC Operator Manual for additional information.

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 of 3.4 Newtons (340,000 Dynes) 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.

III.3 Making Viscosity Measurements

The following procedure is recommended for making a viscosity measurement.

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 (i.e., CAP1000L/2000). The default temperature for high temperature is 50°C (i.e., CAP1000H/2000H). If a cone calibration is to be done immediately after the warm up period, temperature should be set to 60°C (calibration temperature for high temperature instruments) to save some time.
- b) The cone calibration procedure (Appendix B) should have been done for all cones which are used with the instrument. Cone calibration is only 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 (CAP1000L/CAP2000L) 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 (CAP1000H/CAP2000H).

- d) If a printer is to be used, it should be connected (AC power & viscometer to printer cable). The CAP1000/2000 will print automatically when a reading is taken if the printer is connected and “on line.”

Select and attach the cone (Section II.2).

- Note:**
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 1000H or CAP 2000H, 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.

Set the temperature control (Section II.5).

2. Set the cone number.
3. 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.

4. 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.
 3. Release the solvent trap placing it onto the plate over the cone so it does not touch the cone shaft.

5. 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 volatile characteristics of the test sample.

6. Set the **RPM** (Speed). (Section II.4).
7. Set the **Time** for rotating the cone (Section II.6).
8. Select a **Sample Number** (optional, Section II.3).
9. Put the printer on-line (optional, Section II.7).
10. 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 will indicate a deflection from the equilibrium temperature setting as the cone begins rotating. The temperature display indicates the temperature of the plate and the momentary changes show the cycling of the temperature control at high temperature. The precision of the viscosity measurement is maintained within the limits specified in **Table 3.1**.

11. Read the results of the sample test on the printer or write down the test conditions and viscosity results from the viscometer display.
12. Relocate the solvent trap onto the cone adapter and raise the handle.
13. It is recommended to remove the cone for cleaning. However, with care, the cone can be cleaned in place.
14. Clean the viscometer plate.

Note: Cleaning of both the cone and plate should be done before solidification or drying occurs in order to minimize damage.

15. Read the results of the sample test on the printer or write down the test conditions and viscosity results from the viscometer display.
16. Relocate the solvent trap onto the cone adapter and raise the handle.
17. Clean the viscometer plate.

Note: Cleaning of both the cone and plate should be done before solidification or drying occurs in order to minimize damage. **Caution:** Cone and plate may be **HOT**.

IV. PC CONTROL (CAP 2000 VISCOMETER)

The CAP 2000 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 CAP 2000 Viscometer from a PC. CAPCALC for DOS requires a minimum of a 386 processor, 640K RAM, VGA color monitor, serial and parallel ports and hard disk. CAPCALC for Windows requires Windows 3.1 or higher, a processor of 486 or higher, a minimum of 4 megabytes RAM, VGA color monitor, serial and parallel ports, and hard disk. CAPCALC application software displays, prints and stores tabulated data files (Brookfield or Lotus®).

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 2000L) or 50°C and 200°C (CAP 2000H) 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 CAP 2000 is contained in **Appendix E**.

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

APPENDIX A - Cone Numbers - Sample Sizes - Viscosity Ranges

CAP 1000 AND 2000 VISCOMETERS						
Version 1.0						
Cone Number	Shear Rate (sec ⁻¹)	Sample Size (micro liters)	Calibrating Fluid Low Temp Cap at 25°C		Calibrating Fluid High Temp Cap at 60°C	
			Part No.	*Viscosity	Part No.	*Viscosity
01	13.33N	67	CAP1L	- 100 cP	CAP5L & 1H	- 140 cP
02	13.33N	38	CAP2L	- 210 cP	CAP2H	- 280 cP
03	13.33N	24	CAP3L	- 400 cP	CAP6L & 3H	- 380 cP
04	3.33N	124	CAP4L	- 750 cP	CAP4H	- 730 cP
05	3.33N	67	CAP5L & 1H	- 1400 cP	CAP5H	- 1400 cP
06	3.33N	32	CAP6L & 3H	- 4900 cP	CAP6H	- 4700 cP
	N = RPM					

*Approximate Value

Table A1

Cone Number ¹	CAP 1000 VISCOSITY RANGES (POISE)	
	750 RPM	900 RPM
01	0.25 - 2.5	0.21 - 2.08
02	0.5 - 5.0	0.42 - 4.17
03	1.0 - 10.0	0.83 - 8.33
04	2.0 - 20.0	1.67 - 16.67
05	4.0 - 40.0	3.33 - 33.33
06	10.0 - 100.0	8.33 - 83.33

Table A2

Cone Number ¹	CAP 2000 Viscosity Ranges (Poise)	Cone Range Coefficient
01	0.09 - 37.5	1,875
02	0.19 - 75.0	3,750
03	0.38 - 150.0	7,500
04	0.75 - 300.0	15,000
05	1.50 - 600.0	30,000
06	3.75 - 1,500.0	75,000

Table A3

Cone Number ¹	Cone Angle (degrees)	Cone Radius (cm)
01	0.45	1.511
02	0.45	1.200
03	0.45	0.953
04	1.8	1.200
05	1.8	0.953
06	1.8	0.702

Table A4

¹Number is marked on the cone shaft

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 06

To determine the full scale viscosity range (FSR) for any cone/speed, divide the Cone Range Coefficient (refer to **Table A3**) by the rotational speed (RPM).

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

CAP 2000 RANGES FOR CONES 07 THROUGH 99

Spindle Multiplier Constant (SMC):

SMC = (supplied by the manufacturer)

Shear Rate Constant (SRC):

SRC = (supplied by the manufacturer)

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

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

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

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

$$N = \text{RPM}$$

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

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

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

EXAMPLE: CAP 2000L Viscometer; Cone (02); running at 685 RPM; temperature 25.0°C; % FSR = 73.8. Determine the viscosity (poise), shear stress (dynes/cm²), shear rate (sec⁻¹).

Using **Equation A1**, determine the full scale viscosity range at 685 RPM:

$$\text{Full Scale Viscosity Range (poise)} = \frac{3,750}{685} = 5.47 \text{ poise}$$

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

$$\text{Viscosity (poise)} = 5.47 \text{ (poise)} \times \frac{73.8}{100} = 4.04 \text{ poise}$$

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

$$\text{Shear Rate (sec}^{-1}\text{)} = \frac{(2)(3.1416)(685)}{(60)(\text{sine } 0.45)} = 9,133 \text{ sec}^{-1}$$

Using **Equation A3**, determine the shear stress:

$$\text{Shear Stress (dynes/cm}^2\text{)} = (4.04)(9,133) = 36,897 \text{ dynes/cm}^2$$

APPENDIX B - Calibration Procedures

Verification of Calibration

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.

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 A1)**, 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 measurements at three (3) rotational speeds (RPM) giving results within the 10% to 100% full scale viscosity range of the selected cone.

Verify the results to have a precision according to the information in **Section III, Table 3.1**.

If the calibration is outside the precision limits (refer to **Table 1**), proceed with the following **Cone Calibration**.

Cone Calibration

A special feature of the **CAP Series** Viscometers allows the user to perform cone calibration using NIST Fluids.

Refer to **Appendix A (Table A1)** and choose the viscosity standard fluid for the cone being calibrated.

Place the appropriate amount of sample (refer to **Appendix A, Table A1**) onto the viscometer plate in the center directly below the cone. Pull the handle down (**gently**), locking it into the lowest position, placing the cone in contact with the plate.

NOTE: The solvent trap should be utilized when calibrating.

1. Press the **CONE** key. The current cone number (two digits) appears on the right of the display.
2. Using the **CONE** key alternating with the **INDEX** key, enter the two digit number of the cone being calibrated.
3. After entering the second digit of the cone number, pressing the **CONE** key selects the cone and displays the message:

A rectangular box with a black border containing the text "CALIBRATE ? NO" in a bold, sans-serif font.

Figure B1

Toggling the **INDEX** key displays the words **NO** and **YES**.

4. Press the **INDEX** key to display the word **YES**.
5. **Cone 01 to 06**

Press the **CONE** key and the viscometer displays the message:

A rectangular box with a black border containing the text "SET TEMP 25.0°C" in a bold, sans-serif font.

Figure B2

Using the **TEMP** and **INDEX** keys, enter the viscosity standard fluid calibration temperature.

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 at 60°C for “H” Series CAP Viscometers.

Upon pressing the **TEMP** key to accept the last digit of the calibration temperature, the viscometer displays the message:

A rectangular box with a black border containing the text "FLUID = 00000 cP" in a bold, sans-serif font.

Figure B3

Using the **CONE** and **INDEX** keys, enter the viscosity of the standard fluid in **centipoise (mPa·s)**.

NOTE: Calibration is performed using **CENTIPOISE (mPa·s)** values, **NOT POISE** values, for the Viscosity Standard Fluid.

Viscosity is entered as a five (5) digit number referencing from **RIGHT** to **LEFT**.

Example: Viscosity of 433 centipoise (mPa·s). Enter 00433.
 Viscosity of 12,500 centipoise (mPa·s). Enter 12500.

Note: If an incorrect value is entered for the Viscosity Standard Fluid, press the **STOP** key and begin over at **Step 1**.

Zero viscosity is not allowed.

Pressing the **CONE** key after entering the fifth digit displays the message:



TEMP. = 25.0°C

Figure B4

Verify that the calibrating temperature, as shown in the display, is correct and stable. If the value is incorrect, press **STOP**, return to **Step 1** and begin again.

Press the **RUN** key to calibrate the cone. The screen will display:



CALIBRATING (_ _)

Figure B5

NOTE: The 2 digits in parentheses identify the cone that is being calibrated.

When calibration is completed, rotation will stop and the screen will display:



CAL COMPLETE

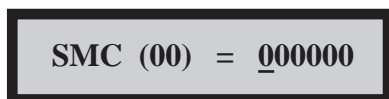
Figure B6

Pressing the **PRINT** key sends the calibration data to the printer port (**Figure B14**) and returns the **CAP** to the main screen.

6. Custom Cones

Custom cone spindles are available from Brookfield Engineering. For further information, contact Technical Sales, Brookfield USA. The following information relates to calibrating custom cone spindles.

Pressing the **CONE** key after completing **Step 4**, the viscometer displays the message:



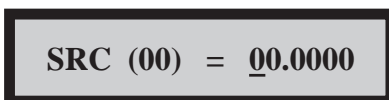
SMC (00) = 000000

Figure B7

Using the **CONE** and **INDEX** keys, enter the **Spindle Multiplier Constant (SMC)**. Refer to **Appendix A**.

Note: All Zeros are not accepted.

Upon pressing the **CONE** key to accept the last digit of the **SMC** value, the viscometer displays the message:



SRC (00) = 00.0000

Figure B8

Using the **CONE** and **INDEX** keys, enter the Shear Rate Constant (**SRC**). Refer to **Appendix A**.

Note: All Zeros are not allowed.

Upon pressing the **CONE** key to accept the last digit of the **SRC** value, the viscometer displays the message:

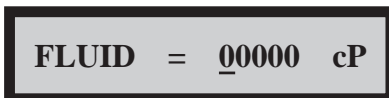


SET TEMP 25.0°C

Figure B9

Using the **TEMP** and **INDEX** keys, enter the calibration temperature.

Upon pressing the **TEMP** key to accept the last digit of the calibration temperature, the viscometer displays the message:



FLUID = 00000 cP

Figure B10

Using the **CONE** and **INDEX** keys, enter the viscosity of the standard fluid in **centipoise (mPa·s)**.

NOTE: Calibration is performed using **CENTIPOISE (mPa·s)** values, **NOT POISE** values, for the Viscosity Standard Fluid.

Viscosity is entered as a five (5) digit number referencing from **RIGHT** to **LEFT**.

Example: Viscosity of 433 centipoise (mPa·s). Enter 00433.
Viscosity of 12,500 centipoise (mPa·s). Enter 12500.

Note: If an incorrect value is entered for the Viscosity Standard Fluid, press the **STOP** key and begin over at **Step 1**.

Zero viscosity is not allowed.

Pressing the **CONE** key after entering the fifth digit displays the message:

TEMP. = 25.0°C

Figure B11

Verify the calibrating temperature is correct and stable. If the value is incorrect, press **STOP**, return to **Step 1** and begin again.

Press the **RUN** key to calibrate the cone. The screen will display:

CALIBRATING (00)

Figure B12

When calibration is completed, rotation will stop and the screen will display:

CAL COMPLETE

Figure B13

Pressing the **PRINT** key sends the calibrating parameters to the printer port (**Figure B14**) and returns the CAP to the main screen.

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 B14

APPENDIX C - Glossary of Screen Displays

“CAL COMPLETE”	-	Cone calibration complete
“CALIBRATE? NO”	-	Toggle to select cone calibration
“CALIBRATE? YES”	-	Toggle to select cone calibration
“CALIBRATING (00)”	-	Calibrating cone No. (00)
“CALL FOR SERVICE”	-	System error is found
“CAP 1000L”	-	Model No. for CAP 1000L (5°C to 75°C)
“CAP 1000H”	-	Model No. for CAP 1000H (50°C to 200°C)
“CAP 2000L”	-	Model No. for CAP 2000L (5°C to 75°C)
“CAP 2000H”	-	Model No. for CAP 2000H (50°C to 200°C)
“CGS UNITS”	-	Viscosity and Shear Stress in CGS units (P and dynes/cm ²)
“EXTERNAL CONTROL”	-	External control mode (CAP 2000)
“FLUID = 00000 cP”	-	Fluid viscosity entry for cone calibration
“100% = 0000 P”	-	Full Scale Viscosity Range (FSR) for cone (00) after set speed entry
“SAMPLE No. 0000”	-	Sample No. 0000 entry
“SELECT CONE 00”	-	Cone No. (00) entry
“SET RPM 0000”	-	Motor speed entry
“SET RUN TIME 000”	-	Set timer entry
“SET TEMP 00.0°C”	-	Temperature entry for CAP 1000L and 2000L
“SET TEMP 000.0°C”	-	Temperature entry for CAP 1000H and 2000H
“SI UNITS”	-	Viscosity and Shear Stress in SI units (Pa•s and N/m ²)
“SMC (00) = 000000”	-	SMC entry for cone No. (00)
“SR: 00000/SEC”	-	Shear Rate for cone (00) after set speed entry
“SRC (00) = 00.0000”	-	SRC entry for cone No. (00)
“TEMP = 000.0°C”	-	Display current temp. for auto zero and cone calibration
“ 25.0°C”	-	Main screen
“USE FLUID (00)”	-	Use cal. fluid for cone No. (00) when auto zeroing

APPENDIX D - 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 will 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 E - Communications

Printer Output - CAP 1000 & CAP 2000

On the CAP Viscometer end, the cable connection 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

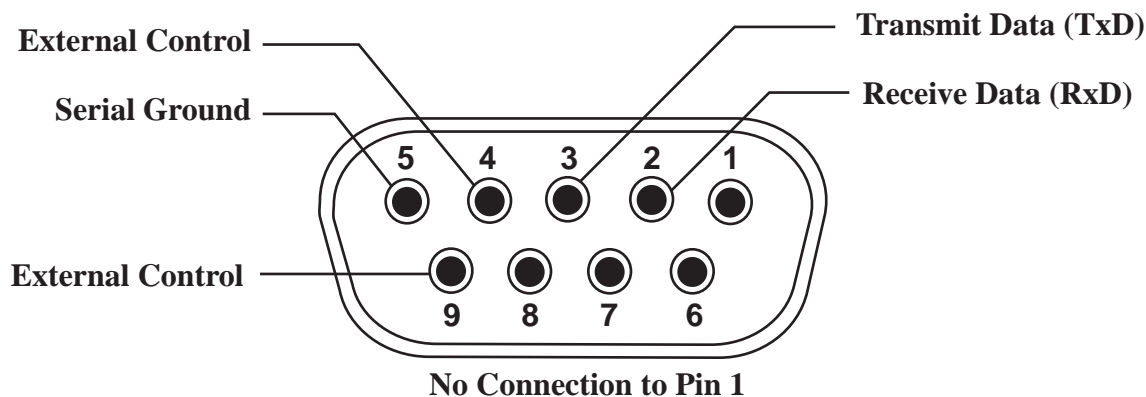


Figure E1

The following pages review the transmit/receive commands between the CAP 2000 and a computer (Table E1), the byte status interpretation (Table E2) 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>	Sets current speed and starts motor; 032H <= yyy <= 7D0H rpm; (yyy = hexadecimal speed); 50 rpm <= speed <= 2000 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
Tttt<CR>	T<ss><CR>	Sets current temperature and controls to it; 15EH <= ttt <= 2EEH; cold model (5°C to 75 °C) 15EH <= ttt <= 7D0H; hot model (50°C to 200°C) ttt is the desired temperature multiplied by 10; all ttt values shall be padded to 3 characters with leading zeros; sets illegal value bit in status byte if ttt is outside limits
R<CR>	R<vvvvvvffffrrrrrttcc><ss><CR>	Returns a data packet to the host; all of the following values are in hexadecimal format; vvvvvv viscosity (multiplied by 100) ffff % torque (multiplied by 100) rrrrrr shear rate (multiplied by 100) ttt °C temperature (multiplied by 10) cc cone
I<CR>	I<i><ss><CR>	Identify the viscometer and firmware in use (See legend for description of i)
Sc<CR>	Sc<ss><CR>	Selects cone to be used cc cone number in hexadecimal
Kccvvvvvveeeeeea aaaaa <CR>	Kccvvvvvrrrrrrraaaaa<ss><CR>	Calibrate a new cone; the response will not be returned to the host until the calibration is complete; all of the following values are in hexadecimal format; cc cone number vvvvvv viscosity of calibration fluid (centipoise) eeeeee shear rate constant of cone (multiplied by 10000) aaaaaa cone multiplier constant if there is an error, bit 7 of the status byte is set;
Invalid command	??<CR>	Invalid command received

TABLE F1 - CAP 2000 Interface Commands

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:

- <CR> - carriage return
- <ss> - status byte; returned as two hexadecimal digits (see Table 2 for complete description)
- <i> - identification string of the viscometer in use; This string may be one of the following:
 - CAPLOxxx - used for the cold model (75°C maximum)
 - CAPHIxxx - used for the hot model (200°C maximum)

where xxx is the firmware version number multiplied by 100 (i.e. for firmware version 1.15, xxx would be 115).

- <yyy> - speed input (hexadecimal); all speeds are three characters padded with leading zeroes.
- <ttt> - temperature sent to or from the CAP 2000(hexadecimal); temperature values sent to the CAP 2000 must be multiplied by 10 before transmission; temperature values received from the CAP 2000 must be divided by 10; all temperature inputs are three characters padded with leading zeroes.
- <ffff> - % torque values returned from the CAP 2000 (hexadecimal); % torque values received from the CAP 2000 must be divided by 100; all torque values are four characters padded with leading zeroes.
- <vvvvvv>- viscosity sent to or from the CAP 2000 (hexadecimal); viscosity values sent to the CAP 2000 must be multiplied by 100 before transmission; viscosity values received from the CAP 2000 must be divided by 100; all viscosity values are six characters padded with leading zeroes.
- <rrrrrr> - shear rate values sent from the CAP 2000 (hexadecimal); shear rate values are multiplied by 100 before transmission; all shear rate values are six characters padded with leading zeroes.
- <cc> - cone number (hexadecimal); all cone numbers are two characters padded with leading zeroes.
- <eeeeee>- shear rate constant of a cone to be calibrated (hexadecimal); shear rate constants must be multiplied by 10000 before being sent to the CAP 2000; all shear rate constant values are six characters padded with leading zeroes.
- <aaaaaa>- cone multiplier constant (hexadecimal); all cone multiplier constant values are six characters padded with leading zeroes.

INTERPRETATION OF BYTE STATUS

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Viscometer not zeroed	x	x	x	x	x	x	x	0
Viscometer zeroed	x	x	x	x	x	x	x	1
Motor off	x	x	x	x	x	x	0	x
Motor on	x	x	x	x	x	x	1	x
Over torque (> 115.0%)	x	x	x	x	x	1	0	x
Valid torque (<115.0%)	x	x	x	x	x	0	x	x
Value outside limits ¹	x	x	x	x	1	x	x	x
Value within limits	x	x	x	x	0	x	x	x
Calibration error	1 ²	x	x	x	x	x	x	x

Table E2 - Status Byte (always returned as two hex digits)

- NOTES:**
- 1 - 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.
 - 2 - 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 CAP 2000 responds with an **ICAPHI10000** indicating a high temperature CAP 2000 with version 1.00 firmware and a status byte of 0.
3. The host sends a **T190**. The CAP 2000 begins controlling to 40.0C and responds with **T01**.
4. The host sends **V1F4**. The CAP 2000 ramps to 500 rpm and responds with **V03** 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 **T0B** indicating a temperature request outside the limits of the instrument.
6. The host sends an **R**. The CAP 2000 responds with **R002B1115950A25A83E80103** indicating a viscosity reading of 110.25 Poise, a torque reading of 55.25%, a shear rate of 6650 1/sec, a sensed temperature of 100.0C, 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.

SAMPLE PROGRAM FOR EXTERNAL COMPUTER CONTROL OF CAP 2000 VISCOMETER

This program can be used with GWBasic, Basic, Basica, or QuickBasic. The complete program or any portion thereof may be freely used but not resold. Please note that little or no error checking is performed in this program. It is supplied to provide a working example of the CAP 2000 interface commands.

```
1000 `
1005 ` CAP 2000 External Mode Command Protocol Demonstration
1010 ` Copyright 1994, Brookfield Engineering Labs
1015 ` Written by Greg Krysko
1020 `
1025 `
1030 CLS
1035 PRINT SPC(26); "Brookfield Engineering Labs"
1040 PRINT SPC(20); "CAP 2000 External Mode Demonstration Program"
1045 PRINT SPC(32); "Copyright 1994"
1050 PRINT
1055 PRINT "This program is intended to demonstrate the use of the RS-232 com-
mand "`
1060 PRINT "set employed by the Brookfield Engineering Labs CAP 2000 Viscometer
"
1065 PRINT "in its External mode. This program and/or any of the commands used
"
1070 PRINT "within may be freely used in your own applications."
1075 PRINT
1080 PRINT "Press any key to continue..."
1085 GOSUB 1490 ` Wait for a keypress
1090 CLS
1095 GOSUB 1655 ` Initialize variables
1100 OPEN "COM1:9600,N,8,1,CS,DS,CD" FOR RANDOM AS #1' Open com port #1
1160 INPUT "Enter a cone number: "; CONE
1161 INPUT "Enter sample temperature (øC):"; SETTEMP
1162 CAPVALUE = CONE
1165 CMDLEN = 2
1170 GOSUB 1595 ` Convert cone to hex
1175 CAPCOMMAND$ = "S" + HEXVALUE$
1176 GOSUB 1815 ` Send command to CAP 2000
1177 GOSUB 1870 ` Wait for CAP 2000 response
1180 PRINT
1181 PRINT "The CAP 2000 will bring the sample temperature to"; SETTEMP; "deg
C."
1185 PRINT "The viscometer will then ramp to 100 RPM and will increment"
1190 PRINT "its speed by 100 RPM every 30 seconds. At the end of each"
1195 PRINT "30 second interval, a data point will be taken and displayed"
1200 PRINT "on the screen. This will continue until a data point is taken"
1205 PRINT "at 1000 RPM at which point the CAP 2000 will return to 0 RPM."
1210 PRINT
1215 PRINT "Press any key to continue..."
1220 GOSUB 1490 ` Wait for a keypress
1221 CAPVALUE = SETTEMP * 10 ` Set value to be made hex
1222 CMDLEN = 3 ` Set pad length
1223 GOSUB 1595 ` Convert Temp value to hex
1224 CAPCOMMAND$ = "T" + HEXVALUE$ ` Temperature command
1225 GOSUB
```

```

1815                                     \ Send command to CAP 2000
1226 GOSUB 1870                           \ Wait for CAP 2000 response
1228 WHILE TEMPERATURE <> SETTEMP
1229 CAPCOMMAND$ = "R"                     \ R command fetches data
1230 GOSUB 1815                             \ Send command to CAP 2000
1231 GOSUB 1870                             \ Wait for CAP 2000 response
1232 GOSUB 1920                             \ Calculate data
1233 CLS
1234 LOCATE 1, 1                             \ Set cursor position
1235 PRINT "øC=";
1236 PRINT USING "####.#"; TEMPERATURE     \ Print temperature (øC)
1237 WEND
1240 CLS
1241 PRINT SPC(27); "Sample CAP 2000 Data: CONE"; CONE
1242 PRINT SPC(27); "-----"
1243 PRINT
1256 WHILE RPM <= 1000                       \ Repeat until RPM > 1000
1257 CAPVALUE = RPM                          \ Set value to be made hex
1258 GOSUB 1595                              \ Convert RPM value to hex
1259 PRINT "RPM=";
1260 PRINT USING "####"; RPM;                \ Print RPM
1265 PRINT SPC(3);
1270 CAPCOMMAND$ = "V" + HEXVALUE$        \ Speed command
1275 GOSUB 1815                              \ Send command to CAP 2000
1280 GOSUB 1870                              \ Wait for CAP 2000 response
1285 GOSUB 1540                              \ Count desired time
                                           \ interval (10 secs)
1290 CAPCOMMAND$ = "R"                     \ R command fetches data
1295 GOSUB 1815                              \ Send command to CAP 2000
1300 GOSUB 1870                              \ Wait for CAP to repsond
1305 GOSUB 1920                              \ Calculate data
1310 PRINT "%=";
1315 PRINT USING "##.#"; TORQUE;            \ Print % torque
1320 PRINT SPC(2);
1325 PRINT "Poise=";
1330 PRINT USING "#####.##"; VISC;        \ Print viscosity (Poise)
1335 PRINT SPC(2);
1340 PRINT "D/Cmy=";
1345 PRINT USING "####.#"; SSTRESS;        \ Print shr stress (d/cm^2)
1350 PRINT SPC(3);
1355 PRINT "1/sec=";
1360 PRINT USING "####.#"; SRATE;          \ Print shear rate (1/sec)
1365 PRINT SPC(3);
1370 PRINT "øC=";
1375 PRINT USING "####.#"; TEMPERATURE     \ Print temperature (øC)
1380 RPM = RPM + 100                         \ Increment RPM by 100
1385 WEND                                    \ End WHILE from line 1240
1390 CAPVALUE = 0                           \ Reset speed to 0 RPM
1395 GOSUB 1595                              \ Convert RPM to hex
1400 CAPCOMMAND$ = "V" + HEXVALUE$        \ Speed command
1405 GOSUB 1815   \ Send command to CAP 2000
1410 PRINT
1415 PRINT SPC(25); "Speed Set Execution Complete!"
1420 GOSUB 2080                              \ Close Com channel
1425 END

```

```

1430 `
1435 `
1440 ` Routine used to insert a delay (approximately 50 milliseconds)
1445 ` between each character sent to the CAP 2000.
1450 `
1455 FOR DLY = 1 TO 50
1460 NEXT DLY
1465 RETURN
1470 `
1475 `
1480 ` Routine that waits for a keystroke
1485 `
1490 KEYSTROKE$ = ""
1495 WHILE KEYSTROKE$ = ""
1500 KEYSTROKE$ = INKEY$
1505 WEND
1510 RETURN
1515 `
1520 `
1525 ` Routine to count elapsed seconds. It is used to count the time
1530 ` interval between each data point taken.
1535 `
1540 T1 = TIMER                                ` Gets seconds since
                                                ` midnight
1545 T2 = T1
1550 WHILE (T2 - T1) < TINTERVAL              ` Loop until time elapsed =
                                                ` Tinterval
1555 T2 = TIMER
1560 WEND
1565 RETURN
1570 `
1575 `
1580 ` Routine to convert a decimal value to a hexadecimal string that the
    `CAP 2000 understands
1590 `
1595 `
1600 HEXVALUE$ = HEX$(CAPVALUE)                ` Convert to hexadecimal
1605 ISLENOK = CMDLEN - LEN(HEXVALUE$)        ` Pad the string with
                                                ` leading
1610 WHILE ISLENOK > 0                        ` 0's until its length is
                                                ` CMDLEN
1615 HEXVALUE$ = "0" + HEXVALUE$
1620 ISLENOK = ISLENOK - 1
1625 WEND
1630 RETURN
1635 `
1640 `
1645 ` Initialize variables and constants
1650 `
1655 CR$ = CHR$(13)
1660 RPM = 100
1665 TEMPERATURE = 0

```

```

1670 TINTERVAL = 30
1675 RETURN
1795 `
1800 `
1805 ` Routine to send commands to the DV-III
1810 `
1815 GOSUB 2035
1820 CAPCOMMAND$ = CAPCOMMAND$ + CR$           ` Append a carriage return
                                                ` to command
1825 FOR CMD = 1 TO LEN(CAPCOMMAND$)
1830 PRINT #1, MID$(CAPCOMMAND$, CMD, 1);      ` Send one character at a
                                                ` time
1835 GOSUB 1455                                ` Delay between characters
1840 NEXT CMD
1845 RETURN
1850 `
1855 `
1860 ` Routine to receive a response from the DV-III
1865 `
1870 RESP$ = ""
1875 WHILE RIGHT$(RESP$, 1) <> CR$           ` Wait for a carriage return
1880                                           ` If data in input buffer,
                                                ` retrieve it
1885 IF LOC(1) > 0 THEN RESP$ = RESP$ + INPUT$(LOC(1), #1)
1890 WEND
1895 RETURN
1900 `
1905 `
1910 ` Routine to parse response to an R command
1915 `
1920 HEXRESP$ = MID$(RESP$, 8, 4)             ` Extract characters 8-11
1921 GOSUB 1990                                ` Convert to decimal
1922 TORQUE = DECIMALNUM / 100                 ` Divide torque by 100
1923 HEXRESP$ = MID$(RESP$, 2, 6)           ` Extract characters 2-7
1924 GOSUB 1990                                ` Convert to decimal
1925 VISC = DECIMALNUM / 100                  ` Divide viscosity by 100
1926 HEXRESP$ = MID$(RESP$, 12, 6)          ` Extract characters 12-17
1927 GOSUB 1990                                ` Convert to decimal
1928 SRATE = DECIMALNUM / 100                 ` Divide shear rate by 100
1929 SSTRESS = VISC * SRATE                   ` Calculate shear stress
1930 HEXRESP$ = MID$(RESP$, 18, 3)          ` Extract characters 18-20
1931 GOSUB 1990                                ` Convert to decimal
1932 TEMPERATURE = DECIMALNUM / 10           ` Divide temperature by 10
1965 RETURN
1970 `
1975 `
1980 ` Hex to decimal conversion of a hex string
1985 `
1990 HEXRESP$ = "&H" + HEXRESP$             ` Append hexadecimal
                                                ` identifier
1995 DECIMALNUM = VAL(HEXRESP$)              ` Convert hex string to a
                                                ` decimal value

```

```
2000                                     ` If overflow, take the
                                         ` complement
2005 IF SGN(DECIMALNUM) = -1 THEN DECIMALNUM = 65536! + DECIMALNUM
2010 RETURN
2015 `
2020 `
2025 ` Routine to clear the com port input buffer
2030 `
2035 WHILE LOC(1) > 0                     ` If data in input buffer
2040 DUMMY$ = INPUT$(LOC(1), #1)         ` Dump it out
2045 GOSUB 1455
2050 WEND
2055 RETURN
2060 `
2065 `
2070 ` Routine to close communications channel
2075 `
2080 CLOSE #1
2085 RETURN
```

APPENDIX F - 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

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

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

Brookfield Engineering Labs. Vertriebs
Att: Kurt Kaiser
Barbarossastrasse 3
D-73547 Lorch, Germany
Telephone: 7172/927100 FAX: 7172/927105