DR-7
DIRECT READING FERROGRAPH
USER MANUAL

November 2022 Revision F

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Model: ___________________________________

Serial Number: ____________________________

Date of Purchase: __________________________

Windows Product Serial Number: ____

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1. Introduction

The Direct Reading Ferrograph is a trending instrument, providing readings which measure the amount of metallic particles, both large (DL) and small (DS) in a known oil sample. The numbers given do NOT relate to any other numbers such as parts per million (ppm). The DL and DS numbers of the DR-7 will correspond to those reading generated by a DR-5 and will be slightly higher than a DR-3. In turn these numbers can be used to calculate the wear particle count (WPC).

The DR-7 is much more versatile than its predecessors. Running on a Windows platform allows users to quickly upgrade DR software to the latest version, interface through the internet, and set up e-mail capabilities. The USB connections can easily be used to set up multiple DR-7 units together and connect to the user lab software. The provided Ethernet port allows users to network into their current systems and to each externally.

The first Direct Reading Ferrograph was developed in the early 1970's as the whole science of Ferrography was being developed under a contract with the US Navy. Early DR Instruments were large and had to be adjusted before every test. The large density particles and small density particles had to be read separately by turning a switch. Over the years, the Direct Reader (DR) progressed from the original manual instrument to a Duplex. The Duplex was a manual DR with a Ferrogram Maker in the same instrument. The DR-2 was the next version which contained the first attempt at a self-adjusting instrument. Throughout the years the DR-3, DR-5 and DR-6 series of Instruments were created, finally with this current DR-7 design.

During the development of the Ferrography instruments, it was discovered the most sensitive locations for detecting a changing wear situation were found, this point was determined to be at the entry point of the magnets, at a position approximately 5 millimeters downstream. Particles of 5 microns or greater collected at the entry point. Particles with the size of 1-2 microns collect at the 5 mm position. Accordingly, the Direct Reader Ferrograph was designed to quantify particles into these two size ranges. This is where the Density Large (DL) and Density Small (DS) numbers come from. These densities are found by shining a monochromatic light through the bottom of the glass part of the precipitator tube. The amount of light cut off by the particle builds up in the glass tube, and therefore blocks the sensors, and this blockage is read by sensors. The DR then converts this attenuated light into the DL and DS readings.

The digital output has a range of 0 to 190 units. A reading of 100 units corresponds to approximately one-half of the area covered and is the recommended upper limit. For readings greater than 100, the instrument response is non-linear due to the particles piling on top of one another so that less light is attenuated. Trico recommends not using a reading over 90 and the instrument indicates a warning message to indicate that the sample should be diluted.

Because this is a trending instrument, results on the same sample will vary due to accuracy of sample preparation, sample temperature, settling of the particles, and other factors. Comparative unit testing proves that a given sample can produce results repetitively within a range on a single DR-7 and across multiple units.

2. Packing List and Assembly

After receiving the DR-7, check the package for any shipping damage, and report the damage to the carrier that delivered the package to you. Shipping damage is the receiver's responsibility.

Packing items:

1 – DR-7 Direct Reading Ferrograph Unit
1 – Stainless Steel Sample Vial Holder
1 – Stainless Steel 125 ml Beaker
3 – Spare "End of Oil Sensor" Doors
1 – Universal Power Cord
1 – Spare 1A Fuse
1 – DR-7 User's Manual
1 – Calibration Tube PN: 43021

2.1 – DR-7 Unit Assembly

Required tools for Assembly:
1 – #2 Philips Head Screwdriver

1. Remove the 125 ml beaker from the packing paper. Place the beaker into the recessed cup for waste collection.
2. The drain tube on the right (facing the instrument) bulkhead should be placed into beaker. During factory conformity testing a test liquid is circulated through the pump tubing to verify function and check units for leakage. Excess fluid may still be in the tubing upon arrival. After time the drain tube will become hard and brittle. A new tube can be attached using the tubing cut from a used precipitator tube as a replacement.
3. Remove the two screws from the top of the instrument where the vial holder goes. Place the stainless vial holder on top of the tower with the fingers pointing toward you and thread the two screws back into the holes at the top left side of the Instrument. Tighten the screws using a #2 Phillips head.
4. Plug the universal power cord into the back of the DR-7 into the power jack and then into an electrical outlet.
   NOTE: If the electric supply is other than 120v, 60/50 Hz, the standard Universal Power Cord provided will need to be replaced or adapted to the host country's receptacle. Ensure that the power supplied is within the range outlined in the specifications of this manual. It is the user's responsibility to supply the correct plug for the available power. Install the correct plug, then plug the power supply into the back of the DR-7 and then into the electrical outlet.

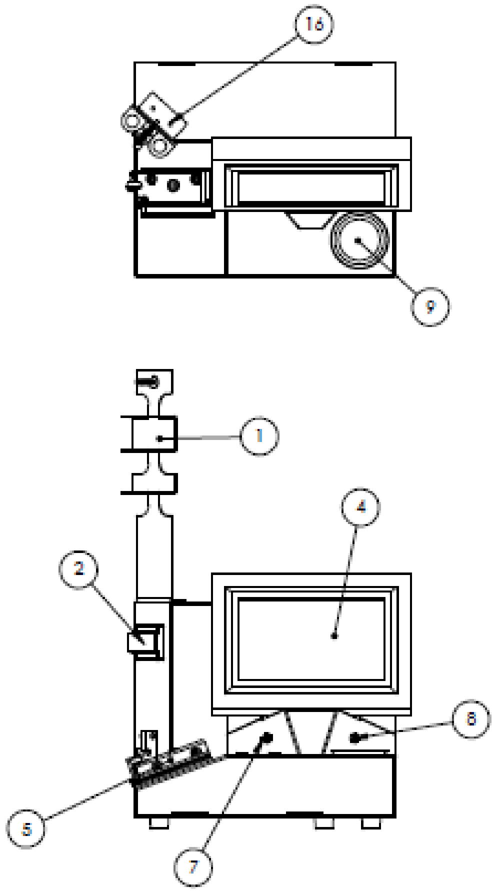
To lift and move the DR-7, turn off the instrument and disconnect the power cord and the computer cable, if attached. Place your hands under the instrument two thirds of the way back and lift. This will balance the instrument while lifting.

3. Specification and Operating Parameters

Physical Specifications		
Length (Front to Back):	9.00 in.	22.8 cm
Width (Side to Side):	12.00 in.	30.5 cm
Height:	19.75 in.	50.2 cm
Weight (Instrument Only):	13 lbs.	5.9 kg
Power		
Voltage:	100-240V AC	
Frequency:	50/60 Hz	
Amperage:	1A	
Instrument contains a 1A power fuse located at the power plug inlet		
Hardware		
Operating system:	Windows 10 IoT	
Memory:	64 GB Flash	
External USB Ports:	2 x USB "A"	
Ethernet Connection:	RJ45 cat 5	
RAM:	4 GB DDR2 RAM	
Processor:	Intel® Celeron® CPU N2807 @ 1.58 Ghz	
Environmental Conditions		
For indoor use on a solid level surface without movement or vibration.		
Use in a well-ventilated area.		
Room temperature:	50ºF to 85ºF	10ºC to 29ºC
Humidity:	5% to 50% non-condensing	

CAUTION: DO NOT operate the DR-7 with the back panel removed. Unplug the DR-7 from the power supply before removing the back panel for adjustments. Check with Trico before removing as this could void the unit warranty. All other repairs must be done at the factory.

4. DR-7 Nomenclature



This section introduces the user to the major components of the DR-7 Direct Reading Ferrograph Instrument. The following subparagraphs discuss the major components, their location, and the nomenclature for each item on the DR-7 Direct Reading Ferrograph Instrument shown above.

1) **Vial Holder:** Holds two sample vials and mounts on the top of the DR-7 with two screws. Do not use this as a handle to pick up the unit.
2) **End of Oil Sensor:** The end of oil sensor will sense the meniscus created in the precipitator capillary tubing when the test is completed, automatically freezing the DL and DS readings. The DR-7 will record the readings if the sensor is bypassed by pressing the STOP button when the technician determines that the test is completed.
3) **Tubing Guide:** Used to bend and guide the capillary tubing without kinking from the vertical position to the inclined magnet assembly. Tubing is held in place by weaving it through the three pins.
4) **LCD Screen:** This touch screen displays the set up and operational screens which have several options available besides the calibration menu.
5) **Optics Assembly:** Holds the glass precipitator tube assembly.
6) **Magnet Assembly:** Magnets designed to attract the ferrous particles on the bottom of the glass precipitator tube to obtain the DL and DS readings.
7) **Left Bulkhead:** Where the end of the precipitator tube connects to the pump head.

8) **Right Bulkhead:** The drain connects here and goes into the waste beaker. Drain tubes can be made by taking the tubing off the end of a used precipitator tube.
9) **125 ml Waste Beaker:** Used to catch the used oil. Discard the mixture of oil and solvent properly when nearing the end of the drain tube.
10) **Back Cover:** Removable with eight (8) screws. Check with the factory before removing as this could void the unit warranty.
11) **Windows Product ID Number/ DR-7 Model and Serial Number:** The Windows Product ID number is located on the back of the unit and is used for Windows product support through Microsoft. The DR-7 Model, and Serial Number Label is located on the bottom or back of the unit and used when calling Trico for DR-7 support. Record these numbers on the DR-7 user manual for future reference.
12) **Ethernet Network Jack:** Ethernet cable may be used to download the DR-7 data to a database and utilize internet/ intranet Windows functions.
13) **Power Input Jack:** The standard universal power cord supplied with the unit is first plugged into the power input jack and then plugged into the power receptacle that supplies appropriate power within the unit specifications.
14) **On-Off Power Rocker Switch:** Red indicates "ON" position, black indicates "OFF" position.
15) **USB Ports**: External peripheral devices such as the provided mouse, keyboard or monitor may be utilized through the USB connections, provided they are compatible with Windows.
16) **Vial Mounting Screw Location:** During assembly, screws provided with the unit are threaded into the top location shown to hold the vial assembly onto the unit.

NOTE: Tampering with the Instrument will void the warranty.

5. Consumables and Accessories

It will become necessary to reorder the consumables to continue testing on the DR-7 unit. This section contains reordering information. Many of the test equipment items should not be reused. Contaminated devices can cause inaccurate or incorrect interpretation.

Part # 73-0050 Pipette Tips- GLASS (Package of 200) – Disposable glass tips used with the pipettor.

Part # 73-0060 Sample Vials (Package of 250) – Disposable glass vial holds the oil and heptane and fit properly into the vial holder.

Part # 73-0090 Sample Vial Rack – Will hold up to 18 sample vials in preparation for testing.

Heptane – A filtered solvent used to thin the oil sample for testing to run through the precipitator tube at a quicker rate. The fixer can be used to clean between the optics assembly and magnet assembly. This solvent is non-carcinogenic, but flammable. (n-Heptane 99+% for Spectrophotometry can be purchased from VWR at https://us.vwr.com or call 1-800-932-5000)

Part # 74-0020 Diluent Oil – Used when the oil sample tested exceeds a DL or DS reading of 90 or more and the sample must be diluted to get a reading under 90 units.

Part # 74-0040 Precipitator Tubes (Package of 250) – This disposable tube carries the oil sample from the sample vial, over the magnet assembly to the waste bottle. The precipitator tube is constructed of four parts. The first is a 33" piece of capillary tubing. This runs into a 4-inch piece of glass and is held in place by a black shrink tube. A piece of tygon tubing is added to the other end of the glass to connect the glass tube with the left bulkhead.

Part # 74-0250 Grease Solvent – An agent used to dissolve grease into a form that can be tested with the DR-7 unit.

Part # 75-0010 Bottle Top Dispenser, 1 ml – Use in the fixer bottle to dispense one milliliter of heptane with each pump.

Part # 75-0030 Pipette Dispenser (Pipettor) – Used to draw one milliliter of the oil sample for the test.

Part # 75-0040 Pipette Tips- PLASTIC (Package of 250) – Disposable plastic tips used with the pipettor.

Part # 76-0030 Wear Particle Atlas – A guide to wear particle identification containing photographs of critical wear particles found in used lubricating oil, illustrative case histories, and operational procedures for wear debris analysis.

Part # 43021 DR-7 Calibration Tube - Used in calibration procedure to correct unit light intensity output.

Part # DR-7FIL - Used for calibration purposes on the DR-7 to confirm the calibration and alignment readings over time.

NOTE: Part # 73-0060, Part # 74-0040, and Part # 73-0050 must be discarded after one use in order to eliminate cross contamination.

CAUTION: Heptane and Part # 74-0250 Grease Solvent are considered hazardous materials and should be handled with caution and disposed of properly. Consult the Safety Data Sheet (SDS) enclosed with these chemicals for more information.

6. Oil Sample Preparation

6.1 – Preparing an Oil Sample for Testing

Gravimetric settling of wear particles in lubricating oil starts immediately after a sample is left standing. To obtain a representative sample from a larger sample, the particles must be evenly dispersed. To make a homogenous mixture, the following procedure is recommended:

1. The oil should be in a clear container to allow for observation of the oil and large contaminants. Make sure the container is two-thirds full to allow for agitation to completely mix the particles into the oil, thus giving the sample a homogenous mixture.
2. Heat the oil to approximately 150°F (65°C). This is according to ASTM standard procedure to keep the particles suspended as long as possible.
3. Remove from the heat source and vigorously shake the bottle.
4. With the pipettor and clean pipette tip, remove 1 ml of oil and dispense into a clean sample vial.
5. Add 1 or 2 ml of heptane to the 1 ml of oil in the sample vial. The viscosity of the oil determines the amount of heptane added to the oil in the sample vial. For high-viscosity fluids add 2 ml of heptane to reduce the viscosity. This will allow the viscous oil to flow along the precipitator tube at a similar rate as lower viscosity fluids. For low-viscosity fluids 1 ml of heptane is enough to provide fluid flow through the precipitator tube. It does not matter if 1 or 2 ml of heptane is used, as long as the required 1 ml of oil is used for each test. However, higher viscosity samples moving at too slow of a rate will affect particle deposition by increasing the amount material deposited on the DL compared to the DS.
6. The quicker a sample is tested, the better the results. Allowing the sample to settle in the test vial may cause bunching of particles in the precipitator tube since most of the material will be collected at the bottom of the vial and deposited in the precipitator tube around the DL sensor. To avoid this, use the prepared sample as soon as possible or re-mix the sample before testing so that wear particles are properly dispersed.

6.2 – Dilutions

Readings on the DR-7 greater than 90 in the 1:1 or 1:2 dilution modes are not linear due to the particles piling on top of one another. When the DR-7 readings reach 90, the test is invalid and should be repeated using a dilution of the base sample.

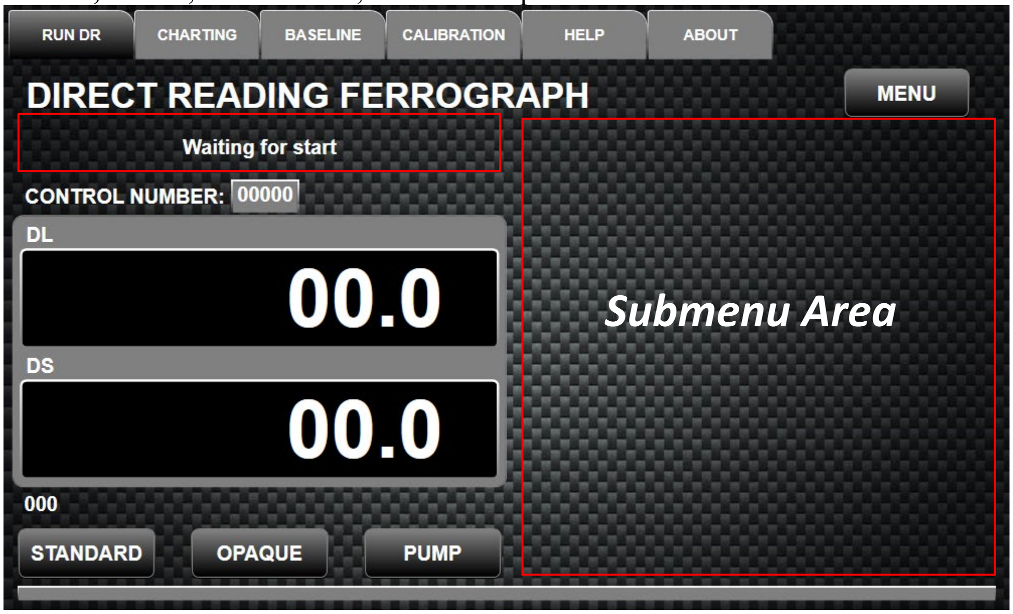
1. To prepare dilutions, start with the base mixture. In a clean sample vial, place 1ml of the base mixture. To this add 9 ml of diluent oil. This will make a 10:1 dilution.
2. In another clean sample vial, place 1ml of the 10:1 dilution. To this, add the heptane as done to make the base solution (1 or 2 ml). This is the 10:1 sample to be run on the DR-7.
3. On the RUN DR tab MENU display, change the dilution ratio to 10:1 and the readings will be corrected for this dilution. The upper limit will automatically be changed to 900 instead of 90. If the DL and DS readings go over 900 a 100:1 dilution must be made.
4. To make a 100:1 dilution, start with 1 ml of the 10:1 dilution and add 9 ml of the diluent oil. Take 1 ml of this dilution and the standard amount of heptane in a clean sample vial to run the 100:1 dilution. Change the dilution ration to 100:1 in the menu so the final DL and DS readings will be corrected for the dilution and the upper limit of the test will be changed to 9000.
5. When the dilution factor is changed, the DR-7 will automatically multiply the DL and DS readings to give you the correct dilution readings and the limits of the test will be increased. This means that in a normal test the display will warn the user if the reading goes over 90. In a 10:1 dilution, that number increases to 900 if the DR-7 is set at that dilution ratio. The 100:1 would have a high limit of 9000.

NOTE: If the dilution factors are not changed in the menu, the DL and DS readings must be multiplied by the dilution factor to get the correct readings. In a 10:1 dilution the DL and DS readings would have to be multiplied by 10.

7. Operating Procedures

Always use the DR-7 on a sturdy, level surface in a well-ventilated room. To start the DR-7 system, flip the rocker switch on the back of the unit to the "ON" position. The operating system will automatically start booting and the Trico logo will illuminate. Once the windows system has booted the DR-7 program will automatically open to the RUN DR tab, otherwise there is a shortcut on the desktop to launch the DR-7 program.

At system startup the main DR-7 menu appears. The first start up screen is shown below. This start up screen allows the user to quickly change settings, calibrate optics or end of oil sensor or start the testing process. At the very top of the main menu six tabs appear: **RUN DR, CHARTING, BASELINE, CALIBRATION, HELP**, and **ABOUT**, which are explained in further detail.



7.1 – RUN DR Tab

The Run DR tab is the functional work areas for operating the DR-7 system and allows users to change settings on the fly, or operate the program and circulate the pump.

Located on the right side of the RUN DR tab is the Submenu Selection Area. In this area all sub menues will appear when the MENU, STANDARD, or OPAQUE buttons are selected.

In the left half of the screen two black blocks appear indicating the DL and DS numbers during the test. Above these blocks, system messages will appear prompting the user or indicating warning messages when parameters are out of range.

Three touch buttons are also located at the lower left side of the screen under the DL and DS reading boxes. These buttons allow the user to start tests using the STANDARD or OPAQUE functions. By pressing these buttons, a new menu appears in the submenu selection area for running the specific test.

The PUMP button, when pressed rotates the peristaltic pump one revolution and can be used to start the sample flow through the precipitator tube if the sample viscosity is too high and flow is unable to be achieved through the current rotation settings. The PUMP button should only be used to start the flow and should not be continually used to process the sample at a faster pace. Doing so will give false DL and DS readings because of inconsistency of flow over the magnet assembly.

The DR-7 displays the time (in seconds) that each sample takes to complete. The sample time is defined as the time required from when the DR-7 detects the oil at its DL and DS sensors, to the time the last of the oil passes the end of oil sensor. The timer is located under the DL and DS blocks just above the STANDARD button indicated as 000.

Knowing the time each sample takes to complete can be used to catch a bad sample test. For example, if previous samples required an average of 200 seconds to complete and the next sample, of the same oil, requires only 100 seconds, the sample test is in error and must be repeated. Sample times will vary somewhat, however, significant differences in time are usually caused by false tripping of the end of oil sensor by a large particle in the sample. This requires adjustment to the end of oil sensor's threshold or bypassing the End of Oil Sensor by leaving the capillary tube outside of the sensor during the test. See the END OF OIL SENSOR CALIBRATION in section 8. Calibration of this manual. The time will retain the last sample time until the next sample is started.

If, for some reason, a sample is running through the precipitator tube for 12 minutes, the DR-7 will end the test and freeze the readings at this time. "TIMED OUT" will appear next to the timer below the DL and DS boxes. This might be caused by the sample being too viscous. The sample should be thinned with more heptane or diluent oil and run again for accurate results.

7.1.1 – STANDARD Operation

The black shrink tubing should be placed against the left edge of this assembly to run the test to ensure no light intrusion. A depress lever is located to the left of the optics assembly to open and hold the precipitator gate in the up position to allow for the precipitator insertion under the optics. Moving the lever forward opens the gate while moving the lever back will close the gate. When closing the gate, the lever should be pushed back until its stops which will clamp and hole the precipitator tube.

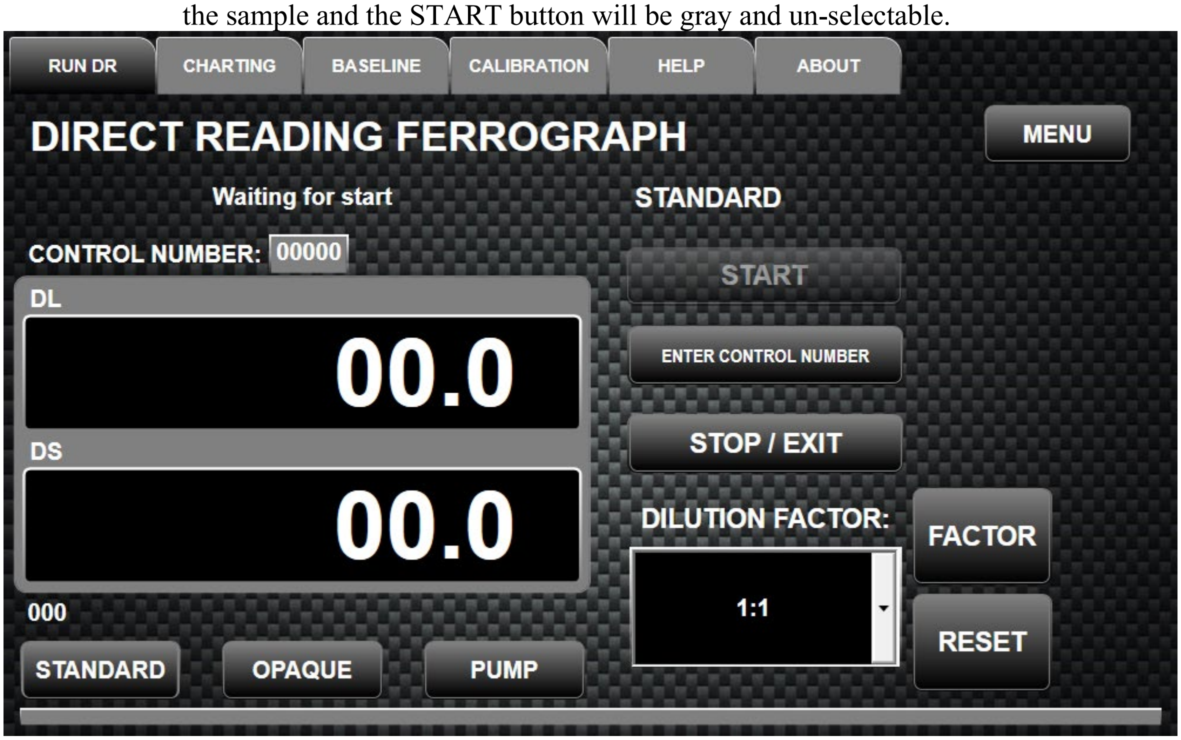
1. Mix the oil sample as described in section 6.1 *Preparing an Oil Sample for Testing* of this manual. Put the sample in the vial tube holder at the top of the instrument.

2. Install a precipitator tube by first moving the depress lever forward on the left-hand side of the optics assembly to open and hold the precipitator gate in the up position. Insert the glass part of the precipitator tube under the optics block and then move the lever backwards while pressing down on the gate until its stops to hold the precipitator tube in place. The black shrink tubing of the precipitator tube should be tight against the left-hand side of the Optics Block. Next, place the short end of tygon tubing onto the barb fitting on the left bulkhead barb under the display screen.

3. Weave the capillary tube between the tubing guide pins as shown below. Weaving the tube through the pins will help keep the precipitator tube from sliding out of position. Then place the capillary tube in the center groove of the end of oil sensor and close the door by snapping it shut. Be careful not to pinch the tubing with the door.

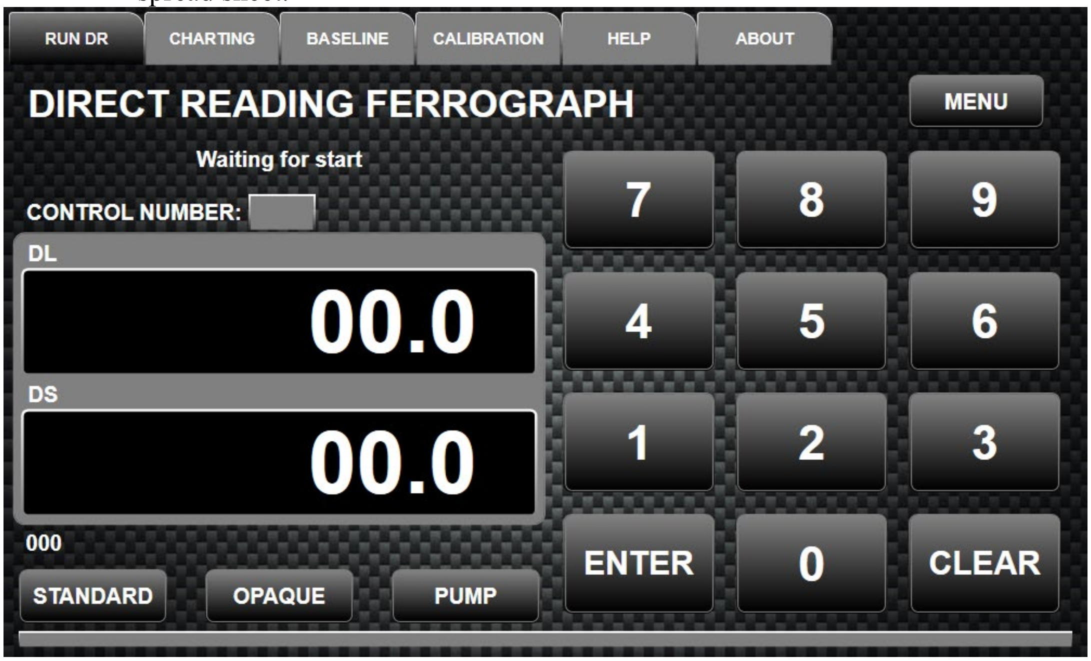
4. Place the end of the capillary tube in the oil sample in the vial holder until it touches the bottom of the sample vial and press the tubing into the spring at the top of the sample vial holder to hold the tubing in place.

5. Press the STANDARD button.
   a. "YES" Control Number is Required in MENU Settings
      i. A system message will indicate that the user will need to enter a control number for the sample and the START button will be gray and un-selectable.



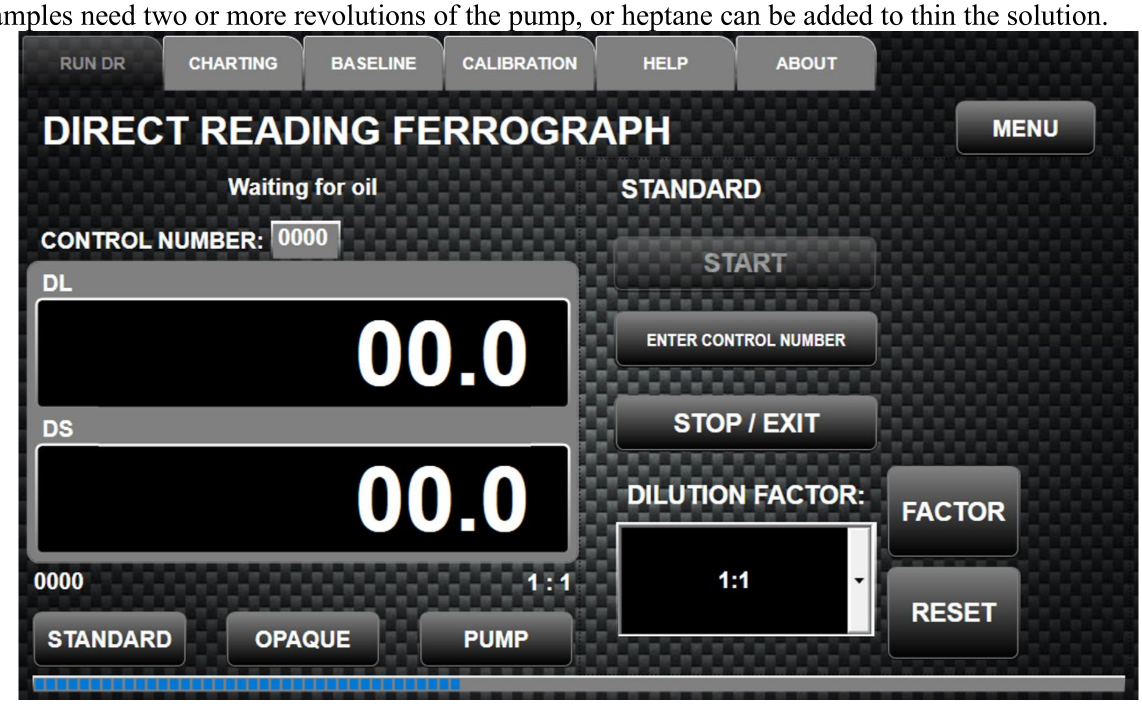
      ii. Press the ENTER CONTROL NUMBER button and the keypad will now appear.
      iii. Enter the control number. Make sure the control number is correct and press ENTER, otherwise press CLEAR to clear out the control number to enter a new one. Entering a control number will store the data into a coma separated values (csv) file, in which

a script can be written to load the data into a given lab data tracking software or spread sheet.



iv. After ENTER has been selected the keypad will disappear and the RUN DR will again be displayed.

6. Press START and the unit will begin the test until it is completed. When pressed the pump activates and starts the siphoning effect in the precipitator tube. For full suction to begin, the oil level in the precipitator tube must flow past the bottom of the vial in the vial holder. If this does not happen the viscosity of the solution is too viscous, and the PUMP button can be pressed until flow starts. The default for pump revolutions is set at 2 and can be changed by changing the settings in the MENU. Thin oil samples only need one revolution of the peristaltic pump to start the flow. Thicker oil samples need two or more revolutions of the pump, or heptane can be added to thin the solution.



7. As oil flows through the precipitator tube, the Display Messages will change through the following phrases, colored white, letting the operator know the progression of the test.
    - Waiting for Start
    - Waiting for Oil
    - Oil – Start Testing
    - Waiting on End of Oil
    - Done – Waiting for Start

8. When DONE – WAITING FOR START appears the DL and DS readings will be frozen. This is when the DL and DS readings are recorded for the oil sample; but only if a control number was entered for the sample. This data is written to the DR-7 data folder of the program and can be accessed through windows explorer under the C:\Programs\Trico folder. If downloading data, your software will need a script written to pull this data from the file. Files are named per control number along with a date time stamp.

9. This completes a STANDARD test, and another test can then be performed. Remove the used precipitator tube and install a new one for the next test to give accurate results.

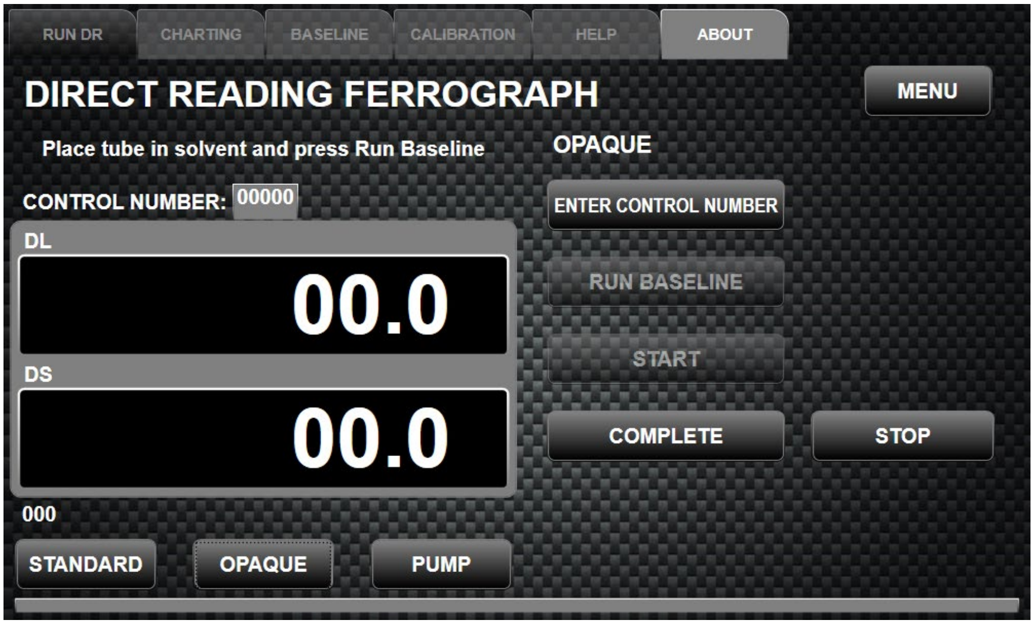
NOTE: While the test is running the precipitator tube should not be moved or readjusted in the holder. Doing so will give false readings and inaccurate results. If a problem occurs remove and discard the precipitator tube and oil sample to begin a new test.

7.1.2 – OPAQUE Operation

An opaque sample is defined as one which is too dark to read under the optical sensors. Usually, samples filled with carbonaceous material produce a reading of 190 in one or both sensors as soon as they start to flow through the glass section of the precipitator tube. These dark particles cut off all the monochromatic light going to the sensors. Diesel oil is a good example of an opaque sample. If an opaque sample is run as a regular sample on the DR-7, the top line of the display will read TOO DARK – USE OPAQUE.

A special procedure is used to test opaque samples. Filtered heptane is run through the DR-7 to establish a baseline for the wash fluid. The opaque sample is then run using the same precipitator tube. After the oil has drained from the sample vial, heptane is used again to wash out the dark oil in the precipitator tube while the magnet assembly holds the metallic wear particles in place to provide the actual DL and DS readings.

The first time the DR-7 is used for an opaque test, you are prompted to perform a baseline test using heptane. This baseline will stay in the DR-7's memory until the program is shutdown. A sample vial of the heptane does not have to be run at the beginning of every test for a baseline, just at the end to wash away the dark oil.

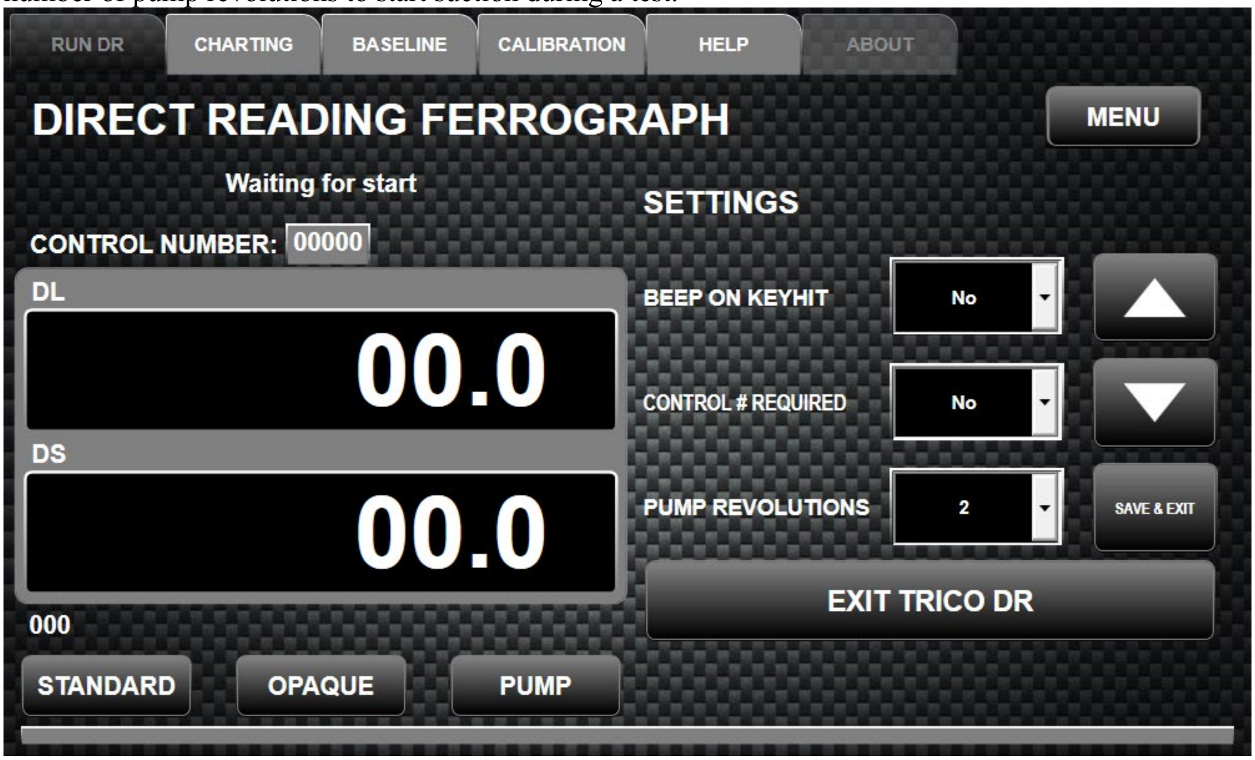


Running an Opaque Sample:

1. Press the OPAQUE button.
2. Enter the control number, if used, by pressing the ENTER CONTROL NUMBER button, as explained in the Standard Operation section.
3. Pump 4 ml of heptane into a clean sample vial to be placed in the vial holder on top of the DR-7 next to the prepared oil sample.
4. A base line must be created the first time an opaque sample is run. Place the small end of the precipitator tube in the sample vial of heptane and press RUN BASELINE.
5. When the DR-7 is calibrated on the heptane, the pump will reverse and shut off the flow of the heptane. At this point change the precipitator tube to the sample vial with the oil sample, inserting the tube all the way to the bottom of the sample vial. Press the START button and this starts the flow again.
6. When the last of the oil sample is in the precipitator tube, quickly move the tube to the vial that contains the heptane. This will wash the dark material out of the precipitator tube, and you will get the actual DL and DS readings. By moving the precipitator tube in and out of the heptane, air bubbles will be introduced into the capillary tube. These bubbles will help remove the opaque oil and nonmagnetic material in the precipitator tube.
7. When the heptane is gone and the flow has stopped in the capillary tube, take the DL and DS readings. Press the COMPLETE button to save these readings.
8. To start another opaque test. Place a newly prepared sample into the vial holder along with a sample vial of heptane for washing. Replace the precipitator tube and place the capillary tube end into the new sample and then push the START button again to use existing baseline that was established with the first opaque test. Run this test with the capillary end of the precipitator tube in the oil sample transferring it to the heptane at the end of the test to flush the precipitator tube and obtain the DL and DS readings.
9. To end the OPAQUE operation press STOP to exit out.

7.1.3 – MENU Button

The MENU button is in the upper right corner of the RUN DR tab. By pressing this button, the DR-7 settings menu appears in the Submenu Selection area. Different settings can be selected from the pull-down menu to control beep on key hit, if a control number is required per sample before testing, and the number of pump revolutions to start suction during a test.



Selections can be made by touching the desired setting pull down and hitting the up or down arrows to the side to scroll through the selections. After all changes are made press the SAVE & EXIT button to set the new selections and then exit to exit out of the menu. Default settings are, Beep on key hit: No, Control number required: No, Pump revolutions: 2.

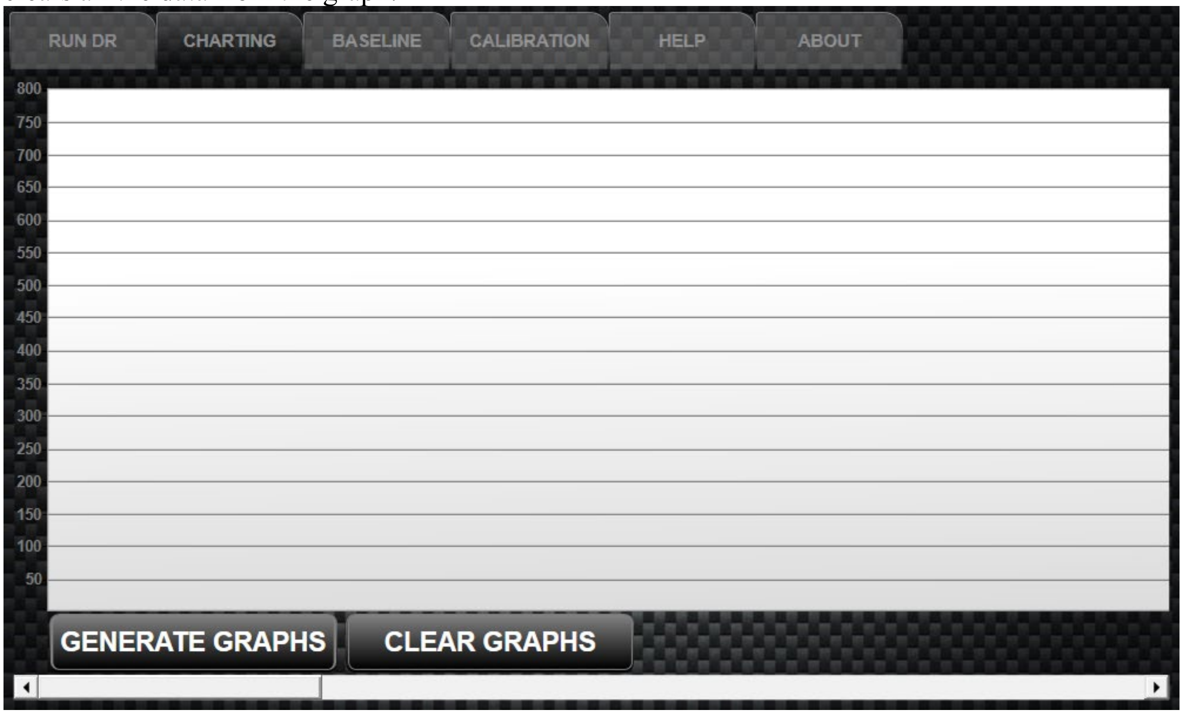
7.1.4 –Shutdown Procedures

To close the DR-7 program and exit to Windows, enter the MENU Screen under the RUN DR Tab and press the EXIIT button. In doing this the user enters the Windows Desktop screen. Here is all of the functions of a normal Windows based operating system. To shut down the power fully, either use the shortcut on the desktop, or go to the start menu and click on shutdown to close the operating system. This may take a few seconds to close windows applications and fully shut down.

Once the operating system is fully shut down and the touch screen turns black the user may flip the rocker switch on the back of the unit to the “OFF” position. By turning the power off, the illuminated Trico logo will dim to black.

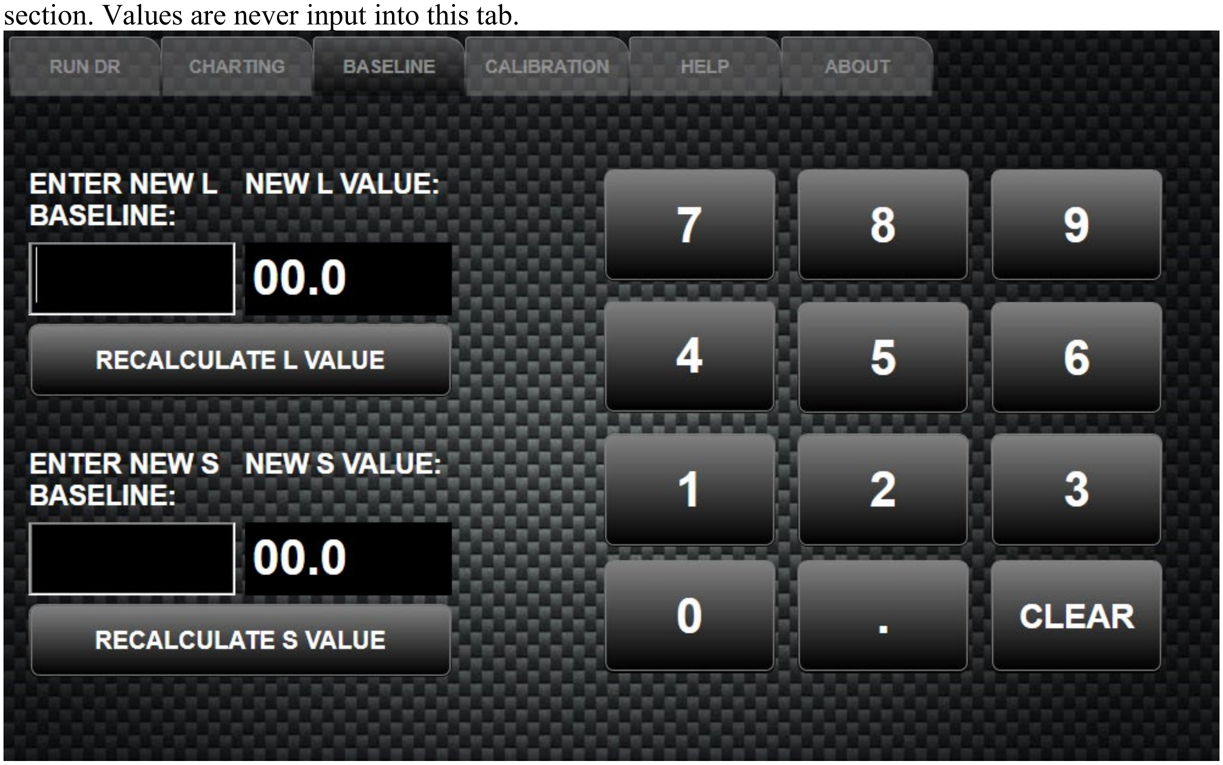
7.2 – CHARTING Tab

The Charting Tab is the function that will plot the DL and DS. Pressing GENERATE GRAPHS button will graph the L and S Base levels and L and S Count levels over time. Pressing CLEAR GRAPHS then clears all the data from the graph.



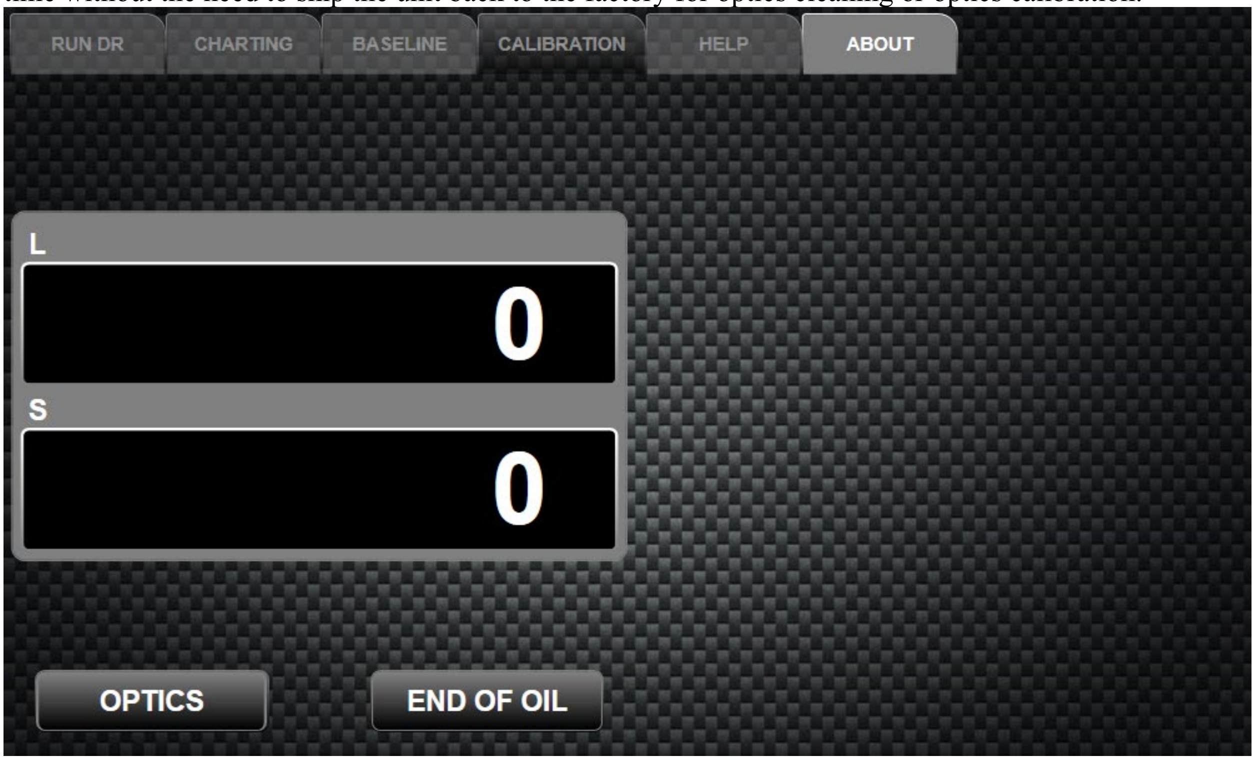
7.3 – BASELINE Tab

The Baseline Tab is used when runing Opaque samples and is covered under the *Opaque Operation* section. Values are never input into this tab.



7.4 – CALIBRATION Tab

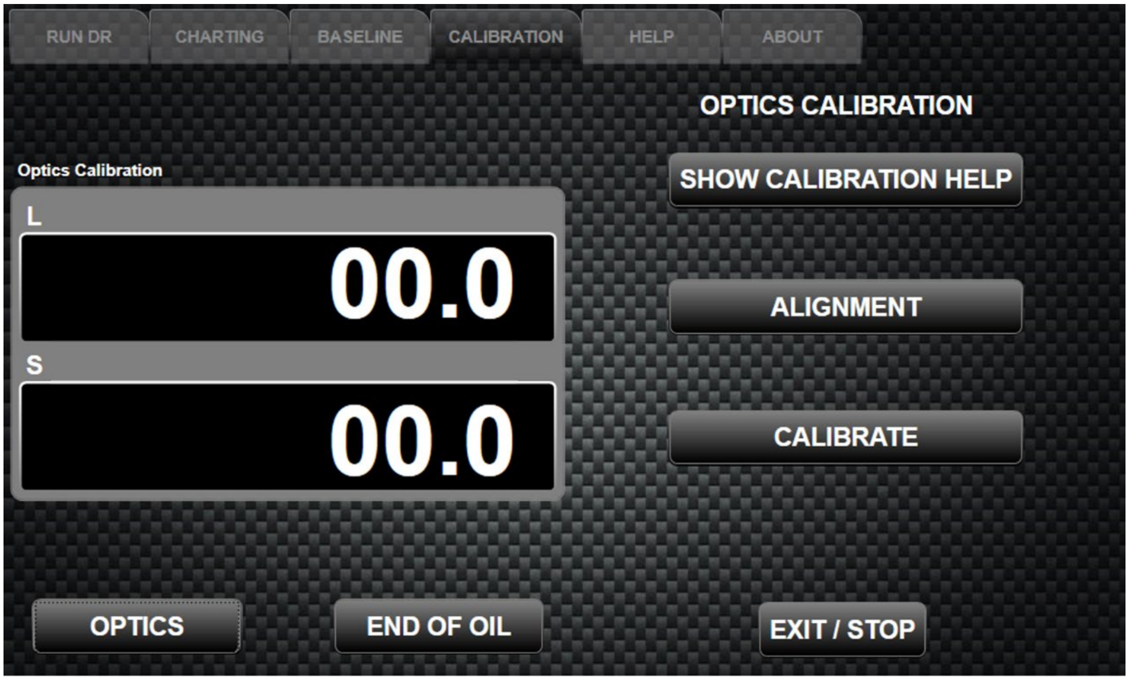
The DR-7 has two calibration features OPTICS calibration and END OF OIL sensor calibration located in the CALIBRATION tab. This helps maintain optimum performance during operation. This is controlled by the lab technician when maintenance and cleaning is performed or performed on a routine basis before sample testing. These features are in place to allow the equipment to be in service for lengthy periods of time without the need to ship the unit back to the factory for optics cleaning or optics calibration.



7.4.1 – OPTICAL Calibration

The optics guide block is aligned with the LED light source during factory alignment calibration. Unlike previous DR versions, the optics block should never be removed for cleaning (see section 9 Maintaining the DR-7). The new design of the Optics block uses a special fluid filled calibration tube for both the alignment procedure during the factory build, and in calibrating the LED light source by the lab technician.

The LED light source calibration should be done daily, or every time the instrument is turned on. This is done by selecting the OPTICS button in the CALIBRATION tab. In the process, the fluid filled calibration tube is used to focus light changes in the instrument. In addition, an *OPTICAL CALIBRATION CHECK* is used to check the optical calibration to ensure the unit falls within a specified range. This check should be performed monthly if the unit is used frequently. Although increased sensitivity has been enhanced throughout the development of this instrument, because of particle distribution and other variables within the oil sample being tested, the DR-7 is still considered a trending instrument.



To calibrate the LED light source in the OPTICS submenu:

1. Insert the Optics Calibration Tube (Part #43021) supplied with the unit by lifting the gate and placing the tube under the optics sensor. Close the gate and ensure the Calibration tube protrudes evenly from both ends of the optics block.

> **NOTE:** The tube should be wiped down to clean fingerprints or smudges from the glass. Before inserting the tube, inspect the tube for air bubbles which could affect the reading. If air bubbles are present in the area to be inserted into the sensor path, place the calibration tube back into the holder and stand it upright to allow air to move to the top end of the glass tube.

2. Select the CALIBRATION tab.
3. Press the OPTICS button.
4. Press the CALIBRATE button in the submenu. The DR-7 will automatically calibrate the light intensity by determining the maximum intensity and then balancing the optical channels to a predetermined offset to produce the most effective results.
5. After the Calibration is finished the numbers in the DL and DS will read around 2550 and the message will appear "Complete" in the message area.
6. Press EXIT/STOP to save the calibration.
7. Remove the Calibration tube and place it back into the holder, then press the RUN DR tab to return to the test area.

> **NOTE:** The ALIGNMENT button is used only by factory technicians to mechanically align the optics to the light source. Users do not need to use this feature. Accidently pressing the button will not affect the instrument readings. Allow the alignment program to reach its target and then press the EXIT/STOP button. Then conduct the LED light source calibration outlined in the steps above.

7.4.1.1 – Optical Calibration Check with Trico #DR7-FIL

Optical Calibration Checks are performed on the DR-7 optics using the neutral density films and calibration tube purchased separately in the DR-7 Neutral Density Calibration test kit, Trico Part # DR7-FIL. Following this procedure will check the optical sensors are within limits and the correct readings are being obtained from the instrument. The test kit comes with three specific neutral density filters used in the development of the DR instruments. Neutral density filters can vary in density range, use only those filters provided in the test kit which have been specifically graded for the purpose of the DR calibration check. Neutral Density films can vary due to manufacturing variances, and each kit should be measured to establish its own set of calibration numbers. Follow the calibration guild provided with the Calibration test kit to refine reading ranges.

> **NOTE:** Neutral density filters should be handled with care. Fingerprints, smears, or scratches will change the calibration readings. Density filters from older model DR's can still be used on the DR-7. However, note the changes in instrument reads in the table below.

Checking Optical Calibration:

1. Make sure the Optics block and photocell area is clean and free of dirt and oil.
2. Insert the glass Calibration tube (PN:43021) from the calibration kit into the optics by pressing the lever forward on the left side of the optic block, lifting the gate and then sliding the calibration tube into place.
3. On the RUN DR tab press STANDARD and then START. Enter a false control number if needed.
4. Insert a filter under the sensor area and quickly remove it.
5. The screen will now say “Oil- Starting Test”. Wait for this message to change to “Waiting on End of Oil” and then insert the filter under the sensors again and hold steady until the readings stop climbing.
6. Record the reading.
7. Repeat the same procedures for the two other density filters.

> **NOTE:** When inserting and removing density films, failure to remove films during sensor zeroing will cause L and S reading to output 30 units lower than expected since sensors will zero on the density filter.

Typical neutral density filter reading ranges for the L and S:

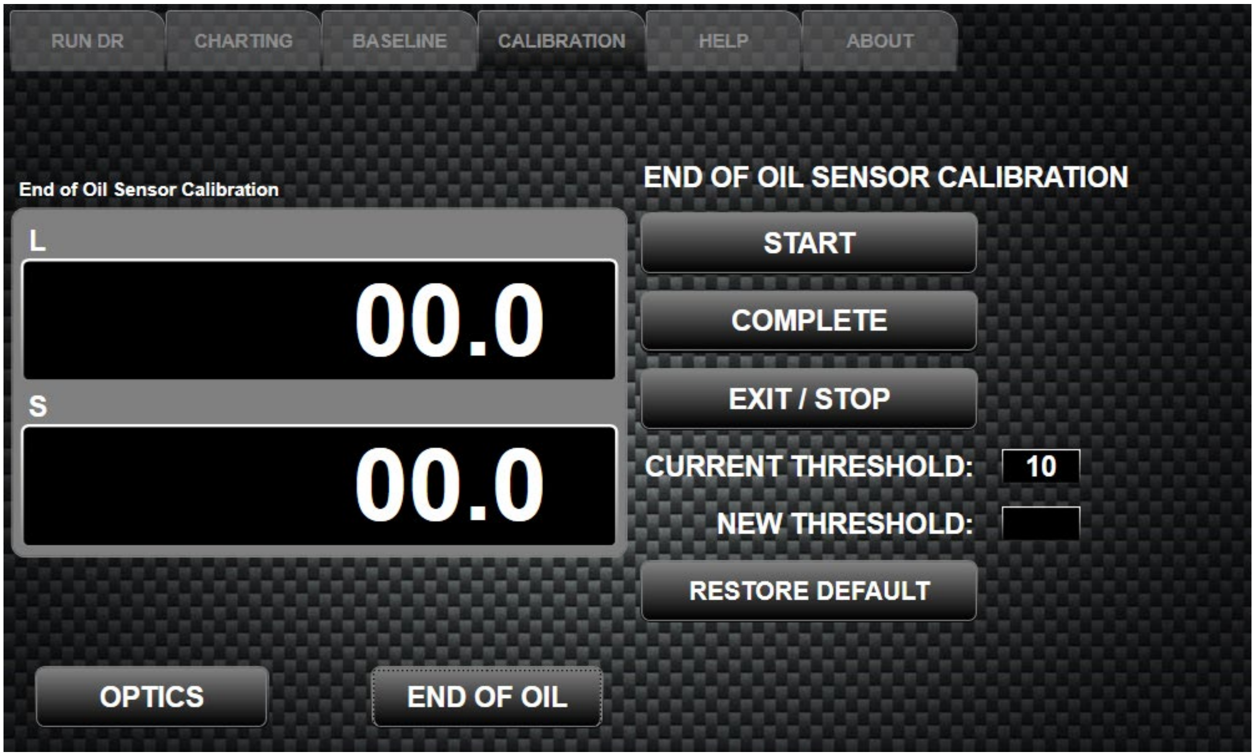
Filter Density	L/ S Typical Mean Reading	L/S Range
.10	35	31-42
.20	66	60-74
.30	89	81-98

Calibration Check Troubleshooting:

<table>
<tr><th>Issue</th><th>Reason</th><th>Solution</th></tr>
<tr><td rowspan="5">All density filter values out of range</td><td>Values out of range <10 units</td><td>Recalibrate LED light source and recheck</td></tr>
<tr><td rowspan="4">Value out of range > 10 units</td><td>Optical sensor zeroed on density film, repeat check following procedure</td></tr>
<tr><td>Recalibrate LED light source and recheck</td></tr>
<tr><td>Photocell detector faulty, replace photocell</td></tr>
<tr><td>Optics block out of alignment, consult Trico</td></tr>
<tr><td>Only one density filter value out of calculated range</td><td>Value out of range <10 units</td><td>Check density film for scratches, smears, or fingerprints</td></tr>
</table>

7.4.2 – END OF OIL Sensor Adjustment

The end of oil sensor detects the meniscus created in the capillary tube when the sample vial has emptied and freezes the DL and DS readings completing the sample test. Occasionally, you may encounter oils that contain large particles that are big enough to prematurely trigger the end of oil sensor. To prevent this, the sensor's sensitivity can be adjusted. This is done by testing oil suspected of containing large particles using the DR-7's end of oil calibration feature in the CALIBRATION tab. This procedure is useful when conducting a large batch of samples with large particle properties. For single samples the alternate method is suggested to bypass the End of Oil sensor.



To adjust the end of oil sensor:

1. Select the CALIBRATION tab.
2. Press the END OF OIL button to calibrate the end of oil sensor.
3. Press START and run the sample as usual.
4. Throughout the test the end of oil sensor's min and max values will be displayed.
5. When the sample vial has emptied, press EXIT/ STOP **before** the oil meniscus goes past the end of oil sensor in the precipitator capillary tube.
6. The program will then take the absolute value of the larger number, min or max and set the new threshold by adding 10 to the number. For example, if the largest number was 20, which represents the largest particle seen by the sensor, the program then adds 10 to the number and sets the new threshold value. The end of oil threshold is set at the factory to 10. This is usually sufficient for most oils, and you may never have to change this value.
7. To set the end of oil sensor back to the default setting press the default button and the threshold number will be set back to 10.

Alternative method (bypassing the sensor):

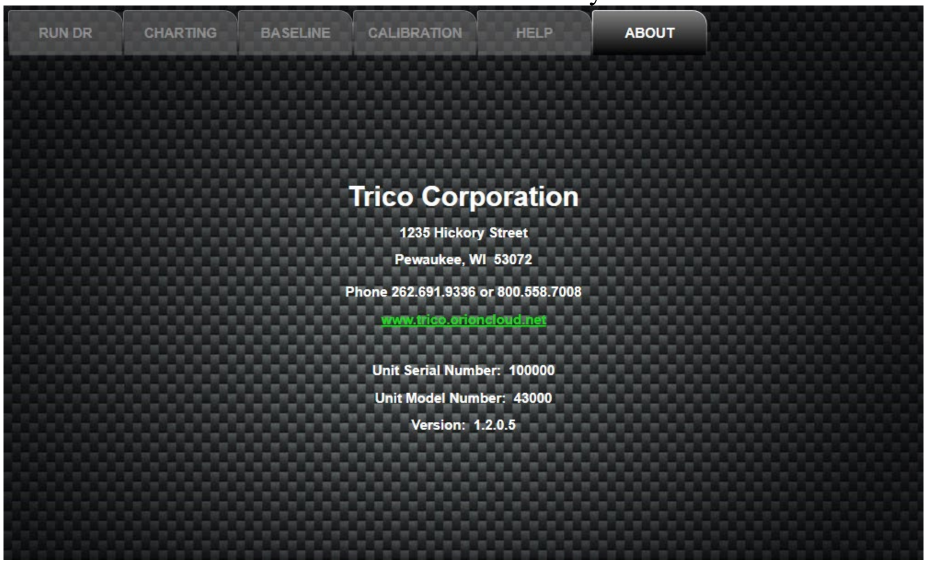
1. Remove the precipitator capillary tube from the End of Oil sensor.
2. Run the sample using the STANDARD test procedures.
3. When the oil meniscus has been observed in the precipitator capillary tube moving below the End of Oil sensor, place a small piece of paper into the End of Oil sensor area to trigger the end of the test. Otherwise, the STOP button may be pressed as well when the technician determines that the test is completed. This will automatically freeze the DL and DS data and write the information to the csv file if a control number was entered. It will also pump the remaining liquid from the precipitator tubing to minimize excess oil spillage.

7.5 – HELP Tab

The DR-7 has a HELP tab that contains a link to the last version of the manual that was loaded onto the machine when the unit shipped from the factory. This is not an internet link and will have to manually be updated if needed.

7.6 – ABOUT Tab

The DR-7 has an ABOUT tab that contains the unit number, serial number, and software version number of the instrument. Additionally, the Trico Contact information if there if any issues arise, which the Serial number of the instrument will be needed to determine the factory information.



8. Downloading and Understanding DR Data

The DR-7 can store data files containing output data generated through each test. Entering a control number will store the data into a coma separated values (csv) file located in the DR root folder under \Programs\Trico\DR. A specialized script can be written through the host lab firmware to load the data into a given lab data tracking software or into a spread sheet. If using a lab database software, a script will need to be written to pull these files into lab firmware. Connection to the DR-7 can be completed through the internet or by USB.

Spread Sheet Example:

Control Number	DR Serial #	Opaque	Dilution	DL	DS	PLP	WPC	Date time
5063090	103122AB1	N	1	37.65	21.86	26.53	59.5	10/31/2022, 12:24 PM

Example:
Control Number: 05063090
DR Unit ID: 103122AB1
Opaque: N
Dilution: 1

DL: 37.65
DS: 21.86
PLP: 26.53
WPC: 59.50

10/31/2022, 12:24 PM

8.1 – Quantifying DR Data

Quantitative information obtained by ferrography signals can be used as an indication to the change in the wear situation of a machine in operation. The two readings of D_L and D_S correspond to the concentration of large and small particles in the sample. As particles enter a gradient magnetic field, the DR-7 quantifies particles into two size ranges by reading light intensity changes at two known locations on the precipitator tube. Magnetic particle separation is nearly 100% effective for ferromagnetic particles larger than .1µm and virtually all unwanted carbon and dirt particles are carried away by the oil and heptane solution. Large particles >5µm are deposited onto the bottom of the precipitator tube within a few millimeters of entering the magnetic field, while smaller particles 1-2µm will be deposited from the leading edge of the magnet to approximately 5mm away.

During normal machine operation, microscopic wear particles are formed by the removal or deformation of interacting surfaces. The wear rate in which particles are generated tends to be constant when the machine operates normally and in a steady state. Over a period of time the number of particles in the lubricating oil will reach a dynamic balance and D_L particles being generated will equal the number of particles being lost through settling, filtering and other loss mechanisms. Therefore, under normal steady state conditions D_L particle size concentrations will remain similar, while D_S particles stay suspended, and concentrations gradually rise over time. (See Figures 8.1 A&B)

Consequently, when the D_L and D_S numbers, under normal steady state wear, trend closer together, this indicates larger particles have precipitated out and most of the particle concentration present are small particles. In abnormal wear modes, except for corrosive wear, large particle concentrations will increase. D_L and D_S data obtained can be processed in several ways to easily identify abnormal wear modes. Most common methods are Severity of Wear index, Cumulative Plots, Wear Particle Concentration (WPC) and Percentage Large Particle (PLP).

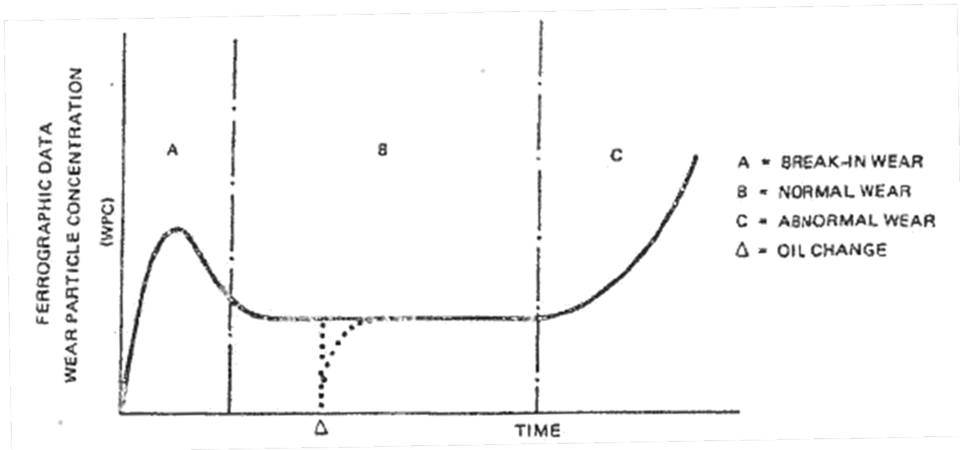


Figure 8.1A Typical Large Particle Profile

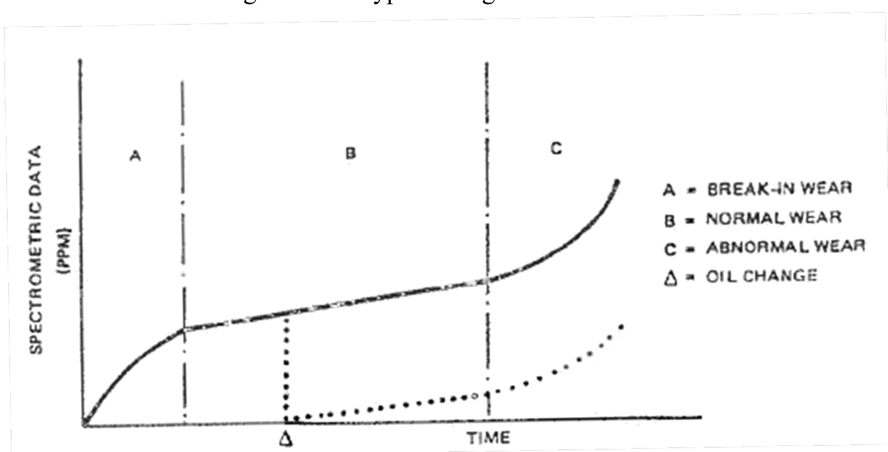


Figure 8.1B Typical Small Particle Profile

If the Severity of Wear Index is plotted as a function of operating time, it will respond in a more volatile manner than plotting either the D_L or D_S reading over time. Severity of Wear can be calculated using the product of the indication of concentration and the indication of size distribution.

indication of concentration = $D_L + D_S$
indication of size distribution = $D_L - D_S$

Severity of Wear Index = $(D_L + D_S)(D_L - D_S)$ or $D_L (D_L - D_S) = D_L^2 - D_S^2$

Another method, Cumulative Plots may be used where each new reading is added to the sum of all of the previous readings resulting in a straight line, if the readings are the same and the intervals in which they are plotted are the same (See Figure 8.2). A variation to this method uses the cumulative concentration and the cumulative size distribution plotted on the same graph. A normally operating machine will produce two straight diverging lines, but a machine in distress will cause both plots to increase in slope.

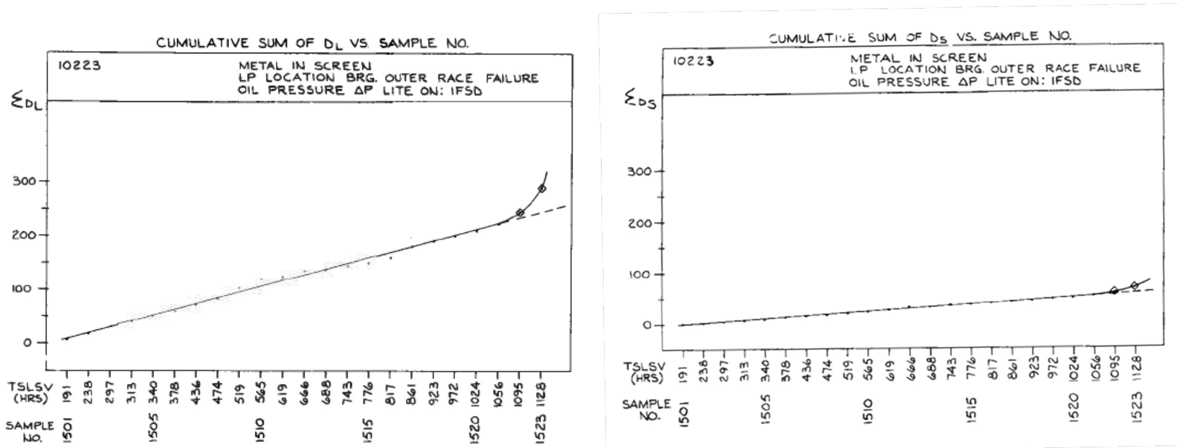


Figure 8.2 Example of D_L and D_S Cumulative plots

Variation of plots:
cumulative concentration = $\sum(D_L+D_S)$
cumulative size distribution = $\sum(D_L-D_S)$

Wear Particle Concentration (WPC) and Percentage Large Particle (PLP) was a method developed for on-line ferrography, which is applicable to DR readings or ferrogram readings. An increase in the plots of both the WPC and the PLP indicates abnormal wear.

$WPC = (D_L + D_S)/V$, V = *Volume of Sample in ml*

$\overline{WPC} = \sum WPC / N$, N = *Number of Samples include*

$PLP = ((D_L - D_S)/(D_L + D_S)) \times 100$

As more samples are taken for a particular piece of equipment, a baseline for Wear Particle Concentration (WPC) can be generated by calculating its mean for a given number of samples. For a single piece of equipment, several samples are needed to generate a baseline. If more than one machine that is identical in setup and operation is included in the sampling program, then deriving a baseline can be faster by using the WPC of those samples. However, every piece of equipment generates wear in a different array of particle size and concentration. Setting a baseline for multiple machines can quickly derive a parameter to work from, but a true baseline should be established for each individual machine in the long term.

Using the standard deviation from the WPC mean, generic alert levels can be set to give an indication as to where the data is indicating severity of wear, when there is no historic data. Of course, every situation is different and setting alert levels should be carefully considered depending on the machine tolerances associated.

WPC Standard Deviation (s) = $\sqrt{(\sum WPC \times (\sum WPC^2/N))} / (N-1)$

First Warning Level = $WPC + 2s$

Red Alert Level = WPC +3s

8.2 – D_L and D_S Readings
Flow rates through the precipitator tube have some effect on particle deposition across the precipitator tube assembly. All precipitator tubes are pressure dropped during assembly within the limits needed to maintain a certain consistent flow rate. D_L and D_S readings are susceptible to changes as the flow rate decreases. Decreasing the flow rate by a factor of 2 will see an average overall increase of D_L and D_S reading of 15%. Therefore, more viscous oils need 2ml of heptane to thin them to an acceptable viscosity.

Sample time is the easiest indicator of a sample that is too viscous. Typical sample times are between 200 to 300 seconds. Sample times that are much greater will cause particles to concentrate at the beginning of the precipitator tube, instead of precipitating along the entire length of the tube area. Samples which take long periods of time to run indicate the viscosity is too viscous and should be thinned to maintain comparable DR data.

When readings increase several units and then decrease, it is an indication that large non-magnetic particles are passing by the sensor location. This can be caused by large dirt particles or minute air bubbles. However, these do not affect the particles that have precipitated to the bottom of the tube, since dirt particles will tend to remain in the middle of the fluid flow and air bubbles will rise to the top portion of the tube.

As discussed in the previous section, when the D_L and D_S numbers trend close together, this indicates larger particles have precipitated out and most of the particle concentration present in the oil sample are small particles. This indicates the machine wear has reached an equilibrium state where large particles are being generated at the rate in which they precipitate out or are removed from the system through filtration or other means. The remaining smaller particles gradually increase over time as they tend to stay suspended (See Figure 8.1 A&B).

Typically, in non-steady state machinery the value of the D_L will be greater than the D_S. Cumulative plots of the data will show diverging lines, where the slop of the D_L will be greater than the D_S. This indicates increasing large particles.

On occasion, a sample will produce a D_S value greater than the D_L. For these cases, there is a high concentration of small particles that are small enough that they stay suspended in solution and tend to settle further down the precipitator tube after entering the magnetic field. Therefore, with relatively low large particle concentration and a very high small particle concentration the magnitude of the D_S value can be higher.

All versions of DR instruments calculate values of the D_L and D_S based on percentage of light blockage, amplifying, and calculating the signals into the D_L and D_S units. These numbers generated for the D_L and D_S are unitless, based on the light emittance over each of the sensors. The calculations conducted are based on known analytical ferrograph results in comparisons to the DR making the values of D_L and D_S relative to size concentrations of wear particles. At very low concentrations of both D_L and D_S, a zero value can be possible. A zero does not necessarily mean there are no particles in the sample, but rather the concentration is so low that there is not enough material to cause a difference in light blockage of the sensors, or to block the sensors. Data is used for trending wear as in section 8.2 Quantifying DR Data.

9. Maintaining the DR-7

The DR-7 requires little maintenance except keeping the instrument clean and oil free and keeping the LED's sensors calibrated.

9.1 – Sensor Cleaning

Eventually over time dirt and oil will build up in the sensor area. Routine cleaning will eliminate possibilities of sensor reading errors caused by dirty or oily sensors. Dirt deposits can lead to obstruction of light generated by the LED's, which in turn will increase DL and DS readings.

To clean the sensor area, follow the procedure below:

1. Close the DR-7 program and shutdown the Windows operating system.

2. Once the operating system is shut down, turn off the DR-7 and unplug the power cord.

3. Remove the sensor cable coming out the top of the optics holder assembly by loosening the set screw with a 0.05-inch Allen wrench. The set screw is located on the left side of the optic holder assembly.

4. Gently pull upwards on the optics cable, removing the optics.

> **NOTE:** Ensure the position of the optics are correctly inserted the same way when re-installing into the block, otherwise DL and DS readings will be inverted. A letter L and S are stamped into the nylon insert. The L should be positioned into the left side of the optics holder socket.

5. Clean the two optical sensors with heptane or isopropyl alcohol and dry them by gently blowing them off with air. If the optical sensors come out of their sockets, they can be reinserted with the short lead placed into the upper socket. The socket is designed to only allow the sensor to be inserted one way.

6. Ensure the Optics Assembly is clean by lifting the gate and cleaning the area where the precipitator tube is inserted, paying attention to thoroughly cleaning the light source area.

7. Reinsert the optics making sure that they are fully seated in the optics block. Ensure that the L marking on nylon insert is facing to left-hand side of the instrument.

8. Tighten the small Allen set screw on the side of the block to hold the optics in place.

9. Turn the Instrument back ON and follow the directions given on the screen or in section 7.3.1 – **OPTICAL CALIBRATION** of the manual to conduct optical light source calibration.

> NOTE: Never remove the optics block from the magnet assembly or tamper with the adjustment screws located on the top and sides of the optics block. Doing so will misalign the optics with the light source. The optics are aligned and calibrated during the unit production assembly process. If this happens contact Trico for support.

10. Limited Warranty

Trico warrants to the original purchase only, that these Ferrographic instruments and/or Ferrographic supplies, and accessories (the "Product") are free from defect in material and workmanship and will remedy any such defect according to the terms of this Limited Warranty.

Trico will repair (or at its option, replace) at no charge any defective component(s) of Trico's instruments for twelve (12) months from date of purchase. Trico will repair (or at its option, replace) at no charge any defective component(s) of Trico's supplies and accessories for ninety (90) days from date of purchase.

To make request or claim for service under this Limited Warranty, the original purchaser must return the Product, shipping prepaid, in the original shipping container or equivalent, to Trico, after receiving return authorization from Trico and assuming the risk of loss or damage in transit.

This Limited Warranty shall not apply if the Product has been damaged due to abuse, negligence, misuse, misapplication, or accident after the Product has been shipped. Trico does not warranty any damage caused by third party or malicious software.

ALL EXPRESS AND IMPLIED WARRATNTIES FOR THIS PRODUCT, INCLUDING THE WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, ARE LIMITED IN DURATION TO A PERIOD OF ONE (1) YEAR FROM THE DATE OF PURCHASE FOR INSTRUMENTS AND NINETY (90) DAYS FOR SUPPLIES AND ACCESSORIES, AND NO WARRANTIES, WHETHER EXPRESS OR IMPLIED, WILL APPLY AFTER THESE PERIODS.

IF THIS PRODUCT IS NOT IN GOOD WORKING ORDER AS WARRANTED ABOVE, YOUR SOLE REMEDY SHALL BE REPAIR OR REPLACEMENT AS PROVIDED HERE. IN NO EVENT WILL TRICO BE LIABLE TO YOU FOR ANY DAMAGES, INCLUDING ANY LOST PROFITS, LOST SAVINGS OR OTHER INCIDENTAL OR CONSEQUENTIAL DAMAGES ARISING OUT OF THE USE OR INABILITY TO USE SUCH PRODUCT, EVEN IF TRICO HAS BEEN ADVISED OF THE POSSIBLITY OF SUCH DAMAGES, OR FOR ANY CLAIM BY ANY OTHER PARTY.

This warranty gives you specific legal rights, and you may also have other rights which may vary from state to state. If any provision of this Limited Warranty is held to be unenforceable for any reason, it shall be modified rather than voided, if possible, to achieve the intent of the parties. In such an event, all provisions of this Limited Warranty shall be deemed valid and enforceable to the full extent.

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