

BROOKFIELD DIGITAL RHEOMETER

MODEL DV-III Operating Instructions

Manual No. **M/91-210-I297**



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I. INTRODUCTION

The Brookfield DV-III Programmable Rheometer measures fluid parameters of Shear Stress and 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-III. The principle of operation of the DV-III 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 measuring range of a DV-III (in centipoise) 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:

Model	Spring Torque	
	dyne-cm	milli Newton - m
LVDV-III	673.7	.0673
RVDV-III	7,187.0	.7187
HADV-III	14,374.0	1.4374
HBDV-III	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-III Rheometer 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-III Rheometer display.

The digital display reads from 00.0-99.9 in the % mode. Overrange is indicated by "EEE"; underrange is "---".

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.

I.1 Components

Component	Part Number
DV-III Rheometer	depends on model
Powerbase, includes:	DVP-2Y
Leveling Screws (3)	VS-3
Upright Rod	VS-20
Jam Nut	VS-21
Clamp Assembly	VS-27

Component	Part Number
Spindle Set with Case LVDV-III set of four spindles or RVDV-III set of seven spindles or HA/HBDV-III set of seven spindles <i>For Cone/Plate versions: a spindle wrench, one cone spindle and sample cup Part No. CP-44Y replace the spindle set.</i>	depends on model SSL SSR SSH
Power Cord for 115 VAC for 230 VAC	depends on model DVP-65 DVP-66
RTD Temperature Probe	DVP-94Y
Ribbon Cable	DVP-32
Guard Leg: LVDV-III RVDV-III	B-20Y B-21Y
Carrying Case	DVP-71Y
Operator Manual	M/91-210
<i>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>	

I.2 Utilities

Autosensing Power Supply:

Input Voltage: 85 - 265 VAC
Input Frequency: 47 - 440 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

Speed Range: 0-250 RPM, 0.1 RPM increments

Viscosity Accuracy: $\pm 1.0\%$ of full scale range for a specific spindle running at a specific speed.

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

Temperature accuracy: $\pm 1.0^\circ\text{C}$ from -100°C to 150°C
 $\pm 2.0^\circ\text{C}$ from +150°C to 300°C

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 attached printer or PC. See Appendix H of Brookfield application software program called RHEOCALC.

Weight:	Gross Weight	35 lbs	15.9 kg
	Net Weight	32 lbs	14.5 kg
	Carton Volume	2.0 cu ft	.057 m ³

I.4 Battery Back-Up

When the Rheometer is turned off or there is a power failure, a built-in battery saves spindle parameters (used to calculate centipoise, shear rate and shear stress), default settings and the test data from the last program test run .

Battery life is greater than 10 years. The battery is replaceable by Brookfield Engineering Labs.

I.5 Set-Up

- 1) Place the upright rod into the hole at the front of the base. The rack gear and clamp assembly should face the rear of the base (see Figure 1). 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).

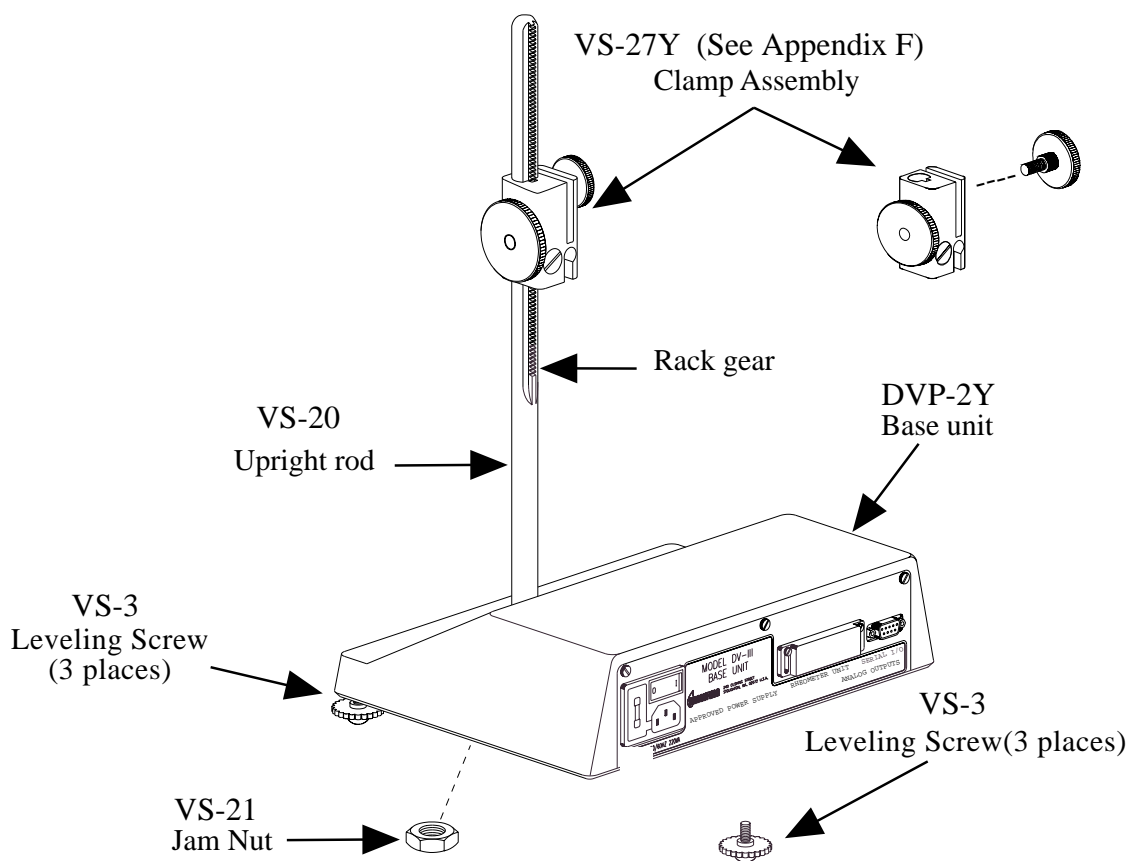


Figure 1 (Rear View)

- 2) Insert the mounting handle on the back of the DV-III into the hole on the clamp assembly (Figure 2).

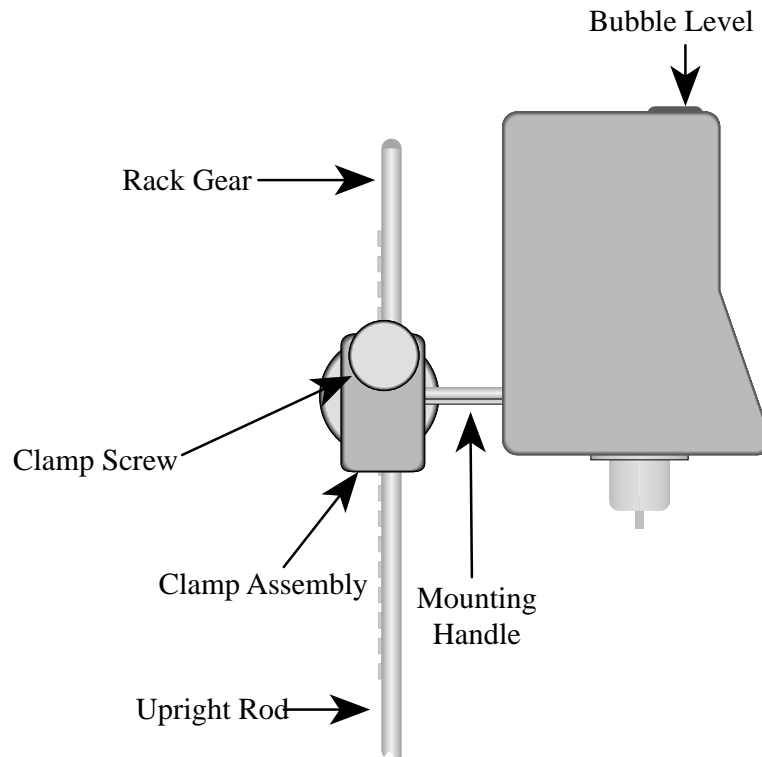


Figure 2

- 3) Tighten the DV-III clamp Screw (Figure 2).

Note: If the clamp assembly moves along the upright rod too freely, tighten the tension screw (see Appendix F).

- 4) Select the ribbon cable end with the adjacent, heavy, black mass. Insert this end of the ribbon cable into the DV-III Rheometer head. Insert the other end of the ribbon cable into the connector on the DV-III base (see Figure 3).

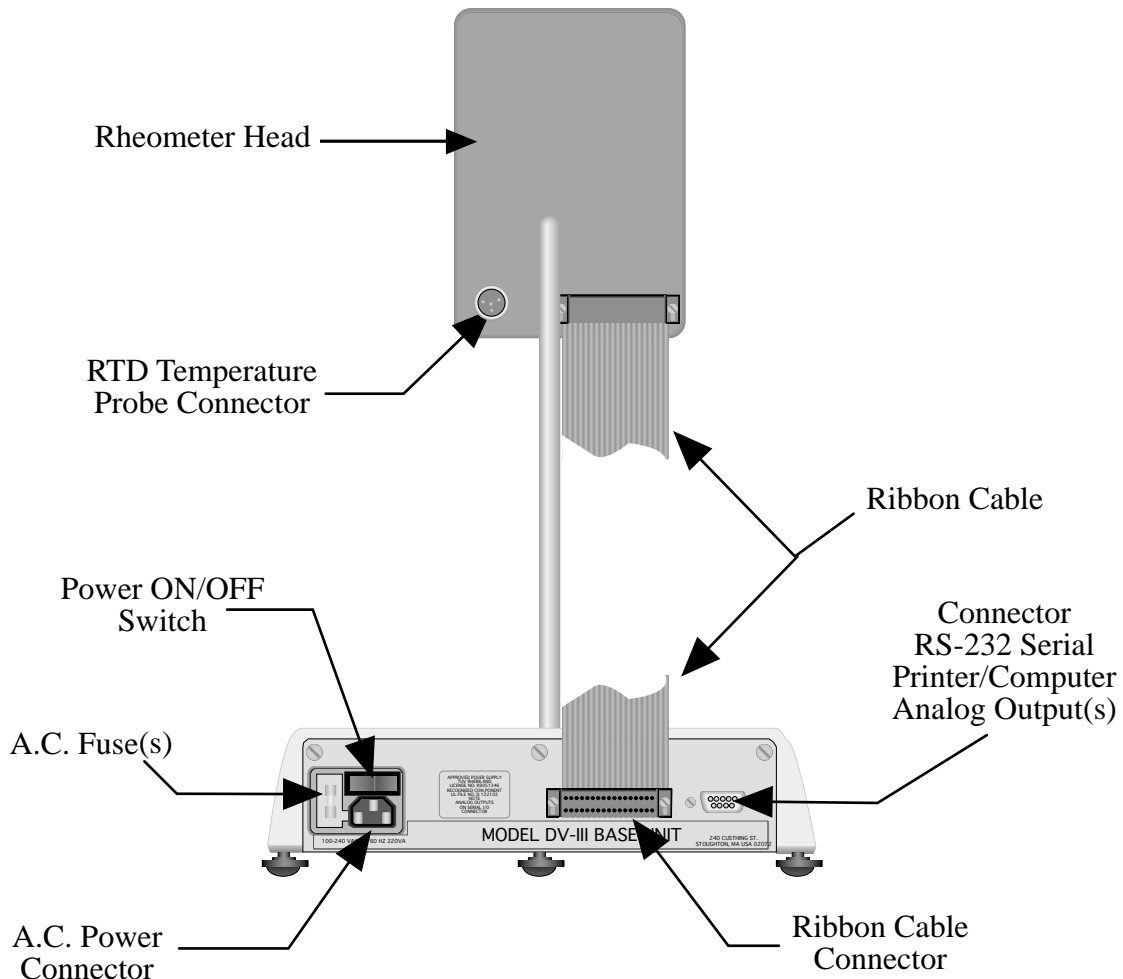


Figure 3

- 5) Connect the RTD probe to the socket on the back side of the DV-III Rheometer (Figure 3).
- 6) The Rheometer must be leveled before the instrument is zeroed and readings are taken. The level is adjusted using the three leveling screws on the base. Adjust so that the bubble level on top of the DV-III (Figures 1, 2) is centered within the circle.
- 7) Make sure that the AC power switch at the rear of the base unit is in the OFF position. Connect the AC plug to the socket on the back of the DV-III base and plug it into the appropriate AC line.

The DV-III must be earth grounded to ensure against electronic failure!!

- 8) Temperature monitoring is assured (after the instrument has stabilized) to within $\pm 1.0^{\circ}\text{C}$ in the range -100°C to $+150^{\circ}\text{C}$ and within 2°C in the range 150°C to 300°C .
- 9) For Cone/Plate models refer to Appendix A.

I.6 Key Functions

Figure 4 shows the control keys on the face of the DV-III Rheometer. The following describes each key's function.

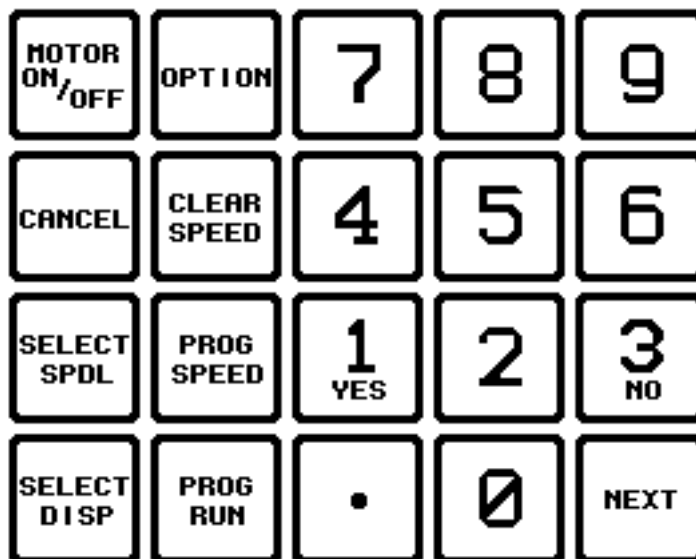


Figure 4



MOTOR ON/OFF

Turns the motor on or off.



CANCEL

Cancels any operation, and returns screen display to the main screen.



SELECT SPDL

Allows selection of and accepts the spindle to be used.



SELECT DISP

Selects the parameter to be displayed:

- %** Viscometer Torque (%)
- cP** Viscosity (cP or mPa·s)
- SS** Shear Stress (Dynes/cm² or Newtons/m²)
- SR** Shear Rate (1/Sec)



OPTION

Configures the DV-III printer output; changes between °C and °F temperature; sets high and low alarms; displays and/or prints test data; selects either CGS or SI units; sets printer handshakes.



CLEAR SPEED

Removes a test program from memory.



PROG SPEED

Constructs a test program. Allows you to review/modify an existing test program. Executes a selected program.



PROG RUN

Starts a test program, and chooses which steps to run, and in what order. Also moves from one step to the next when entering a step program.



NUMBER KEYS (0 through 9)

Sets speeds and choose items from various dialog screens and the option menu.



NEXT

Functions as an ENTER key similar to a computer by serving to accept a keyboard entry.

II. GETTING STARTED

II.1 Autozero

Before readings may be taken, the Rheometer must be autozeroed. This is done each time the power switch is turned on or any time the user chooses. The Rheometer will guide you through the procedure, as follows:

Turn power switch on; as shown in Figure 5, the screen indicates that the DV-III is in the standalone mode (is not connected to a computer) and gives the version of the operating firmware (the built in program which controls the instrument) and a two-digit alphanumeric code which indicates the Model number (see Table D2 in Appendix D; the code tells the spring torque rating of your Rheometer).

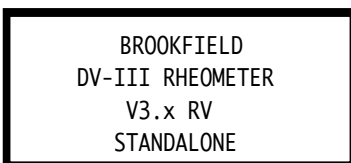


Figure 5

No key press is necessary. After a short pause the display will read **“REMOVE SPINDLE, LEVEL RHEOMETER AND PRESS THE MOTOR ON/OFF KEY TO: AUTOZERO.”** Before beginning the autozero procedure, Brookfield recommends that you allow 10 minutes for the instrument to warm up.

After pressing the MOTOR ON/OFF key, the screen “flashes” for approximately 15 seconds while the DV-III autozeros.

After 15 seconds the display reads **“AUTOZERO IS COMPLETE REPLACE SPINDLE AND PRESS NEXT KEY.”** Press the NEXT key.

After pressing the NEXT key, the main screen is displayed and the DV-III is ready for a Spindle Code Entry (Figure 6).

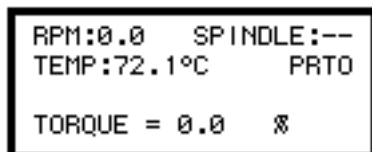


Figure 6

II.2 Spindle Entry

The DV-III must have a Spindle Entry Code number to calculate Viscosity, Shear Rate and Shear Stress values. The DV-III 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 of this manual). Note that the DV-III will remember the Spindle Entry Code which was in use when the power was turned off. Therefore, the following example is used when the instrument is turned on for the first time, or when you change spindles. This example assumes that the DV-III has been zeroed and that the NEXT key has been pressed after autozero, as instructed by the screen.

The starting screen is the main screen display (Figure 6). Pressing the SELECT SPDL key causes the cursor to blink under the field for the first number of the Spindle Entry Code (Figure 7).

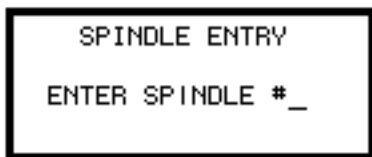


Figure 7

Enter the two digit code for the spindle you intend to use. Spindle Entry Code numbers are found in Appendix D. Pressing the SELECT SPDL key once more accepts the spindle entered. If the spindle number entered was not valid, an error message will be momentarily displayed and you will have to re-enter your spindle selection.

II.3 Non-Programmed Viscosity Measurements

Often, a viscosity measurement at only one or two rotational speeds is required. The DV-III may be run where speed is entered and the Viscosity, Torque %, Shear Stress or Shear rate values are read from the display. After the DV-III has been leveled and the autozero procedure described earlier has been done, the spindle is attached, and the test fluid is in the proper position. The procedure is:

- 1) Insure that the correct spindle number is shown at the end of the first line on the display. If the number shown is not for the spindle you are using, change to the correct spindle number using the procedure in the previous section *Spindle Entry*.
- 2) Insure the motor is on. If the first line of the display reads *MOTOR: OFF*, press the MOTOR ON/OFF key and the display will show RPM: 0.0.
- 3) Enter the required speed by pressing the appropriate numeric keys. Figure 8 shows 11 rpm has been entered.

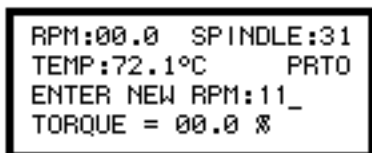


Figure 8

- 4) Press the NEXT key to accept the speed and start the motor.
- 5) Viscosity, % Torque, Shear Rate and Shear Stress values are alternately displayed by pressing the SELECT DISP key to scroll through the values. Figure 8 shows the display for % torque. To run other speeds, repeat Steps 3 and 4.
- 6) Stop the motor by either pressing the MOTOR ON/OFF key, or by setting the motor speed to zero (0) RPM as per steps 3 and 4 above.

Note: The data points taken at these speeds are not saved in the Rheometer memory. When in Program mode, as explained in the next section, the data points are saved.

III. PROGRAM MODE TESTING

The DV-III can store 10 speed set programs and each program may have up to 25 steps. The program locations are numbered 0 through 9.

There are two types of test programs:

- 1) **Next Speed Set** where the test speeds are programmed, and the operator must signal the DV-III to change speeds (and therefore take a reading) by pressing the NEXT key.
- 2) **Prog Speed Set** where the DV-III will perform the test automatically.

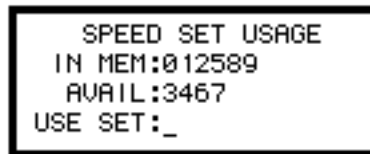
Each step of a program has two variables - speed and hold time. The reading is taken at the end of the hold time interval in a Prog Speed Set or when the NEXT key is pressed in a Next Speed Set.

If the first step hold time interval is 0 seconds, the program is a Next Speed Set type. If the first step interval is 1 second or more, the program is a Prog Speed Set type.

III.1 Next Mode Speed Set Program

To create a Next Speed Set Program, proceed as follows:

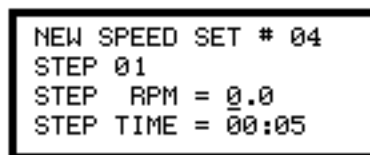
- 1) Press the PROG SPEED key.
- 2) Choose and enter an available speed set program from the list on the screen using the numeric keys to enter the location number. The screen will automatically switch from Figure 9 to Figure 10. In Figure 9, the available speed sets shown are: 3,4,6,7.



```
SPEED SET USAGE
IN MEM:012589
AVAIL:3467
USE SET:_
```

Figure 9

- 3) Figure 10 indicates speed set 4 was selected. Enter the first step speed using the numeric keys. The speed must be between 0.1 rpm and 250.0 rpm, in increments of 0.1 rpm.



```
NEW SPEED SET # 04
STEP 01
STEP RPM = 0.0
STEP TIME = 00:05
```

Figure 10

- 4) Press the NEXT key to accept the first step speed. The cursor moves to the time field.
- 5) Enter the first step time by entering all zeros in the field.
- 6) Press the NEXT key to accept the first step time. The cursor moves back to the first step speed field.
- 7) Press the NEXT key again and the first program step is accepted and the screen displays step number two with cursor waiting for the first entry of the speed field.
- 8) Enter each new speed (up to a maximum of 25) and press the NEXT key to accept each new speed.

- 9) If the program is to have less than 25 steps, the End Program Entry command is given by entering "0" for the step speed as the final program step. If the program is to have 25 steps, entry is ended automatically after the 25th step.

Next Mode Speed Set Notes:

- a) The NEXT key has three functions:
 - 1) Accept the value just entered.
 - 2) Move the cursor between the speed and time field for the first step.
 - 3) Move from step field to step field.
- b) If any value other than zero (0) is entered as the time value in the first step, the program will not be a Next Speed Set Program.
- c) Zero (0) RPM is not a valid speed in Next mode.

III.2 Prog Mode Speed Set Program

To create a Prog Speed Set Program, proceed as follows:

- 1) Press the PROG SPEED key.
- 2) Choose an available speed set program from the list on the screen using the numeric keys to enter the location number. The screen, as explained in the preceding section, will automatically switch from Figure 9 to Figure 10.
- 3) Enter the first step speed using the numeric keys. The speed must be between 0.0 rpm and 250.0 rpm, in increments of 0.1 rpm.
- 4) Press the NEXT key to accept the first step speed. The cursor moves to the time field.
- 5) Enter the first step time which may be any time other than 00:00 and must be between 1 second and 99 minutes, 59 seconds. The format is *MM:SS* (Minutes:Seconds). The default time is 00:05.
- 6) Press the NEXT key to accept the time entry. The cursor moves back to the speed field.

Note: If you wish to change any entry in either the speed or time field, you need only enter (write over) the entry and accept again by pressing the NEXT key.
- 7) Press the PROG RUN key to accept the first step. The display changes to the second step.
- 8) Repeat steps 3 through 7 for as many steps (up to a maximum of 25 steps) as are required.
- 9) If the program is to have less than 25 steps, the End Program Entry command is given by entering "0" for both step speed and time values as the final program step. If the program is to have 25 steps, the entry mode is ended automatically after the 25th step.

Prog Mode Speed Set Notes:

- a) The NEXT key has two functions:
 - 1) Accepts the value just entered.
 - 2) Moves the cursor between the speed field and the time field.
- b) In any Prog Speed mode program, the step time that you accept in any step is presented as the default time for the next step.

Example: If the time in step 3 is 30 seconds (00:30), when the display changes (to step 4) 00:30 will appear in the time field as the new default time.

You now have two choices:

- i) The time may be changed to another (01:30, for instance) following steps 4 through 6 above (the new time will overwrite the old time automatically).
- ii) The default time of 00:30 may be accepted by pressing the NEXT key after the speed entry (to accept the speed) and then the PROG RUN key to move to the next step. In this case, by not pressing the NEXT key to accept the previous time (00:30), the sequence automatically moves to the next Prog Speed step.

If the time was changed from 00:30 to 01:30 (and accepted by pressing the NEXT key), this time would become the default time for the next Prog Speed step.

- c) If a mistake is made in entering speed or time, it may be corrected by pressing the NEXT key twice to move out of the field you are in and back into the field to be changed.

Example: If the speed entered was 25.5, and 25.3 was required, the NEXT key is pressed twice after 25.5 is entered. This would move the cursor back to the beginning of the speed field. 25.3 is entered, overwriting the 25.5 entry.

- d) The DV-III will accept 0 (zero) as a valid speed, but will not accept 0 as a valid time in a Prog Speed mode program.

III.3 Reviewing NEXT and PROG Speed Set Programs

You must select the Review/Modify Option when you wish to review or modify a program.

- 1) From the main screen, press the PROG SPEED key and enter the number of the speed set program to be reviewed or modified. You can only select from the "IN MEM" line on the screen display. Figure 11 shows speed set 2 was selected.

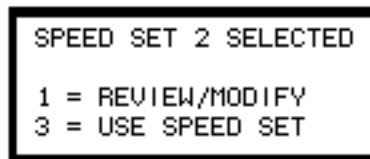


Figure 11

Now press 1 = Review/Modify (or from the "Program Complete" box after a program has been entered, press the number 1 key Review/Modify).

- 2) To review program steps, press the PROG RUN key and scroll through the steps.
- 3) To modify the speed and time fields you enter new values; press the NEXT key to accept them and to move between the fields. After you have modified a step you press PROG RUN to move to the next step in the program.
- 4) Press the CANCEL key to exit and accept any changes you may have made.

III.4 Using a Speed Set Program from Memory

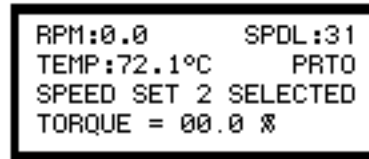
To use a speed set immediately after it is entered, begin with the Program Complete screen shown in Figure 12.



```
PROGRAM COMPLETE
SPEED SET #2
1 = PROGRAM/MODIFY
3 = USE SPEED SET
```

Figure 12

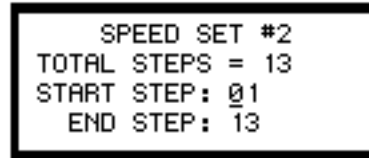
- 1) Press the number 3 key: Use Speed Set. The screen display will be similar to Figure 13.



```
RPM:0.0      SPDL:31
TEMP:72.1°C  PRTO
SPEED SET 2 SELECTED
TORQUE = 00.0 %
```

Figure 13

- 2) Press PROG RUN. The screen in Figure 14 appears.



```
SPEED SET #2
TOTAL STEPS = 13
START STEP: 01
END STEP: 13
```

Figure 14

- 3) Enter the step which will be the starting step. Note that all steps, or just a portion of the steps may be used. Additionally, the steps may be run in reverse order.

The steps used are always consecutive; that is if steps 2, 3, 4 and 5 of a 10 step program are to be used, steps 1, 6, 7, 8, 9, and 10 will not be used.

- 4) Press the NEXT key to move the cursor to the End Step field. This accepts the start step number.
- 5) Enter the number of the step you want to be the end step.
- 6) Press the NEXT key to accept the End Step.
- 7) Press the PROG RUN key to start the test.
- 8) Alternatively, you may simply bypass the Start Step,End Step sequence and use all of the program steps, as programmed, by pressing the PROG RUN key in step 4 above.

If a speed set is memory resident (i.e. was written and stored previously), the procedure to use a speed set begins with the main screen (Figure 6).

- 1) Press the PROG SPEED key.
- 2) Enter the number of the speed set to be used from the IN MEM line (see Figure 9).
- 3) Follow steps 1 through 6 as outlined earlier in this section.

Speed Set Usage Notes:

- 1) When a speed set is used, all the captured test data is stored in memory until another speed set test is run. When the next (either a *new* or *memory resident*) speed set test begins, the last captured test data is over-written.
- 2) After a speed set is executed, the data is retained in memory by the DV-III even if the power switch is turned off.
- 3) To halt a running program, press the PROG RUN key. Spindle rotation will stop and the following screen will be displayed:



Figure 15

Press PROG RUN to continue the program where you left off. The step time will pick up at the time it halted. Press the CANCEL key to stop the program.

III.5 Operator Lock-Out

Operator Lock-Out is used in conjunction with a speed set program that is loaded and ready to run. It locks out most of the operating functions, leaving the operator with access to the SELECT DISP, MOTOR ON/OFF, PROG RUN, NEXT and CANCEL keys. This reduces the chance for errors in data gathering. Only the speed set program, which you choose for lockout, will run. You cannot inadvertently change the current *spindle entry* and thus have incorrect Viscosity, Shear Rate or Shear Stress data.

The procedure for setting Lock-Out is as follows. Start from the main screen after power up, Autozero and Select SPDL entry have been completed:

- 1) Press the PROG SPEED key.
- 2) Select a speed set.
- 3) Press the number 3 key to use the speed set (as shown in Figure 11).
- 4) Press PROG RUN.
- 5) Press OPTION and the Lock-Out Options screen will be displayed.

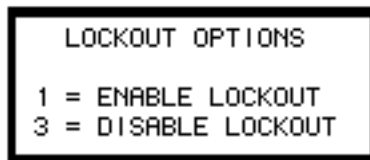


Figure 16

- 6) Press the NUMBER 1 key to Enable Lock-Out and the screen changes to the step sequence screen (Figure 14) ready for you to select your step sequence.
- 7) Press PROG RUN and the program begins running in Lock-Out mode. Note that the top line of the DV-III main screen is changed to display the letters **LK** indicating that the DV-III is

operating in the Lock-Out mode.

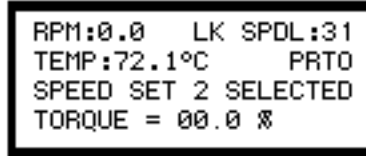


Figure 17

To review data, print data or exit the Lock-Out mode, you have to disable lock-out.

- 1) Press the PROG RUN key.
- 2) Press the OPTION key and the Lock-out Options screen will be displayed.
- 3) Press NUMBER 3 to disable Lock-Out and the screen changes to the step sequence screen (Figure 14) ready for you to select your step sequence.
- 4) Press CANCEL and you are returned to the main screen.

Refer to Section IV. The Options Menu, for data review and/or printing.

III.6 Clearing a Speed Set from Memory

If a speed set program is no longer required it may be deleted from memory using the following procedure. From the main screen:

- 1) Press the CLEAR SPEED key.
- 2) Enter the number of the speed set you wish to clear.
- 3) Press key number **1** = YES to clear the speed set.
- 4) Press CANCEL to return to the main screen.

Note: You cannot CLEAR a speed set from memory if it is loaded and ready to run (as shown in Figure 13). You must remove it from the selected use position first. You can unload (but *not* delete) the currently loaded program using the following procedure. From the main screen:

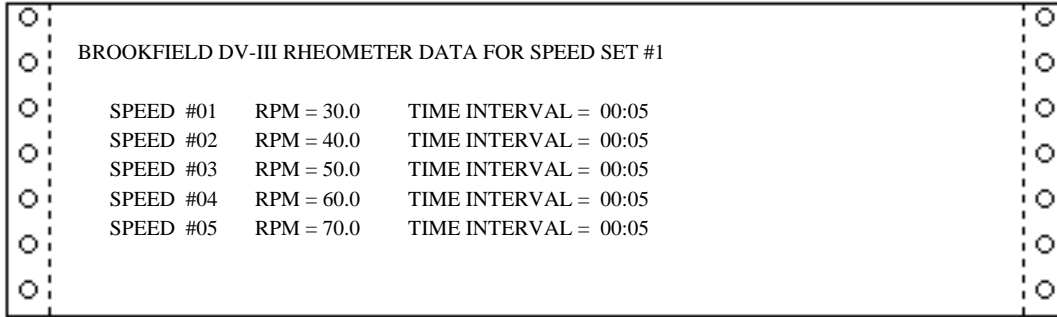
- 1) Press the PROG SPEED key twice.

III.7 Printing a Speed Set Stored in Memory

Speed set programs stored in any of the 10 speed set memory locations may be printed to the serial printer. The following procedure is used starting from the main screen:

- 1) Press the PROG SPEED key.
- 2) Select the speed set to be printed. (See Figure 9)
- 3) Press key NUMBER 1 = Review/Modify. (See Figure 11)
- 4) Press the OPTION key.
- 5) In response to the screen display, make sure your printer is ready for printing, then press any

key. The speed set program will be printed on the attached printer as shown below.



BROOKFIELD DV-III RHEOMETER DATA FOR SPEED SET #1		
SPEED #01	RPM = 30.0	TIME INTERVAL = 00:05
SPEED #02	RPM = 40.0	TIME INTERVAL = 00:05
SPEED #03	RPM = 50.0	TIME INTERVAL = 00:05
SPEED #04	RPM = 60.0	TIME INTERVAL = 00:05
SPEED #05	RPM = 70.0	TIME INTERVAL = 00:05

Figure 18

IV. THE OPTIONS MENU

The OPTION key is used to display the Options Menu screen. The Options Menu provides choices of the following options:

OPTIONS MENU	
1 PRINT	4 C -> F
2 ALARMS	5 CGS -> SI
3 DATA	6 HSK ON

Figure 19

1 - PRINT	set modes, when a serial printer is attached
2 - ALARMS	setting-high, low, and motor On/Off limits
3 - DATA	review of captured data
4 - C TO F	choice of temperature display
5 - CGS TO SI	choice of CGS or SI units
6 - HKS (ON/OFF)	handshake serial printer communication parameter

IV.1 Print Options

The DV-III is equipped with an RS-232 compatible serial output, which may be used with a serial printer. The output characteristics are described in Appendix G.

The DV-III is designed to print with an X-on/X-off protocol, whereby the rheometer will not send test data to the printer unless and until the printer sends it a signal saying that it is ready to receive data. If the DV-III cannot tell that the printer is ready or connected, it assumes that the data has been received and printed. Unfortunately, there is no design standard for the X-on/X-off communication between printer and the transmitting device (DV-III). If you are not using a Brookfield serial printer, you may have to experiment with the HSK ON/OFF setting to see if you can use the X-on/X-off protocol. If possible, we suggest setting HSK to ON. To check your system, we suggest the following:

- 1) Setup the printer and connect to the DV-III.
- 2) Set the DV-III to PRTN mode.

Press the OPTION key.
Press NUMBER 1 in the Options Menu.
Press NUMBER 3 to set PRTN.
- 3) The screen will change to the Options Menu.
- 4) Press NUMBER 6 to read "6 HSK On".
- 5) Press the CANCEL key to return to the main screen.
- 6) Enter a motor speed.
- 7) Press the NEXT key.

This should cause the printer to print one line of data. If there is no communication between the DV-III and the printer, a message screen will appear advising that the printer is not ready (Figure 20):

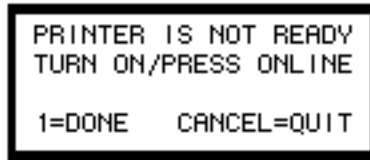


Figure 20

If the printer is connected correctly, and is “on line”, but does not print, this indicates that the printer is not using the X-on/X-off protocol and HKS should be set to “OFF”. Press the CANCEL key to return to the main screen, then:

- 1) Press the OPTION key to display the Options Menu.
- 2) Press the NUMBER 6 key to set HSK to OFF.
- 3) Press the CANCEL key to return to the main screen.
- 4) Press the NEXT key to print a line of data.

If the printer still does not print, check all printer connections, power switch and function modes. Be sure the printer is on-line ready to receive data.

Test data may be printed in the following manner:

- 1) After each step in a Next Speed Set mode or Prog Speed Set mode program when the print option is set to **3** = PRINT NEXT/LINE (PRTN).
- 2) At the conclusion of a data gathering sequence. Before the data gather takes place, the DV-III is set to STOP PRINTING (PRTO) mode. Press the OPTION key. Press 1 in the OPTIONS menu. Press 1 to set PRTO. Run the test. The data is automatically stored in the DV-III.

The *Options Menu* (3 DATA) is used to print the test data.

- 3) Printed continuously when the print option is set to **2** = CONTINUOUS PRINT (PRTC). Data is printed as quickly as possible (approximately one line per second). A sample of this print mode is shown in *Figure 21*.

○	RPM=70.0	MD=2R	SPL=31	%=42.3	cP=969	D/CM2=230	1/SEC=23.8	T=22.2C	○
○	RPM=70.0	MD=2R	SPL=31	%=42.3	cP=969	D/CM2=230	1/SEC=23.8	T=22.2C	○
○	RPM=70.0	MD=2R	SPL=31	%=42.4	cP=966	D/CM2=230	1/SEC=23.8	T=22.2C	○
○	RPM=70.0	MD=2R	SPL=31	%=42.4	cP=966	D/CM2=230	1/SEC=23.8	T=22.2C	○
○	RPM=70.0	MD=2R	SPL=31	%=42.4	cP=971	D/CM2=231	1/SEC=23.8	T=22.2C	○
○	RPM=70.0	MD=2R	SPL=31	%=42.4	cP=969	D/CM2=231	1/SEC=23.8	T=22.2C	○
○	RPM=70.0	MD=2R	SPL=31	%=42.3	cP=969	D/CM2=230	1/SEC=23.8	T=22.2C	○
○	RPM=70.0	MD=2R	SPL=31	%=42.3	cP=969	D/CM2=230	1/SEC=23.8	T=22.2C	○
○									○
○									○

Figure 21

The print option status is clearly displayed on the main screen at all times. For example, as shown earlier in Figures 6, 8 and 13, “PRTO” indicates that the print mode in these cases is “PRINT OFF”.

IV.2 Alarm Options

There are three adjustable alarm settings: **LO ALARM %**, **HI ALARM %** and **MOTOR OFF %**. The values are set in the Set Alarms mode. Alarms are used to signal the operator that the fluid is out of specification. The alarms are set in % torque values, not Viscosity, Shear Stress or Shear Rate values. The range of values which may be entered for each alarm and their default values are:

LO ALARM:

Minimum value: 10%
Maximum value: 99.9%
Default value: 10%

HI ALARM:

Minimum value: 0%
Maximum value: 100%
Default value: 99.9%

MOTOR OFF:

Minimum value: 0%
Maximum value: 115%
Default value: 110%

The procedure for entering and enabling alarm values is as follows starting from the main screen:

- 1) Press the OPTION key to display the Options Menu.
- 2) Press the NUMBER 2 key to display the Alarms Options screen.
- 3) Press the NUMBER 1 key to View/Set Alarms.
- 4) Enter the LO ALARM % torque value. The new entry will overwrite the default values.
- 5) Press the NEXT key to accept the LO ALARM % value and move the cursor to the HI ALARM % field.
- 6) Enter the HI ALARM % torque value. The new entry will overwrite the default values.
- 7) Press the NEXT key to accept the HI ALARM % value, the cursor moves to the MOTOR OFF % field.
- 8) Enter the MOTOR OFF % torque value. The new entry will overwrite the default value.
- 9) Press the NEXT key to accept the MOTOR OFF % value.

The cursor has moved to the LO ALARM % field. If you wish to change the first entry, the value may now be entered. The NEXT key must be pressed after the new entry to accept this new value. If you wish to change any of the other values of HI ALARM % or MOTOR OFF %, you can proceed to over-write them using the NEXT key to accept the new values.

- 10) Press the OPTION key to return to the ALARMS OPTIONS screen.
- 11) Press the NUMBER 3 key to enable (turn on) / disable (turn off) the alarms.

12) Press CANCEL to exit.

NOTE: The LO ALARM is tripped after the % torque reading goes above the alarm setting and then falls below the setting. The beeping may be shut off by either the % torque reading rising above the alarm setting or by pressing the motor ON/OFF key.

The HI ALARM is tripped after the % torque reading goes above the alarm setting. The beeping may be shut off by either the % torque reading falling below the alarm setting or by pressing the motor ON/OFF key.

The MOTOR OFF is tripped after the % torque reading goes above the motor off setting. The DV-III stops rotating and the instrument beeps. Pressing any key turns off the beep.

IV.3 Data Options

The Review Data menu allows data review of the most recently completed speed set program. Data may be reviewed on the DV-III screen, on a serial printer, or both. The procedure for reviewing data after a test is as follows:

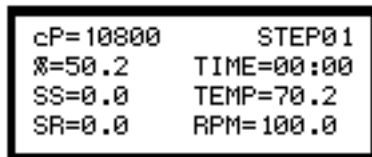
- 1) At the conclusion of a speed set program, the DV-III will prompt to press the NEXT or PROG RUN key. Press the NEXT key to return to the main screen.
- 2) Press the OPTION key.
- 3) Press the NUMBER 3 key to display the Review Data screen (Figure 22).



```
REVIEW DATA
1 = SCREEN ONLY
2 = SCREEN & PRINTER
3 = PRINTER ONLY
```

Figure 22

- 4) Select one of the review modes: press “NUMBER 1” for DV-III screen only, “NUMBER 2” for DV-III screen and printer, or “NUMBER 3” for printer only. Note that you should select options 2 and 3 only if the printer is connected and “on-line.”
- 5) If NUMBER 1 or NUMBER 2 were pressed, data from the first step is either displayed on the screen (Figure 23) or displayed and printed. Press the NEXT key to scroll through and display/print the remaining step data.



```
cP=10800      STEP01
%=50.2       TIME=00:00
SS=0.0       TEMP=70.2
SR=0.0       RPM=100.0
```

Figure 23

- 6) If the NUMBER 3 key (printer only) is selected, the DV-III prompts to “**READY PRINTER PRESS ANY KEY**” or “**PRINTER IS NOT READY TURN ON/PRESS ONLINE**”. A sample of printed output is shown in Figure 24.

○	Sample Name: _____	○
○	Operator Name: _____	○
○	Date: 06/21/91 Time: 10:06 Model: 2R Spindle: 31	○
○	#01 RPM=30.0 %=18.2 cP=970 D/CM2=100 1/SEC=10.2 T=22.1C TIME=00:05	○
○	#02 RPM=40.0 %=24.3 cP=972 D/CM2=132 1/SEC=13.6 T=22.1C TIME=00:05	○
○	#03 RPM=50.0 %=30.3 cP=969 D/CM2=164 1/SEC=17.0 T=22.1C TIME=00:05	○
○	#04 RPM=60.0 %=36.3 cP=967 D/CM2=197 1/SEC=20.4 T=22.1C TIME=00:05	○
○	#05 RPM=70.0 %=42.3 cP=966 D/CM2=230 1/SEC=23.8 T=22.1C TIME=00:05	○
○		○
○		○

Figure 24

Review data notes:

- 1) The DV-III stores data from the most recent speed set program test. When a subsequent speed set program is run, any test data in memory will be overwritten and the previous data will be lost.
- 2) If the “Printer Only” option is selected, the date, time of day, model and spindle number are printed with the test results. The DV-III does not store time and date when it is turned off; therefore, the time and date must be entered when printing the first time after start-up.

The date is entered as 6 consecutive digits in mm/dd/yy or, dd/mm/yy format. The time is entered in 4 consecutive digits for 24 hour format; for example, 2:30PM is entered as 1430 hours.

ENTER TIME & DATE

DATE :

TIME :

Figure 25

Press the option key to start printing after date/time entry.

- 3) The DV-III may be set-up to “handshake” (using **XOn/XOff** protocol) or not handshake when connected to a serial printer. If you opt to use the handshake mode, your printer is “on line”, all cable connections are correct and your printer is set for handshake mode, then data should appear on your printer immediately. If it does not appear, and instead you see the message: “**PRINTER IS NOT READY TURN ON/PRESS ONLINE**” then you should turn the handshake option off. This is done from the Options menu as described previously in the section “Print Options” (see Section IV.1).

IV.4 Temperature Display °C or °F

The DV-III will display temperature in either °F or °C. The choice is made from the *Options* screen. From the main screen, the procedure is:

- 1) Press the OPTION key.
- 2) Press the number **4** key to change the display from °F to °C (or °C to °F).
- 3) Press the CANCEL key to return to the main screen.

Table 1

Temperature Accuracies For Programmable Rheometer Model DV-III	
Temperature Range	Temperature Accuracy
-100°C to +150°C	±1.0°C
+150°C to +300°C	±2.0°C

IV.5 Units Display CGS or SI

The DV-III will display viscosity, shear stress and shear rate in either **CGS** or **SI** units. The choice is made from the Options screen. From the main screen, the procedure is:

- 1) Press the OPTION key.
- 2) Press the number NUMBER 5 key to change the display from CGS to SI (or SI to CGS).
- 3) Press the CANCEL key to return to the main screen.

Note: After selecting a units change, a recalculation of all data currently stored in the rheometer will occur. Exit from the Options menu will result in an immediate display of data in the selected format.

IV.6 HSK (Hand Shake)

The DV-III is designed to print with X-on/X-off protocol, whereby the rheometer will not send test data to the printer unless and until the printer sends it a signal saying that it is ready to receive data. If the DV-III can not tell that the printer is ready or connected, it assumes that the data has been received and printed. Unfortunately, there is no design standard for the X-on/X-off communication between printer and the transmitting device (DV-III). If you are not using a Brookfield serial printer, you may have to experiment with the HSK ON/OFF setting to see if you can use the X-on/X-off protocol. If possible, we suggest setting HSK to ON. Refer to Section IV.1.

Once this option is set, the DV-III remembers the last handshake state.

IV.7 Diagnostics

On DV-III Rheometers with firmware Version 3.0, the diagnostics routines may be executed by holding the SELECT DISP key when the rheometer power switch is turned on.

The necessary instructions are given via "on screen" instructions with one exception: when the keyboard test is run, the operator must press every key on the control panel.

Note that the transducer alignment section of the program is used by authorized Brookfield service technicians and is not used in normal circumstances. The procedure for activating Diagnostics from the main screen is:

- 1) Press the OPTION key.
- 2) Press the NUMBER 5 key.
- 3) Follow the instructions on the screen.

APPENDIX A - Cone/Plate Rheometer Set-Up

The Cone/Plate (C/P) version of the DV-III Rheometer 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, Part No. CP-44Y) up towards the cone until two small pins (one in the cone, the second mounted on the plate) contact slightly, and then by separating (lowering) the plate 0.0005inch (0.013mm).

Note that the Cone/Plate Rheometer requires the use of a 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 Rheometer is set up on the DVP-2Y stand and has been zeroed and leveled with no cone attached. Cone CP-40 is used in the illustrations. The water bath is on, set at the same test temperature that you will use when measuring the viscosity of your sample and is connected to the sample cup (Figure A1). Allow enough time for the bath to reach the test temperature. The Rheometer should be set at 10 RPM with motor OFF.

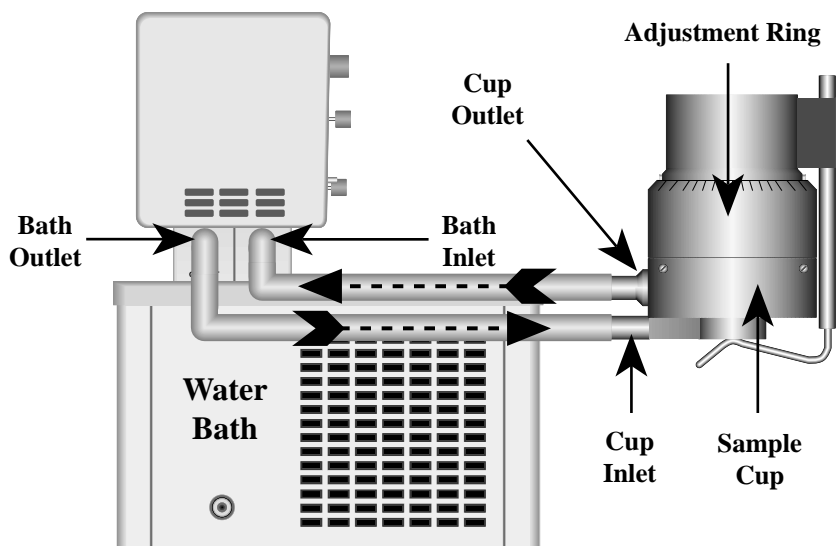


Figure A1

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

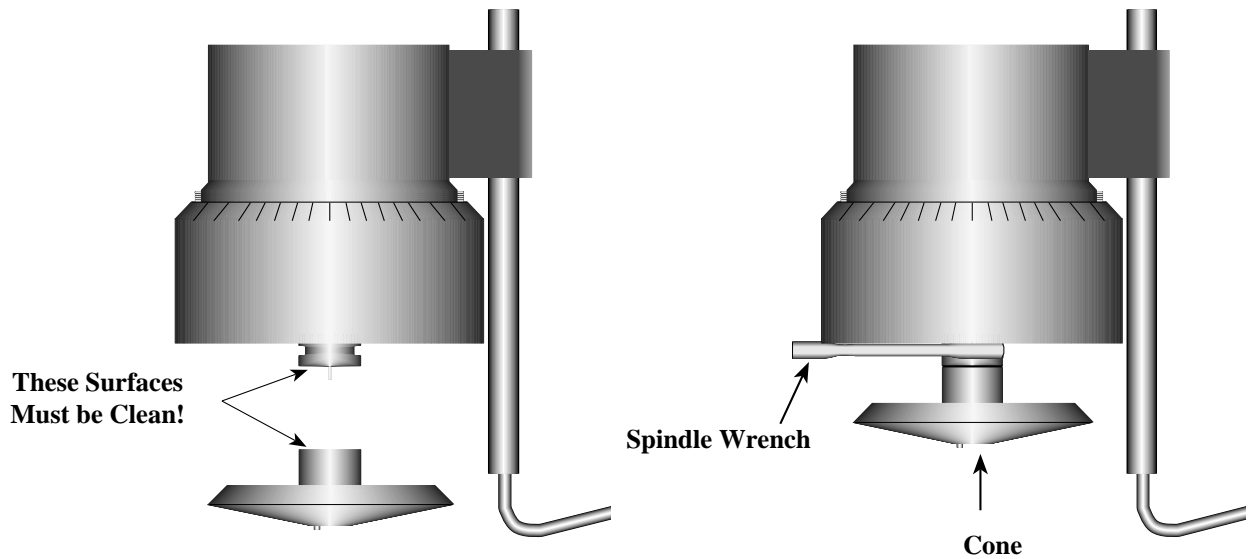


Figure A2

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.

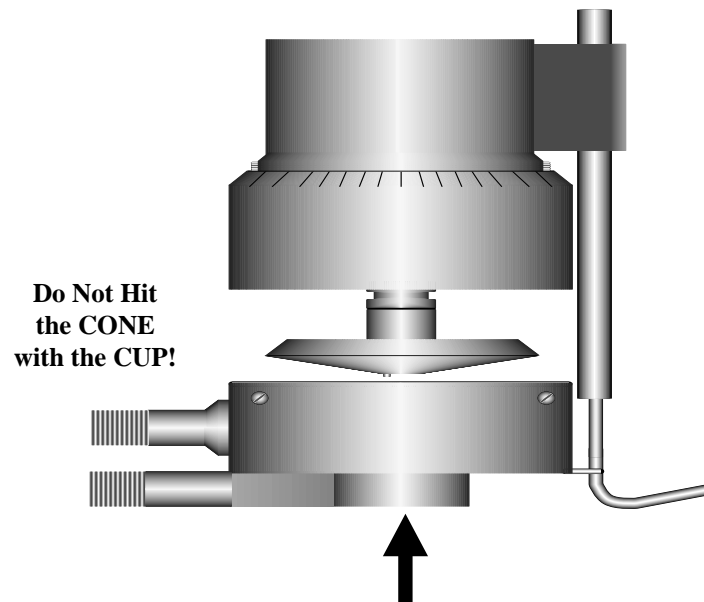


Figure A3

Start the DV-III running at 10 rpm. Readings of % (Torque) will be utilized for setting the cone/plate gap. 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 0.0% (Figure A4).

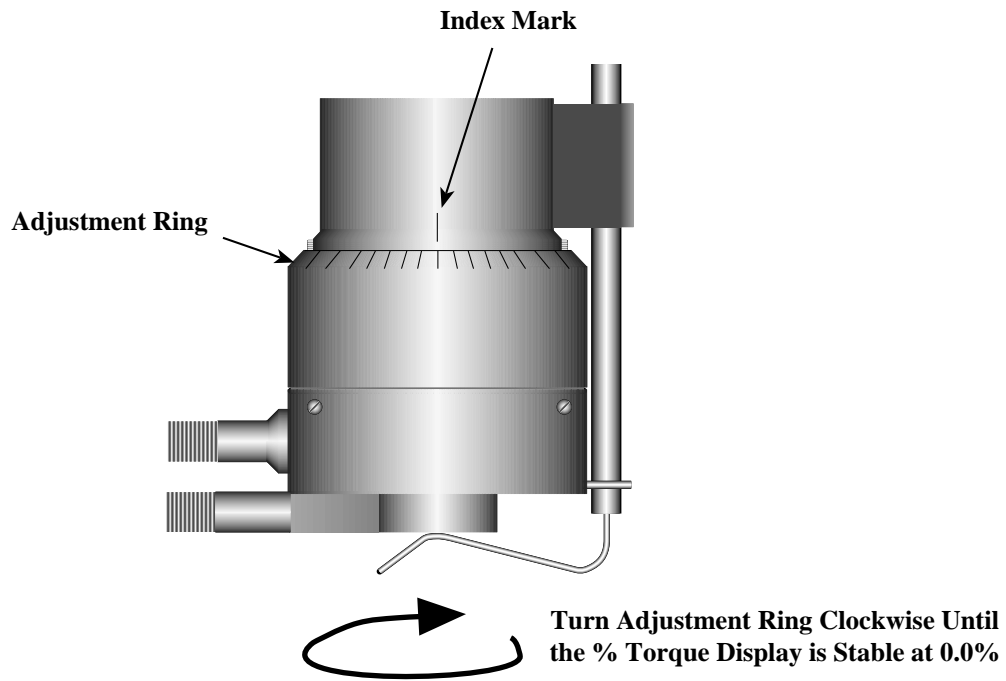


Figure A4

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 Rheometer % display (Figure A5). Remember that you are trying to raise the cup 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 adjustment ring until the display reading jumps from 0.0 to 0.4% (HA and HB models) or from 0.0 to 0.6% (RV models) or 0.0 to 1.0% (LV models). This is the HIT POINT. The cup may have to be adjusted up and down several times before this deflection is satisfactorily reached. The LV series DV-III Rheometer will be the *most sensitive*.

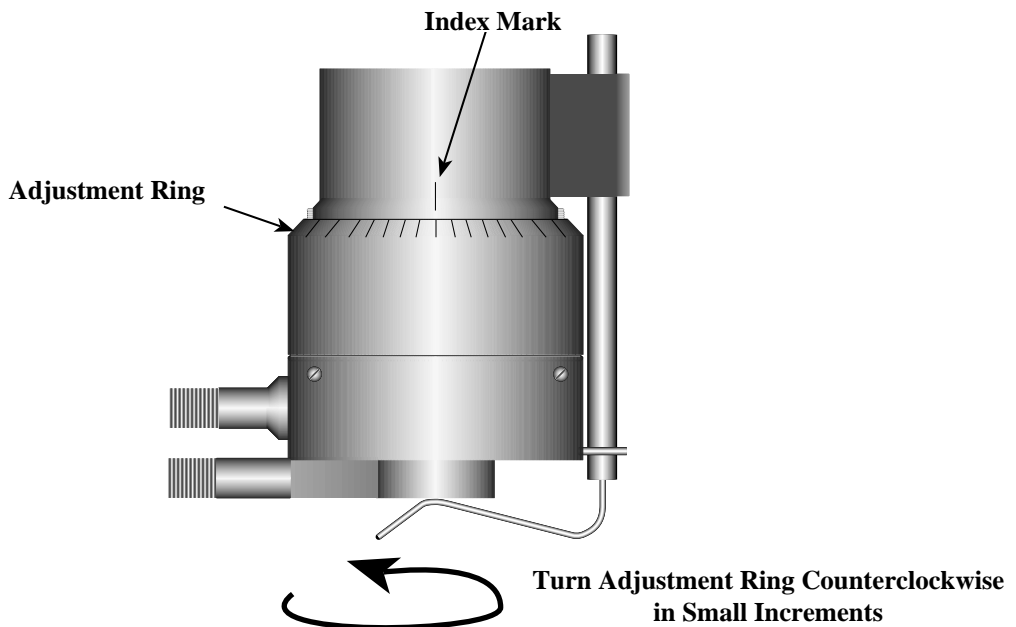


Figure A5

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).

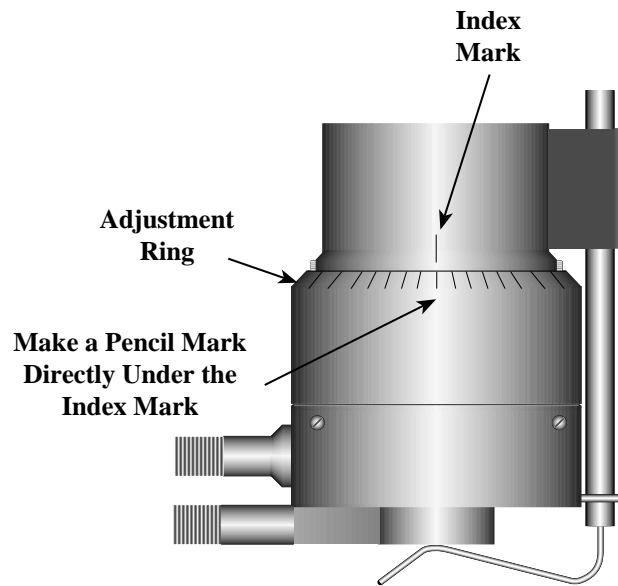


Figure A6

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). This is a very important step because if it is not done, the pins may touch constantly and may cause wear and damage to the cone, cup and instrument. The Rheometer is now mechanically set and ready for sample measurement (Figure A7).

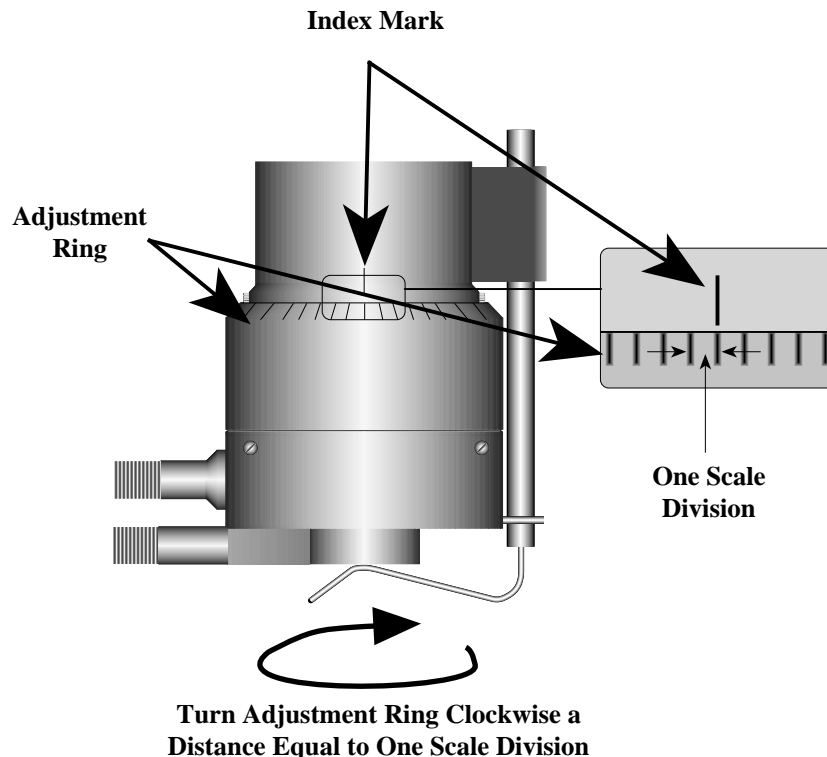


Figure A7

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).

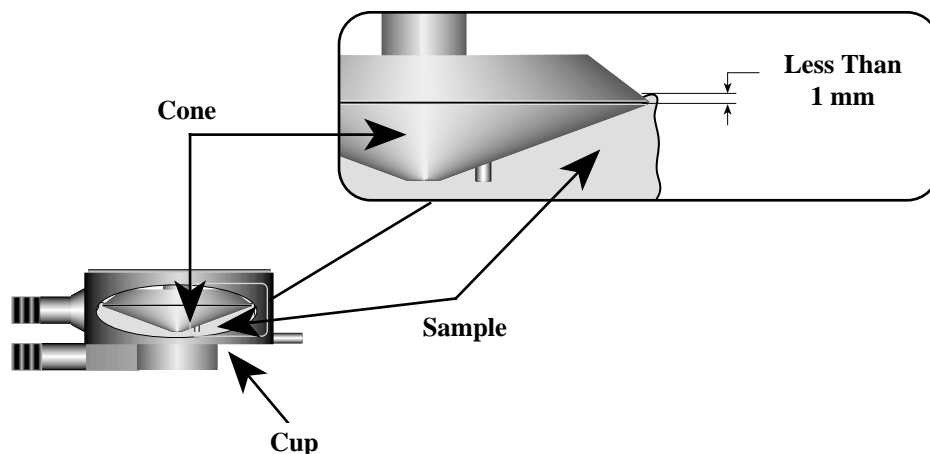


Figure A8

- Notes:**
- The cup may be removed without resetting the gap.
 - Remove the spindle from the Rheometer 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 above procedures for mechanically adjusting the setting of the cone spindle to the plate.
- Refer to Table A1, and determine the correct sample volume required for the selected spindle.
- 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-III Rheometer, 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 Rheometer reading should be 97% torque and 9.7 cP viscosity ± 0.197 (0.1 cP for the viscometer plus 0.97 cP for the fluid). The accuracy is a combination of Rheometer and fluid tolerance (refer to Interpretation of Calibration Test Results).

- 4) With the Rheometer stopped, remove the sample cup and place the viscosity standard fluid into the cup.
- 5) Connect the sample cup to the Rheometer. Allow sufficient time for temperature to reach equilibrium. Typically 15 minutes is the maximum time that you must wait. Less time is required if the spindle and cup are already at test temperature.
- 6) Measure the viscosity and record the Rheometer reading in both % torque and centipoise (cP).

Notes: 1. Mineral oil viscosity standard fluids are recommended for use with Brookfield Cone/Plate Viscometers when measuring at shear rates $>500 \text{ sec}^{-1}$ or when measuring viscosity above 5000 cP.

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

APPENDIX B - Viscosity Ranges

The table below (Universal Spindle Ranges) lists the Spindle Range Coefficients for all spindles used on DV-III Rheometers. Dividing the coefficient number by any of the 2,500 Rheometer speeds will give the full scale viscosity range for a Rheometer/spindle/speed combination.

Universal Spindle Ranges

Spindle	Entry Code	Spindle Range Coefficient			
		Rheometer Series			
		LV	RV	HA	HB
RV1	01	937	10,000	20,000	80,000
RV2	02	3,750	40,000	80,000	320,000
RV3	03	9,375	100,000	200,000	800,000
RV4	04	18,750	200,000	400,000	1,600,000
RV5	05	37,500	400,000	800,000	3,200,000
RV6	06	93,750	1,000,000	2,000,000	8,000,000
RV7	07	375,000	4,000,000	8,000,000	32,000,000
HA1	01	937	10,000	20,000	80,000
HA2	02	3,750	40,000	80,000	320,000
HA3	03	9,375	100,000	200,000	800,000
HA4	04	18,750	200,000	400,000	1,600,000
HA5	05	37,500	400,000	800,000	3,200,000
HA6	06	93,750	1,000,000	2,000,000	8,000,000
HA7	07	375,000	4,000,000	8,000,000	32,000,000
HB1	01	937	10,000	20,000	80,000
HB2	02	3,750	40,000	80,000	320,000
HB3	03	9,375	100,000	200,000	800,000
HB4	04	18,750	200,000	400,000	1,600,000
HB5	05	37,500	400,000	800,000	3,200,000
HB6	06	93,750	1,000,000	2,000,000	8,000,000
HB7	07	375,000	4,000,000	8,000,000	32,000,000
LV1	61	6,000	64,000	128,000	512,000
LV2	62	30,000	320,000	640,000	2,560,000
LV3	63	120,000	1,280,000	2,560,000	10,240,000
LV4	64	600,000	6,400,000	12,800,000	51,200,000
LV5	65	1,200,000	12,800,000	25,600,000	102,400,000
T-A	91	18,750	200,000	400,000	1,600,000
T-B	92	37,440	400,000	800,000	3,200,000
T-C	93	93,600	1,000,000	2,000,000	8,000,000
T-D	94	187,200	2,000,000	4,000,000	16,000,000
T-E	95	468,000	5,000,000	10,000,000	40,000,000
T-F	96	936,000	10,000,000	20,000,000	80,000,000
Spiral	70	98,400	1,050,000	2,100,000	8,400,000
ULA	00	600	6,400	12,800	51,200

Universal Spindle Ranges

Spindle	Entry Code	Spindle Range Coefficient			
		Rheometer Series			
		LV	RV	HA	HB
DIN-81	81	3,420	36,500	73,000	292,000
DIN-82	82	3,420	36,500	73,000	292,000
DIN-83	83	11,340	121,300	242,600	970,400
DIN-85	85	1,144	12,200	24,400	97,600
DIN-86	86	3,420	36,500	73,000	292,000
DIN-87	87	11,340	121,300	242,600	970,400
SC4-14	14	117,200	1,250,000	2,500,000	10,000,000
SC4-15	15	46,880	500,000	1,000,000	4,000,000
SC4-16	16	120,000	1,280,000	2,560,000	10,240,000
SC4-18	18	3,000	32,000	64,000	256,000
SC4-21	21	4,688	50,000	100,000	400,000
SC4-25	25	480,000	5,120,000	10,240,000	40,960,000
SC4-27	27	23,440	250,000	500,000	2,000,000
SC4-28	28	46,880	500,000	1,000,000	4,000,000
SC4-29	29	93,750	1,000,000	2,000,000	8,000,000
SC4-31	31	30,000	320,000	640,000	2,560,000
SC4-34	34	60,000	640,000	1,280,000	5,120,000
SC4-37	37	23,440	250,000	500,000	2,000,000
CP-40	40	307	3,270	6,540	26,160
CP-41	41	1,151	12,280	24,560	98,240
CP-42	42	600	6,400	12,800	51,200
CP-51	51	4,800	51,200	102,400	409,600
CP-52	52	9,216	98,300	196,600	786,400

Notes: RV spindle ranges are calculated with the RV Guard Leg in use.
 LV spindle ranges are calculated with the LV Guard Leg in use.

Example 1: Determine the full scale viscosity range of the LV3 spindle running on an RV series Rheometer at 45 RPM.

Spindle Speed = 45 RPM

LV3 Spindle Range Coefficient for RV series Rheometer = 1,280,000

$$\text{Full Scale Viscosity Range} = \frac{1,280,000}{45} = 28,444 \text{ cP (mPa}\cdot\text{s)}$$

Example 2: Determine the full scale viscosity range of the LV3 spindle running on a 2xHA Rheometer at 103.5 RPM.

Spindle Speed = 103.5 RPM

LV3 Spindle Range Coefficient for 2xHA Rheometer = 2 x 2,560,000

$$\text{Full Scale Viscosity Range} = \frac{5,120,000}{103.5} = 49,468 \text{ cP (mPa}\cdot\text{s)}$$

Note: The maximum viscosity that should be taken from the DV-III Rheometer is at 100% of any full scale spindle/speed range.

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

Viscosity Range (cP)		
Viscometer	Min	Max
LVDV-III	15	6,000,000
RVDV-III	100	40,000,000
HADV-III	200	80,000,000
HBDV-III	800	320,000,000

Small Sample Adapter

Spindle	Shear Rate (s ⁻¹)	Viscosity (cP)			
		LV cP	RV cP	HA cP	HB cP
14	0 - 80	47.0 - 1,171,000	500.0 - 12,500,000	1,000.0 - 25,000,000	4,000 - 100,000,000
15	0 - 96	19.0 - 468,650	200.0 - 5,000,000	400.0 - 10,000,000	1,600 - 40,000,000
16	0 - 58	48.0 - 1,199,700	512.0 - 12,800,000	1,024.0 - 25,600,000	4,100 - 102,400,000
18	0 - 264	1.3 - 30,000	12.8 - 320,000	25.6 - 640,000	103 - 2,560,000
21	0 - 186	1.9 - 46,865	20.0 - 500,000	40.0 - 1,000,000	160 - 4,000,000
25	0 - 44	192.0 - 4,790,000	2,050.0 - 51,200,000	4,100.0 - 102,400,000	16,400 - 409,600,000
27	0 - 68	9.4 - 234,325	100.0 - 2,500,000	200.0 - 5,000,000	800 - 20,000,000
28	0 - 56	18.8 - 468,650	200.0 - 5,000,000	400.0 - 10,000,000	1,600 - 40,000,000
29	0 - 50	37.5 - 937,300	400.0 - 10,000,000	800.0 - 20,000,000	3,200 - 80,000,000
31	0 - 68	12.0 - 300,000	128.0 - 3,200,000	256.0 - 6,400,000	1,024 - 25,600,000
34	0 - 56	24.0 - 600,000	256.0 - 6,400,000	512.0 - 12,800,000	2,048 - 51,200,000
37	0 - 72	9.4 - 234,325	100.0 - 2,500,000	200.0 - 5,000,000	800 - 20,000,000
82	0 - 258	1.4 - 10,000	15.0 - 10,000	30.0 - 10,000	120 - 10,000
83	0 - 258	4.6 - 50,000	50.0 - 50,000	100.0 - 50,000	400 - 50,000

Thermosel

Spindle	Shear Rate (s ⁻¹)	Viscosity (cP)			
		LV cP	RV cP	HA cP	HB cP
18	0 - 264	1.3 - 30,000	12.8 - 320,000	25.6 - 640,000	103 - 2,560,000
21	0 - 186	1.9 - 46,865	20.0 - 500,000	40.0 - 1,000,000	160 - 4,000,000
27	0 - 68	9.4 - 234,325	100.0 - 2,500,000	200.0 - 5,000,000	800 - 20,000,000
28	0 - 56	18.8 - 468,650	200.0 - 5,000,000	400.0 - 10,000,000	1,600 - 40,000,000
29	0 - 50	37.5 - 937,300	400.0 - 10,000,000	800.0 - 20,000,000	3,200 - 80,000,000
31	0 - 68	12.0 - 300,000	128.0 - 3,200,000	256.0 - 6,400,000	1,024 - 25,600,000
34	0 - 56	24.0 - 600,000	256.0 - 6,400,000	512.0 - 12,800,000	2,048 - 51,200,000
81	0 - 258	1.4 - 10,000	15.0 - 10,000	30.0 - 10,000	120 - 10,000

UL Adapter

UL Spindle	Shear Rate (1/SEC)	Viscosity (cP)			
		LVDV-III	RVDV-III	HADV-III	HBDV-III
YULA-15 or 15Z	0 - 122.4	1.0 - 2,000	3.2 - 2,000	6.4 - 2,000	25.6 - 2,000

Note: LV DV-III - Minimum viscosity, 1.0 cP at 60RPM, 10% of full scale range.

Note: RV,HA,HB-III - Minimum viscosity; 3 cP, 6 cP and 24 cP, at 230.9 RPM, 10% of full scale range.

Din Adapter

DAA Spindle	Shear Rate (1/SEC)	Viscosity (cP)			
		LVDV-III	RVDV-III	HADV-III	HBDV-III
85	0 - 258	0.6 - 5,000	6.1 - 5,000	12.2 - 5,000	48.8 - 5,000
86	0 - 258	1.8 - 10,000	18.2 - 10,000	36.5 - 10,000	146 - 10,000
87	0 - 258	5.7 - 50,000	61.0 - 50,000	121 - 50,000	485 - 50,000

Spiral Adapter

Spiral Spindle	Shear Rate (1/SEC)	Viscosity (cP)			
		LVDV-III	RVDV-III	HADV-III	HBDV-III
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 Rheometer

Cone Spindle	Shear Rate (1/SEC)	Viscosity (cP)			
		LVDV-IIIC/P	RVDV-IIIC/P	HADV-IIIC/P	HBDV-IIIC/P
CP-40	0 - 1500	0.15 - 3,065	1.7 - 32,700	3.3 - 65,400	13.1 - 261,000
CP-41	0 - 400	0.58 - 11,510	6.2 - 122,800	12.3 - 245,600	49.1 - 982,400
CP-42	0 - 760	0.3 - 6,000	3.2 - 64,000	6.4 - 128,000	25.6 - 512,000
CP-51	0 - 768	2.4 - 47,990	25.6 - 512,000	51.2 - 1,024,000	205 - 4,096,000
CP-52	0 - 400	4.6 - 92,130	49.2 - 983,000	98.3 - 1,966,000	393 - 7,864,000

Helipath with T-Bar Spindles

T-Bar Spindle	Viscosity (cP)			
	LVDV-III	RVDV-III	HADV-III	HBDV-III
T-A	156 - 187,460	2,000 - 2,000,000	4,000 - 4,000,000	16,000 - 16,000,000
T-B	312 - 374,920	4,000 - 4,000,000	8,000 - 8,000,000	32,000 - 32,000,000
T-C	780 - 937,300	10,000 - 10,000,000	20,000 - 20,000,000	80,000 - 80,000,000
T-D	1,560 - 1,874,600	20,000 - 20,000,000	40,000 - 40,000,000	160,000 - 160,000,000
T-E	3,900 - 4,686,500	50,000 - 50,000,000	100,000 - 100,000,000	400,000 - 400,000,000
T-F	7,800 - 9,373,000	100,000 - 100,000,000	200,000 - 200,000,000	800,000 - 800,000,000

In taking viscosity measurements with the DV-III Rheometer 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-III Rheometers 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 Rheometer 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 around 70 RPM
- 4) SC4-18/13R: 1.25 cP at around 240 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, there are variables that can affect a viscosity measurement. These variables may be related to the instrument (Rheometer) or the test fluid. Variables related to the test fluid deal with the rheological properties of the fluid, while instrument variables would include the Rheometer design and the spindle geometry system utilized.

Rheological Properties

Fluids have different rheological characteristics that can be described by Rheometer 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 RPM's) and are called Newtonian over the Shear Rate range they are measured.
- Non-Newtonian** - These fluids have different viscosities at different shear rates (different RPM's). 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 Rheometer 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 Rheometer 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 Rheometer at a constant speed, recording viscosity (cP) values over time and find that the viscosity (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.

Rheometer Related Variables

Most fluid viscosities are found to be non-Newtonian. They are Shear Rate dependent on the measurement conditions. The specifications of the Rheometer spindle and chamber geometry will affect the viscosity readings. If one reading is taken at 25 rpm, and a second at 50 rpm, the two viscosity (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) Rheometer model
- 5) Spindle used (if using LVDV-III(#1-4) or RVDV-III(#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 code which is entered using the SPDL key on the DV-III key pad. The entry code allows the DV-III 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 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
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
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

Table D1 (continued)

SPINDLE	ENTRY CODE	SMC	SRC
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
Spiral Adapter	70	105	0.677
Thermosel DIN spindle	81	3.7	1.29
SSA DIN spindle for 13R or 13RP chamber	82	3.75	1.29
SSA DIN spindle for 7R or 7RP chamber	83	12.09	1.29
ULA DIN spindle	85	1.22	1.29
ULA DIN spindle	86	3.65	1.29
ULA DIN spindle	87	12.13	1.29

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

Table D2

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

The full scale viscosity range for any DV-III 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-III Torque Constant from Table D2
SMC = Spindle Multiplier Constant listed in Table D1

The Shear Rate calculation is:

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

Where:

SRC = Shear Rate Constant from Table D1

Using Non-standard spindles with DV-III

Spindle Entry 99 allows entry of spindle constants which the DV-III will use to calculate Viscosity, Shear Rate and Shear Stress for spindles in boundary conditions other than the 600ml beaker or specified chamber.

The spindles must conform to geometries that allow for mathematical calculations of Shear Rate and Shear Stress i.e. coaxial cylinder.

Two constants are required:

- a) **SMC** (Spindle Multiplier Constant) which is used to calculate cP value.
- b) **SRC** (Shear Rate Constant) which is used to calculate Shear Rate and Shear Stress.

If SRC=0 (Example, LV #1-4, RV,HA,HB #1-7 spindles), Shear Rate and Shear Stress values are not calculated and can not be displayed.

The SMC value for a spindle may be calculated as follows:

- a) For new spindle conditions you calculate the SMC using a Newtonian fluid of known viscosity (Brookfield Viscosity Standard). This is done in the container with the new dimensions at the controlled temperature specified for the viscosity standard fluid.
- b) The new full scale viscosity range is calculated for a selected RPM:

$$R1 = \frac{100 n}{Y}$$

Where:

R1 = The new full scale viscosity range
n = The viscosity (in cP) of the Newtonian fluid
Y = The Torque % reading at the selected RPM

- c) The SMC Value is then calculated:

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

Where:

TK = DV-III Torque Constant from Table D2

The SRC value may be calculated for cylindrical spindle geometry using the following equation:

$$\text{Shear Rate (1/sec)} = \frac{2\omega R_c^2 R_b^2}{\chi^2 [R_c^2 - R_b^2]}$$

Where:

R_c = Radius of the container (in centimeters)

R_b = Radius of the spindle (in centimeters)

χ = Radius at which the shear rate is to be calculated (normally the same value as R_b ; in centimeters)

ω = Angular velocity of the spindle (Rad/Sec)

$$\omega = \frac{2\pi}{60} * N$$

N = Spindle speed in RPM

The procedure for entering SMC and SRC values is:

- 1) From the main screen, press SELECT SPDL. Note that the spindle select screen (Figure 7) will display the last entered spindle.
- 2) Enter “99” using the numeric entry keys.
- 3) Press SELECT SPDL and Figure D1 is displayed.

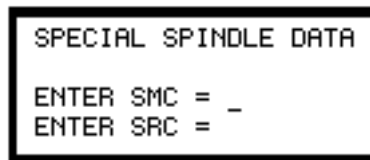


Figure D1

Note that the values for the last entered SMC and SRC coefficients will be displayed at this time if you had previously entered values for these coefficients.

- 4) Enter the SMC value.
- 5) Press the NEXT key to accept the SMC entry. The cursor will move to the SRC field.
- 6) Enter the SRC value.
- 7) Press the NEXT key to accept the SRC value (the cursor will move back to the SMC field).
- 8) Press the SELECT SPDL key to accept both entries. This will return you to the main screen and SPINDLE 99 will be displayed. Please note that an attempt to press the SELECT SPDL key with invalid SMC and SRC entries results in an error message being displayed.

APPENDIX E - Calibration Procedures

The accuracy of the DV-III 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-III should be set according to the operating instructions. The water bath should be stabilized at test temperature. Rheometers 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
<u>Viscosity (cP)</u>	<u>Viscosity (cP)</u>	<u>Three Viscosity/Temperatures**</u>
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-III into measurement position (with guard leg if LV or RV series Rheometer is used).
- 3) Attach the spindle to the Rheometer. 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 Rheometer.
- 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 Rheometer 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 viscosity fluid standard to within the combined accuracies of the Rheometer and the standard (as discussed in the section entitled, Interpretation of Calibration Test Results).

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-III.
- 4) Allow 30 minutes for the viscosity standard, sample chamber and spindle to reach test temperature.
- 5) Measure the viscosity and record the Rheometer 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. A two-step process is recommended for the Thermosel:

- A) Evaluate the calibration of the Viscometer alone according to the procedure outlined in Appendix E, “Calibration Procedure for LV (#1-4) and RV,HA,HB (#1-7) Brookfield spindles.”
- B) Evaluate the Viscometer with Thermosel according to the procedure listed below:
 - a) 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).
 - b) Place the sample chamber into the Thermo Container.
 - c) 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-III.
 - d) Allow 30 minutes for the viscosity standard, sample chamber and spindle to reach test temperature.
 - e) Measure the viscosity and record the Rheometer 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-III.
- 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 Rheometer 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-III Rheometer.

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-III 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 above procedures for mechanically adjusting the setting of the cone spindle to the plate.
- 2) Refer to Appendix A, Table A1, and determine the correct sample volume required for the selected spindle.
- 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-III 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 Rheometer reading should be 97% torque and 9.7 cP viscosity ± 0.197 cP (0.1 cP for the rheometer plus 0.97 cP for the fluid). The accuracy is a combination of Rheometer 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 Rheometer. Allow sufficient time for temperature to reach equilibrium. Typically 15 minutes is the maximum time that you must wait. Less time is required if spindle and cup are already at test temperature.
- 6) Measure the viscosity and record the Rheometer reading in both % torque and centipoise (cP).

- Notes:**
- 1) The spindle must rotate at least five (5) times before a viscosity reading is taken.
 - 2) The use of Brookfield Viscosity Standard fluids in the range of 5 cP to 5000 cP is recommended for cone/plate instruments. Please contact Brookfield Engineering Laboratories or an authorized dealer if your calibration procedure requires more viscous standards.

- 3) Select a viscosity standard fluid that will give viscosity readings between 10% and 00% of full scale range. Refer to Appendix B for viscosity ranges of cone spindles. Do not use a silicone viscosity standard fluid with a viscosity value greater than 5000 cP with a Cone/Plate Viscometer. Brookfield offers a complete range of mineral oil viscosity standards suitable for use with Cone/Plate Viscometers as shown in Table E2. Consult with Brookfield or an authorized dealer to determine which fluid is appropriate.

Table E2

MINERAL OIL VISCOSITY STANDARD FLUIDS	
BEL Part No.	Viscosity (cP) 25°C
B31	31
B210	210
B750	750
B1400	1,400
B2000	2,000
B11000	11,000
B20000	20,000
B80000	80,000
B200000	200,000
B420000	420,000

Interpretation of Calibration Test Results:

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

The DV-III is accurate to (+/-) 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-III 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 $(122.57 + 500) \text{ cP} = (+/-) 622.57 \text{ cP}$.
- 4) Therefore, any viscosity reading between 11,634.4 and 12,879.6 cP indicates that the Rheometer is operating correctly. Any reading outside these limits may indicate a Rheometer 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. Its 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.

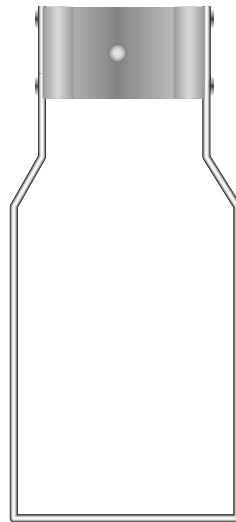
The calibration of the Brookfield Viscometer/Rheometer is determined using a 600 ml Low Form Griffin Beaker. The calibration of LV and RV series instruments includes the guard leg. The beaker wall (for HA/HB instruments) or the guard leg (for LV/RV instruments) define what is called the “outer boundary” 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.

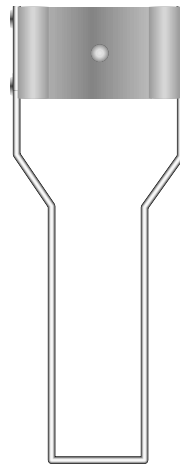
The recommended procedures of using a 600 ml beaker and the guard leg are difficult for some customers to follow. The guard leg is one more item to clean. In some applications the 500 ml of test fluid required to immerse the spindles in a 600 ml beaker is not available. In practice, a smaller vessel 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 - VS-27Y Clamp Assembly

The VS-27Y Clamp assembly holds the DV-III on the upright rod and thus supports it on the base. The parts are shown in **Figure F1**.

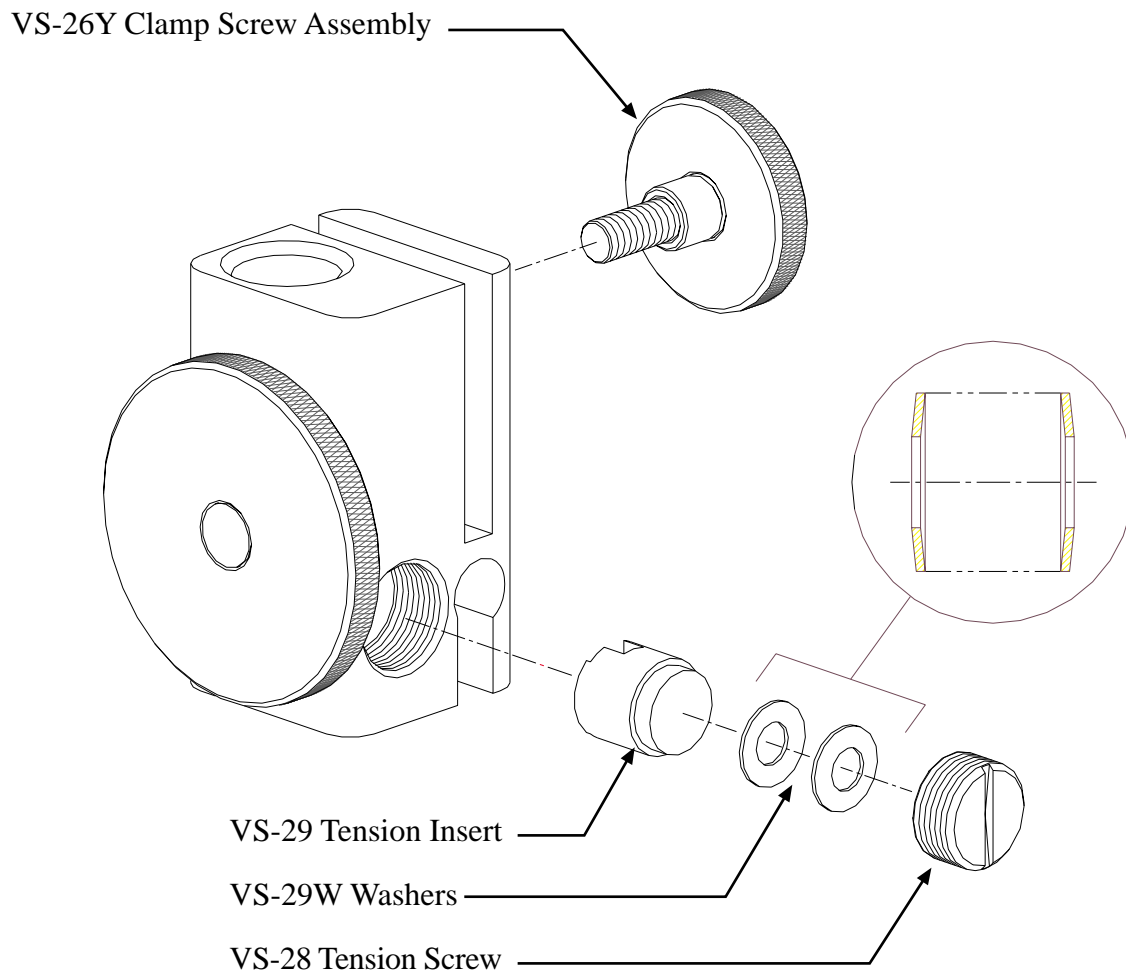


Figure F1

If the clamp is taken off the upright rod, the tension insert (Part No. VS-29) must be properly aligned for the clamp to fit back onto the upright rod.

When the tension insert (Part No. VS-29) is inserted, its slot must be in the vertical position parallel to the upright rod. If the slot is not in the correct position, the clamp will not slide down over the upright rod. Use a small screw driver or pencil to move it into the correct position. The VS-29W Belleville spring washers must face each other as illustrated. Adjust the VS-28 tension screw so that the clamp assembly is not loose on the upright rod.

APPENDIX G - Communications

The command set used to communicate with the DV-III is as follows:

COMMAND Name	COMMAND from Computer	RESPONSE from DV-III
k (Reset)	< K ><CR>	No Response
E (nable)	< E ><CR>	< E ><ss><CR>
R (etrieve)	< R ><CR>	< R ><vvvv><tttt><ss><CR>
V (elocity)	< V ><xxxx><CR>	< V ><ss><CR>
I (dentify)	< I ><CR>	< I ><ddd><mm><CR>
Z (ero)	< Z ><CR>	< Z ><vvvv><ss><CR>
Illegal String	<????><CR>	<ss><CR>

Where:

- vvvv** = Transducer reading as 4 hex digits. The Rheometer calibration should yield a reading of approximately 0400H when zeroing or at rest, and a reading of approximately 2B00H at 100% torque.
- tttt** = Temperature reading as 4 hex digits. The temperature circuit is normally calibrated to produce a reading of 2700H at 0 (zero) degrees Centigrade with a linear scale of 40 counts per degree C.
- xxxx** = Stepper motor speed as 4 hex digits. The motor speed command from the Host is in RPM with an accuracy of 0.1 RPM. Thus, 0064H (100D) would equal 10.0 RPM. (Note: RPM in decimal notation must be multiplied by 10 when converting to hex.)
- ss** = Status Byte as 2 hex digits.
- ddd** = The ASCII characters "DV3".
- mm** = These 2 characters will be used to represent the model for which the DV-III is configured. The model decoding is shown in Table G1 below.

DV-III Model Decoding	
<Model>	<MM>
LV	LV
2.5LV	4L
5LV	5L
RV	RV
1/4RV	1R
1/2RV	2R
HA	HA
2HA	3A
2.5HA	4A
HB	HB
2HB	3B
2.5HB	4B
5HB	5B

The status byte is decoded as follows:

Status Byte

Action	Command Error	Not Used	Power Up Test	Motor Circuit Failure	Not Used	Motor Speed = 0 (Motor Stopped)	Motor On/Off	Controller Enabled	
Power Up or RESET	0		0	0		1	0	0	
Power Up or Diagnostic Fail	0		1	0		1	0	0	*
Host sends "E"	0		0	0		1	0	1	
Host sends Illegal Command	1		0	0		1	0	0	
Motor Fault Condition	0		0	1		1	0	0	*
Host sends speed > 0 (No Motor Fault)	0		0	0		0	1	1	
Host sends speed > 0 (With Motor Fault)	0		0	1		1	0	0	*
Host sends speed = 0 (No Motor Fault)	0		0	0		1	0	1	
Host sends speed = 0 (With Motor Fault)	0		0	1		1	0	0	*

Figure G1

Note: These values are not updated in the status byte when the listed condition occurs. They are made available when the computer next requests transducer readings or attempts a motor command. The flags are cleared by re-enabling the **DV-III**.

The I(dentify) command is optional and will cause the **DV-III** to respond with the ASCII string "DV3". This command is used as a means of identifying Brookfield instruments connected to a computer serial ports. The **DV-III** is issued the E(nable) command to ascertain its current status. The **DV-III** will respond with an echo of the E(nable) command and will append the current status <ss> existing in the **DV-III**. This 2-digit status byte will provide information as to the rheometer's internal working condition and capability to continue with or to accept new tasks. The Rheometer torque value and current temperature may be obtained by issuing the R(etrieve) command. As with the E(nable) command, no parameters are passed to the **DV-III**. The **DV-III**'s response to this command is to echo the command: R(etrieve) and then follow it with 8 hex digits comprising the current values for the Rheometer torque <vvvv> and the temperature probe reading <tttt>. Any control program written to use the output of the **DV-III** will have to perform all the calculations required for viscosity, shear stress and shear rate. The **DV-III** will be directed to run at a given speed through the use of the V(elocity) command. Unlike the two previous commands, this command requires the parameter <xxxx> which contain the value for the desired speed. The **DV-III** responds to this command by repeating the command: V(elocity) and

appending the status byte <ss> which will, amongst other things, inform the calling program as to whether the motor was turned on and/or whether the desired speed was attained. The Z(ero) command is used to “zero” the DV-III Rheometer. The value returned <vvvv> is usually in the range of 03F0 hex to 0400 hex. This number should be retained and subtracted from every future returned torque reading to obtain the actual Rheometer torque in percent.

DV-III Viscometer Data Calculations

The following formulas should be used to calculate and display the Rheometer data after each packet of data is obtained from the DV-III.

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

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

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

Where:

- RPM = Current Rheometer spindle speed in RPM
- TK = Model spring 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 Rheometer torque in percent expressed as a number between 0 and 100.

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

- RPM = 30 from the example statement.
- TK = 0.09373 from Appendix D for an LV Rheometer.
- 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:

$$\begin{aligned} \text{Viscosity (cP)} &= \frac{100}{\text{RPM}} * \text{TK} * \text{SMC} * \text{Torque} \\ &= \frac{100}{30} * 0.09373 * 32.0 * 62.3 \\ &= 622.9 \text{ cP} \end{aligned}$$

$$\begin{aligned} \text{Shear Rate (1/Sec)} &= \text{RPM} * \text{SRC} \\ &= 30 * 0.34 \\ &= 10.2 \text{ 1/Sec} \end{aligned}$$

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

A sample program demonstrating the above principles is contained in the following listing. Please note that this is an example only and does not include advanced programming techniques or error trapping.

```

1000 '+-----+
1005 '| DV-III External Mode Command Protocol Demonstration |
1010 '| Copyright 1991, Brookfield Engineering Labs           |
1015 '| Written by Greg Krysko                               |
1020 '+-----+
1025 '
1030 CLS
1035 PRINT SPC(26) "Brookfield Engineering Labs"
1040 PRINT SPC(20) "DV-III External Mode Demonstration Program"
1045 PRINT SPC(32) "Copyright 1991"
1050 PRINT
1055 PRINT "This program is intended to demonstrate the use of the RS-232 command "
1060 PRINT "set employed by the Brookfield Engineering Labs Model DV-III Rheometer "
1065 PRINT "in its External mode. This program and/or any of the commands used "
1070 PRINT "within may be freely used in your own applications."
1075 PRINT
1080 PRINT "Press any key to continue..."
1085 GOSUB 1490           ' Wait for a keypress
1090 CLS
1095 GOSUB 1655         ' Initialize variables
1100 OPEN "COM1:9600,N,8,1,CS,DS,CD" AS #1 ' Open com port #1
1105 GOSUB 1695         ' Reset the DV-III
1110 PRINT "Please remove the spindle and press any key to begin the Auto-Zero process."
1115 GOSUB 1490         ' Wait for a keypress
1120 PRINT "Auto-Zeroing..."
1125 GOSUB 1760         ' Send the zero command
1130 BEEP
1135 PRINT "Auto-Zero complete. Replace spindle then press any key to continue."
1140 GOSUB 1490         ' Wait for a keypress
1145 CLS
1150 PRINT "Enter model multiplier (See Table A.2 of Appendix A in the DV-III manual) "
1155 INPUT "Ex: A model LV rheometer has a multiplier of 0.09373 ";MODMULT
1160 PRINT "Enter the spindle SMC (See Table A.1 of Appendix A in the DV-III manual) "
1165 INPUT "Ex: An SC4-31 spindle has an SMC of 32 ";SMC
1170 PRINT "Enter the spindle SRC (See Table A.1 of Appendix A in the DV-III manual) "
1175 INPUT "Ex: An SC4-31 spindle has an SRC of 0.34 ";SRC
1180 PRINT
1185 PRINT "The DV-III will begin running at 10 RPM and will increment"
1190 PRINT "its speed by 10 RPM every 10 seconds. At the end of each"
1195 PRINT "10 second interval, a data point will be taken and displayed"
1200 PRINT "on the screen. This will continue until a data point is taken"
1205 PRINT "at 150 RPM at which point the DV-III will return to 0 RPM."
1210 PRINT
1215 PRINT "Press any key to continue..."
1220 GOSUB 1490         ' Wait for a keypress
1225 CLS
1230 PRINT SPC(31) "Sample DV-III Data"
1235 PRINT SPC(31) "-----"
1240 PRINT
1245 WHILE RPM <= 150 ' Repeat until RPM > 150
1250     GOSUB 1595     ' Convert RPM value to a 4 digit hex string
1255     PRINT "RPM=";
1260     PRINT USING "###.#";RPM; ' Print RPM

```

```

1265 PRINT SPC(3);
1270 DV3COMMAND$ = "V" + HEXRPM$ ' Speed command is a V + hex speed value
1275 GOSUB 1815 ' Send command to DV-III
1280 GOSUB 1870 ' Wait for DV-III to respond
1285 GOSUB 1540 ' Count desired time interval (10 secs)
1290 DV3COMMAND$ = "R" ' R command gets torque and temp data
1295 GOSUB 1815 ' Send command to DV-III
1300 GOSUB 1870 ' Wait for DV-III to repsond
1305 GOSUB 1920 ' Calculate data
1310 PRINT "%=";
1315 PRINT USING "###.#";TORQUE; ' Print % torque
1320 PRINT SPC(3);
1325 PRINT "cP=";
1330 PRINT USING "#####.#";VISC; ' Print viscosity (cps)
1335 PRINT SPC(3);
1340 PRINT "D/Cm2=";
1345 PRINT USING "#####.#";SSTRESS; ' Print shear stress (d/cm2)
1350 PRINT SPC(3);
1355 PRINT "1/SEC=";
1360 PRINT USING "#####.#";SRATE; ' Print shear rate (1/SEC)
1365 PRINT SPC(3);
1370 PRINT "°C=";
1375 PRINT USING "#####.#";TEMPERATURE ' Print temperature (°C)
1380 RPM = RPM + 10 ' Increment RPM by 10
1385 WEND ' End WHILE from line 1240
1390 RPM = 0 ' Reset speed to 0 RPM
1395 GOSUB 1595 ' Convert RPM value to a 4 digit hex string
1400 DV3COMMAND$ = "V" + HEXRPM$ ' Speed command is a V + hex speed value
1405 GOSUB 1815 ' Send command to DV-III
1410 PRINT
1415 PRINT SPC(25) "Speed Set Execution Complete!"
1420 GOSUB 2080 ' Close Communications channel
1425 END
1430 '
1435 '+-----+
1440 '| Routine to insert a delay (approx 50 milliseconds) |
1445 '| between each character sent to the DV-III. |
1450 '+-----+
1455 FOR DLY = 1 TO 50
1460 NEXT DLY
1465 RETURN
1470 '
1475 '+-----+
1480 '| Routine that waits for a keystroke |
1485 '+-----+
1490 KEYSTROKE$ = ""
1495 WHILE KEYSTROKE$ = ""
1500 KEYSTROKE$ = INKEY$
1505 WEND
1510 RETURN
1515 '
1520 '+-----+
1525 '| Routine to count elapsed seconds. Used to count |
1530 '| the time interval between each data point taken. |
1535 '+-----+
1540 T1 = TIMER ' Gets seconds since midnight
1545 T2 = T1

```

```

1550 WHILE (T2 - T1) < TINTERVAL          ' Loop until time elapsed = Tinterval
1555     T2 = TIMER
1560 WEND
1565 RETURN
1570 '
1575 '+-----+
1580 '| Routine to convert a decimal speed to a four digit |
1585 '| hexadecimal string that the DV-III understands.   |
1590 '+-----+
1595 TEMPRPM = RPM * 10                    ' Multiply the speed by 10
1600 HEXRPM$ = HEX$(TEMPRPM)              ' Convert to hexadecimal
1605 ISFOUR = 4 - LEN(HEXRPM$)            ' Pad the string with leading
1610 WHILE ISFOUR > 0                      ' 0's until its length is 4
1615     HEXRPM$ = "0" + HEXRPM$
1620     ISFOUR = ISFOUR - 1
1625 WEND
1630 RETURN
1635 '
1640 '+-----+
1645 '| Initialize variables and constants                  |
1650 '+-----+
1655 CR$ = CHR$(13)
1660 RPM = 10
1665 TINTERVAL = 10
1670 RETURN
1675 '
1680 '+-----+
1685 '| DV-III Reset Procedure                            |
1690 '+-----+
1695 RESP$ = ""
1700 WHILE LEFT$(RESP$,1) <> "E"           ' Check for a valid reset
1705     DV3COMMAND$ = "K"                 ' K command (reset DV-III)
1710     GOSUB 1815                         ' Send the command
1715     DV3COMMAND$ = "E"                 ' E command (enable the DV-III)
1720     GOSUB 1815                         ' Send the command
1725     GOSUB 1870                         ' Wait for the DV-III to respond
1730 WEND
1735 RETURN
1740 '
1745 '+-----+
1750 '| Routine to auto-zero the DV-III                    |
1755 '+-----+
1760 DV3COMMAND$ = "Z"                     ' Z command (zero the DV-III)
1765 GOSUB 1815                             ' Send the command
1770 GOSUB 1870                             ' Wait for the DV-III to repsond
1775 HEXRESP$ = MID$(RESP$,2,4)           ' Parse out characters 2-5 from the response
1780 GOSUB 1990                             ' Convert this 4 digit hex string to decimal
1785 ZEROOFFSET = DECIMALNUM              ' This is the zero offset
1790 RETURN
1795 '
1800 '+-----+
1805 '| Routine to send commands to the DV-III            |
1810 '+-----+
1815 GOSUB 2035
1820 DV3COMMAND$ = DV3COMMAND$ + CR$       ' Append a carriage return to command
1825 FOR CMD = 1 TO LEN(DV3COMMAND$)
1830     PRINT #1, MID$(DV3COMMAND$,CMD,1); ' Send one character at a time

```



```

1835     GOSUB 1455                ' Delay between characters
1840 NEXT CMD
1845 RETURN
1850 '
1855 '+-----+
1860 '| Routine to receive a response from the DV-III      |
1865 '+-----+
1870 RESP$ = ""
1875 WHILE RIGHT$(RESP$,1) <> CR$          ' Wait for a carriage return
1880                                     ' If data in input buffer, retrieve it
1885     IF LOC(1) > 0 THEN RESP$ = RESP$ + INPUT$(LOC(1),#1)
1890 WEND
1895 RETURN
1900 '
1905 '+-----+
1910 '| Routine to parse response to an R command          |
1915 '+-----+
1920 HEXRESP$ = MID$(RESP$,2,4)            ' Extract characters 2-5
1925 GOSUB 1990                          ' Convert to decimal
1930 TORQUE = (DECIMALNUM - ZEROOFFSET)/100 ' Subtract zero offset from torque
1935 HEXRESP$ = MID$(RESP$,6,4)          ' Extract characters 6-9
1940 GOSUB 1990                          ' Convert to decimal
1945 TEMPERATURE = (DECIMALNUM - 4000)/40 ' Calculate temperature
1950 VISC = (100/RPM) * MODMULT * SMC * TORQUE ' Calculate viscosity
1955 SSTRESS = MODMULT * SMC * SRC * TORQUE ' Calculate shear stress
1960 SRATE = SRC * RPM                   ' Calculate shear rate
1965 RETURN
1970 '
1975 '+-----+
1980 '| Hex to decimal conversion of a 4 digit hex string  |
1985 '+-----+
1990 HEXRESP$ = "&H" + HEXRESP$          ' Append hexadecimal identifier
1995 DECIMALNUM = VAL(HEXRESP$)         ' Convert hex string to a decimal value
2000                                     ' If overflow, take the complement
2005 IF SGN(DECIMALNUM) = -1 THEN DECIMALNUM = 65536! + DECIMALNUM
2010 RETURN
2015 '
2020 '+-----+
2025 '| Routine to clear the com port input buffer        |
2030 '+-----+
2035 WHILE LOC(1) > 0                    ' If data in input buffer
2040     DUMMY$ = INPUT$(LOC(1),#1)      ' Dump it out
2045     GOSUB 1455
2050 WEND
2055 RETURN
2060 '
2065 '+-----+
2070 '| Routine to close communications channel          |
2075 '+-----+
2080 CLOSE #1
2085 RETURN

```

Running this program from within **GWBASICO** produces output as shown on the next page.

Brookfield Engineering Labs
 DV-III External Mode Demonstration Program
 Copyright 1991

This program is intended to demonstrate the use of the RS-232 command set employed by the Brookfield Engineering Labs Model DV-III Rheometer in its External mode. This program and/or any of the commands used within may be freely used in your own applications.

Press any key to continue...

Please remove the spindle and press any key to begin the Auto-Zero process.
 Auto-Zeroing..
 Auto-Zero complete. Replace spindle then press any key to continue.

Enter model multiplier (See Table A.2 of Appendix A in the DV-III manual)
 Ex: A model LV rheometer has a multiplier of 0.09373 ? 1
 Enter the spindle SMC (See Table A.1 of Appendix A in the DV-III manual)
 Ex: An SC4-31 spindle has an SMC of 32 ? 25
 Enter the spindle SRC (See Table A.1 of Appendix A in the DV-III manual)
 Ex: An SC4-31 spindle has an SRC of 0.34 ? .34

The DV-III will begin running at 10 RPM and will increment its speed by 10 RPM every 10 seconds. At the end of each 10 second interval, a data point will be taken and displayed on the screen. This will continue until a data point is taken at 150 RPM at which point the DV-III will return to 0 RPM.

Press any key to continue...

Sample DV-III Data

RPM= 10.0	%= 0.4	cP= 87.5	D/Cm2= 3.0	1/SEC= 3.4	°C= 25.6
RPM= 20.0	%= 6.0	cP= 745.0	D/Cm2= 50.7	1/SEC= 6.8	°C= 25.6
RPM= 30.0	%= 11.6	cP= 965.0	D/Cm2= 98.4	1/SEC= 10.2	°C= 25.7
RPM= 40.0	%= 17.3	cP= 1078.8	D/Cm2= 146.7	1/SEC= 13.6	°C= 25.7
RPM= 50.0	%= 22.9	cP= 1142.5	D/Cm2= 194.2	1/SEC= 17.0	°C= 25.7
RPM= 60.0	%= 28.5	cP= 1187.5	D/Cm2= 242.3	1/SEC= 20.4	°C= 25.7
RPM= 70.0	%= 34.2	cP= 1221.1	D/Cm2= 290.6	1/SEC= 23.8	°C= 25.6
RPM= 80.0	%= 39.9	cP= 1245.6	D/Cm2= 338.8	1/SEC= 27.2	°C= 25.7
RPM= 90.0	%= 45.6	cP= 1266.7	D/Cm2= 387.6	1/SEC= 30.6	°C= 25.7
RPM=100.0	%= 51.4	cP= 1285.0	D/Cm2= 436.9	1/SEC= 34.0	°C= 25.7
RPM=110.0	%= 57.2	cP= 1300.9	D/Cm2= 486.5	1/SEC= 37.4	°C= 25.7
RPM=120.0	%= 62.9	cP= 1310.6	D/Cm2= 534.7	1/SEC= 40.8	°C= 25.7
RPM=130.0	%= 69.0	cP= 1326.2	D/Cm2= 586.2	1/SEC= 44.2	°C= 25.8
RPM=140.0	%= 74.8	cP= 1335.9	D/Cm2= 635.9	1/SEC= 47.6	°C= 25.8
RPM=150.0	%= 80.7	cP= 1344.7	D/Cm2= 685.8	1/SEC= 51.0	°C= 25.8

Speed Set Execution Complete!

Ok

Output Connections

The DV-III has two analog voltage outputs available for strip chart recording and one RS232 output for computer or serial printer.

The analog voltages are:

- 0 - 1 volt DC corresponding to 0 to 100 Torque %
- 0 - 4 volts DC corresponding to -100 °C to +300 °C at 10 millivolts per °C

The location of the connector is shown in Figure G2:

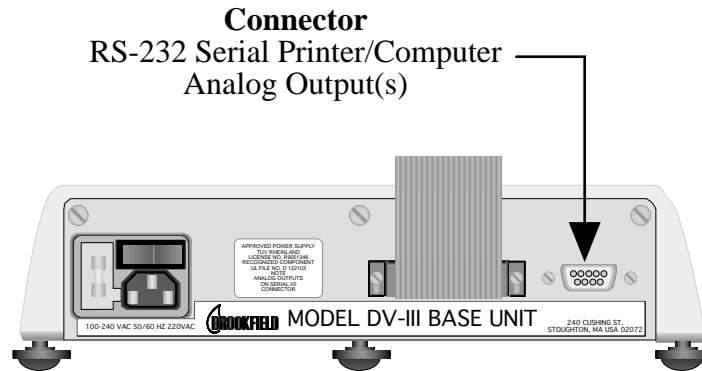


Figure G2

The 9 pin connections are shown in Figure G3:

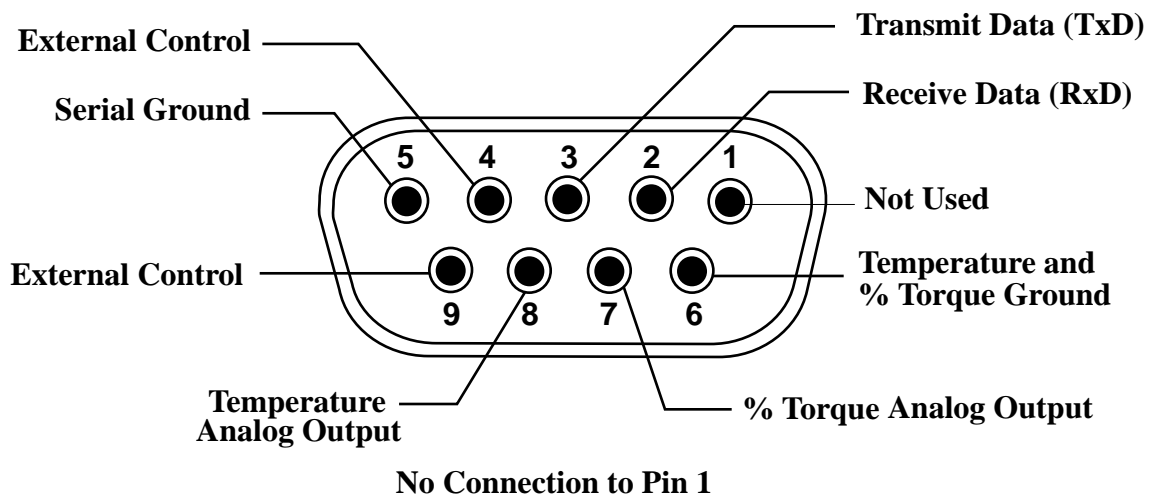


Figure G3

The analog Output Cable (Part No. DVP-96Y) plugs into the 9 pin connector in Figure G3 above. The cable end wires with “spade lugs” are color coded as follows:

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

When connecting the DV-III to a serial printer, use Brookfield Printer Cable (Part No. DVP-81). The cable connections are:

Printer RxD (usually pin 3) to DV-III TxD (pin 3)
Printer Txd (usually pin 2) to DV-III RxD (pin 2)
Printer ground (pin 7) to DV-III serial ground (pin 5)

When connecting a computer to the DV-III, use Brookfield Computer Cable (Part No. DVP-80). The cable connections are:

Com Port RxD (pin 2 (9 pin) or pin 3 (25 pin) to DV-III Txd (pin 3)
Com Port Txd (pin 3 (9 pin) or pin 2 (25 pin) to DV-III RxD (pin 2)
Com Port ground (pin 7) to DV-III Serial Ground (pin 5)

In both the above cases (printer and computer), the RS232 protocol is implemented as follows:

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

Note: Do the following if you supply your own interconnecting cable: On the DV-III end of the serial cable, jump (connect) pins 4 and 9.

APPENDIX H - DVE-50 Probe Clip

Probe Clip DVE-50 is supplied with all model 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.

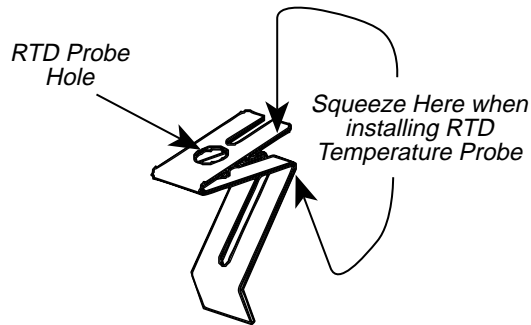


Figure H1

Note: The Probe Clip is not used with the RV guard leg, Part No. B-21Y.

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.

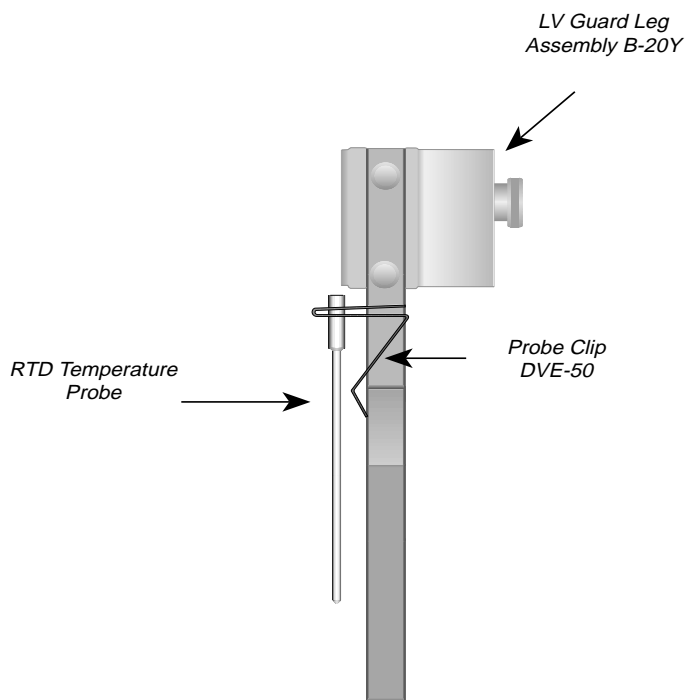


Figure H2

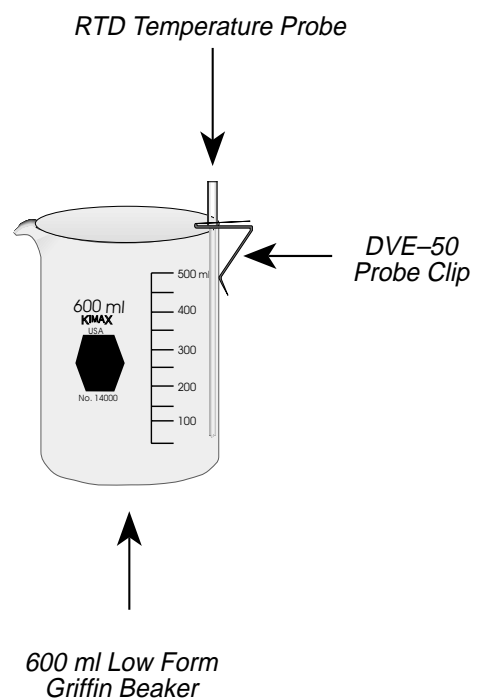


Figure H3

APPENDIX I - Fault Diagnosis and Troubleshooting

A diagnostics option (Option 5) was supplied on DV-III Rheometers with firmware versions up to 2.0. It checks all DV-III electronic components: circuit boards, serial interface, motor control, display and keyboard. This option is used when a malfunction is suspected. Pressing the number 5 key from the Options screen begins the test sequence with instructions provided on the screen.

On DV-III Rheometers with Version 3.0, the diagnostics routines may be executed by holding the SELECT DISP key when the rheometer power switch is turned on.

The necessary instructions are given via “*on screen*” instructions with one exception. When the Keyboard test is run, the operator must press every key on the control panel.

Note that the Transducer Alignment section of the program is used by authorized Brookfield service technicians, and is not used in normal circumstances. The procedure for activating Diagnostics from the main screen is:

- 1) Press the OPTION key.
- 2) Press the number 5 key.
- 3) Follow the instructions on the screen.

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

Spindle Rotates Eccentrically

1. Spindle not screwed securely to coupling
 - Tighten
2. Dirt in spindle or Rheometer coupling
 - Clean
3. 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.

4. 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

Rheometer Will Not Return to Zero

1. Pivot point or jewel bearing faulty
 - Perform calibration check, Section 3.3.9 of *"More Solutions to Sticky Problems"*
 - 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
 - Replace Spindle
 - Contact Brookfield Engineering Laboratories, Inc. or your Brookfield dealer for repair
3. Temperature fluctuation in sample fluid
 - Use temperature bath control
 - Check probe performance in known fluid (ice water)
4. Special characteristic of sample fluid
 - Refer to Appendix C

Recorder Pen Moves in Wrong Direction

1. Output polarity reversed
 - Reverse leads

No Recorder Response

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

Appendix J - 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
<http://www.brookfieldengineering.com>

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

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

Brookfield Viscometers Limited
1 Whitehall Estate
Flex Meadow
Pinnacles West
Harlow, Essex CM19 5TJ, United Kingdom

Telephone: (44) 27/945 1774 FAX: (44) 27/945 1775

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

Brookfield Engineering Laboratories Vertriebs GmbH
Barbarossastrasse 3
D-73547 Lorch, Germany

Telephone: (49) 7172/927100 FAX: (49) 7172/927105