

BROOKFIELD CAP1000+ VISCOMETER

MODEL CAP 1000+

Operating Instructions

Manual No. **M02-312**



SPECIALISTS IN THE
MEASUREMENT AND
CONTROL OF VISCOSITY

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TABLE OF CONTENTS

I. INTRODUCTION	3
I.1 Components	3
I.2 Utilities	4
I.3 Specifications	4
I.4 Installation	5
I.5 Safety Symbols and Precautions	5
I.6 Key Functions	6
I.7 Viscosity and Temperature Display	6
I.8 Cleaning	7
II. GETTING STARTED	8
II.1 Power ON	8
II.2 Cone Spindle Selection and Setting	8
II.3 Speed Setting	10
II.4 Temperature Control Setting	10
II.5 Hold Time Settings	11
II.6 Run Time	11
II.7 Printing	11
II.8 Run and Stop Keys	12
III. OPERATION	13
III.1 Accuracy of Measurement	13
III.2 Repeatability	14
III.3 Making Viscosity Measurements	14
APPENDIX A - Cone Numbers, Sample Sizes, Viscosity Ranges	17
APPENDIX B - Calibration Procedures	20
APPENDIX C - Variables in Viscosity Measurement	23
APPENDIX D - Warranty Repair and Service	25

This manual intended for use with CAP1000+ series viscometers which have serial numbers beginning with a prefix of “**CPN**”.

CAP1000 and 2000 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 are Cone and Plate geometry high shear rate instruments with integrated temperature control of the test sample material. The CAP 1000+ is a fixed shear rate viscometer rotating at 750 RPM and 900 RPM. 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 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 CAP1000+ can also be ordered with a single, customized speed between 5 and 1000 rpm. In this case, the CAP can offer, when necessary, low shear rate capability.

The CAP 1000+ Viscometer selectably display in either the **CGS** or **SI** units (see page 7):

	<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 1000+ Viscometer output 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 1000+ Viscometer	
2. Cone Spindle(s)	CAP-S-0X (X will be shown as a number 1-10)
3. Spindle Case	CAP-106Y
4. Solvent Trap	CAP-118
5. Power Cord: 115V	DVP-65
220V	DVP-66
UK	DE-8
Germany	DE-7
6. Operating Instructions Manual	M/02-312

The following optional items may have been included:

7. Viscosity Standard Fluid for calibration Part No.
.... See Table A-1 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

Input Voltage:	115 VAC or 230 VAC	
Input Frequency:	50/60 Hz	
Power Consumption:	Less than 345 WATTS	
Fuses:	(2) 5x20mm, 3A, 250V, Fast Acting for 125VAC (2) 5x20mm, 1.6A, 250V. Fast Acting 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

Speeds:	750 RPM and 900 RPM <i>or</i> single speed from 5-900 RPM as specified at time of order (see instrument serial tag)		
Temperatures:	CAP 1000+L	5°C (or 15°C below ambient, whichever is higher) to 75°C	
	CAP 1000+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 m ³
	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 1000+ Viscometers <i>must</i> 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)		

I.4 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.

Note: Ensure that both the printer and the CAP-1000+ are off when connecting cables.

I.5 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.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

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:

TEMP

This key selects the temperature entry mode.

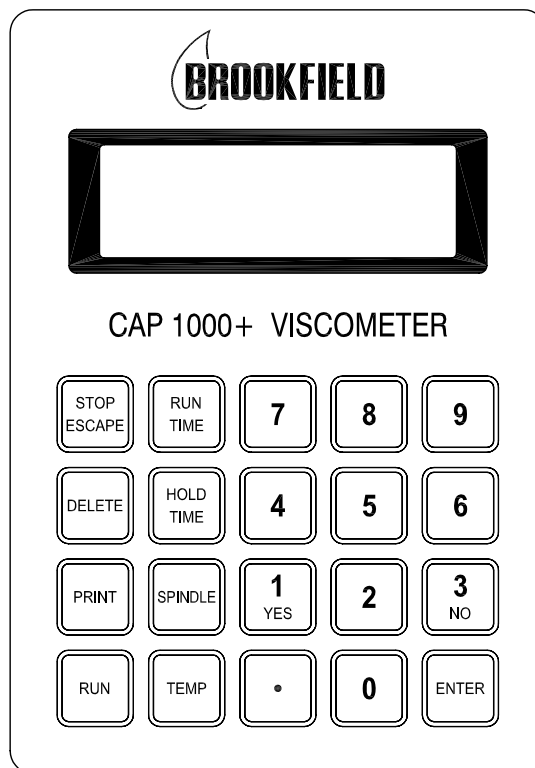


Figure I-1

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 display value is between 0 and 10%, the unit 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 (spindles/cones) and insulation 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 display will sequentially show BROOKFIELD, then the model of the viscometer and the version number. After about four seconds, the **main screen** will be displayed (Figure II-1), indicating the temperature of the sample plate. The instrument will be set to the default temperature.

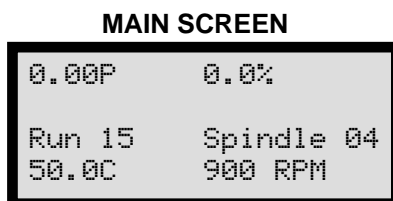


Figure II-1

Default Temperatures

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

Special Functions

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

The CAP-1000+ can be configured to operate at 750 RPM or 900 RPM. This selection is set by choosing **1=SPEED** in the **special functions screen**, then selecting **1=750 RPM** or **2=900 RPM** and pressing **ENTER**.

The CAP-1000+ 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=U** in the **special functions screen**, selecting **1=P**, **2=cP**, **3=Pa•s**, or **4=mPa•s**, and then pressing **ENTER**.

Once the CAP-1000+ has been configured, the instrument must be turned **OFF**. The configuration will be stored in memory.

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:

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

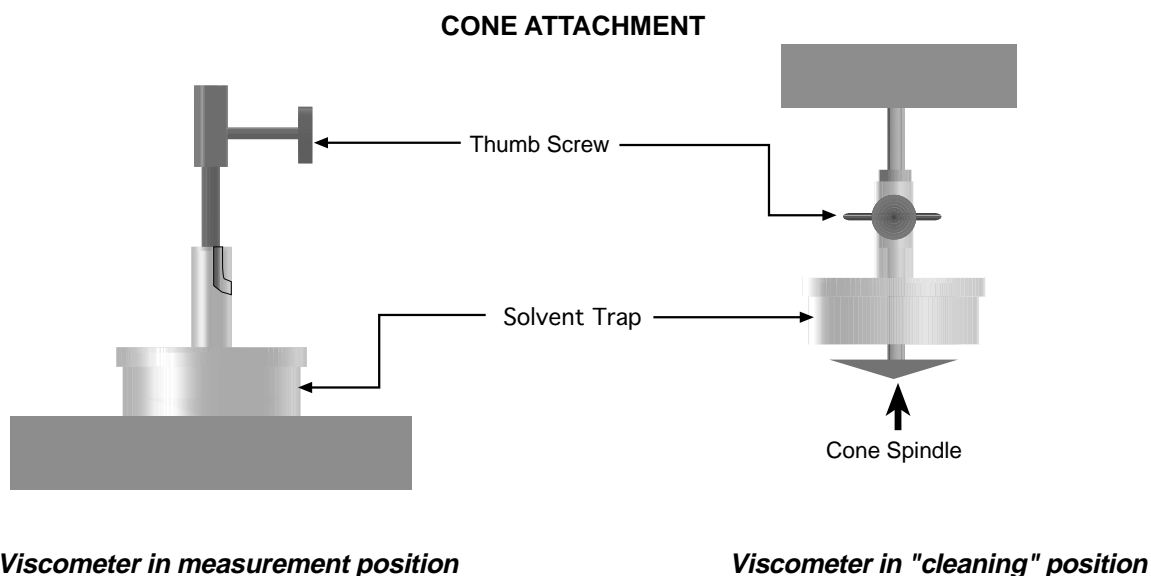


Figure II-2

When using the solvent trap, connect it to the cone 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.

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:

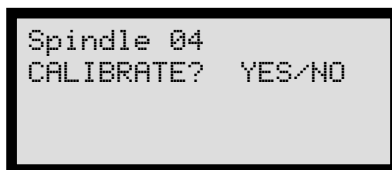


Figure II-3

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 99 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 then **ENTER**. The viscometer will display the **MAIN SCREEN (Figure II-1)**.

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 Setting

The CAP1000+ is a single speed viscometer. It is supplied from the factory in two configurations: standard and custom. The speed of rotation is shown in the lower right corner of the display.

Standard

The CAP1000+ Viscometer is supplied with two speeds: 750 RPM and 900 RPM. All CAP1000+ Viscometers are factory-set at 900 RPM. To change the setting, press and hold the **STOP** key during the power up sequence. Choose "1=SPEED (RPM)" from the special functions screen and select the required speed. This selection will become the default speed.

Custom

The CAP1000+ Viscometer is configured to operate at one speed as specified at the time of order. This speed is indicated on the instrument serial tag.

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

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. 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.

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.

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/ESCAPE** key and press the **PRINT** key.

CAP 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.
-	-	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 of running at the moment the print key is pressed while the cone is rotating. 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 timer 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 and holding the **STOP** and **PRINT** keys simultaneously executes the printing of a new heading (Section II.7).

III. OPERATION

The CAP Series Viscometers rotate a very precisely machined conical spindle over a temperature controlled plate shearing the test sample at a single rotational speed. The CAP 1000+ operates at 750 RPM and 900 RPM.

III.1 Accuracy of Measurement

Table III.1 indicates the accuracy of the viscosity measurement with CAP spindles 1-6. This accuracy 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).

Please contact Brookfield for accuracy information for CAP spindles 07-10.

Table III-1 Accuracy of Viscosity Measurement

CAP 1000+L VISCOMETERS				
Cone	FULLSCALE VISCOSITY RANGE ACCURACY			Over 900 RPM to 1000 RPM
	750 RPM	900RPM		
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%		
CAP 1000+H VISCOMETERS				
Cone	FULLSCALE VISCOSITY RANGE ACCURACY			Over 900 RPM to 1000 RPM
	750 RPM	900RPM		
	10 to 100% FSR	≤50% FSR	>50% FSR	
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		

III.2 Repeatability

The CAP 1000+ Viscometer is 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).

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., CAP1000+L). The default temperature for high temperature is 50°C (i.e., CAP1000+H). 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 (CAP1000+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 (CAP1000+H).
- d) If a printer is to be used, it should be connected (AC power & viscometer to printer cable). The CAP1000+ will print automatically when a reading is taken if the printer is connected and “on line.”

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.

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 (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.

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 sample.

6. Set the **Run Time** for rotating the cone (Section II.6) and the Hold Time.
7. Put the printer on-line (optional, Section II.7).
8. 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 deflection 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 precision of the viscosity measurement is maintained within the limits specified in Table 3.1.

9. Read the results of the sample test on the printer or write down the test conditions and viscosity results from the viscometer display.

10. Relocate the solvent trap onto the cone adapter and raise the handle.
11. It is recommended to remove the cone for cleaning. However, with care, the cone can be cleaned in place.
12. Clean the viscometer plate (refer to Section I.8).

APPENDIX A - Cone Numbers, Sample Sizes, Viscosity Ranges

CAP 1000 AND 2000 VISCOMETERS						
Cone Number ¹	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	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			

Table A-1

Cone Number ¹	CAP 1000 VISCOSITY RANGES (POISE)		Cone Range Coefficient	Cone Angle (degrees)	Cone Radius (cm)
	750 RPM	900 RPM			
01	0.25 - 2.5	0.21 - 2.08	1,875	0.45	1.511
02	0.5 - 5.0	0.42 - 4.17	3,750	0.45	1.200
03	1.0 - 10.0	0.83 - 8.33	7,500	0.45	0.953
04	2.0 - 20.0	1.67 - 16.67	15,000	1.8	1.200
05	4.0 - 40.0	3.33 - 33.33	30,000	1.8	0.953
06	10.0 - 100.0	8.33 - 83.33	75,000	1.8	0.702
07	0.42 - 4.2	0.347 - 3.47	3,150	3.0	2.399
08	1.67 - 16.7	1.39 - 13.9	12,500	3.0	1.511
09	6.67 - 66.7	5.56 - 55.6	50,000	3.0	0.953
10	0.667 - 6.67	0.556 - 5.56	5,000	1.2	1.511

Table A-2

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 1000+ 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).

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

CAP 1000+ 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 1000+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 1000+**, the instrument and viscosity standard fluid error must be combined to calculate the total allowable error.

The **CAP 1000+** 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 1000+** with Spindle 03 at 900 RPM; 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**).

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.

1. Turn on the CAP1000+ 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 temperature (**°C**) and viscosity (**cP**) prompted by the screen.

Note: Viscosity values are always entered in units of **CENTIPOISE (cP)** no matter 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 - 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