THE BROOKFIELD DIGITAL VISCOMETER

MODEL DV-II

Operating Instructions

Manual No. **M/85-160-G**

BROOKFIELD SPECIALISTS IN THE MEASUREMENT AND CONTROL OF VISCOSITY

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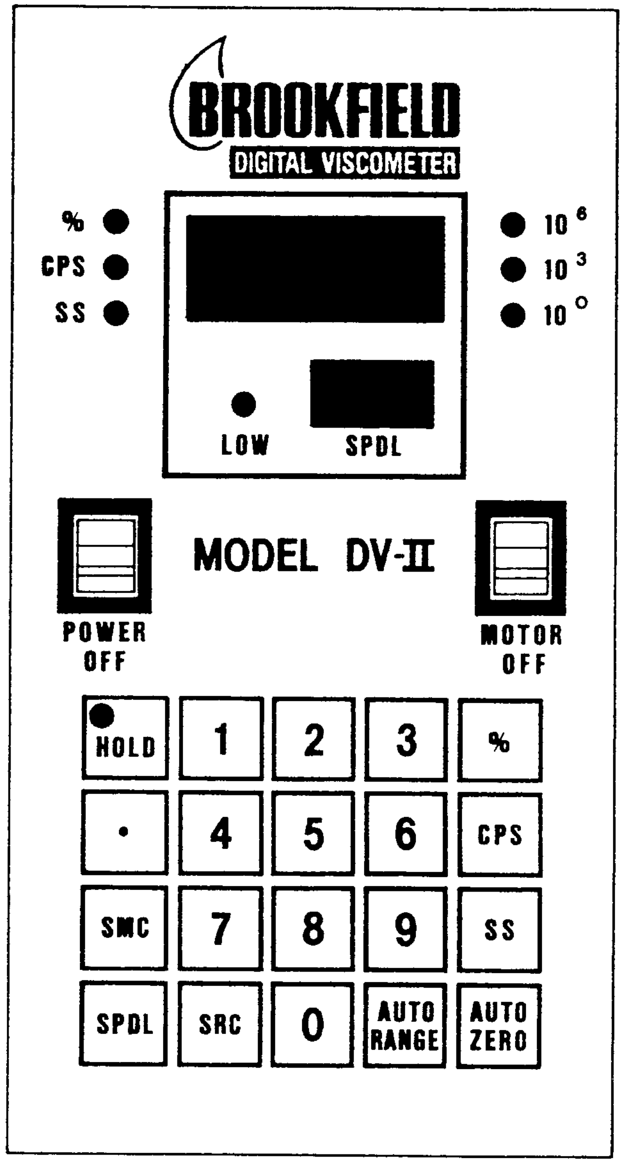
THE BROOKFIELD DIGITAL VISCOMETER MODEL DV-II

The Brookfield Digital Viscometer, Model DV-II, is a laboratory Viscometer which can be utilized with all Brookfield accessories including UL Adapter, Small Sample Adapter, Thermosel and Helipath Stand. Also available as a Wells-Brookfield Cone/Plate Viscometer.

- Continuous display of basic Viscometer reading in **%**
- Continuous display of calculated viscosity in **cps**
- Continuous display of calculated Shear Stress in **dynes/cm^2**
- **Auto Zero** for automatically zeroing the Viscometer
- **Auto Range** for displaying full scale viscosity and shear stress range of any spindle/speed combination, and for verifying special spindle entries
- **Hold** for freezing any display reading
- **Low** indicator for readings below 10% of full scale range
- Programmed to accept all Brookfield spindles and spindle/chamber accessories
- Provides entry of spindle multiplier and shear constants for any spindle design boundary condition
- Continuous analog outputs; 0-10mv and 0-1v
- RS232 transmitting serial interface; 40 character operating at 1200 baud and updated once per second

BROOKFIELD MODEL DV–II
CALCULATING DIGITAL VISCOMETER



85–0304

Principle of Operation

All Brookfield Digital Viscometers, including the Wells-Brookfield Cone/Plate Model DV-II, rotate a sensing element in a fluid and measure the torque necessary to overcome the viscous resistance to the induced movement. This is accomplished by driving the immersed element, which is called a spindle, through a beryllium copper spring. The degree to which the spring is wound, detected by a rotational transducer, is proportional to the viscosity of the fluid.

Continuous readouts of percent full scale, viscosity and shear stress are provided by means of the integral three-digit LED display. The 0-10 mv, or the 0-1v analog output signal can be fed into a variety of indicating or recording devices, and the RS232 output can be connected to any suitable interface.

The Viscometer is able to measure over a number of ranges since, for a given spring deflection, the actual viscosity is inversely proportional to the spindle speed and shear stress is related to the spindle's size and shape. For a material of given viscosity, the drag will be greater as the spindle size and/or rotational speed increase. The minimum viscosity range is obtained by using the largest spindle at the highest speed; the maximum range by using the smallest spindle at the slowest speed.

Measurements made using the same spindle at different speeds are used to detect and evaluate the rheological properties of the test material. Our booklet, "More Solutions to Sticky Problems," discusses the Viscometer's use in this respect.

Cone/Plate Theory

If the axis of a nearly flat conical surface is perpendicular to a flat plate with the cone's apex lying in the plane of the plate, and if either the cone or the plate is rotated with respect to the other about the axis, fluid in the space between the two will be subjected to uniform shear rate.

This, except for small edge effects, follows from the fact that the rate of movement of any point on either surface is proportional to its distance from the axis and that the separation of the surfaces at that point is equivalently proportional to the same radius. The ratio of the rate of movement of the surface (at any point) to the distance of separation is fixed for any speed of rotation, and constant over the entire surface. Since rate of shear is by definition this ratio, it is therefore constant.

By using small angles between cone and plate (less than 4°), substantial rates of shear and hence, shearing stresses, can be achieved with comparatively low rotational speeds, low viscosities and small samples.

Introduction

All Digital Viscometers are powered by a precision synchronous motor. Exact speeds of rotation are assured as the motor will turn erratically and spasmodically if synchronism cannot be maintained.

Speed changes are affected by a transmission having eight speeds. The round speed control knob rotates both clockwise and counter-clockwise. Maximum speed (rpm) will be set at full clockwise rotation and minimum speed at full counter-clockwise rotation. The speed setting is indicated by the number on the knob located opposite the button on the Viscometer housing. Although not absolutely necessary, it is advisable to change speeds while the motor is running.

Viscometers with Spindles and Accessories

LV Viscometers are provided with a set of four spindles and a narrow guard leg; RV Viscometers come with a set of seven spindles and a wider guard leg; HA and HB Viscometers come with a set of seven spindles and no guard leg.

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

Spindles can be identified by the number on the side of the spindle nut.

Cone/Plate Viscometers

Calibration of this Viscometer is accomplished by a simple mechanical procedure. Both the cone spindle and the sample cup have small pins projecting from their surfaces. These pins provide a reference point from which the separation of the spindle and the plate can be set with an accuracy of .0001" or better.

Initial Setup

1. Mount the Viscometer securely on a laboratory stand.

   NOTE: The **position** of the laboratory stand clamp assembly is **important**. Refer to Parts Identification Sheet #82-0330 for proper alignment and positioning of the clamp assembly.

   Level the Viscometer referring to the bubble level on the back of the instrument. If the Viscometer cannot be leveled, recheck the laboratory stand assembly as shown on sheet #82-0330.

2. Verify that the Viscometer's (and recorder's, if used) power requirements match your power source before connecting it to power.

3. If using a recorder: connect Viscometer output cable to recorder terminals. Connect the 0-10mv red wire to the "+" terminal and the black wire to "-". Insert the plug on the other end of the cable into the Viscometer's output receptacle. Set the recorder's input selector (if so equipped) to 10 mv full scale. The 0-1v output signal may also be used for recording.

   NOTE: DO NOT CONNECT OUTPUT CABLE TO POWER!

4. On cone/plate models, connect the fittings on Viscometer sample cup to temperature bath with flexible hose. The lower fitting on the sample cup should be connected to the bath's pump outlet; the upper fitting to the return. All connections should be clamped.

   It is not recommended to operate the Viscometer at sample temperatures in excess of 100 degrees C.

5. If using the RS232 interface, refer to the appendix sections III. and VI. for detail description, output connection and data format.

Key Pad Functions

On power up, the main display is set to "- - -" and the **SPDL** display shows **EE**. The instrument waits for an **AUTO ZERO** and a spindle number entry to be executed before any measurements can be made. Subsequently, all keys when pressed perform a single mode function. The **HOLD**, **SMC**, and **SRC** keys operate as a toggle going into and out of the same mode function. Each functional mode change has associated with it a visual display change. There are no audio acknowledgements.

AUTO ZERO

An **AUTO ZERO** must be done each time power is turned on. You may also Auto Zero at any time. However, this should be done with no spindle attached, Viscometer level and the speed select knob set at either 10 or 12 rpm with the Viscometer running. Pressing the **AUTO ZERO** key forces the main display to flash 00.0 for 10 seconds. Upon completion, the main display is set into the % mode at 00.0 and the RS232 output carries a one time signal placing a **"Z"** in the first character position to signify that an Auto Zero has been completed.

SPDL

This is the **SPinDLe** number entry access key. After pushing this key, the **SPDL** display goes blank and the main display shows **SPE** (spindle entry). Enter the spindle number corresponding to the spindle attached to the Viscometer. Refer to the **SPinDLe** Entry Table (Appendix I.). The Viscometer will accept two displayed digits. If you make a mistake entering, by pressing the wrong key, just continue entering until the two digits you want are displayed. After spindle entry (other than 99) is completed, you must press either **%**, **CPS** or **SS** to proceed with measurements. If a non-programmed number has been entered, or only a single digit, the **SPDL** display will revert to **EE** and you must start again.

Note: You must enter at least two digits.

SPinDLe Entry 99

Spindle entry 99 (i.e. entering the number 99 when the upper digital display shows SPDL) allows entry of the values which the Viscometer uses to calculate CPS and Shear Stress (as well as shear rate if you are using software DV GATHER).

Entry 99 allows calculation of viscosity (in cps) and shear stress (in dynes/cm^2), when using a spindle/chamber (boundary) condition not already programmed into the Viscometer. This includes newly introduced Brookfield spindles or customer designed spindles.

This procedure requires two calculations before starting; the CPS calculation constant called **SMC** and the shear rate constant, or **SRC**. These values are calculated using the following equations:

Equation 1: $$SMC = \frac{[\text{Full Scale Viscosity (CPS)}] \times [\text{RPM}]}{[\text{TK}] \times [10{,}000]}$$

Equation 2: $$SRC = \frac{\text{Shear Rate (sec}^{-1})}{\text{RPM}}$$

Where TK = Viscometer Torque Constant from the following table:

(TK) - Full Scale Torque Constant	Model
0.09373	LV
0.2343	2.5LV
0.4686	5LV
1	RV
0.25	1/4RV
0.5	1/2RV
2	HA
4	2HA
5	2.5HA
8	HB
16	2HB
20	2.5HB
40	5HB

The full scale range of a spindle may be determined measuring a viscosity standard (available from Brookfield) with the spindle in question (using the container you intend to use) and applying the following equation:

$$\text{New Range} = \frac{100N}{x}$$

Where N is the viscosity (in CPS) of the viscosity standard, and x is the % of scale reading (dial reading) from the Viscometer.

Assuming you are using a cylindrical spindle, the shear rate (at the spindle o.d.) may be calculated using the equation found on page 18 of Brookfield booklet "More Solutions to Sticky Problems," section 5.2.1.

If you are using the LV cylindrical spindles, or RV/HA/HB #7 spindle (without guard leg) to make an estimate of shear rate at the spindle o.d. (and to produce a shear stress display on the Viscometer display), you must enter SMC and SRC values for the spindle. These values are:

	SMC	SRC
LV-1	7.68	0.22
LV-2 cyl.	33.48	0.212
LV-3 cyl.	129.31	0.21
LV-4	640.14	0.209
RV/HA/HB-7	400.00	0.209

SMC and SRC

These are the spindle constant access keys associated with spindle entry **99**. Spindle Entry **99** provides access which allows the Viscometer to be programmed for automatic calculation of viscosity (cps) and shear stress (ss) using spindle/boundary conditions other than those shown in the **SPinDLe** Entry Table. **SMC** is the spindle multiplier constant and **SRC** is the shear rate constant as defined in equations **1** and **2**.

This mode function is executed as follows. Press **SPDL** and enter **99** on the SPDL display. Follow this by pressing either **SMC** or **SRC** (toggle in). If **SMC** is pressed, the main display shows "**PPP**". If you press **SRC** the display sets to "**rrr**". You are now ready to enter the constant. The numbers will scroll from right to left replacing the letters; however, you do not have to replace all the letters before toggling out.

Entering SMC/SRC Values

1) Press the **"SPDL"** key.
2) Enter the number **"99"** using the numerical keyboard.
3) Press the key labeled **"SMC"** (you will see "PPP" in the upper display).
4) Enter the number SMC value (these numbers will replace "PPP" as you enter), using the numerical keyboard.
5) Press the key labeled **"SMC."**
6) Press the key labeled **"SRC"** (you will see "rrr" in the upper display).
7) Enter the number SRC value (these numbers will replace "RRR" as you enter), using the numerical keyboard.
8) Press the key labeled **"SRC."** The number 99 should appear in the spindle display (lower display), and you are now ready to make viscosity measurements.

You may verify your SMC/SRC entry by pressing the **AUTORANGE** key on the Viscometer keyboard. This will display full scale CPS value for the Viscometer speed you are using, and the display should agree with your calculations.

HOLD

This is a toggle function key which **HOLDS** the reading on the main display. The light indicates the hold is on. The key must be pressed to turn off the hold (light off).

Note: With a hold on, all display functions are inoperative. The RS232, 0-10mv and 0-1v outputs will continue to be updated with the **HOLD** on.

%

Pressing this key puts the main display reading into the 00.0 to 99.9 mode. This is the standard Brookfield display from which viscosities in centipoise are calculated. The % LED will light up.

CPS

Pressing this key puts the main display reading into a floating point mode which will indicate the **viscosity** in centipoise based upon the spindle attached (SPDL), model of Viscometer, spindle speed and % full scale instrument reading. The cps LED will light up, along with the appropriate exponential power of 10 LED.

SS

Pressing this key puts the main display reading into a floating point mode which will indicate the **shear stress** in dynes/cm^2 based upon the spindle attached (SPDL), model of Viscometer, spindle speed and % full scale instrument reading. Only spindles which have specific boundary conditions are programmed. These include Small Sample Adapter, UL Adapter, Thermosel and Cone/Plate spindles. Standard Viscometer spindles will be indicated as "00.0". When the 99 spindle entry is used, shear stress will be calculated. The SS LED will light up, along with the appropriate exponential power of 10 LED.

AUTO RANGE

Pressing this key places the main display reading into either the **CPS** or the **SS** mode and displays the full scale range based upon the spindle attached (SPDL), model of Viscometer and setting of the speed select knob. Once you have entered **AUTO RANGE** mode you can go back and forth between **CPS** and **SS**. If you change the setting of the speed select knob, you must update the display by pushing the **CPS** key again. You may use the Auto Range key at any time, regardless of motor on or off.

Note: In **AUTO RANGE** the **CPS** and **SS** positions **10** and **19** of the RS232 output will show **"*"**.

There are four ways of exiting **AUTO RANGE**:

1. Press **%**
2. Press **AUTO ZERO**
3. Press **SPDL**
4. Turn power off.

Number Keys

Keys **0** through **9** and the decimal point **"."** are used to enter the spindle numbers and the **SMC** and **SRC** constants. These keys become active when the **SPDL** key is pressed, and when spindle 99 entry is waiting for the **SMC** and **SRC** constants. At all other times, these keys are inoperable.

Initialization

1. Turn power switch "on" (up), energizing Viscometer display. The power switch is on the left side of the front panel.

2. Check bubble level to be sure Viscometer is level. Turn motor switch "on" (up) and set speed selector knob to 10 or 12 rpm (depending on model). The motor switch is on the right side of the front panel.

3. Press AUTO ZERO and the Viscometer will zero position the electronics and pointer shaft displacement. This should be done with no spindle attached.

4. If a recorder is used, it should be zeroed after the Viscometer has been zeroed. The recorder input must be in the "run" mode. After the recorder is zeroed, switch it to the "standby" mode.

5. Turn motor switch "off", placing Viscometer in standby mode.

Operation

Viscometers with Spindles and Accessories

1. Mount guard leg on Viscometer. Attach spindle to lower shaft. Lift the shaft slightly, holding it firmly with one hand while screwing the spindle on with the other (note left-hand thread). Avoid putting side thrust on the shaft.

2. Insert spindle in the test material until the fluid's level is at the immersion groove in the spindle's shaft. Try to avoid trapping air bubbles under the spindle.

You may find it more convenient to immerse the spindle in the fluid before attaching it to the Viscometer. Care should be taken not to hit the spindle against the sides of the fluid container while it is attached to the Viscometer.

3. Press the **SPDL** key and enter the spindle number (refer to Appendix **I**). After the two digit number is entered, press either the %, CPS or SS key.

4. To make a viscosity measurement, turn the motor switch "on", which energizes the Viscometer drive motor. Allow time for the display reading to stabilize. The time required for stabilization will depend on the speed at which the Viscometer is running and the characteristics of the sample fluid.

   The digital display on this Viscometer reads from 00.0-99.9 in the % mode. Overrange is indicated by **"EEE."** Underrange is "- - -." Floating point display is used for the viscosity **(CPS)** and shear stress **(SS)** modes. You can change modes at any time without affecting the viscosity measurement.

Low Reading Indicator

If the Viscometer reading is less than **10%** of the full scale range, the **low** LED indicator will come on. Simultaneously, the RS232 output format will show a **?** in the first character position. The purpose of this indicator is to alert the operator that the measurement is on the low end of the full scale range. This is especially important when using the **CPS** and **SS** modes. The Viscometer will calculate viscosity and shear stress at any upscale reading above zero, and it is recommended to take readings above **10%**.

When using a recorder, switch to the "run" mode to record Viscometer reading. Note that the paper used in the strip chart recorder has a 0-100 scale. The reading on the chart is utilized in the same fashion as the Viscometer display reading when in the % mode.

5. Turn the Viscometer motor switch "off" when changing or cleaning a spindle, changing samples, etc. This is a standby mode in which the electronic circuits of the Viscometer remain energized. It is advisable to leave the power switch "on" between tests to minimize drifting of the Viscometer reading.

   It is recommended, when operating the Viscometer for a lengthy period, that zero be checked occasionally as described above. Remove spindle from the Viscometer before performing this procedure.

6. The interpretation of results and the instrument's use with non-Newtonian and thixotropic materials is discussed in the booklet, "More Solutions to Sticky Problems."

Cone/Plate Viscometers

1. Turn "on" temperature bath and allow sufficient time for sample cup to reach the desired temperature. Adjustments should always be performed at operating temperature.

2. Swing sample cup clip to one side and remove sample cup. Using wrench supplied, hold Viscometer lower shaft and screw on cone spindle, lifting lower shaft slightly at the same time (note left-hand thread). Avoid putting side thrust on the shaft.

   The mating surfaces of the spindle and lower shaft must be clean to prevent eccentric rotation of the spindle.

3. Place sample cup against adjusting ring, being sure to position the notch on the side of the cup around the sample cup clip. Swing clip under cup to secure it in place.

   Avoid hitting the spindle when installing the sample cup. If the display doesn't return to zero after installing the sample cup, unscrew the adjusting ring (turn it to the left) until the display reading returns to zero.

4. Run the Viscometer at 10 or 12 rpm by setting the speed select knob and turning the motor switch "on."

   If the display reading regularly jumps to 0.3 or higher, or will not settle to zero (indicating that the pins in the spindle and the sample cup are contacting), screw the adjustment ring to the left until the reading stabilizes at or near zero.

   If the display reading remains at or near zero, continue to the next step.

5. Turn the adjusting ring to the right in small increments (one or two minor divisions on the ring) while watching the digital display. Turn the adjusting ring until fluctuation of the display reading indicates that the pins have made contact.

   Once contact has been made, back off the adjusting ring (turn it to the left) in small increments until stablization of the display reading indicates that the pins are not contacting.

   Turn the adjusting ring to the right in very small increments (about 1/64") until the display reading fluctuates regularly by a small amount. This determines the point at which the pins are just making contact.

6. Make a pencil mark on the adjusting ring directly under the index mark on the pivot housing. Turn the adjusting ring to the left exactly the width of one minor division. This will separate the pins by exactly .0005".

   The Viscometer is now mechanically set and ready for sample insertion.

   It is recommended that this mechanical procedure be performed every time the spindle is removed from the Viscometer and replaced. The Viscometer's calibration can be checked by the use of Brookfield Viscosity Standards (under controlled temperature conditions only).

7. Remove the sample cup. Place sample fluid in cup according to the table below, being sure that the sample is bubble-free and spread evenly over the surface of the cup. Sample volume must be sufficient to wet the entire face of the spindle and approximately 1.0mm up the spindle's outside edge.

Spindle	**Angle (degrees)**	**Sample Volume (ml)**
CP-40	0.8	0.5
CP-41	3.0	2.0
CP-42	1.565	1.0
CP-51	1.565	0.5
CP-52	3.0	0.5

   Replace the sample cup, being careful not to hit the spindle.

8. Allow sufficient time for the sample fluid to reach the desired temperature.

9. Press the SPDL key and enter the spindle number (refer to Appendix 1). After the two digit number is entered, press either the %, CPS or SS key.

10. To make a viscosity measurement, turn the motor switch "on", which energizes the Viscometer drive motor. Allow time for the display reading to stabilize. The time required for stabilization will depend on the speed at which the Viscometer is running and the characteristics of the sample fluid.

    The digital display on this Viscometer reads from 00.0-99.9 in the **%** mode. Overrange is indicated by **"EEE."** Underrange is "- - -." Floating point display is used for the viscosity **(CPS)** and shear stress **(SS)** modes. You can change modes at any time without affecting the viscosity measurement.

    Low Reading Indicator

    If the Viscometer reading is less than **10%** of the full scale range, the **low** LED indicator will come on. Simultaneously, the RS232 output format will show a **?** in the first character position. The purpose of this indicator is to alert the operator that the measurement is on the low end of the full scale range. This is especially important when using the **CPS** and **SS** modes. The Viscometer will calculate viscosity and shear stress at any upscale reading above zero, and it is recommended to take readings above 10%.

    When using a recorder, switch recorder to "run" mode to record Viscometer reading. Note that the paper used in the strip chart recorder has a 0-100 scale. The reading on the chart is utilized in the same fashion as the Viscometer display reading when in the **%** mode.

11. Turn the Viscometer motor switch "off" when changing or cleaning a spindle, changing samples, etc. This is a standby mode in which the electronic circuits of the Viscometer remain energized. It is advisable to leave the power switch "on" between tests to minimize drifting of the Viscometer reading.

    It is recommended, when operating the Viscometer for a lengthy period, that zero be checked occasionally as described previously. Remove spindle from the Viscometer before performing this procedure.

12. The interpretation of results and the instrument's use with non-Newtonian and thixotropic materials is discussed in the booklet, "More Solutions to Sticky Problems."

A Calibration Check

First verify that the Viscometer is running properly. People are often concerned about the accuracy of their Viscometer. Here are some tests of its mechanical performance.

(A) Variations in power frequency will cause the spindle to rotate at an incorrect speed. If you are in an area where electric clocks are used, this factor may be immediately eliminated. Voltage variations have no effect as long as the deviation is not greater than ± 10% of the nameplate voltage and the frequency remains constant.

Other readily apparent symptoms of improper power supply are: failure of the motor to start, jerky spindle rotation or inconsistent digital display readings.

(B) Damage to the pivot point or jewel bearing will adversely affect the accuracy and repeatability of the Viscometer. The following Oscillation Test will allow you to evaluate the condition of these components:

1. The Viscometer should be mounted and leveled, with no spindle installed and the motor switch in the "off" position.

2. Put the display into the % mode.

3. Turn the spindle coupling by hand to deflect the digital display upscale from its zero position to a reading of 5 to 10 and let it swing back under its own power.

4. If the coupling swings freely and smoothly, and the display returns to zero each time this test is repeated, the pivot point and jewel bearing are in good condition. If it crawls back sluggishly and does not come to rest on zero, the performance of the Viscometer will not be up to specification and it should be serviced.

(C) We have never found a spring made of beryllium copper which showed any change in its characteristics due to fatigue, even after hundreds of thousands of flexings. For this reason, a check of the calibrated spring is usually not necessary. The Auto Zero is provided to compensate for any possible heat-induced drift in the electronic circuitry.

(D) The use of a calibrated viscosity standard is recommended as a final performance check. Test the viscosity standard as you would any sample fluid, carefully following any applicable instructions.

Brookfield Viscosity Standards (calibrated to within 1%) are ideal for this test. The use of fluids other than viscosity standards is not recommended due to the probability of unpredictable rheological behavior.

(E) If the Viscometer passes all of the preceding tests, its performance should be satisfactory. Should the accuracy or operation of the instrument still be suspect, please refer to the troubleshooting suggestions.

Calibration

All models of the Brookfield Digital Viscometer are guaranteed to be accurate to within 1% of whatever full scale range is employed when used in the specified manner. Readings in the % mode should be reproducible to within 0.2% of full scale subject to variations in fluid temperature, etc.

If it is desired to verify the calibration of the Viscometer, Viscosity Standards are available from Brookfield Engineering Laboratories. They are available in various viscosities to suit all models of the Brookfield Digital Viscometer. The Viscometer's calibration should only be checked under controlled conditions of temperature and in accordance with the following procedures:

LV Model (LVTDV-II)

This instrument is calibrated to Bureau of Standards values on the basis of immersion in an infinite body with the guard leg attached. It is accurate to within 1% of full scale when the spindle is centered in any container over 2-3/4" in diameter. Using the Viscometer in smaller containers will reduce the effective range of measurement provided by the #1 and #2 spindles. The calibration of the #3 and #4 spindles is unaffected by the size of the container used as long as the guard leg is attached.

Readings obtained in small containers and/or without the guard can be used only for comparative purposes unless correction factors are used with each spindle and with each container. Our booklet, "More Solutions to Sticky Problems," outlines the procedure to be followed in calculating these factors.

A condition of turbulent flow is created by the #1 spindle when rotating at 60 RPM in materials having viscosities less than 15 cps. If measurements are needed in this region, it is suggested that the UL Adapter accessory be used.

RV Models (RVTDV-II)

The RVTD Viscometer is calibrated to Bureau of Standards values on the basis of the instrument's use, with its guard leg attached, in a 600 cc low form Griffin beaker. If the instrument is used in a larger container, the ranges over which the #1 and #2 spindles measure will be slightly increased. This effect is negligible with the other spindles (#'s 3-7) provided with the unit.

If it is desired to use the RV spindles in containers other than the one specified, it will be necessary to establish correction factors if values of absolute accuracy are required. The booklet, "More Solutions to Sticky Problems" outlines this procedure.

The #1 RV spindle should not be operated at 100 RPM because a condition of turbulent flow is produced, producing inaccurate measurements. The lowest viscosity measurable by the RVTD is 100 cps.

If trouble is experienced in starting the instrument (particularly at a high speed setting), turn it "on" at a lower speed and shift to the higher speed while it is running.

H Models (HATDV-II, HBTDV-II)

Brookfield HA and HB Viscometers are used without guard legs. In all other respects their calibration is based on the same operating conditions as those given above for the RV model. It is not suggested that they be used for the measurement of viscosities below 200 cps.

Cone/Plate Models

All Cone/Plate Viscometers are calibrated to Bureau of Standards values for each cone and plate (cup) combination. Limitations of viscosity range correspond to the model/spindle/speed operation as indicated by the low limit LED (10% of range).

APPENDIX

I. SPinDLe ENTRY TABLE

LV Series

Spindle	SPDL Entry
1	61
2	62
3	63
4	64
5	65

RV/HA/HB Series

Spindle	SPDL Entry
1	01
2	02
3	03
4	04
5	05
6	06
7	07

Small Sample Adapter and Thermosel

Spindle	SPDL Entry	Spindle	SPDL Entry
SC4-14	14	SC4-27	27
SC4-15	15	SC4-28	28
SC4-16	16	SC4-29	29
SC4-18	18	SC4-31	31
SC4-21	21	SC4-34	34
SC4-25	25		

The "BS" version of spindles SC4-27, 28, 29, 31 and 34 use the same spindle entry.

Cone/Plate

Spindle	SPDL Entry
CP-40	40
CP-41	41
CP-42	42
CP-51	51
CP-52	52

UL Adapter

SPDL Entry
00

Helipath Stand

Spindle	SPDL Entry
T-A	91
T-B	92
T-C	93
T-D	94
T-E	95
T-F	96

New Spindle Entry

SPDL Entry

99
Then enter constants **SMC** and **SRC**.

II. Viscometer Model Designations

LV Series	RV Series	HA Series	HB Series
LV - LV	RV - RV	HA - HA	HB - HB
2.5LV - 4L	1/4RV - 1R	2HA - 3A	2HB - 3B
5LV - 5L	1/2RV - 2R	2.5HA - 4A	2.5HB - 4B
			5HB - 5B

III. RS-232 OUTPUT

The RS-232 output signal is updated once every second, except when an **AUTO ZERO** function is initiated. Pressing **AUTO ZERO** halts the output for ten seconds. Upon completion, output commences and a "Z" is placed in the first character position for one update. Subsequent outputs will show the Viscometer configuration prior to the AUTO ZERO execution.

Data Format

40 character ASCII
Baud Rate - 1200
No parity
Transmit only
7 data bits
2 stop bits

Output Format

```
b b - - - - % b b * b b E b C P b b * b b E b S S b 0 0 0 R P M b R V b E E
1   3     6       9 10        14        18 19       23        27  29             34 35 37 38
```

Note: b - is blank (no character)
E - is exponential notation

Character Positions

1 - Query Indicator
- **Z** - Auto Zero completed
- **?** - Display reading is below 10% of full scale range
- **b** - (Blank) Display reading is above 10% of full scale range

3-6 - % display reading
9-14 - Viscosity in cps
10&19 - Overrange and underrange indicator (*)
18-23 - Shear Stress in dynes/cm^2
27-29 - Speed in rpm
34-35 - Viscometer model
37-38 - Spindle entry number
39 - Carriage return
40 - Line feed

Power on, then press AUTO ZERO forces the output signal to hold for 10 seconds while the electronics are reset. At the end of 10 seconds, the output signal will carry a "**Z**" in character position **1** for one output line, and then the "**?**" will be displayed. This sequence will be carried out anytime the AUTO ZERO is pressed. In this way, should you be attached to a printer, you will have a permanent record of the time when you executed an AUTO ZERO.

After a **SPinDLe** entry has been made, the character positions **(37-38)** will show the spindle entry number. The viscosity **(9-14)** and shear stress **(18-23)** character positions will also be activated upon spindle entry.

The Viscometer model is dedicated to the instrument, and positions **(34-35)** will carry the appropriate designation. Refer to the Designations Table for Viscometer models (Appendix II.).

The RPM speed select knob setting will be displayed in positions **(27-29)**. The actual rotational speed will be displayed when the motor switch is **ON**. When it is **OFF**, the RPM will be ".00".

The % reading (percentage of full scale range) will be updated in character positions **(3-6)**. This is the well known Brookfield dial or display reading found on the analog (Dial) and first series Digital Viscometers.

COMMDEMO.BAS PROGRAM

Simple MS Basic program to poll serial port 1 and keyboard alternately. If serial port has data, it is parsed and then printed to the screen. The only keyboard character allowed is the <Esc> key which will stop the program.

For use with: Microsoft BASIC on IBM Pc's and compatibles

Note: Microsoft's Basic Interpreter has trouble when it must access the serial ports. Therefore, lines 225 and 245 should be entered exactly as shown. You may also have to press the F2 <RUN> key repeatedly until the message "Device I/O Error in xxx" does not appear. Even then, the data may appear jumbled and will require that you press the Esc and F2 keys until everything works fine. Sorry about that!!! The program works flawlessly with Microsoft's QuickBasic 4.0, Borland's Turbo Basic and Zedcor's ZBasic.

Owners of GWBASIC will, for some reason, have fewer or none of the problems described above.

```
220   CLS ' Clear display screen
225   OPEN "COM1:1200,N,7,2,CS0,DS0,CD" AS #1 ' Open comm port
230   DS$ = "" ' NULL OUT Data String
235   WHILE KEYPRESSED$ <> CHR$(27) ' Do WHILE/WEND if key pressed is not ESC
240   IF EOF(1) THEN 450 ' If nothing from viscometer, check keyboard
245   WHILE LOC(1) < 40 ' If comm port active, then loop
250   WEND ' around until data string is complete
255   DS$ = INPUT$(LOC(1),#1) ' We have our viscometer string here
260   DS$ = RIGHT$(DS$, LEN(DS$) - 1) ' Strip leading carriage return
265   LF = INSTR(DS$, CHR$(10)) ' Look for trailing line feed
270   IF LF THEN DS$ = LEFT$(DS$, LF - 1) + MID$(DS$, LF + 1) ' Strip linefeeds from
      data string
275   LOCATE 1,1
280   PRINT "Here is DV II Viscometer raw output data string";
285   LOCATE 2,1
290   PRINT DS$;
295 '
300 '  Parse viscometer data string into constituent parts
305 '  ? 00.0% 0.00E0CP 0.00E0SS .00RPM RV 31
310 '
315   TOR$ = MID$(DS$,3,4) ' Torque is char's 3 - 6
320   CPV$ = MID$(DS$,9,4) ' Centerpoise Value is char's 9 - 12
```

```
325   CPE$ = MID$(DS$,14,1) ' Centerpoise Exponent is char 14
330   CPS$ = STR$(VAL(CPV$) * 10 ^ VAL(CPE$)) ' Centerpoise = Centerpoise Value * 10
      ^ Centerpoise Exponent
335   CPS$ = RIGHT$(CPS$, LEN(CPS$) - 1) ' Strip leading blank from string
340   SHV$ = MID$(DS$,18,4) ' SS Value is char's 18 - 21
345   SHE$ = MID$(DS$,23,1) ' SS Exponent is char 23
350   SHS$ = STR$(VAL(SHV$) * 10 ^ VAL(SHE$)) ' SS = SS Value * 10 ^ SS Exponent
355   SHS$ = RIGHT$(SHS$, LEN(SHS$) - 1) ' Strip leading blank from string
360   RPM$ = MID$(DS$,27,3) ' Spindle speed is char's 27 - 29
365   MDL$ = MID$(DS$,34,2) ' Viscometer model is char's 34-35
370   SPD$ = RIGHT$(DS$,2) ' Viscometer spindle is char's 37 - 38
375 '
380 '  Print the parsed viscometer data string
385 '
390   LOCATE 4,1
395   PRINT "Here is viscometer data parsed into its constituent parts"
400   IF VAL(TOR$) < 10 THEN TOR$ = RIGHT$(TOR$, LEN(TOR$) - 1)  ' Strip leading
      zero from TORQUE if < 10%
405   LOCATE 5,10: PRINT "TORQUE %      = ";TOR$
410   IF VAL(T$) >= 0 THEN LOCATE 6,10: PRINT "VISCOSITY Cps = ";CPS$
415   IF VAL(T$) >= 0 THEN LOCATE 7,10: PRINT "SS Dynes/cm^2 = ";SHS$
420   LOCATE 8,10: PRINT "RPM=";          RPM$
425   LOCATE 9,10: PRINT "MODEL=";        MDL$
430   LOCATE 10,10: PRINT "SPINDLE=";     SPD$
435   DS$ = "" ' NULL OUT Data String for next pass
440    LOCATE 12,1
445   PRINT "Press <Esc> key to end program"
450   KEYPRESSED$ = INKEY$ ' Check for <Esc> key press
455   WEND
460   CLOSE #1 ' For completeness, close our serial port
465   CLS ' Clear the screen
470   LOCATE 12, 32
475   PRINT "PROGRAM STOPPED"
480   END
```

IV. Fault Diagnosis/Troubleshooting

The chart below lists some of the more common problems that you may encounter while using your Viscometer, along with the probable causes and suggested cures.

(A) Spindle does not rotate

1. Incorrect power supply
   - Check - must match Viscometer requirements

2. Viscometer not plugged in
   - Connect to appropriate power supply

3. Power switch in "off" position
   - Turn power switch on
4. Shift knob set "between" speeds
   - Rotate knob to higher or lower speed setting

(B) Spindle rotates eccentrically

1. Spindle not screwed securely to coupling
   - Tighten

2. Dirt in spindle coupling
   - Clean

3. Bent spindle
   - Check other spindles - replace any that are bent
   - If all rotate eccentrically - see (B)4

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

4. Spindle coupling bent
   - Return to factory or dealer for repair

(C) Display reads only "00.0"

1. No response to spindle deflection indicates 0-1v or 0-10mv output signal leads shorted
   - Check output connections

2. Hold key is on (light on)
   - Toggle hold off

(D) No display reading

1. Underrange "- - -" (in %, CPS or SS mode)
   - Change spindle and/or speed
   - Perform an Auto Zero

2. Spindle jammed
   - Consult factory or dealer

(E) Display reading over 100

1. Overrange "EEE" (in %, CPS or SS mode)
   - Change spindle and/or speed

(F) Viscometer will not return to zero

1. Pivot point or jewel bearing faulty
   - Perform calibration check
   - Return to factory or dealer for repair

(G) Display reading will not stabilize

1. Check for erratic spindle rotation - may be caused by incorrect power supply or mechanical fault
   - Return to factory or dealer for repair

2. Bent spindle or spindle coupling
   - Check

3. Temperature fluctuation in sample fluid

4. Characteristics of sample fluid

(H) Inaccurate readings

1. Incorrect spindle/speed selection
2. Incorrect **SPinDLe** entry
3. Non-standard test parameters
4. Temperature fluctuations
5. Incorrect equipment selection

(I) Recorder pen moves in wrong direction

1. Output polarity reversed
   - Reverse leads

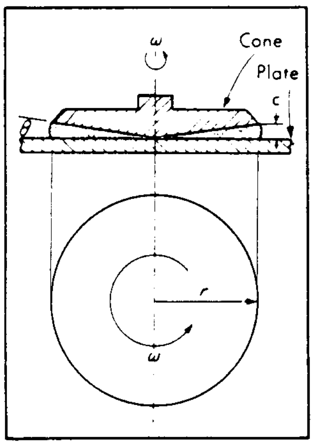
(J) No recorder response

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

V. Cone/Plate Mathematics

Cone and Plate geometry, as illustrated, is the fixation of a conical vertex perpendicular to and in point contact with a flat plate. When the cone is made very obtuse (θ less than 4°) and rotated at constant speed (ω), precise viscosity measurements are obtained at absolute and uniform values of shearing rate and stress.

Viscosity (poise) is the ratio of shear stress to shear rate. Shear stress is related to the summation of torque (T) over the conical surface. Shear rate is related to the cone rotational speed (ω), and gap width (c) at any radial distance (r) from the center of the rotating cone.



The ratio of (ω r) and (c) is a constant for any value of (r). Since (c) is a maximum at cone radius (r), the shear rate is related to (ω) and sin (θ).

For the Wells-Brookfield Cone/Plate Viscometer, the mathematical relationships are:

$$\text{Shear Stress (dynes/cm}^2\text{)} = \frac{T}{\tfrac{2}{3}\pi r^3}$$

$$\text{Shear Rate (Sec}^{-1}\text{)} = \frac{\omega}{\sin\theta}$$

$$\underset{\text{(mPa·s)}}{\underset{\text{(Centipoise)}}{\text{Viscosity}}} = \frac{\text{Shear Stress} \times 100}{\text{Shear Rate}}$$

Where:

T = % Full Scale Torque (dyne-cm)
r = Cone Radius (cm)
ω = Cone Speed (rad/sec)
θ = Cone Angle (degrees)

Cone Radius:
CP 40, CP 41, CP 42 — 2.4 cm
CP 51, CP 52 — 1.2 cm

Note: When calibrating 2.4cm diameter cone spindles CP-51 or 52 at shear rates greater than 384 sec $^{-1}$, use Brookfield Viscosity Standards 5,000 cps or lower.

Viscometer Model Series	Full Scale Torque Dyne Centimeters
LV	673.7
RV	7187.0
HA	14,374.0
HB	57,496.0

Range Tables

All ranges are in centipoise.
(1 cps = 1 mPa·s)

Note: When calibrating 2.4cm diameter cone spindles CP-51 or 52 at shear rates greater than 384 sec-1, use Brookfield Viscosity Standards 5,000 cps or lower.

LVTDV-IICP

3.0° Cone Spindle

SPEED (RPM)	SHEAR RATE (SEC^{-1})	CONE # CP-41 2 ml SAMPLE	CONE # CP-52 0.5 ml SAMPLE
60	120.0	19.2	155.33
30	60.0	38.4	310.66
12	24.0	96.0	776.64
6	12.0	192.0	1,553.3
3	6.0	384.0	3,106.6
1.5	3.0	768.0	6,213.1
0.6	1.2	1,920.0	15,532.8
0.3	0.6	3,840.0	31,065.6

1.565° Cone Spindle

SPEED (RPM)	SHEAR RATE (SEC^{-1})	CONE # CP-42 1 ml SAMPLE	CONE # CP-51 0.5 ml SAMPLE
60	230.0	10.00	80.90
30	115.0	20.00	161.80
12	46.0	50.00	404.50
6	23.0	100.00	809.00
3	11.50	200.00	1,618.00
1.5	5.75	400.00	3,236.0
0.6	2.30	1,000.0	8,090.0
0.3	1.15	2,000.0	16,180.0

0.8° Cone Spindle

SPEED (RPM)	SHEAR RATE (SEC^{-1})	CONE # CP-40 0.5 ml SAMPLE
60	450.0	5.14
30	225.0	10.28
12	90.0	25.70
6	45.0	51.40
3	22.5	102.80
1.5	11.25	205.60
0.6	4.50	514.00
0.3	2.25	1,028.0

RVTDV-IICP

3.0° Cone Spindle

SPEED (RPM)	SHEAR RATE (SEC^{-1})	CONE # CP-41 2 ml SAMPLE	CONE # CP-52 0.5 ml SAMPLE
100	200	122.88	983
50	100	245.76	1,966
20	40	614.40	4,915
10	20	1,228.8	9,830
5	10	2,457.6	19,660
2.5	5	4,915.2	39,320
1.0	2	12,288.0	98,300
0.5	1	24,576.0	196,600

1.565° Cone Spindle

SPEED (RPM)	SHEAR RATE (SEC^{-1})	CONE # CP-42 1 ml SAMPLE	CONE # CP-51 0.5 ml SAMPLE
100	384.0	64	512
50	192.0	128	1,024
20	76.8	320	2,560
10	38.4	640	5,120
5	19.20	1,280	10,240
2.5	9.60	2,560	20,480
1.0	3.84	6,400	51,200
0.5	1.92	12,800	102,400

0.8° Cone Spindle

SPEED (RPM)	SHEAR RATE (SEC^{-1})	CONE # CP-40 0.5 ml SAMPLE
100	750.0	32.70
50	375.0	65.40
20	150.0	163.50
10	75.0	327.00
5	37.5	654.00
2.5	18.75	1,308.0
1.0	7.50	3,270.0
0.5	3.75	6,540.0

HBTDV-IICP

3.0° Cone Spindle

SPEED (RPM)	SHEAR RATE (SEC^{-1})	CONE # CP-41 2 ml SAMPLE	CONE # CP-52 0.5 ml SAMPLE
100	200	983	7,864
50	100	1,966	15,728
20	40	4,915	39,321
10	20	9,830	78,643
5	10	19,660	157,286
2.5	5	39,320	314,572
1.0	2	98,300	786,430
0.5	1	196,600	1,572,860

1.565° Cone Spindle

SPEED (RPM)	SHEAR RATE (SEC^{-1})	CONE # CP-42 1 ml SAMPLE	CONE # CP-51 0.5 ml SAMPLE
100	384.0	512	4,096
50	192.0	1,024	8,192
20	76.8	2,560	20,480
10	38.4	5,120	40,960
5	19.2	10,240	81,920
2.5	9.6	20,480	163,840
1.0	3.84	51,200	409,600
0.5	1.92	102,400	819,200

0.8° Cone Spindle

SPEED (RPM)	SHEAR RATE (SEC^{-1})	CONE # CP-40 0.5 ml SAMPLE
100	750.0	262
50	375.0	524
20	150.0	1,310
10	75.0	2,620
5	37.5	5,240
2.5	18.75	10,480
1.0	7.50	26,200
0.5	3.75	52,400

VI. Specifications

Power Supply:	115V/60 Hz 230V/50 Hz or 115V/50 Hz 230V/60 Hz	

Analog Interface

Output Signals:	0-10mv DC Red (+) For recording Black (-)	0-1v DC Yellow (+) Green (-) For analog to digital interface or optional recording
Output Impedence:	1k ohms	20k ohms

Digital Interface

RS-232 Signal:	Asynchronous, talker only No handshaking No error detection	Two wire point to point Transmit on white lead Ground on blue lead
Transmission:	Half duplex - no parity 7 data bits - 2 stop bits 1200 baud - standard ASCII	

DV Gather Hardware Requirements

Computer:

IBM PC, PC-AT, PC-XT or True Compatable

CGA Color Graphics

RS232 Serial Port for Viscometer

Printer Port

DOS 2.0 or higher operating system

Minimum 512K RAM

Viscometer/Computer Connection:

All Model DV-II Viscometers are supplied with signal output cable, Brookfield part number DVC-18Y. The RS232 leads must be connected to the appropriate connector (9 or 25 pin) as follows:

9 Pin:	White (Transmit)	to Pin 2
	Blue (Ground)	to Pin 5
25 Pin:	White (Transmit)	to Pin 3
	Blue (Ground)	to Pin 7

VII. Repairs and Service

Any Brookfield Digital Viscometer used in the United States requiring repair or service should be returned to:

Brookfield Engineering Laboratories, Inc.
240 Cushing Street
Stoughton, Massachusetts 02072
Telephone: (617) 344-4310/4313 Telex: 924-497 Fax: (617) 344-7141

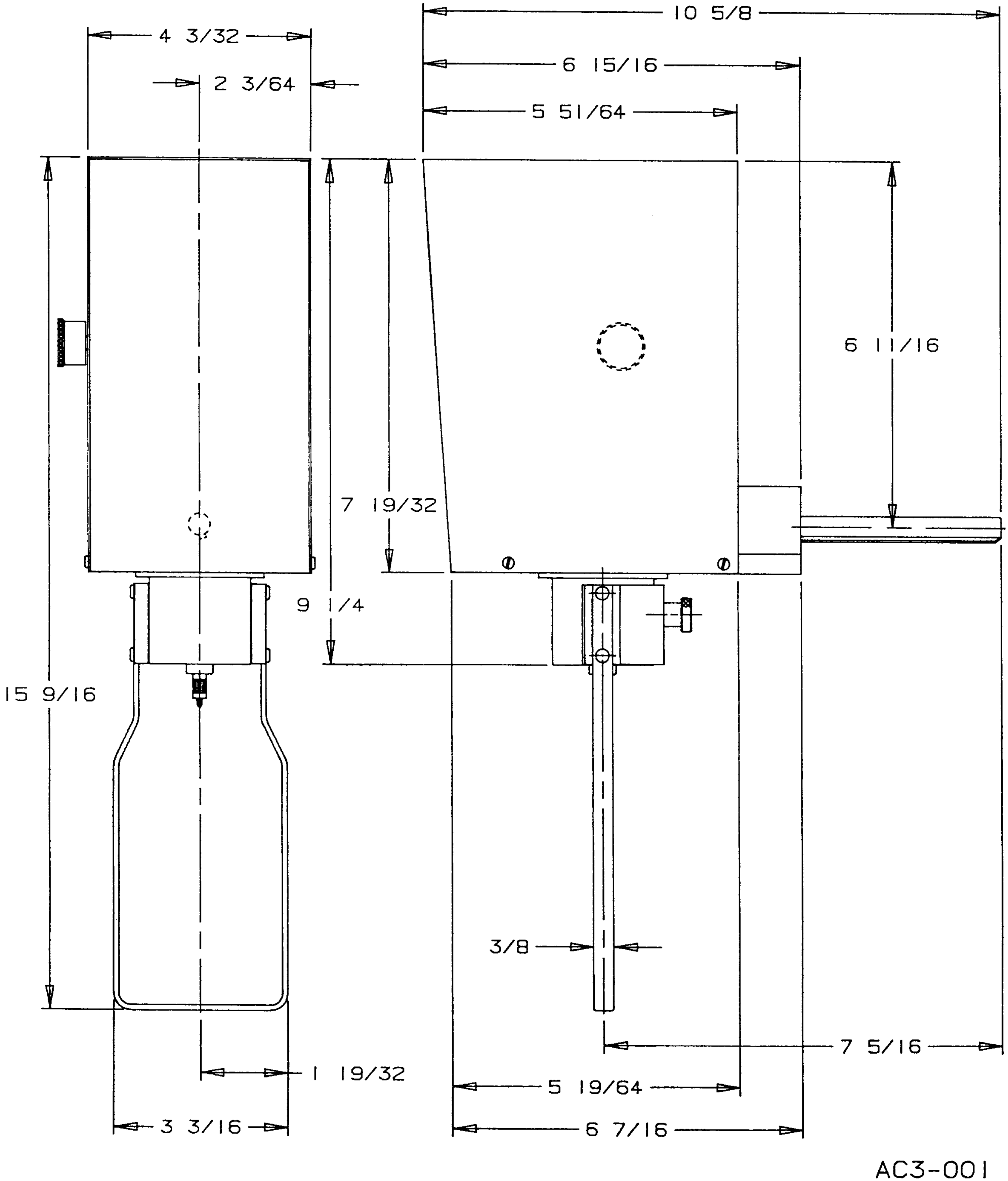
The Viscometer should be shipped in its carrying case together with all the spindles originally provided with the instrument.

For service on Viscometers located outside the United States, consult the dealer from whom you purchased the instrument.

VIII. Warranty

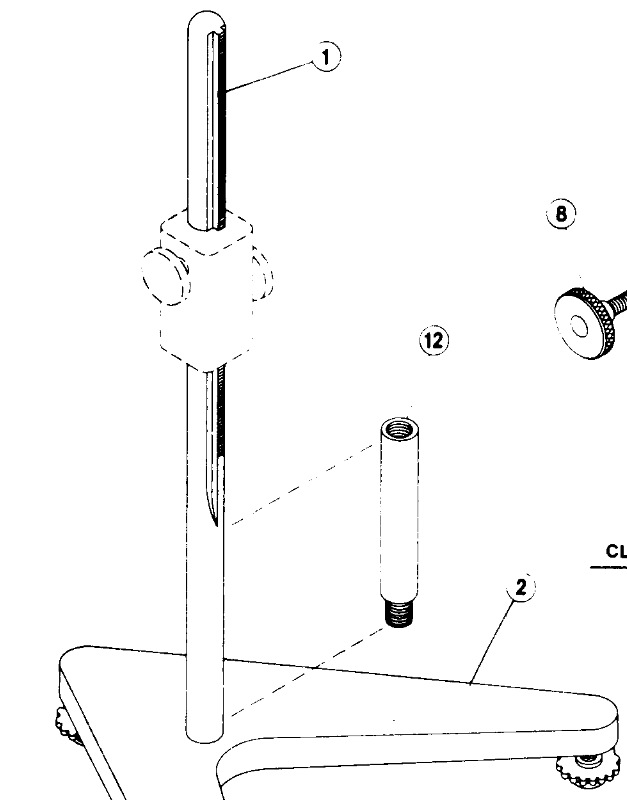
Brookfield Viscometers are guaranteed for one year from date of purchase against defects in materials and workmanship. The Viscometer must be returned to the manufacturer, or dealer, for no charge warranty service. Transportation is at purchaser's expense.

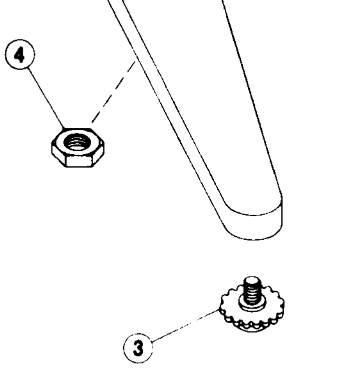
DVI & DVII HEAD DIMENSIONS
(WITH RV GUARD LEG & PIVOT CUP)

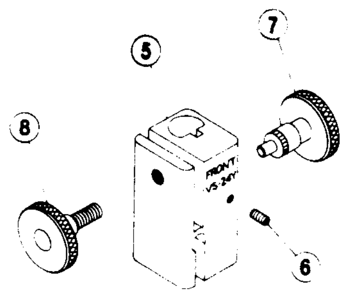


MODELS A & A-E LABORATORY STANDS

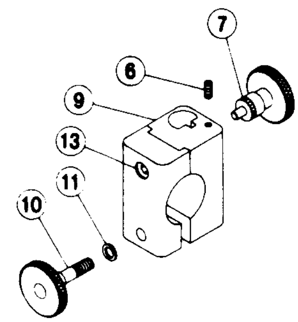
PARTS IDENTIFICATION







VS - 24Y
MODEL A
CLAMP ASSEMBLY



VS - 17AY
MODEL A-E
CLAMP ASSEMBLY

ITEM	PART NO.	DESCRIPTION	QTY.
1	VS–20	UPRIGHT ROD	1
2	VS–1	BASE	1
3	VS–3	LEVELING SCREW	3
4	VS–21	JAM NUT	1
5	VS–24	CLAMP	1
6		10–32 X 3/8 SET SCREW	1
7	VS–7Y	GEAR SCREW ASSEMBLY	1
8	VS–26Y	CLAMP SCREW ASSEMBLY	1
9	VSXA–17Y	CLAMP ASSEMBLY	1
10	VS–6AY	MODEL A-E CLAMP SCREW ASSEMBLY	1
11		1/4 I.D. X 3/8 O.D. WASHER	1
12	BLM–4E	ROD EXTENSION - 4" LONG	OPTIONAL
	BLM–4E–2	ROD EXTENSION - 8" LONG	OPTIONAL
13		1/4–20 X 3/4 HEX SOC HD SCREW	1

MODELS A & A-E LABORATORY STAND INSTRUCTIONS

Unpacking

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

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

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

Assembly

Screw the leveling screws into the base. Insert the threaded end of the upright rod into the hole in the top of the base and attach the jam nut to the rod on the underside of the base. With the rod gear rack facing forward (toward the "V" in the base), gently tighten the jam nut. When using the rod extension, screw the threaded end of the upright rod into the extension, then insert the threaded end of the rod extension into the base.

Viscometer Mounting

Dial Viscometers:

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

Digital Viscometers:

Insert the Viscometer mounting rod into the hole (with the cut-away slot) in the clamp assembly. Adjust the instrument level until the bubble is centered from right to left and tighten the clamp knob (clockwise). **Note:** If the Digital Viscometer cannot be leveled, check to insure that the rod is installed with the gear rack facing forward (toward the "V" in the base).

Explosion Proof Viscometers:

Remove the hex socket screw (item 13) from the clamp assembly and separate the clamp. Place the handle of the Viscometer against the clamp/rod assembly and reinstall the clamp and hex socket screw. Adjust the instrument level until the bubble is centered from right to left and tighten the clamp knob (clockwise).

Caution: Do not tighten the clamp knob unless the handle core is inserted in the clamp assembly.

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

The small screw on the clamp assembly may be loosened or tightened as necessary to provide smooth height adjustment and adequate support for the Viscometer.