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Lubricity Evaluation Monitor

Part No. 113-00

Instruction Manual

Updated 9/23/24

Ver. 9

OFI Testing Equipment, Inc.

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Introduction

The Lubricity Evaluation Monitor (LEM) measures relative friction factors under ambient temperature and pressure. It is designed to provide lubricity comparisons between different fluid systems and/or fluid additives. The unit can utilize frictional materials such as sandstone or casing.

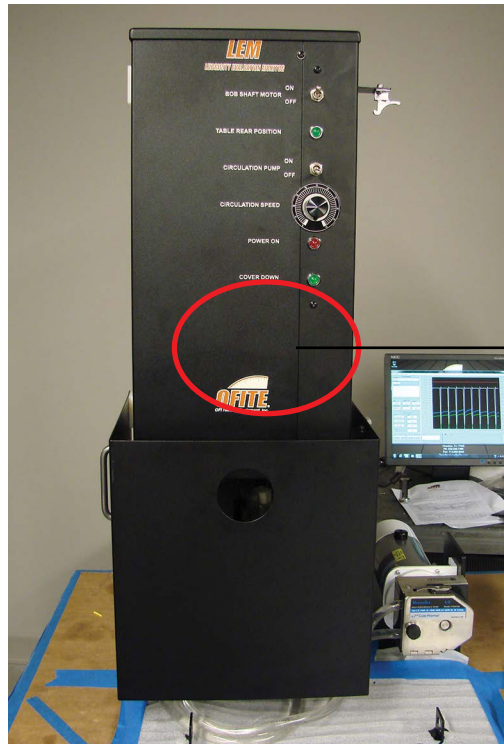
Description

The LEM provides fluid lubricity characterization by measuring the friction factor between a rotating bob and a simulated wellbore or rock sample immersed in the fluid of interest. The friction factor (cF) is calculated using the following equation:

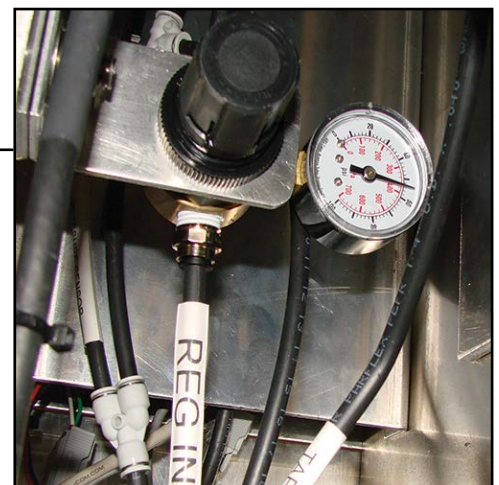
$cF = \tau / (F * d)$, where τ is the torque, F is the side load and d is the diameter. The side load is periodically relieved to allow fluid refreshment in the bob/well bore interface. Load is applied with a pneumatic cylinder with a computer controlled pressure regulator and torque is measured with a rotational torque meter. Fluid is circulated around the bob and sample wellbore during testing.

Specifications

- Electrical Supply: 220 Volts
- Air Supply: 60–100 PSI
- Sample cup capacity: 350 mL
- Range of Mud Weights: 0.83–18.0 lb
- Torque Transducer Maximum Range: 100 lbf-in
- Torque Resolution: +/- 0.1% of full scale combined
- Maximum Side Load: 60 lbf
- Maximum Rotational Speed: 200 RPM
- Speed of Circulating Pump: 20–500 RPM
- Calibration: Coefficient of Friction of Water = .32–.36
- Test Cell Material: Acrylic
- Bob Material: 4140 Steel - Rockwell Hardness of 37



To ensure that the gauge is set at 60 PSI, check the Regulator and Gauge which are located underneath the front panel. There is no need for adjustment.



Components

#113-00-003	Quick Connect Fitting for Cell, Male
#113-00-004	Quick Connect Fitting for Cell, Female
#113-00-008	Pressure Transducer, 60 PSI
#113-00-009	Gauge, Calibration
#113-00-010	Torque Transducer
#113-00-013	Masterflex Peristaltic Pump
#113-00-014	Tygon Tubing, 1 Foot, Qty: 4
#113-00-020	Pressure Precision Regulator
#113-00-022	Gauge, 1.5", 100 PSI, 1/8" NPT
#113-00-050	Acrylic Cell
#113-00-058A	Acrylic Cell, 5.25"
#113-00-058B	Acrylic Cell, 4"
#113-00-060	Axle, Calibration
#113-00-061	Bob Shaft
#113-00-070-1	Sandstone Sample, Berea, Qty. 12
#113-00-071	Sample Retainer, Qty. 4
#113-00-073-2	Adapter Plate, Rock Specimen
#113-00-222-1	Casing Sample N80
#113-00-224	Arm, Calibration
#122-077	10 Amp Fuse, Qty. 10
#130-78-21	O-ring for Cell, Viton 70D

Tools

#113-00-082	Collet Wrench
#113-00-223	1 1/4" Back Up Wrench
3/16"	Combination Wrench

Optional

#113-00-101	Heat Cup for LEM
#113-00-509	Cartridge Heater, 200 Watt
#130-76-03	Thermocouple, Type J
#152-37	AC Power Cord
#171-49	Temperature Control Unit, 115 Volt
#172-09	Fuse, 10 Amp

Quick Start

1. Connect the LEM to a secure power source, the computer, and an air supply. See the support image on page 5.
2. Make sure that the bob shaft motor and circulation pump switches are "OFF".
3. Switch on Main power in back of LEM.
4. Power up the computer and start the software.
5. Turn on the air system and listen for leaks.
6. Calibrate the torque. See page 16. Log the calibration readings.
7. Install the bob.
8. Prepare the wellbore sample. See page 9.
9. Install the test chamber without test fluid to align the bob with the sample inside the cell. See page 11.
10. Remove the test chamber and fill it with test fluid.
11. Install the test chamber with fluid to the LEM and install the flex hose. See page 11.
12. Close the protective safety guard.
13. Create test information and perform a test. See page 12.

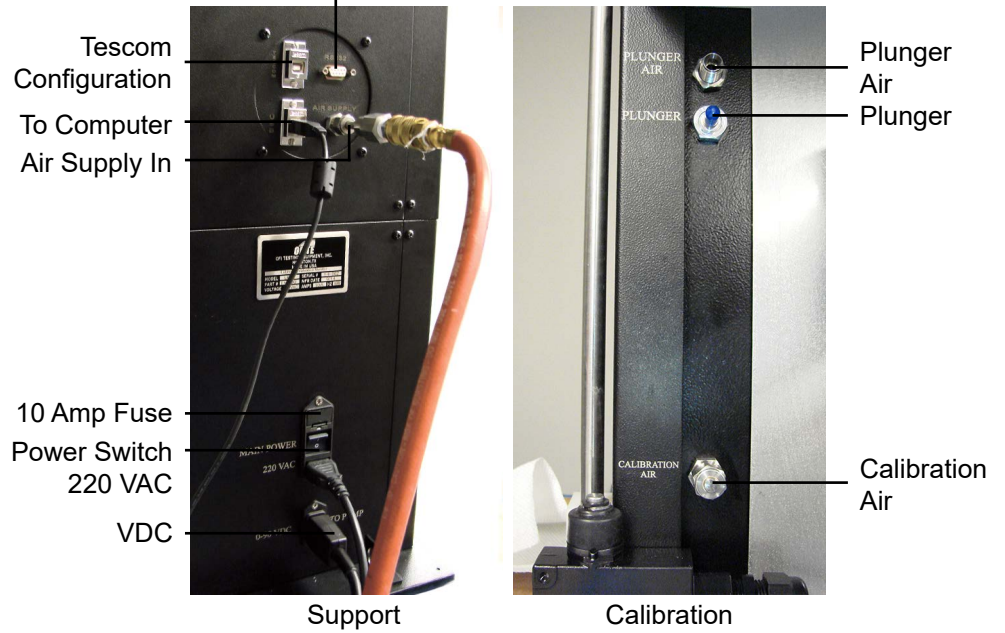
Controls Layout

The main panel is located on the front of the machine, the support panel is at the rear and the calibration panel at the lower left. The controls layout can be seen in the following photos:



Main

Serial Cable
For Torque



Support

Calibration

Functional Descriptions



Bob System

The bob rotation system consists of a computer-controlled DC motor controller driving a 90° gear motor. Rotary motion is transferred through a shaft mounted torque meter. The bob shaft assembly is held in place by a collet system. Wrenches are provided to loosen the collet for bob shaft removal.

Make sure that the bob shaft motor is always “OFF” before removing/ installing the bob shaft.

Side Load System

The side-load system uses a computer controlled pressure regulator to supply controlled pressure to a pneumatic cylinder attached to the sample holder. A separate pressure transducer is used to feed the pressure (i.e. side load) to the computer. A series of solenoid valves are used to provide safe operation. A push-back function is available to periodically relieve the side load to allow new fluid between the bob and sample. A pressure port to verify calibration is provided in the calibration control panel.

Fluids System

The fluid system is designed to immerse the bob and sample in the test fluid. Circulation is provided with a peristaltic pump (#113-00-013). The test chamber is held onto the side load cylinder with an easily removed strap clamp. The pump easily opens to release the flexible tubing so the intact circulation system can be removed to a separate location for cleaning and disassembly. Quick-connect fittings on the tubing allow for cleaning between test fluids. Tools are provided to allow easy disassembly of the chamber and frictional samples are easily changed with standard hand tools.

Automated Control and Data Acquisition

The unit is designed to run using Windows PC. A USB interface exists between the computer and the machine. RS232 and USB ports are used during maintenance for the torque meter. Test data is stored in a text file suitable for import into commercially available spreadsheet software if more detailed analysis is required. Bob rotation, side-load, and the sample push-back function are all controlled by the personal computer.

Safety Features

Various safety features have been designed into the operation and maintenance of the unit. When the front sliding guard is opened to expose the test chamber, the bob rotation stops, and pneumatic pressure to the side-load cylinder is released. The test cell and circulation system removes as a single assembly for ease of clean up. Specialized tools ease the disassembly of the test cell. Routine calibrations can be performed without opening covers and exposing personnel to internal components.

Setup

Hardware

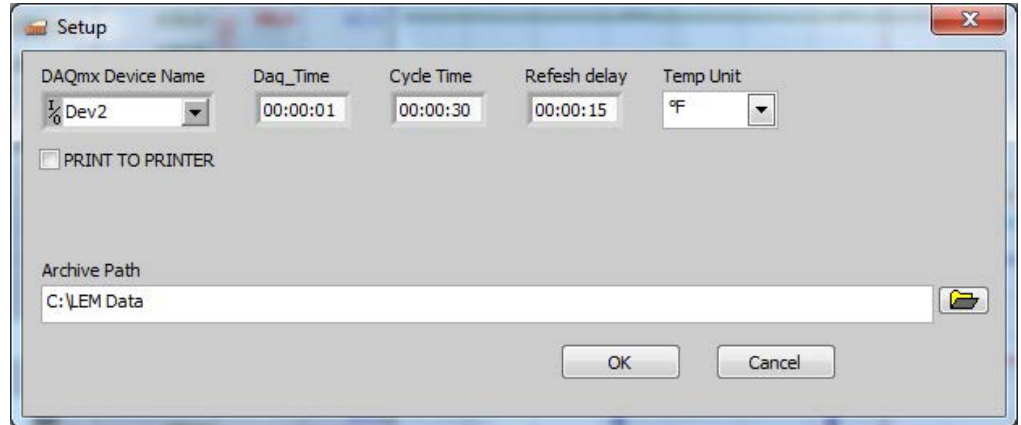
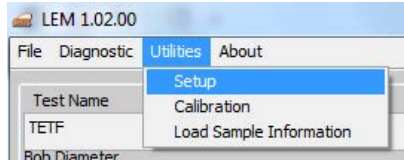
1. Plug the unit into an appropriate power source.
2. Connect an air source to the port on the back.
3. Connect the computer to the USB port.
4. Turn the Main Power switch ON.
5. Open the LEM software by clicking the icon on the desktop.
6. Set the BOB SHAFT MOTOR switch to ON.
7. Click ENABLE MOTOR and enter a desired RPM. The bob shaft should start to turn.
8. Lift the safety cover and plastic stop. The bob should stop rotating.
9. Set the BOB SHAFT MOTOR switch to OFF.
10. Lower the safety cover.



Operation of the safety cover system must be checked upon installation, calibration, or equipment movement. Do not use the equipment without an operating safety cover.

Setup

Software



Select "Setup" from the Utilities menu.

DAQmx Device Name

Indicates which device is collecting data.

Daq_Time

Indicates how often data is being read. (HH:MM:SS)

Cycle Time

Indicates how long between side-load refresh. (HH:MM:SS)

Refresh Delay

Indicates how long the side-load is disengaged during the test. (HH:MM:SS)
The time can be used to make adjustments to test fluid while data is not being collected.

Sample Installation



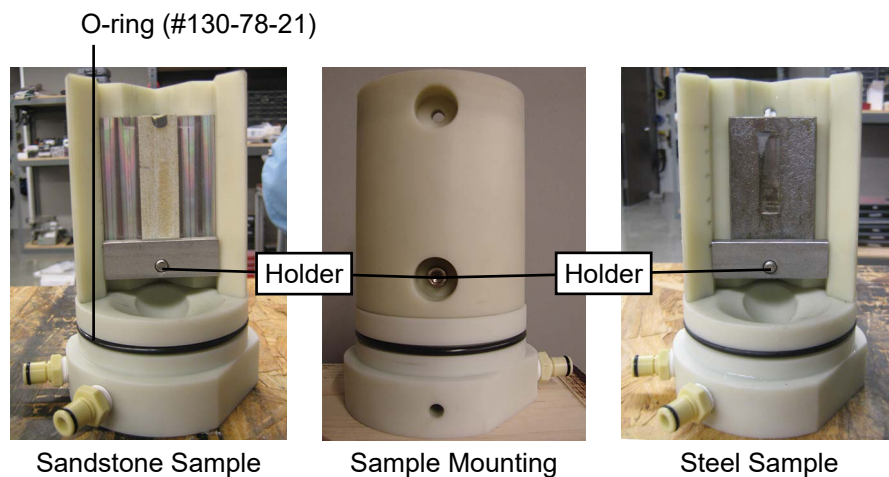
Sandstone Sample Preparation

1. Soak the sandstone in water (WBM test) or oil (OBM test).
2. Insert the sample and tighten the holder nuts to prevent the sample movement during the test.
3. Use a new sample for each different lubricant. Sandstone samples cannot be cleaned.

Steel Sample Preparation

1. Insert the sample and tighten the holder nuts.

DO NOT OVER TIGHTEN.



2. Assemble the mud cell with the 4" acrylic body.
3. Install the bob into the LEM and apply a small amount of grinding compound to the bob surface.
4. Install the mud cell in the machine. Start LEM rotation. Apply 25–30 lbf of load.
5. Continue until there is a small groove in the casing sample the length of the test bob.

Test Cell Bodies Standard and Short



5 ¼" Cell Body

4" Cell Body

6. Remove the 4" cell. Thoroughly clean the cell and casing with water and detergent. Clean both the steel sample and the bob with acetone or other alcohol based agents. Do not touch the steel sample or bob without wearing gloves.

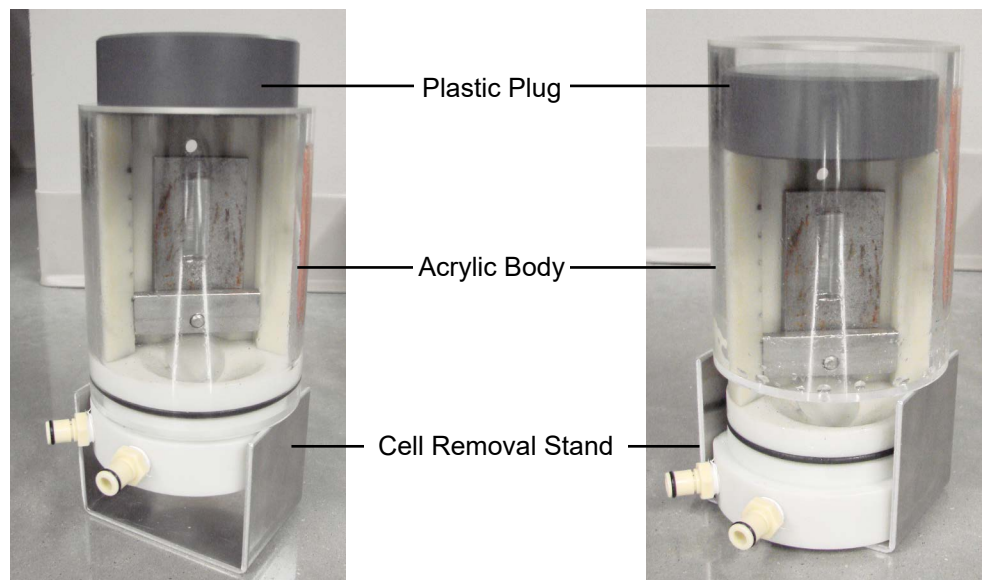
DO NOT remove the steel sample from the cell.

7. Assemble the cell with the 5 ¼" acrylic cell.

The main pump switch must be off prior to installing the test chamber.

Disassembly

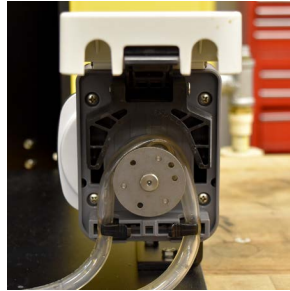
1. Remove the clear acrylic body from the mud cell base.
2. Pour the liquid out of the cell.
3. Separate the acrylic body by placing the test cell in the aluminum cell removal stand, inserting the plastic plug on top, and pushing firmly down on the plug.



Test Cell Body Removal

Test Chamber Installation

1. Check the bob condition. The bob should have an even surface and a smooth knurl profile.
2. Install the bob and the assembled cell. Check the sample/bob alignment inside the mud cell.



Flex Hose Installation

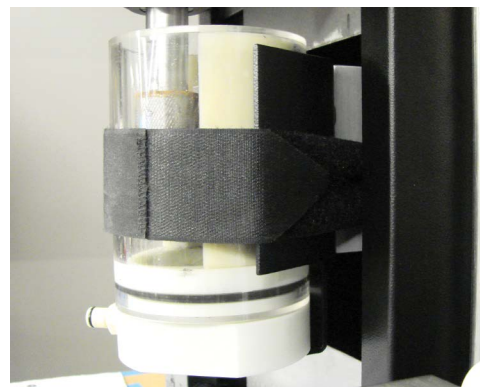
3. Attach the flex hose to the test cell using quick connects.



Tip

Inspect the hose prior to each use as the pump tends to wear holes at mating surfaces.

4. Fill the test chamber with 325 mL of test fluid.
5. Position the test cell so the pin is in line with the hole in test chamber.
6. Secure the cell assembly with the Velcro strap.



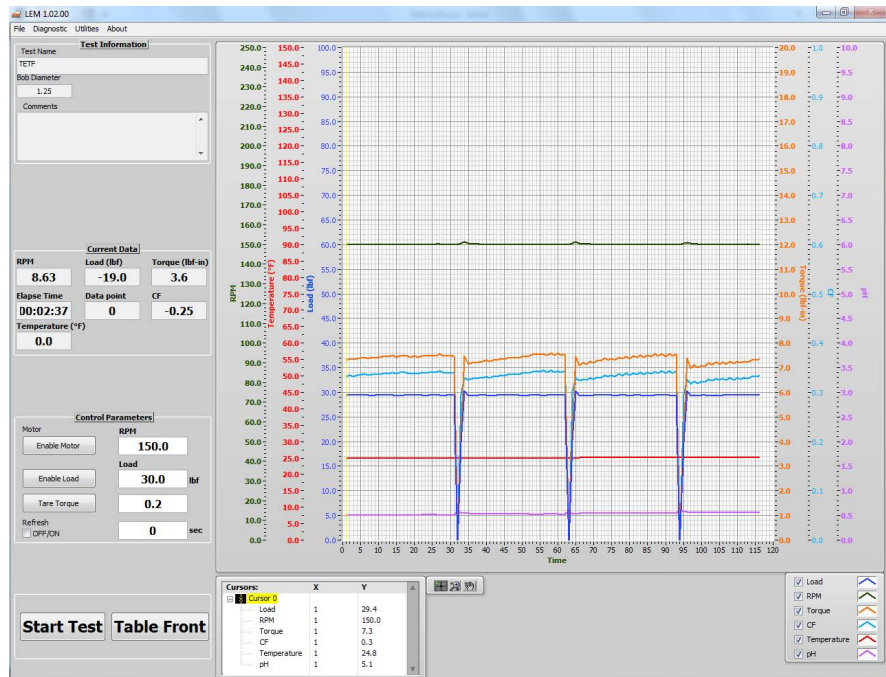
7. Install the flex hoses into the peristaltic pump. The hose end from the right side of chamber (output) goes to top of pump head.

8. Lower the safety guard.

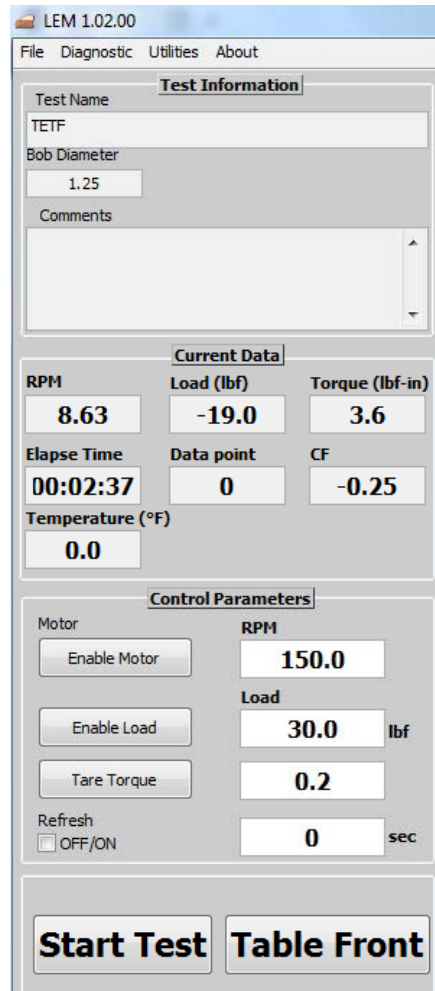


Test Procedure

1. Inspect the bob condition.
2. Install the sample and bob.
3. Install the assembled cell without test fluid and align the sample with the bob inside the cell. Remove the cell and fill with test fluid.
4. Install the test chamber with fluid in the machine and insert flex hose into the pump. Make sure the fluid completely covers the sample.
5. Start LEM program by clicking the LEM icon on the desktop.



Program Entry Screen

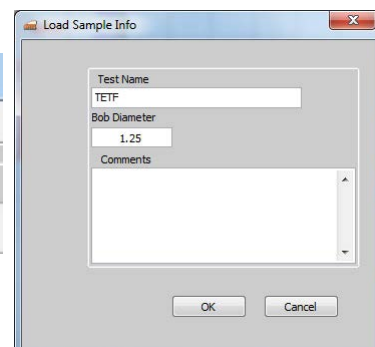
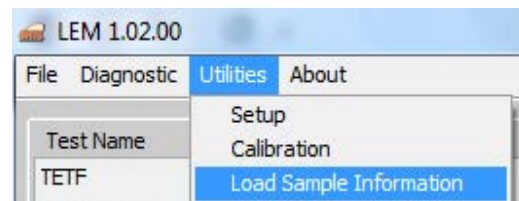


6. Enter a Test Name (a file name will be selected automatically based on that information).
7. Enter a test description and test parameters (You can type in the values for RPM, Load, and Torque). If needed, you can change bob diameter on this screen (COF calculation is based on this number).



Note

If you click the **START** button without entering a test name, a “Load Sample Info” window will appear to edit or confirm the Test Name, Bob Diameter, and comments. This window can also be found by clicking the **Load Sample Info** button in the **Utilities Tab**.





LEM Front Panel with Indicator Lights

8. Lower the guard. The **Power On** and **Cover Down** lights on the front panel will turn on. Turn the **Bob Shaft Motor** and mud **Circulation Pump ON**.
9. Click **ENABLE MOTOR** in the software and wait (approximately 1 minute) until the RPM reading is close to set point.
10. Click **TARE TORQUE** to zero the torque transducer.

The CF value should remain around 0.00.

11. Click **TABLE FRONT** to apply side force to the bob then **START TEST** to begin data collection. The program allows you to choose two operating conditions for machine operation and data collection.

The **Refresh** option in Control Parameters determines how soon, after a refresh, the software will resume collecting data. To turn this option on, place a check in the box. Then enter a time (seconds) in the box next to it. The software will wait this number of seconds after a refresh before collecting data. When this option is turned off (unchecked), the software will be collecting data immediately after a refresh. No data will ever be collected during a refresh.

12. Run the machine to collect about 600 data points or until stable COF readings are obtained. Click **STOP TEST** and **TABLE BACK**. The data file will be saved automatically. Turn the **Bob Shaft Motor** and **Circulation Pump OFF**. Lift the guard to stop the machine. Remove the tubing from the pump and remove the cell. Wash the cell and bob with detergent.
13. Click **EXIT** prior to closing program to turn off outputs.



Important

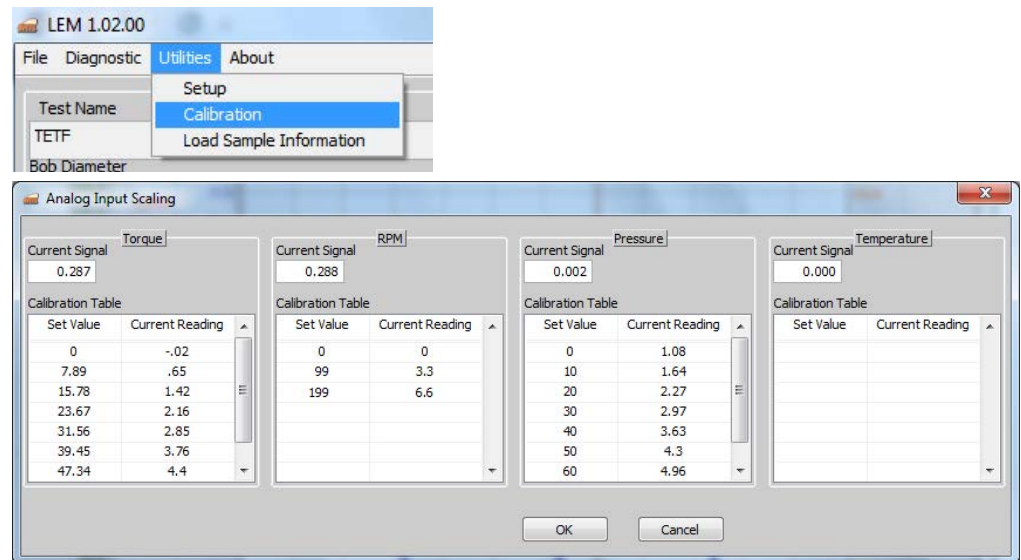


Note

Calibration

Torque, RPM, and Pressure

The LEM comes pre-calibrated. The following steps should only be done if output values change radically. Select **Calibration** from the **Utilities** menu.



Torque Calibration

Determine the measured torque value (see page 16). Enter this value in the **Set Value** field and enter the value from the **Current Signal** field into the **Current Reading** field.

RPM Calibration

1. Open the Calibration Screen.
2. In the Calibration Table, enter the following values:

Set Value	Current Reading
0	0
300	10

Pressure Calibration

The pressure should only be calibrated by an OFITE technician after replacing the pressure transducer.

Temperature Calibration

Place the thermocouple in a dry block calibrator and set the temperature to 100°F (37.8°C). When the temperature has stabilized, enter the temperature from the dry block into the **Set Value** field and enter the value from the **Current Signal** field into the **Current Reading** field. Now repeat this process at 200°F (93.3°C).

Torque Calibration

Setup



Rear view during operation

Make sure the Bob Shaft Motor and Circulation Pump switches are OFF. It will cause severe damage to the unit and the operator if the motor and pump switches are not off prior to calibration.

1. Install the Shaft Locking Pin.
 - a. Insert the pin into the access port on the side of the LEM.
 - b. Manually rotate the bottom of the shaft slowly until the hole for the locking pin can be felt. Push the locking pin into the shaft.
 - c. Tighten the locking nut onto the pin.

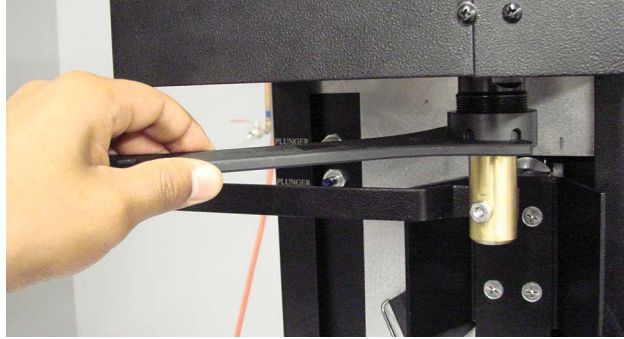


Pin Out

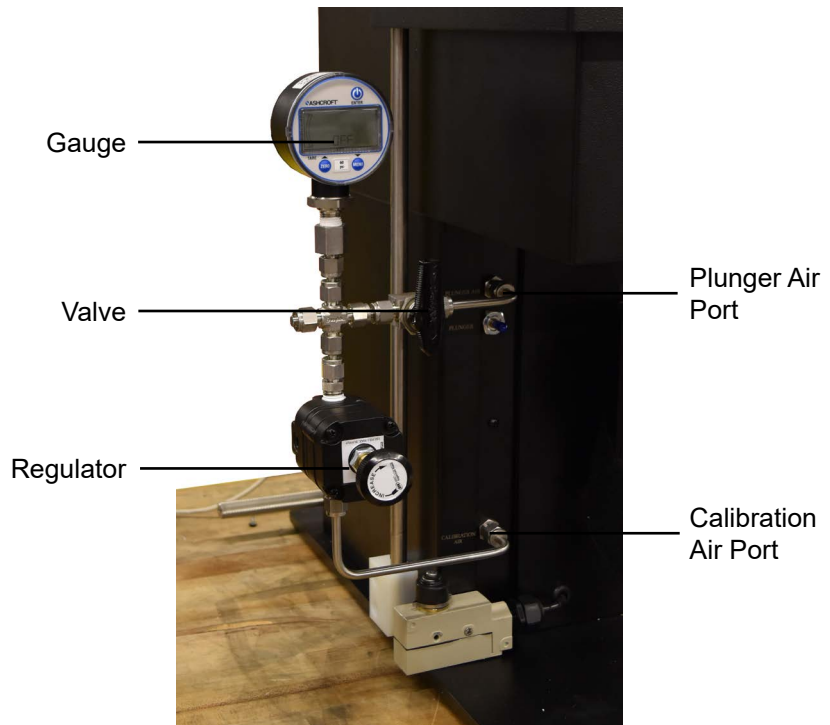


Pin In With Cap

2. Install the Torque Arm.
 - a. Align the torque arm on the shaft so that the arm is level with the plunger and is centered with the shaft, paralleled to the front face of the LEM.
 - b. Tighten the torque arm with the provided wrench.



3. Install the calibration assembly with the valve connected to the Plunger port and the regulator connected to the Calibration Air port.



Calibration Assembly

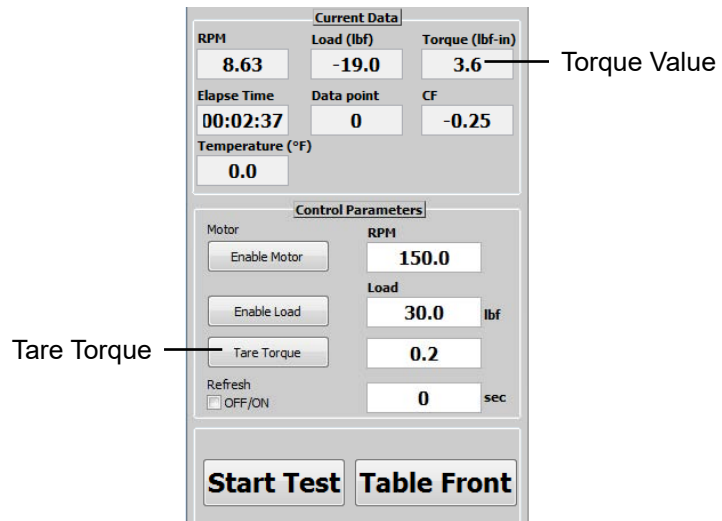
Make sure that the valve is in the closed (off) position before installing.



Torque Calibration Procedure

1. Adjust the regulator so that the pressure gauge reaches a desired known PSI which is displayed on the gauge.

Once the regulator has been adjusted, air will travel through the calibration hose assembly up to the closed ball valve but not to the plunger port.



2. Press the TARE TORQUE button and ensure that the CF value is at 0.00.
3. To create torque, open the ball valve to activate the plunger and apply pressure to the torque arm.
4. In the Torque section of the Analog Input Scaling screen (see page 15), enter the value from the Current Signal field into the Current Reading field.

Heat Cup

The optional Heat Cup (#113-00-101) can be used to heat the sample up to 180°F (82.2°C). The included Temperature Control Unit (#171-49) uses a digital temperature controller to maintain the temperature during testing.

Installation

1. Remove the acrylic cylinder from the test cell.
2. Place the stainless steel heating jacket onto the cell base.
3. Remove the hose fittings from the cell base.
4. Wrap the new stainless steel fittings with Teflon tape and screw them into the cell base.

Operation

1. Place the test sample into the Heat Cup and secure it as described on page 9.
2. Install the Heat Cup without test fluid and align the sample with the bob inside the cell. Remove the Heat Cup and fill it with test fluid.
3. Insert one thermocouple into the space behind the sample and plug it into the port on the underside of the LEM unit.
4. Insert the other thermocouple into the hole in the top of the jacket and plug it into the port on the front or back of the Temperature Control Unit.
5. Plug the heater into the front or back of the Temperature Control Unit.

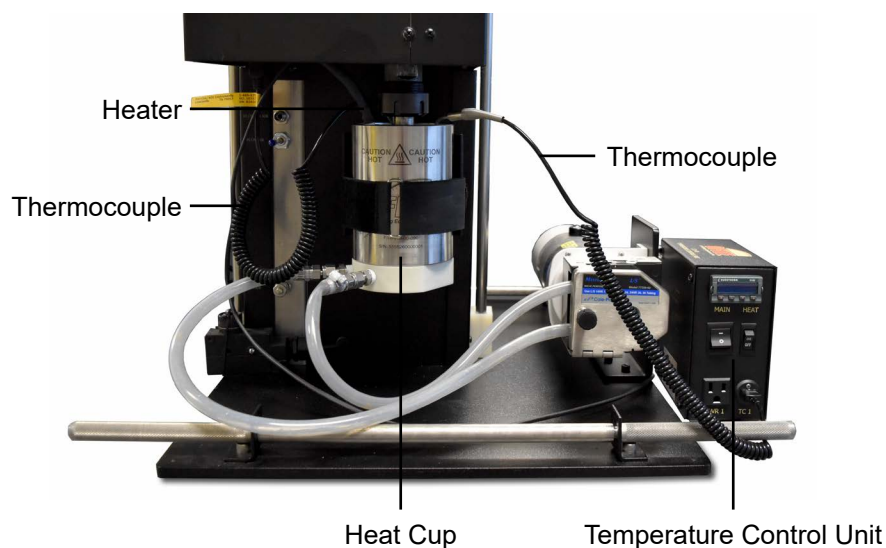
Thermocouple -
To LEM

Heater



Thermocouple - To
Temperature Control
Unit

6. Place the Heat Cup in the LEM unit and secure it with the strap.



7. Turn the Temperature Control Unit on. The display will show the current temperature.
8. Use the up and down arrows to set the temperature. Refer to the instruction manual for the Temperature Control Unit for more information.
9. When the test is complete, use the down arrow to set the temperature to 0.



After the test the cell will be very hot! Do not touch it until it has cooled completely.

10. After the cell has cooled, remove it from the unit and clean it thoroughly.

Removing the Hoses

The Heat Cup can be properly cleaned without removing the hoses. However, the hoses were designed to be removed for replacement or if additional cleaning is necessary.

1. Place a 9/16" wrench on the fitting attached to the Heat Cup. Hold the fitting in place.
2. Place another 9/16" wrench on the fitting attached to the hose. Carefully unscrew and remove the fitting.



Make sure the fitting attached to the Heat Cup remains stationary. If it turns, it could damage the connection to the Heat Cup.

Standardize the Shaft and Sample

1. Connect the unit to air and to the computer.
2. Install a clean and undamaged bob shaft (#113-00-061).
3. Prepare the cell for testing with a casing sample (#113-00-222-1) and the 4" acrylic cell (#113-00-058B).
 - a. Insert the sample and tighten the holder nuts. Do not over tighten.
 - b. Assemble the mud cell with the 4" acrylic body.
4. Prepare the cell for grinding using course grinding compound.
 - a. Coat the shaft with grinding compound.
 - b. Set the speed to 150 rpm and press the Enable Motor button.
 - c. Press the Table Front button to put the sample and bob shaft into contact.
 - d. Set the load at 60 lbf and enable.
5. Grind using course grinding compound for 1 hour, applying compound every 10 minutes.



Tip

To apply new compound, press the Table Back button and use a brush to coat the center of the sample and shaft with grinding compound.

6. Grind using fine grinding compound for 2 hours, applying compound every 10 minutes.
7. Remove and completely clean all components in a sonic bath.
8. Clean the shaft and sample with acetone.

DO NOT get acetone on the acrylic cell.



Important

9. Check for a smooth contact surface on the shaft and sample.
10. Reinstall the cell and shaft and add 350 mL of deionized water.
11. Connect the hoses to the pump.
12. Make sure the sample and shaft are not in contact. You may need to press the Table Back button.
13. Set the speed to 150 rpm, enable the motor, and allow the unit to run for 2 minutes.

14. Set the load to 40 lbf and enable the load.
15. Press the Tare Torque button.
16. Press the Table Bront button to have the sample and shaft make contact.
17. Let the unit run for 5 minutes to confirm the value is stable at 34 ± 2 .
18. Enter the Test Name.
19. Press the Start Test button and record 5 minutes of the unit at 34 ± 2 .
20. Press the Stop Test button, turn off the load and motor, and remove the cell.
21. Clean the unit and cell completely.

Warranty and Return Policy

Warranty:

OFI Testing Equipment, Inc. (OFITE) warrants that the products shall be free from liens and defects in title, and shall conform in all respects to the terms of the sales order and the specifications applicable to the products. All products shall be furnished subject to OFITE's standard manufacturing variations and practices. Unless the warranty period is otherwise extended in writing, the following warranty shall apply: if, at any time prior to twelve (12) months from the date of invoice, the products, or any part thereof, do not conform to these warranties or to the specifications applicable thereto, and OFITE is so notified in writing upon discovery, OFITE shall promptly repair or replace the defective products. Notwithstanding the foregoing, OFITE's warranty obligations shall not extend to any use by the buyer of the products in conditions more severe than OFITE's recommendations, nor to any defects which were visually observable by the buyer but which are not promptly brought to OFITE's attention.

In the event that the buyer has purchased installation and commissioning services on applicable products, the above warranty shall extend for an additional period of twelve (12) months from the date of the original warranty expiration for such products.

In the event that OFITE is requested to provide customized research and development for the buyer, OFITE shall use its best efforts but makes no guarantees to the buyer that any products will be provided.

OFITE makes no other warranties or guarantees to the buyer, either express or implied, and the warranties provided in this clause shall be exclusive of any other warranties including ANY IMPLIED OR STATUTORY WARRANTIES OF FITNESS FOR PURPOSE, MERCHANTABILITY, AND OTHER STATUTORY REMEDIES WHICH ARE WAIVED.

This limited warranty does not cover any losses or damages that occur as a result of:

- Improper installation or maintenance of the products
- Misuse
- Neglect
- Adjustment by non-authorized sources
- Improper environment
- Excessive or inadequate heating or air conditioning or electrical power failures, surges, or other irregularities
- Equipment, products, or material not manufactured by OFITE
- Firmware or hardware that have been modified or altered by a third party
- Consumable parts (bearings, accessories, etc.)

Returns and Repairs:

Items being returned must be carefully packaged to prevent damage in shipment and insured against possible damage or loss. OFITE will not be responsible for equipment damaged due to insufficient packaging.

Any non-defective items returned to OFITE within ninety (90) days of invoice are subject to a 15% restocking fee. Items returned must be received by OFITE in original condition for it to be accepted. Reagents and special order items will not be accepted for return or refund.

OFITE employs experienced personnel to service and repair equipment manufactured by us, as well as other companies. To help expedite the repair process, please include a repair form with all equipment sent to OFITE for repair. Be sure to include your name, company name, phone number, email address, detailed description of work to be done, purchase order number, and a shipping address for returning the equipment. All repairs performed as "repair as needed" are subject to the ninety (90) day limited warranty. All "Certified Repairs" are subject to the twelve (12) month limited warranty.

Returns and potential warranty repairs require a Return Material Authorization (RMA) number. An RMA form is available from your sales or service representative.

Please ship all equipment (with the RMA number for returns or warranty repairs) to the following address:

OFI Testing Equipment, Inc.
Attn: Repair Department
11302 Steeplecrest Dr.
Houston, TX 77065
USA

OFITE also offers competitive service contracts for repairing and/or maintaining your lab equipment, including equipment from other manufacturers. For more information about our technical support and repair services, please contact techservice@ofite.com.