BROOKFIELD MODEL TT100

IN-LINE VISCOMETER

Installation, Operation, and Maintenance Instructions

Manual No. M/97-520-A899

BROOKFIELD

SPECIALISTS IN THE
MEASUREMENT AND
CONTROL OF VISCOSITY

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Section 1 - In-Line Viscometer Description

Introduction

The Brookfield Model TT100 In-Line Viscometer is a highly sensitive versatile instrument that measures process fluid viscosity in a fully flooded product stream under pressure or vacuum. Brookfield In-Line Viscometers are unaffected by changes in pressure, laminar flow, or density.

The TT100 In-Line Viscometer generates a 4 - 20 milliampere (mA) or 0 - 10 Volts DC (VDC) signal proportional to process fluid viscosity. The signal is stable, can be transmitted over long distances with minimal loss, and is not affected by noise. Adjustable electronic damping maintains signal quality under severe process conditions.

The TT100 In-Line Viscometer, shown in Figures 1-1 and 1-2, can be used in a variety of industrial applications where the viscosity of chemical, coating, fuel oil, and many other process fluids must be controlled or monitored.

Features and Benefits

The TT100 In-Line Viscometer incorporates the following features:

- Easy start-up, operation, and cleaning
- Instantaneous response
- Optional selectable dual viscosity range
- Continuous linear output signal (4 - 20 mA) or (0 - 10 VDC)
- Coaxial cylinder measurement geometry for viscosity values at defined shear rates
- Optional temperature compensation

The TT100 In-Line Viscometer provides the following benefits:

- Highly sensitive measuring system unaffected by changes in pressure, laminar flow, or density.

- Can be cleaned-in-place thereby minimizing downtime.
- Eliminates manual procedure for lab viscosity analysis. Provides early detection of anomalous processing.
- Accurate and proven control - optimizes product consistency and quality.
- Provides a permanent record for quality control when used with a recorder or integrated computer system.
- Due to the unique design of the torsion element, pressure does not affect its response.
- Operates continuously and instantly responds to changes in viscosity.
- Minimal pressure drop.
- Linear output signal is proportional to viscosity and compatible with most industrial process control equipment.
- Installs directly in-line or in a by-pass line.
- Optional features and accessories are available to enhance In-Line Viscometer performance.

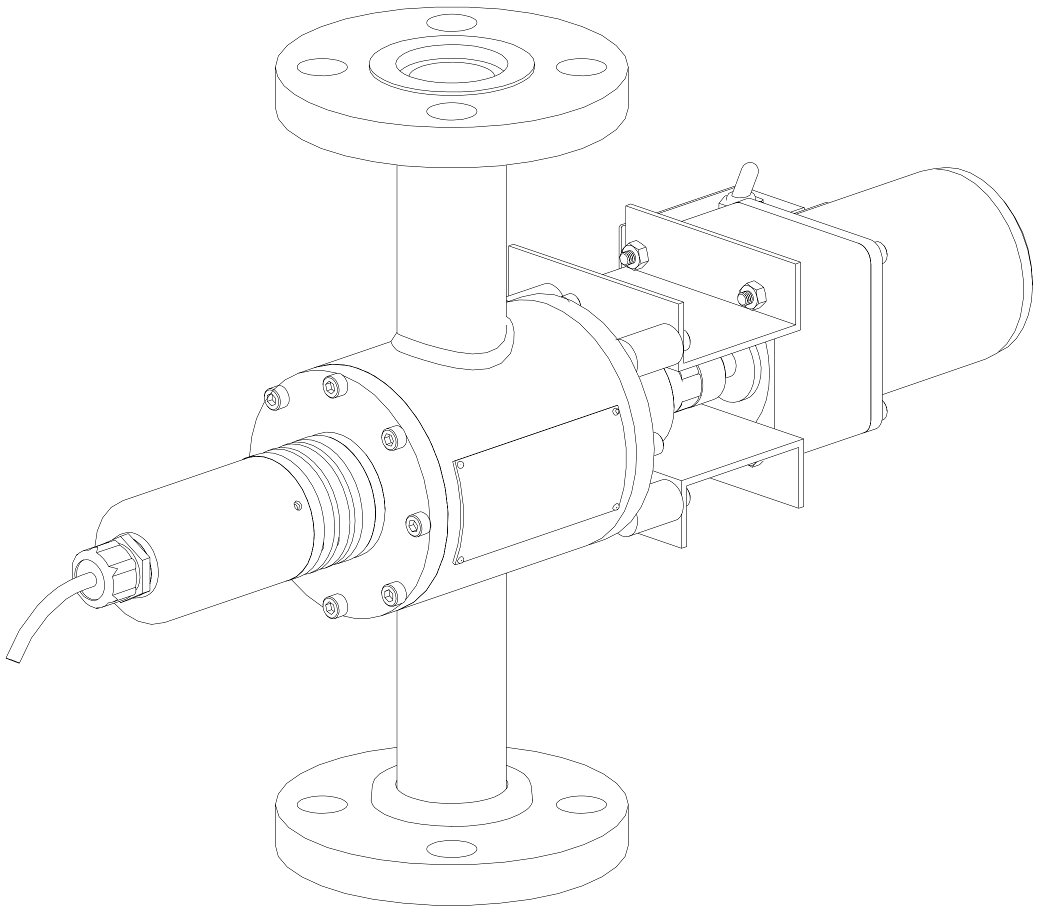
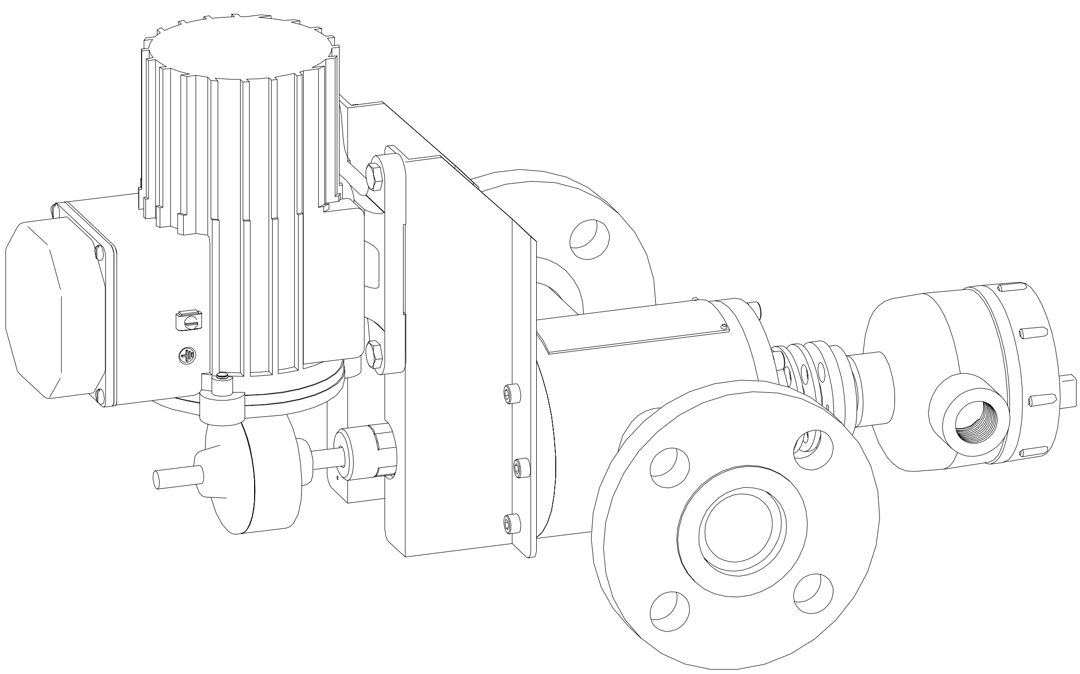


Figure 1-1: Typical TT100 In-Line Viscometer with Oriental Motor



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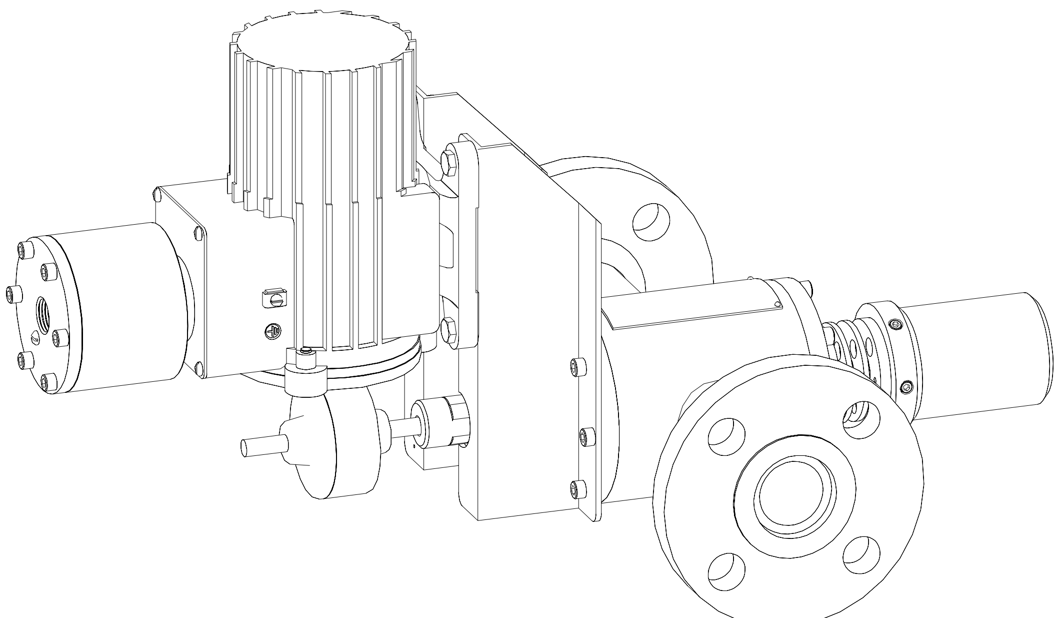


NEMA 7

Figure 1-2: Typical TT100 In-Line Viscometer with Groschopp Motor

Theory of Operation

The product stream flows through the inlet into the TT100 In-Line Viscometer measuring chamber, as shown in Figure 1-3, where it pushes against a cylinder or rotor driven by a drive motor. The rotation of the rotor causes a gentle pumping action forcing the product to flow into the measuring annulus between the rotor and the stator. The viscous drag of the product on the stator is resisted by a torsion element which transmits an angular deflection signal to a rotary transformer drive transducer. This signal is processed through solid state torque sensor electronics in a remote enclosure to produce a linear 4 - 20 mA signal proportional to the viscometer's viscosity range.

Measuring range and shear rate can be varied by changing rotational speed (via gearbox or by speed control) or by changing the rotor and/or stator as specified in Table D-1. Refer to **Appendix D** for more information on changing geometrical components.

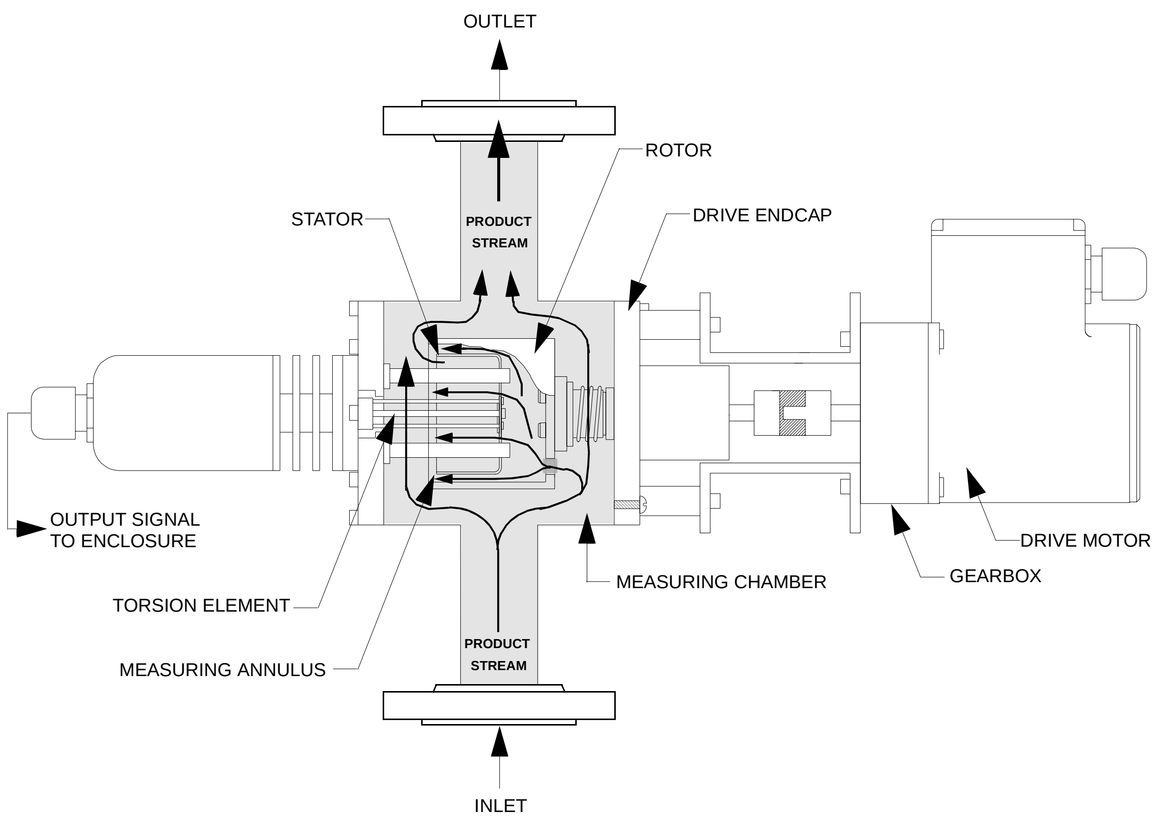


Figure 1-3: TT100 In-Line Viscometer Product Stream Flow

Correlation with Other Measurements

Typically, there is a difference between laboratory and process viscosity measurements. Laboratory measurements, for a given fluid, are usually higher than process measurements.

Viscosity measurements are unique among common types of fluid measurement in that, for most fluids, numerical values that are generated are dependent upon flow conditions in the fluid being measured (shear rate or velocity gradient). Other factors such as temperature change, turbulence, and pressure among the most prominent, also affect the readings.

Frequently it may become necessary to *correlate* readings provided by your on-line viscometer to those factors that influence viscosity obtained by other methods. The correlation consists of holding the viscosity dependent factors constant, as mentioned above, and plotting the on-line viscosity value against the other reading as shown in Figure 1-4. A successful empirical correlation will assure the process operator that an on-line reading can be matched to a viscosity value derived by the other method. The correlation of these readings may be instrumental in educating process operators how the process stream relates to bench-top derived viscosity measurements.

Many factors beyond those noted above, which are more difficult to control in an on-line situation than in a laboratory environment, can potentially affect your correlation. Refer to **Appendix A** and contact Brookfield Engineering Laboratories, Inc. for assistance in generating an empirical correlation.

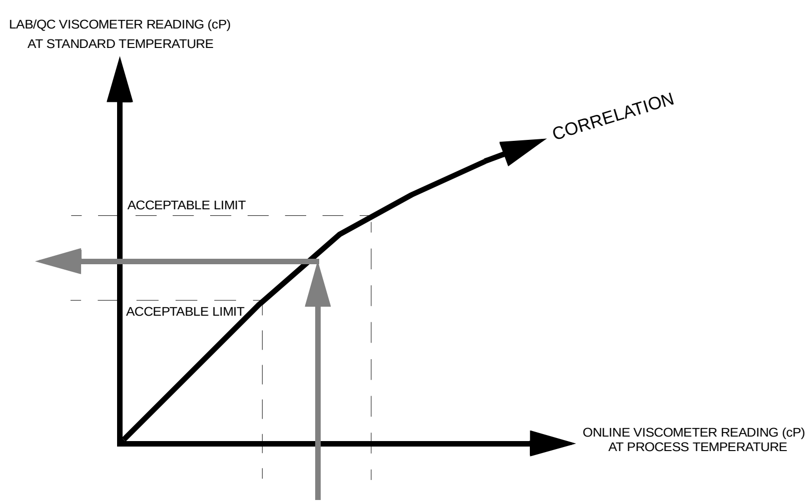


Figure 1-4: In-Line Viscometer Correlation with Other Measurement Techniques

Specifications

The TT100 In-Line Viscometer is available in standard or optional configurations as listed in Table 1-1.

Table 1-1: Model TT100 In-Line Viscometer Specifications

Parameter	Standard Configuration	Optional Configuration*
Viscosity Range (See Note 1)	10 - 500,000 cP	10 - 500,000 cP
Shear Rate Range	10 - 1000 sec^{-1}	0.02 - 12,000 sec^{-1}
Temperature Range (See Note 2)	-40º - 300º F	-40º - 500º F
Pressure Range (See Note 3)	0 - 200 psi	Vacuum to 500 psi
Reproducibility	± 0.5% of span	± 0.5% of span
Signal Output	4 - 20 mA	0 - 20 mA, 0 - 10 VDC
Power Requirements	115VAC 50/60Hz 100 Watts	230VAC 50/60 Hz 100 Watts
Chamber	300 Series S/S 1 inch NPT (Female) inlet and outlet	316 S/S wetted parts construction 1, 1 1/2, or 2 inch threaded or flanged, 4 inch flanged
Motor	Single-speed synchronous	Multiple-speed with speed control
Dimensions	5 x 5 x 17 inches (127 x 127 x 431.8 mm)	5 x 5 x 17 inches (127 x 127 x 431.8 mm)
Construction	NEMA 4 Water tight and dust tight	Refer to Appendix D
Weight	50 lbs. (23 kg)	50 lbs. (23 kg)

* Optional Configurations offer dual range capability, custom mounting and/or special viscosity ranges and shear rates.

NOTE 1: Range is calibrated with a 0 cP lower limit. The upper limit can be any value between 10 - 500,000 cP.
NOTE 2: Under certain conditions, temperatures as high as 700º F may be accommodated.
NOTE 3: Under certain conditions, pressures as high as 1000 psi may be accommodated.

Required Utilities

The TT100 In-Line Viscometer requires the utility connections listed in Table 1-2 to operate.

Table 1-2: Utility Requirements

Parameter	Value
Supply Voltage	115/230 VAC
Line Frequency (See Note 1)	50 or 60 Hz
Power	100 Watts
Flushing Requirements (See Note 2)	3 - 10 gpm 30 - 40 psig 1/8 inch pipe thread endcap connection
Barrier Fluid Pressure (See Note 3)	20 psi above maximum process flow pressure

NOTE 1: Variations in line frequency will affect instrument span and accuracy.
NOTE 2: If viscometer is equipped with flushing option.
NOTE 3: If viscometer is equipped with double mechanical seals.

Current Draw - Starting & Running

The normal running power requirement for TT100 In-Line Viscometer is 100 watts. However, the instantaneous starting current requirement for the TT100 drive motor can be at least five times greater.

Brookfield Engineering Laboratories, Inc. recommends that any inverter, transformer, or similar device that is used with the Model TT100 should be rated at 750 volt-amperes or greater.

Cleaning

To ensure proper viscometer operation, it is important to properly clean or flush the viscometer at regularly scheduled intervals. Solids can build up on the opposing cylinder surfaces and interfere with the angular movement of the stator and torsion element and their movement in relation to the stop posts which protrude through the stator. Additionally, solids can build up at the mechanical seal which may affect its ability to maintain leak-free operation.

The user must establish cleaning procedures and cleaning fluids. Clean-In-Place (CIP) is strongly recommended as the cleaning procedure of choice. In addition to CIP, the user may choose the flushing option in order to direct cleaning fluid to the internal components to enhance the cleaning process. The third choice for cleaning is to manually clean the internal components. This is not a recommended practice due to the damage that can be caused on the torsion element when exposed to this manual cleaning.

The clean-in-place procedure can be accomplished with high flow rate cleaning fluid or steam.

NOTE: *The cleaning fluid must be compatible with the seal. Steam Temperature should not be higher than the temperature rating of the viscometer.*

In some instances, the instrument installation can be plumbed with 2 three-way valves with the cleaning fluid introduced and drained through the side ports of these valves.

The flushing option, available in the TT100, is offered in either or both endcaps. When in use, the cleaning fluid is introduced towards the internal components through directional spray nozzles. This cleaning procedure should be accomplished with the measuring chamber void of any process fluid and the cleaning fluid at a pressure of approximately 30-40 psi and a flow rate of 3-10 gpm.

Refer to **Section 5 - Maintenance** for clean-in-place or flushing procedures.

Component Identification

The following paragraphs provide a brief description of each component within the TT100 In-Line Viscometer. Refer to Figure 1-5 for the component location within the viscometer.

Torque Sensor Assembly

The Torque Sensor Assembly contains the torsion element, armature, and field coil. These components generate an electrical signal proportional to the viscous drag of the process fluid which is sent to the torque sensor electronics enclosure for signal processing.

Sensing Endcap

The Sensing Endcap contains the torque sensor assembly and all related components.

Stator

The Stator, which is mounted on the torsion element, applies torque generated by viscous drag to the torsion element. The dimensions of the stator, in conjunction with the rotor, are critical to the accuracy of the viscometer. Many different stator sizes are available which provide different viscometer measurement ranges.

Stop Posts

The stop posts limit stator/torsion element movement to prevent torsion element damage.

Inlet/Outlet

The Inlet and Outlet are provided with an appropriate connection type and allows process fluid to enter or exit the viscometer. Either connection may be used to allow process fluid to enter or exit the viscometer.

Rotor

The Rotor is a hollow cylinder which constantly rotates around the stator, driven by the motor. The rotation of the rotor moves process fluid in the measuring annulus which results in viscous drag on the stator. Rotors are available that contain additional surface holes to allow a faster turnover of process fluid in the measuring annulus. Different rotor sizes are also available.

Drive Endcap

The Drive Endcap supports the rotor, mechanical seal, drive shaft, bearings and bearing housing, motor, and all related mechanical components.

Motor Cable

The Motor Cable supplies electrical power to the motor from the motor control enclosure, or directly from a power source.

Gearbox

The Gearbox reduces rotational speed and allows the drive shaft to rotate slower than the motor. The rotational speed of the drive shaft is determined by Brookfield Engineering Laboratories, Inc. based upon customer viscosity range requirements.

Drive Motor

The Drive Motor is an electric motor which provides a constant rotational speed to the gear box, drive coupling, and viscometer drive shaft. The drive motor is usually a single-speed synchronous motor but is also available in a controlled variable speed induction motor for custom applications.

Drive Coupling

The Drive Coupling connects the viscometer drive shaft to the gear box. The drive coupling contains a rubber cushion (or bronze cushion for high temperature applications) to isolate the viscometer from motor vibration.

Bleed Screw

The Bleed Screw is used to vent air from the viscometer which may be trapped within the measuring chamber.

Measuring Chamber

The Measuring Chamber is the area in which process fluid viscosity is measured. Process fluid may flow through it in either direction.

Measuring Annulus

The Measuring Annulus is the space between the stator and rotor. Process fluid is continuously *sheared* within the measuring annulus which creates viscous drag on the stator.

Sensing Cable

CAUTION

Changing the length of the sensing cable will affect viscometer calibration. Refer to **Appendix A** and contact Brookfield Engineering Laboratories for more information.

The Sensing Cable carries the electrical signal that is proportional to the viscous drag of the process fluid. The signal is sent to the torque sensor electronics enclosure for processing. The Sensing Cable also carries an excitation current from the torque sensor electronics enclosure to the torque sensor assembly.

Torsion Element

The Torsion Element, which is part of the torque sensor assembly, senses the torque from the viscous drag on the stator. The twist or deflection of the torsion element is proportional to the torque applied to it.

Heat Baffle

The Heat Baffle, which is sometimes referred to as an *insulator*, dissipates heat from the viscometer that has been transferred from the process fluid. The transfer of heat to the baffle protects the field coil from high temperatures.

Torque Sensor Electronics Enclosure

The Torque Sensor Electronics Enclosure contains a circuit board which processes the signal from the torque sensor assembly and generates a linear electrical signal (4 - 20 mA) proportional to the viscosity of the process fluid in the measuring annulus. The circuit board also provides an excitation current to the field coil.

The 4 - 20 mA signal can be:

- Observed on a readout display
- Transmitted to a personal computer for process monitoring and control
- Recorded for process control records

Motor Control Enclosure

The Motor Control Enclosure accepts 115/230 VAC and supplies appropriate power to the drive motor. The enclosure also contains the motor ON/OFF power switch and optional motor speed controller for variable speed motor applications.

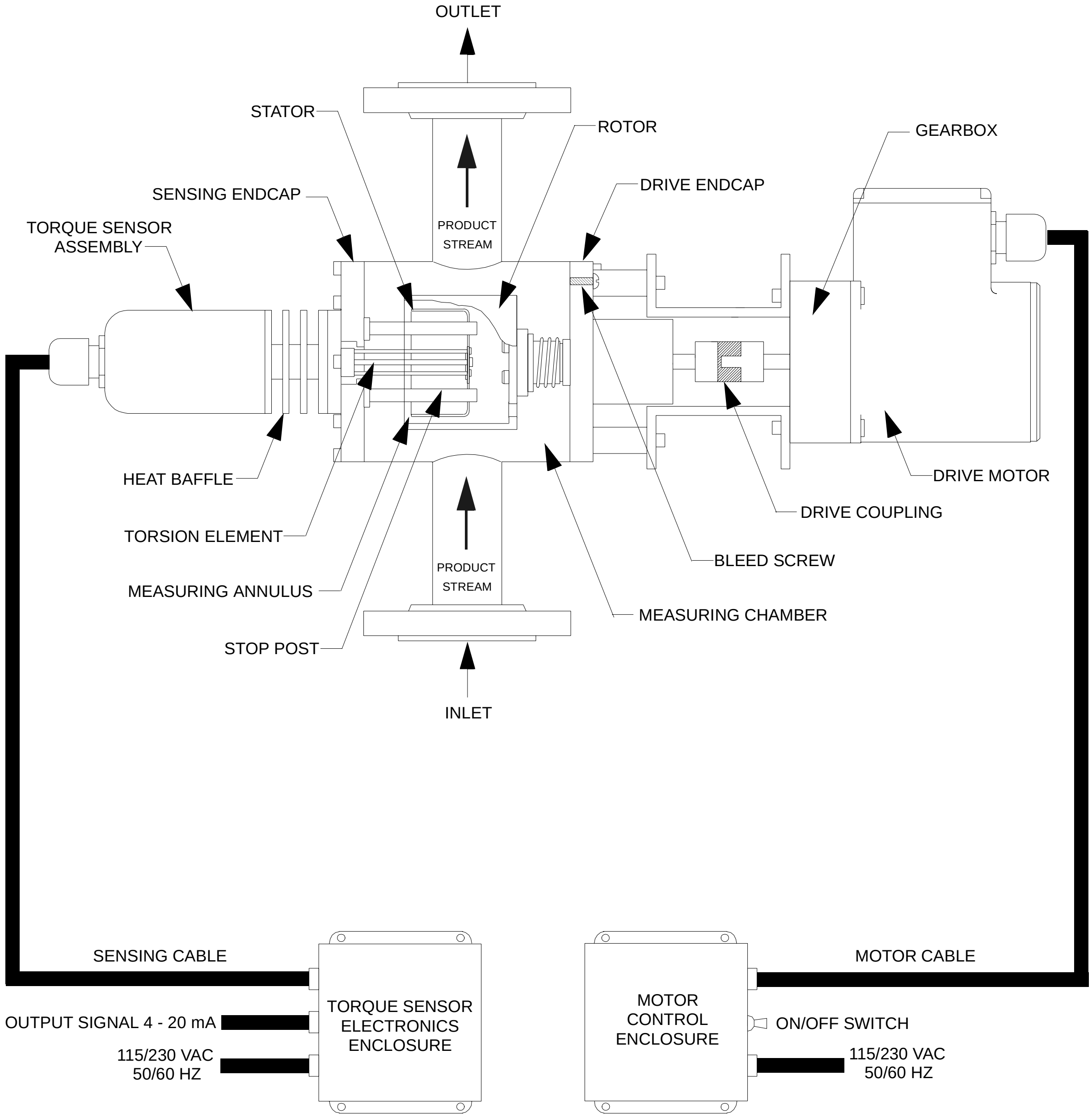


Figure 1-5: Typical Model TT100 In-Line Viscometer Component Identification (NEMA 4 Shown)

Options

The following optional equipment is available to enhance the operation of the TT100 In-Line Viscometer when installed within certain product stream applications. Refer to **Appendix A** and contact Brookfield Engineering Laboratories, Inc. for more information on these options and accessories.

Double Mechanical Seal

A double mechanical seal can be installed in the following the service conditions which are too severe for the standard (single) mechanical seal:

- Vacuum
- Abrasive Slurries
- Toxic Fluids
- Fluids which harden when exposed to air and/or elevated temperatures

Elliptical Baffle

The Elliptical Baffle can be installed when measuring highly viscous or low flow product streams to direct sufficient flow through the annulus.

Perforated Rotor

The Perforated Rotor can be installed to increase product turnover within the measuring annulus.

Serrated Stator

The Serrated Stator can be installed to ensure shearing by overcoming slippage between the stator and the fluid being measured. The serrated stator is useful with certain product streams such as slurries.

Flushing Endcap

The Flushing Endcap design facilitates cleaning the measuring annulus and torsion element. Compatible solvent can be introduced under pressure when cleaning while the In-Line Viscometer is on-line and empty of process fluid.

Accessories

The following accessories are available to display, control, and record data from the TT100 In-Line Viscometer.

- Analog Display
- Digital Display
- Controller
- Recorder
- Temperature Indication
- Temperature Compensation

Section 2 - Installation

Unpacking and Inspection

NOTE: *Upon receipt, inspect the shipping carton and viscometer components for shipping damage. Report any damage to the shipping company immediately.*

The shipping carton should contain the following components:

- TT100 In-Line Viscometer
- Torque Sensor Enclosure and Cable
- Motor Controller Enclosure and Cable
- Instruction Manual
- Calibration Bars and Tools
- Optional Equipment

NOTE: *Make sure the calibration bars are kept in a safe place and accessible for use during calibration.*

Installation Requirements

NOTE: *Refer to the TT100 In-Line Viscometer Specification sheet to determine the configuration of the viscometer.*

The TT100 In-Line Viscometer must be installed in a manner that will optimize its performance. The installation requirements are:

- Provide a continuous product stream to the viscometer with a minimum time lag between changes in process and their effects on the viscometer. This stream must be representative of other process fluid.

- Install the viscometer so that it is always full of fluid without air pockets or voids. Upflow line mounting is recommended as shown in Figure 2-1. Avoid pipe configurations which allow air or solids to collect in the viscometer. The viscometer can only measure the viscosity of fluids contained in the measuring annulus.

- Provide a continuous product stream flow rate of 0.5 to 20 GPM that produces a pressure drop of less than 25 psi.

NOTE: *The estimated resistance to flow of a 1, 1.5, or 2 inch TT100 is equivalent to that of an average 3 inch globe valve.*

- Provide a straight pipe leading into the viscometer that is at least ten times the pipe diameter in length.

- Know the product stream's rheology and how it responds to other factors occurring in the process such as temperature, pH, pressure, etc. Control or monitoring of the product stream's temperature may be required.

- Power: Single phase, 115 or 230 VAC 50 or 60 Hz

- For NEMA 7 applications, the customer must provide a 600 VAC, 18 Gauge, two conductor with ground viscometer power cable between the Motor Control Enclosure and the viscometer motor which must conform to local electrical codes.

- Flushing connection: 1/8 inch-27 NPT thread in either endcap
  5 - 10 GPM of flushing fluid at 40 - 90 psig.

- If equipped, double mechanical seals require clear barrier fluid under pressure at 20 psi above maximum process pressure connected to a 1/8 inch standard pipe thread connection in the drive endcap. No flow is required, but venting of air from the seal is required to avoid premature seal wear.

- If the viscometer is to be cleaned in place, isolation valves, flow boosters, or other auxiliary items may be required.

Calculating Minimum Straight Pipe Length

NOTE: *The TT100 In-Line Viscometer does not require special supports or special pipe alignment. The housing is symmetrical with respect to the flow direction.*

Refer to Figure 2-1 and the following procedure to install the viscometer.

1. Calculate the minimum straight pipe length leading to the viscometer as follows:

   Pipe Diameter x 10 = minimum straight pipe length

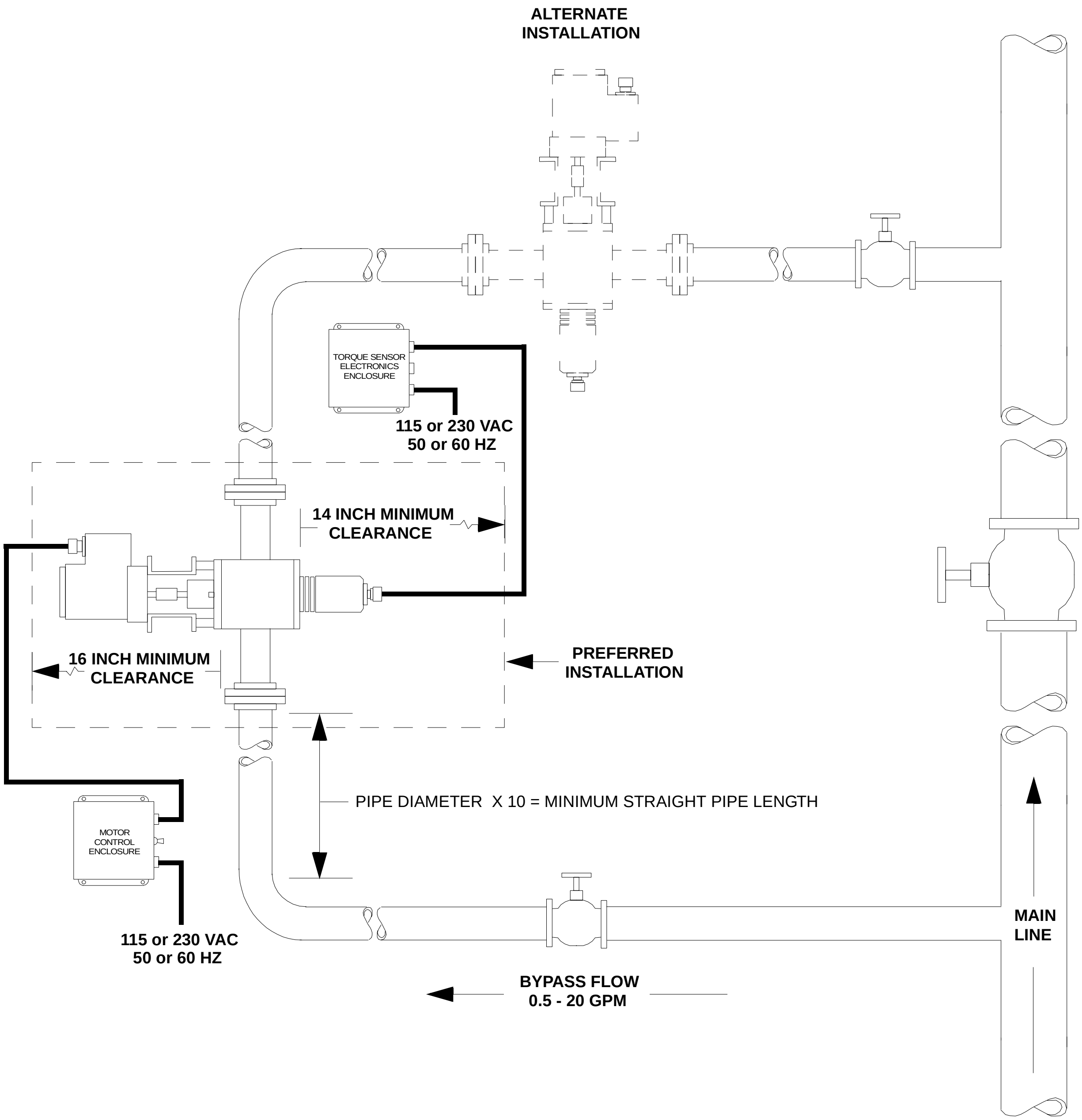
2. Select an installation location that will provide clearances of 14 inches from the sensing endcap, and 16 inches from the chamber side as shown in Figure 2-1.
3. Using standard plumbing practices for the appropriate viscometer flange type, install the viscometer in the *preferred* position as shown in Figure 2-1.
4. If equipped, install the flushing fluid supply using the appropriate valves.
5. If equipped, install the double mechanical seal barrier fluid supply using appropriate valves as follows:
   a. Connect the barrier fluid to the lower valve.
   b. Vent the barrier fluid from the upper valve.

NOTE: *The viscometer may be equipped with an optional pressure sensing switch which is mounted on the double mechanical seal housing. If the appropriate barrier fluid pressure is not sensed, the motor will not operate.*

Installation

NOTE: *Refer to the TT100 In-Line Viscometer Specification sheet to determine the configuration of the viscometer.*

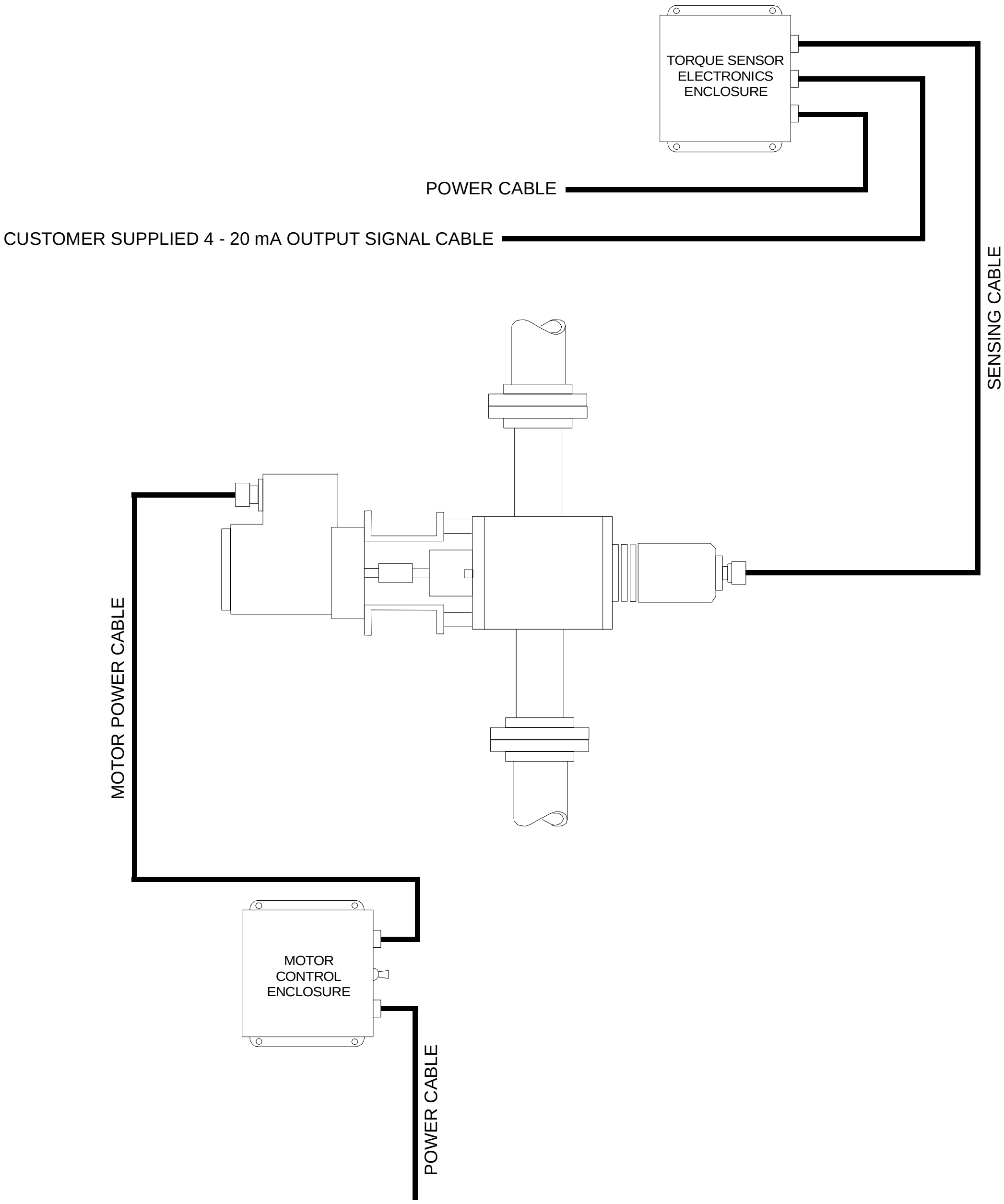
1. Depending upon your configuration, refer to the appropriate installation diagram as shown in Figures 2-2 through 2-4 to install the viscometer.



***NOTE:** When installing the viscometer in the alternate position, rotate the viscometer on the pipe axis to minimize pockets where air or solids may collect.*

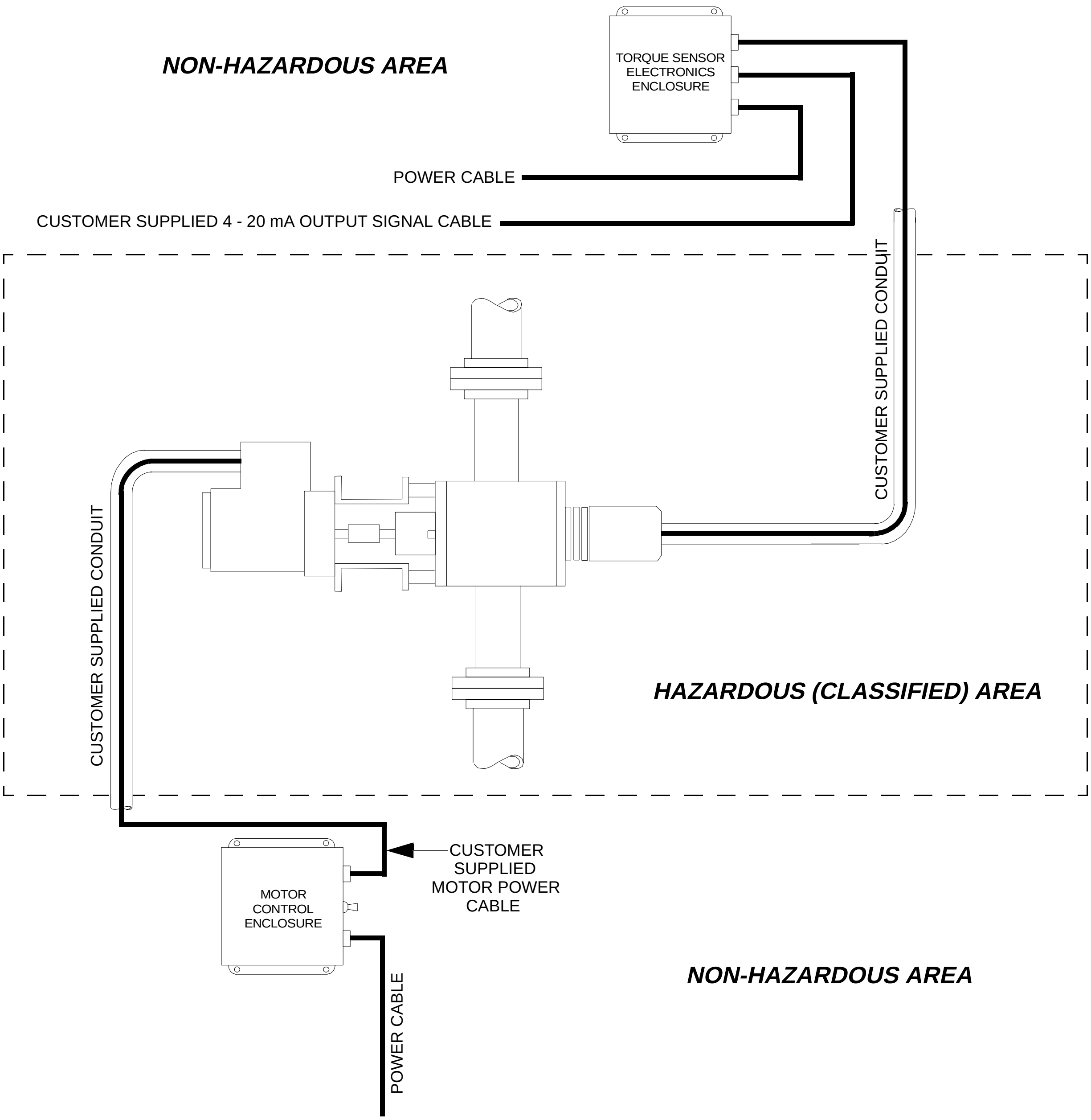
***NOTE:** For all viscometers, position the drive endcap bleed screw in the UP position to assist in the venting of gases.*

Figure 2-1: Typical In-Line Viscometer Installation



NOTE: *REFER TO DRAWING NUMBER CA1-001 (115 VAC) OR CA1-047 (230 VAC) IN APPENDIX B FOR ELECTRICAL CONNECTIONS.*

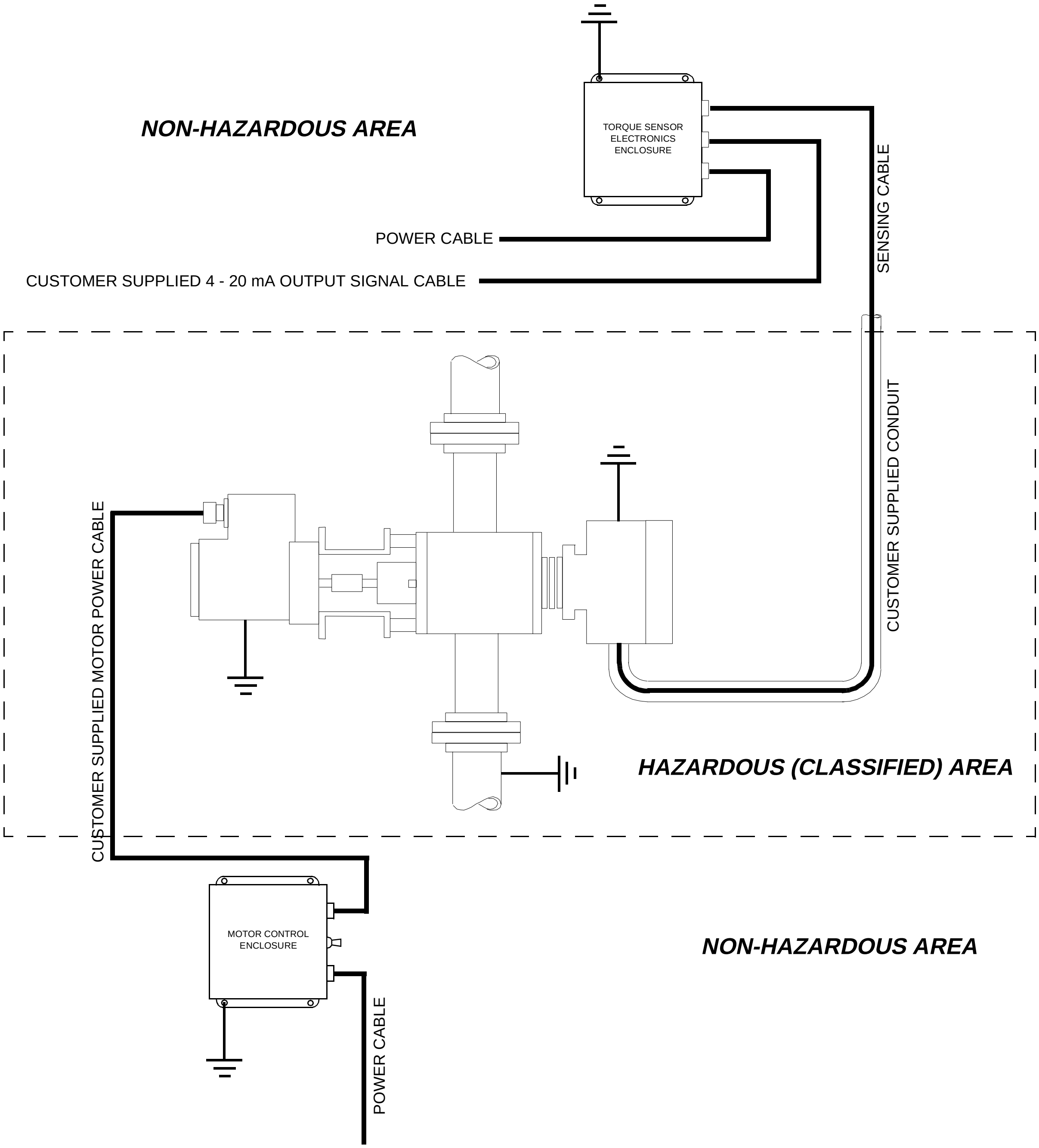
Figure 2-2:NEMA 4 - 115 or 230 VAC 50/60 Hz Installation



NOTE: *REFER TO DRAWING NUMBER CA1-035 IN APPENDIX B FOR ELECTRICAL CONNECTIONS.*

NOTE: *ALL CONNECTIONS SHALL BE TERMINATED ACCORDING TO FACTORY MUTUAL NEMA 7 SPECIFICATIONS.*

Figure 2-3:NEMA 7 - Explosion Proof 115 VAC 50/60 Hz Installation



NOTE: *REFER TO DRAWING NUMBER CA1-024 (115 VAC) OR CA1-025 (230 VAC) IN APPENDIX B FOR ELECTRICAL CONNECTIONS.*

NOTE: *ALL CONNECTIONS WITHIN HAZARDOUS AREA SHALL BE TERMINATED ACCORDING TO CENELEC SPECIFICATIONS.*

Figure 2-4:CENELEC - 115 or 230 VAC 50/60 Hz Installation

Flushing Connections

NOTE: *The flushing connections and lines, which may be connected to one or both endcaps, are application specific.*

1. Remove the flushing connection plug from each endcap.
2. Install the flushing line connector in the respective endcap.
3. Connect the flushing lines to the connectors on each endcap.
4. Proceed with **Section 3 -Calibration**.

Section 3 - Calibration

Introduction

The TT100 In-Line Viscometer is custom calibrated at the factory and shipped ready for service. Brookfield Engineering Laboratories, Inc. recommends that certain calibration procedures be performed after any of the following events have occurred:

- Installation
- Disassembly and Cleaning
- Component Replacement

The flowcharts in Figures 3-1, 3-2, and 3-3 describe the appropriate calibration procedures that should be performed after installation, disassembly and cleaning, and component replacement.

CAUTION

The length of the sensing cable should not be changed. Contact Brookfield Engineering Laboratories, Inc. for more information.

CAUTION

The viscometer must be empty of process fluid, clean, and free of obstructions before it can be calibrated. Refer to **Section 5 - Maintenance** and perform the appropriate cleaning procedure for the process fluid application.

Tools Required

The tools listed in Table 3-1 are required for calibrating the TT100 In-Line Viscometer.

Table 3-1: Tools Required

Tool	Quantity
Digital Volt Meter	1
#18 - 24 AWG Insulated Wires - 6 inches long	2
Medium Straight Blade Screwdriver	1
Small Straight Blade Screwdriver	1
5mm Hex Wrench	1
Calibration Bars	1 or 2*
* Dual range viscometers may be supplied with two calibration bars.	

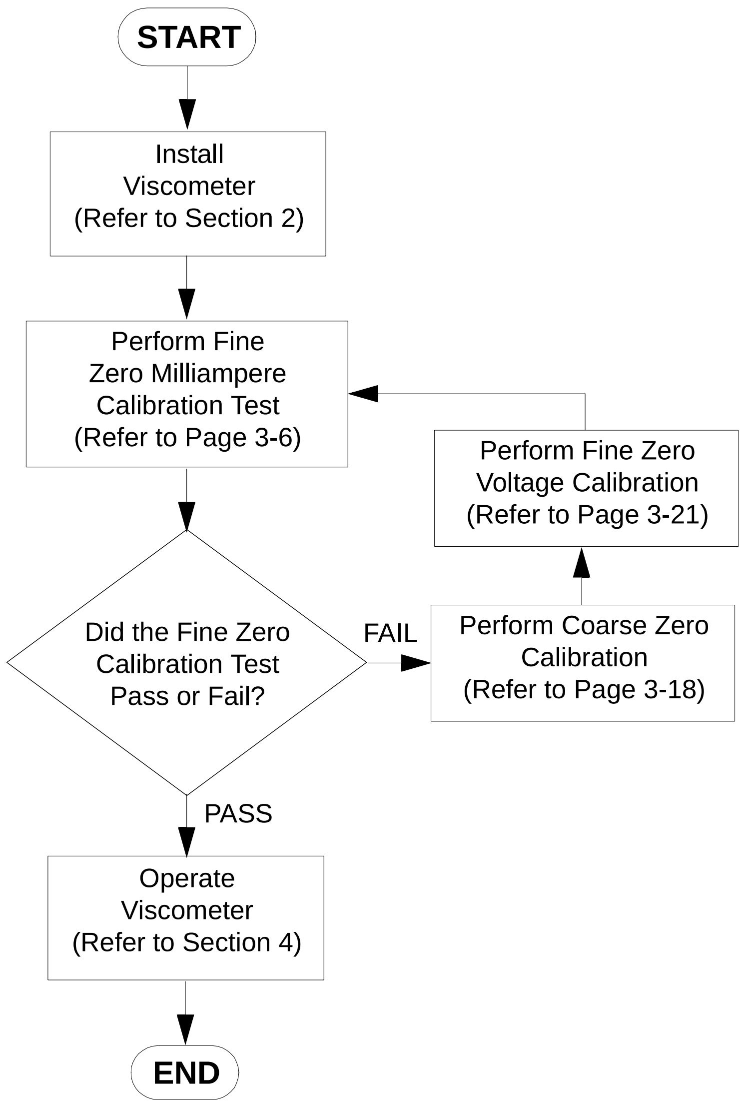
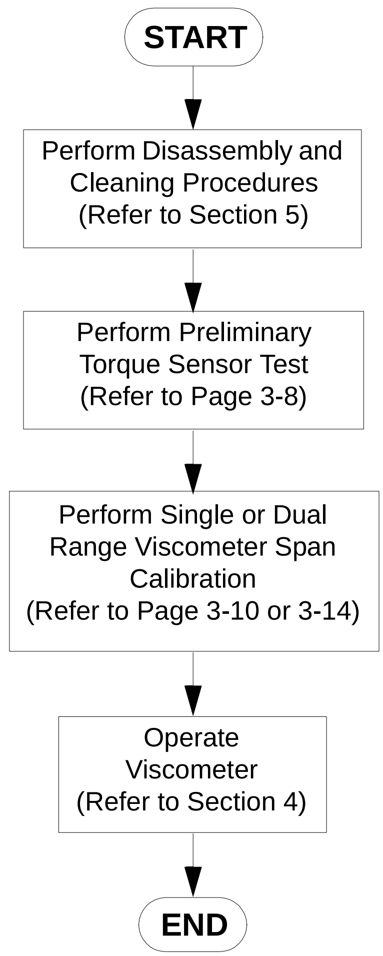


Figure 3-1: Typical Installation Calibration Flowchart



NOTE: *This flowchart assumes that the Microsyn housing cover has not been removed during the cleaning process.*

Figure 3-2: Typical Calibration after Viscometer Disassembly and Cleaning

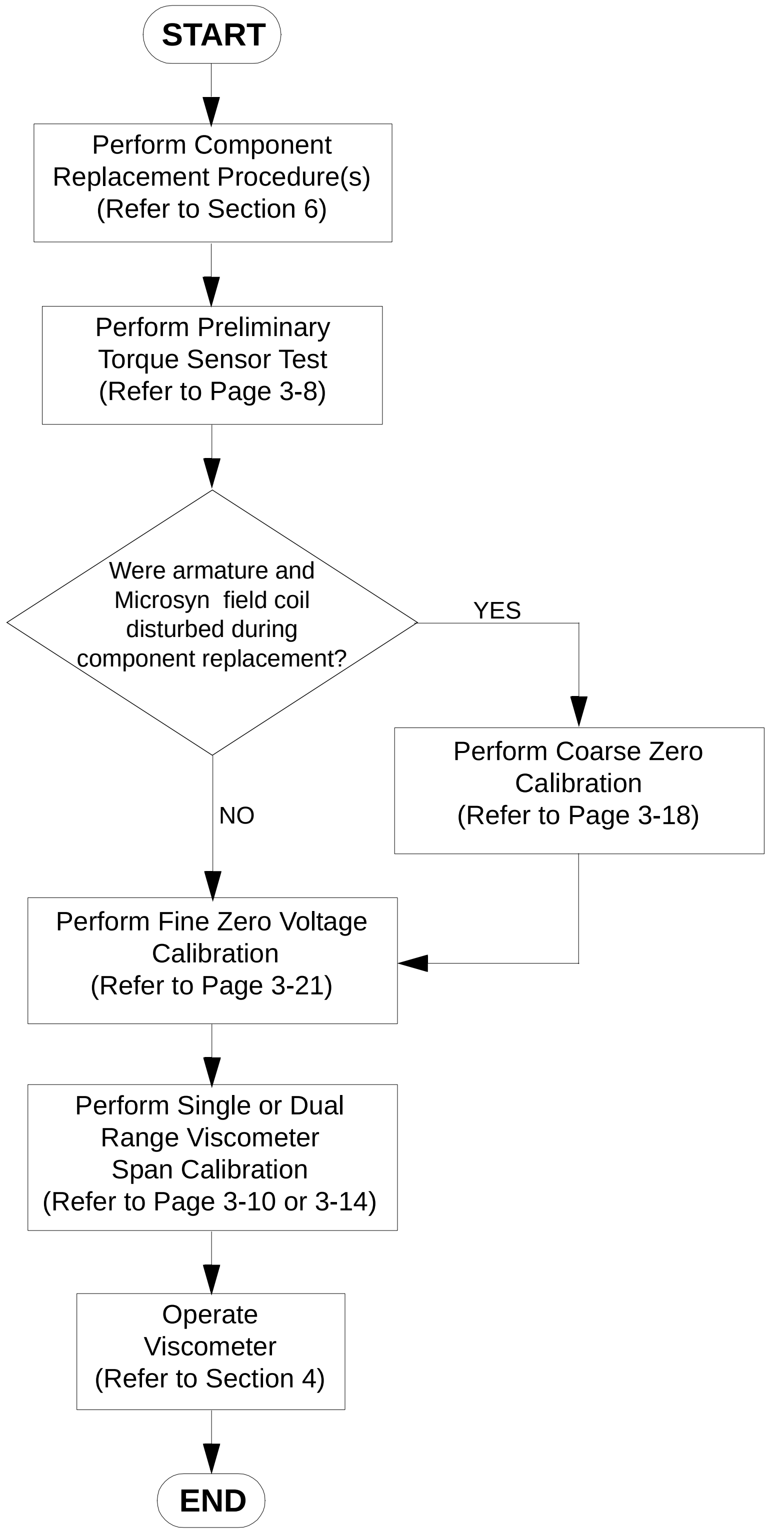


Figure 3-3:Typical Calibration after Component Replacement

Fine Zero Milliampere Calibration Test

The Fine Zero Milliampere Calibration Test should be performed after the viscometer has been installed and before process fluid has been introduced into the viscometer. This procedure ensures that the *zero* position of both the Microsyn field coil assembly and the torque sensor electronics are matched.

CAUTION

The internal components of the viscometer must be empty of process fluid, clean, and free of obstructions before it can be calibrated. Refer to **Section 5 - Maintenance** and perform the appropriate cleaning procedure for the process fluid application.

NOTE: *Refer to Figure 3-4 for torque sensor circuit board component locations.*

1. Turn power OFF to the motor controls and torque sensor electronics enclosure.
2. Open the cover to the torque sensor electronics enclosure.
3. Disconnect milliampere output cable from J1 Pins 1 and 2 on the torque sensor electronics circuit board.
4. Perform the following steps to allow Digital Volt Meter (DVM) connections to the torque sensor printed circuit board:
    a. Cut two lengths of #18 - 24 AWG wire 6 inches long.
    b. Strip approximately 1/8 inch of insulation off each end.
    c. Connect the first wire to J1-Pin 1.
    d. Connect the second wire to J1-Pin 2.
5. Set the Digital Volt Meter (DVM) to the 0 - 20.00 mA scale.
6. Connect the DVM positive lead to the wire installed on J1-Pin 1.
7. Connect the DVM negative lead to the wire installed on J1-Pin 2.
8. Turn power ON to the torque sensor electronics enclosure.
9. Adjust R18 (or the Remote Zero potentiometer if so equipped) until the DVM indicates 4.00 mA.

NOTE: *If 4.00 mA cannot be achieved, perform the Coarse Zero Calibration procedure.*

10. Turn power OFF to the torque sensor electronics enclosure.

11. Remove the DVM connections and wires from J1 on the circuit board.
12. Reconnect the milliampere output cable to J1 Pins 1 and 2 on the torque sensor electronics circuit board.
13. Install the enclosure cover.
14. Turn power ON to the torque sensor electronics enclosure.
15. Refer to **Section 4 - Operation**.

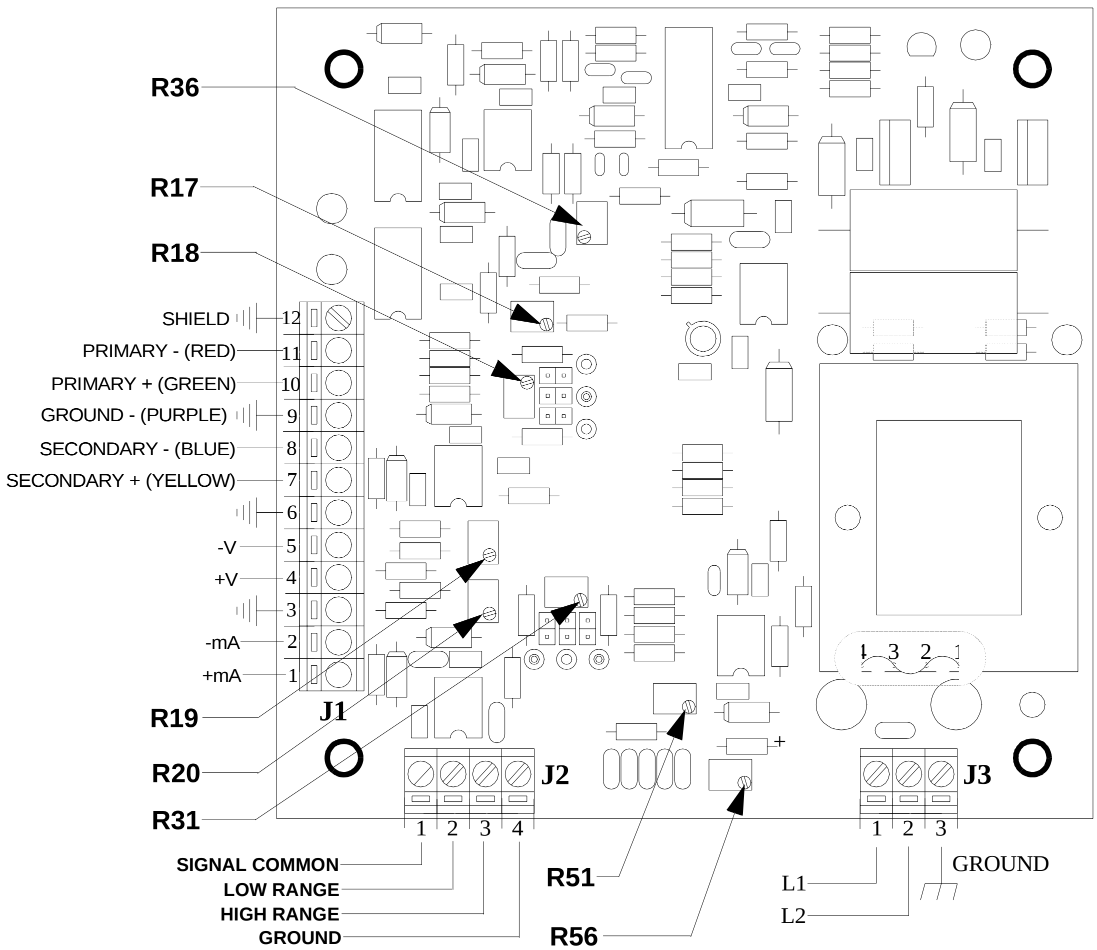


Figure 3-4:Torque Sensor Electronics Board Adjustment Component Locations

Preliminary Torque Sensor Test

Perform the following checks to make sure the torque sensor is not damaged before calibrating the viscometer.

1. Remove the sensing endcap from the viscometer as follows:

CAUTION

The internal components of the viscometer must be empty of process fluid, clean, and free of obstructions before it can be calibrated. Refer to **Section 5 - Maintenance** and perform the appropriate cleaning procedure for the process fluid application.

Handle the sensing endcap assembly with care when removing it from the measuring chamber. Damage to the torsion element may result by contacting the stator with the rotor.

   a. Remove seven of the eight screws that secure the sensing endcap to the measuring chamber.

   b. While holding the sensing endcap in position, remove the last screw and carefully remove the sensing endcap from the measuring chamber.

   c. Carefully place the sensing endcap flange in a vise to hold it secure and parallel to the work surface as shown in Figure 3-5.

2. Visually inspect the torsion element to make sure the wires are straight and square. Gently straighten any minor deviations.

3. Check for the absence of friction within the torque sensor assembly by performing the following steps:

   a. Cut two lengths of #18 - 24 AWG wire 6 inches long.

   b. Strip approximately 1/8 inch of insulation off each end.

   c. Remove the cover from the torque sensor electronics enclosure.

   d. Connect the first wire to J1-Pin 1 torque sensor printed circuit board.

   e. Connect the second wire to J1-Pin 2 torque sensor printed circuit board.

   f. Set the Digital Volt Meter (DVM) to the 0 - 20.00 mA scale.

g. Connect the DVM positive lead to the wire installed on J1-Pin 1.

h. Connect the DVM negative lead to the wire installed on J1-Pin 2.

i. Turn power ON to the torque sensor electronics enclosure.

j. *Gently* apply torque to the stator, as shown in Figure 3-5, and observe the DVM display for a rapid, smooth response to the torque applied to a maximum of + 20.00 mA.

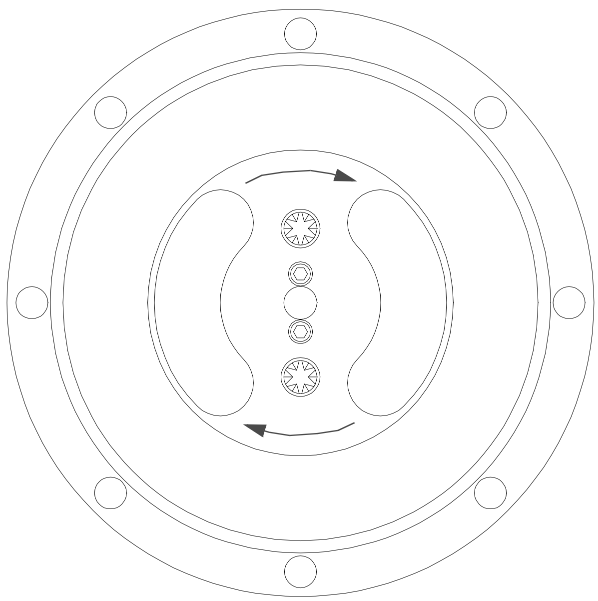


Figure 3-5: Applying Torque to the Stator

k. Release the stator and note the final (zero) position DVM reading.

l. Repeat steps j and k to apply torque in the opposite direction.

m. Repeat steps j - l several times. If the zero position DVM readings from one direction of torque are not within ± 0.05 mA and from opposite directions within ± 0.1 mA, then the viscometer will not be able to be calibrated. Refer to **Appendix A** and call Brookfield Engineering Laboratories, Inc. for assistance.

n. Proceed with Single or Dual Range Viscometer Calibration.

Single Range Viscometer Span Calibration

In this procedure, a calibration bar will be used to simulate torque the torsion element will encounter during single range measurement of your specific process fluid. Span calibration allows the torque sensor electronics to be adjusted for the specific range gain in milliamperes from the no torque or (zero point) set at 4.00 mA through 20.00 mA with the calibration bar applied.

CAUTION

The internal components of the viscometer must be empty of process fluid, clean, and free of obstructions before it can be calibrated. Refer to **Section 5 - Maintenance** and perform the appropriate cleaning procedure for the process fluid application.

NOTE: *This procedure must be performed before process fluid is introduced into the viscometer.*

NOTE: *The value of the calibration bar is determined by viscosity range, torque range, and the geometry of the cylinders and should not be considered to represent full scale.*

NOTE: *Refer to the range information within the **Viscosity & Calibration Data** on the Viscometer Specification Sheet, that came with your viscometer, for the appropriate single range calibration information to be used for this calibration procedure.*

NOTE: *Refer to Figure 3-4 for torque sensor circuit board component locations.*

1. Turn power OFF to the motor controls and torque sensor electronics enclosure and remove the cover.
2. Remove the sensing endcap from the viscometer as follows:

CAUTION

Handle the sensing endcap assembly with care when removing it from the measuring chamber. Damage to the torsion element may result by contacting the stator with the rotor.

   a. Remove seven of the eight screws that secure the sensing endcap to the measuring chamber.

b. While holding the sensing endcap in position, remove the last screw and carefully remove the sensing endcap from the measuring chamber.

NOTE: *Both the torsion element axis and the calibration bar axis must be within 8º of horizontal for calibration within the limits of the instrument.*

3. Carefully place the sensing endcap flange in a vise to hold it secure and parallel to the work surface as shown in Figure 3-6.
4. Make sure the torsion element is clean. Refer to **Section 5 - Maintenance** for more information.
5. Disconnect milliampere output cable from J1 Pins 1 and 2 on the torque sensor electronics circuit board.
6. Perform the following steps to allow Digital Volt Meter (DVM) connections to the torque sensor printed circuit board:
   a. Cut two lengths of #18 - 24 AWG wire 6 inches long.
   b. Strip approximately 1/8 inch of insulation off each end.
   c. Connect one wire to J1-Pin 1.
   d. Connect the second wire to J1-Pin 2.
7. Depending upon your viscometer's range (refer to viscometer specification sheet), verify that the range jumper wire between J2-Pin 1 and J2-Pin 3 (HIGH range) or J2-Pin 1 and J2-Pin 2 (LOW range).
8. Turn power ON to the torque sensor electronics enclosure.
9. Set the digital volt meter (DVM) to the 0 - 20.00 mA scale.
10. Connect the DVM positive lead to the wire on J1-Pin 1.
11. Connect the DVM negative lead to the wire on J1-Pin 2.
12. Observe the DVM reading. Adjust R18 for 4.00 mA.

NOTE: *If you cannot obtain 4.00 mA by adjusting R18, set R18 to mid point (approximately* 7.5 *turns) and then perform the Fine Zero Voltage Calibration procedure.*

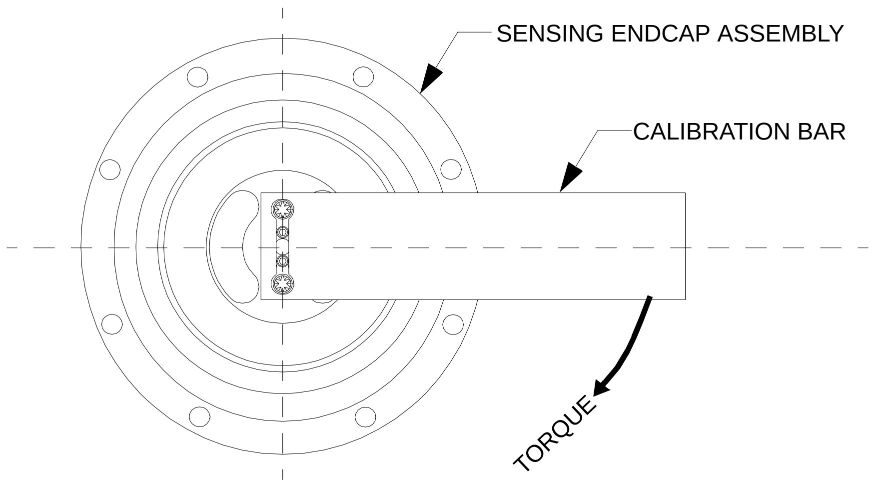
NOTE: *To ensure proper span calibration, make sure the calibration bar is installed as shown in Figure 3-6.*

NOTE: *Both the torsion element axis and the calibration bar axis must be within 8º of horizontal for calibration within the limits of the instrument.*

CAUTION

Do not apply extra torque beyond that which is provided by the calibration bar. Damage to the torsion element may result.

13. Install the calibration bar, that came with your viscometer, on the stator mounting screws, parallel to the work surface, and in the direction to which torque will be applied, as shown in Figure 3-6.



NOTE: *The viscometer may actually be calibrated to sense torque in either direction. The viscometer motor can be wired to rotate in either direction. Calibration and the direction of rotation must be matched. The standard calibration method is shown in Figure 3-6.*

Figure 3-6: Calibration Bar Installation

14. Adjust R20 for the single LOW range or R51 for the single HIGH range mA value shown on the Viscometer Specification Sheet.
15. Remove the calibration bar. The DVM should indicate 4.00 ± .02 mA.

NOTE: *If steps 13 and 14 cannot be achieved, refer to* ***Appendix A*** *and call Brookfield Engineering Laboratories, Inc. for assistance.*

16. Repeat steps 12 - 14 to ensure calibration repeatability.
17. Turn power OFF to the torque sensor electronics enclosure.
18. Remove the DVM wire connections from the torque sensor electronics circuit board.

19. Reconnect the milliampere cable to J1 Pins 1 and 2 on the torque sensor electronics circuit board and install the enclosure cover.

CAUTION

Handle the sensing endcap assembly with care when installing it into the measuring chamber. Damage to the torsion element may result by contacting the stator with the rotor.

20. Remove the sensing endcap from the vise and carefully install it into the viscometer.
21. Install the sensing endcap mounting bolts and tighten them in a rotational pattern.
22. Turn power ON to the torque sensor electronics enclosure.

CAUTION

Do not run the motor without fluid in the viscometer. Damage to the mechanical seals may result.

Dual Range Viscometer Span Calibration

In this procedure, calibration bars will be used to simulate a torque the torsion element will encounter during dual (high and low range) measurement of your specific process fluid. Span calibration allows the torque sensor electronics to be adjusted with the calibration bar applied for the specific range gain in milliamperes from the no torque (zero point) set at 4.00 mA through 20.00 mA.

CAUTION

The internal components of the viscometer must be empty of process fluid, clean, and free of obstructions before it can be calibrated. Refer to **Section 5 - Maintenance** and perform the appropriate cleaning procedure for the process fluid application.

NOTE: *Refer to the high and low range information within the* ***Viscosity & Calibration Data*** *on the Viscometer Specification Sheet, that came with your viscometer, for the appropriate range calibration information to be used for this calibration procedure. Only one calibration bar may be supplied with dual range units if the same bar is used to calibrate both ranges.*

1. Turn power OFF to the motor controls and torque sensor electronics enclosure and remove the cover.
2. Remove the sensing endcap from the viscometer as follows:

CAUTION

Handle the sensing endcap assembly with care when removing it from the measuring chamber to prevent damage to the torsion element.

   a. Remove seven of the eight screws that secure the sensing endcap to the measuring chamber.
   b. While holding the sensing endcap in position, remove the last screw and carefully remove the sensing endcap from the measuring chamber.

3. Place the sensing endcap flange in a vise to hold it secure and parallel to the work surface as shown in Figure 3-7.
4. Make sure the torsion element is clean. Refer to **Section 5 - Maintenance** for more information.

5. Perform the following steps to allow Digital Volt Meter (DVM) connections to the torque sensor printed circuit board:
   a. Cut two lengths of #18 - 24 AWG wire 6 inches long.
   b. Strip approximately 1/8 inch of insulation off each end.
   c. Connect one wire to J1-Pin 1.
   d. Connect the second wire to J1-Pin 2.
6. Connect a range jumper wire between J2-Pin 1 and J2-Pin 3 (HIGH range).
7. Turn power ON to the torque sensor electronics enclosure.

NOTE: *To ensure proper span calibration, make sure the calibration bar installed as shown in Figure 3-7.*

8. Set the digital volt meter (DVM) to the 0 - 20.00 mA scale.
9. Connect the DVM positive lead to the wire on J1-Pin 1.
10. Connect the DVM negative lead to the wire on J1-Pin 2.
11. Observe the DVM reading. Adjust R18 for 4.00 mA.
12. Move the range jumper wire between J2-Pin 1 and J2-Pin 2 (LOW range).
13. Observe the DVM reading. It should indicate 4.00 mA.
14. Move the range jumper wire between J2-Pin 1 and J2-Pin 3 (HIGH range).

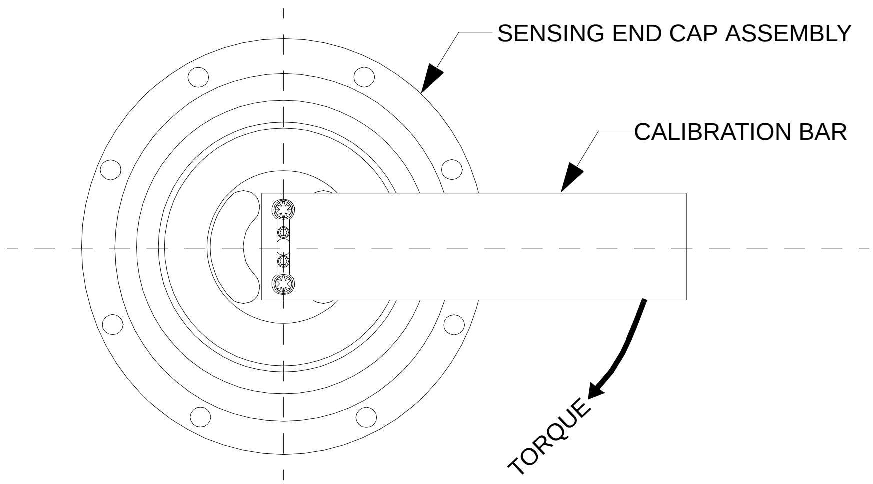
NOTE: *If 4.00 ±.02 mA is not displayed on the DVM after switching the range jumpers, then perform the Fine Zero Voltage Calibration procedure.*

CAUTION

Do not apply extra torque beyond that which is provided by the calibration bar. Damage to the torsion element will result.

15. Install the heaviest of the two calibration bars that came with your viscometer, on the stator mounting screws, parallel to the work surface, and in the direction to which torque will be applied, as shown in Figure 3-7.

NOTE: *Some dual range viscometers may be supplied with one calibration bar. If so, only one calibration bar will be shown on the viscometer specification sheet.*



NOTE: *Torque may be applied in the opposite direction for some viscometer models.*

Figure 3-7: Calibration Bar Installation

16. Adjust R51 for the HIGH range mA value shown on the Viscometer Specification Sheet.

NOTE: *If 4.00 ±.02 mA cannot be achieved in step 16, refer to* **Appendix A** *and call Brookfield Engineering Laboratories, Inc. for assistance.*

17. Remove the calibration bar. The DVM should indicate 4.00 ± .02 mA.
18. Remove the range jumper wire from J2-Pin 3 and connect it to J2-Pin 2 (LOW range).
19. Observe the DVM reading.

NOTE: *If 4.00 ±.05 mA is not displayed on the DVM after switching the range jumpers, then perform the Fine Zero Voltage Calibration procedure.*

20. Install the lightest of the two calibration bars, that came with your viscometer, on the stator mounting screws, parallel to the work surface as shown in Figure 3-7.
21. Adjust R20 for the mA LOW range value shown on the Viscometer Specification Sheet.

NOTE: *If 4.00 ±.02 mA cannot be achieved, refer to* **Appendix A** *and call Brookfield Engineering Laboratories, Inc. for assistance.*

22. Remove the calibration bar. The DVM should indicate 4.00 ± .02 mA
23. Repeat steps 11 - 22 to ensure calibration repeatability.

24. Turn power OFF to the torque sensor electronics enclosure.
25. Remove the DVM wire connections from the torque sensor electronics circuit board.
26. Reconnect the milliampere cable to J1 Pins 1 and 2 on the torque sensor electronics circuit board and install the enclosure cover.
27. Remove the sensing endcap from the vise and careful install it into the viscometer.
28. Install the sensing endcap mounting bolts and tighten them in a rotational pattern.
29. Turn power ON to the torque sensor electronics enclosure.

CAUTION

Do not run the motor without fluid in the viscometer. Damage to the mechanical shaft seals may result.

Coarse Zero Calibration

CAUTION

If the sensing endcap has been disassembled, then **Coarse Zero Calibration** must be checked before fine zero voltage calibration can occur. Failure to check the coarse zero calibration may cause problems with fine zero voltage calibration. If the sensing endcap has not been disassembled, then fine zero voltage calibration can be performed without checking the coarse zero calibration.

The internal components of the viscometer must be empty of process fluid, clean, and free of obstructions before it can be calibrated. Refer to **Section 5 - Maintenance** and perform the appropriate cleaning procedure for the process fluid application.

1. Turn power OFF to the motor controls and torque sensor electronics enclosure.
2. Remove the Microsyn housing cover as follows:
   a. Using a wrench, loosen and remove the signal cable strain relief nut. Slide the nut, ring, and insulator down the cable.
   b. Remove the screws from the Microsyn housing cover.
   c. Rotate and lift the housing cover off the assembly and slide it down the cable.
3. Open the cover to the torque sensor electronics enclosure.
4. Connect a range jumper wire between J2-Pin 1 and J2-Pin 3 (HIGH range).
5. Set R31 to its mid point position (approximately 7.5 turns).
6. Turn power ON to the torque sensor electronics enclosure.
7. Perform the following steps to allow Digital Volt Meter (DVM) connections to the torque sensor printed circuit board:
   a. Cut two lengths of #18 - 24 AWG wire 6 inches long.
   b. Strip approximately 1/8 inch of insulation off each end.
   c. Connect the first wire to J1-Pin 2.
   d. Connect the second wire to J1-Pin 4.
8. Set the DVM to the 0 - 10 VDC scale.
9. Connect the DVM positive lead to the wire installed on J1-Pin 4.

10. Connect the DVM negative lead to the wire installed on J1-Pin 2.
11. Loosen, but do not remove the Microsyn field coil assembly mounting screws as shown in Figure 3-8.
12. Rotate the Microsyn field coil assembly, as shown in Figure 3-8, until 0 ± .2 VDC is observed on the DVM. Tighten the mounting screws.

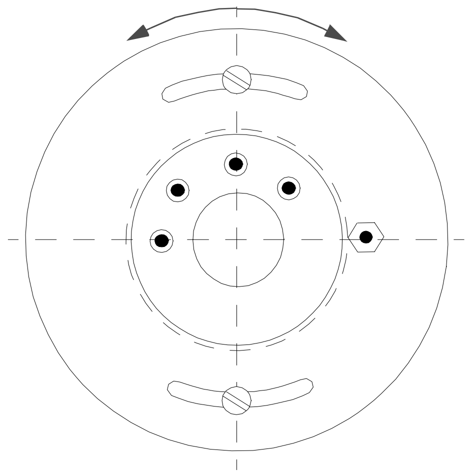


Figure 3-8: Microsyn Field Coil Assembly Rotation

13. Remove the sensing endcap from the viscometer as follows:

CAUTION

Handle the sensing endcap assembly with care when removing it from the measuring chamber. Damage to the torsion element may result by contacting the stator with the rotor.

a. Remove seven of the eight screws that secure the sensing endcap to the measuring chamber.
b. While holding the sensing endcap in position, remove the last screw and carefully remove the sensing endcap from the measuring chamber.

NOTE: *Both the torsion element axis and the calibration bar axis must be within 8º of horizontal for calibration within the limits of the instrument.*

14. Carefully place the sensing endcap flange in a vise to hold it secure and parallel to the work surface.

15. Rotate the stator as shown in Figure 3-9. The DVM should increase in a positive direction. If the DVM reading does not increase in a positive direction, loosen the Microsyn field coil mounting screws and rotate the field coil to obtain the next possible 0 ± .2 VDC position. Tighten the screws.

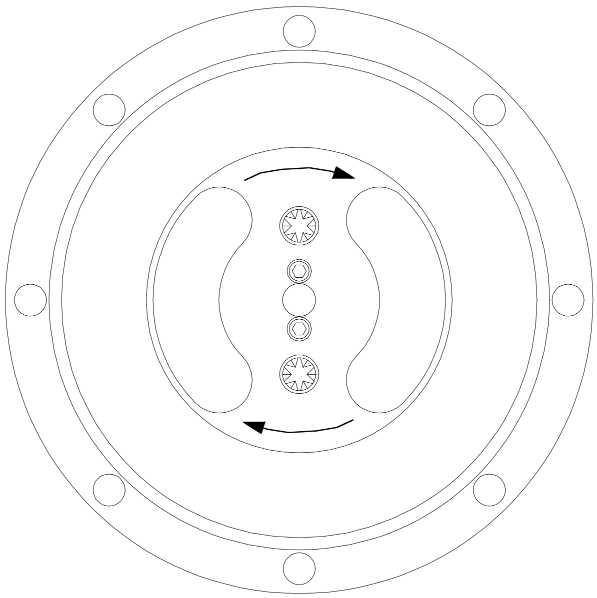


Figure 3-9: Stator Direction of Rotation

16. Rotate the stator once again as shown in Figure 3-9. The DVM should increase in a positive direction.
17. Proceed with **Fine Zero Voltage Calibration**.

Fine Zero Voltage Calibration

CAUTION

The internal components of the viscometer must be empty of process fluid, clean, and free of obstructions before it can be calibrated. Refer to **Section 5 - Maintenance** and perform the appropriate cleaning procedure for the process fluid application.

Fine Zero Voltage Calibration ensures that the *zero* voltage level has been properly calibrated.

This procedure can be used to perform fine zero voltage adjustment once the viscometer has been installed, or after a component requiring calibration has been replaced.

1. Turn power OFF to the motor controls and torque sensor electronics enclosure.
2. Open the cover to the torque sensor electronics enclosure.
3. Perform the following steps to allow Digital Volt Meter (DVM) connections to the torque sensor printed circuit board:
   a. Cut two lengths of #18 - 24 AWG wire 6 inches long.
   b. Strip approximately 1/8 inch of insulation off each end.
   c. Connect the first wire to J1-Pin 2.
   d. Connect the second wire to J1-Pin 4.
4. Turn power ON to the torque sensor electronics enclosure.
5. Adjust R31 on the torque sensor printed circuit board to its mid-point position (approximately 7.5 turns).
6. Connect the range jumper wire between J2-Pin 1 and J2-Pin 3 (HIGH range).
7. Set the digital volt meter (DVM) to the 0 - 10 VDC scale.
8. Connect the DVM positive lead to the wire on J1-Pin 4.
9. Connect the DVM negative lead to the wire on J1-Pin 2.
10. Adjust R31 until the DVM indicates 0 ±.005 VDC.
11. Remove the range jumper wire from J2-Pin 3 and connect it to J2-Pin 2 (LOW range).
12. Verify the DVM indicates 0 ±.005 VDC. If not, adjust R31 to 0 ±.005 VDC.

13. Proceed with **Single or Dual Range Viscometer Span Calibration**.

Section 4 - Operation

Introduction

Once the TT100 In-Line Viscometer has been installed as described in **Section 2 - Installation** and calibrated as described in **Section 3 - Calibration**, the viscometer is ready to be used.

CAUTION

Do not proceed with the operation of the viscometer unless the calibration has been verified as described in *Fine Zero Milliampere Calibration Test* in **Section 3 - Calibration**.

Mechanical Seal Requirements

The TT100 In-Line Viscometer is provided with mechanical face seals which prevents the leakage of process fluid into or from the measuring chamber at the drive shaft entry point. The seals are designed for continuous operation only if lubricated (wetted) by a film of clear fluid at their point of face contact.

CAUTION

Do not operate the viscometer motor for more than five (5) revolutions when the measuring chamber is empty. The mechanical seals may be damaged.

Do not operate a TT100 In-Line Viscometer equipped with a double mechanical seal unless the seal housing is supplied with an appropriate pressurized fluid as described in **Section 2 - Installation**.

Normal Operation Observations

The following conditions are considered to be normal while the TT100 In-Line Viscometer is operating:

- The drive motor will be hot to the touch.

- The TT100 In-Line Viscometer generates a continuous output signal that is proportional to the apparent viscosity of the process fluid being measured.

- Depending upon the viscosity, flow rate, and resultant mixing in the measuring chamber, the viscometer will respond quickly to the introduction of new process fluid.

- Since shear conditions, temperature, shear history may differ between the viscometer and another measurement, it is not unusual for numerical values to differ. Refer to *Correlation with Other Measurements* in **Section 1 - Introduction** for more information.

- If solids are allowed to form on the internal surfaces of the viscometer, they may alter span by changing the measuring annulus dimensions. Solids may also limit the torsion element motion . Refer to *Cleaning In Place* in **Section 5 - Maintenance** for more information.

Interlocks

Viscometer interlocks are options that prevent the viscometer from being damaged due to abnormal process fluid temperature or double mechanical seal assembly pressure. The interlocks prevent the viscometer motor from being activated when below the calibrated setpoint.

CAUTION

Do not disconnect an interlock from the viscometer. Viscometer damage may result.

Start-up

Once the TT100 In-Line Viscometer has been installed as described in **Section 2 - Installation** and proper calibration has been verified as described in **Section 3 - Calibration**, the viscometer can be energized.

CAUTION

Do not energize the TT100 In-Line Viscometer motor equipped with a double mechanical seal housing unless the fluid pressure has been applied. Damage to the double mechanical seal assembly may occur.

Do not operate the TT100 In-Line Viscometer motor for more than five (5) revolutions when the measuring chamber is empty. The mechanical seals may be damaged.

Do not operate the TT100 In-Line Viscometer motor if the process fluid temperature or double mechanical seal assembly pressure is not within normal operating specifications. Damage to the viscometer may result.

1. If the TT100 In-Line Viscometer is equipped with a double-seal housing, apply the barrier fluid.
2. Add process fluid to the viscometer as follows:
   a. Loosen, but do not remove the bleed screw.
   b. Allow the process fluid to slowly flow into the viscometer until the fluid flows out of the bleed screw opening.
   c. Tighten the bleed screw.
3. Check the viscometer motor for proper operation by performing the following steps:
   a. Set the **POWER** switch on the Torque Sensor Electronics Enclosure to the ON position.
   b. Set the **POWER** switch on the Motor Control Enclosure to the ON position.
   c. Observe the display device. The torque sensor output signal should increase in a positive direction.

Shutdown

CAUTION

Do not allow the process fluid to dry or solidify. Damage to the TT100 In-Line Viscometer may result.

1. Shut the TT100 In-Line Viscometer OFF by performing the following steps:
   a. Set the **POWER** switch on the Torque Sensor Electronics Enclosure to the OFF position.
   b. Set the **POWER** switch on the Motor Control Enclosure to the OFF position.
   c. If equipped with a double mechanical seal assembly, *release* the pressure on the pressurized seal fluid.

Section 5 - Maintenance

Introduction

There are three different methods for cleaning the internal components of the TT100 Process Viscometer. The Clean-in-Place method, which is typically used, provides minimal downtime and effective cleansing of the viscometer during process system cleaning. The Flushing method is used when additional internal viscometer cleansing is required. The Disassembly and Cleaning method is used when the process system is seriously contaminated and the viscometer cannot otherwise be cleaned.

Clean-In-Place

NOTE: *The solvent used for cleaning the viscometer is dependent upon the process fluid being measured.*

1. Refer to **Section 4 - Operation** and perform the *Shutdown* procedure.

NOTE: *It may be preferable to isolate the section of pipe in which the viscometer is installed from the main process system.*

2. Drain the process fluid from the system or isolated section of pipe in which the viscometer is installed.
3. Fill the system, or isolated section of pipe in which the viscometer is installed, with cleaning fluid.
4. If equipped with a double mechanical seal assembly, apply the barrier pressurized fluid pressure.

NOTE: *The time duration of step 5 varies by the amount of process fluid build-up and its cleaning characteristics.*

5. Set the **POWER** switch on the Motor Control Enclosure to the ON position. Allow the viscometer motor to operate until the viscometer is clean.
6. Set the **POWER** switch on the Motor Control Enclosure to the OFF position.
7. Drain the cleaning fluid from the system or isolated section of pipe in which the viscometer is installed
8. Refer to **Section 4 - Operation** and perform the *Start-up* procedure.

Flushing

NOTE: *This procedure assumes that flushing connections have been made to the TT100 Viscometer as defined in* ***Section 2 - Installation****.*

NOTE: *The solvent used for cleaning the viscometer is dependent upon the process fluid being measured.*

1. Refer to **Section 4 - Operation** and perform the *Shutdown* procedure.

NOTE: *If possible, isolate the section of pipe in which the viscometer is installed from the main process system.*

2. Drain the process fluid from the system or isolated section of pipe in which the viscometer is installed.

NOTE: *The time duration of step 3 varies by the amount of process fluid build-up.*

3. With the system drain valve open, open the flushing fluid valve and allow the fluid to flow through the viscometer and out through the drain valve.
4. Close the flushing fluid valve.
5. Close the process fluid system drain.
6. Refer to **Section 4 - Operation** and perform the *Start-up* procedure.

Disassembly and Cleaning

The following procedures will guide you through this process. The solvent used for cleaning the viscometer is dependent upon the process fluid being measured.

CAUTION

Always replace endcap O-rings when disassembling and cleaning the viscometer. Refer to Appendix A and contact Brookfield Engineering Laboratories, Inc. to order replacement O-rings.

CAUTION

Depending upon the application, the torsion element and other internal components may be coated with Teflon. Make sure the solvent being used does not harm Teflon. Do not scrape surfaces coated with Teflon.

Cleaning the Sensing Endcap Assembly

WARNING

Make sure power has been turned OFF at the motor and torque sensor electronics enclosures before servicing the viscometer.

1. Shut power OFF to the motor and torque sensor electronics enclosures.

CAUTION

Handle the sensing endcap assembly with care when removing it from the measuring chamber to prevent damage to the torsion element.

2. Remove seven of the eight screws that secure the sensing endcap to the measuring chamber as shown in Figure 5-1.
3. While holding the sensing endcap in position, remove the last screw and carefully remove the sensing endcap from the measuring chamber as shown in Figure 5-1.

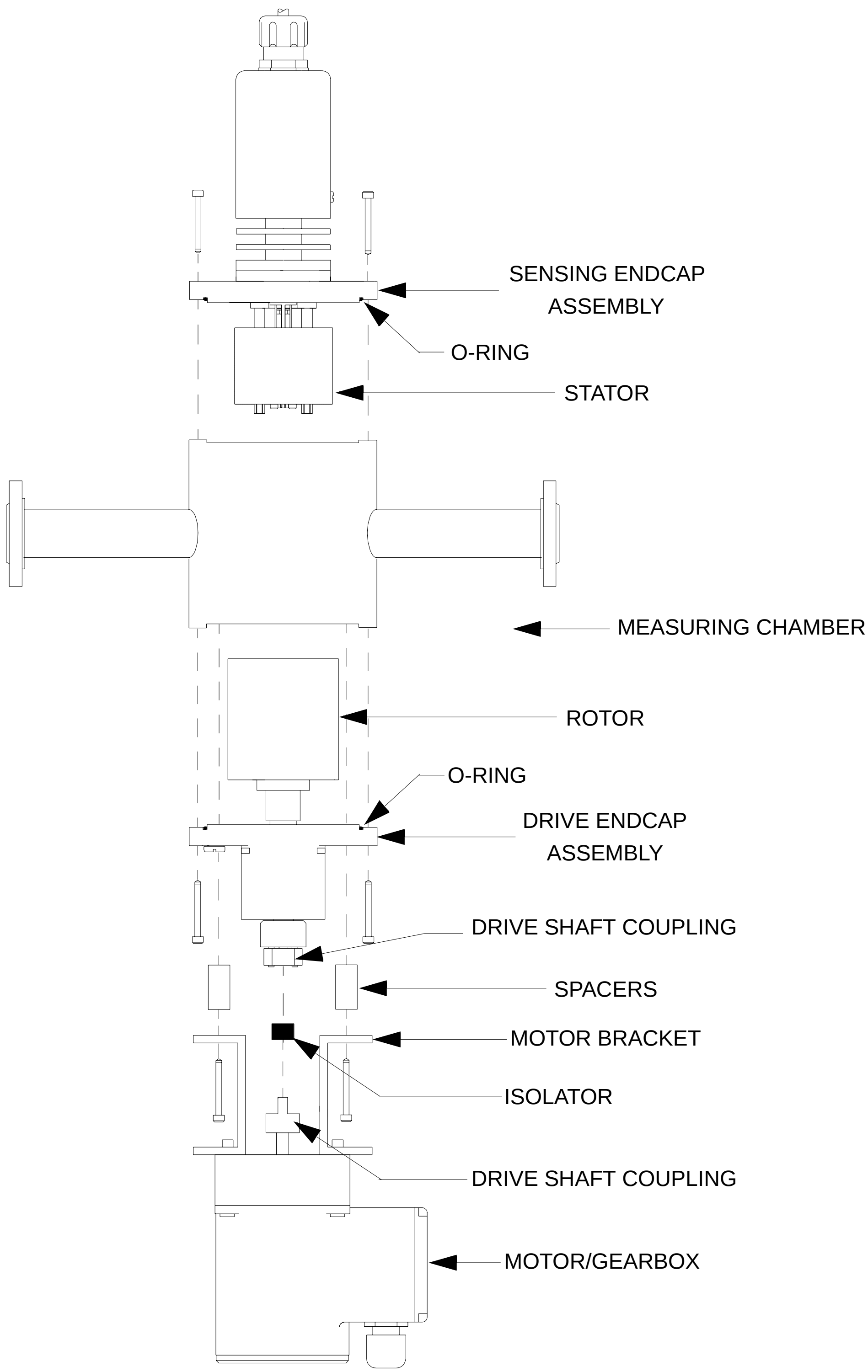


Figure 5-1: Typical Viscometer Disassembly for Cleaning

4. Using an appropriate solvent, carefully clean any process fluid build-up from the outside of the stator, between the stop posts and the stator as shown in Figure 5-2, from the inside of the stator, and from the flange. If required, remove the stator to clean the inside diameter as follows:

CAUTION

If the torsion element is coated with Teflon (blue/green color), make sure the solvent being used does not harm Teflon. Do not scrape surfaces coated with Teflon. Do not touch the torsion element with a sharp object. Clean only by using a stream of solvent or soft bristle brush

Do not apply torque to the torsion element while removing the stator mounting screws. Damage to the torsion element may result.

a. Remove the mounting screws from the top of the stator as shown in Figure 5-2.
b. Carefully remove the stator as shown in Figure 5-2.

CAUTION

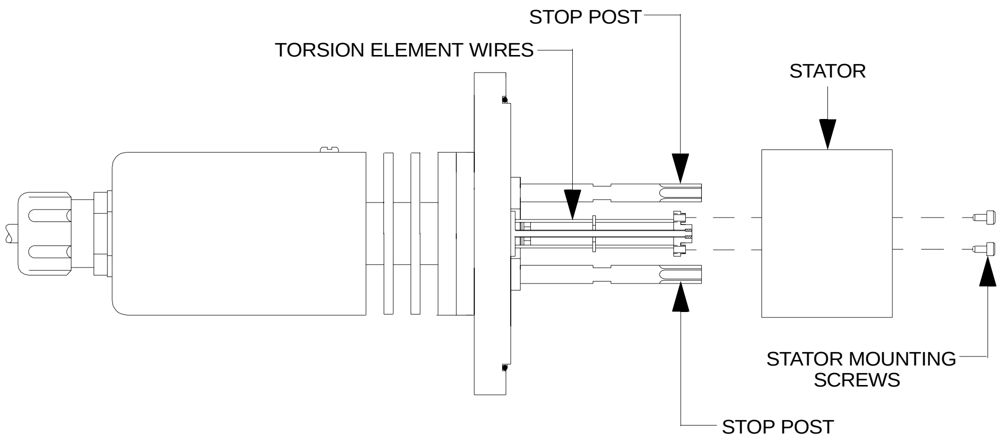
Visually inspect the torsion element wires. They should be straight and parallel to each other. If they are not, refer to **Appendix A** and contact Brookfield Engineering Laboratories, Inc. for a replacement torsion element.

c. Clean the inside and outside of the stator.

CAUTION

Be careful not to damage the torsion element wires if step d is performed.

d. If normal cleaning procedures are not successful, use solvent and a soft bristle brush and carefully clean between the torsion element wires as shown in Figure 5-2.



NOTE: *There are many different versions of the sensing endcap. Your viscometer may look different from the viscometer shown in Figure 5-2.*

Figure 5-2: Typical Stator Removal and Torsion Element Wire Cleaning

5. Carefully install the stator and install the mounting screws but do not tighten.

NOTE: *The stop posts must be centered within the holes on the stator as shown in Figure 5-3 to ensure free movement of the stator.*

CAUTION

Do not apply torque to the torsion element while installing the stator mounting screws. Damage to the torsion element may result.

6. With the stator mounting screws loose, rotate the stator so the stop posts are aligned in the center of the holes in the stator as shown in Figure 5-3. Tighten the stator mounting screws and check the alignment of the stop posts.

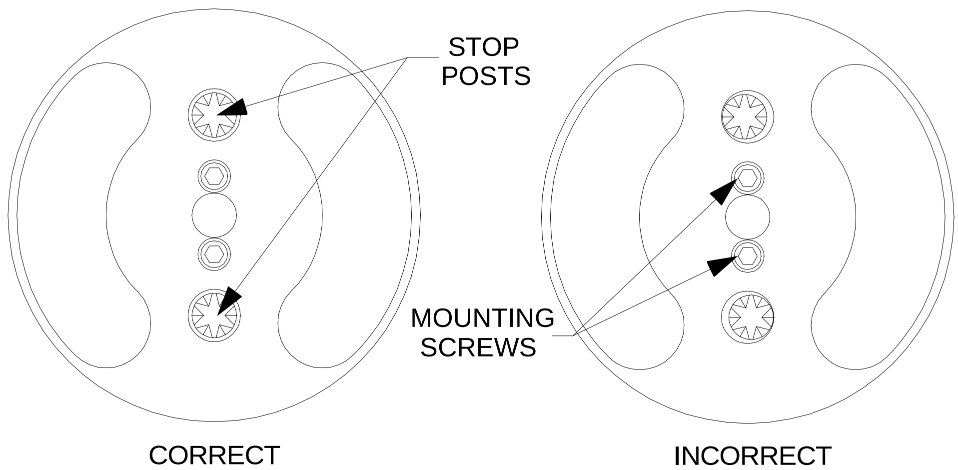


Figure 5-3: Stator Installation and Stop Post Centering

NOTE: *If the stop posts will not align in the center of the stator holes, remove the mounting screws and rotate the stator 180º. Install the screws and repeat step 6. The stop posts may also be bent slightly to insure correct alignment. Refer to* ***Appendix A*** *and contact Brookfield Engineering Laboratories if the stop posts cannot be properly aligned.*

7. Place the sensing endcap assembly in a safe place and proceed with **Cleaning the Drive Endcap Assembly and Measuring Chamber**.

Cleaning the Drive Endcap Assembly and Measuring Chamber

In order to remove and clean the drive endcap, the drive motor, gearbox, and mounting bracket must be removed from the measuring chamber. They can be removed as one unit as shown in Figure 5-1.

CAUTION

Do not remove the drive endcap assembly as a unit unless the sensing end-cap has been removed first.

1. Note the orientation of the drive motor bracket and measuring chamber. The bracket should be reinstalled in the same position during assembly.

2. Remove the drive motor bracket mounting screws and spacers (if applicable) from the measuring chamber as shown in Figure 5-1.

NOTE: *Inspect the weep holes for signs of process fluid leakage. If leakage has occurred, the mechanical seal and bearings should be replaced. Refer to* ***Section 6 - Service*** *for more information.*

3. Separate the drive shaft coupling between the measuring chamber and the drive motor. Retain the isolator for later use.
4. Remove the drive endcap mounting screws and remove the drive endcap from the measuring chamber as shown in Figure 5-1.
5. Using solvent, clean the inside of the measuring chamber and the inlet and outlet tubes.

CAUTION

If the rotor is coated with Teflon (blue/green color), make sure the solvent being used does not harm Teflon. Do not scrape surfaces coated with Teflon.

6. Clean the inside and outside diameter of the rotor.
7. Make sure the rotor spins freely and the rotor is not asymmetrical.

NOTE: *If the rotor does not spin freely, or is* asymmetrical*, refer to* ***Appendix A*** *and contact Brookfield Engineering Laboratories for assistance.*

Reassembly

1. Install the O-ring and drive endcap on the measuring chamber as shown in Figure 5-1 using the mounting screws. Tighten the mounting screws in a rotational pattern.
2. Install the isolator on the drive shaft coupling shown in Figure 5-1.
3. Connect the drive motor shaft to the drive shaft coupling and rotate the drive motor and bracket into the correct position.
4. Install the drive motor and bracket as shown in Figure 5-1 using the mounting screws. Tighten the mounting screws in a rotational pattern.
5. Turn power to the motor controller enclosure ON and allow the motor to operate for a few revolutions to ensure the drive shaft coupling is properly aligned.

6. Turn power to the motor controller enclosure OFF.

CAUTION

Do not damage the torsion element when installing the drive endcap assembly into the measuring chamber.

7. Refer to **Section 3 - Calibration** and perform the calibration procedures shown in Figure 3-2.

Elliptical Baffle Precautions

NOTE: *The following information only applies to viscometers that are equipped with the optional elliptical baffle.*

The optional elliptical baffle is installed on viscometers at the factory. The baffle is held in position by a slight compression between endcaps and will become loose as endcap mounting screws are removed. The baffle will be withdrawn from the measuring chamber along with the drive endcap and must be installed with the drive endcap.

CAUTION

The elliptical baffle must be oriented within the measuring chamber so that it does not bisect the inlet/outlet pipe. Make sure the baffle is positioned properly prior to final tightening of the endcap mounting screws during reassembly.

Section 6 - Service

Introduction

The TT100 In-Line Viscometer is a highly-reliable and rugged unit that requires little maintenance. Section 6 provides information on component replacement.

CAUTION

Always replace endcap O-rings when disassembling and cleaning the viscometer. Refer to Appendix A and contact Brookfield Engineering Laboratories, Inc. to order replacement O-rings.

To order replacement parts, Refer to **Appendix A** and contact Brookfield Engineering Laboratories, Inc. When ordering replacement assemblies, make sure that all associated components (gaskets, O-rings, etc.) have been ordered to ensure the new assemblies can be properly installed.

CAUTION

The internal components of the viscometer must be empty of process fluid, clean, and free of obstructions before it can be serviced. Refer to **Section 5 - Maintenance** and perform the appropriate cleaning procedure for the process fluid application.

Tools Required

Table 6-1 provides a list of tools that are required for viscometer service. Refer to **Appendix A** and contact Brookfield Engineering Laboratories, Inc. for price and availability of the special tools listed in Table 6-1.

Table 6-1: Tools Required

Tool	Tool P/N
Armature Assembly Wrench	TT100-1T
Insulator Centering Fixture	TT100-101TY
Medium Straight Blade Screwdriver	N/A
Standard Hex Wrench Set	N/A
Metric Hex Wrench Set	N/A
Large Adjustable Wrench	N/A
Snap Ring Pliers	N/A
Mallet	N/A
Center Punch	N/A
Motor Gearbox Lubricant (See Note)	N/A
NOTE: Use motor gearbox lubricant Mobil Lith AW #00 without EP Additives or equivalent.	

Sensing Endcap Service

This procedure provides instructions for disassembling the sensing endcap, identifying and replacing damaged components, and assembling the sensing endcap.

Disassembly

WARNING

Make sure power has been turned OFF at the motor and torque sensor electronics enclosures before servicing the viscometer.

1. Shut power OFF to the motor and torque sensor electronics enclosures.

CAUTION

Handle the sensing endcap assembly with care when removing it from the measuring chamber to prevent damage to the torsion element.

2. Remove seven of the eight screws that secure the sensing endcap to the measuring chamber as shown in Figure 6-1.
3. While holding the sensing endcap in position, remove the last screw and carefully remove the sensing endcap from the measuring chamber as shown in Figure 6-1.
4. Remove the stator mounting screws and remove the stator from the sensing endcap assembly as shown in Figure 6-2.
5. Refer to Figure 6-2 and remove the Microsyn housing cover as follows:
   a. Using a wrench, loosen and remove the signal cable strain relief nut. Slide the nut, ring, and insulator down the cable.
   b. Remove the screws from the Microsyn housing cover.
   c. Rotate and lift the housing cover off the assembly and slide it down the cable.
6. Disconnect the wires from the Microsyn field coil and ground stud.
7. Remove the Microsyn field coil mounting screws and cable clamp and remove the field coil from the sensing endcap assembly.

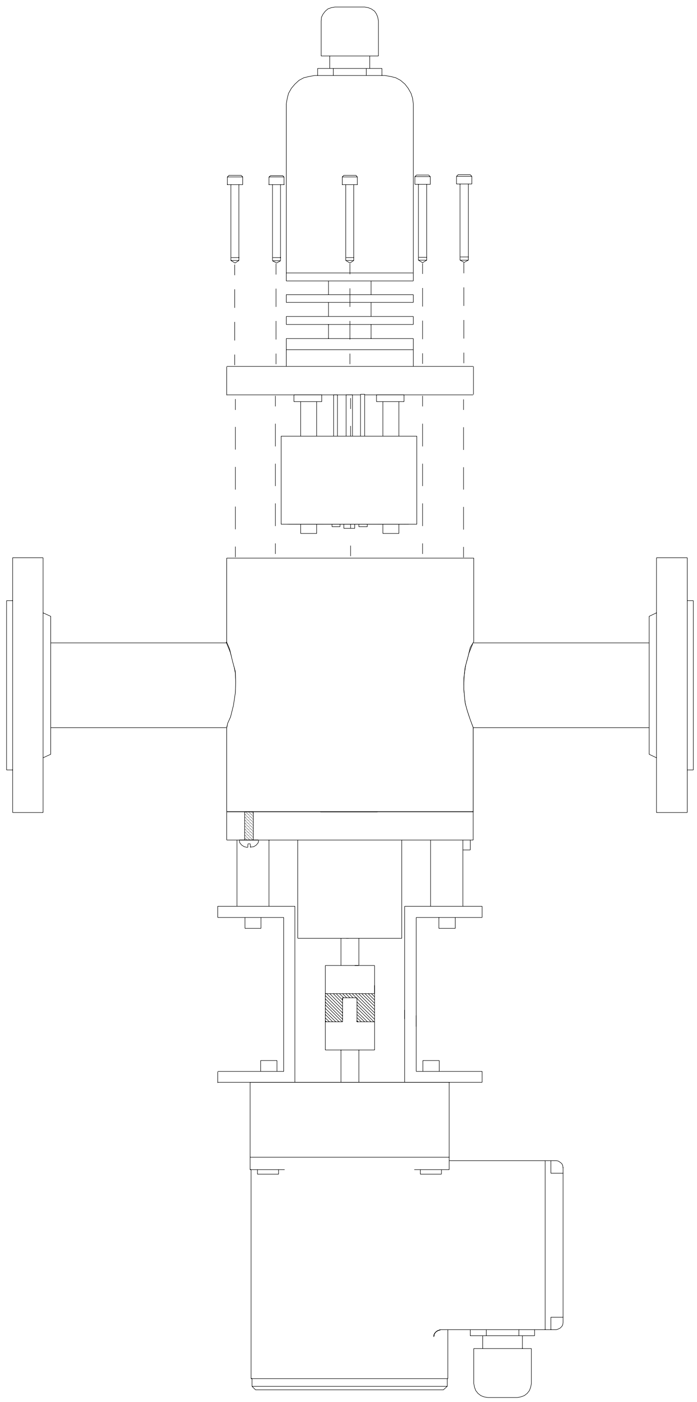


Figure 6-1: Sensing Endcap Removal

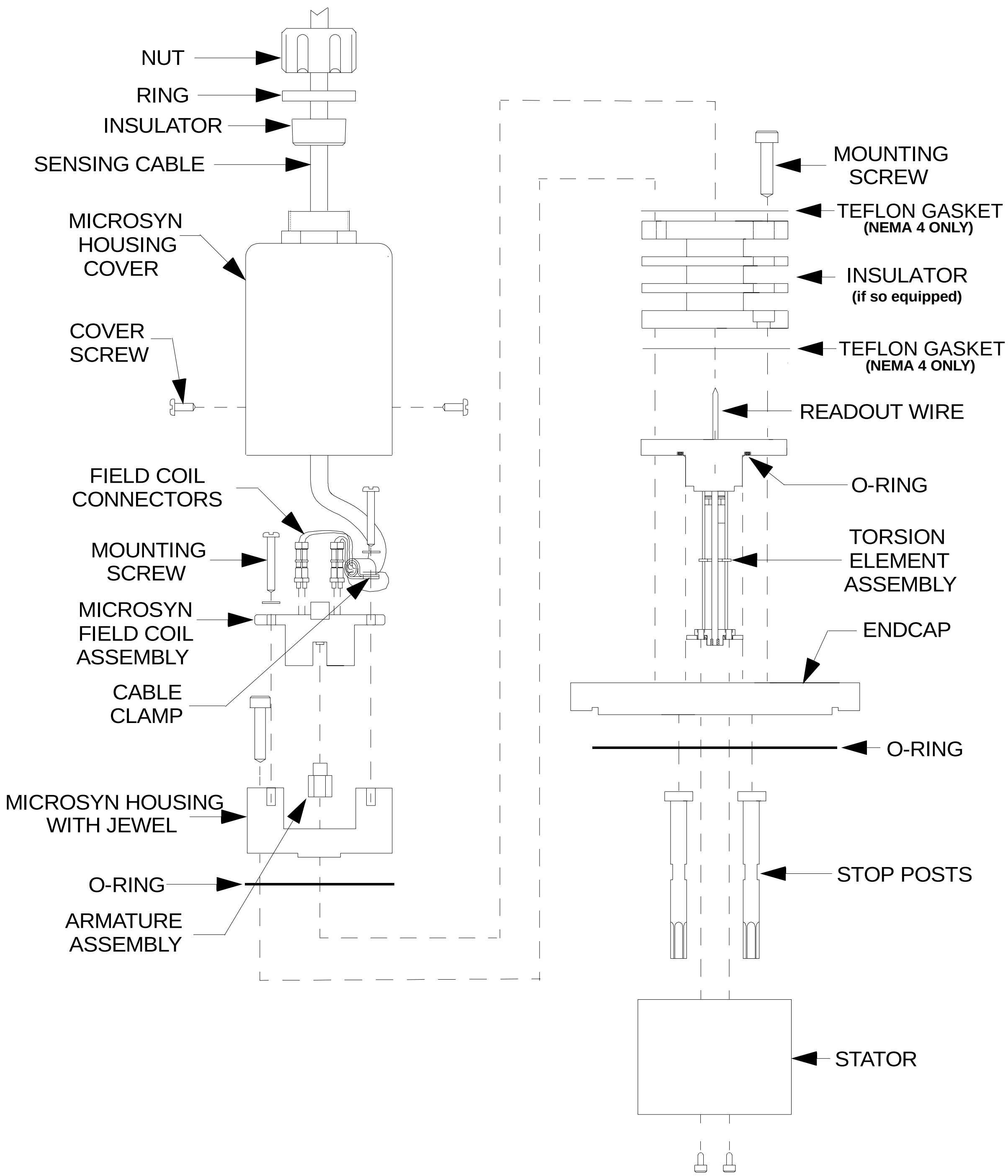


Figure 6-2: Sensing Endcap Disassembly

8. Refer to Figure 6-3 and perform an electrical test on the Microsyn field coil as follows:
   a. Set the DVM to measure resistance (Ω).
   b. Connect the positive lead of the DVM to Pin 1.
   c. Connect the negative lead of the DVM to Pin 2.
   d. The DVM should indicate 2.0 ± 1 Ω.
   e. Connect the positive lead of the DVM to Pin 3.
   f. Connect the negative lead of the DVM to Pin 4.
   g. The DVM should indicate 1500 ± 500 Ω.
   h. If the measured values correspond with the specifications in steps d and g, then proceed with step 9. If the measured values do not correspond with the specifications in steps d and g, then the Microsyn field coil must be replaced. Refer to **Microsyn Field Coil Replacement** within this section.

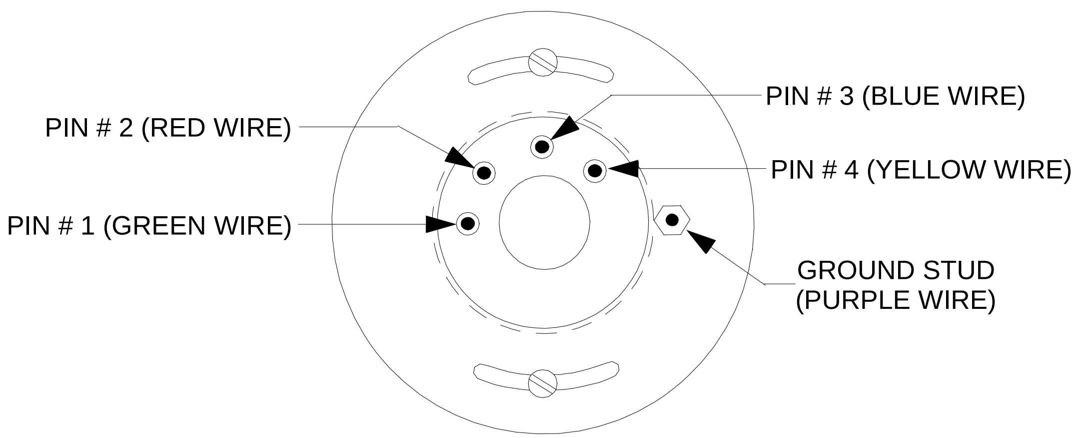


Figure 6-3: Microsyn Field Coil Pin Identification

9. Refer to Figure 6-4 and remove the armature assembly as follows:
   a. Using the Brookfield Engineering Laboratories, Inc. armature wrench P/N TT100-1T, hold the armature in place.
   b. Using a 9/32 inch wrench, loosen the armature clamping nut and remove the armature assembly.

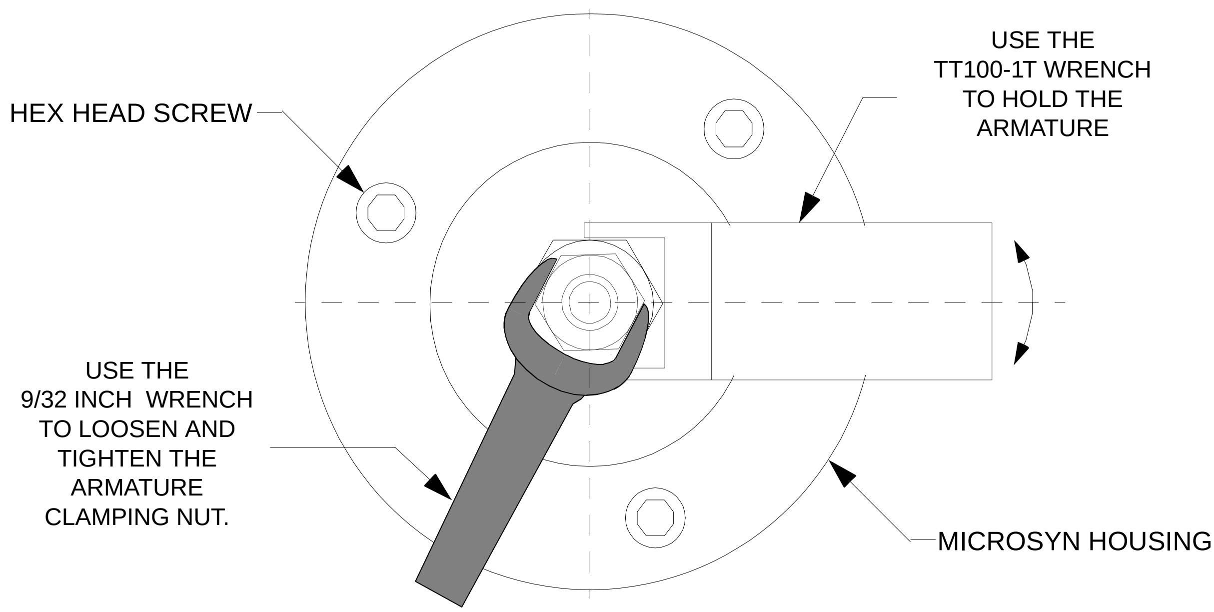


Figure 6-4: Removing the Armature Clamping Nut

10. Loosen and remove the three hex head cap screws, as shown in Figure 6-4, which secure the Microsyn housing to the insulator.

CAUTION

Be careful not to break the sapphire jewel within the Microsyn housing when performing step 11.

11. Carefully slide the Microsyn housing off the center wire of the torsion element.
12. Clean and inspect the center wire as follows:
    a. Using contact cleaner or other non-residue cleaner, gently clean the length of the center wire.
    b. Inspect the surface of the center wire that contacts the jewel. If this area is scored, viscometer reproducibility problems may occur. Refer to **Appendix A** and contact Brookfield Engineering Laboratories, Inc. for a replacement torsion element.

13. Clean and inspect the sapphire jewel as follows:

    a. Using contact cleaner or other non-residue cleaner and a toothpick, gently clean the sapphire jewel. Use compressed air to ensure all particles have been removed from the sapphire jewel.

    b. Using a magnifying glass, inspect the sapphire jewel to make sure it is not cracked or chipped. If the sapphire jewel is damaged, refer to **Appendix A** and contact Brookfield Engineering Laboratories, Inc. for a replacement Microsyn housing assembly.

NOTE: *If your viscometer does not have an insulator located under the Microsyn housing, then proceed with step 16.*

14. Loosen and remove the three hex head cap screws that hold the insulator to the endcap.
15. Carefully remove the insulator with damaging the torsion element center wire.
16. Rotate the torsion element flange and gently pull until the endcap and the torsion element have been separated.

NOTE: *NEMA 4 type sensing endcaps have two teflon gaskets on either side of the insulator. Replace the gaskets if they are damaged. NEMA 7 or CENELEC type sensing endcaps do not have teflon gaskets.*

17. Carefully clean all disassembled parts with an appropriate solvent.
18. Proceed with **Sensing Endcap Assembly**.

Microsyn Field Coil Replacement

WARNING

Make sure power has been turned OFF at the motor and torque sensor electronics enclosures before servicing the viscometer.

1. Shut power OFF to the motor and torque sensor electronics enclosures.
2. Using a wrench, loosen and remove the signal cable strain relief nut from the sensing endcap as shown in Figure 6-2. Slide the nut, ring, and insulator down the cable.
3. Remove the Microsyn housing cover screws as shown in Figure 6-2.
4. Rotate and lift the Microsyn housing cover off the assembly and slide it down the cable as shown in Figure 6-2.

5. Remove the wire connectors from the Microsyn field coil.
6. Remove the mounting screws, cable clamp, washers, and purple ground wire from the Microsyn field coil, as shown in Figure 6-2, and remove the Microsyn field coil from the sensing endcap.
7. Install the new Microsyn field coil.
8. Install the mounting screws, cable clamp, and washers. Do not tighten the screws.
9. Refer to Figure 3-3 in **Section 3 - Calibration**.

Torque Sensor Printed Circuit Board Replacement

WARNING

Make sure power has been turned OFF at the motor and torque sensor electronics enclosures before servicing the viscometer.

1. Shut power OFF to the motor and torque sensor electronics enclosures.
2. Open the cover on the torque sensor electronics enclosure.
3. Disconnect the power cable and ground connections from J3 as shown in Figure 6-5.
4. Disconnect the sensing cable connections from J1 as shown in Figure 6-5.
5. Disconnect the display device from J1-T1 and T2.
6. Remove the printed circuit board mounting screws, as shown in Figure 6-5, and remove the circuit board from the enclosure.
7. Install the new printed circuit board using the mounting screws.

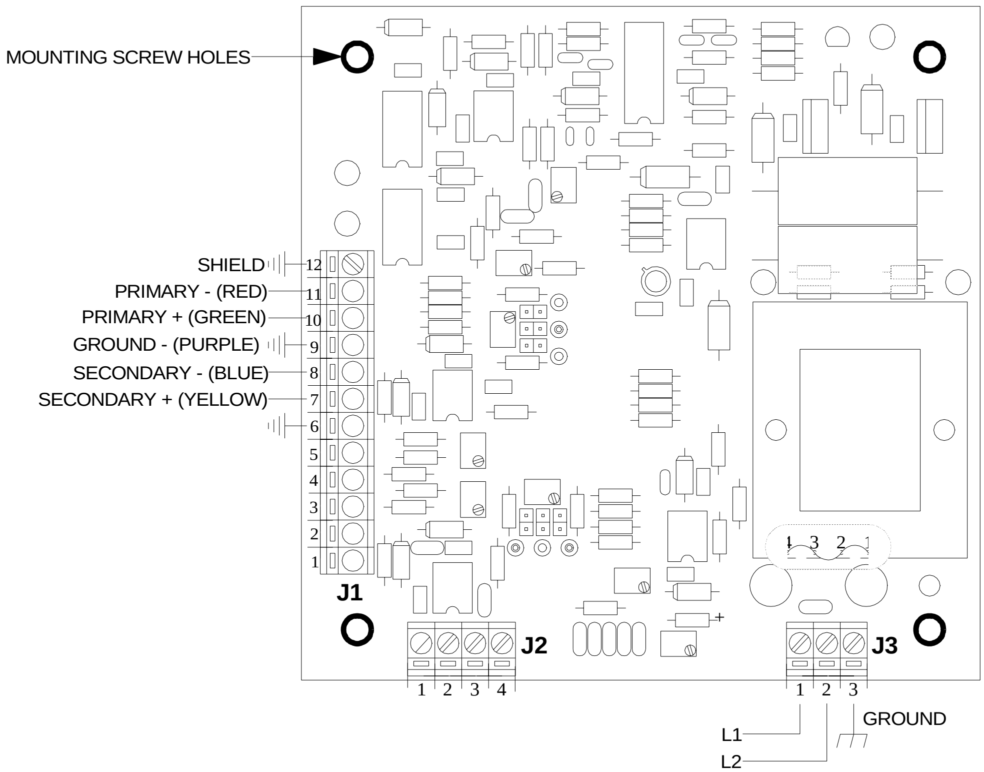


Figure 6-5:Torque Sensor Electronics Enclosure Signal and Power Connection Locations

8. Make the following electrical connections:
   a. Connect the **L1** power wire to J3-T1.
   b. Connect the **L2** power wire to J3-T2.
   c. Connect a **GROUND JUMPER** wire between the cover ground stud and J3-T3.
   d. Connect the **RED** sensor wire to J1-T11.
   e. Connect the **GREEN** sensor wire to J1-T10.
   f. Connect the **PURPLE** sensor wire to J1-T9.
   g. Connect the **BLUE** sensor wire to J1-T8.
   h. Connect the **YELLOW** sensor wire to J1-T7.
   i. Connect the **GROUND** power wire to the ground stud.
   j. Connect the **SHIELD** wire to J1-T12.
   k. Connect the wire connectors to the Microsyn field coil as shown in Figure 6-5.
   l. Connect the display device to J1-T1 and T2.

m. Remove the range jumper from the old circuit board and connect it to the same terminals on J2.

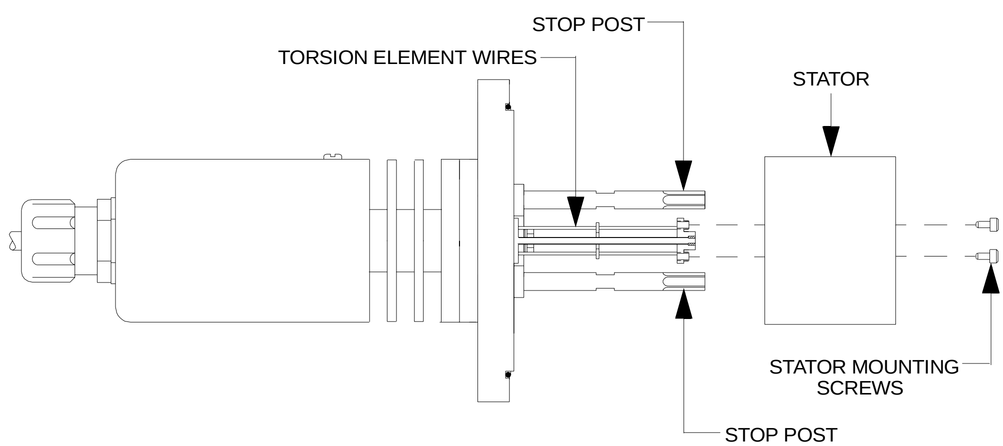
9. Refer to Figure 3-3 within **Section 3 - Calibration**.

Torsion Element Replacement

WARNING

Make sure power has been turned OFF at the motor and torque sensor electronics enclosures and the viscometer is empty and dry before servicing the viscometer.

1. Shut power OFF to the motor and torque sensor electronics enclosures.
2. Remove seven of the eight screws that secure the sensing endcap to the measuring chamber.
3. While holding the sensing endcap in position, remove the last screw and carefully remove the sensing endcap from the measuring chamber.
4. Remove the two mounting screws from the top of the stator as shown in Figure 6-6.



NOTE: There are many different versions of the sensing endcap. Your viscometer may look different from the viscometer shown.

Figure 6-6:Stator Removal

5. Carefully remove the stator.
6. Place the sensing endcap in a cylindrical device (vessel, can, etc.) that will support the flange and allow the torsion element to be suspended without contact.
7. Using a wrench, loosen and remove the signal cable strain relief. Slide the nut, ring, and insulator down the cable.
8. Remove three screws from the Microsyn housing cover as shown in Figure 6-2.
9. Rotate and lift the housing cover off the assembly and slide it down the cable.
10. Remove the wires from the Microsyn field assembly.
11. Remove the two mounting screws, cable clamp, and washers from the Microsyn field assembly.

CAUTION

Do not bend or damage the torsion element wire or sapphire jewel when removing the Microsyn field coil.

12. Lift and remove the Microsyn field coil.
13. Using special wrench P/N TT100-1T, hold the assembly and loosen the armature assembly nut with a 9/32 inch wrench and remove the assembly from the center wire.
14. Remove the three Microsyn field coil mounting screws.
15. Carefully rotate the Microsyn field coil and lift it straight up and remove it from the torsion element wire.

NOTE: *When cleaning the sapphire jewel, use contact cleaner, or another solvent that will not leave a residue on the sapphire jewel.*

16. Using contact cleaner and toothpicks, clean the sapphire jewel opening . Apply compressed air to the opening to ensure all particles have been removed.
17. Inspect the sapphire jewel for cracks or chips. Refer to **Appendix A** and call Brookfield Engineering Laboratories, Inc. if jewel damage has been discovered.
18. Inspect the O-ring and replace it if it shows sign of wear or damage.

NOTE: *NEMA 4 type sensing endcaps have two teflon gaskets on either side of the insulator. NEMA 7 and CENELEC type sensing endcaps do not have gaskets.*

19. Remove the Teflon gasket.

NOTE: *Depending upon the application, the viscometer may contain none, 1, or 2 insulators.*

CAUTION

Do not bend or damage the torsion element wire or when removing the insulators.

20. Using a hex wrench, remove the insulator(s), gasket(s), and mounting screws as required.
21. Using a mallet and a center punch, tap the torsion element flange to remove the torsion element. Discard the torsion element.
22. Remove the shipping guards from the new torsion element.
23. Proceed with **Sensing Endcap Assembly**.

Sensing Endcap Assembly

CAUTION

Do not bend the torsion element center wire or otherwise damage the torsion element when assembling the viscometer.

1. Insert the O-ring into the groove of the torsion element.
2. Insert the torsion element into the endcap and rotate the torsion element so that the stator screws line up with the stop post correctly as shown in Figure 6-7.
3. Place a teflon gasket on the torsion element flange.
4. Place the insulator on top of the teflon gasket and align the mounting screw holes.

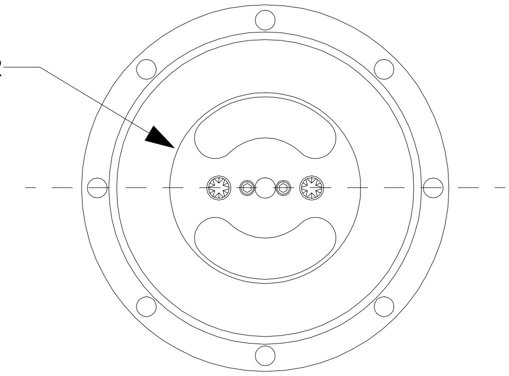


Figure 6-7:Torsion Element and Endcap Alignment

5. Insert the mounting screws and using a hex wrench, rotate the screws into position but do not tighten them.
6. Place the insulator centering fixture (P/N TT-100-101TY) into the insulator.
7. Repeat steps 4 - 6 for each insulator.
8. Using a hex wrench, tighten the mounting screws and remove the centering fixture.
9. Place an O-ring on the Microsyn housing.
10. Place a second teflon gasket on the insulator.
11. Carefully slide the torsion element center wire through the sapphire jewel in the Microsyn field coil until it contacts the insulator.
12. Insert the mounting screws into the holes and tighten them using a hex wrench.

NOTE: *Do not tighten the armature clamping nut in step 13.*

13. Install the armature clamping nut on the armature assembly.
14. Carefully slide the armature assembly down the torsion element center wire until it touches the sapphire jewel.

CAUTION

The sapphire jewel may be damaged if the height of the armature assembly is not set properly. Non-repeatability of signal will result.

15. Set the height of the armature assembly as follows:
    a. Place the armature wrench P/N TT100-1T, on the armature hold the armature in place as shown in Figure 6-4.
    b. Using a small ruler to measure, lift the armature assembly 1/16 of an inch.
    c. Using a 9/32 inch wrench, tighten the armature clamping nut.
16. Carefully install the stator and install the mounting screws but do not tighten.

NOTE: *The stop posts must be centered within the holes on the stator as shown in Figure 6-8 to ensure proper calibration and operation of the viscometer.*

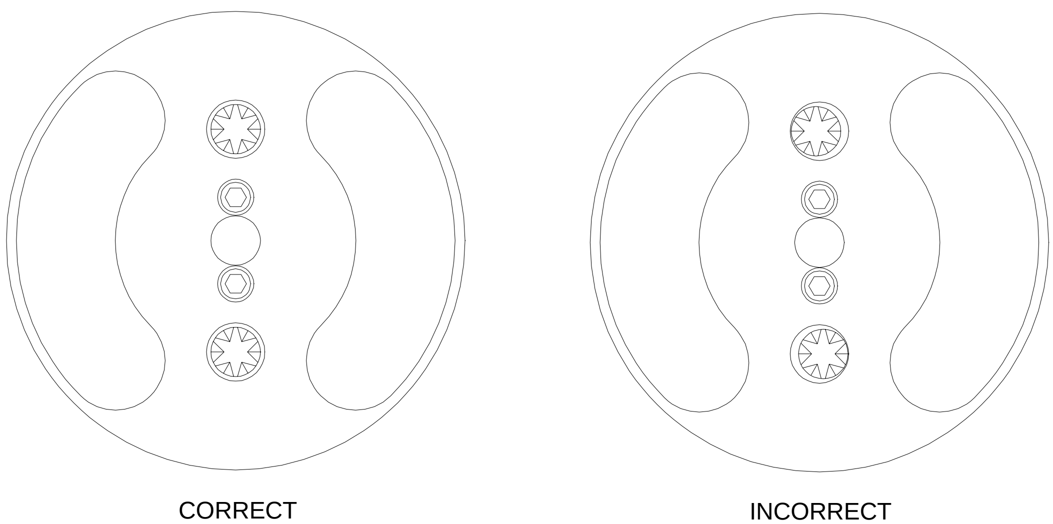


Figure 6-8: Stator Installation and Stop Post Centering

17. With the stator mounting screws loose, rotate the stator so the stop posts are aligned in the center of the holes in the stator as shown in Figure 6-8. Tighten the stator mounting screws and check the alignment of the stop posts.

NOTE: *If the stop posts will not align in the center of the stator holes, remove the mounting screws and rotate the stator 180º. Install the screws and repeat step 17. The stop posts may also be bent slightly to insure correct alignment. Refer to* ***Appendix A*** *and contact Brookfield Engineering Laboratories if the stop posts cannot be properly aligned.*

18. Install the O-ring into the sensing endcap and turn the assembly over.

19. Place the Microsyn field coil assembly on the Microsyn housing and align the mounting screw holes.
20. Insert the mounting screws and washers and tighten the screws.
21. Refer to Figure 3-3 within **Section 3 - Calibration**.

Drive Endcap Service

The drive endcap should only require service if the gaskets or mechanical seals need to be replaced, or if a bearing has seized.

Motor and Gearbox Test

WARNING

Make sure power has been turned OFF at the motor and torque sensor electronics enclosures before servicing the viscometer.

1. Note the orientation of the drive motor bracket and measuring chamber. The bracket should be reinstalled in the same position during assembly.
2. Remove the drive motor bracket mounting screws and spacers (if applicable) from the measuring chamber as shown in Figure 6-9.
3. Separate the drive shaft coupling between the measuring chamber and the drive motor. Retain the isolator for later use.
4. Turn power ON to the motor control enclosure.
5. Check the motor for unusual noises or vibration. Turn motor power OFF. If there is an unusual noise or vibration, the motor, gearbox or capacitor may be defective. Refer to step 6.
6. Refer to Figure 6-10 and check the motor and gearbox as follows:
   a. Remove the screws that secure the motor to the gearbox.
   b. Separate the motor and gearbox.
   c. Turn power ON to the motor control enclosure.
   d. Check the motor for unusual noises or vibrations. Turn power OFF.
7. Proceed as follows:
   a. If there are unusual noises or vibration, then the motor or capacitor is defective. Refer to **Appendix A** and contact Brookfield Engineering Laboratories for assistance.

b. When the replacement motor arrives, refer to **Motor Replacement** within this section.

c. When the replacement capacitor arrives, refer to **Capacitor Replacement** within this section.

d. If there are no unusual noises or vibrations, then the gearbox is defective. Refer to **Appendix A** and contact Brookfield Engineering Laboratories for a replacement gearbox.

e. When the replacement gearbox arrives, refer to **Gearbox Replacement**.

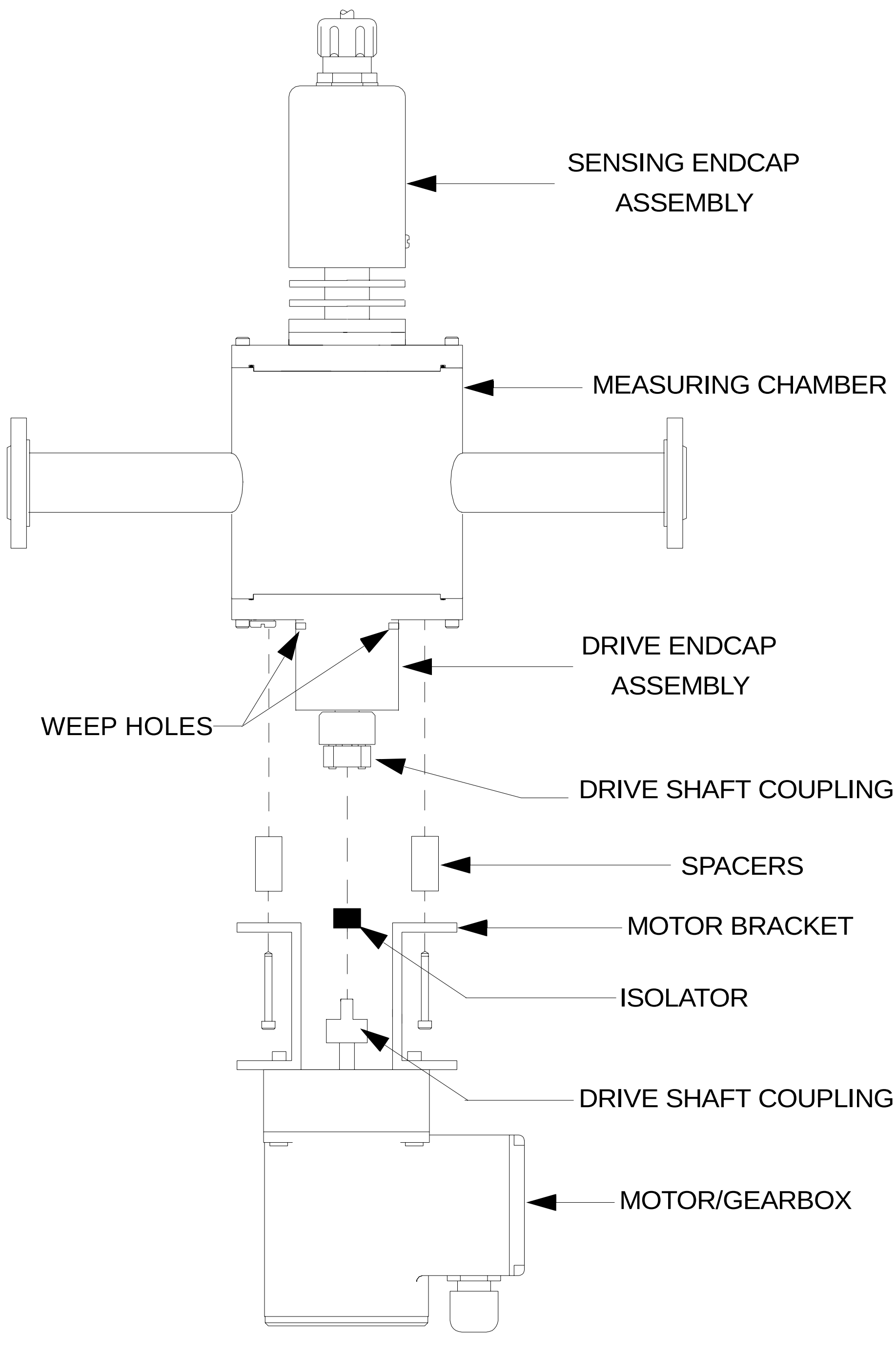


Figure 6-9: Motor Bracket Removal

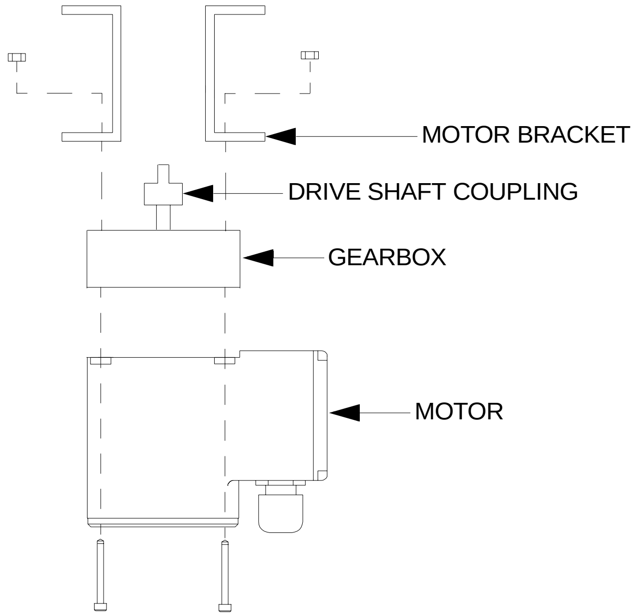


Figure 6-10: Motor and Gearbox Disassembly

Disassembly

CAUTION

The drive endcap should only be disassembled if process fluid is leaking from the seals or weep holes.

Handle the drive endcap assembly with care when removing it from the measuring chamber to prevent damage to the torsion element.

NOTE: *Inspect the weep holes for signs of process fluid leakage. If leakage has occurred, the mechanical seals should be replaced. Refer to* ***Mechanical Seal Replacement*** *in this section for more information.*

1. Shut power OFF to the motor and torque sensor electronics enclosures.
2. Remove seven of the eight screws that secure the drive endcap to the measuring chamber as shown in Figure 6-1.

3. While holding the drive endcap in position, remove the last screw and carefully remove the drive endcap from the measuring chamber as shown in Figure 6-1.
4. Note the position of the drive endcap to the measuring chamber. The drive endcap must be installed in the same position during assembly.

CAUTION

If the rotor is coated with Teflon (blue/green color), make sure the solvent being used does not harm Teflon. Do not scrape surfaces coated with Teflon.

5. Place the rotor end of the drive endcap assembly on the work surface.
6. Using a hex wrench, loosen the set screw and remove the drive shaft coupling from the drive shaft as shown in Figure 6-12.
7. Remove the snap ring from the drive shaft.
8. Remove the bearing support mounting screws and remove it.
9. Inspect the bearings in the bearing support for damage. If the bearings are seized or damaged, refer to **Appendix A** and contact Brookfield Engineering Laboratories for replacement bearings. Once the replacement bearings have been received, refer to **Bearing Replacement**. If the bearings are not damaged, proceed with step 11.
10. Remove the second snap ring and lift the seal support, seal seat, and drive endcap from the shaft.
11. Loosen the set screws on the seal head and remove it from the shaft. If the seal head face is scored, damaged, contains solids, or the wedge ring or ring is damaged, refer to **Appendix A** and contact Brookfield Engineering Laboratories for a replacement seal head.
12. Check the drive shaft for scoring or damage where the wedge ring or O-ring is located. Refer to **Appendix A** and contact Brookfield Engineering Laboratories for a replacement drive shaft.
13. Remove the seal seat and retaining ring from the drive endcap.
14. Inspect seal seat and O-ring for wear and replace if required.

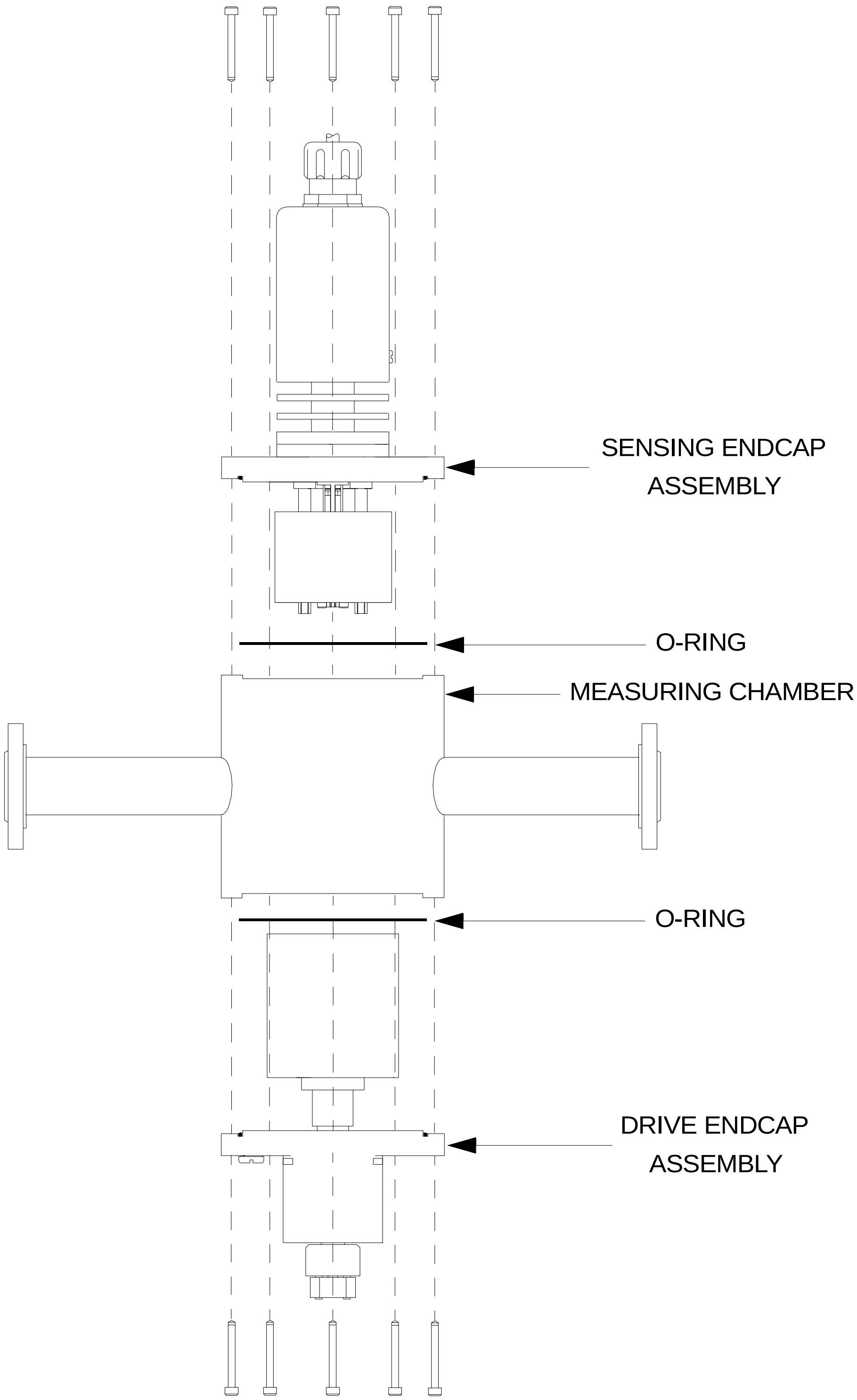


Figure 6-11:Drive Endcap Removal

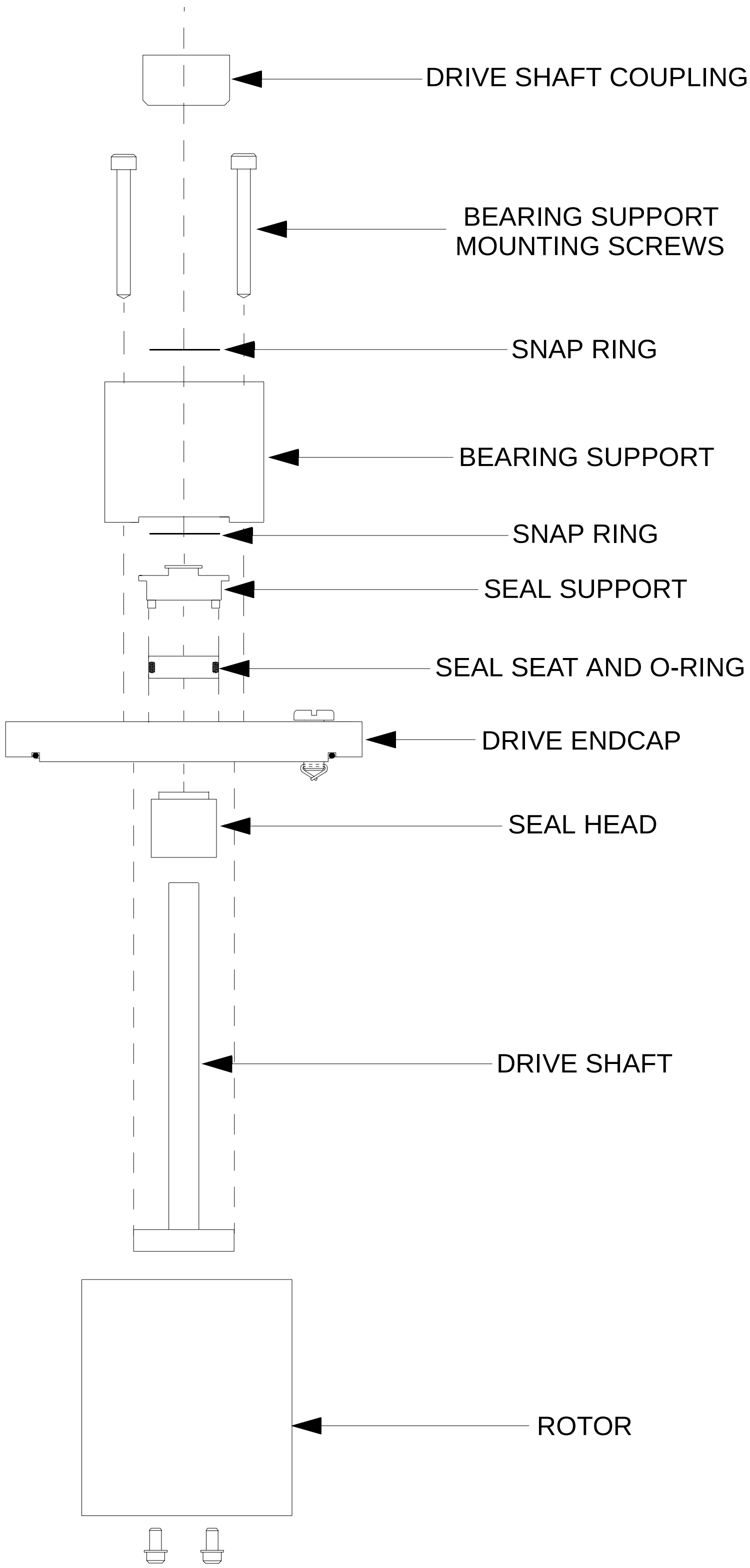


Figure 6-12:Drive Endcap Disassembly (with Single Mechanical Seal)

Capacitor Replacement

WARNING

Make sure power has been turned OFF at the motor and torque sensor electronics enclosures before replacing the capacitor.

1. Turn power OFF to the Motor and torque sensor electronics enclosure.
2. Remove the Motor Control enclosure cover.
3. Disconnect the capacitor connections and remove the capacitor.
4. Install the new capacitor and connect the leads.
5. Install the Motor Control enclosure cover.
6. Turn power ON to the Motor Enclosure.

Oriental Motor Replacement

WARNING

Make sure power has been turned OFF at the motor and torque sensor electronics enclosures before replacing the oriental motor.

1. Turn power OFF to the Motor and torque sensor electronics enclosure.
2. Disconnect the power cable from the oriental motor.
3. Remove the defective motor and gearbox from the viscometer as described in **Drive Endcap Service**.
4. Remove the gearbox mounting screws from the motor and separate the gearbox and motor as shown in Figure 6-10.
5. Install the power cord according to Figure B-1.
6. Attach the existing gearbox to the replacement motor using the previously removed mounting screws.
7. Turn power ON to the motor control enclosure.
8. Check the motor for unusual noises or vibrations. Turn power OFF.
9. Proceed with **Drive Endcap Assembly**.

Oriental Motor Gearbox Replacement

1. Remove the motor and defective gearbox and associated brackets from the viscometer as described in **Drive Endcap Service**.
2. Remove the gearbox mounting screws from the motor and separate the gearbox and motor as shown in Figure 6-10.
3. Attach the replacement gearbox to the existing motor using the previously removed mounting screws.
4. Turn power ON to the motor control enclosure.
5. Check the gearbox for unusual noises or vibrations. Turn power OFF.
6. Proceed with **Drive Endcap Assembly**.

Groschopp Motor Replacement

WARNING

Make sure power has been turned OFF at the motor and torque sensor electronics enclosures before replacing the oriental motor.

1. Turn power OFF to the Motor and torque sensor electronics enclosure.
2. Disconnect the power cable from the oriental motor.
3. Remove the four hex bolts from the motor bracket and remove the motor as shown in Figure 6-13.
4. Remove the three gearbox mounting screws and washers and remove the gearbox.

CAUTION

Support the motor shaft and spline gear to prevent damaging these components during step 3.

5. Using an awl and a mallet, remove the pin from the spline gear. Remove the spline gear from the motor shaft.
6. Using an awl and a mallet, install the spline gear and pin on the replacement motor.
7. Apply gearbox lube to the gearbox.

8. Carefully install the gearbox on the replacement motor using the previously removed mounting screws and washers.

NOTE: *Do not tighten the screws.*

9. Align the motor drive shaft coupling halves and install the motor on the mounting bracket.
10. Install and tighten the motor mounting screws and washers.
11. With the gearbox mounting screws loose, adjust the position of the gearbox until the motor drive shaft coupling halves are parallel to each other. Tighten the gearbox mounting screws.

NOTE: *If needed, refer to the viscometer specification sheet to determine the appropriate drawing reference for step 12.*

12. Install the power cable according to the appropriate Figure in **Appendix B**.
13. Turn power ON to the motor control enclosure.
14. Check the gearbox for unusual noises or vibrations. Turn power OFF.
15. Proceed with **Drive Endcap Assembly**.

Groschopp Motor Gearbox Replacement

1. Remove the four hex bolts from the motor bracket and remove the motor as shown in Figure 6-13.
2. Remove the three gearbox mounting screws and washers and remove the gearbox.
3. Using a hex wrench, loosen the set screw and remove the drive shaft coupling half from the gearbox shaft.
4. Install the drive shaft coupling half on the replacement gearbox shaft and tighten the set screw.
5. Apply gearbox lube to the replacement gearbox.
6. Carefully install the replacement gearbox on the motor using the previously removed mounting screws and washers.

NOTE: *Do not tighten the screws.*

7. Align the motor drive shaft coupling halves and install the motor on the mounting bracket.
8. Install and tighten the motor mounting screws and washers.

9. With the gearbox mounting screws loose, adjust the position of the gearbox until the motor drive shaft coupling halves are parallel to each other. Tighten the gearbox mounting screws.

NOTE: *If needed, refer to the viscometer specification sheet to determine the appropriate drawing reference for step 10.*

10. Install the power cable according to the appropriate Figure in **Appendix B**.
11. Turn power ON to the motor control enclosure.
12. Check the gearbox for unusual noises or vibrations. Turn power OFF.
13. Proceed with **Drive Endcap Assembly**.

Bearing Replacement

This procedure provides instructions for installing new bearings in an existing bearing support.

1. Remove the bearing support as described in **Drive Endcap Service** procedure within this section.
2. Carefully remove the upper bearing from the bearing support.
3. Carefully remove the lower bearing from the bearing support.
4. Place the upper bearing into the mounting hole of the bearing support.
5. Using your fingers, press the upper bearing into the bearing support.
6. Place the lower bearing into the mounting hole of the bearing support.
7. Using a your fingers, press the lower bearing into the bearing support.
8. Proceed with **Drive Endcap Assembly**.

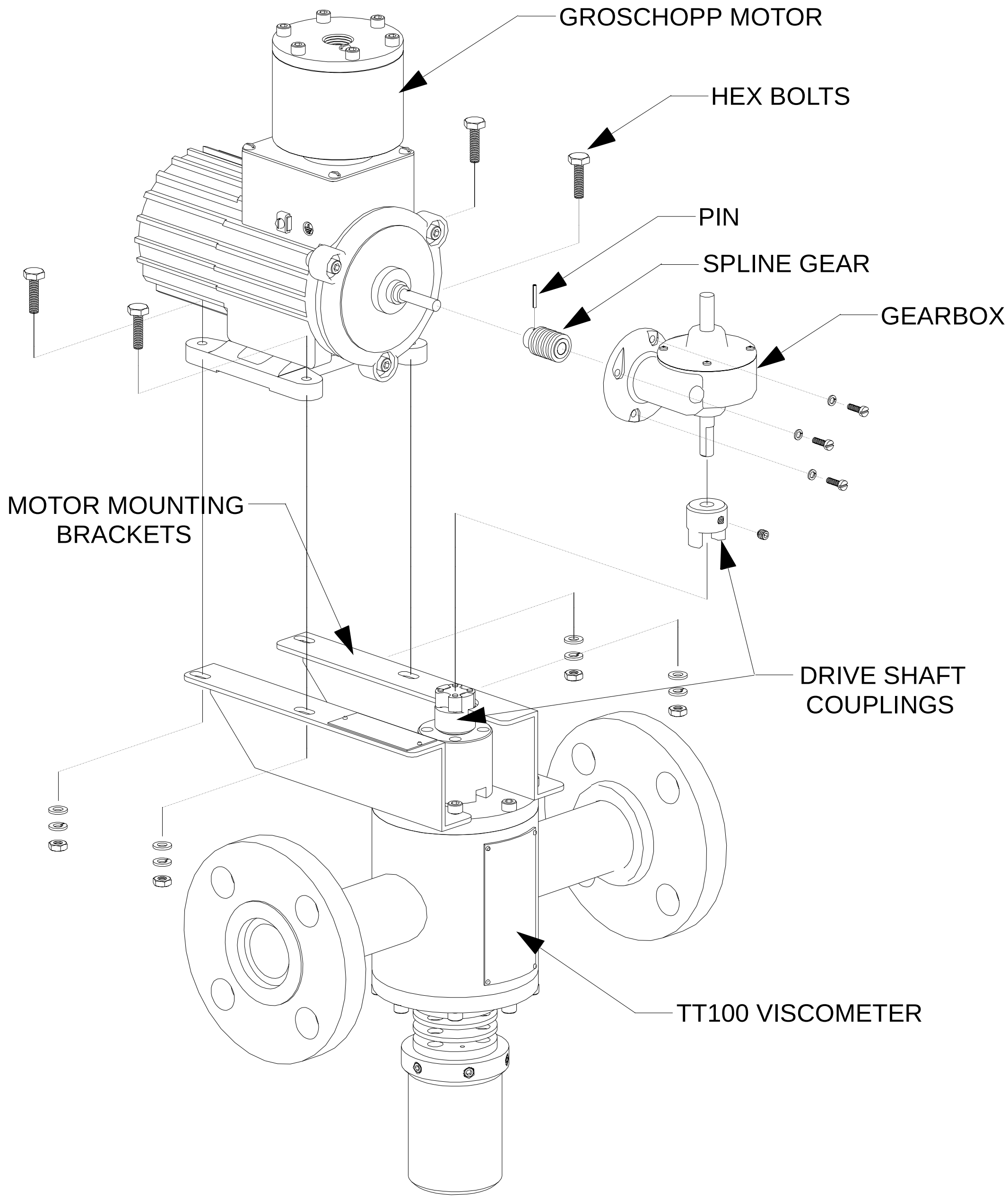


Figure 6-13: Groschopp Motor and Gearbox Disassembly

Drive Endcap Assembly

1. Apply light oil to the wedge ring in the seal head or O-ring.
2. Compress the seal head assembly and slide the seal head onto the shaft until it bottoms out. Tighten the four set screws.
3. Using O-ring lube, lube the O-ring on the seal seat and finger press the seal seat back into the drive endcap.
4. Turn the drive endcap over and insert the seal support and align the notches to the back side of the seal seat.
5. Make sure both sealing faces are clean then apply light oil to both sealing faces.
6. Place the drive endcap on the shaft and slide it down the shaft until the sealing faces meet.
7. Install the first snap ring into the groove on the shaft.
8. Place the bearing support on the shaft and slide it down until it bottoms out on the drive endcap.
9. Install and tighten the four drive endcap mounting screws.
10. Compress the seal head and place the second snap ring into the groove on the shaft.
11. Install the drive shaft coupling and tighten the set screw.
12. Install the isolator.
13. Rotate the shaft and make sure it spins smoothly. If the shaft does not spin smoothly, check for proper snap ring location, improperly located seal components, or defective bearings.
14. Carefully install the drive endcap assembly into the measuring chamber.
15. Install and tighten the mounting screws.
16. Connect the motor drive shaft to the drive endcap assembly.
17. Install the drive motor bracket on the measuring chamber in the original position.
18. Install the drive motor bracket mounting screws and tighten.
19. Install the sensing endcap assembly.

Double Mechanical Seal Assembly Replacement

1. Remove the barrier fluid connections from the viscometer.
2. Note the orientation of the drive motor bracket and measuring chamber. The bracket should be reinstalled in the same position during assembly.

3. Remove the drive motor bracket mounting screws and spacers (if applicable) from the measuring chamber as shown in Figure 6-9.
4. Separate the drive shaft coupling between the measuring chamber and the drive motor. Retain the isolator for later use.

CAUTION

Do not damage the torsion element when removing the drive endcap.

5. Remove the drive endcap mounting screws and remove the drive endcap from the measuring chamber.
6. Remove the rotor mounting screws and washers as shown in Figure 6-14.
7. Remove the rotor as shown in Figure 6-14.
8. Remove the double mechanical seal assembly mounting screws from the drive endcap as shown in Figure 6-14.
9. Separate the drive endcap from the double mechanical seal assembly.

NOTE: *Refer to* ***Appendix A*** *and contact Brookfield Engineering Laboratories, Inc. to make arrangements to return the used double mechanical seal assembly for repair.*

10. Install a new O-ring on the replacement double mechanical seal assembly.
11. Install the replacement double mechanical seal assembly into the drive endcap.

CAUTION

Make sure the O-ring is in the correct position before tightening the mechanical seal mounting screws.

12. Install and tighten the double mechanical seal mounting screws.
13. Install the rotor mounting screws and washers as shown in Figure 6-14.
14. Install the drive shaft coupling and isolator on the end of the drive shaft.
15. Install the O-ring on the drive endcap assembly and carefully install the drive endcap assembly into the measuring chamber.

16. Install and tighten the mounting screws.
17. Connect the motor drive shaft to the drive endcap.
18. Install the drive motor bracket on the measuring chamber in the original position.
19. Install the drive motor bracket mounting screws and tighten.
20. Connect the barrier fluid connectors.

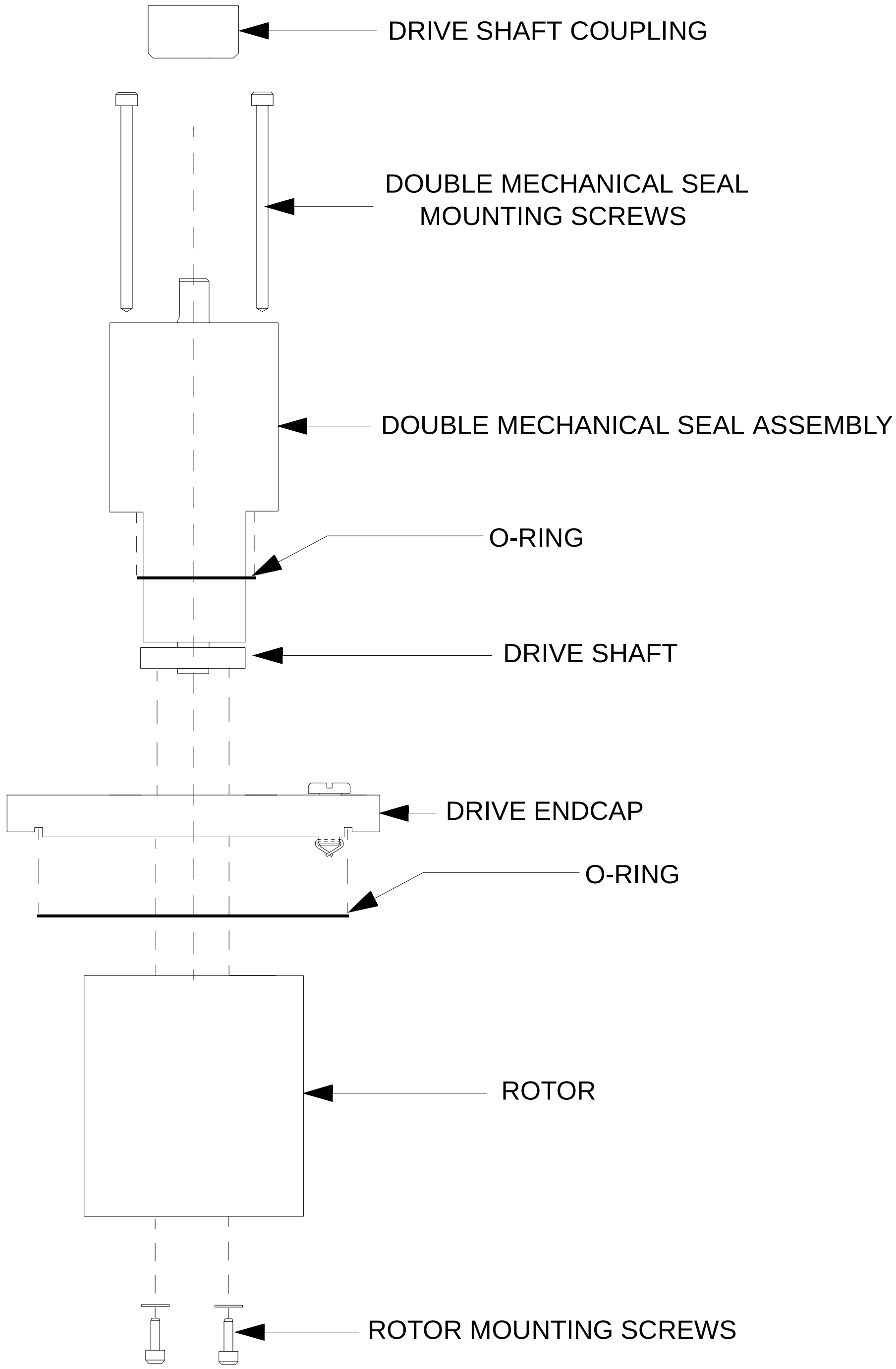


Figure 6-14: Drive Endcap Disassembly (with Double Mechanical Seal)

Section 7 - Troubleshooting

Introduction

The information in Section 7 will help you troubleshoot problems when they occur. The problems presented in Table 7-1 are followed by possible causes and corrective actions. The causes and corresponding actions are listed in their order of probability of occurrence.

Technical Inquiries

Refer to **Appendix A** and call Brookfield Engineering Laboratories, Inc. if you are in need of assistance.

Table 7-1: Process Fluid Leaks

Problem	Possible Cause	Corrective Action
Leak between chamber and sensing endcap.	Damaged O-ring	Refer to **Sensing Endcap Service** in Section 6 and replace the O-ring.
Leak between sensing end-cap and torsion element.	Damaged O-ring	Refer to **Sensing Endcap Service** in Section 6 and replace the O-ring.
Leak at Microsyn housing	Damaged torsion element	Refer to **Sensing Endcap Service** in Section 6 and replace the torsion element.
Leak from drive shaft seal/ bearing housing of single mechanical seal viscometer	Damaged mechanical seals	Refer to **Mechanical Seal Replacement** in Section 6 and replace the mechanical seals.
Leak from drive shaft seal/ bearing housing of double seal mechanical seal viscometer	Damaged O-ring or double seal housing	Refer to **Double Mechanical Seal Assembly Replacement** in Section 6 and replace the double seal assembly or O-ring.

Table 7-2: Drive Motor

Problem	Possible Cause	Corrective Action
Motor noticeably hot during operation	Normal operation	None
Motor will not operate, or must be assisted to operate	Damaged motor or gearbox	1. Refer to **Motor and Gearbox Test** in Section 6.
	Damaged drive shaft bearings or seal support seizure.	2. Refer to **Drive Endcap Service** in Section 6 and check the bearings.
	Process system pressure or temperature setpoint has been reached.	3. Repair process system as required.
	Damaged pressure or temperature interlock.	4. Refer to **Motor and Gearbox Test** in Section 6.
	Motor wired incorrectly.	5. Refer to **Motor Control Enclosure Installation** in Section 2.
Motor runs in either direction depending upon assistance	Damaged phase-shifting capacitor in motor.	Refer to **Capacitor Replacement** in Section 6 and replace the capacitor.
Motor rotation does not match torque response.	Torque sensor response not properly calibrated.	Refer to **Figure 3-1** in Section 3.
	Motor wiring incorrect.	Refer to **Appendix B** for correct motor wiring information.

Table 7-3: Calibration Errors

Problem	Possible Cause	Corrective Action
No output, no change in output when torqued, or no response to calibration attempts.	1. No power to torque sensor electronics and motor control enclosures. 2. Damaged torque sensor electronics board. 3. Damaged Microsyn field coil. 4. Sensing endcap improperly wired	1. Make sure power is applied to the torque sensor and motor enclosures. 2. Refer to **Torque Sensor Printed Circuit Board Replacement** Section 6. 3. Refer to **Microsyn Field Coil Replacement** in Section 6**.** 4. Refer to **Figure 6-3** in Section 6.
No change in output when motor is energized or when fluid changes. No torque response.	1. Viscometer is not completely flooded with process fluid. 2. Motor is not operating. 3. Solids build-up within viscometer. 4. Open or shorted wiring to Microsyn field coil assembly. 5. Damaged Microsyn field coil assembly. 6. Damaged torsion element.	1. Refer to **Section 2** and make sure viscometer is installed properly. 2. Refer to **Table 7-2**. 3. Refer to **Section 5** and clean the viscometer. 4. Refer to **Sensing Endcap Service** in Section 6. 5. Refer to **Microsyn Field Coil Replacement** in Section 6. 6. Refer to **Torsion Element Replacement** in Section 6.

Table 7-3: Calibration Errors (Continued)

Problem	Possible Cause	Corrective Action
Reverse Torque Response	1. Coarse zero calibration incorrect. 2. Reverse motor rotation. 3. Transducer wired incorrectly.	1. Refer to **Coarse Zero Adjustment** in Section 3. 2. Refer to **Table 7-2** in Section 7. 3. Refer to **Figure 6-3** in Section 6.
Partial torque Response	1. Coarse zero calibration incorrect. 2. Excessive load (above 600 ohms) on output. 3. Solids build-up within viscometer. 4. Incorrect/shorted Microsyn field coil wiring. 5. Excessive friction on readout wire at jewel. 6. Damaged torsion element. 7. Span calibration incorrect. 8. Loose or misaligned armature assembly. 9. Optional elliptical baffle installed incorrectly.	1. Refer to **Coarse Zero Adjustment** in Section 3. 2. Reduce load. 3. Refer to **Section 5** and clean the viscometer. 4. Refer to **Sensing Endcap Service** in Section 6. 5. Refer to **Sensing Endcap Service** in Section 6. 6. Refer to **Sensing Endcap Service** in Section 6. 7. Refer to **Single or Dual Range Span Calibration** in Section 3. 8. Refer to **Sensing Endcap Service** in Section 6. 9. Refer to the **Elliptical Baffle Precautions** in Section 5.

Table 7-4: Correlation/Application

Problem	Possible Cause	Corrective Action
Viscometer ranging is too high. Reading is consistently less than 10% of scale.	1. Viscometer is empty, partially empty, or contains trapped air.	1. Refer to **Section 2** and make sure viscometer is installed properly.
	2. No turnover of fluid in measurement zone or viscometer.	2. Refer to **Section 2** and make sure viscometer is installed properly.
	3. Improper calibration.	2. Refer to **Figure 3-1** in Section 3.
	4. Wrong operating range selected or viscometer is not calibrated for dual range operation.	3. Refer to **Appendix A** and call customer support for assistance.
	5. Fouling of torsion element and inner cylinder by solids.	4. Refer to **Section 5** and clean the viscometer.
Viscometer ranging is too low. Reading is consistently greater than 90% of scale.	1. Possible torsion element damage.	1. Refer to **Sensing End Cap Service** in Section 6.
	2. Improper calibration.	2. Refer to **Figure 3-1** in Section 3.
	3. Wrong operating range selected or viscometer is not calibrated for dual range operation.	3. Refer to **Appendix A** and call customer support for assistance.

Table 7-4: Correlation/Application (Continued)

Problem	Possible Cause	Corrective Action
Viscometer reading continuously over 100% of scale.	1. Damaged torsion element.	1. Refer to **Sensing End Cap Service** in Section 6.
	2. Solids in measuring chamber.	2. Refer to **Disassembly and Cleaning** in Section 5.
	3. Incorrect wiring on Sensing end cap.	3. Refer to **Sensing End Cap Service** in Section 6.
Viscometer reading is different from bench top viscometer.	1. Rheology of process fluid may produce these results.	1. Refer to **Correlation with other Measure ments** in Section 1.
	2. Temperature difference between process fluid on-line and fluid at bench top.	2. Ensure that both readings are taken at the same temperature or refer to **Correlation with Other Measure ments** in Section 1.

Appendix A - Customer Support

Introduction

Use the following information to Contact Brookfield Engineering Laboratories, Inc. for technical assistance or service:

Brookfield Engineering Laboratories, Inc.
11 Commerce Boulevard
Middleboro, Massachusetts 02346 U.S.A.
TEL: 508-946-6200
800-628-8139 (USA only - excluding MA)
FAX: 508-946-6262

Please have the following information available when calling so that we may assist you:

- Product Part Number
- Product Serial Number
- Product Application
- Specific Problem Area
- Hours of Operation
- Equipment Type

Appendix B - Drawings

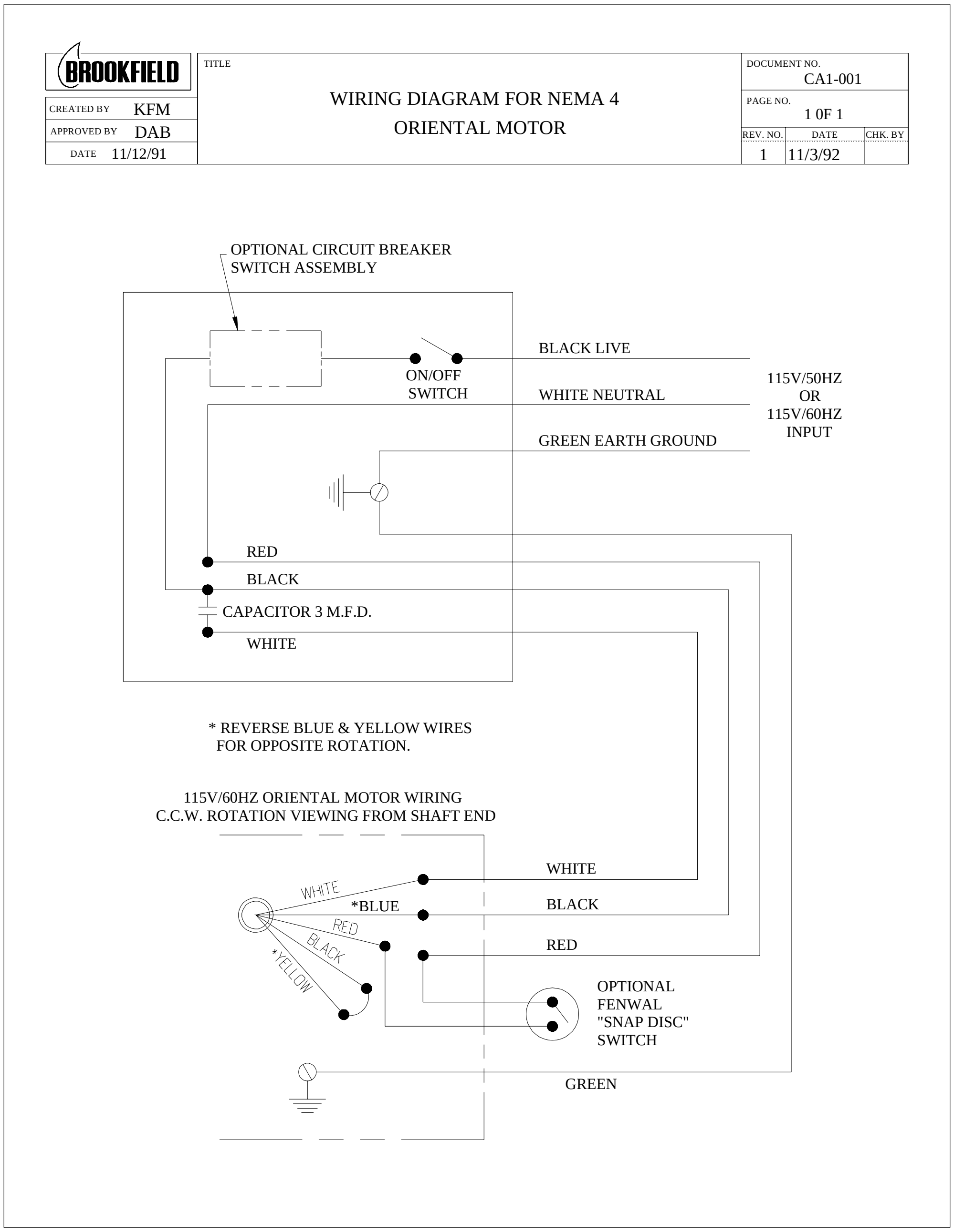
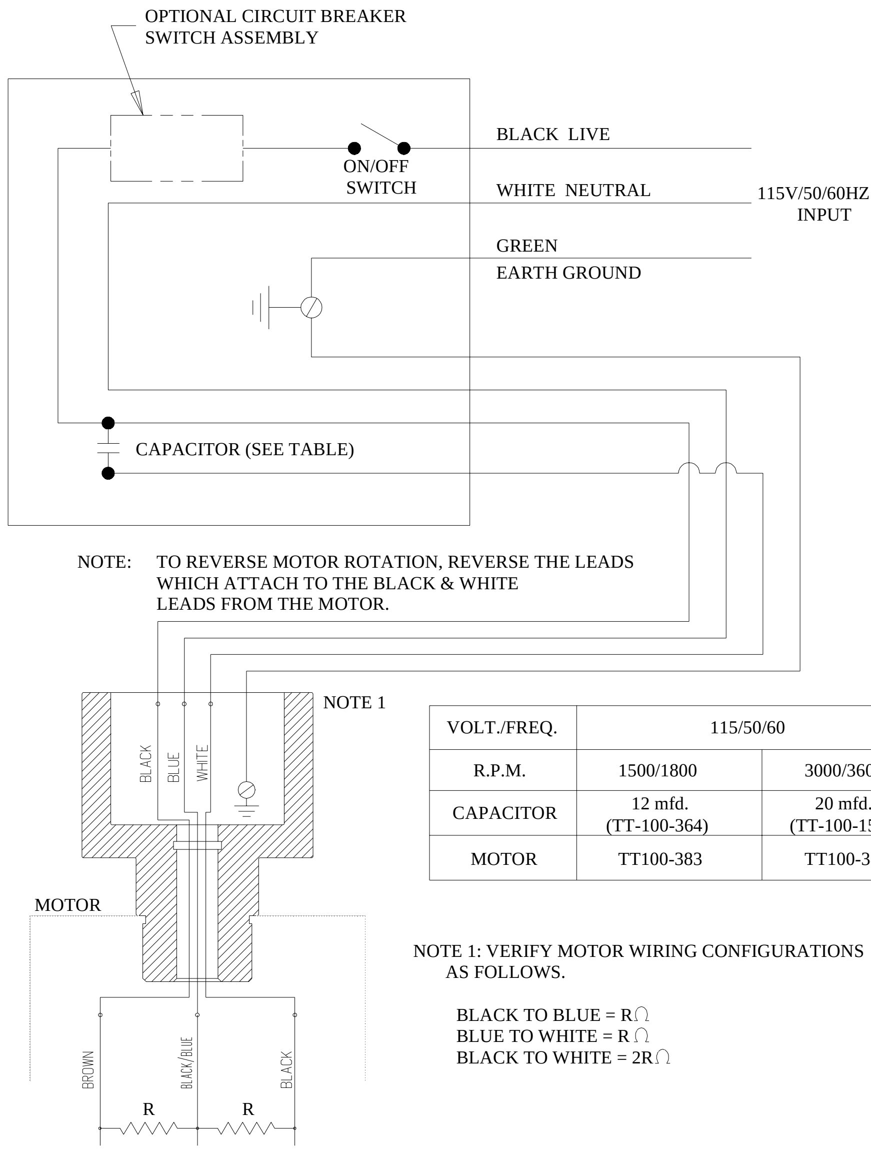


Figure B-1:NEMA 4 Oriental Motor Wiring Diagram

CREATED BY KFM	TITLE MODEL TT100 & TT200 WIRING DIAGRAM FOR 115 VAC GROSCHOPP MOTOR FACTORY MUTUAL APPROVED (EXPLOSION PROOF)	DOCUMENT NO. CA1-035
APPROVED BY DJO		PAGE NO. 1 OF 1
DATE 8/30/94		REV. NO. 3 / DATE 4/30/99 / CHK. BY



VOLT./FREQ.	115/50/60	
R.P.M.	1500/1800	3000/3600
CAPACITOR	12 mfd. (TT-100-364)	20 mfd. (TT-100-152)
MOTOR	TT100-383	TT100-384

NOTE 1: VERIFY MOTOR WIRING CONFIGURATIONS AS FOLLOWS.

BLACK TO BLUE = RΩ
BLUE TO WHITE = RΩ
BLACK TO WHITE = 2RΩ

Figure B-2:Groschopp Motor Wiring Diagram (Factory Mutual Housing)

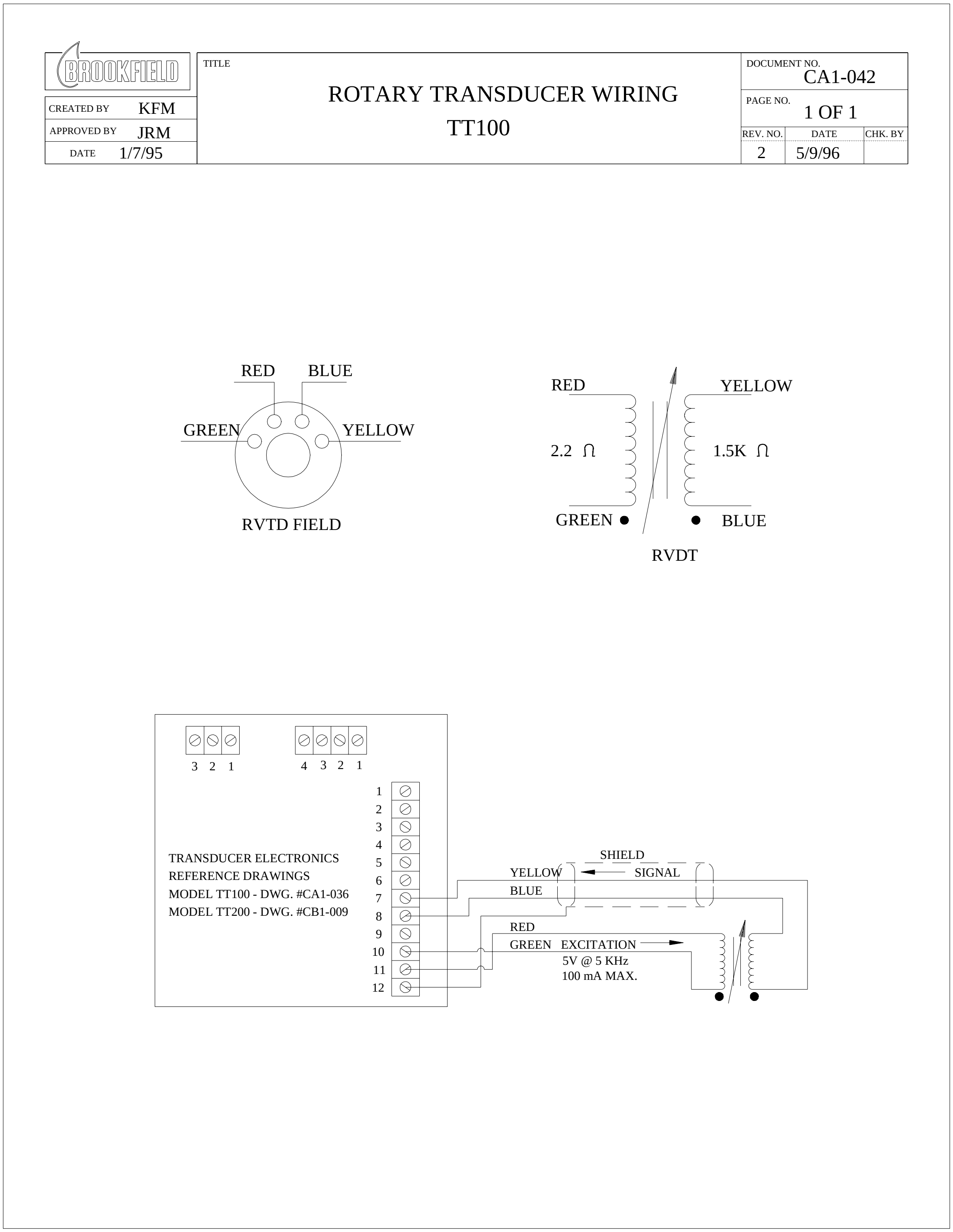


Figure B-3:Torque Sensor Wiring Diagram

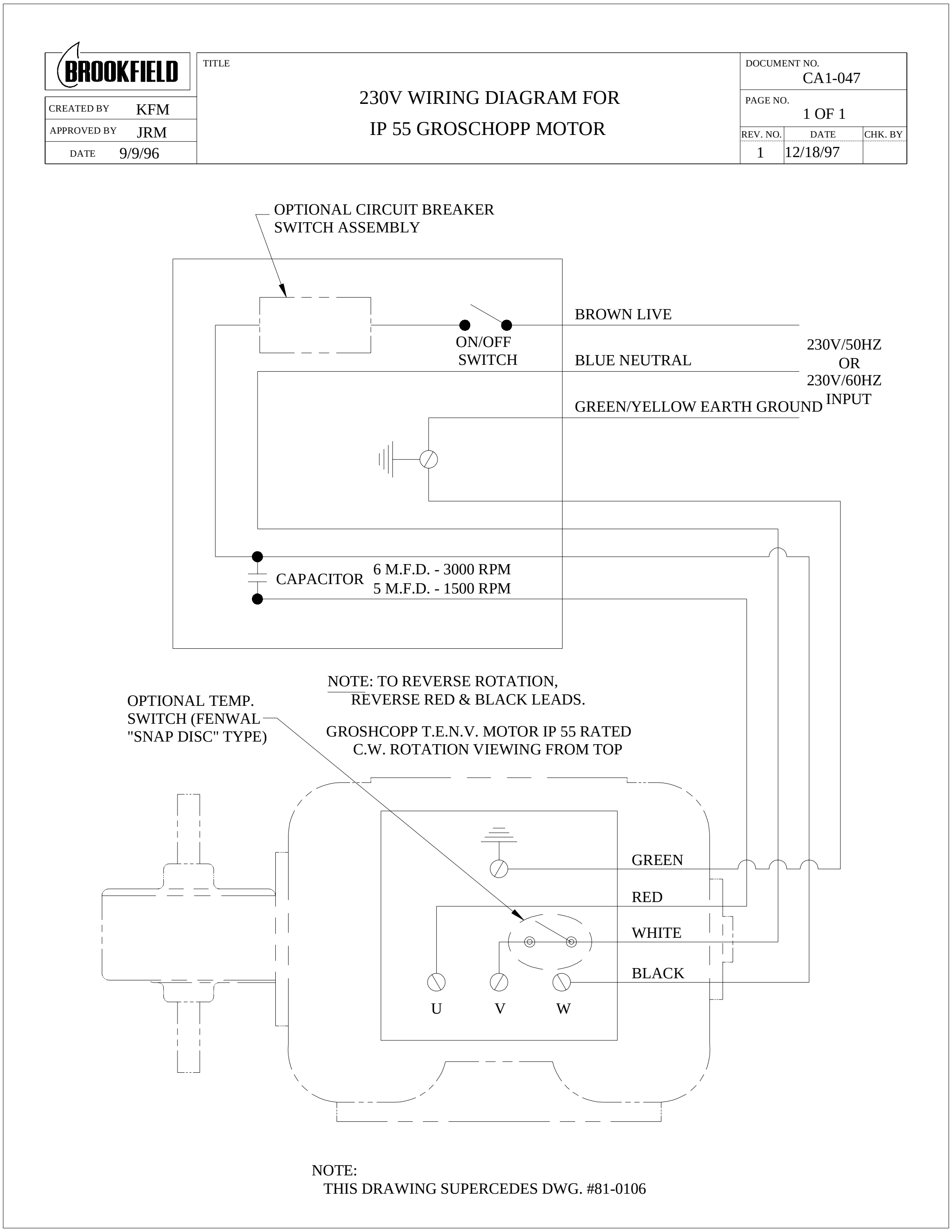


Figure B-4:230 VAC Wiring Diagram for IP 55 Groschopp Motor

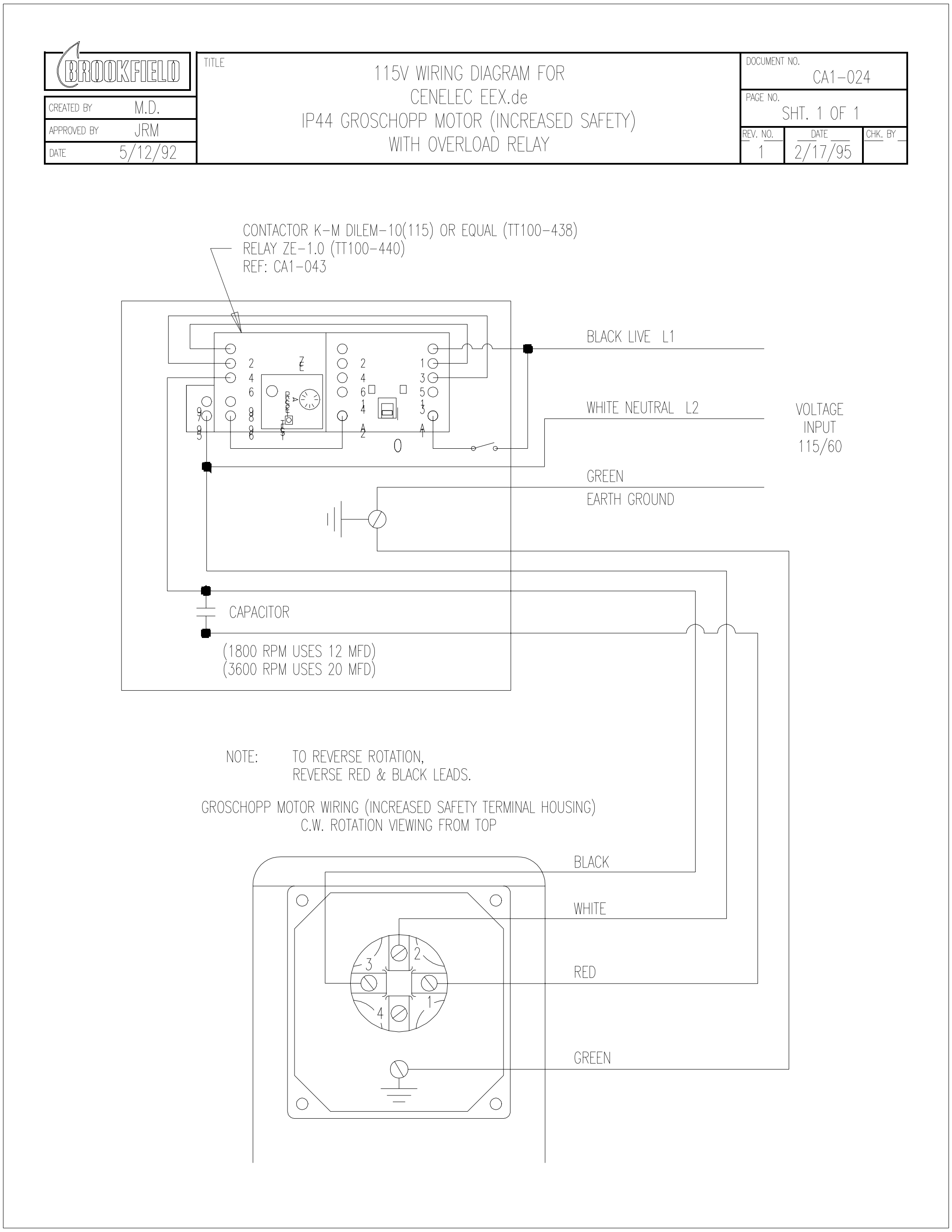


Figure B-5:CENELEC 115 VAC Groschopp Motor Wiring Diagram

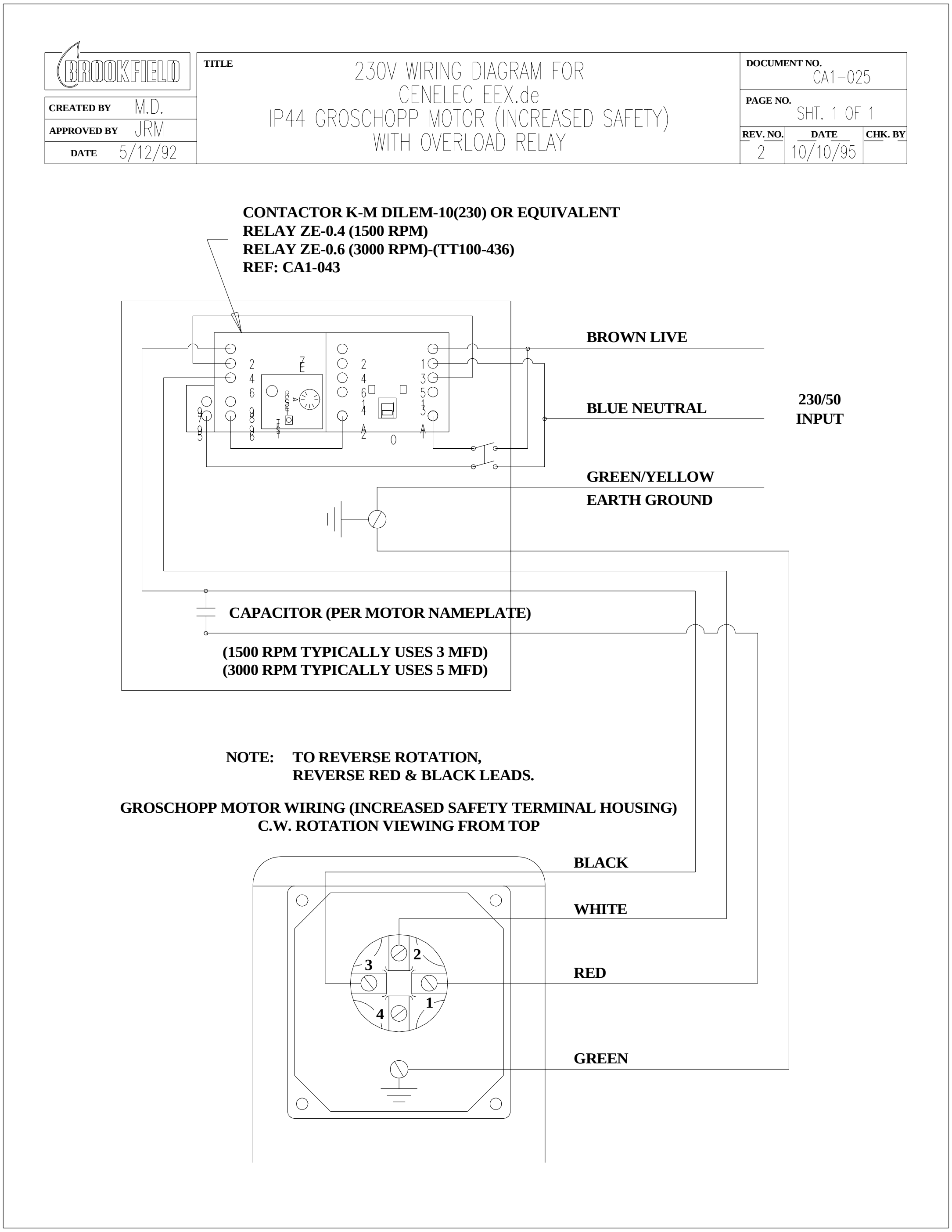
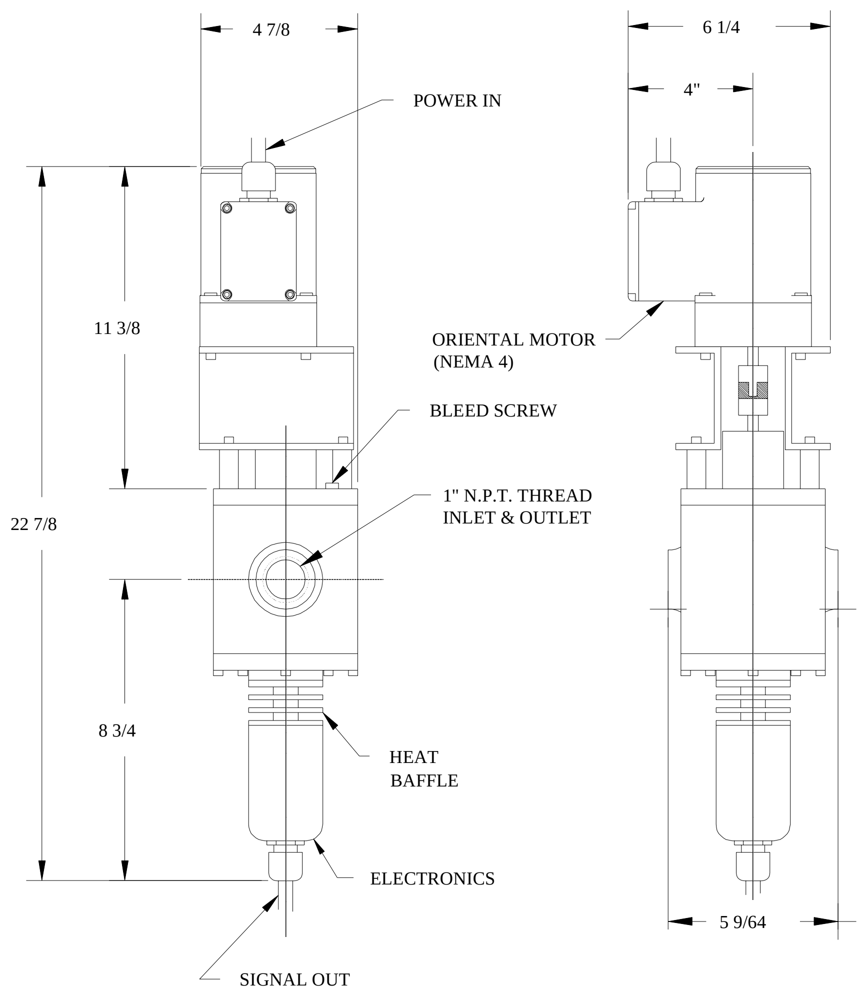


Figure B-6:CENELEC 230 VAC Groschopp Motor Wiring Diagram

BROOKFIELD	TITLE TT100 INLINE VISCOMETER WITH 1" N.P.T. FEMALE INLET/OUTLET AND ORIENTAL MOTOR (NEMA 4)	DOCUMENT NO. CA3-067
CREATED BY KFM		PAGE NO. 1 0F 1
APPROVED BY		REV. NO. / DATE / CHK. BY
DATE 8/19/94		

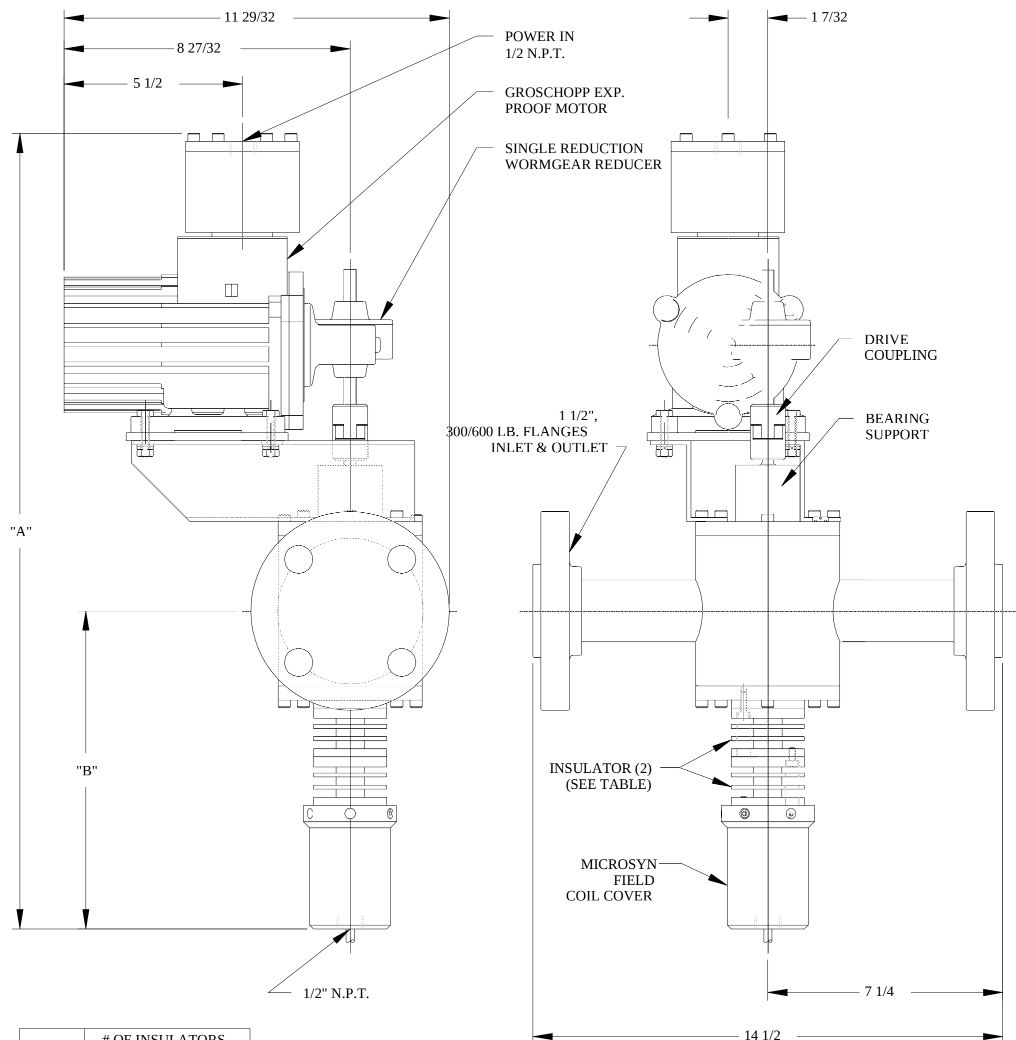


NOTE:

INSTRUMENT RATINGS FOR PRESSURE, TEMPERATURE & VISCOSITY
REFER TO INSTRUMENT SPECIFICATION SHEET CA5-007

Figure B-7:TT100 In-Line Viscometer (NEMA 4 with Oriental Motor)

BROOKFIELD	TITLE TT100 EXPLOSION-PROOF VISCOMETER (NEMA 7) WITH 1 1/2" INLET/OUTLET, 300/600 LB. FLANGES AND GROSCHOPP EXPLOSION-PROOF MOTOR	DOCUMENT NO. CA3-074
CREATED BY KFM		PAGE NO. 1 OF 1
APPROVED BY HWC		REV. NO. 1 / DATE 2/24/99 / CHK. BY
DATE 1/2/96		



DIM.	# OF INSULATORS 1	2
"A"	23 1/16	24 9/16
"B"	8 5/16	9 13/16

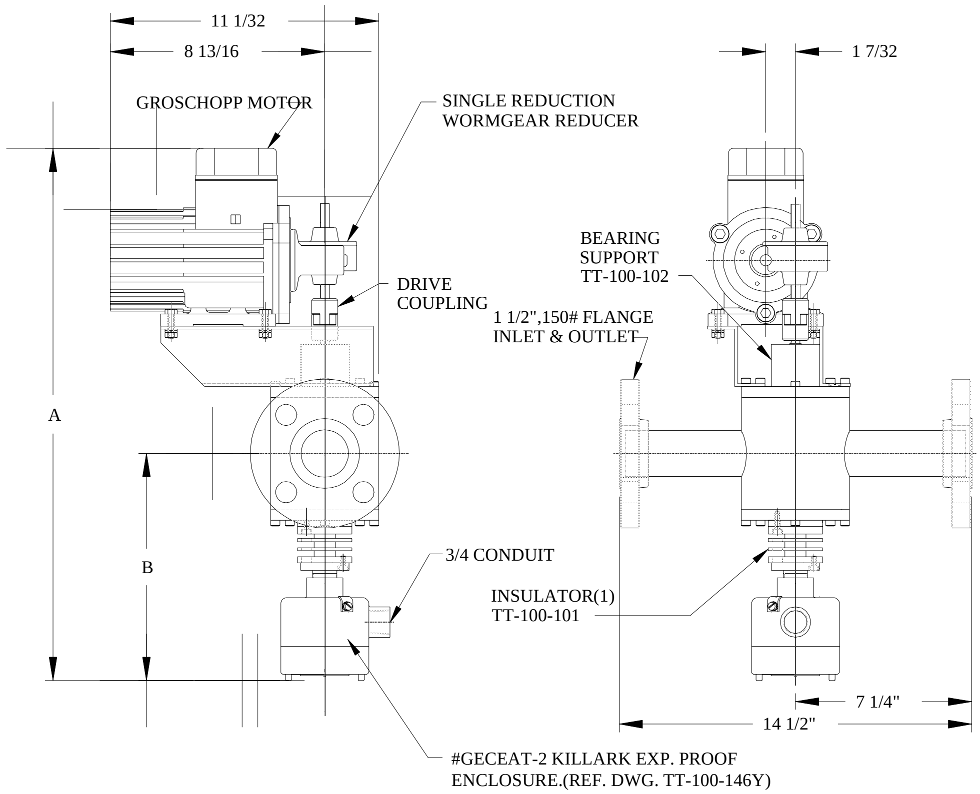
NOTE:

INSTRUMENT RATINGS FOR PRESSURE, TEMPERATURE & VISCOSITY REFER TO INSTRUMENT SPECIFICATION SHEET CA5-007.

Figure B-8:TT100 Viscometer for Hazardous Areas (NEMA 7)

BROOKFIELD

BROOKFIELD	TITLE: TT100 VISCOMETER WITH 1 1/2" 150 LB.INLET/OUTLET FLANGES, FOR HAZARDOUS AREA APPLICATIONS GROSCHOPP MOTOR	DOCUMENT NO. CA3-081
CREATED BY KFM		PAGE NO. 1 OF 1
APPROVED BY JRM		REV. NO 1 / DATE 3/17/99 / CHK. BY
DATE 10/6/97		



DIMENSION	ONE INSULATOR (AS SHOWN)		TWO INSULATORS	
	INCREASED SAFETY MOTOR (SHOWN)	EXPLOSION-PROOF MOTOR	INCREASED SAFETY MOTOR (SHOWN)	EXPLOSION-PROOF MOTOR
A	21 1/2	23 1/2	23"	25"
B	9"	9"	10 1/2	10 1/2

NOTES:

POWER LEADS TO CAPACITOR & SWITCH MOUNTED
IN SEPARATE ENCLOSURE IN NON-HAZARDOUS AREA.
(VOLTAGE & FREQUENCY PER SPEC. SHEET).

INSTRUMENT RATINGS FOR PRESSURE, TEMPERATURE & VISCOSITY:
REFER TO INSTRUMENT SPEC. SHEET.

Figure B-9:TT100 Viscometer for Hazardous Areas (CENELEC)

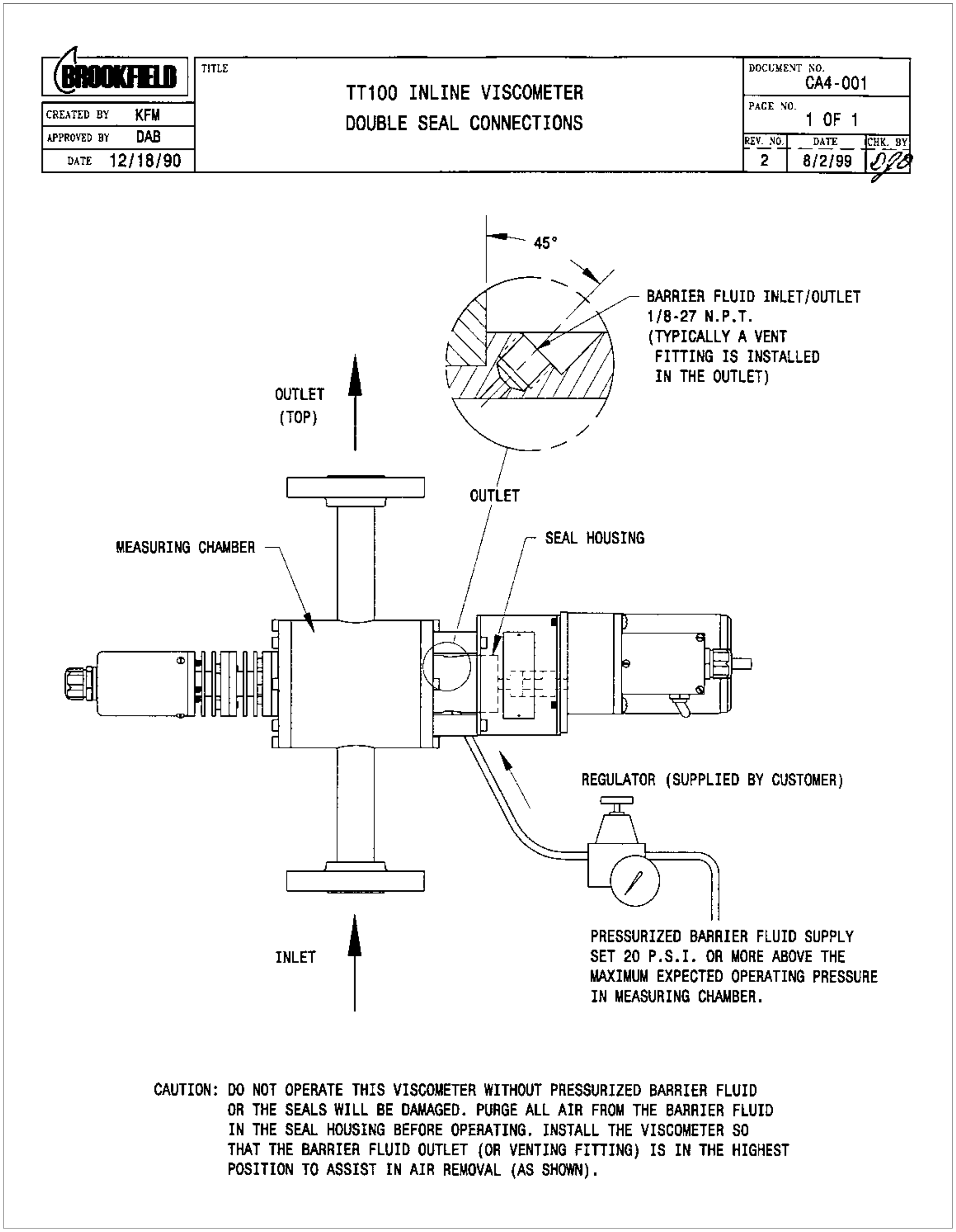


Figure B-10:TT100 In-Line Viscometer Double Mechanical Seal Connections

Appendix C - Viscosity Range Change

Introduction

The model TT100 viscometer operates under defined shear conditions. As a single speed instrument, the viscometer measures viscosity at one specific shear rate as determined by the speed of rotation and the internal measuring geometry.

Depending on the application, the model TT100 viscometer can be redesigned, with minimal effort, to change the measured viscosity range and/or the shear conditions. With the design of this viscometer, the viscosity range is inversely proportional to speed, and shear rate.

With the limited single-point viscosity measurement, on a bench-top (laboratory) viscometer, little is known about the viscosity of the process fluid while it flows under different conditions in the process stream. Therefore, we normally provide some built-in flexibility in the measured viscosity range and shear rate to allow changes to be made in instrument ranging after initial shipment.

Changing Range or Shear Rate

Reasons for changing the existing viscosity range:

- Better accuracy; accuracy is defined as ± 1% of full scale range. Accuracy improves with a finer viscosity range.
- Formulation change in the process.
- Over-ranging, requires broader viscosity range.

Reasons for changing the existing shear rate:

- Measure viscosity at a different part of the rheogram curve.
- Correlate/track with bench-top viscosity measurements in the laboratory.

In order to change both the shear rate and viscosity measurement range, the stationary cylinder (stator), and/or the gear box (speed of rotation) must be replaced.

Speed of Rotation Change

If only the speed of rotation is altered, the measured viscosity range changes to the proportion of:

$$\text{SPEED OF ROTATION CHANGE} = \frac{\text{OLD VISCOSITY RANGE X OLD SPEED}}{\text{NEW SPEED}}$$

$$\text{EXAMPLE:} \quad \frac{\text{1000 cP x 100 RPM}}{\text{200 RPM}} = \text{500 cP}$$

By doubling the speed of rotation, the shear rate will double and the measured viscosity range is decreased by a factor of two. If the old measured shear rate was 67 sec^{-1}, the new shear rate will be 134 sec^{-1}. Each stator has a shear rate constant, that when multiplied by the speed of rotation, yields the measured shear rate.

Rule of thumb; with all else equal, by increasing the speed of rotation (rpm), the measured viscosity range is more refined but at a larger shear rate. By decreasing the speed of rotation, the viscosity range broadens and shear rate decreases.

Stator Change

By only changing the stator, the shear rate and viscosity range will change by the ratio of factors for shear rate and geometry (ranging).

$$\text{NEW SHEAR RATE} = \frac{\text{OLD SHEAR RATE X NEW SHEAR RATE FACTOR}}{\text{OLD SHEAR RATE FACTOR}}$$

$$\text{NEW RANGE} = \frac{\text{OLD RANGE X NEW GEOMETRY FACTOR}}{\text{OLD GEOMETRY FACTOR}}$$

Rule of thumb; with all else equal, by changing to a stator which decreases gap size, the viscosity range is more refined, but the shear rate increases. By increasing the measurement zone gap, the viscosity range broadens, but the shear rate decreases.

Torsion Element Change

The third item which may be replaced, or have its response (calibration) altered is the torsion element or viscosity sensing device. There are four different torsion elements available, each capable of being calibrated over relatively wide limits, depending upon the sensitivity required. By only changing the torsion element, or its calibration, the viscosity range will change without changing the shear rate.

NOTE: *Torsion element replacement should be accomplished by the factory or an experienced maintenance technician.*

Electronic Change

The output signal can be altered by changing resistors on the torque sensor electronics board in order to change calibration/and change viscosity sensing ranges. Refer to **Appendix A** and contact Brookfield Engineering Laboratories for more information.

A selectable high/low range provision exists within the electronics board for greater accuracy. Factory calibration for both ranges is optional. If not selected at the time of purchase, dual range calibration may be added. Refer to **Appendix A** and contact Brookfield Engineering Laboratories for more information.

Summary

Viscosity range can be accomplished with any of four methods, in usual order of practicality; most to least:

a. Stator Replacement

b. Gearbox Replacement

c. Electronics Adjustment

d. Torsion Element Replacement

NOTE: *Refer to Tables C-1 and C-2 for shear rate factors and geometry factors for all rotor/stator combinations.*

Table C-1: Shear Rates and Factors for 2.440 ID Rotor

Stators/RPM	Shear Rate SEC^{-1}/RPM	Geometry Factor Uncoated	Geometry Factor Teflon Coated
TT100-4	2	1.101	1.02
TT100-4B	4	0.504	0.476
TT100-4C	1.161	2.804	1.91
TT100-4CZ	1.161	1.916	1.88
TT100-4D	0.67	4.13	3.817
TT100-4E	0.37	12.5	-
TT100-4F	-	29.41	-
TT100-4G	1.42	1.353	1.333
TT100-4H	0.34	13.513	-
TT100-4VS1	0.891	2.445	2.347
TT100-4VS2	1.67	1.205	1.147
Serrated	1.00	1.962	1.60

Table C-2: Shear Rates and Factors for 1.450 ID Rotor

Stators/RPM	Shear Rate SEC^{-1}/RPM	Geometry Factor Uncoated	Geometry Factor Teflon Coated
TT100-4N	1.703	4.55	4.55
TT100-4F	-	13.661	-

Appendix D - Agency Approvals

Introduction

The following agencies have given the TT100 In-Line Process Viscometer their approval for operation in the areas listed in Table D-1.

Table D-1: Agency Approvals - TT100 In-Line Process Viscometer

Viscometer	Approval	Approval Agency	Protection Concept
TT100-XP	Class 1, Division 1 and 2, Group C and D (NEMA 7)	Factory Mutual (FM)	Hazardous area use: explosion proof.
TT100-XP with stepper motor	Class 1, Division 1 and 2, Group D (NEMA 7)	Factory Mutual (FM)	Hazardous area use: explosion proof.
TT100-EX w/o motor	EEx d IIB T6 (CENELEC)	Electrical Equipment Certification Service (EECS)	Hazardous area use: flame proof.
With motor	EEx de IIC T4 (CENELEC)		Hazardous area use: flame proof and increased safety
TT100 all models	CE		Radiated Emissions

Appendix E - Warranty Information

Guarantee

We hereby guarantee this Brookfield Viscometer to be free from defects in workmanship and materials. If found to be defective in workmanship or materials upon being returned, within one year from the date of purchase to our factory, it will be repaired or replaced at the factory without charges. Transportation charges shall be at the owner's expense.

However, if upon being so returned and after inspection, we determine that the instrument has been subjected to tampering, careless handling, improper or faulty application or installation, the above guarantee shall not be applicable and we shall have the right in any such case to make a charge to cover the cost of repairs or servicing. Brookfield Engineering Laboratories, Inc. assumes and shall have no liability for consequential damages resulting from the use or misuse of the instrument.

The foregoing guarantee is in lieu of all other guarantees or warranties, expressed or implied, and of all other obligations or liabilities, contractual or otherwise, either to the original purchaser of said instrument or to any other person whomsoever.

Glossary

Control High and Low Limits

The measured values, expressed in engineering units, which cause control output to change.

Centipoise/milli-pascal-seconds

Units of absolute viscosity. The viscosity of water at room temperature is 1 centipoise or 1 milli-pascal-second.

Correlation

A relationship, usually shown as a graph, between one measurement and another. When correlating two viscosity measurements, it must be shown that a particular value from one measurement always corresponds to a particular value in the other. The conditions (method, temperature, amount of rotations, etc.) should remain constant to obtain this correlation.

Cup Seconds

The amount of time required for a given fluid to flow completely from an efflux cup through its chamber and accurately machined bottom orifice.

Dyne-centimeter/milli-Newton-meter

Units of torque that is measured as a force acting at a distance from a reference point, such as the axis of rotation of an object.

Engineering Units

Units of viscosity as displayed on the readout panel of a viscometer. These units may be in centipoise, or other units which relate to absolute viscosity, such as cup seconds.

Full Scale

The upper limit, in engineering units, of a viscometer. For Brookfield Process Viscometers, this value must be calculated from the torque capacity, rotational speed, and the spindle design of the instrument.

Laboratory Measurements

Viscosity measurements made off-line by a different instrument, usually for purposes of quality control. Due to the unique nature of viscosity measurement, the numerical value of this measurement may not agree with that measured by Brookfield Process Viscometers.

Laminar Flow

Flow which occurs when layers of fluid move uniformly with respect to one another, without mixing between elements.

Measuring Chamber

The container through which a fluid is caused to flow, in laminar flow conditions, and where its viscosity is measured.

Repeatability

The ability of an instrument to measure the same value whenever identical conditions of viscosity are presented to it. For Brookfield Process Viscometers, deviation is expressed as a percentage of full scale.

Shear Rate

The speed at which layers of fluid move with respect to one another. Also known as velocity gradient.

Shear Stress

The force per unit area required to move layers of fluid with respect to one another.

Spindle

The cylindrical object which is rotated in the fluid by the viscometer. Its motion in the fluid causes a resistance called viscous drag which is measured by the instrument as % torque. Its rotation causes fluid shearing to occur.

Turbulent Flow

Flow which occurs when fluid moves randomly with respect to other elements of fluid, with mixing between elements.

Viscous Drag

The resistance to rotation produced by an object such as a spindle when it is rotated in a fluid.

Viscosity

A measure of the internal resistance within a fluid to resist flow. Mathematically defined as shear stress divided by shear rate. Sometimes called absolute viscosity.

4-20 mA Signal

The continuous electrical output produced by a viscometer which is proportional to the % torque being measured and also proportional to the scale. For Brookfield Process Viscometers, 4 mA = 0 cP, 12 mA = half of full scale, and 20 mA = full scale, linear between 0cP and full scale.

% Torque

Brookfield Process Viscometers function as a rotating torque meter, whose response is linear with respect to viscosity. A % torque measurement displays the proportion of full scale which a measured fluid produces. This factor is applied to full scale in order to give a measurement in engineering units.

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