

BROOKFIELD CAP 2000+

Viscometer

Operating Instructions

Manual No. **M02-313-I0916**



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This manual intended for use with CAP 2000+ 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 AMETEK Brookfield or your local authorized dealer to obtain this manual.

I. INTRODUCTION

The CAP 2000+ Series Viscometers are medium to high shear rate instruments with Cone Plate geometry and integrated temperature control of the test sample material. Rotational speed selection ranges from 5 to 1000 RPM. Viscosity measurement ranges depend upon the cone spindle and the rotational speed (shear rate). Viscosity is selectively displayed in units of centipoise (cP), poise (P), milliPascal seconds (mPa•s) or Pascal seconds (Pa•s). Temperature control of sample is possible between either 5°C (or 15°C below ambient, whichever is higher) and 75°C or 50°C and 235°C depending on viscometer model.

The CAP 2000+ Viscometer can display either **CGS** or **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) |
| Shear Rate: | SEC ⁻¹ | SEC ⁻¹ | |
| Speed: | RPM | RPM | |
| Temperature: | °C | °C | |

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

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

I.1 Components

The following items are included; see Figure I-1

| | <u>Part No.</u> |
|--|---|
| 1. CAP 2000+ 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 | C1K-63 |
| 5. Foam Shipping Insert..... | CAP-122 |
| 6. Power Cord: 115V..... | DVP-65 |
| 220V | DVP-66 |
| UK..... | DE-8 |
| Germany | DE-7 |
| 7. Operating Instructions Manual | M02-313 |

The following optional items may have been included:

| | <u>Part No.</u> |
|---|--|
| 8. Viscosity Standard Fluid for calibration | See Table III-5 and III-6 in Section III |

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 AMETEK Brookfield or your local authorized 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.

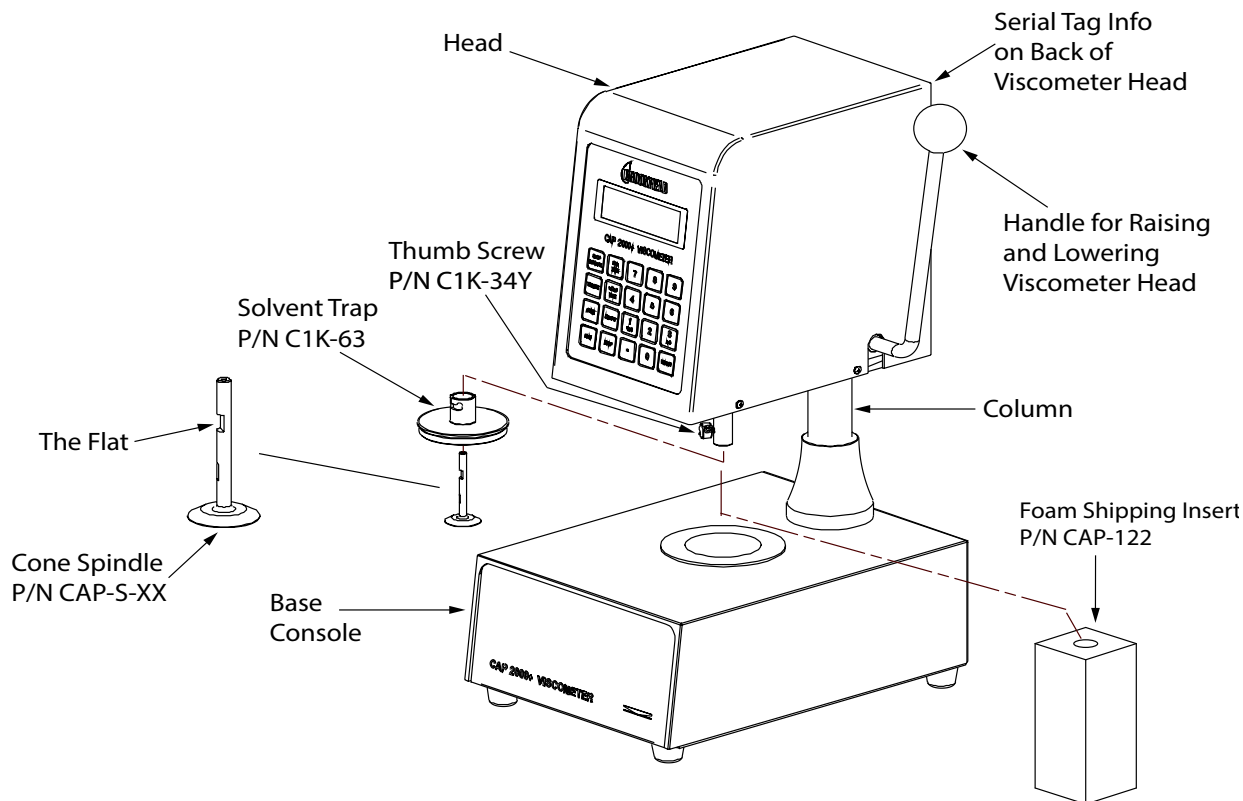


Figure I-1: Components

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

Torque Range Options: High Torque - 18,100-181,000 dyne•cm (designated on serial tag as CAP)
Low Torque - 797-7,970 dyne•cm (designated on serial tag as 23 CAP)

Speeds: Variable speed from 5-1000 RPM

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

| | | | |
|---------|-------------------|--------------------------------|--------------------------------|
| Weight: | Gross Weight | 36 lb | 16.3 kg |
| | Net Weight | 27 lb | 12.3 kg |
| | Carton Volume | 4.9 cu ft | 0.15 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.
Solvent Trap (P/N C1K-63) is made of teflon.

Operating Environment: CAP 2000+ Viscometers **must** be operated within the following
ambient temperatures: **+5°C (41°F) to 40°C (104°F)**
and humidity: **20% to 80% R.H. (non-condensing atmosphere)**

Electrical Certifications:

Conforms to CE Standards: BSEN 61326: Electrical equipment for measurement, control and laboratory use - EMC requirements.

NOTICE TO CUSTOMERS:



This symbol indicates that this product is to be recycled at an appropriate collection center.

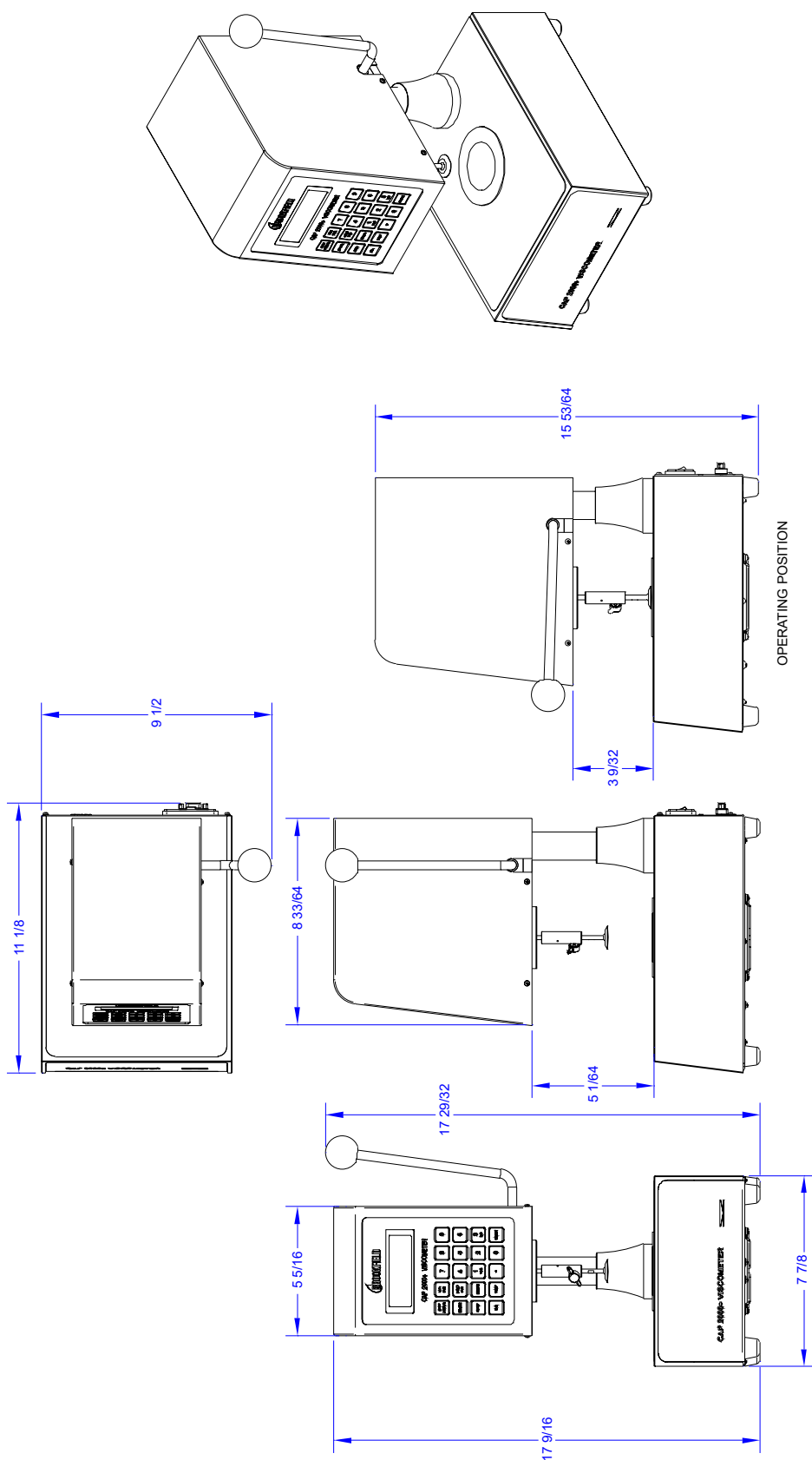
Users within the European Union:

Please contact your dealer or the local authorities in charge of waste management on how to dispose of this product properly. All AMETEK Brookfield offices and our network of representatives and dealers can be found on our website: www.brookfieldengineering.com.


Users outside of the European Union:

Please dispose of this product according to your local laws.

I.4 Dimensional Details



I.5 Installation

 **DO NOT** lift the viscometer by the handle or head! LIFT only by the base console or column!

- 1) Set the viscometer on a clean level bench surface.
- 2) **Remove shipping foam insert (P/N CAP-122) from the plate area on the CAP Viscometer.** Store the foam insert for future use when shipping or transporting CAP Viscometer.

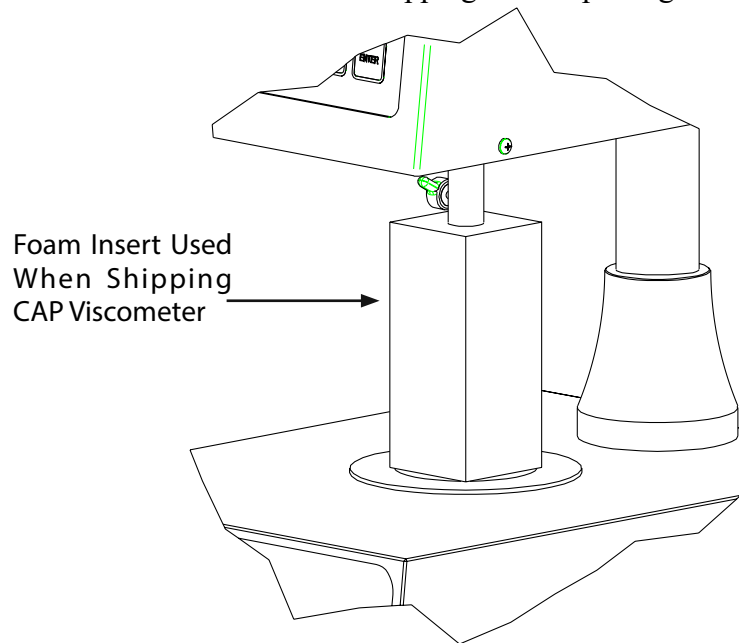




Figure I-2: Detail of Foam Insert

- 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 back of the viscometer head.**

 **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 2000+ are off when connecting cables.

I.6 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.7 Key Functions

Figure I-3 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 clears entered values for input selections.

PRINT

This key sends data to the parallel printer.

RUN

This key starts spindle rotation.

RUN TIME

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

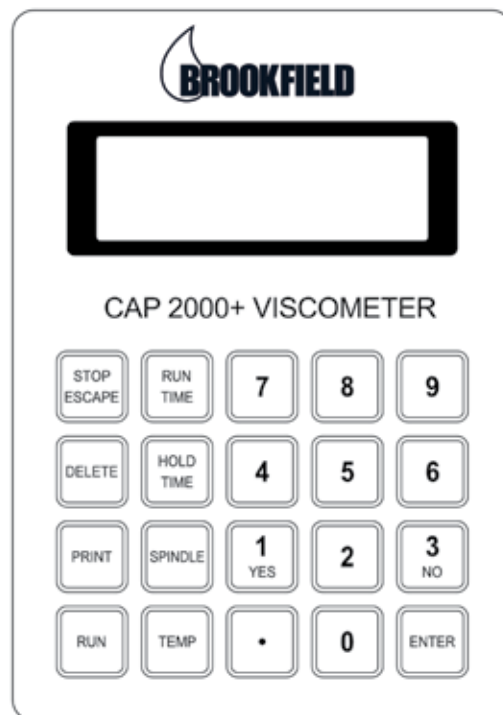


Figure I-3

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.

I.8 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 torque reading of 10% when making viscosity measurements. If the torque value is between 0 and 10%, the display will flash to indicate an under range condition. If the viscometer final reading is below zero, negative values will be displayed.

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

I.9 Cleaning

Instrument, Keypad & Painted Surfaces:

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

Immersed Components (spindles/cones) and temperature controlled plate:



Note: Sample plate and spindle may be hot. Use care when using solvents.

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.

Do not use metal objects to clean the plate surface, as scratching of the plate may occur and compromise cone calibrations.

Solvent Trap:

Solvent Trap (P/N C1K-63) is made of Teflon. Clean with non abrasive cloth and solvent appropriate for sample material that is not aggressive to Teflon.



Do not use metal objects to clean the plate surface, as scratching of the plate may occur and compromise cone calibrations.



Immersed components (cone spindle) may be at an elevated temperature. Use caution when cleaning hot surfaces. Use caution when applying solvents to hot surfaces. Refer to the MSDS for the specific solvent for proper handling techniques.

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

II. GETTING STARTED

II.1 Power On

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

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

| |
|---|
| BROOKFIELD CAP 2000+ VISCOMETER VERSION 1.10 1.0 CAP |
|---|

Figure II-1A

Start-up Screen for High Torque CAP

| |
|--|
| BROOKFIELD CAP 2000+ VISCOMETER VERSION 1.10 22.7 CAP |
|--|

Figure II-1B

Start-up Screen for Low Torque CAP

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

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

Figure II-2

The instrument will be set to the default temperature:

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

If the CAP 2000+ Viscometer is connected to a PC via the serial port on the rear of the base console, the main screen display is EXTERNAL.

Special Functions

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

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

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

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

Note: When operating the CAP 2000+ with shear rate as the method of speed control, the shear rate value entered may be adjusted based on the shear rate multiplier for the spindle. For example: if using cone 4 (shear rate multiplier of 3.33), an entered shear rate of 51 1/SEC will be displayed as 50 1/SEC.

II.2 Cone Spindle Selection and Setting

Raise the viscometer handle to its highest position.

The CAP cones have viscosity ranges as shown in Tables III-1 and III-2. After selecting the appropriate cone for the viscosity range to be utilized, *carefully* attach the cone to the viscometer as shown in Figure II-3.

Be sure to insert the spindle completely into the adapter sleeve; align the flat (see Figure I-1) on the spindle with the thumb screw and then tighten.

When using the solvent trap (Figure II-3), 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.

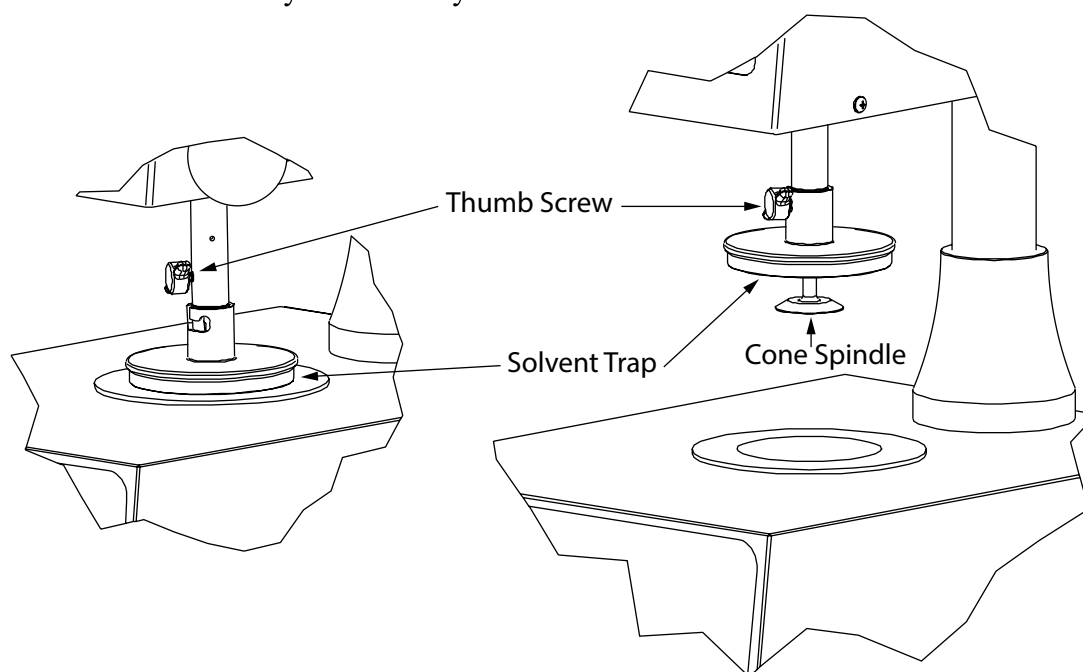


Figure II-3: Cone Attachment

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

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

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

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

| | |
|--------------------------|--------|
| Spindle 04 CALIBRATE? | YES/NO |
|--------------------------|--------|

Figure II-4

If you are using the CAP Viscometer for the first time or have just received the instrument back from being serviced, press YES and see Section III. Cones supplied at the time of order are calibrated to the viscometer by Brookfield prior to shipment, but should still be verified with a calibration check prior to use for the first time. Cones purchased separately at a later time by the user must also be calibrated prior to making viscosity measurements. If you have 2 cone spindles that are identical (have the same number), you must do a cone calibration when you swap them.

Otherwise, there is no requirement to perform a cone calibration (Select NO).

- 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 **Section III**).
 2. A special feature of the CAP series viscometers allows the user to perform a cone calibration with viscosity standard fluids. (Refer to Section III.4)
 3. Cones entered as 11 through 99 must be first calibrated following the directions in Section III.

If you are not going to calibrate the cone, continue by pressing the **NO** key, then the **ENTER** key. The viscometer will display the **MAIN SCREEN (Figure II-2)**. Should you subsequently run a test and observe that the instrument is reading all “0s”, the “P” for Poise is flashing, and the “%” symbol is flashing, then the cone spindle you are using is not calibrated. You must perform the cone spindle calibration to rectify the problem.

If you are going to calibrate the cone, press the **YES** key, and follow the calibration instructions in Section III.4 - Cone Calibration.

II.3 Speed Setting

The CAP 2000+ is a variable speed viscometer. The speed of rotation is shown in the lower right corner of the display. To change the speed of rotation, enter the new speed using the number keys. The new speed will be shown in the lower right hand corner of the display. To accept the new speed, press **ENTER**.

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

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

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

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

Data entry must be in whole numbers.

II.4 Temperature Control Setting

Press the **TEMP** key and the current temperature setting will blink. The default temperature on start-up is **25.0°C** on low temperature models and **50.0°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

Use the number keys to type in the required set point. The temperature can be set in increments of **0.1°C**. You can turn off the temperature control on a high temperature unit by entering 0.

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

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

II.6 Run Time

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

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.

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 TIME** key is pressed. The display will shown "MANUAL". When the **RUN TIME** key is released, the spindle will stop rotating.

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

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

| Speed | Run |
|-------------|------------|
| 50-1000 RPM | 12 seconds |
| 20-50 RPM | 20 seconds |
| 5-20 RPM | 30 seconds |

II.7 Printing

Pressing the **PRINT** key at any time sends information on test parameters to the printer port.

Note: Calculated parameters (Viscosity, Full Scale Range, Shear Stress) will be displayed only after the spindle has rotated sufficiently to allow for accurate data. If print is pressed before these parameters are displayed, then no data will be included in the print string.

To print a heading, press and hold the **STOP/ESCAPE** key and press the **PRINT** key. Then start the test by pressing the **RUN** key. Press the **PRINT** key whenever data is desired during the test.

Example of CAP 2000+ PRINT OUTPUT showing heading and data.

| 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 |

Figure II-5

A maximum value of 999 seconds can be printed in the time column when running in manual **TIMER** mode (00). Over 999 seconds will print **EEEE**.

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.

At the end of a test, data will automatically be sent to the printer port.

II.8 Run and Stop Keys

The **RUN** key has three functions:

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

The **STOP** key has three functions:

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

II.9 Parameter Display

The parameter display will appear, as shown in Figure II-6, immediately after the **RUN** key is pressed. All relevant measurement parameters will be shown for 5 seconds including speed, shear rate, run time, hold time and spindle. The display will return to the default screen after five seconds.

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

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

Figure II-6

III. OPERATION

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

III.1 Full Scale Range and Accuracy of Measurement

Full Scale Range (FSR) viscosity is the maximum viscosity that can be measured and occurs when the % torque is 100. Brookfield AMETEK recommends that viscosity measurements be made between 10 and 100% torque.

There are two tables to consult for viscosity range information, depending on which torque model viscometer you purchased. To determine which torque model you have, consult the serial tag of your viscometer or the certificate of calibration that accompanied the instrument or the display on power up.

23CAP 2000+ = **Low Torque**

CAP 2000+ = **High Torque**

Full Scale Range (FSR) is based on the cone spindle your are using, the torque model of your viscometer, and the speed of spindle rotation. The tables below provide information on FSR by torque model for the most common factory set speeds:

Table III-1: Full Scale Range Viscosity for **LOW TORQUE** Viscometer

| Cone Number | Cone Constant Range | Shear Rate Constant | FSR at 100 RPM | FSR at 500 RPM | FSR at any RPM |
|-------------|---------------------|---------------------|----------------|----------------|------------------|
| 01 | 1875 | 13.33N | 0.83 | 0.17 | $1875/(22.7*N)$ |
| 02 | 3750 | 13.33N | 1.65 | 0.33 | $3750/(22.7*N)$ |
| 03 | 7500 | 13.33N | 3.30 | 0.66 | $7500/(22.7*N)$ |
| 04 | 15000 | 3.33N | 6.61 | 1.32 | $15000/(22.7*N)$ |
| 05 | 30000 | 3.33N | 13.22 | 2.64 | $30000/(22.7*N)$ |
| 06 | 75000 | 3.33N | 13.04 | 6.61 | $75000/(22.7*N)$ |
| 07 | 3150 | 2N | 1.39 | 0.28 | $3150/(22.7*N)$ |
| 08 | 12500 | 2N | 5.51 | 1.10 | $12500/(22.7*N)$ |
| 09 | 50000 | 2N | 22.03 | 4.41 | $50000/(22.7*N)$ |
| 10 | 5000 | 5N | 2.20 | 0.44 | $5000/(22.7*N)$ |

N= RPM

Poise x 100 = centiPoise

Table III-2: Full Scale Range Viscosity for **HIGH TORQUE** Viscometer

| Cone Number | Cone Constant Range | Shear Rate Constant | FSR at 100 RPM | FSR at 400 RPM | FSR at 750 RPM | FSR at 900 RPM | FSR at any RPM |
|-------------|---------------------|---------------------|----------------|----------------|----------------|----------------|----------------|
| 01 | 1875 | 13.33N | 18.75 | 4.69 | 2.50 | 2.08 | 1875/(N) |
| 02 | 3750 | 13.33N | 37.50 | 9.38 | 5.00 | 4.17 | 3750/(N) |
| 03 | 7500 | 13.33N | 75.00 | 18.75 | 10.00 | 8.33 | 7500/(N) |
| 04 | 15000 | 3.33N | 150.00 | 37.50 | 20.00 | 16.67 | 15000/(N) |
| 05 | 30000 | 3.33N | 300.00 | 75.00 | 40.00 | 33.33 | 30000/(N) |
| 06 | 75000 | 3.33N | 750.00 | 187.50 | 100.00 | 83.33 | 75000/(N) |
| 07 | 3150 | 2N | 31.50 | 7.88 | N/A | N/A | 3150/(N) |
| 08 | 12500 | 2N | 125.00 | 31.25 | N/A | N/A | 12500/(N) |
| 09 | 50000 | 2N | 500.00 | 125.00 | N/A | N/A | 50000/(N) |
| 10 | 5000 | 5N | 50.00 | 12.50 | 6.67 | 5.56 | 5000/(N) |

N= RPM

Poise x 100 = centiPoise

*Use of this cone at this RPM is not recommended

You can also determine FSR for any speed selection that is not in the above tables by doing a simple calculation:

- For Low Torque CAP instruments:

Cone range constant / (22.7 * N) = FSR (Poise) where N = RPM

- For High Torque CAP instruments:

Cone range constant / N = FSR (Poise) where N = RPM

The last column in the above tables shows this calculation.

III.2 Accuracy of Viscosity and Temperature

The following tables indicate the accuracy of the viscosity measurement for the CAP 2000+ Viscometer using CAP spindles 01-10. This accuracy depends on both the rotational speed of the cone and the percent of Full Scale Range (%FSR) in Poise at which the viscosity is measured. Accuracy is stated in Poise (P) and is calculated as a % of the FSR viscosity.

To calculate accuracy:

- Determine FSR viscosity in Poise for the torque model, cone spindle, and speed of rotation, using the information in Tables III-1 or III-2.
- Find the column that best defines the speed of rotation used for the measurement and your reported % FSR from the measurement.
- Consult the table below to determine the accuracy of your measurement.
- Multiply the accuracy by the FSR viscosity if you need your accuracy stated in Poise.

Table III-3: Accuracy for **LOW TORQUE** Viscometer

| Cone Number | ≤ 500 RPM |
|-------------|-------------|
| | 10-100% FSR |
| 01 | ± 2% |
| 02 | ± 2% |
| 03 | ± 2% |
| 04 | ± 2% |
| 05 | ± 2% |
| 06 | ± 2% |
| 07 | ± 2% |
| 08 | ± 2% |
| 09 | ± 2% |
| 10 | ± 2% |

Table III-4: Accuracy for **HIGH TORQUE** Viscometer

| Cone Number | ≤ 400 RPM | 750 RPM | 900 RPM | 900 RPM |
|-------------|-------------|-------------|-----------|-----------|
| | 10-100% FSR | 10-100% FSR | ≤ 50% FSR | > 50% FSR |
| 01 | ± 2% | ± 2% | ± 2% | ± 4% |
| 02 | ± 2% | ± 2% | ± 2% | ± 4% |
| 03 | ± 2% | ± 2% | ± 2% | ± 4% |
| 04 | ± 2% | ± 3% | ± 3% | ± 6% |
| 05 | ± 2% | ± 4% | ± 4% | ± 8% |
| 06 | ± 2% | ± 5% | ± 5% | ± 10% |
| 07 | ± 2% | N/A | N/A | N/A |
| 08 | ± 2% | N/A | N/A | N/A |
| 09 | ± 2% | N/A | N/A | N/A |
| 10 | ± 2% | ± 2% | ± 2% | ± 2% |

* Use of this cone at this RPM is not recommended.

The specification of temperature accuracy on CAP Viscometers is stated below:

LOW TEMP UNITS:

- In ambient conditions of 15°C to 30°C, temperature accuracy is +/- 0.5°C.
- In ambient conditions of 5°C to 15°C or 30°C to 40°C, temperature accuracy is +/- 1.0°C.

HIGH TEMP UNITS:

- In ambient conditions of 15°C to 30°C, accuracy is +/- 0.5°C when the temperature set point on the viscometer is 50°C to ≤100°C.
- In ambient conditions below 15°C or above 30°C, accuracy is +/- 2.0°C when the temperature set point on the viscometer is 50°C to ≤100°C.
- In ambient conditions of 15°C to 30°C, accuracy is +/- 1.0°C when the temperature set point on the viscometer is 101°C to 235°C.

III.3 Calibration Verification

Accuracy of the CAP 2000+ Viscometer can be verified by performing a calibration verification. Go to www.brookfieldengineering.com to view a video on the procedure.

The cones/spindles that were shipped with the viscometer were calibrated to the viscometer by Brookfield prior to shipment. If your viscometer was returned to Brookfield or an authorized dealer, then any cones/spindles that were returned for service will have been calibrated to the viscometer prior to shipment.

When you receive the instrument, perform a calibration verification on each cone spindle to ensure that each spindle is measuring correctly. Use the appropriate viscosity standard fluid defined in Table III-5 or III-6 for each spindle. This will ensure that everything is in good working order and that the instrument and/or cone spindles have not experienced a change during shipment. If the calibration verification fails, then you can take advantage of the CAP Viscometer's unique feature which allows the operator to recalibrate each cone spindle to the CAP Viscometer (See Section III.4).

Calibration verification of your viscometer should also be performed when viscosity readings with your product are suspect. Verifying the calibration will determine if the cone needs to be recalibrated to the instrument. This will help you to determine if the discrepant readings on your product are due to cone/instrument performance, or your method or your product. Complete cone recalibration is discussed in Section III.4.

To perform a cone calibration verification, you will need a mineral oil from Table III-5 or Table III-6. Determine what range model CAP 2000+ Viscometer you have (Low Torque or High Torque), which temperature range (L = Low, H = High; consult the instrument serial tag) and what cone you are using.

You must use the following method to verify calibration of each cone spindle.

1. Attach solvent trap and spindle and lower viscometer head. Put the cone in the down position, and make sure that the solvent trap is covering the spindle.
2. Allow the viscometer to stabilize for at least 30 minutes at 25°C (Low Temp units) or at 60°C (High Temp) if the temperature that you normally operate is different; otherwise, wait 5 minutes, then make sure the cone is in the down position and that the solvent trap is on.
3. At the end of the temp stabilization period, dispense the appropriate volume of fluid (consult Table III-5 or Table III-6). Figure III-1 shows how to dispense the fluid onto the plate and determine visually if the amount is appropriate.

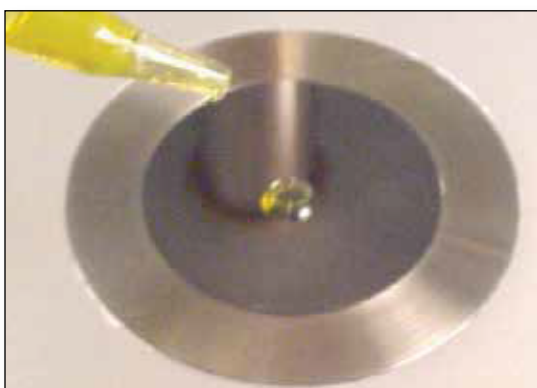


Figure III-1a



Figure III-1b



Figure III-1c



Figure III-1d

4. Run a viscosity test and record the viscosity value when the reading has stabilized.
5. Compare the recorded viscosity to the actual value of the standard and verify that it falls within the accuracy limits stated in Tables III-3 and III-4. The allowable accuracy is calculated by adding 1% of the value for the viscosity standard fluid to the product of (% accuracy x FSR) for the spindle/speed in use. This combined value (in Poise or cP) gives an allowable window around the actual viscosity value of your standard. If your measured viscosity falls within this window, the verification passes.

Example:

CAP-03 spindle on High Torque Low Temp CAP Viscometer running at 900 RPM. Viscosity standard has nominal value at 25°C of 354 cP or 3.54 P; 1% = 3.54 cP or 0.0354 P. FSR = 8.33 P from Table III-2; use 2% accuracy calculation from Table III-4 since viscosity standard < 50% of FSR. Accuracy for viscometer with CAP-03 spindle is therefore 2% X 8.33 P = 0.1666 P. Add 0.0354 P to 0.1666 P to determine the allowable accuracy ± 0.2020 P. The measured viscosity value with CAP-03 spindle must be within ± 0.202 P or 20.2 cP of the viscosity standard to pass calibration.

6. If the test fails, repeat again to make sure that every step was performed correctly. If the test fails again, perform a cone calibration according to the procedure in Section III.4.

Table III-5: Viscosity Standard Fluids for Calibration of CAP Spindles on **LOW TORQUE** Viscometer

| LOW TORQUE | LOW TEMP | | | |
|------------|----------------|--------------------|-----------|----------------------------|
| Cone | Fluid Part No. | Nominal Value (cP) | Temp (°C) | Sample Size (micro liters) |
| CAP-S-01 | CAP0L | 57 | 25 | 67 |
| CAP-S-02 | CAP1L | 89 | 25 | 38 |
| CAP-S-03 | CAP2L | 177 | 25 | 24 |
| CAP-S-04 | CAP3L | 354 | 25 | 124 |
| CAP-S-05 | CAP4L | 708 | 25 | 67 |
| CAP-S-06 | CAP5L | 1417 | 25 | 32 |
| CAP-S-07 | CAP1L | 89 | 25 | 1700 |
| CAP-S-08 | CAP3L | 354 | 25 | 400 |
| CAP-S-09 | CAP5L | 1417 | 25 | 100 |
| CAP-S-10 | CAP2L | 177 | 25 | 170 |

| LOW TORQUE | HIGH TEMP | | | |
|------------|----------------|--------------------|-----------|----------------------------|
| Cone | Fluid Part No. | Nominal Value (cP) | Temp (°C) | Sample Size (micro liters) |
| CAP-S-01 | CAP0H | 57 | 60 | 67 |
| CAP-S-02 | CAP1H | 89 | 60 | 38 |
| CAP-S-03 | CAP2H | 177 | 60 | 24 |
| CAP-S-04 | CAP3H | 354 | 60 | 124 |
| CAP-S-05 | CAP4H | 708 | 60 | 67 |
| CAP-S-06 | CAP5H | 1417 | 60 | 32 |
| CAP-S-07 | CAP1H | 89 | 60 | 1700 |
| CAP-S-08 | CAP3H | 354 | 60 | 400 |
| CAP-S-09 | CAP5H | 1417 | 60 | 100 |
| CAP-S-10 | CAP2H | 177 | 60 | 170 |

Table III-6: Viscosity Standard Fluids for Calibration of CAP Spindles on **HIGH TORQUE** Viscometer

| HIGH TORQUE | LOW TEMP | | | |
|-------------|----------------|--------------------|-----------|----------------------------|
| Cone | Fluid Part No. | Nominal Value (cP) | Temp (°C) | Sample Size (micro liters) |
| CAP-S-01 | CAP1L | 89 | 25 | 67 |
| CAP-S-02 | CAP2L | 177 | 25 | 38 |
| CAP-S-03 | CAP3L | 354 | 25 | 24 |
| CAP-S-04 | CAP4L | 708 | 25 | 124 |
| CAP-S-05 | CAP5L | 1,417 | 25 | 67 |
| CAP-S-06 | CAP6L | 3,542 | 25 | 32 |
| CAP-S-07 | CAP7L | 1,328 | 25 | 1700 |
| CAP-S-08 | CAP8L | 5,313 | 25 | 400 |
| CAP-S-09 | CAP9L | 21,250 | 25 | 100 |
| CAP-S-10 | CAP10L | 236 | 25 | 170 |

| HIGH TORQUE | HIGH TEMP | | | |
|-------------|----------------|--------------------|-----------|----------------------------|
| Cone | Fluid Part No. | Nominal Value (cP) | Temp (°C) | Sample Size (micro liters) |
| CAP-S-01 | CAP1H | 89 | 60 | 67 |
| CAP-S-02 | CAP2H | 177 | 60 | 38 |
| CAP-S-03 | CAP3H | 354 | 60 | 24 |
| CAP-S-04 | CAP4H | 708 | 60 | 124 |
| CAP-S-05 | CAP5H | 1,417 | 60 | 67 |
| CAP-S-06 | CAP6H | 3,542 | 60 | 32 |
| CAP-S-07 | CAP7H | 1,328 | 60 | 1700 |
| CAP-S-08 | CAP8H | 5,313 | 60 | 400 |
| CAP-S-09 | CAP9H | 21,250 | 60 | 100 |
| CAP-S-10 | CAP10H | 236 | 60 | 170 |

III.4 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. This also allows the user to purchase a new cone spindle and perform the calibration in your plant.

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 Tables III-5 and III-6 to choose the calibration fluid for the spindle being calibrated.

1. Turn on the CAP 2000+ Viscometer.
2. Attach solvent trap to coupling shaft.
3. Attach spindle.
4. Place appropriate amount of sample 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**) value printed on the label.

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, from instrument cold start.
11. Select the spindle speed.

All of the spindles used with the low torque CAP 2000+ instruments should be calibrated at 100 RPM when using the recommended viscosity standard fluids. This practice will calibrate the instrument at approximately the middle of the Full Scale Range.

Spindles used with the high torque CAP 2000+ and the recommended viscosity standard fluids may be calibrated at any speed.

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

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

When calibration is complete, spindle rotation will stop and the “CALIBRATION COMPLETE” screen is displayed. (See Figure III-2). Press ENTER to continue.

CALIBRATION COMPLETE
PRESS ENTER TO CONTINUE

If the viscometer is connected to a printer, the display will show “Press Print or Press Enter to continue”. Press the PRINT key and the printout (Figure III-3) will automatically be generated. There will be values for the listed variables. The operator can enter the information by hand on the bottom of the printout.

| 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 III-3

III.5 Repeatability

The CAP 2000+ Viscometer is repeatable to $\pm 0.5\%$ of the full scale viscosity range (FSR). Due to shear heating considerations which occur 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 AMETEK Brookfield or your local authorized dealer for details on the above information.

III.6 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 have 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. You may choose to warm up at the temperature of test. 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) or 25°C for low temperature instruments to save some time.
- b) The cone calibration procedure 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 (CAP 2000+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 (CAP 2000+H).
- d) If a printer is to be used, it should be connected (AC power & viscometer to printer cable). The CAP 2000+ will print automatically when a reading is taken if the printer is connected and “on line.”

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

- Notes:**
- a. Lock the cone tightly into the adapter.
 - b. 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.

3. Set the temperature control (Section II.5).
4. Set the cone number.
5. 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.



6. Secure trap on shaft. **Caution: Solvent trap may be hot, spindle & plate too.** Raise the handle. Place the sample to be measured onto the plate below the cone and solvent trap. Don't use plastic spatulas/syringes if the plate temperature is above 50°C. Refer to **Table III-5 or III-6** for recommended sample sizes. Lower the cone and solvent trap.

- Notes:**
- a. Lower the handle **gently**. **DO NOT FORCE THE CONE ONTO THE PLATE.**
 - b. The sample must completely cover the face of the cone and extend beyond the edge of the cone about 1.0 mm (see Figure III.3).
 - c. 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.

7. 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.

8. Set the **Run Time** for rotating the cone (Section II.6) and the Hold Time.
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 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 III.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. Caution: HOT surface!



13. It is recommended to remove the cone for cleaning. However, with care, the cone can be cleaned in place. Caution: HOT surface!



14. Clean the viscometer plate (refer to Section I.8). Caution: HOT surface!

III.7 Computer Control

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 Windows requires Windows NT or higher. CAPCALC application software displays, prints and stores tabulated data files (Brookfield, Excel).

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

Additional information on the communications protocol for CAP 2000+ is contained in **Appendix B**.

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

APPENDIX A - 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.

The 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. The specifications of the Viscometer cone and plate geometry will affect the viscosity readings. For example, if one reading is taken at 750 rpm, and a second at 900 rpm, the two viscosity values 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 Spindle used: Cone Angle and Cone Diameter
 3. Test temperature
 4. Cone Spindle speed [or the shear rate]
 5. Length of time to rotate cone spindle before recording the viscosity reading
 6. Sample volume sufficient to cover the face of the cone

APPENDIX B - Communications

Printer Output - CAP 2000+

The cable connection on the CAP 2000+ Viscometer is a standard 25 pin parallel printer cable connector.

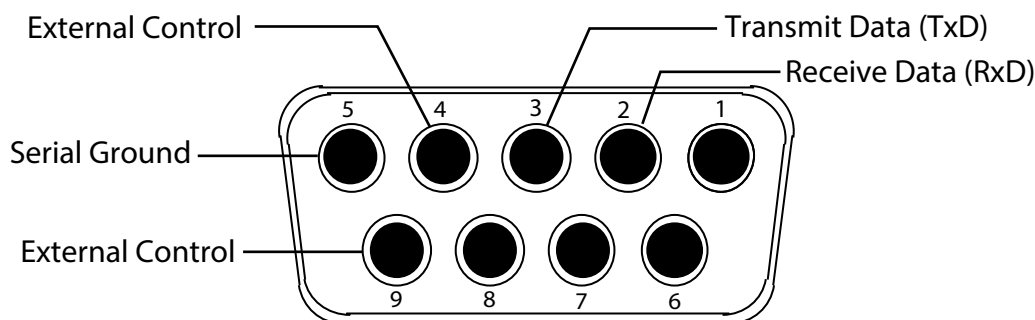
RS 232 Output - CAP 2000+

When connecting the CAP 2000+ to a computer, use Brookfield Computer Cable (Part No. DVP-80). If you are **not using** the Brookfield computer cable, jump (connect) pins 4 and 9 (refer to **Figure 1**) 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:

Baude rate: 9600
Parity: None
Data bits: 8
Stop bits: 1
Flow control: None



No Connection to Pin 1

Figure 1

The following pages review the transmit/receive commands between the CAP 2000+ and a computer (Table B-2), the byte status interpretation (Table B-1) and a sample program for external control of the CAP 2000+ Viscometer.

Table B-1: CAP 2000+ TRANSMIT/RECEIVE COMMANDS FOR COMPUTER COMMUNICATION

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

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

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

Table B-2: INTERPRETATION OF BYTE STATUS

| | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 |
|---|----------------|-------|-------|-------|-------|-------|-------|
| Motor Off | x | x | x | x | x | x | 0 |
| Motor On | x | x | x | x | x | x | 1 |
| Over SFR ($\geq 115.0\%$) ¹ | x | x | x | x | x | 1 | x |
| Valid FSR ($< 115.0\%$) | x | x | x | x | x | 0 | x |
| Value Outside Limits ² | x | x | x | x | 1 | x | x |
| Value Within Limits | x | x | x | x | 0 | x | x |
| Calibration Error | 1 ³ | x | x | x | x | x | x |
| ¹ Bit 2 is set in response to an R command (request for information) only. ² If an input is received that is outside the allowable limits for a command, Bit 3 shall be set for the response to that command only. Once the response to the command has been sent to the host, Bit 3 shall be cleared again. ³ This bit is set in response to a calibration command if an error occurred in the respective operation | | | | | | | |

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

APPENDIX C - Online Help and Additional Resources

www.brookfieldengineering.com**

The Brookfield website is a good resource for additional and self-help whenever you need it. Our website offers a selection of “how-to” videos, application notes, conversion tables, instructional manuals, material safety data sheets, calibration templates and other technical resources.

<http://www.youtube.com/user/BrookfieldEng>

Brookfield has its own YouTube channel. Videos posted to our website can be found here as well as other “home-made” videos made by our own technical sales group.

Viscosityjournal.com

Brookfield is involved with a satellite website that should be your first stop in viscosity research. This site serves as a library of interviews with experts in the viscosity field as well as Brookfield technical articles and conversion charts. Registration is required, so that you can be notified of upcoming interviews and events, however, this information will not be shared with other vendors, institutions, etc..

Article Reprints

- **Available in Print Only**
- Brookfield has an extensive library of published articles relating to viscosity, texture and powder testing. Due to copyright restrictions, these articles cannot be emailed. Please request your hardcopy of articles by calling our customer service department directly or by emailing: marketing@brookfieldengineering.com
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- Brookfield has a growing number of published articles that can be downloaded directly from the Brookfield website. These articles can be found on our main site by following this path: [http://www.brookfieldengineering.com/support/documentation/article reprints](http://www.brookfieldengineering.com/support/documentation/article%20reprints)

More Solutions to Sticky Problems

Learn more about viscosity and rheology with our most popular publication. This informative booklet will provide you with measurement techniques, advice and much more. It's a must-have for any Brookfield Viscometer or Rheometer operator. More Solutions is available in print and also as a downloadable pdf on the Brookfield website by following this path:

<http://www.brookfieldengineering.com/support/documentation>

Training/Courses

Whether it is instrument-specific courses, training to help you better prepare for auditing concerns, or just a better understanding of your methods, who better to learn from than the worldwide leaders of viscosity measuring equipment? Visit our Services section on our website to learn more about training.

** Downloads will require you to register your name, company and email address. We respect your privacy and will not share this information outside of AMETEK Brookfield.

APPENDIX D - Packing Instructions to Return a Brookfield CAP Viscometer for Repair or Calibration

Package the viscometer for shipment as outlined below.

Return the viscometer to the attention of the Repair Department (see address below).

RUSH SERVICE MUST BE INDICATED ON THIS FORM AND CLEARLY MARKED ON THE OUTSIDE OF YOUR SHIPPING PACKAGE.

- ☒ Remove and return all spindles (properly packed for shipping). DO NOT RETURN WITH THE SPINDLE ATTACHED.
- ☒ Clean excess testing material off the instrument.
- ☒ Include MSDS sheets for all hazardous materials tested with this instrument.
- ☒ If you have shipping foam block, as shown in Figure 1, please use it to support the shaft. If you don't, use a suitable material of similar length.



Figure 1

- ☒ Enclose the instrument in a plastic bag.
- ☒ Pack the instrument in its original case. Cases are available for immediate shipment from Brookfield. If the case is not available, take care to wrap the instrument with enough material to support it. Avoid using foam peanuts or shredded paper.
- ☒ Fill out page 1 of this Laboratory Repair Return Form with as much information as possible to help expedite your service. If you do not have this form, you can download it from our website: www.brookfieldengineering.com/support/maintenance
-or -
Email us at CCS@brookfieldengineering.com
TEL 508-946-6200 or 800-628-8139 FAX 508-923-5009
- ☒ Package the instrument and related items in a strong box for shipping. Mark the outside of the box with handling instructions.
Example: "Handle with Care" or
"Fragile - Delicate Instrument"
"Rush" if appropriate
- ☒ Contact Brookfield or our authorized dealer for Return Authorization Number. Mark number on outside of package and on Repair Return Form.

APPENDIX E - Warranty Repair and Service

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 **AMETEK Brookfield** or the authorized dealer from whom it was purchased for a warranty evaluation. Transportation is at the purchaser's expense. Remove the spindle from the viscometer and attach the shipping foam block (see Figure I-2) to prevent shipping damage. The Viscometer should be shipped in the original packaging provided with the instrument along with any spindles that need service. If returning to Brookfield, please contact us for a return authorization number prior to shipping.

***For a copy of the Repair Return Form, go to the Brookfield website,
www.brookfieldengineering.com***

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

AMETEK Brookfield
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 AMETEK Brookfield or the dealer from whom you purchased the instrument.

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

AMETEK (GB) Limited
Brookfield Technical Centre
Stadium Way
Harlow, Essex CM19 5GX, England

Telephone: (44) 1279/451774 Fax: (44) 1279/451775
www.brookfield.co.uk

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

AMETEK GmbH
Hauptstrasse 18
D-73547 Lorch, Germany

Telephone: (49) 7172/927100 Fax: (49) 7172/927105
www.brookfield-gmbh.de

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

AMETEK Commercial Enterprise (Shanghai) Co., Ltd
Suite 905, South Tower, Xindacheng Plaza
193 Guangzhou Da Dao Bei, Yuexiu District
Guangzhou, 510075 P. R. China

Telephone: (86) 20/3760-0548 Fax: (86) 20/3760-0548
www.brookfield.com.cn

On-site service at your facility is also available from Brookfield. Please contact our Service Department in the United States, United Kingdom, Germany or China for details.