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BROOKFIELD DIGITAL VISCOMETER

MODEL DV-II+

Operating Instructions

Manual No. **M/92-161-I496**

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I. INTRODUCTION

The Brookfield **DV-II+** Viscometer measures fluid viscosity at given shear rates. Viscosity is a measure of a fluid's resistance to flow. You will find a detailed description of the mathematics of viscosity in the Brookfield publication "*More Solutions to Sticky Problems*" a copy of which was included with your **DV-II+**.

The principal of operation of the **DV-II+** is to drive a spindle (which is immersed in the test fluid) through a calibrated spring. The viscous drag of the fluid against the spindle is measured by the spring deflection. Spring deflection is measured with a rotary transducer. The measurement range of a **DV-II+** (in centipoise or milliPascal seconds) is determined by the rotational speed of the spindle, the size and shape of the spindle, the container the spindle is rotating in, and the full scale torque of the calibrated spring.

There are four basic spring torque series offered by Brookfield:

<u>Model</u>	<u>Spring Torque</u>	
	<u>dyne-cm</u>	<u>milli Newton - m</u>
LVDV-II+	673.7	0.0673
RVDV-II+	7,187.0	0.7187
HADV-II+	14,374.0	1.4374
HBDV-II+	57,496.0	5.7496

The higher the torque calibration, the higher the measurement range. The measurement range for each torque calibration may be found in **Appendix B**.

All units of measurement are displayed according to either the CGS system or the SI system.

1. Viscosity appears in units of centipoise (shown as "cP") or milliPascal-seconds (shown as mPa•s) on the **DV-II+** Viscometer display.
2. Shear Stress appears in units of dynes/square centimeter ("D/cm²") or Newtons/square meter ("N/m²").
3. Shear Rate appears in units of reciprocal seconds ("1/SEC").
4. Torque appears in units of dyne-centimeters or Newton-meters (shown as percent "%" in both cases) on the **DV-II+** Viscometer display).

The equivalent units of measurement in the SI system are calculated using the following conversions:

	<u>SI</u>		<u>CGS</u>
Viscosity:	1 mPa•s	=	1 cP
Shear Stress:	1 Newton/m ²	=	10 dyne/cm ²
Torque:	1 Newton-m	=	10 ⁷ dyne-cm

References to viscosity throughout this manual are done in CGS units. The **DV-II+** Viscometer provides equivalent information in SI units.

I.1 Components

- 1) **DV-II+** Viscometer
- 2) Model A Laboratory Stand
- 3) Spindle Set with Case (4 spindles for **LVDV-II+**; 7 Spindles for **RV**, **HA** and **HBDV-II+**). For Cone/Plate versions: a spindle wrench, one cone spindle and sample cup (Part No. CP-44Y) replace the spindle set.
- 4) Power cord
- 5) RTD Temperature Probe and DVE-50 Probe Clip
- 6) Guard Leg (**LVDV-II+** and **RVDV-II+** only)
- 7) Carrying Case

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 agent immediately. Any shipping damage must be reported to the carrier.

I.2 Utilities

Input Voltage: 115 VAC or 230 VAC
 Input Frequency: 50/60 Hz
 Power Consumption: Less than 20 WATTS

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: **LV DV-II+**: 0.0, 0.3, 0.6, 1.5, 3, 6, 12, 30, 60, 0.0, 0.5, 1, 2, 2.5, 4, 5, 10, 20, 50, 100

RV/HA/HBDV-II+: 0.0, 0.5, 1, 2, 2.5, 4, 5, 10, 20, 50, 100, 0.0, 0.3, 0.6, 1.5, 3, 6, 12, 30, 60

Weight:	Gross Weight	20 lbs.	9 kg.
	Net Weight	17 lbs.	7.7 kg.
	Carton Volume	1.65 cu. ft.	0.05 m ³

Temperature sensing range: -100°C to 300°C (-148°F to 572°F)

Analog Torque Output: 0 - 1 Volt DC (0 - 100% Torque)

Analog Temperature Output: 0 - 4 Volts DC (10mv / °C)

RS232 Compatible Serial Port for use with an attached printer or PC.

I.4 Set-Up

- 1) Place the upright rod into the base (refer to assembly instructions in **Appendix H**). The rack gear and clamp assembly should face the front of the base. The upright rod is held in place with the jam nut which is attached from the bottom of the base. Tighten this nut with a suitable wrench (spanner). Attach leveling feet.
- 2) Insert the mounting handle on the back of the **DV-II+** Viscometer into the hole on the clamp assembly. Be sure that the clamp screw, VS-24Y, is loose.
- 3) Tighten the VS-24Y clamp screw. Adjust viscometer to be as close to level as possible while tightening VS-24Y.
- 4) Connect the **RTD** probe to the socket on the rear panel of the **DV-II+**.
- 5) The Viscometer must be leveled. The level is adjusted using the three leveling screws on the base. Adjust so that the bubble level on top of the **DV-II+** is centered within the circle.

Note: Check level periodically during use.

- 6) Make sure that the AC power switch at the rear of the **DV-II+** is in the **OFF** position. Connect the power cord to the socket on the back panel of the instrument and plug it into the appropriate AC line. *The AC input voltage and frequency must be within the appropriate range as shown on the name plate of the Viscometer.*

Note: The DV-II+ must be earth grounded to ensure against electronic failure!!

- 7) Temperature monitoring is assured (after the instrument has stabilized) to within $\pm 1.0^{\circ}\text{C}$ in the range -99.9°C to $+150^{\circ}\text{C}$ and within $\pm 2.0^{\circ}\text{C}$ in the range 150°C to 300°C .
- 8) For Cone/Plate models, refer to **Appendix A**.

I.5 Key Functions

Figure 1 shows the control keys on the face of the **DV-II+** Viscometer. The following describes the function of each key.



UP ARROW

This key is used to scroll **UP** (in an increasing value direction) through the available speed or spindle tables.



DOWN ARROW

This key is used to scroll **DOWN** (in a decreasing value direction) through the available speed or spindle tables.

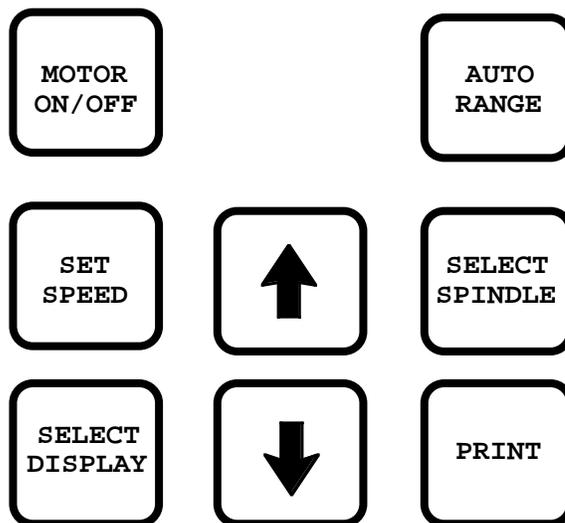


Figure 1

MOTOR ON/OFF

Turns the motor **ON** or **OFF**.

SET SPEED

Causes the **DV-II+** to begin running at the currently selected speed. This key is used for Time to Torque and Timed Stop Tests (see Section II.10 - Timed Modes for Viscosity Measurement).

SELECT DISPLAY

Selects the data parameter to be displayed:

%	Viscometer Torque (%)
cP	Viscosity (cP or mPa·s)
SS	Shear Stress (dynes/cm ² or Newtons/m ²)
SR	Shear Rate (1/sec)

Note: Pressing and holding the **Select Display** key during power on will enable the temperature display for units of either $^{\circ}\text{C}$ or $^{\circ}\text{F}$ (see page 12).

AUTO RANGE

Presents the maximum (100% torque) viscosity attainable using the selected spindle at the current viscometer spindle speed. This feature is functional when the motor is running.

Note: Pressing and holding the **Auto Range** key during power on will enable the display to be selected for either **CGS** or **SI** units of measurement (see page 11).

SELECT SPINDLE

Initiates spindle selection on the first press and then selects the currently scrolled-to spindle when pressed a second time. This key is used for Time to Torque and Timed Stop Tests (see Section II.10 - Timed Modes for Viscosity Measurement).

PRINT

Selects printing and non-printing modes when a printer is attached.

II. GETTING STARTED

II.1 Autozero

Before readings may be taken, the Viscometer must be Autozeroed. This action is performed each time the power switch is turned on. The display window on the Viscometer will guide you through the procedure as follows:

Turn the power switch (located on the rear panel) to the **ON** position. This will result in the following screen display:



BROOKFIELD DVII+
RV VISCOMETER

Figure 2

After a few seconds, the following screen appears:



BROOKFIELD DVII+
VERSION 4.1

Figure 3

No key press is required at this point. After a short time, the display will clear and the following will be displayed:



REMOVE SPINDLE
PRESS ANY KEY

Figure 4

After removing the spindle and pressing any key, the **DV-II+** begins its Autozero. The screen will flash "Autozeroing."

After approximately 15 seconds, the display shows "**Replace Spindle Press Any Key**".



REPLACE SPINDLE
PRESS ANY KEY

Figure 5

Pressing any key at this point results in the display of the **DV-II+** default screen:

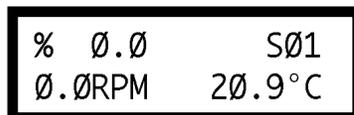


Figure 6

The display will vary slightly depending upon the status of temperature and last spindle entered.

II.2 Spindle Selection

LVDV-II+ Viscometers are provided with a set of four spindles and a narrow guardleg; RVDV-II+ Viscometers come with a set of seven spindles and a wider guardleg; HADV-II+ and HBDV-II+ Viscometers come with a set of seven spindles and no guardleg. (See **Appendix E** for more information on the guardleg.)

The spindles are attached to the viscometer by screwing them to the lower shaft. Note that the spindles have a **left-hand thread**. The lower shaft should be held in one hand and the spindle screwed to the left. The face of the spindle nut and the matching surface on the lower shaft should be smooth and clean to prevent eccentric rotation of the spindle. Spindles can be identified by the number on the side of the spindle coupling nut.

The **DV-II+** must have a Spindle Entry Code number to calculate Viscosity, Shear Rate and Shear Stress values. The **DV-II+** memory contains parameters for all standard Brookfield spindles and the two digit entry code for each spindle (the complete list of entry codes may be found in **Appendix D**).

Note: The **DV-II+** will remember the Spindle Entry Code which was in use when the power was turned off.

Pressing the **SELECT SPINDLE** key will cause the character **S** on the top line of the display to begin to *blink*. It will *blink* for about three seconds. If the **UP** or **DOWN Arrow** keys are pressed (while **S** is blinking) the two character spindle value to the right of the **S** character will begin to change (in either an increasing or decreasing direction depending upon which **Arrow** key is pressed) for each press of the key. If the **Arrow** key is pressed and held, the display will scroll through the spindle codes for as long as the **Arrow** key is depressed. When it reaches the last item in the list (either at the *top* or *bottom* of the list) the spindle code displayed will “*roll-over*” to either the first or last spindle code and the scroll action will continue.

When the desired spindle code is displayed, release the **Arrow** key to halt further scrolling. Press the **SELECT SPINDLE** key once again. This will cause the **S** character to cease *blinking* and the new spindle code will be accepted for use in viscometer calculations.

Note: You have approximately three seconds in which to press the **SELECT SPINDLE** key before the *blinking* stops. If you fail to press the **SELECT SPINDLE** key before the *blinking* stops you will have to repeat the above steps and re-select the desired spindle.

The **DV-II+** will begin to calculate using the new spindle parameters as soon as the **SELECT SPINDLE** key is *pressed the second time*.

Note: The number **99** spindle is for use with special spindles when using **Brookfield’s DVGATHER+** or **WINGATHER** computer programs. Refer to the **DVGATHER+** or **WINGATHER** manuals for further information on using “**99**” spindles.

The **DV-II+** may also be programmed at **Brookfield Engineering** for “special” user spindles. These “special” spindles will show up on the spindle scroll list starting with designation “**AA**” and continuing through “**AZ**”. Contact **Brookfield Engineering** regarding your needs for special spindles.

II.3 Speed Selection & Setting

There are 18 speeds programmed into the standard **DV-II+**. These speeds correspond to the standard **LVT, RVT, HAT, HBT, LVF** and **RVF** dial models. If the **DV-II+** is an **LV**, the speed set will start at speed 0.0. It will then scroll up through the **LV** speeds, pass through speed 0.0 again, and then scroll up through the **RV** speeds at which point it will pass through speed 0.0 again and will then repeat the above sequence. If the **DV-II+** is an **RV (HA and HB)** “type”, the inverse of the above will occur. The **DV-II+** will start at 0.0 and scroll through the **RV** speeds, pass through 0.0 again and then scroll through the **LV** speeds until it again reaches speed 0.0. The speed sets are described in **Table 1**.

Table 1

DV-II+ Speed Sets	
LV Instruments	RV/HA/HB Instruments
0.0	0.0
0.3	0.5
0.6	1.0
1.5	2.0
3.0	2.5
6.0	4.0
12.0	5.0
30.0	10.0
60.0	20.0
0.0	50.0
0.5	100.0
1.0	0.0
2.0	0.3
2.5	0.6
4.0	1.5
5.0	3.0
10.0	6.0
20.0	12.0
50.0	30.0
100.0	60.0

The **DV-II+** may also be programmed with “special” speed sets. A list of special speed sets is included in **Appendix F**. Please consult **Brookfield Engineering** or your local dealer/distributor for any special speed requirements not addressed by the standard or special speed sets.

To *select* a Viscometer speed first press either the **UP** or **DOWN** arrow keys which will cause the area to the right of **RPM** (on the bottom line) to display the currently *selected* speed. **Figure 7** shows the **DV-II+** had been operating at 6.0 RPM, and the current *selected* speed is 6.0 RPM.

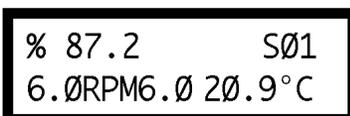


Figure 7

If the **Arrow** key is pressed *just once* and then released, the characters **RPM** will *blink* for three seconds, then will cease *blinking* resulting in no change to the speed entry.

Note: The speed selection process remembers the last value of scrolled-to speed so that the next time you initiate a speed change (by pressing an **Arrow** key), the **DV-II+** will begin its scroll display from the last entered value.

The last-scrolled-to speed does not necessarily have to be the same as the speed at which the **DV-II+** is currently running. The user may operate at a given speed and pre-set the **DV-II+** to the next desired speed before that speed will be used. For example, if the **DV-II+** is currently running at 6.0 RPM and was *previously* scrolled to 12 RPM, a *single* press of *either* **Arrow** key would result in the **Figure 8** screen display:

% 87.2	SØ1
6.ØRPM12	2Ø.9°C

Figure 8

Pressing the **SET SPEED** key would cause the **DV-II+** to begin running at 12 RPM.

If the user did not press the **SET SPEED** key, the **DV-II+** would continue to run at its current speed of 6 RPM. In fact, you may scroll to a new speed (12 RPM in this example) and press the **SET SPEED** key at any future time (without further pressing an **Arrow** key) to *immediately* cause the **DV-II+** to run at the new speed. Pressing the **Arrow** key at any time reminds the operator of what was selected for the next speed.

If an **Arrow** key is pressed and held the **DV-II+** will scroll up (or down) through the speed table. When it reaches the last speed in the list (either at the *top* or *bottom* of the list) the speed displayed will "roll-over" to either the first or last speed in the table and the scroll action will continue.

When the required speed is displayed, release the **Arrow** key to halt further scrolling. You have approximately two seconds (before the *blinking* **RPM** stops) in which to press the **SET SPEED** key to immediately begin rotation at the new speed.

Pressing the **MOTOR ON/OFF** key stops the Viscometer spindle rotation. Pressing this key sets the **DV-II+** to 0.0 RPM and causes the screen display to change as shown in **Figure 9**:

% 89.7	S31
1ØØRPM	2Ø.9°C

Figure 9

Pressing the **MOTOR ON/OFF** again immediately starts the **DV-II+** running at the **last scrolled-to-speed**. If you had been running at 12 RPM, pressed **MOTOR ON/OFF** and then re-started the **DV-II+** by pressing **MOTOR ON/OFF** once again, you would again be running at 12 RPM. However, if while the motor was off you had scrolled to a new speed of 0.5 RPM, pressing the **MOTOR ON/OFF** key would start the **DV-II+** running at 0.5 RPM.

Note: During both spindle or speed selection and scrolling operations, the **DV-II+** will continue to calculate and display Viscometer data as selected.

II.4 Display Selection

Viscometric data (% , cP, SS, SR) is displayed on the left side of the top line. You may “step” through the four display options by pressing the **SELECT DISPLAY** key. For example, if the **DV-II+** were currently displaying % (**Torque**) as shown in **Figure 10**:

% 89.7	S31
100RPM	20.9°C

Figure 10

The first press of the **SELECT DISPLAY** key would display viscosity in **cP** (or mPa·s), see **Figure 11**:

cP 123.4	S31
100RPM	20.9°C

Figure 11

The next press of the **SELECT DISPLAY** key would display **SS** (Shear Stress) in **Dynes/Cm²** (or Newtons/m²).

SS 41.8	S31
100RPM	20.9°C

Figure 12

The next press of the **SELECT DISPLAY** key would display **SR** (Shear Rate) in **1/Sec.**

SR 34	S31
100RPM	20.9°C

Figure 13

One more press of the **SELECT DISPLAY** key would result in a re-display of the % (**Torque**) screen, as shown in **Figure 10**.

Note: You may step through the display at any time. This will not interrupt any Viscometer calculations that are in progress.

II.5 Autorange and CGS or SI Units Selection

The **AUTO RANGE** key allows you to determine the maximum calculated viscosity (full scale reading) possible with the current spindle/speed setting. Pressing the key *at any time* will cause the current viscosity display to change and show *that maximum* viscosity. The screen area formerly displaying temperature display will now display a flashing “%100.0” to indicate this special condition. This maximum viscosity and flashing %100.0 value will be displayed for as long as the **AUTO RANGE** key is depressed. **Figure 14** shows the **AUTO RANGE** function for the situation where the No. 1 LV spindle is rotating at 60 rpm. The full scale range is 100.0 cP (or 100.0 mPa·s).

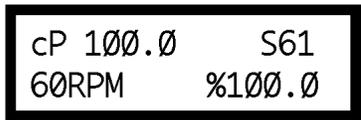


Figure 14

- Note:**
1. If the **MOTOR** is **OFF** or the RPM is **0.0**, the maximum viscosity displayed will be **0.0** cP (or 0.0 mPa·s).
 2. While the Viscometer is in the Auto Range mode, any data sent to an attached printer or computer reflects the displayed values (i.e. Auto Range values).

Pressing and holding the **AUTO RANGE** key during power on will enable the selectable display to be read in either CGS or **SI** units. To change the unit format:

1. Turn the power off.
2. Press and hold the **AUTO RANGE** key and turn the power **ON**.

The **DV-II+** will retain the unit selection when the viscometer is turned **OFF**.

	<u>CGS</u>	<u>SI</u>
Viscosity	cP	mPa·s
Shear Stress	dyne/cm ²	N/m ²
Shear Rate	sec ⁻¹	sec ⁻¹
Torque	%	%

DV-II+ Viscometers without this function can be updated. Contact Brookfield or your local Brookfield dealer for this service.

II.6 Out of Range

The **DV-II+** gives indications for out of specification or out-of-range operation. When % (**Torque**) readings exceed 100.0 % (over-range), the display changes to that shown in **Figure 15**:



Figure 15

EEEE will also appear when viscosity or shear stress are over range. You must change either speed or spindle to correct this condition. If you operate at spindle speeds that produce % (**Torque**) below 10.0 % (under-range), the **DV-II+** displays % (**Torque**), **cP** (**Viscosity**) and **SS** (**Shear Stress**) preceded by a “?” as shown in **Figure 16**:



Figure 16

Negative % (Torque) will be displayed as shown in **Figure 17**:

% -0.1	S31
0.5RPM	20.9°C

Figure 17

cP (Viscosity) and **SS (Shear Stress)** values will be displayed as "- - - -" when the % (Torque) is below zero.

Figure 18 is an example of the printed output of each of the above conditions.

RPM=50	MD=RV	SPDL=29	%=51.4	cP=10280	D/CM2=1285	1/SEC=12.5	T=25.5C
Normal Print String							
RPM=50	MD=RV	SPDL=29	%=EEEE	cP=EEEE	D/CM2=EEEE	1/SEC=12.5	T=25.5C
Over-Range							
?RPM=50	MD=RV	SPDL=29	%=5.2	cP=1040	D/CM2=130	1/SEC=12.5	T=25.5C
Under-Range							
RPM=50	MD=RV	SPDL=29	%=-0.1	cP=- - - -	D/CM2=- - - -	1/SEC=0.0	T=25.5C
Negative Torque							

Figure 18

II.7 Temperature Display

The **DV-II+** will display the temperature measured by its **RTD** temperature probe. Temperature may be displayed in either °C (Centigrade) or °F (Fahrenheit) units depending upon the start-up operations. If the **DV-II+** is started normally, the default temperature display will be in °C (Centigrade) units as shown in the **Figure 19**:

% 87.9	S31
100RPM	21.7°C

Figure 19

However, if you press and hold the **SELECT DISPLAY** key while turning on the **DV-II+** the temperature will be displayed in °F (Fahrenheit).

If you turn on the **DV-II+** with the temperature probe disconnected, or remove the temperature probe at any point after power-up, the display will indicate "- - - -°C".

The four "dashes" indicate the absence of the probe. If you were displaying temperature in Fahrenheit units the **C** would be displayed as an **F**.

TABLE 2

Temperature Accuracies For Digital Viscometer Model DV-II+	
Temperature Range	Temperature Accuracy
-100°C to +150°C	±1.0°C
+150°C to +300°C	±2.0°C

II.8 Printing

The DV-II+ will print data to an attached Serial printer. The printer must be attached to the rear panel **SERIAL AND ANALOG** output connector. See **Appendix G** for the connection requirements. The printer must be configured as follows:

Baud Rate	9600
Data Bits	8
Stop Bits	1
Parity	None
Handshake	None

Data may be printed in two ways:

1. Pressing the **PRINT** key once (for less than three (3) seconds) will result in the printing of one standard print line.
2. If the **PRINT** key is pressed and held for more than three (3) seconds, the user will be presented with the following screen:



PRINT INTERVAL
SET MIN'S: 00

Figure 20

Here the user is being asked to enter the time interval (in minutes and seconds) between successive print strings. First, as depicted above the user is asked for the minutes entry and then by pressing the print key the seconds entry as shown below:



PRINT INTERVAL
SET SEC'S: 00

Figure 21

The print interval maximum limits are **99** minutes and **59** seconds.

3. The method for entering the minutes and seconds values is accomplished by using the **UP** or **DOWN** arrow keys. The **PRINT** key is used to advance from the minutes to seconds entries and as the exit key after the user has input the seconds value.

Note: The value for minutes or seconds must be other than zero or you will not be able to exit this mode.

4. After the final press of the **PRINT** key, the **DV-II+** will immediately begin sending out print strings at the selected user print rate. To stop continuous printing, the user must press and hold the **PRINT** key for three (3) seconds.
5. Only after the user again presses and holds the **PRINT** key for three (3) seconds will you be asked for the minute and seconds entries. The previously selected values for time interval will be retained in **EEPROM** so as to be available at the next power-up. Thus, if the user wishes to again print continuously at the previous print interval, you will only have to press the **PRINT** key three (3) times; once to accept the minutes entry; once to accept the seconds entry, and once to exit and begin printing.

Note: On **DV-II+** Viscometers with serial number DE27812 or higher, the RS-232 output is automatically active after **Auto Zero** is executed.

The RS-232 output **MUST** be active (printing continuously) when using a computer and **DVGATHER+** software.

II.9 Operation

The following general procedure is used for making viscosity measurements. Brookfield recommends the use of a 600 ml Low Form Griffin type beaker when using LV/RV/HA/HB spindles in order to obtain data that verifies proper calibration of the DV-II+ Viscometer (see Appendix E).

1. Mount the guardleg on the **DV-II+** Viscometer (LV and RV series). Attach the spindle to the lower shaft. Lift the shaft slightly, holding it firmly with one hand while screwing the spindle on with the other (note left-hand thread). Avoid putting side thrust on the shaft.
2. Insert and center spindle in the test material until the fluid's level is at the immersion groove in the spindle's shaft. With a disc-type spindle, it is sometimes necessary to tilt the instrument slightly while immersing to avoid trapping air bubbles on its surface. (You may find it more convenient to immerse the spindle in this fashion before attaching it to the Viscometer.)
3. To make a viscosity measurement, follow the instructions in **II.2** and **II.3**. Allow time for the indicated reading to stabilize. The time required for stabilization will depend on the speed at which the Viscometer is running and the characteristics of the sample fluid. For maximum accuracy, readings below 10% should be avoided.
4. Press the MOTOR ON/OFF key and turn the motor "**OFF**" when changing a spindle or changing samples. Remove spindle before cleaning.
5. Interpretation of results and the instrument's use with non-Newtonian and thixotropic materials is discussed in the booklet, "*More Solutions to Sticky Problems*", and in **Appendix C, Variables in Viscosity Measurements**.

II.10 Timed Modes for Viscosity Measurement

The **Timed Modes** allow the viscometer user to implement **Timed Stop** and **Time to Torque** capabilities with the **DV-II+** Viscometer. These features will allow the user to set up the viscometer (i.e. select spindle and speed) and then record readings for a fixed period of time (**Timed Stop**) or until a set torque value is attained (**Time to Torque**). A series of menus will ask the user to input minutes and seconds (**Timed Stop**) or % torque (**Time to Torque**) and will then begin timing when the user presses the **MOTOR ON/OFF** key to **ON**. A message will be displayed showing time remaining (or time elapsed) and the appropriate display item (viscosity or torque) will be updated

continuously during the event. Upon completion, the viscometer will display a screen stating that the test is complete and will also display the final recorded value for the viscosity in the first case, and the time in minutes and seconds to reach the torque limit in the second case. Pressing the **UP** or **DOWN** arrow keys will allow alternate data to be examined and pressing any other key (except the **PRINT** key) will bring the user back to the default (normal) viscometer display with the motor **OFF**. If the user wishes to run another test, repeat the above steps.

II.10.1 Set Up

1. The user must first select the temperature scale in °C or °F and the display unit option: **CGS** or **SI**.
2. The user then selects (via the **UP** and **DOWN** arrows) the spindle speed.
Note: If 0.0 RPM is the selected speed setting (the default after executing **AUTOZERO**) the timed modes can be executed; however, the results will be meaningless showing no viscosity values.
3. Next, the user selects the spindle number corresponding to the spindle attached.
4. Now, the user presses the **MOTOR ON/OFF** key to ensure that the motor is **OFF**. Setting the motor to the **OFF** condition sets up the viscometer for executing the **Timed Modes**.
5. The user presses the **SET SPEED** and **SELECT SPINDLE** keys *simultaneously* to enter either of the timed test modes. Immediately the following screen appears:



Figure 22

6. The user presses either the **UP** or **DOWN** arrow key to select the test method of choice and is immediately presented with the corresponding opening screen.

II.10.2 Timed Stop Implementation

1. After pressing the **UP** arrow key when in the display of **Figure 23**, the user is presented with the following screen:



Figure 23

Using the **UP** and **DOWN** arrow keys, the user enters a value for the minutes portion of the time to stop. This value can be as high as 99 minutes.

- When satisfied, the user presses the **SELECT SPINDLE** key again to enter the seconds setting display:



TIMED STOP
SET SEC'S: 00

Figure 24

Using the **UP** and **DOWN** arrow keys, the user enters a value for the seconds portion of the time to stop. This value will be between 0 and 59 seconds.

Note: The value for minutes or seconds must be other than zero or you will not be able to exit this mode.

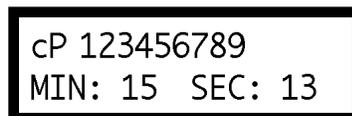
The user presses the **SELECT SPINDLE** key one more time to end his time input at which point the viscometer will display the following screen:



TIMED STOP:PRESS
MOTOR ON/OFF

Figure 25

- At this point, the user need only press the **MOTOR ON/OFF** key to begin the timed stop operation. Any other key will abort the process and the user will have to begin again by *simultaneously* pressing the **SET SPEED** and **SELECT SPINDLE** keys.
- We will assume that the user pressed the **MOTOR ON/OFF** key to **ON** and is now presented with the following screen for the duration of the timed run:



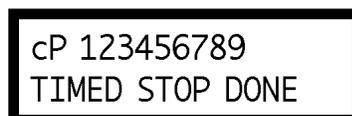
cP 123456789
MIN: 15 SEC: 13

Figure 26

Note:

- When this mode has begun, a press of the **MOTOR ON/OFF** key will interrupt the Timed Stop sequence and return the user to normal operation.
- Also see **Comments on Print Mode Operation in Section II.10.4** for a description of print options available on **DV-II+** during the Timed Stop run.

The seconds display will decrement from 59 to zero (0) in one (1) second intervals. When seconds reaches zero (0), the minutes value will decrement by one (1) minute. This will continue until all of the time has elapsed at which point the viscometer will display the following screen:



cP 123456789
TIMED STOP DONE

Figure 27

At this point, the viscometer will stop the motor and continue to display this screen until any key except the **UP** or **DOWN** arrow key or the **PRINT** key is pressed. The user presses the **UP** or **DOWN** arrow keys to view the Torque and Speed that were current at the Timed Stop completion. This display would appear as follows:



```
%=76.4  RPM=100
TIMED STOP DONE
```

Figure 28

The display will switch between that of **Figures 27** and **28** for each press of either the **UP** or **DOWN** arrow key. Pressing any key except the **UP** or **DOWN** arrow keys or **PRINT** key will cause the viscometer to exit the Timed Stop mode and resume normal operation.

Note:

1. The user can press the **PRINT** key while in either of these two screens (**Figures 27** and **28**) to send one standard print string to the attached printer as many times as the user presses the **PRINT** key. Pressing any other key will exit this mode and return the viscometer to normal operation.
2. For the Timed Stop method, the **DV-II+** Viscometer will retain the last value for the time interval in **EEPROM** so that it will become the default the next time the user elects to use this method.

II.10.3 Time to Torque Implementation

1. After pressing the **DOWN** arrow key when in the display of **Figure 22**, the user is presented with the following screen:



```
TIMED TORQUE
SET TORQUE: 00%
```

Figure 29

Using the **UP** and **DOWN** arrow keys, the user enters a value for the torque level which the viscometer must achieve. This value can be as high as 99%.

Note: The value for torque must be other than zero or you will not be able to exit this mode.

2. The user presses the **SELECT SPINDLE** key one more time to end the torque input at which point the viscometer will display the following screen:

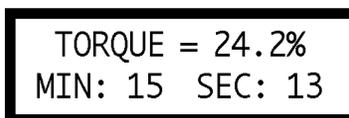


```
TIMED TORQ:PRESS
MOTOR ON/OFF
```

Figure 30

The time to torque value can be as high as **99** minutes and **59** seconds.

3. At this point, the user need only press the **MOTOR ON/OFF** key to begin the timed torque operation. Any other key will abort the process and he will have to begin again by *simultaneously* pressing the **SET SPEED** and **SELECT SPINDLE** keys.
4. We will assume that the user pressed the **MOTOR ON/OFF** key to **ON** and is now presented with the following display for the duration of the timed torque run:



```
TORQUE = 24.2%
MIN: 15 SEC: 13
```

Figure 31

Note:

1. When this mode has begun, a press of the **MOTOR ON/OFF** key will interrupt the time to torque operation and return the user to normal operation.
2. Also, see **Comments on Print Mode Operation** in **Section II.10.4** for a description of print options available on **DV-II+** during the Time to Torque run.

The seconds display will increment from zero (0) to 59 in one (1) second intervals and the current value of the viscometer torque will be updated continuously. When seconds reach 59, the minutes value will increment by one (1) minute. This will continue until the user selected torque value is attained at which point the viscometer will display the following screen:



```
22M 54S TO 85%
TIMED TORQ DONE
```

Figure 32

At this point, the viscometer will stop the motor and continue to display this screen until the user presses the **UP** or **DOWN** arrow keys or the **PRINT** key to view the viscosity that was current at the Timed Torque completion. The display would appear as follows:



```
cP 123456789
TIMED TORQ DONE
```

Figure 33

The display will switch between that of **Figures 32** and **33** for each press of either the **UP** or **DOWN** arrow key. Pressing any key except the **UP** or **DOWN** arrow key or the **PRINT** key will cause the viscometer to exit the Timed Torque mode and resume normal operation.

Note:

1. The user can press the **PRINT** key while in either of these two screens (**Figures 32** and **33**) to send one standard print string to the attached printer as many times as the user presses the **PRINT** key. Pressing any other key will exit this mode and return the viscometer to normal operation.
2. For the Time to Torque method, the **DV-II+** Viscometer will retain the last entered torque in **EEPROM** for use when the user elects to perform a time to torque test again.

II.10.4 Comments on Print Mode Operation

The high-speed-print jumper (between pins four (4) and nine (9) on the RS-232 plug found on the Brookfield PC Cable - Part No. DVP-80) is used exclusively with Brookfield's **DVGATHER+** and **WINGATHER** software. This jumper if in place will override all of the above and will immediately place the **DV-II+** into the maximum print speed mode. When in this high speed print mode, the ability to access either of the timed modes from the front panel will not be allowed and **PRINT** key presses will be ignored. When the user returns to stand-alone operation with a printer, you will remove the Brookfield PC cable (with the high-speed jumper) and replace it with the Brookfield Printer Cable (Part No. DVP-81) or any standard serial printer cable which will re-enable the print modes described above.

Additionally, the **DV-II+** user can set up a desired print interval time, then set the viscometer to the continuous print mode and finally initiate either of the timed modes of operation. While setting up timed mode parameters, continuous print operation will cease. However, upon starting the timed operation, the **DV-II+** will output an initial data string to the printer and then continue printing data strings (at the user defined time interval) for the duration of the timed run. At the end of the timed run, continuous printing will again be disabled and the user may print single strings (of the final data point) at your option until exiting the timed mode. Upon returning to the default operation mode, continuous printing will again resume at the user selected time interval. In a similar manner, if the user is in the one-print-per-key-press mode when entering the timed mode of operation, you will be able to print data strings at any time during the timed mode by pressing the **PRINT** key when output is desired.

APPENDIX A - Cone/Plate Viscometer Set-Up

The Cone/Plate version of the **DV-II+** Viscometer uses the same operating instruction procedures as described in this manual. However, the gap between the cone and the plate must be mechanically adjusted before measurements are made. This is done by moving the plate (built into the sample cup, CP-44Y) up towards the cone until two small pins (one in the cone, the second mounted on the plate) contact, and then separating (lowering) the plate 0.0005inch (0.013mm).

Note that the Cone/Plate Viscometer **REQUIRES** the use of a good circulating temperature bath controlling temperature to within (+/-) 0.1 °C. The bath is connected to the ports on the CP-44Y sample cup.

The following example assumes that the C/P Viscometer is set up on the Model A stand, and has been zeroed with no cone attached. Cone CP-40 is used in the example. The water bath is on, set at the proper temperature (the adjustment procedure must be done at test temperature) and is connected to the sample cup. The Viscometer should be set at 0 rpm with **MOTOR ON**.

Connect sample cup ports to the water bath inlet and outlet, and set the bath to the test temperature. Allow enough time for the bath to reach the test temperature (**Figure A1**).

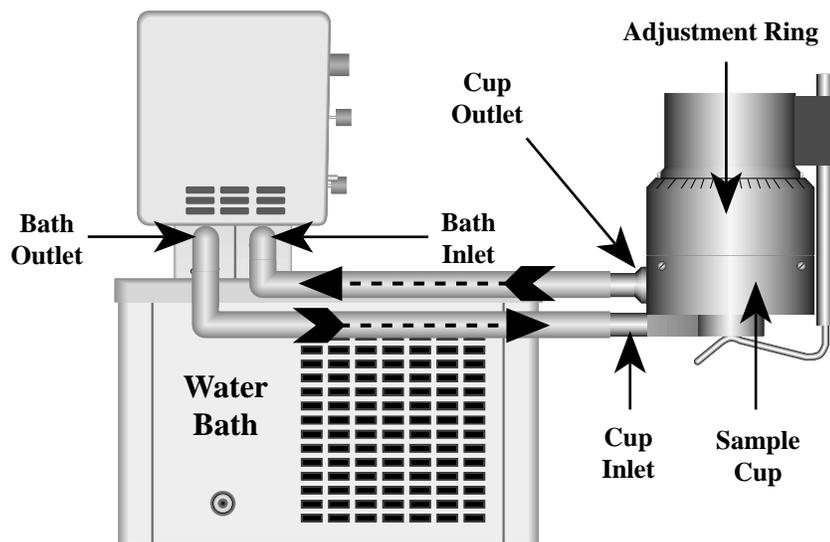


Figure A1

Remove sample cup and attach the cone to the Viscometer (Note: left hand threads), using the spindle wrench to hold the Viscometer shaft (**Figure A2**). **Note:** Lift up gently on the spindle wrench.

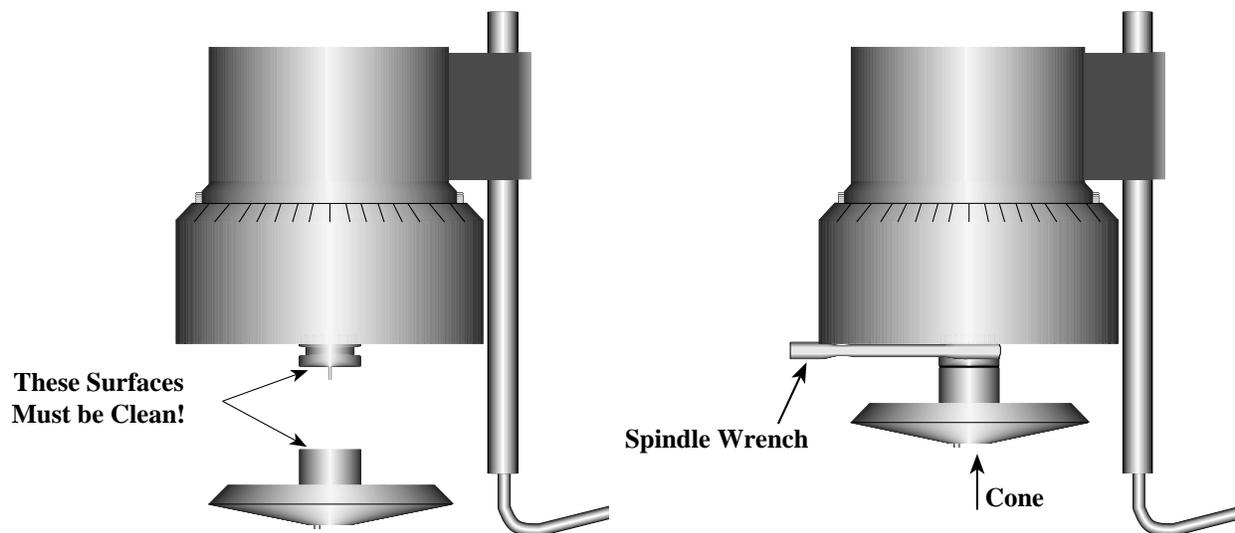


Figure A2

Attach the sample cup and swing the clip under the cup to secure it in place. ***Take care to avoid hitting the cone with the cup*** (Figure A3). **Note:** Do not add test sample during the gap setting procedure.

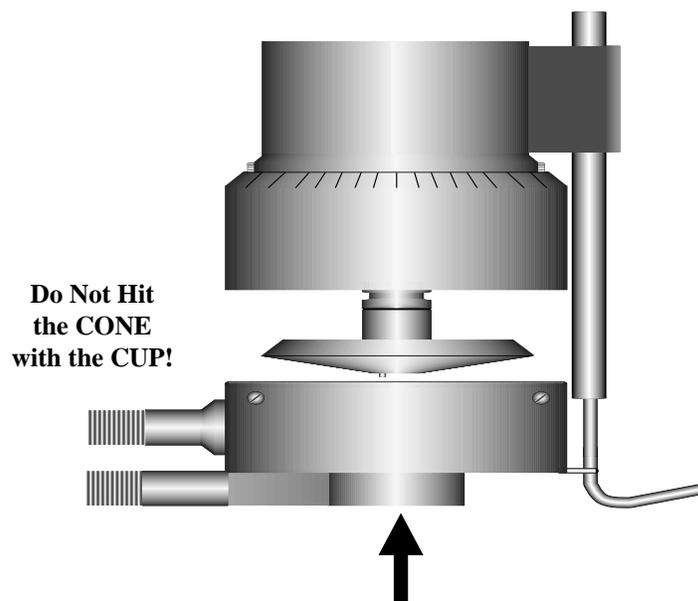


Figure A3

Set and start the **DV-II+** running at 10 rpm. Choose to display "%" information by pressing **SELECT DISPLAY** (see Section II.4 for details).

If the display reading jumps to 0.4% of scale (or higher), or will not settle to zero (indicating that the pins on the cone and cup are hitting), unscrew the adjustment ring by turning it to the left (clockwise as you look down on the instrument) until the reading settles at 0 (**Figure A4**).

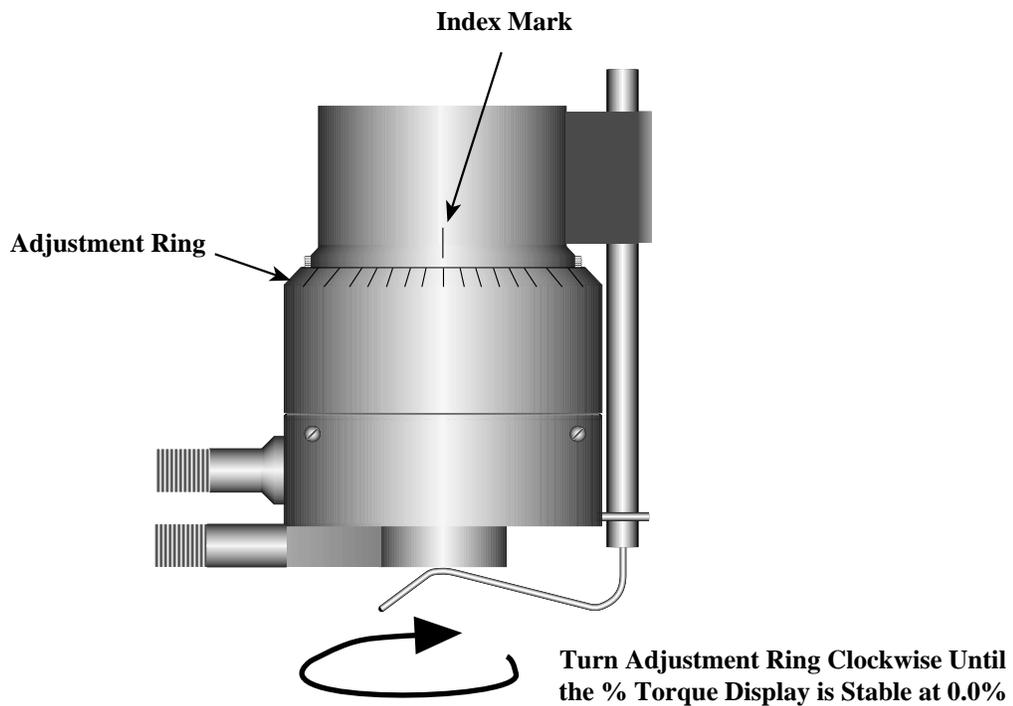


Figure A4

Turn the adjustment ring to the right (counterclockwise as you look down on the instrument) in small increments (one or two divisions of the ring) while watching the Viscometer display. Remember that you are trying to lower the cone so that the pin in the cone touches the pin in the cup. Once you have found this hit point, you can "back off" to create the desired gap between cone and cup. *You must wait at least 6 seconds between movements of the ring.* Turn the adjusting ring until the display reading jumps from 0 to 0.5% (**HB** Models) or from 0 to 1.0% (**LV**, **RV** and **HA** Models). This is the **HIT POINT**. The cup may have to be adjusted up and down several times before this deflection is satisfactorily reached. **LV** series **DV-II+s** will be the *most sensitive* (**Figure A5**).

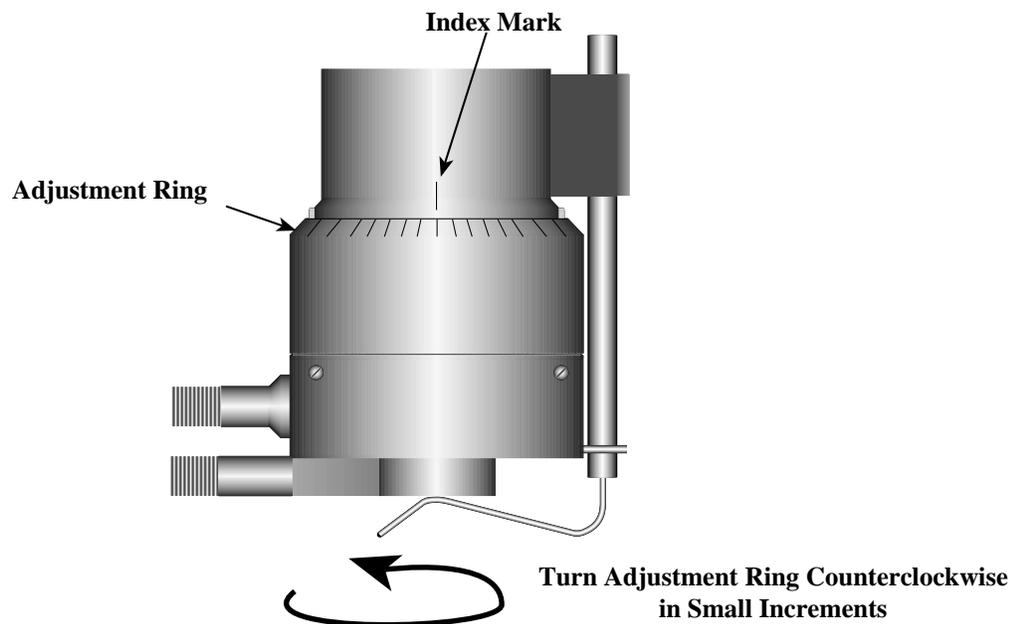


Figure A5

When you are satisfied the pins are just hitting (by observing acceptable % readings), make a pencil mark on the adjustment ring directly under the index mark on the pivot housing (**Figure A6**).

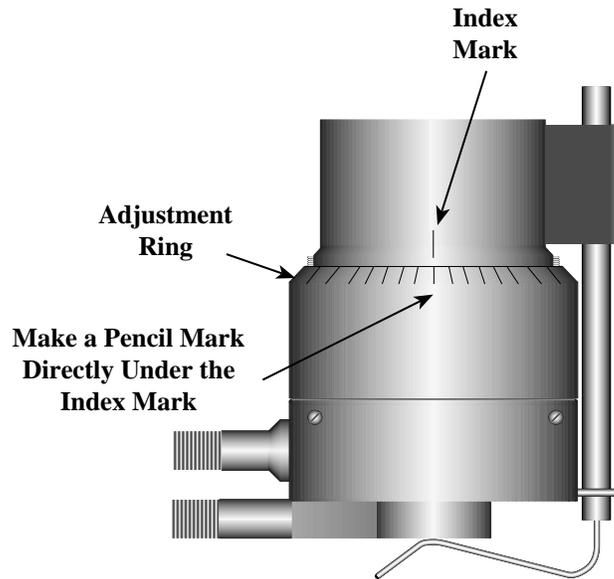


Figure A6

Turn the adjustment ring to the left (clockwise as you look down on the instrument) exactly the width of one division from the pencil mark you have just made. This will separate the pins by 0.0005" (0.013 mm). Allowing the pins to touch constantly may cause wear and damage to the cone, cup and instrument. The Viscometer is now mechanically set and ready for sample measurement (**Figure A7**).

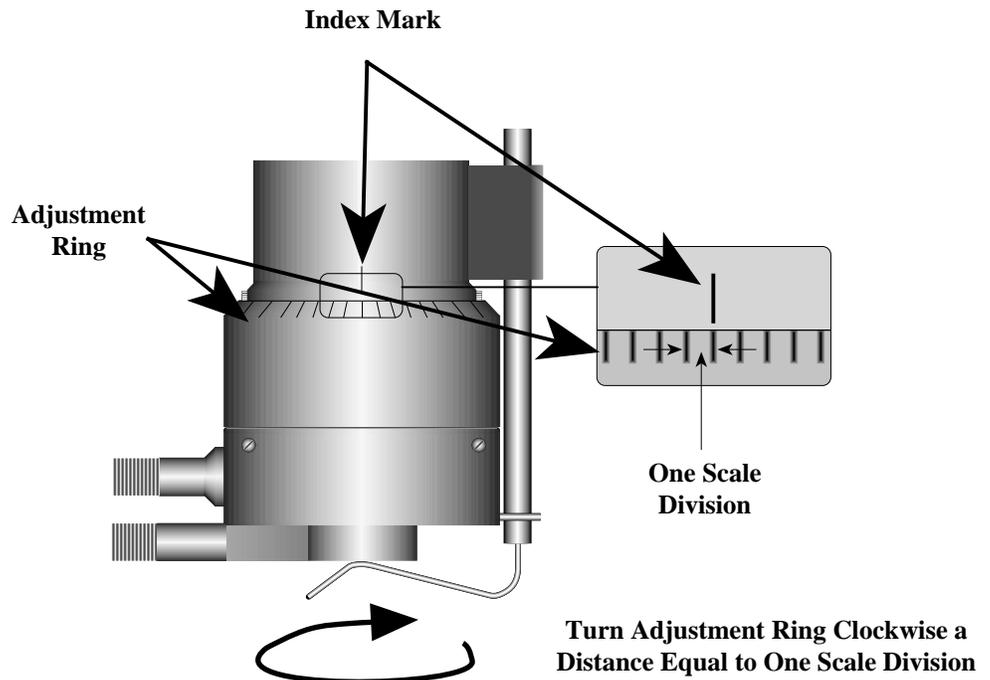


Figure A7

Each of the five available cones has a specific sample volume, as shown in **Table A1**. Note that the correct amount of sample fluid should cover the cone face and back up over the edge less than 1mm as shown in (**Figure A8**).

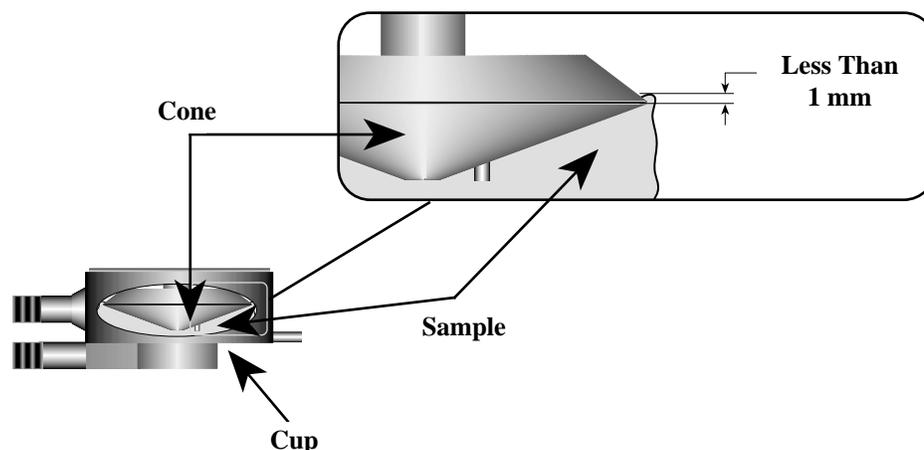


Figure A8

- Notes:**
- The cup may be removed without resetting the gap.
 - Remove the spindle from the viscometer when you clean it.
 - Reset the hit point every time the spindle is attached.

<u>Cone</u>	<u>Sample Volume</u>	<u>Cone Angle</u>
CP-40	0.5 ml	0.8°
CP-41	2.0 ml	3.0°
CP-42	1.0 ml	1.565°
CP-51	0.5 ml	1.565°
CP-52	0.5 ml	3.0°

Calibration Procedure for Cone/Plate Viscometers:

- Follow the procedures outlined in **Appendix A** for mechanically adjusting the setting of the cone to the plate.
- Refer to **Table A1**, and determine the correct sample volume required for the spindle to be utilized.
- Select a viscosity standard fluid that will give viscosity readings between 10% and 100% of full scale range. Refer to **Appendix B** for viscosity ranges of cone spindles. Consult with Brookfield or an authorized dealer to determine which fluid is appropriate.

It is best to use a viscosity standard fluid that will be close to the maximum viscosity for a given cone spindle/speed combination.

Example: LVDV-II+ Viscometer, Cone CP-42, Fluid 10
Having a viscosity of 9.7 cP at 25°C

At 60 RPM, the full scale viscosity range is 10.0 cP. Thus, the Viscometer reading should be 97% torque and 9.7 cP viscosity ± 0.197 (closer to ± 0.2) cP. The accuracy is a combination of Viscometer and fluid tolerance (refer to **Interpretation of Calibration Test Results**).

- 4) With the viscometer stopped, remove the sample cup and place the viscosity standard fluid into the cup, waiting 10 minutes for temperature equilibrium.
- 5) Connect the sample cup to the Viscometer. Allow 10 minutes for temperature to reach equilibrium.
- 6) Measure the viscosity and record the Viscometer reading in both % torque and centipoise (cP).

Note: The spindle must rotate at least five (5) times before a viscosity reading is taken.

Appendix B - Viscosity Ranges

LV(#1-4) and RV,HA,HB(#1-7) Viscometers

Viscosity Range (cP)		
Viscometer	Minimum	Maximum
LVDV-II+	15	2,000,000
RVDV-II+	100	13,300,000
HADV-II+	200	26,600,000
HBDV-II+	800	106,400,000

Small Sample Adapter and Thermosel

SSA & T-Sel Spindle	Shear Rate (1/SEC)	Viscosity (cP) LVDV-II+
16	0 - 29.0	120 - 400,000
18	0 - 132.0	3 - 10,000
25	0 - 22.0	480 - 1,600,000
31	0 - 34.0	30 - 100,000
34	0 - 28.0	60 - 200,000
81	0 - 129.0	3.4 - 10,000
82	0 - 129.0	3.4 - 10,000
83	0 - 129.0	11.3 - 37,898

SSA/T-Sel Spindle	Shear Rate (1/SEC)	Viscosity (cP)		
		RVDV-II+	HADV-II+	HBDV-II+
14	0 - 40.0	1,250 - 4,165,000	2,500 - 8,330,000	10,000 - 33,360,000
15	0 - 48.0	500 - 1,660,000	1,000 - 3,320,000	4,000 - 13,280,000
21	0 - 93.0	50 - 167,000	100 - 334,000	400 - 1,336,000
27	0 - 34.0	250 - 830,000	500 - 1,660,000	2,000 - 6,640,000
28	0 - 28.0	500 - 1,660,000	1,000 - 3,320,000	4,000 - 13,280,000
29	0 - 25.0	1,000 - 3,330,000	2,000 - 6,660,000	8,000 - 26,640,000
81	0 - 129.0	36.5 - 10,000	73.0 - 10,000	292.0 - 10,000
82	0 - 129.0	36.5 - 10,000	73.0 - 10,000	292.0 - 10,000
83	0 - 129.0	121.3 - 50,000	242.6 - 50,000	970.4 - 50,000

UL Adapter

UL Spindle	Shear Rate (1/SEC)	Viscosity (cP)			
		LVDV-II+	RVDV-II+	HADV-II+	HBDV-II+
YULA-15 or 15Z	0 - 122.4	1.0 - 2,000	6.4 - 2,000	12.8 - 2,000	51.2 - 2,000
ULA-DIN-Y	0 - 129.1	1.0 - 3,800	10.6 - 5,000	21.2 - 5,000	84.8 - 2,000

DIN Adapter Accessory

DAA Spindle	Shear Rate (1/SEC)	Viscosity (cP)			
		LVDV-II+	RVDV-II+	HADV-II+	HBDV-II+
85	0 - 129	1.2 - 3,812	12.2 - 5,000	24.4 - 5,000	97.6 - 5,000
86	0 - 129	3.4 - 10,000	36.5 - 10,000	73.0 - 10,000	292.0 - 10,000
87	0 - 129	11.3 - 37,898	121.3 - 50,000	242.6 - 50,000	970.4 - 50,000

Spiral Adapter

Spiral Spindle	Shear Rate (1/SEC)	Viscosity (cP)			
		LVDV-II+	RVDV-II+	HADV-II+	HBDV-II+
SA-70	.677 - 67.7 (1 - 100 RPM)	98.4 - 98,416	1,050 - 1,050,000	2,100 - 2,100,000	8,400 - 8,400,000

The maximum viscosity ranges correspond to a spiral spindle rotational speed of 1.0 RPM. Lower spindle speeds are possible but the pumping action within the spiral chamber may not be sufficient to provide meaningful viscosity data.

Cone/Plate Viscometer

Cone Spindle	Shear Rate (1/SEC)	Viscosity (cP)			
		LVDV-II+C/P	RVDV-II+C/P	HADV-II+C/P	HBDV-II+C/P
CP-40	0.0 - 750	0.30 - 1,028	3.3 - 10,900	6.6 - 21,800	26.2 - 87,200
CP-41	0.0 - 200	1.15 - 3,840	12.3 - 41,000	24.6 - 82,000	98.4 - 328,000
CP-42	0.0 - 384	0.60 - 2,000	6.4 - 21,300	12.8 - 42,600	51.2 - 170,400
CP-51	0.0 - 384	4.85 - 16,180	51.2 - 171,000	102.4 - 342,000	409.6 - 1,368,000
CP-52	0.0 - 200	9.33 - 31,100	98.3 - 328,000	196.6 - 654,000	786.4 - 2,624,000

Helipath with T-Bar Spindles

T-Bar Spindle	Viscosity (cP)			
	LVDV-II+	RVDV-II+	HADV-II+	HBDV-II+
T-A	156 - 62,400	2,000 - 400,000	4,000 - 800,000	16,000 - 3,200,000
T-B	312 - 124,800	4,000 - 800,000	8,000 - 1,600,000	32,000 - 6,400,000
T-C	780 - 312,000	10,000 - 2,000,000	20,000 - 4,000,000	80,000 - 16,000,000
T-D	1,560 - 624,000	20,000 - 4,000,000	40,000 - 8,000,000	160,000 - 32,000,000
T-E	3,900 - 1,560,000	50,000 - 10,000,000	100,000 - 20,000,000	400,000 - 80,000,000
T-F	7,800 - 3,120,000	100,000 - 20,000,000	200,000 - 40,000,000	800,000 - 160,000,000

In taking viscosity measurements with the **DV-II+** Viscometer there are two considerations which pertain to the low viscosity limit of effective measurement.

- 1) Viscosity measurements should be accepted within the equivalent % Torque Range from 10% to 100% for any combination of spindle/speed rotation.
- 2) Viscosity measurements should be taken under laminar flow conditions, not under turbulent flow conditions.

The first consideration has to do with the precision of the instrument. All **DV-II+** Viscometers have a full scale range precision of (+/-) 1% of any spindle/speed rotation. We discourage taking readings below

10% of range because the potential viscosity error of (+/-) 1% is a relatively high number compared to the instrument reading.

The second consideration involves the mechanics of fluid flow. All rheological measurements of fluid flow properties should be made under laminar flow conditions. Laminar flow is flow wherein all particle movement is in layers directed by the shearing force. For rotational systems, this means all fluid movement must be circumferential. When the inertial forces on the fluid become too great, the fluid can break into turbulent flow wherein the movement of fluid particles becomes random and the flow can not be analyzed with standard math models. This turbulence creates a falsely high Viscometer reading with the degree of non-linear increase in reading being directly related to the degree of turbulence in the fluid.

For the following geometries, we have found that an approximate transition point to turbulent flow occurs:

- 1) No. 1 LV Spindle: 15 **cP** at 60 RPM
- 2) No. 1 RV Spindle: 100 **cP** at 50 RPM
- 3) UL Adapter: 0.85 **cP** at 60 RPM

Turbulent conditions will exist in these situations whenever the RPM/cP ratio exceeds the values listed above.

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 **cP** values over time and find that the **cP** 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 spindle and chamber geometry will affect the viscosity readings. If one reading is taken at 2.5 rpm, and a second at 50 rpm, the two **cP** values produced will be different because the readings were made at different shear rates. The faster the spindle speed, the higher the shear rate.

The shear rate of a given measurement is determined by: the rotational speed of the spindle, the size and shape of the spindle, the size and shape of the container used and therefore the distance between the

container wall and the spindle surface.

A repeatable viscosity test should control or specify the following:

- 1) Test temperature
- 2) Sample container size (or spindle/chamber geometry)
- 3) Sample volume
- 4) Viscometer model
- 5) Spindle used (if using **LVDV-II+** (#1-4) or **RVDV-II+** (#1-7) attach the guard leg)
- 6) Test speed or speeds (or the shear rate)
- 7) Length of time or number of spindle revolutions to record viscosity.

Appendix D - Spindle and Model Codes

Each spindle has a two digit entry code which is entered via the keypad on the **DV-II+**. The entry code allows the **DV-II+** to calculate Viscosity, Shear Rate and Shear Stress values.

Each spindle has two constants which are used in these calculations. The Spindle Multiplier Constant (**SMC**) used for viscosity and shear stress calculations, and the Shear Rate Constant (**SRC**), used for shear rate and shear stress calculations. Note that where **SRC** = 0, no shear rate/shear stress calculations are done and the data displayed is zero (0) for these functions.

Table D1

SPINDLE	ENTRY CODE	SMC	SRC
RV1	01	1	0
RV2	02	4	0
RV3	03	10	0
RV4	04	20	0
RV5	05	40	0
RV6	06	100	0
RV7	07	400	0
HA1	01	1	0
HA2	02	4	0
HA3	03	10	0
HA4	04	20	0
HA5	05	40	0
HA6	06	100	0
HA7	07	400	0
HB1	01	1	0
HB2	02	4	0
HB3	03	10	0
HB4	04	20	0
HB5	05	40	0
HB6	06	100	0
HB7	07	400	0
LV1	61	6.4	0
LV2	62	32	0
LV3	63	128	0
LV4	64	640	0
LV5	65	1280	0
Spiral	70	105	0.677
T-A	91	20	0
T-B	92	40	0
T-C	93	100	0
T-D	94	200	0
T-E	95	500	0
T-F	96	1000	0
ULA	00	0.64	1.223
TSEL-DIN-81	81	3.7	1.29
SSA-DIN-82	82	3.75	1.29
SSA-DIN-83	83	12.09	1.29
ULA-DIN-85	85	1.22	1.29
ULA-DIN-86	86	3.65	1.29
ULA-DIN-87	87	12.13	1.29

Table D1 (continued)

SPINDLE	ENTRY CODE	SMC	SRC
SC4-14	14	125	0.4
SC4-15	15	50	0.48
SC4-16	16	128	0.2929
SC4-18	18	3.2	1.32
SC4-21	21	5	0.93
SC4-25	25	512	0.22
SC4-27	27	25	0.34
SC4-28	28	50	0.28
SC4-29	29	100	0.25
SC4-31	31	32	0.34
SC4-34	34	64	0.28
SC4-37	37	25	0.36
CP40	40	0.327	7.5
CP41	41	1.228	2
CP42	42	0.64	3.8
CP51	51	5.12	3.84
CP52	52	9.83	2

Table D2 lists the model codes and spring torque constants for each Viscometer model.

Table D2

MODEL	TK	MODEL CODE ON DV-II+ SCREEN
LVDV-II+	0.09373	LV
2.5xLVDV-II+	0.2343	4L
5xLVDV-II+	0.4686	5L
1/4 RVDV-II+	0.25	1R
1/2 RVDV-II+	0.5	2R
RVDV-II+	1	RV
HADV-II+	2	HA
2xHADV-II+	4	3A
2.5xHADV-II+	5	4A
HBDV-II+	8	HB
2xHBDV-II+	16	3B
2.5xHBDV-II+	20	4B
5xHBDV-II+	40	5B

The full scale viscosity range for any **DV-II+** model and spindle may be calculated using the equation:

$$\text{Full Scale Viscosity Range [cP]} = \text{TK} * \text{SMC} * \frac{10,000}{\text{RPM}}$$

Where:

TK = **DV-II+** Torque Constant from **Table D2**

SMC = Spindle Multiplier Constant from **Table D1**

The Shear Rate calculation is:

$$\text{Shear Rate (1/Sec)} = \text{SRC} * \text{RPM}$$

Where:

SRC = Shear Rate Constant from **Table D1**

Appendix E - Calibration Procedures

The accuracy of the **DV-II+** is verified using viscosity standard fluids which are available from Brookfield Engineering Laboratories or your local Brookfield agent. Viscosity standards are Newtonian, and therefore, have the same viscosity regardless of spindle speed (or shear rate). Viscosity standards, calibrated at 25°C, are shown in **Table E1**.

Container size: For Viscosity Standards <30,000 cP, use a 600 ml Low Form Griffin Beaker having a working volume of 500 ml.

For Viscosity Standards ≥30,000 cP, use the fluid container.

Inside Diameter: 3.25"(8.25cm)

Height: 4.75"(12.1cm)

Note: Container may be larger, but may not be smaller.

Temperature: As stated on the fluid standard label: (±) 0.1°C

Conditions: The **DV-II+** should be set according to the operating instructions. The water bath should be stabilized at test temperature. Viscometers with the letters “**LV**” or “**RV**” in the model designation should have the guard leg attached.

Table E1

Normal 25°C Standard Fluids		High Temperature Standard Fluids
Viscosity (cP)	Viscosity (cP)	Three Viscosity/Temperatures**
5	5,000	HT-30,000
10	12,500	HT-60,000
50	30,000	HT-100,000
100	60,000	
500	100,000	**25°C, 93.3°C, 149°C
1,000		Refer to Brookfield catalog for more information.

Brookfield Viscosity Standard Fluid General Information

We recommend that Brookfield Viscosity Standard Fluids be replaced on an annual basis, one year from date of initial use. These fluids are pure silicone and are not subject to change over time. However, exposure to outside contaminants through normal use requires replacement on an annual basis. Contamination may occur by the introduction of solvent, standard of different viscosity or other foreign material.

Viscosity Standard Fluids may be stored under normal laboratory conditions. Disposal should be in accordance with state, local and federal regulations as specified on the material safety data sheet.

Brookfield Engineering Laboratories does not recertify Viscosity Standard Fluids. We will issue duplicate copies of the Certificate of Calibration for any fluid within two years of the purchase date.

Brookfield Viscosity Standard Fluids are reusable provided they are not contaminated. Normal practice for usage in a 600 ml beaker is to return the material from the beaker back into the bottle. When using smaller volumes in accessories such as Small Sample Adapter, UL Adapter or Thermosel, the fluid is normally discarded.

Calibration Procedure for LV(#1-4) and RV,HA,HB(#1-7) Brookfield Spindles

- 1) Place the viscosity standard fluid (in the proper container) into the water bath.
- 2) Lower the **DV-II+** into measurement position (with guard leg if **LV** or **RV** series Viscometer is used).
- 3) Attach the spindle to the Viscometer. If you are using a disk-shaped spindle, avoid trapping air bubbles beneath the disk by first immersing the spindle at an angle, and then connecting it to the Viscometer.
- 4) The viscosity standard fluid, together with the spindle, should be immersed in the bath for a minimum of 1 hour, stirring the fluid periodically, prior to taking measurements.
- 5) After 1 hour, check the temperature of the viscosity standard fluid with an accurate thermometer.
- 6) If the fluid is at test temperature ($\pm 0.1^{\circ}\text{C}$ of the specified temperature, normally 25°C), measure the viscosity and record the Viscometer reading.

Note: The spindle must rotate at least five (5) times before readings are taken.

- 7) The viscosity reading should equal the **cP** value on the fluid standard to within the combined accuracies of the Viscometer and the viscosity standard (as discussed in the section entitled, **Interpretation of Calibration Test Results**, page 37).

Calibration Procedure for a Small Sample Adapter

When a Small Sample Adapter is used, the water jacket is connected to the water bath and the water is stabilized at the proper temperature:

- 1) Put the proper amount of viscosity standard fluid into the sample chamber. The amount varies with each spindle/chamber combination. (Refer to the Small Sample Adapter instruction manual).
- 2) Place the sample chamber into the water jacket.
- 3) Put the spindle into the test fluid and attach the extension link, coupling nut and free hanging spindle (or directly attach the solid shaft spindle) to the **DV-II+**.
- 4) Allow 30 minutes for the viscosity standard, sample chamber and spindle to reach test temperature.
- 5) Measure the viscosity and record the Viscometer reading.

Note: The spindle must rotate at least five (5) times before a viscosity reading is taken.

Calibration Procedure for a Thermosel System

When a Thermosel System is used, the controller stabilizes the Thermo Container at the test temperature.

- 1) Put the proper amount of HT viscosity standard fluid into the HT-2 sample chamber. The amount varies with the spindle used. (Refer to the Thermosel instruction manual).
- 2) Place the sample chamber into the Thermo Container.
- 3) Put the spindle into the test fluid and attach the extension link, coupling nut and free hanging spindle (or directly attach the solid shaft spindle) to the **DV-II+**.
- 4) Allow 30 minutes for the viscosity standard, sample chamber and spindle to reach test temperature.
- 5) Measure the viscosity and record the Viscometer reading.

Note: The spindle must rotate at least five (5) times before a viscosity reading is taken.

Calibration Procedure using UL or DIN UL Adapters

When a UL or DIN UL Adapter is used, the water bath is stabilized at the proper temperature:

- 1) Put the proper amount of viscosity standard fluid into the UL Tube. (Refer to the UL Adapter instruction manual).
- 2) Attach the spindle (with extension link and coupling nut) onto the **DV-II+**.
- 3) Attach the tube to the mounting channel.
- 4) Lower the tube into the water bath reservoir, or if using the ULA-40Y water jacket, connect the inlet/outlets to the bath external circulating pump.
- 5) Allow 30 minutes for the viscosity standard, sample chamber and spindle to reach test temperature.
- 6) Measure the viscosity and record the Viscometer reading.

Note: The spindle must rotate at least five (5) times before a viscosity reading is taken.

Calibration Procedure using a Helipath Stand and T-Bar Spindles

When a Helipath Stand and T-Bar spindles are used:

Remove the T-bar spindle and select a standard LV(#1-4) or RV,HA,HB(#1-7) spindle. Follow the procedures for LV(#1-4) and RV,HA,HB(#1-7) Brookfield spindles outlined above.

T-Bar spindles should not be used for verifying calibration of the **DV-II+** Viscometer.

Calibration Procedure for Spiral Adapter

- 1) Place the viscosity standard fluid (in the proper container) into the water bath.
- 2) Attach the spindle to the viscometer. Attach chamber (SA-1Y) and clamp to the viscometer.
- 3) Lower the **DV-I+** into measurement position. Operate the viscometer at 50 or 60 RPM until the chamber is fully flooded.

- 4) The viscosity standard fluid, together with the spindle, should be immersed in the bath for a minimum of 1 hour, stirring the fluid periodically (operate at 50 or 60 RPM periodically), prior to taking measurements.
- 5) After 1 hour, check the temperature of the viscosity standard fluid with an accurate thermometer.
- 6) If the fluid is at test temperature ($\pm 0.1^{\circ}\text{C}$ of the specified temperature, normally 25°C), measure the viscosity and record the viscometer reading.

Note: The spindle must rotate at least five (5) times for one minute, whichever is greater before readings are taken.

- 7) The viscosity reading should equal the **cP** value on the viscosity fluid standard to within the combined accuracies of the viscometer and the standard (as discussed in the section entitled, **Interpretation of Calibration Test Results**).

Calibration Procedure for Cone/Plate Viscometers:

- 1) Follow the procedures outlined in **Appendix A** for mechanically adjusting the setting of the cone to the plate.
- 2) Refer to **Appendix A, Table 1**, and determine the correct sample volume required for the spindle to be utilized.
- 3) Select a viscosity standard fluid that will give viscosity readings between 10% and 100% of full scale range. Refer to **Appendix B** for viscosity ranges of cone spindles. Consult with Brookfield or an authorized dealer to determine which fluid is appropriate.

It is best to use a viscosity standard fluid that will be close to the maximum viscosity for a given cone spindle/speed combination.

Example: LVDV-II+ Viscometer, Cone CP-42, Fluid 10
Having a viscosity of 9.7 cP at 25°C

At 60 RPM, the full scale viscosity range is 10.0 cP. Thus, the Viscometer reading should be 97% torque and 9.7 cP viscosity ± 0.197 (closer to ± 0.2) cP. The accuracy is a combination of Viscometer and fluid tolerance (refer to **Interpretation of Calibration Test Results**).

- 4) With the viscometer stopped, remove the sample cup and place the viscosity standard fluid into the cup, waiting 10 minutes for temperature equilibrium.
- 5) Connect the sample cup to the Viscometer. Allow 10 minutes for temperature to reach equilibrium.
- 6) Measure the viscosity and record the Viscometer reading in both % torque and centipoise (cP).

Note: The spindle must rotate at least five (5) times before a viscosity reading is taken.

Interpretation of Calibration Test Results:

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

The **DV-II+** is accurate to (\pm) 1% of any full scale spindle/speed viscosity range.

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

Example: Calculate the acceptable range of viscosity using RVDV-II+ with RV-3 Spindle at 2 RPM; Brookfield Standard Fluid 12,500 with a viscosity of 12,257 cP at 25°C:

- 1) Calculate full scale viscosity range using the equation:

$$\text{Full Scale Viscosity Range [cP]} = \text{TK} * \text{SMC} * \frac{10,000}{\text{RPM}}$$

Where: **TK** = 1.0 from **Table D2**
SMC = 10 from **Table D1**

$$\text{Full Scale Viscosity Range} = \frac{1 * 10 * 10,000}{2} = 50,000 \text{ cP}$$

The viscosity is accurate to (+/-) 500 cP (which is 1% of 50,000)

- 2) The viscosity standard fluid is 12,257 cP. Its accuracy is (+/-)1% of 12,257 or (+/-)122.57 cP.
- 3) Total allowable error is (122.57 + 500) cP = (+/-) 622.57 cP.
- 4) Therefore, any viscosity reading between 11,634.4 and 12,879.6 cP indicates that the Viscometer is operating correctly. Any reading outside these limits may indicate a Viscometer problem. Contact the Brookfield technical sales department or your local Brookfield dealer/distributor with test results to determine the nature of the problem.

The Brookfield Guardleg

The *guard leg* was originally designed to protect the spindle during use. The first applications of the Brookfield Viscometer included hand held operation while measuring fluids in a 55-gallon drum. It is clear that under those conditions the potential for damage to the spindle was great. Original construction included a sleeve that protected the spindle from side impact. Early RV guard legs attached to the dial housing and LV guard legs attached to the bottom of the pivot cup with a twist and lock mechanism.

The current guard leg is a band of metal in the shape of the letter U with a bracket at the top that attaches to the pivot cup of a Brookfield Viscometer/Rheometer. Because it must attach to the pivot cup, the guard leg cannot be used with a Cone/Plate instrument. A guard leg is supplied with all LV and RV series instruments, but not with the HA or HB series. It's shape (shown in *Figure 1*) is designed to accommodate the spindles of the appropriate spindle set; therefore, the RV guard leg is wider than the LV due to the large diameter of the RV #1 spindle. They are not interchangeable.

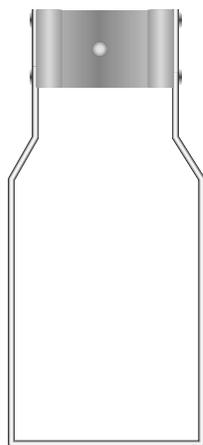
The calibration of the Brookfield Viscometer/Rheometer is determined using a 600 ml Low Form Griffin Beaker. The calibration of LV and RV series instruments includes the guard leg. The beaker wall (for HA/HB instruments) or the guard leg (for LV/RV instruments) define what is called the "outer boundary" of the measurement. The spindle factors for the LV, RV, and HA/HB spindles were developed with the above boundary conditions. The spindle *factors* are used to convert the instrument torque (expressed as the dial reading or %Torque value) into centipoise. Theoretically, if measurements are made with different boundary conditions, e.g., without the guard leg or in a container other than 600 ml beaker, then the spindle factors found on the Factor Finder cannot be used to accurately calculate an absolute viscosity. Changing the boundary conditions does not change the viscosity of the fluid, but it does change how the instrument torque

is converted to centipoise. Without changing the spindle factor to suit the new boundary conditions, the calculation from instrument torque to viscosity will be incorrect.

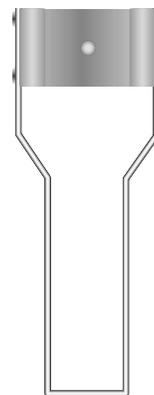
Practically speaking, the guard leg has the greatest effect when used with the #1 & #2 spindles of the LV and RV spindle sets. Any other LV (#3 & #4) or RV (#3 - #7) spindle can be used in a 600 ml beaker with or without the guard leg to produce correct results. The HA and HB series Viscometers/Rheometers are not supplied with guard legs in order to reduce the potential problems when measuring high viscosity materials. HA/HB spindles #3 through #7 are identical to those spindle numbers in the RV spindle set. The HA/HB #1 & #2 have slightly different dimensions than the corresponding RV spindles. This dimensional difference allows the factors between the RV and HA/HB #1 spindles to follow the same ratios as the instrument torque even though the boundary conditions are different.

The recommended procedures of using a 600 ml beaker and the guard leg are difficult for some customers to follow. The guard leg is one more item to clean. In some applications the 500 ml of test fluid required to immerse the spindles in a 600 ml beaker is not available. In practice, a smaller vessel may be used and the guard leg is removed. The Brookfield Viscometer/Rheometer will produce an accurate and repeatable torque reading under any measurement circumstance. However, the conversion of this torque reading to centipoise will only be correct if the factor used was developed for those specific conditions. Brookfield has outlined a method for recalibrating a Brookfield Viscometer/Rheometer to any measurement circumstance in [More Solutions to Sticky Problems](#), Section 3.3.10. It is important to note that for many viscometer users the true viscosity is not as important as a repeatable day to day value. This repeatable value can be obtained without any special effort for any measurement circumstance. But, it should be known that this type of torque reading will not convert into a correct centipoise value when using a Brookfield factor if the boundary conditions are not those specified by Brookfield.

The guard leg is a part of the calibration check of the Brookfield LV and RV series Viscometer/Rheometer. Our customers should be aware of its existence, its purpose and the effect that it may have on data. With this knowledge, the viscometer user may make modifications to the recommended method of operation to suit their needs.



RV Guardleg



LV Guardleg

Appendix F - Special Speed Sets

The following special speeds sets are available from Brookfield Engineering Laboratories. All speeds are in units of RPM.

Table F1

RPM	SPEED SET (RPM)					
Step	SS200	SS150	SS100	SS50	SS25	SSINT
1	0.0	0.0	0.0	0.0	0.0	0.0
2	1.0	0.8	0.5	0.2	0.1	0.3
3	1.4	1.1	0.7	0.3	0.2	0.5
4	1.8	1.4	0.9	0.4	0.3	0.6
5	2.0	1.5	1.0	0.5	0.4	1.0
6	4.0	3.0	2.0	1.0	0.5	1.5
7	6.0	4.0	3.0	1.5	0.7	2.0
8	8.0	6.0	4.0	2.0	1.0	2.5
9	10	7.5	5.0	2.5	1.2	3.0
10	20	15	10	5.0	2.5	4.0
11	40	30	20	10	5.0	5.0
12	60	40	30	15	7.5	6.0
13	80	60	40	20	10	10
14	100	75	50	25	12	12
15	120	90	60	30	15	20
16	140	105	70	35	17	30
17	160	120	80	40	20	50
18	180	135	90	45	22	60
19	200	150	100	50	25	100

Please consult **Brookfield Engineering** or your local dealer/distributor for any special speed requirements not addressed by either the standard speed sets shown in **Table 1** (page 8) or in **Table F1**.

Appendix G - Communications

When using the Brookfield Computer Cable (Brookfield part # DVP-80), the **DV-II+** will output a data string at a rate of approximately 2.5 times per second. When using the Brookfield Printer Cable (Brookfield Part No. DVP-81), the output rate is 1.0 times per second. The **DV-II+** uses the following RS-232 parameters to output these strings:

Baud Rate	9600
Data Bits	8
Stop Bits	1
Parity	None
Handshake	None

The following formulas should be used to calculate and display the Viscometer data after each packet of data is obtained from the **DV-II+**.

$$\text{Viscosity (cP)} = \frac{100}{\text{RPM}} * \text{TK} * \text{SMC} * \text{Torque}$$

$$\text{Shear Rate (1/Sec)} = \text{RPM} * \text{SRC}$$

$$\text{Shear Stress (Dynes/Cm}^2\text{)} = \text{TK} * \text{SMC} * \text{SRC} * \text{Torque}$$

Where:

RPM = Current Viscometer spindle speed in **RPM**

TK = Viscometer torque constant from **Appendix D, Table D2**.

SMC = Current spindle multiplier constant from **Appendix D, Table D1**.

SRC = Current spindle shear rate constant from **Appendix D, Table D1**.

Torque = Current Viscometer torque (%) expressed as a number between 0 and 100.

As an example, consider an **LV** Viscometer using an **SC4-31** spindle, running at 30 **RPM** and currently returning a **Torque** of 62.3 (%). First we list all of the given data and include model and spindle constants from **Appendix D, Tables D1** and **D2**:

RPM = **30** from the example statement.

TK = **0.09373** from **Appendix D** for an **LV** Viscometer.

SMC = **32.0** from **Appendix D** for a type **SC4-31** spindle.

SRC = **0.34** from **Appendix D** for a type **SC4-31** spindle.

Torque = **62.3** from the example statement.

Applying this data to the above equations yields:

$$\text{Viscosity (cP)} = \frac{100}{\text{RPM}} * \text{TK} * \text{SMC} * \text{Torque}$$

$$= \frac{100}{30} * 0.09373 * 32.0 * 62.3$$

$$= 622.9 \text{ cP}$$

$$\text{Shear Rate (1/Sec)} = \text{RPM} * \text{SRC}$$

$$= 30 * 0.34$$

$$= 10.2 \text{ 1/Sec}$$

$$\begin{aligned}
\text{Shear Stress (Dynes/Cm}^2) &= \text{TK} * \text{SMC} * \text{SRC} * \text{Torque} \\
&= 0.09373 * 32.0 * 0.34 * 62.3 \\
&= 63.5 \text{ Dynes/Cm}^2
\end{aligned}$$

The following is a program written in **BASIC** that receives these strings, parses out the appropriate data, performs the above calculations and displays the data to the screen.

```

100 `+
110 `| DV-II+ Communications Demonstration
120 `| Copyright 1992, Brookfield Engineering Laboratories
130 `| Written by Richard Trudell & Greg Krysko
140 `+
150 CLS
160 PRINT SPC(26); "Brookfield Engineering Labs"
170 PRINT SPC(19); "DV-II+ Communications Demonstration Program"
180 PRINT SPC(32); "Copyright 1992"
190 PRINT
200 PRINT "This program is intended to demonstrate the method for obtaining"
210 PRINT "data from the Brookfield Engineering Labs DV-II+ using an RS-232"
220 PRINT "port."
230 PRINT "This program and/or any of the methods used within may be freely"
240 PRINT "used in your own applications."
250 PRINT
260 PRINT "Press any key to continue..."
270 KEYPRESSED$ = ""
280 WHILE KEYPRESSED$ = "" ` Wait for keypress
290     KEYPRESSED$ = INKEY$
300 WEND
310 CLS ` Clear display screen
320 OPEN "COM1:9600,N,8,1,CS,DS,CD" FOR RANDOM AS #1 ` Open com port #1
330 LF$ = CHR$(10) ` Initialize variables
340 ESC$ = CHR$(27)
350 KEYPRESSED$ = ""
360 WHILE KEYPRESSED$ <> ESC$
370     GOSUB 790
380     LF = INSTR(DS$, LF$)
390     IF LF THEN DS$ = LEFT$(DS$, LF - 2)
400     LOCATE 1, 1
410     PRINT "Here is DV-II+ Viscometer raw output data string";
420     LOCATE 2, 1
430     PRINT DS$;
440 `+
450 `| Parse Viscometer data string into constituent parts
460 `+
470 TOR$ = MID$(DS$, 29, 4) ` Torque is char's 29 - 32
480 CPS$ = MID$(DS$, 39, 9) ` Centipoise Value is char's 39 - 47
490 SHS$ = MID$(DS$, 55, 5) ` SS Value is char's 55 - 59
500 SHR$ = MID$(DS$, 67, 5) ` SR Value is char's 67 - 70
510 RPM$ = MID$(DS$, 6, 3) ` Spindle speed is char's 6 - 8
520 MDL$ = MID$(DS$, 13, 5) ` Viscometer model is char's 13 - 17
530 SPD$ = MID$(DS$, 24, 2) ` Viscometer spindle is char's 24 - 26
540 TMP$ = MID$(DS$, 75, 5) ` Temperature starts at char 75

```

```

550  `+                                     +
560  `| Print the parsed Viscometer data string           |
570  `+                                     +
580  LOCATE 4, 1
590  PRINT "Here is Viscometer data parsed into its constituent parts"
600  LOCATE 5, 10: PRINT "RPM           = "; RPM$
610  LOCATE 6, 10: PRINT "MODEL          = "; MDL$
620  LOCATE 7, 10: PRINT "SPINDLE       = "; SPD$; ""
630  LOCATE 8, 10: PRINT "TORQUE %      = "; TOR$
640  LOCATE 9, 10: PRINT "VISCOSITY cP  = "; CPS$
650  LOCATE 10, 10: PRINT "SS Dynes/cm^2 = "; SHS$
660  LOCATE 11, 10: PRINT "SR 1/Sec    = "; SHR$
670  LOCATE 12, 10: PRINT "TEMPERATURE  = "; TMP$
680  DS$ = ""                                     ` NULL OUT DS$
690  LOCATE 13, 1
700  PRINT "Press <Esc> key to end program"
710  IF KEYPRESSED$ <> ESC$ THEN KEYPRESSED$ = INKEY$
720 WEND
730 CLOSE #1                                     ` Close serial port
740 CLS                                         ` Clear the screen
750 LOCATE 12, 32
760 PRINT "PROGRAM STOPPED"
770 END
780 `+                                     +
790 `| Routine to get input from com port           |
800 `+                                     +
810 DS$ = ""
820 WHILE (RIGHT$(DS$, 1) <> LF$) AND (KEYPRESSED$ <> ESC$) ` Wait for a LF 580
    ` If data in inputbuffer, retrieve it
830   IF LOC(1) > 0 THEN DS$ = DS$ + INPUT$(LOC(1), #1)
840   KEYPRESSED$ = INKEY$
850 WEND
860 RETURN

```

Running this program from within **GW BASIC**© produces output as shown below.

Here is **DV-II+** Viscometer raw output data string

```
RPM=50 MD=RV SPDL=29 %=41.4 cP=8280 D/CM2=1035 1/SEC=12.5 T=25.5C
```

Here is Viscometer data parsed into its constituent parts

```

RPM           = 50
MODEL          = RV
SPINDLE       = 29
TORQUE %      = 41.4
VISCOSITY cP  = 8280
SS Dynes/cm^2 = 1035
SR 1/Sec      = 12.5
TEMPERATURE   = 25.5C

```

Press <Esc> key to end program

DV-II+ Serial and Analog Outputs

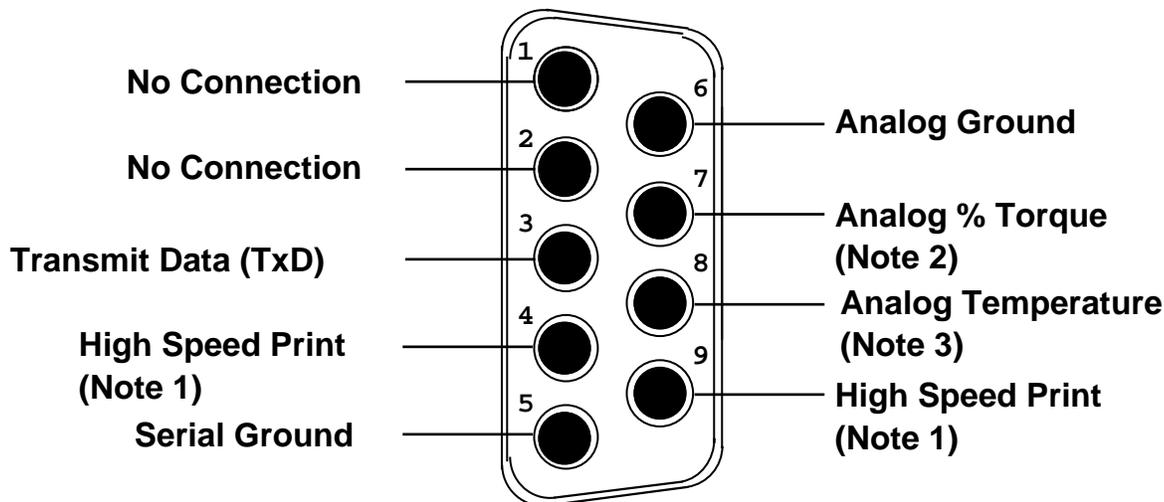


Figure G1

Notes:

1. Placing a jumper across pins 4 and 9 causes the DV-II+ to output printer data at a 3 line-per-second rate. No jumper across pins 4 and 9 retains the once-per-second printer output rate.
2. This is a 0-1 volt d.c. output where 0 volts corresponds to 0% torque and 1 volt corresponds to 100 % torque with a resolution of 1 millivolt (0.1%).
3. This is a 0-4 volt d.c. output where 0 volts corresponds to -100°C and 4 volts corresponds to +300°C with a resolution of 1 millivolt (0.1°C).

Analog Output:

The analog outputs for temperature and % torque are accessed from the 9-pin connector located on the rear panel of the **DV-II+**. The pin connections are shown in **Figure G1**.

The output cable (Part No. DVP-96Y) connections are:

Red Wire:	Temperature Output
Black Wire:	Temperature Ground
White Wire:	% Torque Output
Green Wire:	% Torque Ground

Note: Please contact **Brookfield Engineering Laboratories** or your local dealer/distributor for purchase of the **DVP-96Y** analog output cable.

APPENDIX H - Model A Laboratory Stand

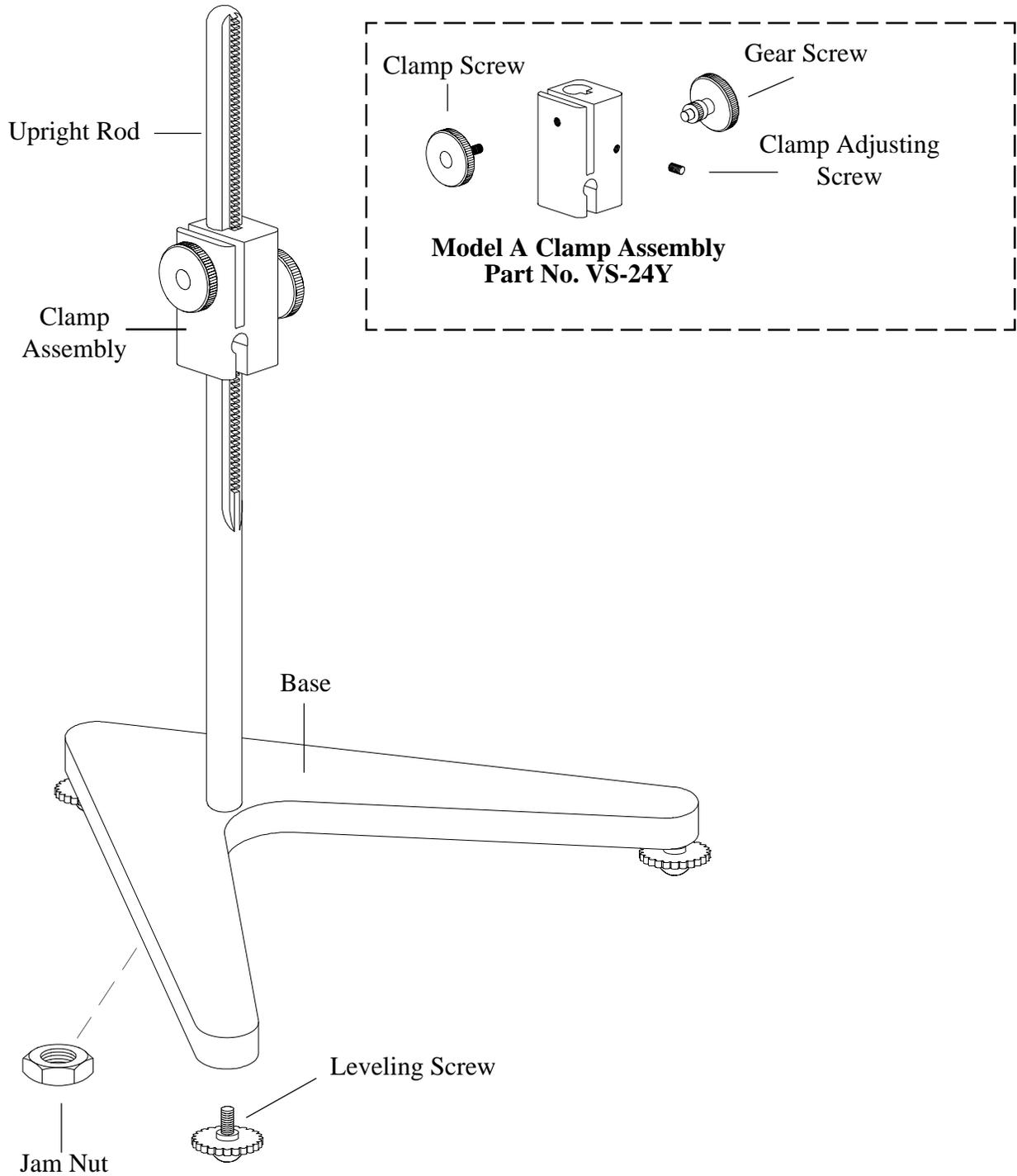


Figure H1

Unpacking

Check carefully to see that all the components are received with no concealed damage.

- | | |
|-------------------|------------------|
| 1 base | 1 jam nut |
| 3 leveling screws | 1 clamp assembly |
| 1 upright rod | |

Remove the three (3) leveling screws from the base and discard the packing material. Remove the jam nut from the upright rod.

Assembly (Refer to Figure H1)

Screw the leveling screws into the base. Insert the threaded end of the upright rod into the hole in the top of the base and attach the jam nut to the rod on the underside of the base. With the rod gear rack facing forward (toward the “V” in the base), gently tighten the jam nut.

Viscometer Mounting

Loosen the Viscometer handle retaining nut (if supplied) and slide it down the power cord. Slide the Viscometer handle (if supplied) toward the cord and remove it from the instrument. Insert the Viscometer handle core into the hole (with the cut-away slot) in the clamp assembly. Adjust the instrument level until the bubble is centered from right to left and tighten the Clamp Screw (clockwise).

Note: The small clamp adjusting screw (Figure H1) on the clamp assembly should be loosened or tightened as necessary to provide smooth height adjustment and adequate support for the Viscometer.

Center the Viscometer relative to the stand base and retighten the jam nut as required. Referring to the Viscometer bubble level, adjust the leveling screws until the instrument is level.

Operation

Rotate the Gear Screw to raise or lower the viscometer.

Appendix I - DVE-50 Probe Clip

Probe Clip DVE-50 is supplied with all model DV-II+ Viscometers, DV-III Rheometers, and Digital Temperature Indicators. It is used to attach the RTD temperature probe to the LV Guard Leg (Part No. B-20Y) or 600 ml low form Griffin beaker. **Figure H1** is a view of the Probe Clip, showing the hole into which the RTD probe is inserted, and the slot which fits onto the LV guard leg. When inserting the RTD probe into the Probe Clip, the upper part of the Clip is compressed by squeezing the points shown in **Figure H1**.

Note: All Viscometer/Rheometer models — except LV — use the Probe Clip as shown in **Figure H3**.

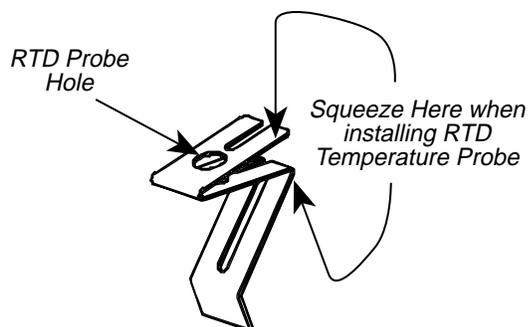


Figure H1

Figure H2 shows the Probe Clip (with RTD temperature probe installed) mounted on the LV guard leg.

Figure H3 shows the Probe Clip mounted in a 600 ml low form Griffin beaker. This mounting may be used with LV, RV, HA and HB series instruments.

Note: The RTD probe must be parallel to the beaker wall so as not to interfere with the viscosity measurement.

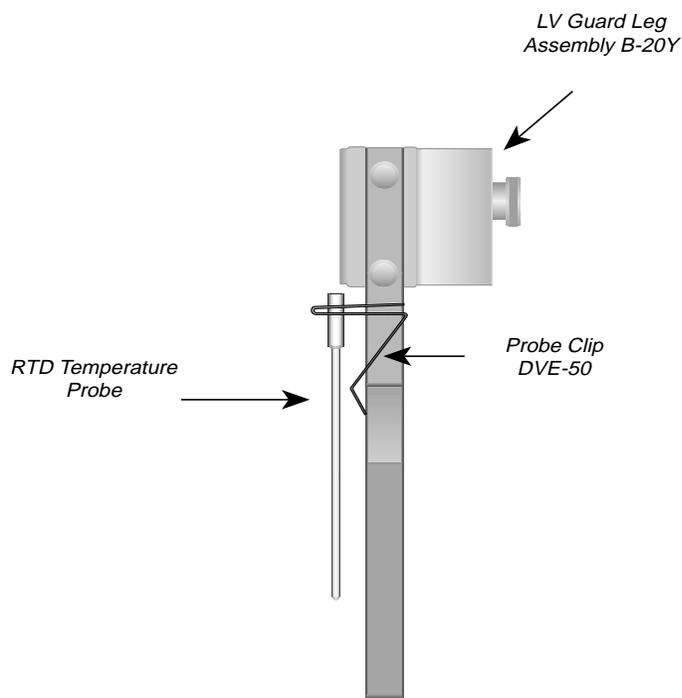


Figure H2

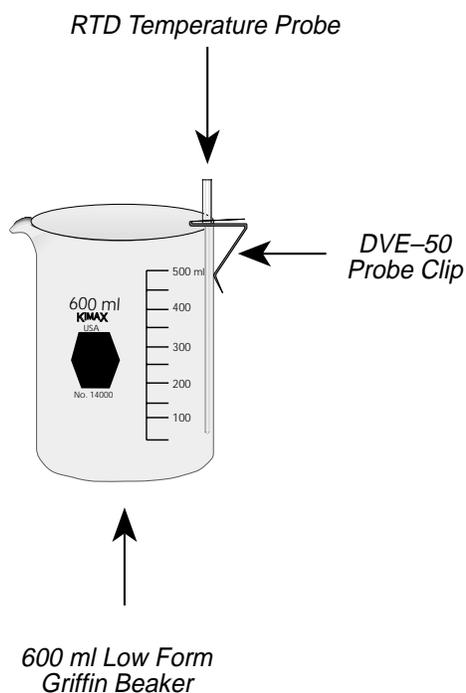


Figure H3

Appendix J - Fault Diagnosis and Troubleshooting

Listed are some of the more common problems that you may encounter while using your Viscometer.

Spindle Does Not Rotate

1. Incorrect power supply
 - Check - must match Viscometer requirements
2. Viscometer not plugged in
 - Connect to appropriate power supply
3. Power switch in “off” position
 - Turn power switch on

Spindle Rotates Eccentrically

1. Viscometer is not level
 - Adjust the laboratory stand
2. Spindle not screwed securely to coupling
 - Tighten
3. Dirt in spindle or Viscometer coupling
 - Clean
4. Bent spindle
 - Check other spindles - replace any that are bent
 - If all rotate eccentrically, contact **Brookfield Engineering Laboratories, Inc.** or your **Brookfield** dealer for repair

Note: Maximum permissible runout is 1/16 inch (1.6 mm) at end of spindle.

5. Spindle coupling bent
 - Contact **Brookfield Engineering Laboratories, Inc.** or your **Brookfield** dealer for repair

No Display Reading

1. Underrange “—” (in cP or SS) when % torque is below zero
 - Change spindle and/or speed
 - Perform an Auto Zero

2. Spindle jammed below zero
 - Contact **Brookfield Engineering Laboratories, Inc.** or your **Brookfield** dealer for repair

Display Reading Over 100

1. Overrange “EEE” (in %, cP, and SS)
 - Change spindle and/or speed

Viscometer Will Not Return to Zero

1. Viscometer is not level
 - Check with spindle out of the sample
 - Adjust the laboratory stand
2. Pivot point or jewel bearing faulty
 - Perform calibration check
 - Contact **Brookfield Engineering Laboratories, Inc.** or your **Brookfield** dealer for repair

Display Reading Will Not Stabilize

1. Check for erratic spindle rotation
 - Verify power supply
 - Contact **Brookfield Engineering Laboratories, Inc.** or your **Brookfield** dealer for repair
2. Bent spindle or spindle coupling
 - Contact **Brookfield Engineering Laboratories, Inc.** or your **Brookfield** dealer for repair
3. Temperature fluctuation in sample fluid
 - Use temperature bath control
4. Special characteristic of sample fluid
 - Refer to **Appendix C**

Inaccurate Readings

1. Incorrect spindle/speed selection
2. Incorrect spindle code entry
3. Non-standard test parameters
4. Temperature fluctuations
5. Incorrect equipment selection
6. Refer to:
 - **Appendix B** - Viscosity Ranges
 - **Appendix C** - Variables in Viscosity Measurement

Recorder Pen Moves in Wrong Direction

1. Output polarity reversed
 - Reverse leads

No Recorder Response

1. Viscometer is at zero reading
2. Recorder is off
3. Output cable leads shorted
4. Recorder is in standby
5. Range setting is incorrect.

Appendix K - 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 no charge warranty service. Transportation is at the purchaser's expense. 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 Laboratories, Inc.

240 Cushing Street
Stoughton, MA 02072 U.S.A.

Telephone: (617) 344-4310 FAX: (617) 344-7141

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