CANNON INSTRUMENT COMPANY®

Ravenfield® BS/C+ HTHS Viscometer

Reference Manual

80.5991

Ravenfield® BS/C+
Reference Manual

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P/N 80.5991

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Overview

The CANNON Ravenfield BS/C+ Viscometer is a compact, high precision, tapered plug viscometer designed to measure the high temperature, high shear viscosity of engine lubricants and other oils according to ASTM D4741, CEC L-36-A-90 and IP 370 as specified by SAE J300 and ACEA. The HTHS BS/C+ Tapered Plug Viscometer also complies to ASTM D4683 with no bias and is capable of testing across a wide range of temperatures and shear rates.

Description

The Ravenfield High Shear Viscometer was specifically designed to perform measurements on the viscosity of oils at shear rates of the order of $10^6\ s^{-1}$ at of 150° C temperature, although these are not limiting conditions.

At the same time, the design was seen as the basis of a new range of viscometers and the possible requirements of many different measuring systems were considered. The major requirements of any instrument for viscosity measurement are **rigidity of construction** and **precision of alignment** of the measuring system. Also required are a convenient method of torque measurement, having constancy and accuracy, and reliable electronics. Further, since media usually exhibit a high temperature coefficient of viscosity, also necessary is a means of controlling and measuring temperature and preferably of raising the temperature of a new sample rapidly.

History, Hardware & Method

The idea of measuring viscosity under high shear conditions first occurred to Albert Kingsbury in the late 19th Century during his pioneering work in the thrust bearing carrying his name. Kingsbury created the tapered plug geometry. In the later part of the 20th Century, Roy Banks and others at BP Research in Sunbury, UK took the earlier Kingsbury work and applied it to the Ferranti-Shirley rheometer in conjunction with a Cannon CCS® rotor and stator. They achieved shear rates of the order of 150-250 k s^{-1}. Jim Taylor of Ravenfield was invited to submit a new instrument design for BP to evaluate that extended the shear rate to at least $10^6\ s^{-1}$ thus leading him to quit his job and run Ravenfield full time. After successful testing, and with a lot of work, method CEC L 36 was born.

Kingsbury's innovation was to allow him to make mechanically difficult measurements of lubricants at relatively high shear rates without having to create a very tightly controlled gap.

The tapered plug, pictured in **Error! Reference source not found.**, is a simple modification of the classic Searle geometry where the inner part spins inside the outer, as opposed to the Couette where the outer spins around the inner.

In the modification, a taper is imposed on the cylindrical surfaces, as shown in Figure 1. By adjusting the height between the components it is possible to precisely fine-tune the gap between the parts since the gap varies as the TAN of the angle of the $Gap \propto HxTan\,\theta$.

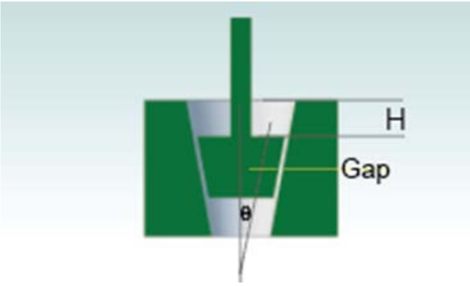


Figure 1: Tapered Plug

An often overlooked problem with concentric cylinder geometries is the variation of shear rate across the gap since shear rate is measured at an infinitesimal cylindrical lamina. The shear rate at the outer wall is higher than the shear rate at the inner wall. The effect is minimized if the ratio of gap-to-radius of the cup is maximized.

Given that the nominal working gap in the Ravenfield HTHS is 2.8µ, and the radius approximately 10,000µ, there is an approximate variation in shear rate across the gap of 1/3000.

Rigidity and Precision

The main base frame and pillar of the instrument are machined from billet aluminum. The moving head of the machine is mounted on a long, pre-loaded base ball slide. This chamber is supported on special plate springs attached to a yoke fastened to the ball slide.

In order to separate the rotor and stator, the yoke carrying the motor and measuring system is raised by a lifting screw operated by a handle on the side of the base.

The yoke is lowered until a hardened steel plate rests on a finely threaded screw with a ball end acting as a kinematic stop. This arrangement gives a fine adjustment to the vertical position of the rotor within the stator, and allows the yoke to be raised and lowered very precisely to the same position. Repeatability is better than ± 2 micron.

The vertical position of the yoke is precisely measured by a digital gauge. The measurement system is designed to account for thermal expansion and is compensated to a degree by opposing vertical expansion of the measurement chamber and its mounting base. A rigid, non-plastic thermal insulator is used between chamber and base. A diagram of the interior of the instrument is outlined in Figure 2.

Temperature Control and Measurement

The measurement system is jacketed by an annular chamber which circulates fluid from an external bath, allowing the temperature of the sample to be closely regulated and rapidly stabilized to the desired temperature. Maximum productivity is reached at 80 tests per day on 40 samples.

Torque Measurement

Torque is measured with plate springs. The resulting movement is measured by a non-contacting inductive transducer. The torque measurement components are mounted as far as possible from the heated components of the apparatus.

The movement measurement is converted electronically into a digital measurement of torque in gram centimeters and selected to give whole numbers.

Torque Drive

The driving motor is a d.c. servomotor that drives through a torque-limiting clutch. This minimizes the damage caused to both rotor and stator should a foreign body enter the system and cause a seizure. The main shaft is designed with a connector driving the rotor through a flexible coupling, ensuring that no side thrust is transmitted to the rotor.

Rotor and Stator

The form and dimensions of the rotor and stator unit follow closely with the design outlined in the paper by Pike, Banks and Kulik “A simple High Shear Viscometer – Aspects of Correlation with Engine Performance” S.A.E. 780981, with the principle of a truncated cone rotating in a tapered bore. The rotor is centered within the stator using flats that permit the formation of a hydro-dynamic wedge of oil and is driven through a universal coupling that aid in allowing the natural forces to work properly and center the rotor.

Ancillary Apparatus

The normal use of the instrument requires ancillary apparatus for waste samples, solvent aspiration and temperature control. This includes temperature controlled bath, waste oil receiver and vacuum pump as shown in Figure 3 in the section “Setup the Ravenfield BS/C+ Viscometer”. A temperature measurement facility is built in to the instrument.

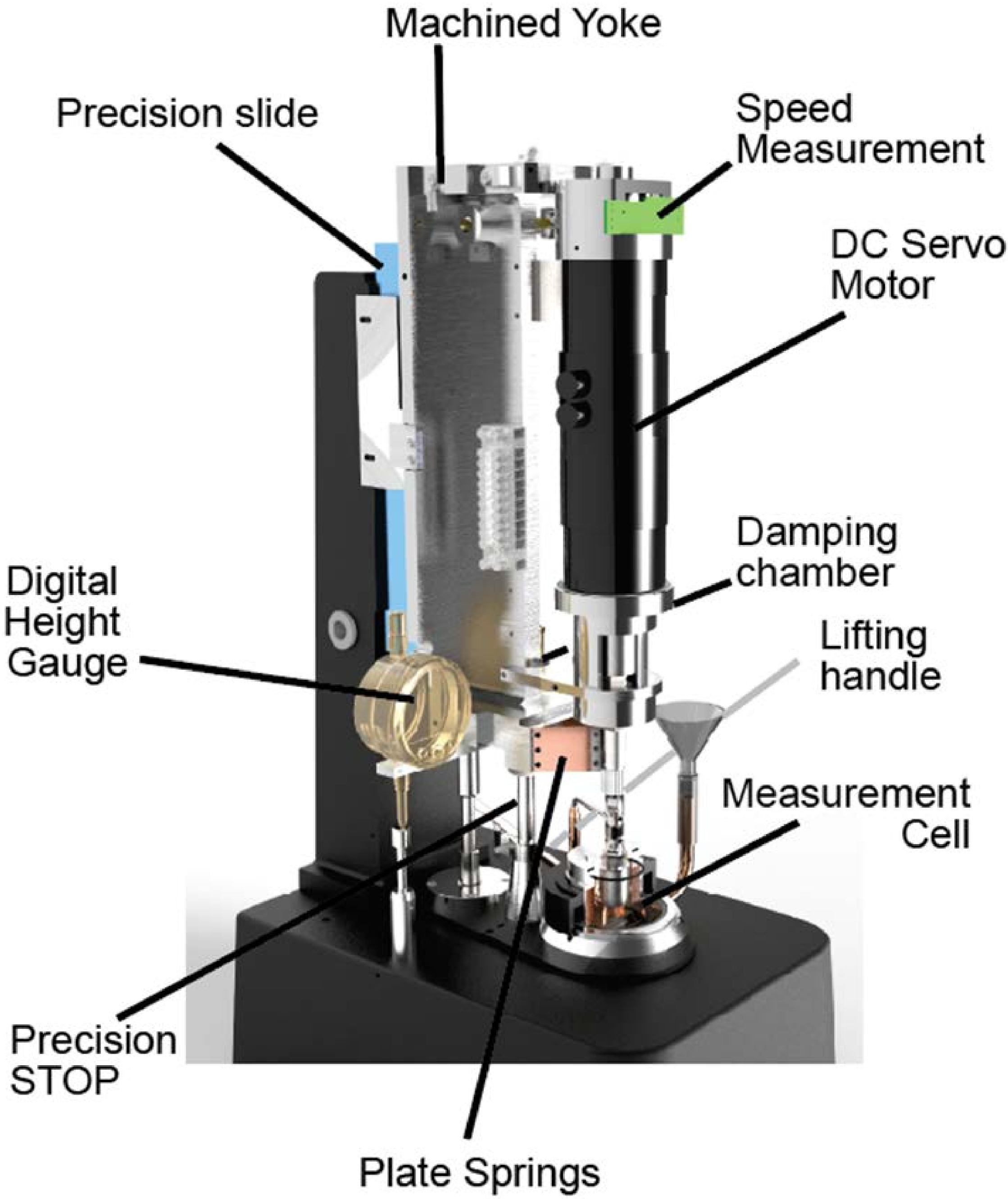


Figure 2: Interior Overview of Instrument Construction

Related Documents

Table 1: Related Documents

Title	Reference Number
Standard Test Method for Measuring Viscosity at High Temperature and High Shear Rate by Tapered-Plug Viscometer	ASTM D4741
Procedure for Gasoline Engine Cleanliness Test	CEC L-36-A-90
Standard Test Method for Measuring Viscosity at High Temperature and High Shear Rate by Tapered-Plug Viscometer	IP 370

Specifications / Compliances

Table 2: Specifications

Specifications	Details
Model	CANNON Ravenfield BS/C+ Viscometer
Methodology	ASTM D4741, CEC L-36-A-90, IP370
Applications	High temperature, high shear viscosity of engine lubricants and other oils
Dimensions (W × D × H) With autosampler	62.2 cm × 38.1 cm × 64.8 cm (24.5 in × 15 in × 25.5 in) 83.3 cm x 41.9 cm x 64.8 cm (32.8 in x 16.5 in x 25.5 in)
Weight With autosampler	30 kg (66 lb) 50 kg (110 lb)
Operational temperature range	40 °C to +180 °C (± 0.02 °C) Accuracy at 150 °C, ± 0.02 °C for viscosity range 1.5 mPa·s (cP) to 5.9 mPa·s (cP) at $10^6 s^{-1}$ shear rate Accuracy at 100 °C, ± 0.02 °C for viscosity range 4.2 mPa·s (cP) to 18.9 mPa·s (cP) at $10^6 s^{-1}$ shear rate
Maximum throughput	>12 tests per hour
Automated sample capacity	1 positions (without autosampler) 22 (with optional model DR autosampler)
Minimum sample	10 mL sample
Viscosity range	Up to 30 mPa-s (cP)* *depending on shear rate and temperature
Power requirements	100 VAC, 50/60 Hz, 1200 W; 115 VAC, 50/60 Hz, 1200 W or 230 VAC, 50/60 Hz, 1200 W
Operating conditions	10% to 75% relative humidity (non-condensing), Installation Category II, Pollution Degree 2
Compliance	CE Mark: EMC Directive (89/336/EEC); Low Voltage Directive (73/23/EC); HI-POT (1900 VDC, 60 sec)

Notes/Cautions/Warnings

Please keep this manual near your system to easily access necessary information while operating or preparing for operation.

Notes, caution, and warnings are used in the manual to call an operator's attention to important details prior to performing a procedure or step. Read and follow these important instructions. Failure to observe these instructions may void warranties, compromise operator safety, and/or result in damage to the instrument.

Notes provide more information about the content that follows.

Cautions alert the operator to conditions that may damage equipment.

Warnings alert the operator to conditions that may cause injury.

Safety precautions

Please observe the following general safety precautions for proper and safe operation of the CANNON Ravenfield BS/C+ high temperature, high shear rate viscometer.

- Only qualified personnel should operate the Ravenfield BS/C+.
- Make sure that you read and understand all operating instructions and safety precautions listed in this manual before installing or operating your unit. If you have questions regarding instrument operation or documentation, contact CANNON Instrument Company®.
- Do not deviate from the installation, operation, or maintenance procedures described in this manual. Improper use of the Ravenfield BS/C+ may result in a hazardous situation and can void the manufacturer's warranty.
- Handle and transport the unit with care. Sudden jolts or impacts may cause damage to components.
- Observe all warning labels. Never remove warning labels.

- Never operate damaged or leaking equipment.
- Unless procedures specify otherwise, always turn off the unit and disconnect the MAINS cable from the power source before performing service or maintenance procedures, or before moving the unit.
- Refer all service and repairs to qualified personnel.

~MAINS	The AC power input must match the electrical specifications of the instrument. Never operate the equipment with a damaged MAINS AC power cable. Use only the manufacturer-supplied MAINS AC power cable. This cable must be inserted into a properly grounded, protective receptacle.

Note regarding safety circuit:

Note: If the head of the instrument is raised, specifically to the height which is necessary to change a rotor, the safety circuit will be tripped.

If the display does not respond to key entries, the safety circuit may have been tripped.

To re-set the safety circuit for normal operation: **The head must be lowered until the safety switch is operated,** turn the motor switch to the cut-off position and then turn it back on again.

Getting Started

Note: White Spirit, also known as Stoddard solvent ASTM D-235 solvent type 1, is a suitable solvent for all purposes of this instrument. Mineral spirits or heptane are also acceptable. Solvent should only be used when the instrument is **below** the flash point of the solvent.

This section covers all steps necessary to set up, calibrate, and run a sample on the Ravenfield BS/C+ HTHS Viscometer. Procedures are intended to be performed in the order written. These are basic, simplified procedures that will familiarize an operator with the instrument. More detailed instructions are provided in other sections.

Unpack and inspect

Unpack and inspect the complete Ravenfield BS/C+ and all accessories as soon as they are received.

Caution: Many components are fragile. Use caution when moving and handling the Ravenfield viscometer and accessories.

1. Carefully unpack the entire contents of the shipment.
2. Refer to the packing list(s) and verify that all materials are received.
3. Inspect materials for defects and shipping damage. Contact your CANNON representative to resolve any issues.

Table 3: Packing List (main components)

Description	Part Number
Ravenfield BS/C+ HTHS	9728-C51
Model DR Autosampler (optional)	9728-C55
Ultrasonic Bath (replacement)	80.5020
Rotor/Stator Replacement	80.5002
20 cSt bath oil (3.8 L/1 gal)	9726-L38

Description	Part Number
Plastic Vials (3 oz. for use with Autosampler/optional)	80.5633
Tool Kit	80.5675
Julabo Heated Circulator	80.5015
Circulator Pipes	80.5019
Digital Depth Gauge	80.5468

Table 4: Contents of Tool Kit

Description	Part Number
Allen wrench – 2.5 mm	80.5465
Allen wrench – 5/32”	80.5685
Wrench – 8 mm	80.5008
Wrench – 10 mm	80.5009
Glass funnel	81.3112
Rotor & Stator	80.5003
Calibration Certificate	N/A
Damping Fluid	80.5006
Constant Level Vacuum Pipe	80.5023
150g Calibration Weight & Cord	80.5299
Clamp Ring	80.5186 or 80.5199 or 80.5348
Platinum Resistance Thermometer (PRT/RTD)	80.5031
Polishing Handle	80.5018
Universal Coupling	80.5010
(4) Viton O-Rings	80.5062
Calibration Oil RL 102	9727-R10.032
Calibration Oil RL 103	9727-R15.032

Description	Part Number
Calibration Oil RL 104	9727-R20.032
Calibration Oil RL 105	9727-R25.032
Calibration Oil RL 106	9727-R30.032
Calibration Oil RL 107	9727-R35.032
Non-Newtonian Reference Oil RL 232	0003-RL232

Setup the Ravenfield BS/C+ Viscometer

The Ravenfield BS/C+ Viscometer should be placed on a firm, level surface either on top of its electronic unit or separately as necessary. Connect the Head Unit to the Electronic Unit. The cables will only fit in the correct orientation. Refer to Figure 3 for a visual representation of the setup of the instrument and ancillary units.

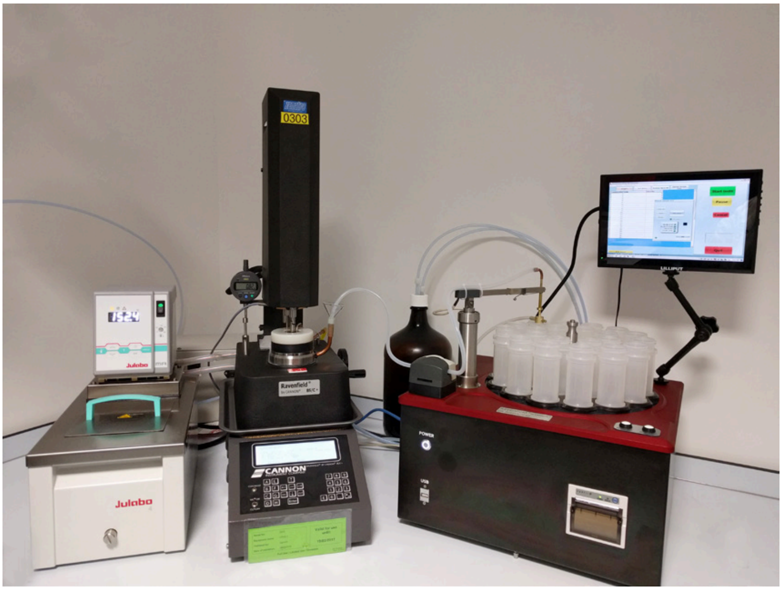


Figure 3: Complete Ravenfield BS/C+ System Assembled with Optional Autosampler

Location of Units

The ancillaries (temperature controlled bath, waste oil receiver and vacuum pump) must be placed in convenient operating positions when installing the instrument.

The measurement head may be placed on the top of the electronic unit (with the pad between) when using the circulating bath supplied by CANNON.

The waste oil receiver must be placed below the instrument so that the oil in the pipe will drain via gravity into the container.

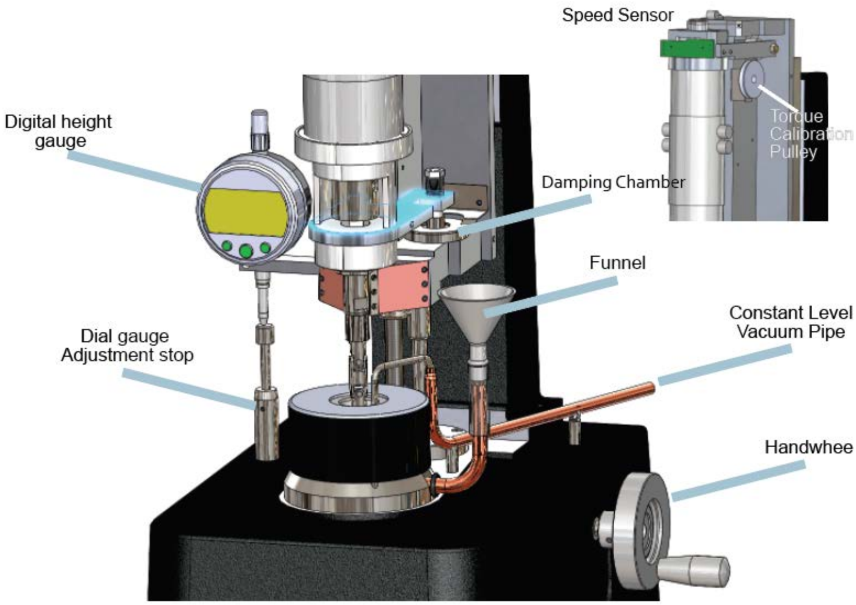


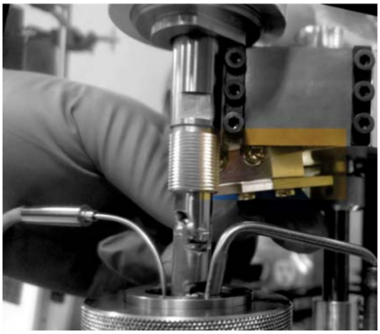
Figure 4: Diagram of Interior of Unit

Inspection and Transit Clamps

The instrument must be inspected upon receipt to ensure that damage has not been caused to the suspension during shipping. Remove the head cover for inspection by removing the four screws securing it. Both springs **must** be flat. This is critical for correct operation.

Removing the Transit Clamp:

Remove the small plastic pad that is fitted on the ball stop. Remove the two rods at the top spring support and remove the block from behind the lower plate springs. Refer to Figure 5 for an image of the lower shipping jig. The two visible balls are pushed gently behind the two spring plates. Pictured in Figure 6 is the upper shipping jig (one of two upper jigs). The rods are pushed into the space between the channel in the top of the instrument yoke and the upper motor end cap.



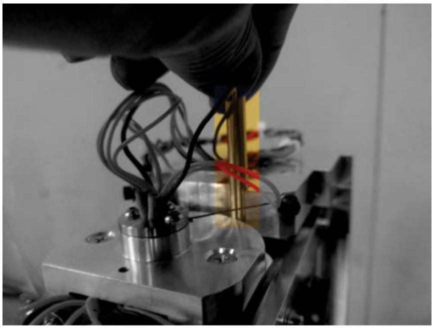


Figure 5: Lower Shipping Jig **Figure 6: Upper Shipping Jig**

Upper Spring:

Two straight wire springs are fitted at the top. These are revealed by the removal of the transit clamps and **must** be straight. This is critical for correct operation.

Damping Chamber

Fill the damping chamber with the provided damping fluid by placing the tube of damping compound at the mouth of the damping chamber and squeeze until the compound runs into the interior of the chamber. Due to the viscosity of the compound it may take an hour or more before the bottom of the chamber is full. Feeding the fluid down one side only will avoid air locks. The damping chamber is found by removing the cover and may be identified by reference to Figure 5.

Vacuum Extract Pipe

Operating procedure requires the use of a constant level pipe to allow samples to be placed into the bottom of the cell via the side arm and removed by the vacuum pump. The pipe is supplied as a standard fitting and should be plugged into the holes in the top of the base casting. The pipe may be fitted in either the left or right side as convenient, and adjusted by bending to fit over the edge of the rotor with the tip of the pipe centered in the gap, approximately 4 mm above the gap. Refer to Figure 7 and Figure 8 for detailed diagrams.

Note: It is easier to fit the pipe after the rotor is in position but it may be placed prior to fitting rotor.

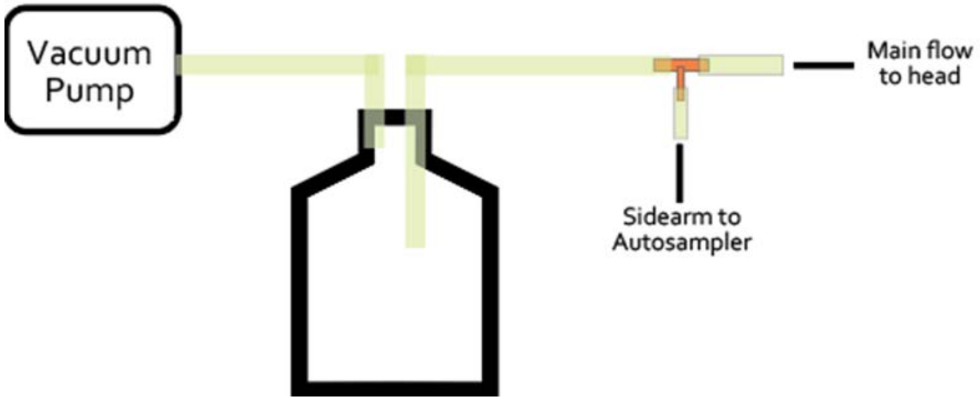


Figure 7: Connections at Vacuum Pump

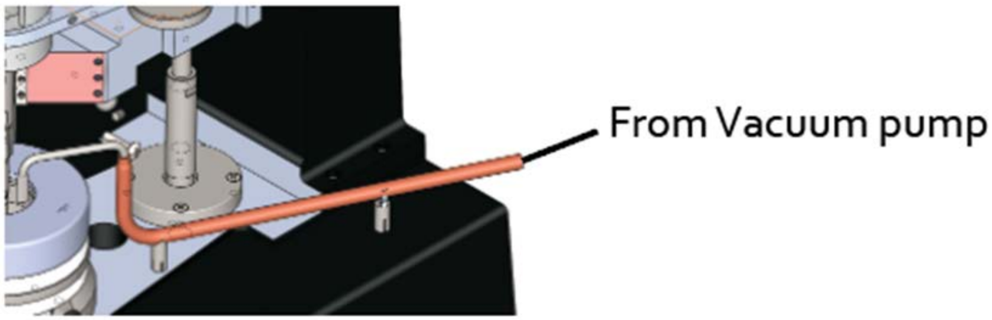


Figure 8: Vacuum Connections at Instrument

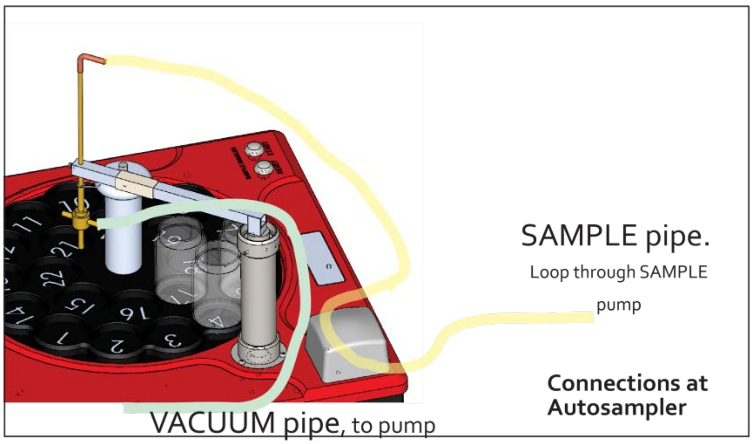


Figure 9: Autosampler Connections

Lead-in Wires

The motor lead-in wires, which pass through the upper bearing, **must not touch each other from the clamp to the bush**. A slight shift in zero will be observed if they are disturbed. This shift may continue for some time.

Serial Number

Please refer to the serial number and model in all communications and queries with CANNON. The serial number is labelled on the back of both the measurement head and the electronics unit. If the label becomes defaced or detached, a serial number label is also attached to the yoke, which becomes visible when the head cover is removed.

Instructions for Moving & Re-Assembling Instrument

While the Ravenfield BS/C+ is a robust instrument, proper care must be taken with all precision instruments and following the instructions provided will help to avoid any damage while moving or re-assembling the apparatus.

1. Remove the rotor and stator from the instrument.
2. Remove the rotor from its flexible coupling. Carefully wrap in tissue and set aside.
3. Disconnect the electrical supplies and all electrical connections.
4. Make sure head cover is securely fitted. Lower the head onto the ball stop. If moving the instrument far, place a packing piece (such as thick cardboard) between the head and ball stop.
5. Using a wrench that fits the pipe fittings and a pair of gripping pliers, remove the heating pipes at the joint nearest the side of the head.
6. Disconnect heating oil pipes from circulator.
7. Drain the pipes and empty circulator. Properly dispose of used oil.
8. Lift the Head Unit away from the top of the Electronics Unit. Avoid bumping or jarring the unit as it is placed on a bench or in a packing case.

Re-assemble the unit by reversing the above steps. Do not place any strain on the pipes entering the side of the base casting when the heating oil pipes are replaced.

Carefully clean the rotor and stator before they are re-fitted. Ideally, clean these components ultrasonically while leaving the rotor assembled to its shaft.

Setting Full Scale Deflection (Span)

Transducer Zero

The zero point of the transducer is adjusted before the instrument is dispatched and does not require re-adjustment unless the internal mechanism is disassembled.

Electrical Setting

The full scale reading may be set by applying a known torque and adjusting the digital reading to match the applied torque. The instrument is supplied calibrated, but calibration may be checked with a method described in the section "Preparing the Calibration Curve".

Adjustment Period

The stability of calibration should not be adjusted more often than every six months. An acceptable maintenance schedule is one adjustment each year (every 12 months).

Fit the Rotor and Stator

The rotor, stator and all parts coming into contact with oil should be thoroughly cleaned. Remove the clamping screw in the end of the Universal Coupling and clean all parts in solvent and an ultrasonic cleaner. A 250 mL beaker can accommodate the universal shaft, screw, sealing ring, clamp ring, rotor and stator with solvent and immersed in an ultrasonic bath. The following images, Figure 10 and Figure 11, detail the various components discussed in this section.

Figure 10: Clean Rotor and Stator Assembly

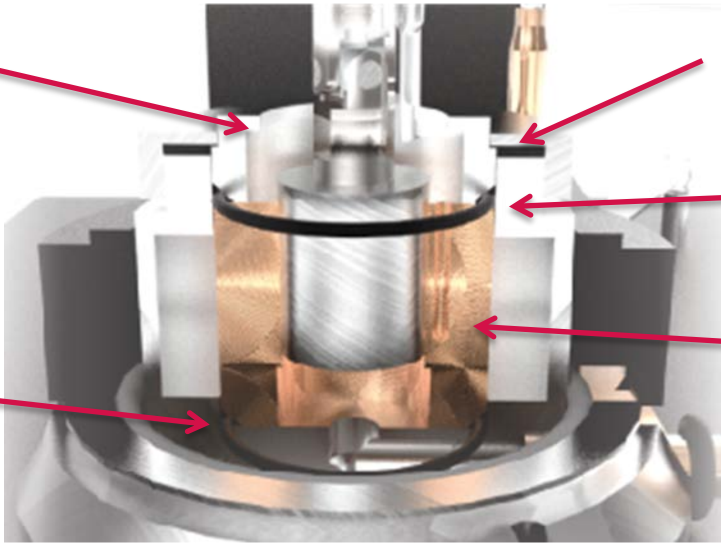


Figure 11: Rotor and Stator Assembly Fitted (section view)

Start Instrument

1. Remove the top plastic cover from the measurement cell.
2. Remove the clamp ring.
3. Place an O-ring at the bottom of the measuring system chamber, making sure that is sitting correctly in the corner of the housing.
4. Insert the cleaned stator into the measuring system with the thermometer pocket at the left hand side. Make sure the stator is sitting squarely in the center of the housing with the chamfered end at the bottom.
5. Place a second O-ring above the stator and position it in the corner.
6. Place the clamping ring on top of the O-ring with the chamfered end at the bottom and replace the crewed cover as tightly as possible using fingers only. Back off the clamping ring by approximately 3 mm to easily remove it after use.
7. Replace the top plastic cover.
8. Fit the cleaned rotor to the universal coupling, noting that the numbered end of the rotor is at the top end. Fit the stainless steel grub screw into the end of the universal coupling with a drop of lubricating oil and lock it tight. Clean the assembly to remove any particles of metal released by the use of tools. Fit this assembly to the motor shaft and use the keys to pinch it tight. At this stage, lower it no further.
9. Insert the platinum resistance thermometer into its pocket, ensuring the probe reaches the bottom of its chamber. Clamp the wire into the clamp provided on the side of the instrument pillar. Note: The pre-bent platinum resistance thermometer is very fragile. Do NOT bend it any further.
10. Set the bath to the desired operating temperature and switch it on. Allow the bath to run until a stable temperature is achieved. At the same time, turn on the Electronic Unit and leave it on to stabilize. Note that the temperature of the platinum resistance thermometer will be lower than the desired temperature because of heat loss in the connecting pipes. This is correct and will be adjusted later to allow for shear heating of the sample.
11. Once the apparatus has been heating for approximately 30 minutes, proceed to the next steps.

Note: The target temperature difference between bath and thermocouple is 4 °C to 5 °C. Greater than 10 °C difference will cause difficulties.

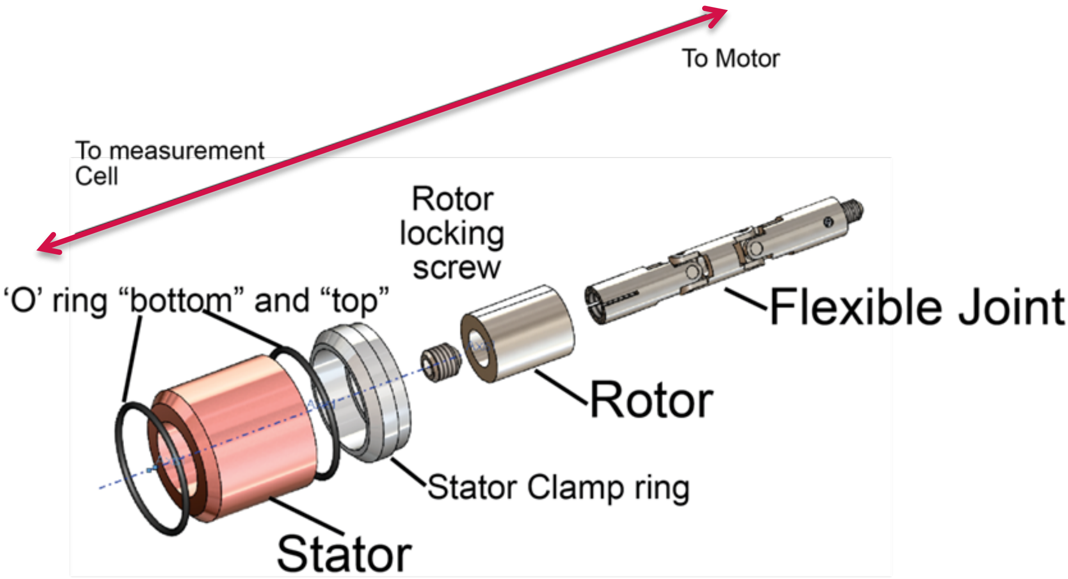


Figure 12: Complete Rotor and Stator Assembly

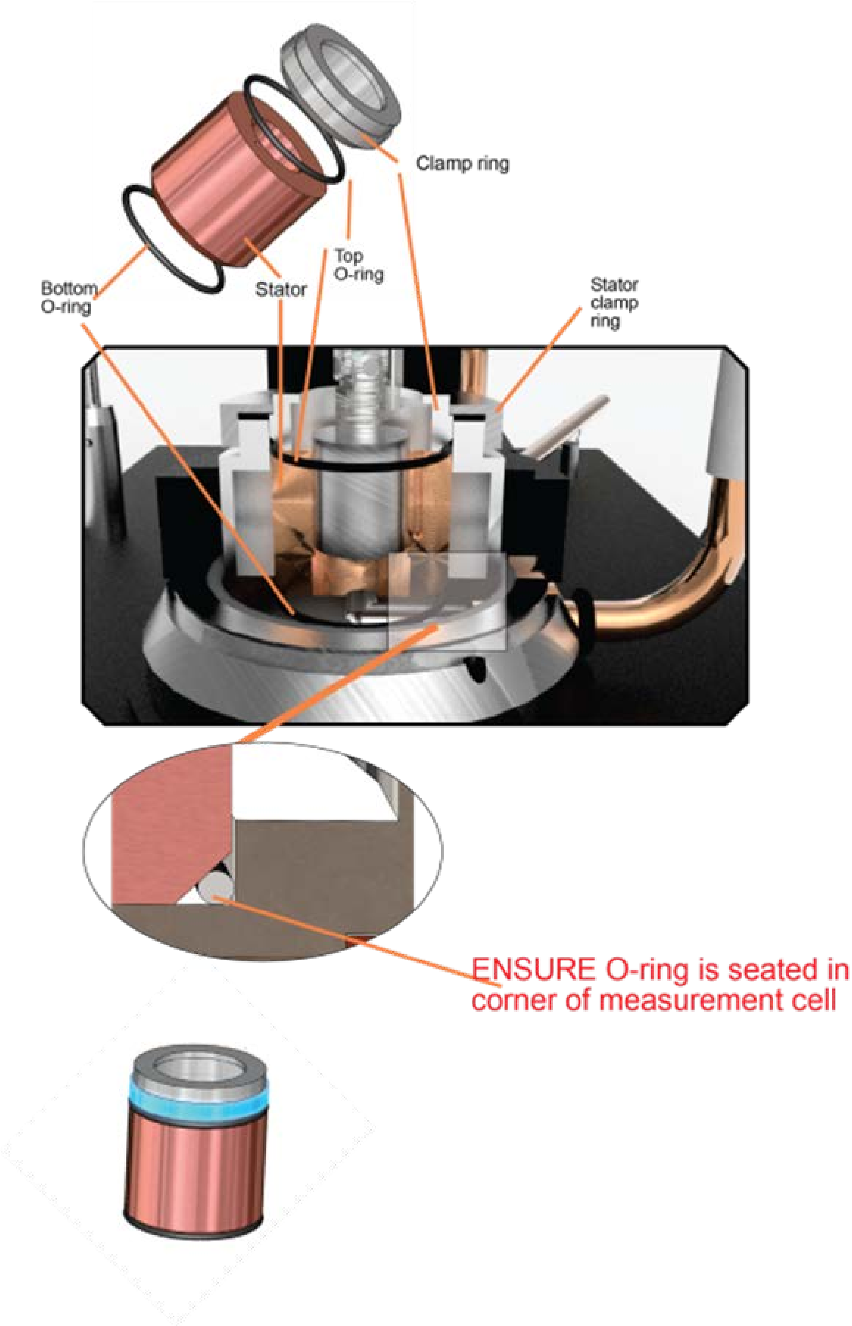
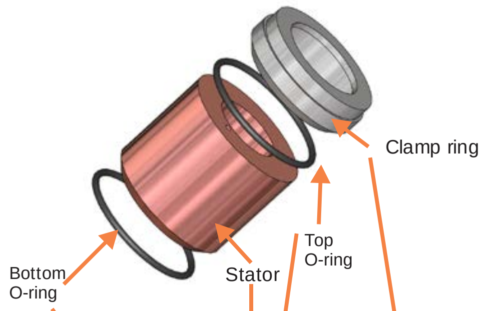


Figure 13: Components for Assembled Stator

All the parts that need to be assembled for the stator.

All parts should be placed in the measurement cell as shown in the section view below.
Pay attention to the position of the BOTTOM O-RING, it must be placed carefully in the bottom corner of the measurement cell base. Failure to do so will cause the O ring to split and leak



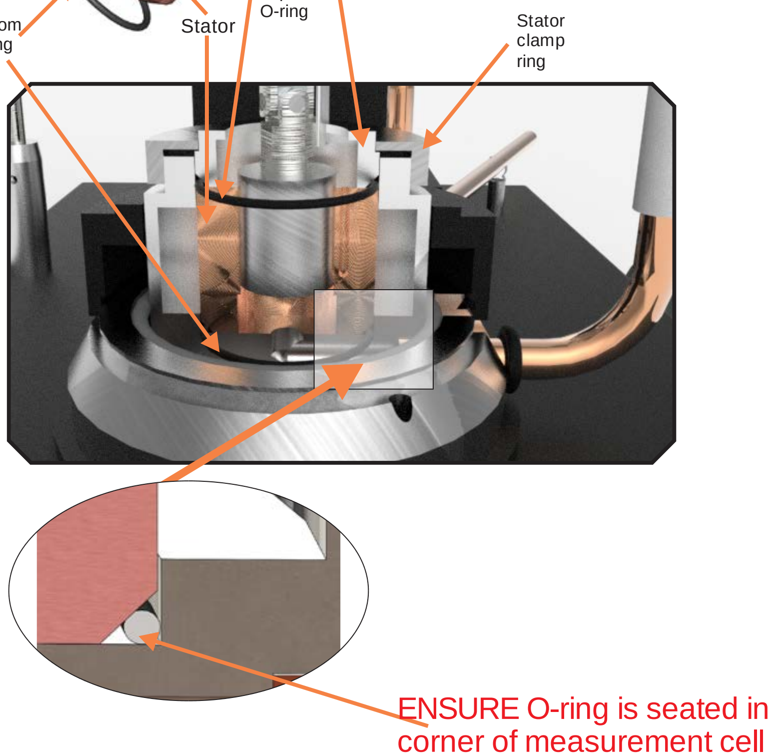


Figure 14: Rotor and Stator Assembly

Set Digital Gauge and Height Zero

Following the previous steps, the system is now at a stable temperature with the rotor lubricated and lowered into the stator. Continue to the next steps.

1. Adjust the vertical position of the rotor until it is flush with the top of the stator. Feel for the "step" between the top of the rotor and the stator using the end of a small Allen key. Refer to Figure 15.

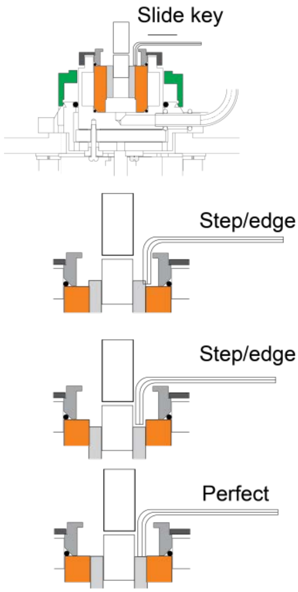


Figure 15: Feeling for Step

2. The height is most conveniently adjusted using the handle to turn the lift screw. The height may also be adjusted by raising the ball stop.

3. Place the digital gauge on its pillar and set it to zero by pressing the **zero** button. Refer to Figure 16 (next page).

4. The ball stop has a screw to adjust the turning friction. This is set to make the stop fairly stiff to turn. **Do not use this as a lock**.

Flush the Stator

5. Attach the funnel to the side arm using the short sleeve of the supplied silicone rubber.

Note: CANNON advises operators to periodically remove and clean the silicone sleeve with solvent.

6. Flush out the stator with solvent several times applied at the top of the rotor, turning the rotor gently with fingers only to ensure that no particles are trapped in the component. Remove the solvent by aspiration at the side arm. This vital step cannot be skipped as any dust or debris must be removed prior to operation.

Caution: Do not skip step 2 as any dust or debris MUST be removed prior to operation.

Calibration Oil

7. Place calibration oil into the measuring system. Use the recommended RL 106 for operation at 150 °C at 10^6 s^{-1}.

Lower the Head

8. Lower the rotor using the handwheel until the dial gauge reads approximately 3 mm. Raise the ball stop until the head is resting on the ball stop, then turn the handwheel a few revolutions to ensure that the lifting screw is sufficiently clear. Do not turn the wheel so far that the driving pins of the lift screw disengage.

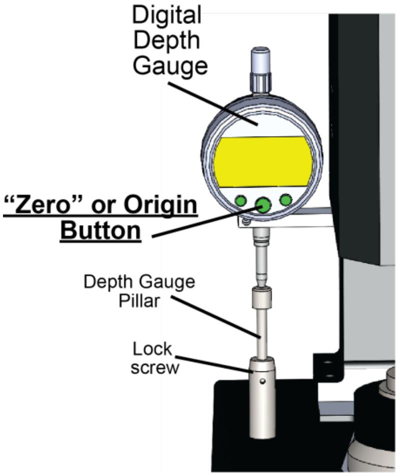


Figure 16: Digital Depth Gauge

Now, proceed to the next section to set up the computer controls for the instrument.

Computer Control

To enter a value, press the keys in the desired sequence and proceed by pressing **ENT**. Correct any mistakes before pressing **ENT** by pressing **CLR** or by moving the cursor within the field with the arrow keys. Checks are programmed into the software to ensure that the values entered are within the accepted range. Values outside that range will not be accepted and the software will request new data.

When switching on the instrument, the machine displays the home screen that includes the model number and software version as seen in Figure 17.

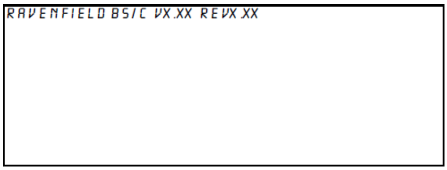


Figure 17: Software Version

The top line ends with an entry of the software version. This may be required for a service request.

After a few seconds the display will clear and show the M**ain Menu** screen as shown in Figure 18.

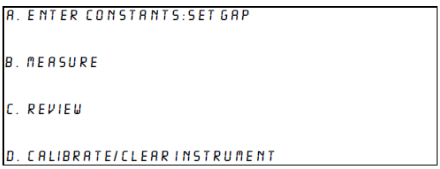


Figure 18: Main Menu Screen

Enter Sample Data

The operator needs to enter the all the necessary data before proceeding with a test. To begin, select **A** from the **Main Menu**. The **Constants** screen will appear as shown in Figure 19.

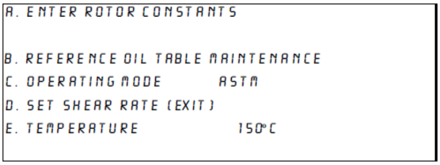


Figure 19: Constants Screen

Enter Rotor Constants

The instrument needs the rotor constants in order to continue. The constants for the rotor/stator system are found on the provided Calibration Certificate. The calibration certificate for these rotors/stators gives a target figure which provides a shear rate of 10^6 s^{-1}.

9. Select **A**. The **Rotor Constants** screen will appear as shown in Figure 20.

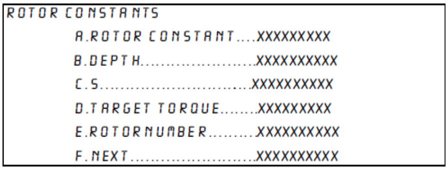


Figure 20: Rotor constants screen

10. To enter a value, press the appropriate letter key and enter the value shown on the data sheet. For instance, press **A** to choose to enter a rotor constant.
11. The selected field will highlight and the screen will flash slowly over the area being entered.
    a. To enter the rotor constant, press **A** then **CLR**, then enter the value from the data sheet. One example of a rotor constant entry is: **3.98E±5** and **ENT.**
12. The numbers are displayed as entered. Press **ENT** to accept the entry.
13. Enter all the data as requested from **A** to **E**. Finally, press **F** when finished. If the data is not entered correctly or is incomplete, the system will display the error message as shown in Figure 21.

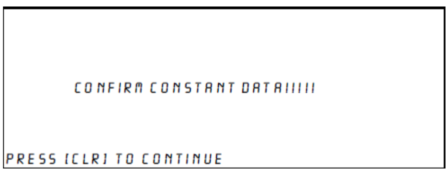


Figure 21: Error/incorrect or incomplete data message

All the required data must be entered for the rotor constants under option **A** of the constants screen.

- Press **B** to enter depth.
- Press **C** to enter constant S.
- Press **D** to enter target torque.
- Press **E** to enter rotor number.
- Press **F** to return to the constants screen.

Reference Oil Table Maintenance

A full table of viscosity and temperature data is stored for the reference oils in use. To access this table, from the constants screen select option **B** and enter the viscosity values at the temperature in use for all the reference oils that are used in day to day operation of the instrument. To access the reference oil table press **B** as shown in Figure 22.

```
         REFERENCE OIL TABLE
REF#          TEMP(°C)    VISC(CP)
XXXXX         XXXXX       XXXXXX
XXXXX         XXXXX       XXXXXX
XXXXX         XXXXX       XXXXXX
              USE ARROWS TO SCROLL
         SCROLL OFF TOP OR BOTTOM TO FINISH
```

Figure 22: Reference Oil Table

The arrow keys will scroll through the fields in the **Reference Oil Table** and the data entry section flashes when it is active. When over the **REF#** field, enter the RL number of the oil in the order in which they will be run. For instance, oil ref RL 104/4 is entered as **104.4.**

- When over the **TEMP** field enter the temperature at which the tests are to be run.
- When over the **VISC** field enter the viscosity of the oil at the stated temperature.

The system allows the creation of different data tables with various test temperatures. The instrument then automatically selects for use only those oils with a viscosity figure at the demanded test temperature.

Exit the **Reference Oil Table** screen by scrolling off the top or bottom of the table.

Set Operating Mode

Choosing **Operating Mode** selects the test method employed by the instrument. Each mode from ASTM, CEC or IP selects 150 °C and $10^6 s^{-1}$. The **Direct Mode** operation option is explained in further sections.

Select the operating mode by pressing **C** until the selected mode is highlighted. Accept the selection by pressing **ENT** or any other key.

Set Operating Temperature

A temperature must be set in order to perform a calibration of the instrument gap. This is not necessary for ASTM, CEC or IP modes, as they automatically adhere to the standard 150 °C conditions. If the operator selects option **E** a warning message appears: **Direct Mode Only**. Clear this message by pressing **CLR**. Option **E** is only available while in **Direct Mode**.

Continuing the "Set Gap" Stage

The instrument is ready to be calibrated once the constants and reference oil data are entered. To proceed, press **D**.

Set Shear Rates

For the first calibration, the instrument is already prepared for testing due to completion of the previous steps. The shear rate screen will appear as shown in Figure 23.

```
LOWER OILED ROTOR INTO STATOR.
FLUSH ROTOR AND STATOR AND ADD FIRST OIL
ZERO DTI.
USE UP/DN ARROW KEYS TO SELECT AN OIL

        VISCOSITY XXX.XX CP AT XXX.X °C
              F. NEXT SCREEN
```

Figure 23: Shear Rate Screen

Use the arrow keys to select the reference oil used for the test. Standard test methods suggest the initial use of oil RL 106. Under non-standard conditions, use the highest viscosity standard in the sequence for the initial settings.

1. Press **F** for "next screen". The new calibration screen will appear as shown in Figure 24.

```
ABANDON OLD CALIBRATION ??
[0] = NO
[1] = YES
[F] = ABORT TO MAIN MENU
```

Figure 24: New Calibration Screen

At the new calibration screen the operator can choose to start a new calibration or amend an existing one.

Caution: There is no method of recovering a calibration after it has been abandoned.

After pressing **F**, the next screen displayed is the calibration screen as shown in Figure 25.

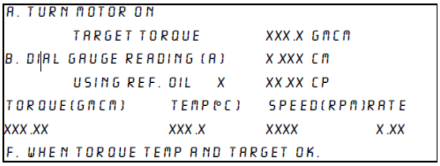


Figure 25: Calibration Screen

2. Fill the funnel with RL 106.
3. Turn on the vacuum.
4. After the funnel has emptied fill the funnel with standard RL 106 again.
5. Lower the head by the side handle until the dial gauge reads 3 mm.
6. Raise the ball stop until it supports the weight of the head, and then turn the side handle about two more revolutions.

The machine is now waiting for the rotor to be lowered to its operating position while the temperature is adjusting to the required measurement.

Sampling Technique

Before proceeding further, refer to previous sections for methods used when introducing or removing sample fluid.

Stop Motor

To stop the motor at any time, press **Stop** on the display. For even faster response, turn the motor/cutoff switch to the **Cutoff** position. The cutoff screen will appear as shown in Figure 26.

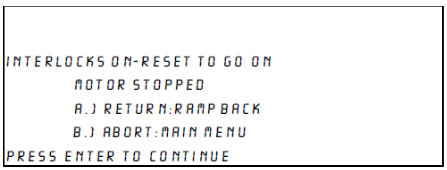


Figure 26: Cutoff Screen

Nothing further will happen until the switch is returned to the **Motor** position.

Press **A** for the motor to ramp back up to speed and display the original menu.

Press **B** to revert back to the **Main Menu**.

Adjust Gap

The Adjust Gap screen appears after the reference oil selection as shown in Figure 27.

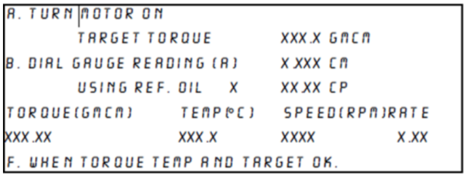


Figure 27: Adjust Gap Screen

1. Turn on the motor by pressing **A.**

The motor will ramp to a speed of 3200 RPM in about 15 seconds. If the interlocks are activated (using the front panel or raising the head) the **Motor Stopped** message will appear. Clear the fault, return the **Motor/Cutoff** switch to **Motor** and continue by pressing **A**.

Note: You may hear the motor audibly changing speed slightly after ramping is completed. This is completely normal and is caused by high precision digital servo system cutting in and stabilizing the motor speed.

2. Adjust the depth of the rotor by slowly lowering the fine adjustment stop. Observe the increase in torque and increase in temperature caused by shear heating. Periodic adjustments of the bath may be necessary.

Entering a New Depth Gauge Reading

When the torque gets near the value displayed under target torque, select **B** and enter the depth gauge reading. Execute this entry by pressing **ENT**. This changes the displayed target torque to a new and better approximation of the correct value. Refer to Appendix "Target Torque" for more information.

The digital depth gauge displays the depth in millimeters. However, the depth must be entered into the instrument in centimeters.

When the displayed torque and target torque are the same, and the target torque does not change when a new depth gauge reading is entered and **B** is pressed, add a sample of calibration oil and confirm the readings.

Note: If this adjustment takes a long time, use a fresh funnel full of oil at five or ten minute intervals.

Use a new sample of oil after the operator is satisfied that the shear rate is correct. Then press **F** when the funnel is empty.

Preparing the Calibration Curve

Next, the **Select Calibration** screen will appear as shown in Figure 28. Use the arrow keys to select a new calibration oil to begin the full calibration process.

```
SELECT CALIBRATION OIL
        TOTAL OILS IN THIS CAL:X
USE UP/DN KEYS TO SELECT AN OIL
        REF:  XXX
 VISCOSITY:  XXX.XX CP AT XXX°C
        F. OIL INSERTED. READY
```

Figure 28: Calibration Screen

Start with the lowest viscosity standards and follow, in sequence, with the higher viscosity standards.

The **TOTAL OILS IN THIS CAL** field provides assistance to ensure proper amount and sequence of oils.

When an oil has been selected and at least two funnels poured in, press **F** to continue to the next screen. The torque, temperature and speed screen will appear as shown in Figure 29.

```
TORQUE       XXX.X              TEMP XXX.X°C
SPEED        XXXX               REF   XXXX
ACCEPT AT XXX.X°C          CALIBRATING NOW
        TEST#       RATE OF RISE......X.XX°C
SELECT A
        B
        C
REPEAT [D]: NEXT STD.[E]:END CAL [F]
```

Figure 29: Torque, Temperature and Speed Screen

1. If the temperature is *above* the accept value, add another funnel full of calibration oil to reduce it to *below* the accept value. The instrument will only take a reading when the temperature is rising through the accept value, not when it is falling. The rate of rise is indicated and should reduce as the accept point is approached.

2. When the temperature reaches the accept point, the torque value is automatically accepted and displayed as **TEST# 1**. The flashing message **CALIBRATING NOW** is replaced with **PRESS FN KEY** indicating it is now possible to press a function key (**D, E** or **F**) or a selection key (**A, B** or **C**).

3. Press **D**. The instrument then displays the **CALIBRATING NOW** message.

4. Pour in another funnel full of reference oil. The instrument waits for the temperature to drop through the accept point and rise back through it. The display then shows **PRESS FN KEY** again.

5. If the two readings agree within 1% then there is no need to repeat the test. Standard test methods mandate that the torque result be calculated from the mean of two torque determinations which agree to within 1%. Therefore, the previous steps must be repeated until two results agree within 1%. This is generally achieved immediately, but difficulties flushing out previous samples may require more tests to achieve the desired result.

6. Select the accepted results from the three shown on screen by pressing the **A, B, C** keys. Selected torque data is then highlighted and an average of two results is automatically calculated and displayed.

7. Having selected two determinations, press the **E** key to go to the previous screen (**SELECT CALIBRATION OIL**) and use the arrow keys to select the next oil to be tested.

8. If the two results do not agree within 1% press the **D** key (**Repeat** key) and continue to add oil. Users may test as many times as desired as the instrument displays a rolling list of the last three results, of which any or all results can be averaged.

9. To finish calibration, select the last torque data from the last oil and press **END CAL (F)** to proceed.

10. If desired, repeat any of the measurements by selecting **E** and retesting a standard oil.

Calibration Complete

After pressing **F** the calibration screen indicates that calibration is complete as shown in Figure 30.

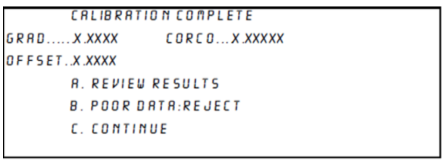


Figure 30: Calibration Complete Screen

Once calibration is complete, the next step is establishing the correlation coefficient. Current test methods set a minimum of .9997. If the correlation coefficient is less than .9997 then test results will not be accurate. The machine needs to be recalibrated.

1. If the correlation is greater than .9999 then press **C**.

2. Press **A**. The results now appear on the screen and can be scrolled through using the arrows. Refer to Figure 31.

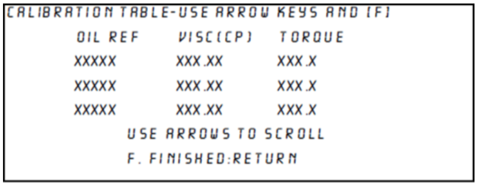


Figure 31: Calibration Table

3. Press **B** to return to the **Select Reference Oil** screen where the torque result can be altered.
4. Select **C** when all information is correct. This takes the user to the measurement stage to complete calibration.

Independent Check on Shear Rate

On the first usage of any calibration curve it is important to cross check the shear rate by using the non-Newtonian reference oil.

Measurement

1. At the **Main Menu** screen, if the machine is already calibrated, choose **B** to measure. Refer to Figure 32.

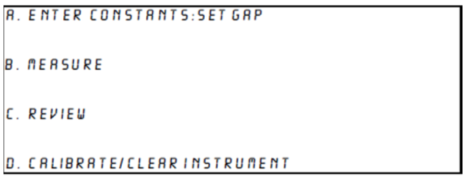


Figure 32: Main Menu Screen

2. Check to ensure that the constant level pump is fitted and the receiver is not full.
3. Turn on the vacuum pump.
4. Insert sample.
5. Enter a reference for the sample:
   a. Press **A**
   b. Enter a reference of up to six characters
   c. Press **ENTER** to continue
6. Press **C**. The torque, temperature and speed screen will appear as shown in Figure 33.

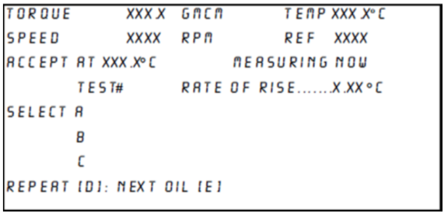


Figure 33: Torque, Temperature and Speed

The torque is automatically accepted as the temperature reaches the **ACCEPT AT** temperature (normally 150 °C) and the torque is displayed. The instrument then exhibits **PRESS FN KEY**.

Press **D** to repeat the test with more of the same oil or press **A**, **B** or **C** to select the measured torque shown on the screen.

- When one torque is selected the instrument automatically calculates the viscosity of the oil in the measurement cell.
- When two or three torque results are selected, the average is automatically used to calculate the displayed viscosity.

7. Repeat steps 4 and 5, noting all determinations and results on the provided reporting sheet (Appendix “Calculations”).

Sampling Technique

The through-flush procedure is the standard to remove old sample materials. This process requires the motor to continue running.

Note: The old sample material must be thoroughly removed. The motor continues running during this procedure.

Prepare for Through-Flush Method

The through-flush method is the standard procedure to remove old sample materials and ensure accurate test reporting.

1. Mount the suction pipe on the top surface of the instrument with its tip approximately 4 mm above the top of the stator and approximately 2 mm away from the rotor drive coupling.
2. Connect the vacuum pipe and turn on the pump.
3. Place between 5 mL and 50 mL of solvent in the funnel. Solvent only needs to be used once per session.

Commence Through-Flush Method

1. Place first sample of oil in funnel. Fill the funnel and turn on the motor.
2. Wait until oil falls into neck of funnel. Place the second sample in funnel and fill the funnel.
3. Generally two funnels are sufficient to remove all previously used oils. If a very viscous oil like RL 107 is used, operators may need to repeat step 2.

Taking a Reading

A reading is taken by observing the torque and the temperature simultaneously as the temperature passes through 150 °C. **Ensure that the rate of temperature rise does not exceed 0.5 °C/sec.** Adjust the bath settings as necessary and repeatedly insert samples to cool the head until satisfactory conditions are obtained.

Normal Use

The instrument is already calibrated in Normal Use. It is only necessary to perform step 2 in the following section, then insert a check sample in step 4, and then proceed to perform calibration and measurements as needed.

Proceed with Normal Use

When the machine is switched off, raise the rotor using the handwheel **at least 2 mm** before it is allowed to cool down in order to avoid rotor damage. Do not raise the rotor out of the cell.

Caution: Rotor must be raised before it is allowed to cool.

Flush the measurement cell with solvent before the instrument is switched on, together with the heating bath, for approximately 60 minutes. After flushing for 60 minutes the rotor may be lowered onto the ball stop and testing may commence.

The use of calibration oil (preferably of a value near to the oils being tested) and a small adjustment of the ball stop is all that is required to re-establish the calibration line.

The calibration line generally remains valid for several months; however, it is recommended that the calibration line is checked at intervals of two or three calibration oils. Standard methods require that the non-Newtonian reference oil is tested every fifth sample as small jumps in calibration may occur due to surface damage of the rotors and stators.

Accidental Seizure

Provided that care is exercised in previous steps and that cleanliness is observed, there is no reason why accidental seizure should occur. But due to human nature and common laboratory conditions, accidental seizure is possible. The instrument incorporates a torque limiting clutch to reduce the damage and most seizures can be recovered by the technique described in Appendix 2 "Polishing Damaged Rotors and Stators".

CANNON advises that Ravenfield BS/C+ users stock a spare rotor and stator with each instrument to reduce down-time. It takes 45 to 60 minutes to replace and recalibrate a rotor/stator pair.

Caution: Switch the motor to **CUTOFF** before raising the rotor from the stator at any time. Do not attempt to pull the rotor from the stator using the lifting screws (either the ball stop or side handle) as this will damage the pivots.

Review Data

Select option **C** from the **Main Menu** to reveal the **VIEW STORED DATA** sub-menu. This sub-menu provides a convenient method of viewing most stored data in the instrument. It is a read-only screen and all entries can be accessed at any time from the **Main Menu** as shown in Figure 34**Error! Reference source not found.**.

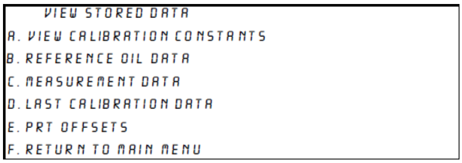


Figure 34: View Stored Data Screen

- Select **A**, **View Calibration Constants**, to show the instrument calibration constants: gradient, offset and correlation coefficients of the calibration curve and the LVDT calibration constants.
- Select **B**, **Reference Oil Data**, to display the Reference Oil Table as shown in the Maintenance screen of the **ENTER CONSTANT: SET GAP** menu. It is not possible to change data in this screen.
- Select **C**, **Measurement Data**, to show recent measurement data together with a reference number. The most recent 20 results are shown on this screen.
- Select **D**, **Last Calibration Data**, to show the last calibration data in the same way that the data appears when reviewing results of a calibration.
- Select **E**, **PRT Offsets**, to display the Platinum Resistance Thermometer offset table. This table records a list of corrections to be automatically applied to the temperature measurements in order to correct for errors in the measurement system.
- Select **F** to return to the **Main Menu**.

Calibrate/Clear Instrument

Select option **D** from **Main Menu** to access the **SET UP INSTRUMENT CONSTANTS** sub-menu as shown in Figure 35. The principal constants LVDT calibration and temperature are measured and calibrated from this sub-menu.

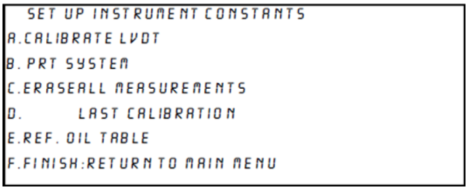


Figure 35: Set Up Instrument Constant Sub-Menu

Calibrating the LVDT

The LVDT is used as the instrument's torque transducer. It has a real offset and gradient which must be determined and stored before any valid data can be measured. In **Normal Use** this function should be used no more than once every six months.

To calibrate the LVDT:

1. Remove the rotor and the top cover of the instrument.
2. Select **A** on screen. The word **ENTER** will flash. Refer to Figure 36.

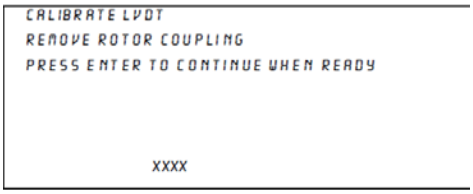


Figure 36: Calibrate LVDT Screen

3. Apply the supplied 150 gram calibrated weight to the head. Press **ENTER** when ready. Refer to Figure 37 and Figure 38.

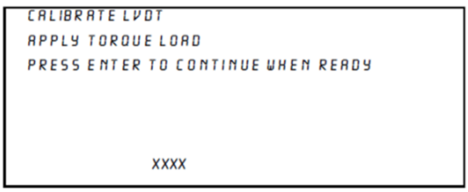


Figure 37: Applying Torque Load

4. You will then be returned to the **Set Up** sub-menu.

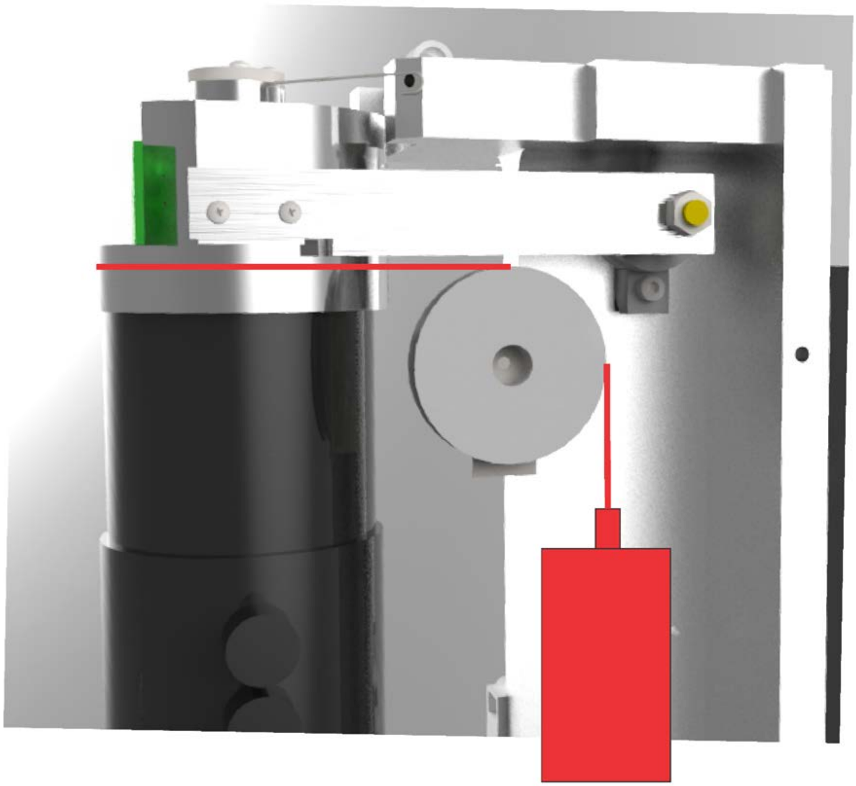


Figure 38: Position of 150 gm Calibration Weight

Calibrating the PRT System

The PRT (Platinum Resistance Thermometer) System is set up using a precision method of measuring temperature and a closely regulated bath.

Caution: The PRT Calibration function should only be performed by authorized personnel.

1. Select option **B** from the menu to select the **PRT Offset Correction** procedure.
2. Select **A** to enter the desired test temperature and enter a new figure in the range of 50 °C to 165 °C. The default temperature is the current operating mode default, often 150 °C.
3. Set the regulated bath to the desired operating temperature. Use the arrow keys to adjust the indicated temperature until it agrees with the reading of your precision measurement system. Refer to Figure 39.

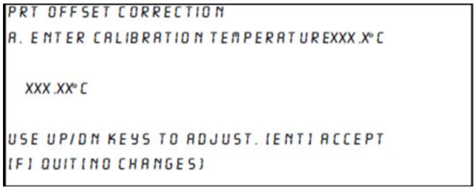


Figure 39: PRT Offset Correction

4. Press **ENTER**.

Note: Separate correction factors are stored for each temperature that a calibration is performed.

Data Erasure

It is possible to erase all data stored within the instrument. This is not generally necessary, but on occasions when it is desired, the options **C**, **D** and **E** of the **Setup Instrument Constants** sub-menu may be employed.

Using a password system can disable these features and prevent any function except measurement. Password function is discussed later in this manual.

Direct Mode Operation

Direct Mode operation provides a means of operating the machine in “non-standard” conditions of shear rate, temperature, speed and gap. Any or all parameters can be altered before calibrating the instrument.

A “Tweak” mode is also provided, allowing expert users to operate the machine almost completely manually. This allows running seized rotors and stators or any special one-off measurements needed.

Direct Mode is entered from the **ENTER CONSTANTS: SET GAP** sub-menu as shown in Figure 40.

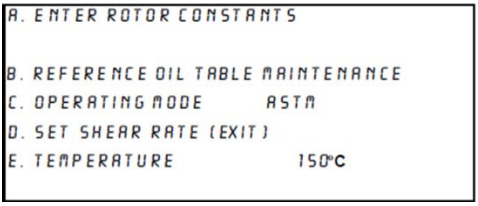


Figure 40: Direct Mode Screen

1. Select option **C: Operating Mode**.
2. Press **C** repeatedly until **Direct Mode** appears in highlighted window.
3. When in **Direct Mode**, choose **F: DIRECT MODE OPTIONS** as shown in Figure 41. Here is it possible to use the machine in non-standard ways.

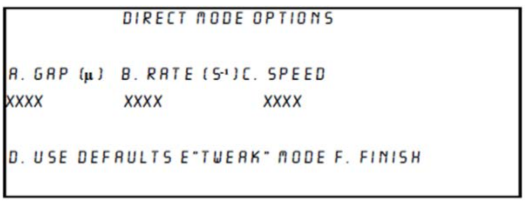


Figure 41: Direct Mode Options Screen

Manual Operation/TWEAK Mode

To enter **TWEAK** mode, press **E**. Refer to Figure 42.

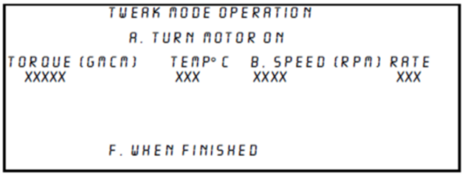


Figure 42: TWEAK Mode

1. Select **B** to set an operating speed.
2. The **SPEED** box will highlight and a speed may be entered.
3. Select **A** to engage motor to speed. The motor ramps up to the desired speed in approximately 15 seconds.
4. To turn motor off gently, press **A**. The motor will ramp down at the same speed it ramped up.

Controlled motor switching is an important measure in reducing the effects of torque offset shifts under multiple shear rate conditions.

Direct Mode Control

Direct Mode makes it possible to calibrate the instrument in a similar manner to conventional operations in ASTM, IP or CEC modes while allowing the user to select different conditions of shear rate, gap or rotor speed. When the **Direct Mode Options** screen is shown, the displayed screen is a calculator system for determining the parameters of operation. A warning message appears if the parameters are out of bounds or not advisable.

1. Select **D** to display the default settings 2.8 micron gap, 3200 RPM corresponding to a shear rate of $10^6 s^{-1}$.
2. Select one parameter to vary. For example, select **C** for speed.
   a. The flashing highlight box flashes over **Speed**.
   b. Enter an amount for speed. For a given speed the gap is held constant and the shear rate for that speed is displayed.

One Parameter Selection Rules

If the first parameter selected is **Speed/C**, then the displayed gap is fixed and the shear rate varies with speed.

If the first parameter is **Rate/B**, then the displayed speed is fixed and the gap varies with rate.

If the first parameter is **Gap/A**, then the displayed rate is fixed and the speed varies with gap.

After one parameter is selected and given a new value or by just pressing Enter, the two parameter selections option is available. With this system the first parameter selected now flashes and a second parameter can be selected to match your choice.

Two Parameter Selection

Select **GAP** first, and then select either Rate or Speed while both are held constant.

Select **SPEED** first, and then select Gap or Rate while both are held constant.

Select **RATE** first, and then select Speed or Gap while both are held constant.

After adjusting the displayed parameters to your choice, press **F** to return to the **ENTER CONSTANTS:SET GAP** sub-menu.

In **Direct Mode** only temperature can be set separately now. Select **E** and set a new temperature. Non-standard temperatures are allowed in this function.

Now, during calibration, the instrument runs at the selected **Direct Mode** speed and the target torque calculations are based on the selected **Direct Mode** shear rate.

Caution: There is no other way to indicate that the instrument is in **Direct Mode** except from the **ENTER CONSTANTS:SET GAP** sub-menu.

Security feature

To prevent erasure of calibration data or any stored data in the instrument, the BS/C+ includes a simple security system which is transparent to the user and, if used, prompts the user each time it is switched on. The incorrect password entry prevents access to any function other than measurements.

Changing Password

Users can change the password by accessing the Main Menu.

1. Select option **D** from Main Menu.
2. **Calibrate/Clear** instrument to bring up the sub-menu.
3. Select option **G** to open the **Change Password** screen. This option is not displayed on screen but is available. Refer to Figure 43.

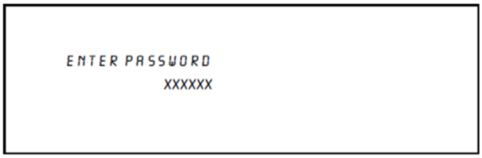


Figure 43: Change Password Screen

4. A six letter password must be entered.

5. Press **ENT** to finish.

The next time the instrument is run, after the initial version screen displays, the following screen will appear as shown in Figure 44.

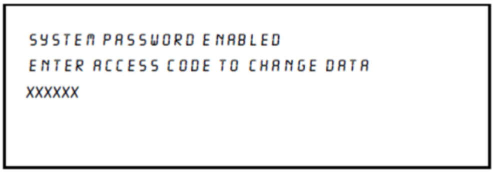


Figure 44: Password Changed Screen

The correct password must be entered before the Main Menu displays. If it is not entered correctly the following message is displayed as shown in Figure 45.

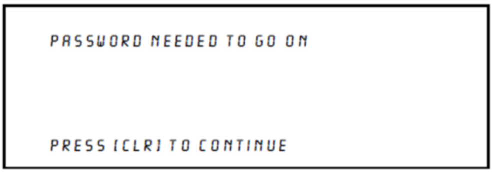


Figure 45: Incorrect Password Screen

Autosampler with Windows

The Ravenfield model DR-IV Autosampler is designed to provide a simple automatic loading mechanism for the BS/C+ HTHS viscometers.

The unit consists of a carousel, sampling arm and sample pump with an integrated PC running Microsoft Windows 10 as well as a provided touch screen. A small ticket printer is also included to produce test reports. A Standard RJ45 100 Base-T connection to laboratory networks is also provided.

The software incorporates a powerful database to store test results, allowing users to follow the results of any named samples over time. Graphs of sample viscosity and check oil can be routinely produced on the integrated printer or any networked printer.

The program also incorporates the ability to automatically process the whole suite of calibration oils and to automatically trim the bath temperature, removing the need for the operator to intervene during testing.

The following sections offer a basic insight into the autosampler. For more detailed information and instructions, please refer to the designated Autosampler Manual or contact your CANNON representative.

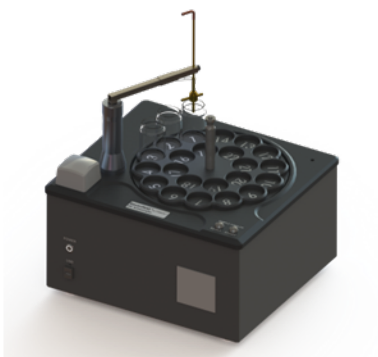


Figure 46: Ravenfield DSR Autosampler

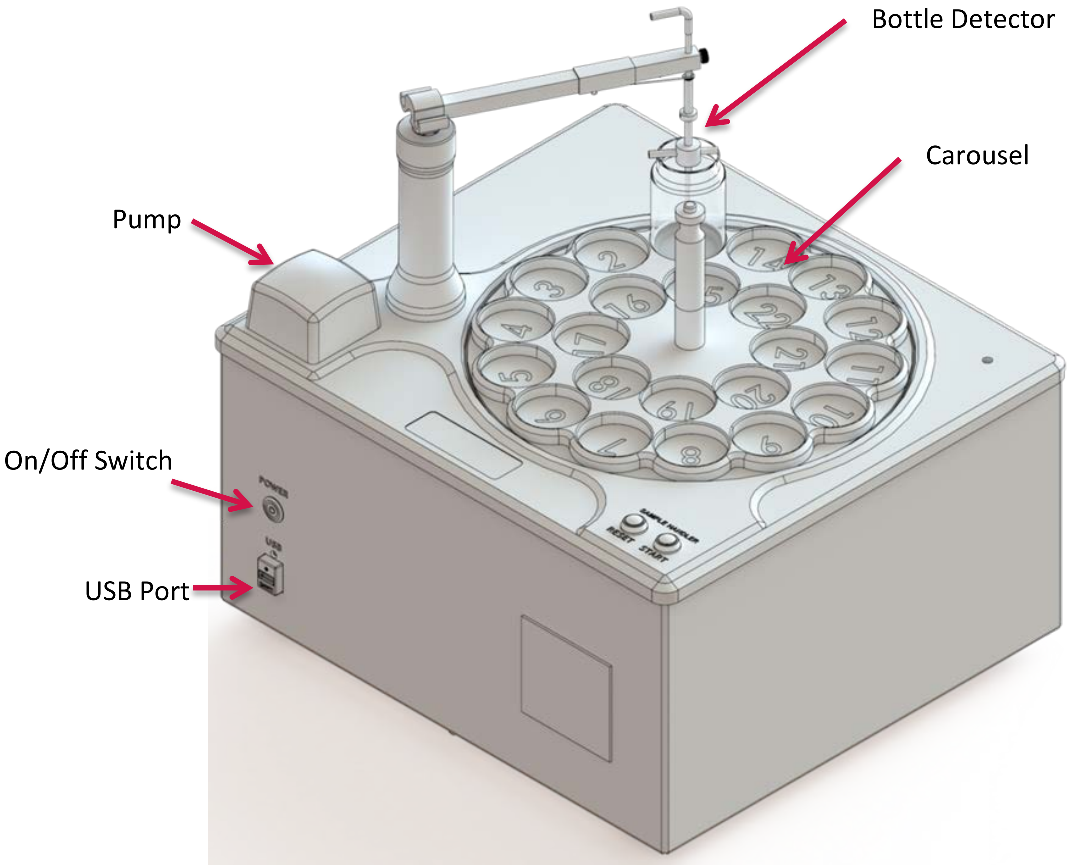


Figure 47: Diagram of Front of Autosampler

Simple Workflow: Calibration

Note: To calibrate, the BS/C+ must have a previous manual calibration stored internally.

1. Power on the PC. If the autosampler DR operating system does not start up automatically, click the DR shortcut on the computer screen to launch the program.
2. Without erasing the existing calibration, set the rotor/stator gap manually.
3. Exit **Calibration** and enter **Measurement** mode. Press **C**. Continue to test to restart the motor.
4. Connect the autosampler feedpipe to the side arm.
5. Place viscosity standard sample vials on the carousel.
6. Identify standard oil samples on carousel in autosampler software. Make sure the samples are loaded in the correct positions (see samples test tab).

7. Verify that the temperature is stable.
8. Press **Start**.
9. Wait until all sample oils have been tested.
10. Review data on screen and check for outliers or other issues.
11. Select points on the displayed graph to be used for calibration.
12. Click **Calculate Constants**.
13. Check returned value of check oil for any issues.
14. If calibration is acceptable, save the calibration to the internal computer by clicking **Save Calibration.**

Simple Workflow: Routine Measurements

Note: The BS/C+ must have a previous manual calibration stored internally. It will automatically retrieve this calibration.

1. Calibrate as described in previous section “Simple Workflow: Calibration”.
2. Click on **Measurement Mode** on the screen.
3. Connect the autosampler feedpipe to the side arm.
4. Pour samples into vials and place vials on the carousel. For a full carousel, ensure that at least three of the samples are check oils.
5. Enter the **Sample IDs** for oils into the software.
6. Press **Start**.
7. Wait until all samples have been tested.
8. Review data on screen.
9. Check performance of check oil over run.
10. Print report.

Warranty

Products limited warranty

In addition to other manufacturers' warranties, CANNON Instrument Company ("the Company") warrants all products (other than reagents and chemicals) delivered to and retained by their original purchasers to be free from defect in material and workmanship for one year from the date of the Company's invoice to the purchaser. For a period of one year from the date of such invoice, the Company will correct, either by repair or replacement at the Company's sole election, any defect in material or workmanship (not including defects due to misuse, abuse, abnormal conditions or operation, accident or acts of God, or to service or modification of the product without prior authorization of the Company) without charge for parts and labor. The determination of whether any product has been subject to misuse or abuse will be made solely by the Company.

The Company shall not be liable for any special, incidental, or consequential damages, or any damage to plant, personnel, equipment or products, directly or indirectly resulting from the use or misuse of any product. Representations and warranties made by any person, including dealers and representatives of the Company, which are inconsistent, in conflict with, or in excess of the terms of this warranty shall not be binding upon the Company unless placed in writing and approved by an officer of the Company.

Reagent and chemical warranty

CANNON Instrument Company ("the Company") warrants all reagents and chemicals sold by the Company and delivered to and retained by their original purchasers to conform to the weight, specifications and standards stated on the package. The Company will, at its sole option, either replace or refund the price (net of freight, handling charges and taxes), of any reagent or chemical sold by the Company which does not conform to such weight, specifications and standards upon the prompt return of the unused portion. Except for replacement or refund of the net price, the Company shall not be liable for any damages occurring as a consequence of the failure of any reagent or chemical sold by the Company to conform to the weight, specifications and standards stated on the package.

Returning a product to CANNON

Before returning a CANNON product for repair or service, make every attempt to identify the problem. If, after careful checking, the problem remains unidentified or unsolved, telephone CANNON Instrument Company (or the local service agent) to consult with a product specialist. If the specialist cannot recommend a simple solution or repair, CANNON will authorize the return of the product through the issuance of a Return Authorization number (RA).

CANNON Telephone Number: 814-353-8000

CANNON Fax Number: 814-353-8007

Products returned to CANNON must be carefully packed. Ship prepaid to the following address:

CANNON Instrument Company
ATTN: Return Authorization # __________
2139 High Tech Road
State College, PA 16803 USA

Required Information – Please Include the Following:

- The Return Authorization number (RA).
- The name and telephone number of the person at your company to contact regarding the product.
- Shipping and billing instructions for the return of the product to your location.
- A detailed explanation of the reason for the return. If the product is not covered by warranty, the customer will be provided with an estimate of the repair costs and asked for approval before any repairs are made. The customer will be required to issue a purchase order for the cost of the repairs.

Hazardous materials

Please contact CANNON before returning a product that could possibly contain hazardous material.

Shipping notification

Products returned without CANNON's prior authorization will not be accepted. The customer may be billed a testing fee if a product is returned to CANNON and found to be working properly.

Replacement Parts List

CANNON carries a full supply of parts in the case that any Ravenfield BS/C+ viscometer components need replaced. Refer to Table 5 for a list of available parts.

Table 5: Replacement Parts List

Description	Part Number
Ultrasonic Bath	80.5020
Rotor/Stator Replacement (complete)	80.5002
O-Rings	80.5005
Service Kit	80.5675
Printer Paper for Model DR Autosampler	80.5634
MAINS AC power cable	74.2110 (US standard) UK ETC
Power supply fuses	Varies
Surge protector	Varies

Appendix 1 - Calculations

The calculations in this section are performed automatically in this fully computerized instrument but are included here for informational purposes.

For any cylindrical viscometer:

$$(1)\quad Shear\ Stress = \frac{torque}{area\ of\ surface}$$

For a Newtonian fluid:

$$(2)\quad Shear\ Rate = \frac{shear\ stress}{viscosity}$$

$$G = shear\ rate$$
$$S = shear\ stress$$
$$h_p = viscosity\ in\ poise$$
$$n_{cs} = viscosity\ in\ centistokes$$

Then from (1) torque (dyne-cm) = $s * area * radius$

And from (2) torque (dyne-cm) = $g * \ h_p * area * radius$

But $h_p = \ n_{cs} * r * \ .01$

$$(3)\ \text{Hence:}\quad \frac{torque\ (gm.-cm) = g*(n_{cs}*r)* .01 * area * radius}{981}$$

Consider the rotor to have the following dimensions:

Axial height = h

(4) The area of the curved surface:

$$\frac{p\ d.h * (360 - 4\ cos^{-1}\frac{t}{d})}{360}$$

Combine (3) and (4):

$$(5)\quad torque\ (gm.-cm) = \frac{g*\left[p\ d* .01*\left(360-4\ cos^{-1}\frac{t}{d}x\right)\right]* n_{cs}*r*height}{[360*2*981]}$$

Note that the term in square brackets is constant for a given rotor/stator system.

$$(6)\text{ i.e. rotor constant} = \frac{p\,d^2 * (360 - 4\cos^{-1}\frac{t}{d})}{[7.063 * 10^7]}$$

The stator is not actually a simple taper socket but is cut away below the active section. Thus the term height in (5), meaning active height, should read either:

"h" if a is less than (s - h) (given as a constant "depth") or

"s – a" if a is greater than "depth"

When setting shear rates considerably below 10^6, or large gaps, it may not be possible for "a" to be greater than "depth" though it will be considerably greater in a pair which has been re-lapped several times used at a gap appropriate to 10^6 sec^{-1}.

This is the system equation: (7) $torque = g * constant * n * r * [h \text{ or } S - a]$

Each rotor/stator pair is given the following constants:

- Rotor constant - Rc
- Depth
- Height- h
- Diameter - d
- Constant - S
- "a" is read directly from the digital gauge when set correctly.

Equation (7) is used to calculate the desired torque with an oil of known viscosity to achieve a specified shear rate.

This torque is proportional to shear rate and even if the factor "S - a" has to be used, the amount of variation in effective height to be expected for shear rates from 2 x 10^5 up to 1 x 10^6 is so small that the torque may be taken as proportional to shear rate.

Further equations may be derived from the above.

Viscosity in centipoise = $(n_{cs} * r) = \frac{torque}{g * constant * (h \text{ or } S - a)}$

$$g = \frac{torque\ in\ gm.cms}{constant\ Rc\ x\ (n_{cs}\ x\ r) * (h\ or\ S - a)}$$

use h if a < depth

use (S – a) if a > depth

Torque is read directly from the digital read out in gm.cms.

Appendix 2 - Polishing Damaged Rotors and Stators

It may be necessary to occasionally re-lap damaged rotors and stators. This is generally a simple procedure unless that damage, often caused by large particles, is severe.

Required Materials:

- Liquid metal polish (i.e. Brasso, Bluebell or similar)
- White spirit, turpentine substitute or mineral spirits
- Soft tissues
- Glass or plastic beakers

Damage and Repair

If the rotor is slightly grooved but without raised edges, no special action is necessary.

If the rotor is grooved and has slightly raised edges it may be possible to reduce the raised edges with a very fine Swiss needle file. The loss of contacting surface will not be great if care is taken.

If the stator is lightly grooved, with or without raised edges, no special action is necessary.

If the stator is deeply grooved, particularly with a definite end to a groove to a groove, then it is likely that the particle causing the damage has become embedded.

- Examine the surface for the particle very carefully and remove it, if possible, using a scalpel blade, or...
- Use a dental burr to cut a shallow hole to ensure the particle will not contact the rotor and become loose. A large apparent loss of contacting surface can be tolerated before any errors become significant.

If the damage is severe, but confined to a region at the top of the position the rotor occupies, then it may be possible to continue to lap until the rotor has moved away from the damaged zone.

Lapping Procedure

Prepare the damaged rotor as noted in the previous section.

1. Pour approximately 5mL of polish into a beaker.
2. Hold the stator in one hand with the rotor, fitted to its shaft and coupling or to a polishing handle in the other. Dip an edge of the rotor into the polishing mixture and place it into the stator.
3. Polish by pressing the rotor lightly into the stator and simultaneously rotating the wrists. The appropriate action is a successive push-twist-pull action. Repeat this several times, then turn the rotor a quarter of a turn to a fresh position.
4. Repeat this action until polishing mixture turns dark. Then wipe it off on tissue, rinse in white spirit, wipe off and repeat step 3. The rotor will change from feeling gritty to smooth. When it is smooth, continue to lap for approximately five minutes.
5. Wipe off the remaining polishing compound and rinse thoroughly in clean white spirit or similar solvent.
6. Using a small amount of fresh compound on a tissue wrapped around your finger, hand polish the surfaces of both rotor and stator.
7. CANNON advises user to separate the rotor from its shaft, removing the grub screw, and clean all components in an ultrasonic bath before re-assembling.
8. If a skilled engineer and Engineer's Blue are available, the components may be blued and examined before step 6. The aim is perfect conformity with very little banding.

Note: The use of a polishing handle is strongly recommended for this procedure and can be provided by CANNON upon request.

Warning: Prior to installation, after lapping, or whenever contamination is suspected, the rotor and stator must be thoroughly cleaned in an ultrasonic bath. Failure to do so can irreparably damage the rotor and stator.

Appendix 3 - Spare Parts

CANNON recommends the spare parts located in Table 6.

In the event of damage to the instrument plate springs we recommend returning the instrument to the factory where the instrument can be put back onto our jigs and fixtures for realignment. If this is not possible we provide a full service kit and video instructions indicating the correct procedure.

Table 6: Spare Parts List

Description	Part Number
One or two sets of Rotors & Stators	80.5003
(10) “O” Rings	80.5115
O-Rings	
Flexible Shaft	
Full Set of Calibration Oils	
RL 102	9727-R10.032
RL 103	9727-R15.032
RL104	9727-R20.032
RL 105	9727-R25.032
RL 106	9727-R30.032
RL 107	9727-R35.032

Appendix 4 - Clearing a Password

If the password is forgotten or incorrectly set it may be erased and reset. Follow the procedure below.

1. Switch off the instrument.
2. Press the space between the **A E** and **–** keys.
3. Switch on and hold until the engineering screen displays.
4. Type access code 369307.

The password is automatically set to zero and operation is unlocked.

Appendix 5 - Target Torque

Target torque is when the measured torque and the target torque are the same, ensuring the test includes fresh oil and the temperature rose slowly through the set point.

As target torque is reached, proceed with the rest of the calibration. Depth will not be changed moving forward.

There is NO absolute figure for the depth of the rotor in the stator. Microscopic surface changes occur during use of the rotor and stator. Therefore, the user must always derive user-specific target torque and depth when the rotor and stator have been levelled and set up.

The target torque on the certificate is the torque which was achieved at intersection in the instrument used during testing, but the torque in another instrument may differ slightly. Refer to Figure 48 for an example of a torque data graph.

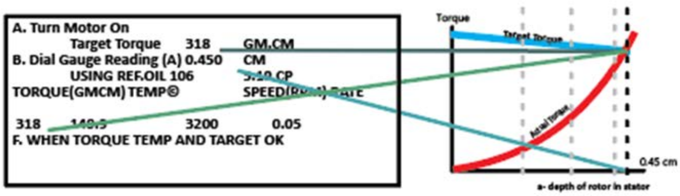


Figure 48: Target Torque

Gap calibration is the adjustment of the height of the rotor in the stator to achieve a known shear rate. Figure 49 is an equation of the torque generated by a sample in a tapered plug rheometer:

$$\text{Torque} = RC \times g \times \eta \times (s-a)$$

where RC is the rotor constant on the calibration certificate (see derivation there)

g is the shear rate.

η is the dynamic viscosity of the sample or standard.

Figure 49: Torque Equation

Figure 50 is a section of a rotor and stator at the dial gauge zero-ing position. Note the parameter, S, which is on the rotor stator calibration certificate. S is the length of the tapered surface of the stator, where measurement torque will be generated.

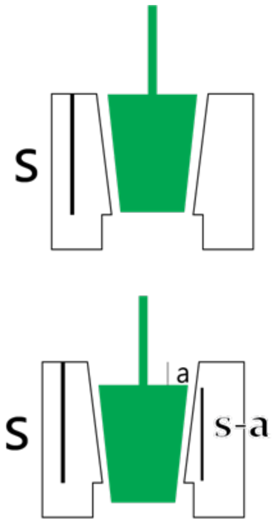


Figure 50: Rotor and Stator

Now we introduce our term "a", the depth that the rotor is inserted into the stator. There is now less surface between the rotor and stator since surface area is lost at the top and the bottom as the rotor sticks out below the tapered surface. The torque generating gap in the Ravenfield BS/C +is very small, so the effect of the protruding part on the torque is also small as a result of the effective "gap" being minimal.

Referring to the equation and our first example in Figure 48, a=0, so the equation becomes the classic concentric cylinder equation. Torque= RC x δ x η x s. In our second example, shown in Figure 51, the active surface of the rotor/stator available to generate torque = (s-a), so as the rotor is lowered into the stator, the torque measured at a certain shear rate will fall, since s-a is always less than s. The increasing shear rate will also be increasing the torque at the same time, since shear rate is proportional to speed/gap.

Figure 51 is a graph showing the two effects together. The torque is rising exponentially as the rotor is lowered.

Let's assume that our initial gap at the dial gauge zero point is 25um (0.025 mm). Every millimeter in depth creates a roughly 5um (0.005 mm) change in gap between the rotor and stator, so if we lower the rotor a whole millimeter our gap changes from 25um to 20um, a 20% change in gap, and therefore a 20% change in shear rate. As the rotor is lowered another millimeter, the actual gap changes by 5um again, but from 20um to 15um, the percentage change is 25%. Lowered another mm, 33%, and again, 50% difference. With evenly placed steps in depth the shear rate does not increase linearly.

Conversely, it can be clearly seen that the equation Torque= Rc x g x η x (s-a) is linear, since it can be re-written as Torque = -ka + ks, where k=Rc.g.η, and which is linear in "a"

Consequently there is a unique point where the torque expected (target) to be generated at that specific height and the actual torque generated at that height will be the same. That is the correct gap for the shear rate being measured (usually, but not limited to, 106 s^{-1}).

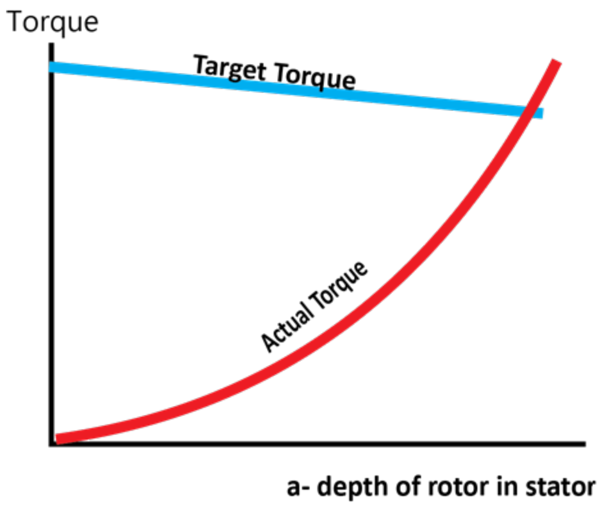


Figure 51: Torque Graph

As a calibration is begun, the rotor is already lowered into the stator by 2.8mm and a standard oil from the collection of pre-entered data is used for measurement. RL 106 is the usual oil for 150˚ C and 106 s^{-1}. **Error! Reference source not found.** shows that the calibration is not correct as the point of the current measured torque (100) is not the same as the target torque (340).

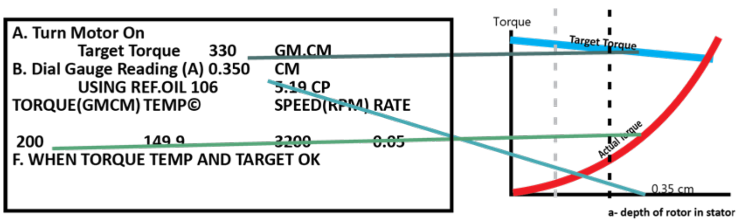


Figure 52: Torque Graph

The next step is to lower the rotor to 0.35 cm. Refer to Figure 53. Generally there is not a destination depth in mind. The operator needs to watch the torque numbers and ensure that the torque doesn't jump up. If the torque creeps up then the motor needs to be stopped with the cutoff switch and investigated, perhaps needing to add fresh oil or raise the rotor and flush it out.

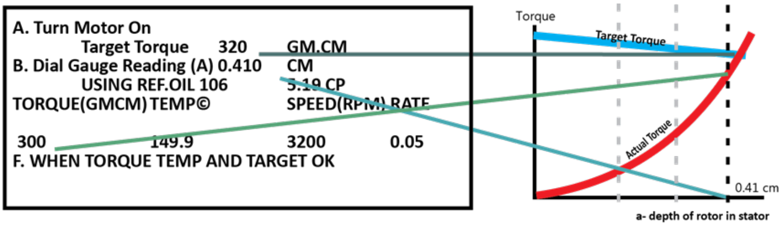


Figure 53: Torque Graph

Figure 54 shows another stage of calibration. With some experience, reducing the number of steps is possible. Now it can be seen that the target is closer and the error is smaller.

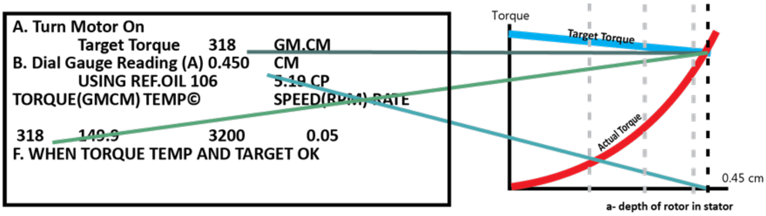


Figure 54: Torque Graph

In the next step the target is even closer. In this stage make small adjustments of the height in the 0.05 mm to 0.01 mm level. Now is the time to add fresh oil and make sure that the rate of rise of temperature through the set point is correct.

In the final step target torque is reached. The measured torque and the target torque are the same as shown in Figure 55, ensuring that volume of oil tested is fresh and that the temperature rose slowly through the set point.

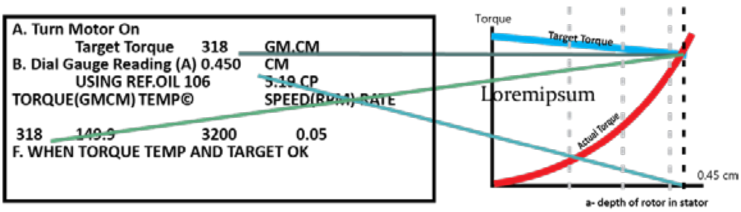


Figure 55: Target Torque

The rest of the calibration can now commence. From now on depth will not be changed.

Note: there is no absolute figure for the depth of the rotor in the stator. Each instrument must derive individual target torque and depth.

There is no absolute figure for the depth of the rotor in the stator. Microscopic surface changes occur during use of the rotor and stator, and each instrument must derive individual target torques and depths on the equipment when the rotor and stator have been levelled and set up.

The target torque on the certificate is the torque which was achieved at intersection in CANNON instrument and laboratory but the torque achieved in another instrument may be slightly different.

Appendix 6 - Instructions for Removing, Cleaning & Re-Fitting the Damping Chamber

Note: The Damping Chamber must be removed before the meaurement head is returned for service. Failure to do so will result in extra service charges.

Removing Damping Chamber:

1. Disconnect the electrical supply.
2. Remove the Head Cover.
3. Remove the Allen screw from the center of the Damping adjustment screw using a 2 mm Allen Key and a small spanner. Keep this screw as it is used when replacing the Damping (below).
4. Slide out the whole Damping chamber.
5. Clean out the damping fluid using a solvent and dry the whole assembly. Do not use any tools as you may remove the lid of the chamber attached with epoxy adhesive.

Replace Damping Chamber:

If performed as described, the performance, centering, alignment and calibration of the instrument should be completely unchanged. Refer to Figure 56.

1. Slip the cleaned Damping chamber under its retaining clip.
2. Adjust its position as necessary until the Damping adjuster can be screwed into the center of the central Damping plate. Do not place pressure on the Damping plate.
3. Replace the Allen screw removed in number 3 of removal (above). Lock it tightly but not excessively.
4. Loosen the adjusting screw until the chamber is free. Slide the chamber around and under its clip, making sure the Damping plate is approximately central in the aperture in the Damping chamber lid.
5. Gently screw down the adjuster until the motor body just ceases to move freely, and then loosen it 1.5 turns. Holding is in this position, fasten the lock nut.

6. Ensure there is no interference between the central Damping plate and the aperture when the motor is moved between stops. Adjust it under its clip until this is correctly fitted.
7. Replace the damping fluid according to instructions provided in manual.

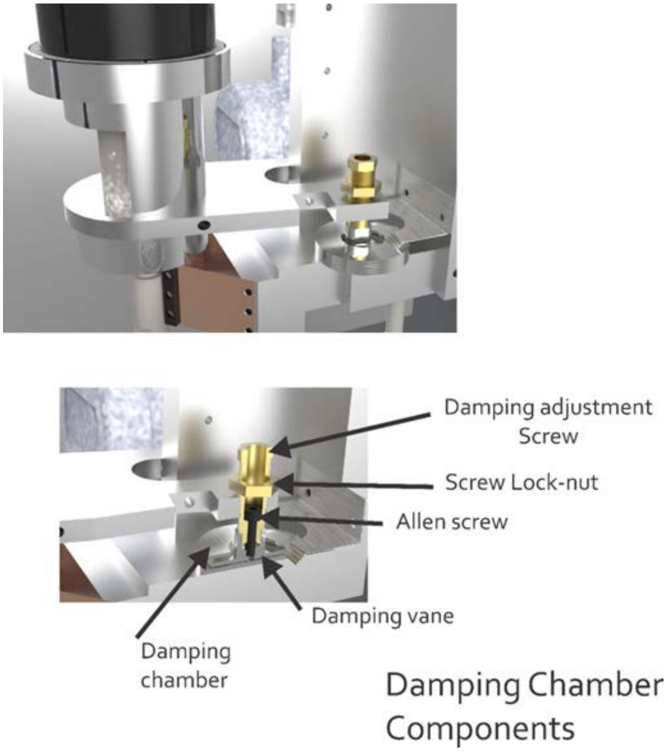


Figure 56: Damping Chamber Components

Appendix 7 - Re-Fitting Plate Springs on Ravenfield BS/C+ Viscometers

These instructions are intended for use by skilled operators, and are only sufficiently detailed for users with engineering training and experience. This process may require at least two people to ensure proper alignment. The supports supplied to protect the springs during delivery are used to set the replacement springs. **DO NOT LOSE THE SUPPORTS.**

1. Disconnect the measurement head electrical connections and pipe connections. Remove the head cover.
2. Remove damper according to previous instructions.
3. Lay the instrument on its back on the bench. Rest the pillar on a wooden block about 38 mm/40 mm thick. Remove the bottom cover by removing three screws. Refer to Figure 57.

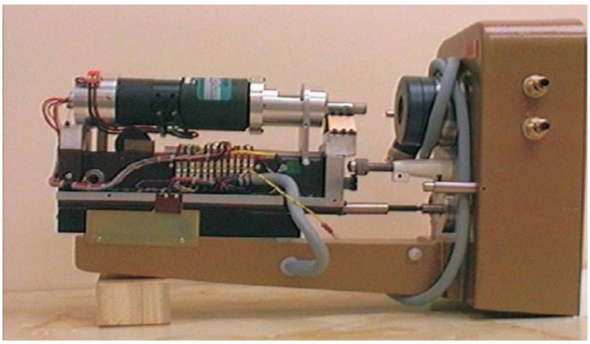


Figure 57: Instrument on its Back with Block for Support

4. Release, but do not remove, the screws holding the front of the plate springs. Refer to Figure 58.

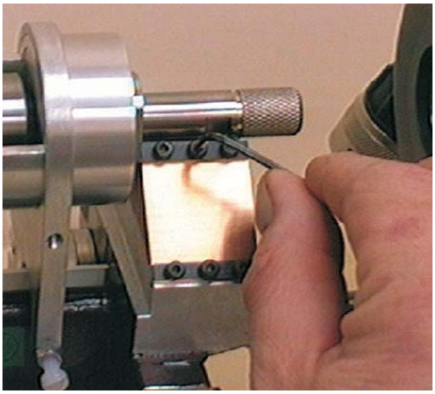


Figure 58: Plate Spring with Screws

5. Release the screws holding the upper wire springs. Slide the two rollers supplied in the Jig Kit in the corners of the notch in the upper part of the yoke. Refer to Figure 59.

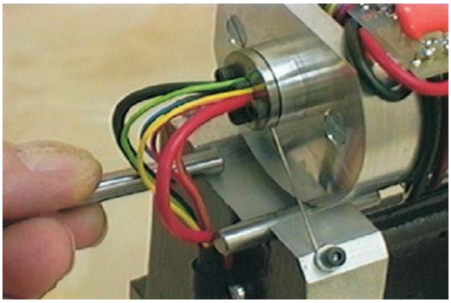


Figure 59: Rollers with Jig Kit

6. Release, but do not remove, all remaining plate spring screws.
7. Slide the block jig with the two balls in its top face under the motor sleeve as shown in Figure 60.

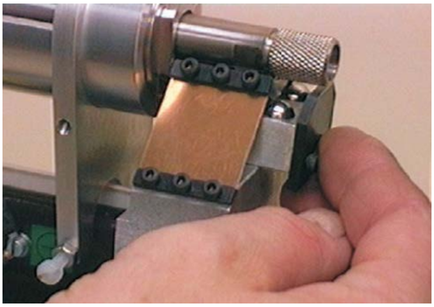


Figure 60: Insert Block under Motor Sleeve

8. Mark the spring clamping plates and then remove all four clamping plates and both plate springs.

9. A small plate with two holes is provided in the Jig Kit. Using two of the screws just removed, fasten the plate to the motor sleeve.
10. Fit the first plate spring to the other side, replacing the clamping plates exactly as they were when they were removed. Leave all the screws loose for the moment.
11. Remove and replace the upper wire springs. Leave the fixing screws loose.
12. Ensure the block jig is pressed against the jig button on the face of the yoke and the lower face of the yoke.
13. Hold the block as described above and slide the motor down until it is touching the jig. Press the plate against the spring plate seat.
14. Hold all these jigs in contact and pinch down the four screws on the wire springs and the six screws on the first plate spring. An assistant may be required for this part of the process.
15. Remove the plate jig.
16. Replace the second plate spring with its clamp plates, replacing the plates as they are removed and not disturbing the rest of the instrument.
17. Tighten all the plate spring screws starting with the four center screws and working around to the rest of the screws in sequence.
18. Carefully slide out the block jig and two rollers. Keep all four parts of the jig bit together.

This completes the plate spring replacement. It is now necessary to re-align the measurement chamber.

Re-Align the Measurement Chamber

Caution: Do not touch the three inner screws marked with red paint as this can cause irreparable harm to the instrument.

1. While the instrument is lying on its back, loosen the three screws marked X.(Do not touch the inner three screws marked with red paint. This will cause irreparable harm.) The three screws marked X should be released only to the point where the measurement chamber is free to slide when pressed from side to side, not to the point where it falls out completely.
2. Raise the instrument to a vertical position. Take care not to place pressure on the motor as this can damage the springs.
3. Remove all covers from the heating chamber. Remove the lower cover by removing the clamping handle, then inserting a broad bladed screwdriver in the provided notch and twisting.
4. Fit the dial test indicator (DTI).

5. Turn the DTI until it is directly over each of the level adjusting screws on the top face of the mounting base. Note the reading. Adjust any two of the screws until the reading is the same at all three positions within ± .001”. Make sure that the DTI is never at its limits.

6. Using a felt marker, mark four lines on the top face of the heating chamber. Lines should be at a 45° angle to the sides of the head. Adjust the DTI to bear on the inside face of the top of the heating chamber. Turn the DTI to one of the three marks and not the reading.

7. Turn the DTI to the opposite mark and note the difference between the two readings.

8. Turn the DTI to the other pair of marks and note the difference in this direction.

9. Decide in which direction the mounting base needs to be moved in order to reduce this variation to less than ± .001” at any point. Turn the DTI to a position where it is necessary to move away from the DTI, tap the base gently with a soft drift and a light hammer until the change of DTI reading is half the difference between that at the opposite sides. Repeat this for the other axis.

Note: It may be necessary to repeat this action several times until the total variation is less that ± .001” as the DTI is turned in a full revolution.

10. Retighten the screws marked X from step 1.

11. Re-check the DTI both inside and on top of the chamber so the variation is less than ± .001”.

12. Remove the DTI, replace the base cover and replace the heating cover.

13. Check that the LVDT core is not touching the inside of the bore.

14. Loosen both limit stop screws.

15. Re-calibrate the torque according to manual instructions.

16. Set the limit stop screws to allow the motor to give readings of approximately -250 to +800 and re-lock the lock nuts.

17. Replace all remaining covers.

Appendix 8 - LVDT Re-Alignment

1. Mount the head on a level surface at a convenient height while it is connected to the electronics unit. Apply power to the instrument and remove the flexible coupling. Lower the head onto the ball stop as in normal calibration.
2. Loosen the Allen screw below the torque transducer one or two turns; tap it gently to loosen the wedge clamp attached. Slide the transducer body lengthways until it read a negative value. Note this value, and then slide it back until it reads 2/3 of this negative value. Refer to Figure 61.

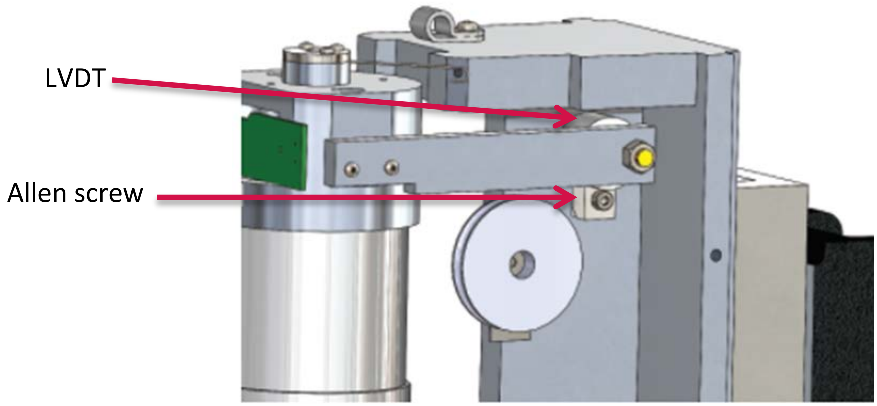


Figure 61: LVDT and Allen Screw

3. Calibrate the instrument in the usual way. Switch instrument off, put Keyswitch to **SET**, wait for movement to cease, and then press **SET** button. Fit the calibration weight, press **SET** button. Switch to **RUN**. Check that the limit stops touching. Check that a slight force on weight makes the reading increase.
4. If instrument reads correctly, loosely re-lock the Allen screw.
5. Calibrate the instrument again.
6. Using the previously used weights, check to ensure a straight line is created.
7. If line is not straight, repeat step 2. This procedure is self-correcting and should be accurate the second time.

Appendix 9 – Calculation Sheet

High Temperature High Shear

Report Form Tests ASTM D 4741m IP 370, CEC L36 A 90

Date ______________________ Operator ____

Rotor/Stator Pair Number ________________________ Target Torque______________ gm/cms

Calibration

Gradient____________________________ Torque Intercept___________________________

Correlation Coefficient ____________________ Viscosity Intercept ____________________

Digital Gauge Reading _______________________

Sample Identity	Torque 1	Torque 2	Torque 3	Mean	Viscosity

Appendix 10 - Julabo® Bath Quick Start

More information and additional languages are available on the Julabo® bath website at www.julabo.com.

All Ravenfield by CANNON HTHS instruments are supplied with Julabo® external heating circulators. This is just a concise, quick-start guide. The full Julabo® manual is included with the bath. Once the instrument has been set up there is little operator input required.

Note: Hot silicone oil at close to test temperature is pumped around the outside of the stator in the instrument. It is important the instrument is warm before commencing work.

Switching On

The bath should be turned on and run at least 30 minutes before beginning work.

1. Turn the **ON** switch to the on position.
2. Press the **OK** (start) button as shown in Figure 62.

Adjusting Set Point

Generally, during routine use the bath set-point is set and not adjusted. During calibration, which uses a wider range of oils to create the critical instrument calibration curve, it is necessary to run the bath at a higher temperature with low viscosity standards and a lower temperature with high viscosity standards.

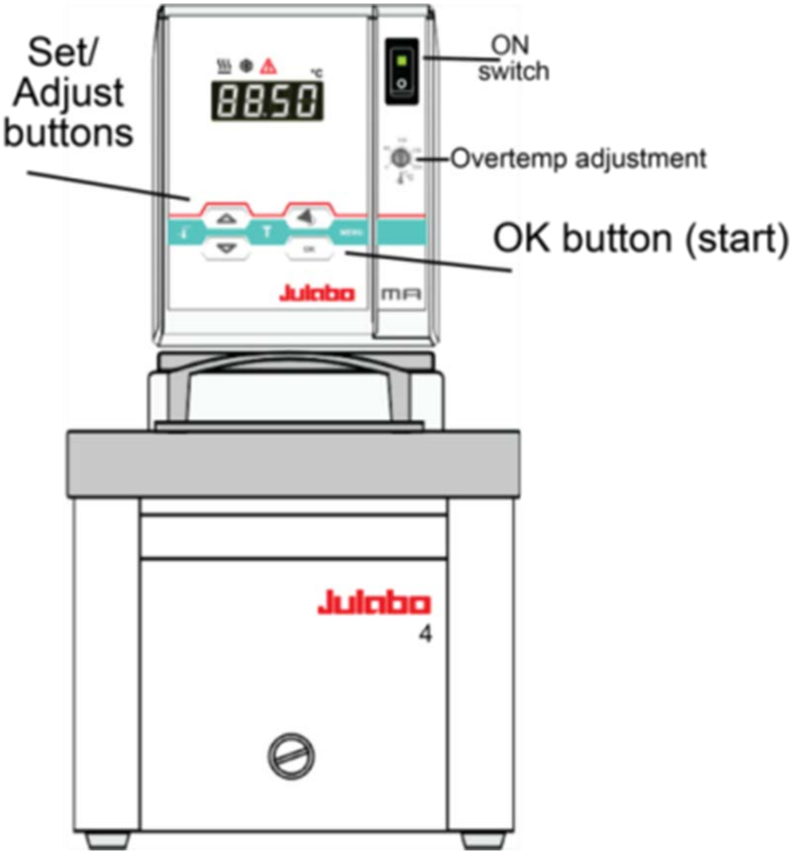


Figure 62: Julabo Display Diagram

Set Up Julabo MA Circulator for Use with Ravenfield by CANNON BS/C+ HTHS Viscometer

Setting the configuration options is done with the circulator in OFF mode. Pressing the (back) key stores the current setting and exits the current menu level.

Note: The set up procedure for the Julabo bath is rarely needed as the unit is configured prior to shipping. These instructions are included in the rare case that the bath is not configured or needs to be set up again.

For Use With or Without the Autosampler

Set Pump Pressure

8. Press **Menu** key. **Pu** is displayed.
9. Press **OK**. Current pump pressure will flash.

10. Press up or down arrow keys until **4** is displayed. Press **OK.**
11. Press back arrow key to return to the **OFF** display.

Set 3 Temperature Mode

1. Press **Menu** key.
2. Press down arrow. **CFG** is displayed, press **OK.**
3. **3SP** is displayed, press **OK.**
4. Press up or down arrow keys until **YES** displays. Press **OK.**
5. Press back arrow twice to return to the **OFF** display.

For Use without Autosampler

Set initial operating temperatures (can also be done while bath is in heating mode).

1. Press **T** key. **tx** is displayed, press up arrow key until **t1** displays
2. Hold **OK** key until the integer digits flash.
3. Press up or down arrows to set the temperature to 155.0 °C and press **OK**.
4. The decimal digits flash, press **OK.**
5. **t1** flashes, press up or down arrows until **t2** is displayed.
6. Hold **OK** until the integer digits flash.
7. Press up or down arrows to set the temperature to 153.0 °C and press **OK**.
8. The decimal digits flash, press the up or down arrows to set temperature to 153.5 °C and press **OK**.
9. **t2** flashes, press down arrow until **t3** displays.
10. Hold **OK** key until the integer digits flash
11. Press up or down arrow to set temperature to 152.0 °C and press **OK**.
12. The decimal digits flash, press **OK**. **t3** flashes.
13. Press back arrow to return to the **OFF** display (or live temperature display if bath is in heating mode).

These temperatures may need adjusting during operation to achieve the correct rate of rise of temperature of less than 0.04 °C per second as the torque reading is taken automatically at the desired test temperature.

For Use with Autosampler

Set Remote Control:

1. Press **Menu** key. Press down arrow until **CFG** is displayed, press **OK**.
2. Press down arrow until **rt** is displayed. Press **OK**.
3. Current remote control setting is displayed. Press up or down arrows until **ON** displays, then press **OK**.
4. Press ↻ back arrow to return to **OFF** screen.

Select Temperature Setpoint 1:

1. Press **T** key. **tx** is displayed. Press up arrow key until **t1** displays.
2. Press **OK**
3. **t1** flashes, enter numbers for temperate 1 setpoint.

Set baud Rate:

1. Press **Menu** key
2. Press down arrow until **CFG** displays. Then press **OK**.
3. Press down arrow until **SEr** displays, press **OK**.
4. **br** is displayed, press **OK.**
5. Current baud rate will flash. Press up or down arrows until **9.6** is displayed.
6. Press **OK.**
7. Press ↻ back arrow to return to **Off** screen.

Set Parity:

1. Press **Menu** key.
2. Press down arrow until **CFG** displays, then press **OK.**
3. Press down arrow until **SEr** displays, then press **OK**.
4. Press down arrow until **Pty** displays, press **OK**.
5. Current parity setting will flash. Press up or down arrows until **o** displays.
6. Press **OK.**

7. Press back arrow to return to the **Off** display.

Set Handshake:

1. Press **Menu** key.
2. Press down arrow until **CFG** displays, then press **OK**.
3. Press down arrow until **SEr** displays and press **OK**.
4. Press down arrow until **HS** displays, press **OK**.
5. Current handshake setting will flash. Press up or down arrows until **SOFt** is displayed. Press **OK**.
6. Press back arrow to return to **Off** display.

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