

Wilks Enterprise, Inc.

140 Water Street · South Norwalk, CT 06854

203 855 9136 · 203 838 9868

www.wilksIR.com · info@wilksir.com

InfraCal[®] Soot Meter

User's Guide

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InfraCal[®] Soot Meter

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1. InfraCal Soot Meter Overview

1.1. Introduction

The InfraCal Soot Meter, is designed to measure suspended “soot” content of used diesel motor oils. Soot, is present in the oil as a finely divided form of carbon black. Carbon absorbs light energy over most of the visible and infrared regions of the electromagnetic spectrum. The amount of energy absorbed is proportional to the soot content of a sample. The InfraCal Soot Meter uses ATR (attenuated total reflectance), also known as internal reflectance, for the determination of soot content.

1.2. Basic measurement concept

The InfraCal Soot Meter uses ATR (attenuated total reflectance), also known as internal reflectance, for the determination of soot content. A simplified schematic drawing of the InfraCal concept is provided in Figure 1.

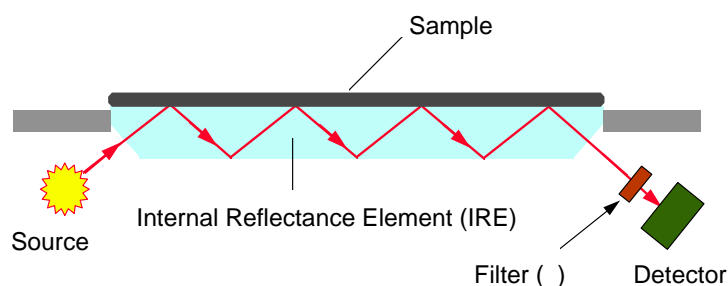


Figure 1: A

Schematic Representation of the Optical Concepts used in the Soot Meter

When a sample is placed on the internal reflectance element (IRE), the light transmitted through the IRE (I_s), to the detector is reduced. In all cases, the light absorption from a sample with suspended carbon will be greater than from clean oil (I_r). The soot concentration is determined by a calculation of the logarithm of the ratio of the light transmission with fresh oil and that of the carbon containing sample (Beer-Lambert law). The Beer-Lambert law assumes a linear relationship between absorbance and concentration. Deviations from linearity are determined by obtaining absorbance values from known (TGA analyzed) samples and an internal calibration table is prepared (Section 4) so that actual % carbon is displayed.

1.3. Analyzer description

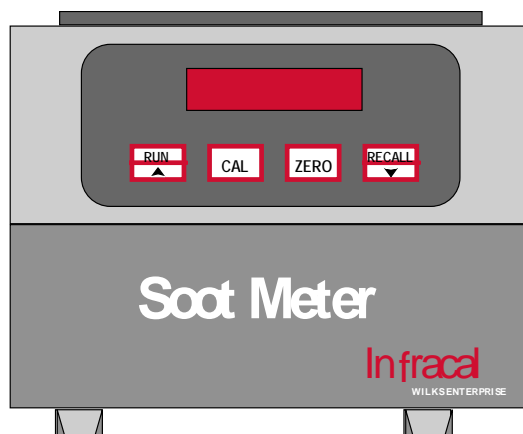


Figure 2: The InfraCal Soot Meter: Front View of Analyzer

1.3.1. Front operating panel

The front panel consists of a 4 digit LED display and four labeled, touch-sensitive push button controls as illustrated in Figure 3. The LED display remains illuminated while the analyzer is plugged in (switched on). When the instrument is on and not in use, the display may either show the result of the last analysis, or it may show *idLE*.

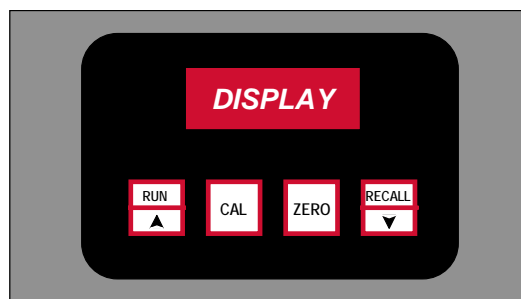


Figure 3: The Display and Control Panel

1.3.2. Back panel

The main power socket for the 12 Volt power supply is located on the back panel. The back panel also provides a standard nine pin, female DB9 connector for serial (RS232-C) data communications with the analyzer. This requires the use of a standard straight through serial data cable. See Section 7 for details of data communications with the Soot Meter. The CAL lockout switch deactivates the front panel CAL button to keep the internal calibration table from being inadvertently changed or turned off. For calibration, the switch is ON (I). After calibration the switch may be moved to the locked position (O). The back panel also contains the CE Mark designation indicating compliance with the codes for operation within the European Community countries, and the analyzer serial number. Make a permanent note of the serial number, and quote this when contacting Wilks Enterprise with a service or warranty related issue.

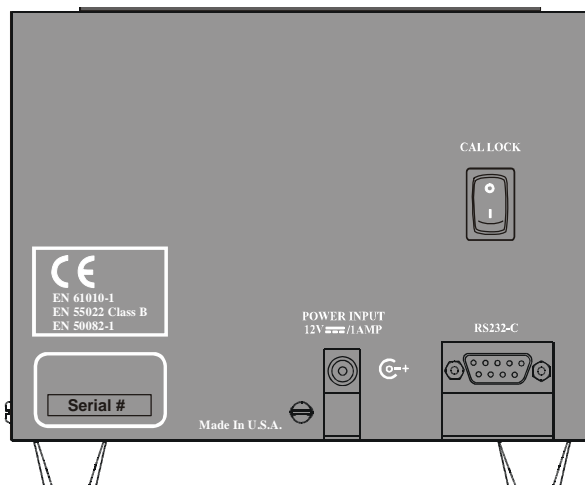


Figure 4: The Soot Meter: Rear view

1.3.3. The Sampling Plate

The sampling plate is an integrated sampling optic and sensing head. It includes the infrared source (modulated) and detector system, which are optically close-coupled to the optical sampling surface (the IRE). This sampling surface is made from cubic zirconia, and is both corrosion resistant and scratch resistant. The sample is applied to this surface via a dropper

(disposable plastic dropping pipettes are recommended) or directly from the end of a engine oil dip stick. After analysis, the oil sample is removed by wiping with either an absorbent paper towel or kimwipes. Typically, no solvents are required for cleaning. If the top surface of the instrument becomes excessively stained by the oil, a hydrocarbon-based solvent is recommended for removal of the oil residues.

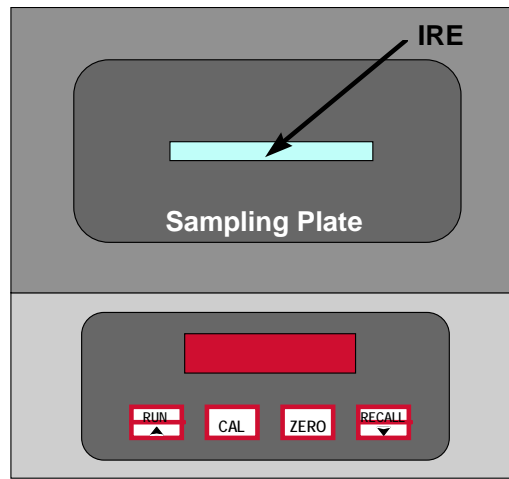


Figure 5: The Soot Meter: Top View

1.3.4 Description of the push button controls



RUN - initiates sample analysis (Section 3). Also used in **CAL** to record a calibration sample (Section 4).



UP arrow control - used to increase numerical values used in the **CAL** function (Section 4).



CAL – Hold for 2 seconds to select calibration type (*uSEr*, *Edit* or *oFF*). Also used to generate a new user calibration. Quickly press and release to print the last result.



ZERO - Hold for 2 seconds to zero balance the instrument (*baL* appears on display during operation (Section 2). Also used to exit **CAL**. Quickly press and release to print the current calibration table.



RECALL - Quickly press and release to recall up to the last ten results (recall mode, section 1.4.3) or to display the average (averaging mode, section 1.4.3). Hold for 2 seconds to reset the printer sequence number.



DOWN arrow control - used to decrease numerical values used in the **CAL** function (Section 4)

1.4. Analyzer features

1.4.1 Internal Calibration:

The Soot Meter is shipped with a factory derived calibration (*FAcT* - see Section 4) which is obtained by specially prepared reference samples. Without the calibration, InfraCal Soot Meter reads in relative absorbance units that are proportional to concentration. An internal microprocessor allows the user to enter a calibration in order to read in the desired units. The

Analyzer contains three different user selectable calibration modes. These are *oFF*, *uSEr* or *Edit*. Section 4 explains the calibration functions in detail.

1.4.2 External Communication:

The InfraCal Soot Meter supports communications to a PC, printer or controller via an RS-232C asynchronous serial communications port. This capability allows for collection of sample measurement data and instrument control by a host computer. It also allows for multiple calibration tables if more than one table is being used with a single instrument.

Specification details for communication parameters are in Section 7.

1.4.3 Recall Function/Averaging Results

The analyzer has the ability to store ten results for use with the averaging function or for local recall and display. Results may be data logged via the serial communications interface to a serial printer available as an accessory or to an external PC (section 7, Analyzer Communications Interface).

1.4.4 Printing the Result

An optional printer can be connected to the analyzer through the RS232C port located on the back. To print the result, momentarily press and release the **CAL** button. The result is printed on one line. The first number printed is a 5-digit sequence number. The sequence number is followed by the result. The remainder of the line contains the date, time and day of the week.

To reset the print sequence number press and hold the **RECALL** button until *PCLr* is displayed. The next result will print as sequence number 000001.

1.4.5 Setting the evaporation timer

The InfraCal Soot Meter contains a built in, user programmable, evaporation timer that is not typically used for soot analysis. The only reason to be concerned with the timer is if the Soot Meter is accidentally set in timer mode.

Timer Programming

The CAL lockout switch must be in the on (I) position to set the timer (see figure 3, section 1.3.2). Press and hold the **RUN** button until the current timer value is displayed. The value is displayed as 1 or 2 digits in minutes and 2 digits in seconds, separated by a period (.). Release the **RUN** button once the current value (initially 0.00) is displayed. Use the up- arrow and down-arrow keys to scroll the timer back to 0.00. Once the desired time has been programmed press the **CAL** button. The display will read *idLE*.

Overriding the Timer

For a zero check or to do a second reading on an evaporated sample, the timer may be overridden. To override the timer, press and release the **RUN** button twice and the analyzer will go directly into the measurement cycle.

2. Getting Started

2.1. Installation

2.1.1 Location

The InfraCal Soot Meter may be installed virtually anywhere. It is not affected by vibration and it can operate over a broad range of ambient temperatures (40°F, 4°C to 110°F, 45°C).

2.1.2 Power Requirements

The analyzer is powered from a 12 volts d.c. power source. A standard 12 volt power supply is provided with the analyzer, and this may be operated from any grounded a.c. outlet (line power requirements: 100 - 250 VAC, 50-60 Hz, 0.5-0.3 amps). When operating, the Soot Meter consumes approximately 8 watts (0.67 amps).

For field use, the instrument may be connected to other sources of 12 volt d.c. power, such as an external battery pack or the cigarette lighter output of an automobile (contact Wilks Enterprise for details). If the lighter output is used, the vehicle engine should be switched off during operation of the analyzer. Use with the engine running may result in the generation of a **bAtt** error code.

Plug in the external 12 volt supply to the power connector at the rear of the instrument. When plugged in, the instrument display will show **init** for a short time. Once the power-on initialization is complete, the instrument displays **idLE**. The Soot Meter is now ready for use.

Note: the connector is polarized with the center pole positive. Failure to use the correct power supply or the correct cable can result in permanent damage to the analyzer and may invalidate the warrant. The InfraCal internal memory, which retains the factory and user calibration tables could be erased from a voltage spike or surge on the 120-220VAC line. The use of a surge protection device between the user's AC line and the 12V DC power supply is recommended to prevent the loss of calibration tables.

2.1.3. Warm up time

For normal operation, it is recommended that the instrument be allowed to warm up for 1 hour prior to use. However, the analyzer is sufficiently stable after 15 minutes, and meaningful measurements may be obtained at this time. If the analyzer is used under the 1 hour warm-up time, frequent checking of the zero is recommended for best results. The longer warm-up time is recommended prior to making critical measurements and when performing analyzer calibration. The Soot Meter draws very little power and, if used daily, it can be left on at all times (unless operated from an external battery pack).

2.2 Zeroing the Analyzer

For initial set-up, establish zero for the analyzer using the following procedure. Once a zero has been established, subsequent zero checks should use the zero check procedure described in section 2.2.2.

2.2.1 Establishing Zero

Ensure that the sample surface clean by wiping with a dry paper towel or kimwipe and no soot residue shows up on the clean wipe.

Add clean base oil to the sample surface

Press and hold the **ZERO** button until the display reads **bAL**. Release the button. A multiplier value to 3 decimal places will be displayed when zero is established. The actual value is only of interest when reporting problems to the factory.

Press **RUN**. The display should read 00 ± 02 . If not, repeat the zero process.

Note: If the sample plate does not have any oil sample on it the values will be negative.

2.2.2 Zero Check

The zero value is retained in permanent memory and is restored each time the instrument is powered up. It is recommended that the zero be checked and (if necessary) reestablished, on a daily basis.

To check the zero value, add clean base oil and press the **RUN** button.

If the result is not ± 0.2 , remove oil and clean with a paper towel or kimwipe, then add new base oil the trough plate.

Check zero again.

If the result is not ± 0.2 , reestablished the zero as described in 2.2.1

3. Analyzing an Oil Sample

The Soot Meter is shipped with a factory derived calibration (*FACT* - see Section 4) which is obtained by specially prepared reference samples, which in turn have been calibrated against well characterized engine oil samples containing suspended soot (as determined by TGA - thermogravimetric analysis). Some interdependency of engine type and oil formulation type may exist, especially if the samples have been stored for a long period. With time, it is believed that aggregation of the suspended soot can occur, and the aggregate possesses slightly different optical characteristics than freshly dispersed soot from an engine. An additional calibration can be generated by a user (*Edit* - see Section 4), and this can be made to override the factory stored calibration.

3.1. Samples - range of applicability and issues for consideration

The analyzer will provide reliable soot content results from zero up to 11+% soot. The maximum value achievable may vary somewhat from analyzer to analyzer but is expected to be somewhere between 11% and 12%. When this maximum value is exceeded, a *notr* warning code (see Section 6) indicates that the light throughput has fallen below an acceptable level, making the results unreliable.

The recommended format for the display is percent (*Pct*), which provides a single decimal place. This is adequate all soot measurements. Measurement accuracy is expected to be around $\pm 0.1\%$ (soot content) for soot values between 0% and 3%, and $\pm 0.2\%$ at values of 3% and above.

Used oil samples can be inherently unstable, and can change characteristics over time. The best results are obtained from samples recently taken from an engine. Samples greater than one or two months old may undergo some physical characteristic changes - such as settling of some of the heavier insolubles and partial aggregation of the suspended particulate. Some samples may even become thixotropic in nature over time. In such cases, vigorous mechanical shaking (or stirring) is recommended in an attempt to homogenize the sample. An ultrasonic bath may also be used to help homogenize a sample.

3.2 Sample Analysis

Apply the sample from a dropper (disposable plastic droppers are recommended) to the entire sampling surface of the Soot Meter. (In the field, the sample can be applied by wiping the engine dip stick directly across the entire sampling surface.)

Press the **RUN** button within a few seconds of applying the sample. The soot content of the sample will appear on the display within 10 seconds.

NOTE: Because the used oil samples may not be completely homogeneous, better precision can be obtained by cleaning the surface and reapplying the same sample. An averaging of three or more readings from successive samples will increase the precision of the reported values

3.3 Sampling Suggestions

When making measurements from samples stored in bottles or other containers, ensure that the oil sample is well mixed before drawing a sample.

For field sampling, draw the sample from the engine while hot, and preferably while the engine is still running. Allow the sample to cool down to ambient temperatures before placing on the Soot Meter sampling surface.

With certain samples, there may be a build-up of charge on the suspended soot particles. Dependent on the charge of the particles, the particles may move towards the sampling surface or away from the surface over time. This is observed as a decrease or an increase in soot values for repeated RUNs. If the oil is overloaded with soot, the carbon particles may slowly settle toward the sampling surface. Neutral samples may decrease in value over time due to thermal effects. For these reasons, it is important that the sample is analyzed as soon as it is placed on the sampling surface, and that only the first value displayed is used for soot content.

4. Analyzer Calibration

4.1 Overview

The Soot Meter contains four different user selectable calibration modes. These are *FACT*, *uSEr*, *Edit* or *oFF*.

The *FACT* mode is used for normal operation. This is the default mode supplied from the factory. This mode selects the pre-loaded factory calibration table that provides accurate measurement up to 11% soot for most fresh used oil samples. This calibration is performed at the factory using the reference oils supplied with the Soot Meter. The reference oils should be used regularly to check the instrument's zero and calibration values.

The *Edit* mode allows the user to edit an existing calibration table or to create one from scratch, using absorption values obtained in the *oFF* mode. This is the preferred method of creating a user calibration as an average of multiple sample measurements can be used to create the calibration points. This allows user to perform a custom calibration for situations where the samples to be measured do not correlate to the factory. If the *Edit* mode is selected and no user calibration exists, the Soot Meter defaults to the factory table.

The *uSEr* mode is not the preferred method to use for calibration of the biodiesel analyzer. Contact Wilks Enterprise, Inc. if you would like to use this method.

In the *oFF* mode the instrument measures soot in arbitrary absorption units that are proportional to % soot content. Higher values indicate increased levels of soot. This mode can be used to collect "raw" data when selecting reference oils to be used for user calibration. The "raw" values can be plotted against the known soot concentration values to select reference samples that best match the absorption curve.

4.2 Selecting the Calibration Mode

The desired Calibration Mode is selected as follows:

Press the **CAL** button for two seconds, until **CAL** appears on the display. Press the **RECALL** button to display the active table, one of *FACT*, *uSEr*, *Edit*, or *oFF*. Press and release the **RECALL** button repeatedly until the desired mode is displayed.

Press the **ZERO** button to exit the calibration mode. *iDLE* will be displayed.

4.3 Selection of suitable calibration standards

Select a set of pre-analyzed samples covering the desired range for the analysis. An ideal calibration set may contain four or five samples, relatively evenly spaced - e.g. 2%, 4%, 6%, 8% and 10% soot content. Ensure that the samples are referenced to the same standard method of analysis - usually TGA (thermogravimetric analysis) or FTIR. Finally, ensure that the samples are stable and thoroughly mixed before calibrating.

Take several samples for each reference value and measure the absorbance value with calibration off. Average the results after discard any obviously erroneous results. Plot the “raw” absorbance values against the known percent soot values to select calibration reference samples that best match the absorption curve.

4.4 Calibration considerations

Calibration standards should be carefully selected to obtain the best results with your Soot Meter. The following notes are provided to aid the user in selection of suitable standards.

Always zero the Soot Meter using a clean fresh oil sample prior to calibration or collecting data for calibration analysis.

Select a set of pre-analyzed samples covering the desired range for the analysis. Ensure that the samples are referenced to the same standard method of analysis - usually TGA (thermogravimetric analysis) or FTIR. Finally, ensure that the samples are fresh, stable and thoroughly mixed before calibrating.

Normally soot concentration values are relatively linear. At higher concentrations some flattening of the absorption curve may exist. The *oFF* mode described in section 4.1 can be used to obtain absorption values for the standards. These values can be plotted against the TGA values. For best results, select calibration standards that, when connected via straight line segments, best trace the curve of all standards for which data is collected.

Finally, standards should be selected that are reasonably spaced apart and not too close to the zero reference. They should also cover the entire measurement range. The lowest concentration standard should measure at least 1.0 in the *oFF* mode. All successive samples should be spaced apart by at least 1.0 absorption units.

4.5 Calibration editing

Calibration editing allows manual entry or modification to zero balance and user calibration data. This technique allows the user to collect a series of absorption results for each calibration point, compute the average value, and manually enter the results into the permanent calibration memory of the analyzer. Data collected for this purpose should always be obtained with the calibration *oFF*.

Press the **CAL** button for two seconds, until **CAL** appears on the display. Press the **RECALL** button to display the active table, one of **FACT**, **uSEr**, **Edit** or **oFF**. Press **RECALL** repeatedly to scroll through the above list until **Edit** is displayed.

After **CAL** is pressed, the display will read **n=** for a short time, followed by the number of entries currently in the calibration table. Scroll to the desired number of entries (0 - 20). **Selecting 0 will erase any existing user calibration table but not the Factory calibration..**

Press **CAL** to proceed. **A0I=** will be displayed followed by the current absorption value for the first calibration table entry. Scroll this to the desired value. Press **CAL** again and the display will read **C0I=** followed by the current percent soot concentration value for the entry. Scroll this to the desired value.

Continue to press **CAL** to step through all absorption and concentration values for the table size entered. Once all entries have been adjusted or created the display will read **idLE**.

Note: All data values must be viewed (and optionally modified) to exit from the calibration editor otherwise the calibration will be deleted from both the edit and user mode. A factory calibration can not be deleted.

NOTE: *The editor imposes limits on data entry values to insure that the created table is valid. Normally, when editing existing table entries the previous value is displayed as a starting point for scrolling. If the previous entry is modified to a higher value than the current entry, scrolling will begin from that value. Scrolling begins from the previous data point when entering new calibration points in the table. During scrolling the minimum value allowed is the value of the previous table entry.*

4.6 Calibration printing

The current calibration table is printed by momentarily pressing and releasing the **ZERO** button when the analyzer is idle. The first line indicates which calibration is active followed by the date and time. The second line gives the headings for the calibration table that follows. ABS represents absorption and CON represents concentration. The table headings are followed by the balance value. One additional line is printed for each calibration table entry. The absorption and concentration values are given.

5. Analyzer Specifications

5.1 External power requirements:

The InfraCal Soot Meter operates off external 12-volt power. The power sources can be either regulated DC power supplies or an external battery. This power can be provided by the user or by Wilks Enterprise, Inc. The suggested minimum requirement specifications for the 12 volt power source applied to the analyzer are described below:

Wall Supply Specifications:

Input: 100-250 VAC, 50-60 Hz, 0.5A
Output: 12 VDC, 1%, 25 Watts

Battery Supply Specifications:

Output: 14 VDC Maximum, 11 VDC Minimum

Load Specifications:

1.5 Amperes Peak

5.2 Physical:

Dimensions: 6.5 in. x 6.5 in. x 5 in. (165 mm x 165 mm x 127 mm)
Weight: 4.5 lb. (2.0 kg.)
Control: Display (output) 4 digit 7 segment red LED,
5/8 in. character height
User (input) 4 multi-function push-button switches
Connectors: Power -- Switchcraft Model 760 plug or equivalent
Communications -- 9-pin D-Sub, female

5.3. Environmental:

Temperature: Non-operating -- 0 F (-18 C) to 125 F (52 C)
Operating -- 40 F (4 C) to 110 F (45 C)

Humidity: Relative -- 10% to 60% non-condensing

5.4. Electrical

Noise: Rejection -- 60 dB minimum

Drift: Short term Ambient --(< 1 Hr.) 0.3% of full scale
Long term Ambient -- (> 1 Hr.) 0.1% of full scale
Temperature -- 0.03% of full scale per degree C
Repeatability -- 0.1% of full scale

Response: On Delay -- 5, 10, 15 or 20 second factory-set intervals
Measure Time -- 5 seconds
Modes -- Local control or remote PC control

Resolution: Conversion -- 16 Bits (0.0015%)

Ranging: Digital Ranging -- 256 step automatic ranging
Analog Range -- 0 to 4.096 volts
Answer Range -- Absolute; 00 to 9999
Percent; 0.0 to 100.0%
Decimal; .00 to 99.99
Measure Range -- Dependant on sample concentration ratio

Measurement Accuracy: 1% of full scale

Measurement Repeatability: 0.1%, 1 digit

Memory: Non-volatile memory for calibration and configuration data

5.5 Calibration:

Electronic zero balance adjustment

Up to 20 point curve fitting calibration

Modes: Edit Table
Off
Factory (special order)

6. Analyzer Error Codes and Warning Codes

6.1 Error Codes

Internal Soot Meter diagnostics provide the following error code displays to aid the user in identifying potential problems and taking corrective action. If any error code is displayed, the user should reinitialize the instrument by depressing any key or temporarily removing and restoring external 12 volt power. If the error code persists, internal or factory service is required.

The following failure codes require factory service:

Er05 This error code indicates the Soot Meter's internal +5 volt regulator is out of tolerance (+4.55 Vmin to +5.45 Vmax) for proper operation.

ErPA This error code indicates the Soot Meter's internal +6.5 volt regulator is out of tolerance (+6.0 Vmin to +7.6 Vmax) for proper operation.

Er-A This error code indicates the Soot Meter's internal -6.5 volt regulator is out of tolerance (-6.0Vmin to -7.6 Vmax) for proper operation.

ErEE This code indicates there is a diagnostic memory error internal to the Soot Meter.

The following error code can be serviced by the user or by the factory:

ErSA This error code indicates the Soot Meter's internal light source cannot be adjusted to the proper energy level required for instrument operation. This error may occur if the source cable has become disconnected, the source is burned out, or if the controller board has failed. The user can observe the source best during initialization. The source is located on the left hand side of the sample surface window. The lamp should be modulating at high intensity while *init* is displayed. During *idLE* the intensity is significantly decreased. If this is not the case the user can repair this condition by removing the instrument cover and reconnecting the source cable (if disconnected), replacing the source or replacing the controller board. Otherwise, the instrument must be returned to the factory for service.

6.2 Warning Codes

bAtt Signifies the external 12 volt source is out of the tolerance specified (+11 Vmin to +14 Vmax) for proper operation of the Soot Meter.

If this error condition occurs when using a wall supply, the user can use a voltmeter to measure the DC level of the external power source. If the power supply is out of tolerance it must be replaced. If Wilks Enterprise supplied the power supply, return it to the factory for replacement. If the external power source has the correct 12 volt level and the Soot Meter still indicates the **bAtt** error code, the analyzer should be returned to the factory for service.

If the external power source is a battery, the user should either replace the battery with a fully charged unit or recharge the low battery before proceeding. The following warning codes can be serviced by the user or by the factory:

notr This warning indicates the energy levels being received by the sample system detectors are below the minimum requirement for accurate signal processing. When this occurs, the measurement cycle is aborted and the **notr** warning is displayed instead of a result. This warning could occur if the lamp has failed. For this condition, the user should follow the service procedure specified for **ErSA**. This warning could also occur in sample applications when the sample's transmission characteristics are close to 0%. For this condition, the user should reexamine the prepared sample.

If the **notr** warning occurs during a run cycle, a new measurement cycle can be initiated in the normal manner.

If the warning occurs during a zero balance cycle, the analyzer zero remains unchanged from its previous value. If the warning occurs during the calibration procedure, the entire calibration procedure must be repeated. The calibrated data is left in an invalid state.

7. Analyzer Communications Interface

7.1. Abstract

The InfraCal Soot Meter supports communications to a PC or other host via an RS-232C asynchronous serial communications port. This capability allows for collection of sample measurement data and instrument control by a host computer. The host can also maintain calibration tables and download them to the instrument as required. This is particularly useful when more than one table is being used with a single instrument.

Specification details for interfacing user customized host software is as follows:

7.2. Physical connection

The InfraCal Soot Meter is connected to the external device via the 9-pin female DB9 connector located on the rear panel in the lower left-hand corner. The InfraCal Soot Meter operates as a DCE device. To connect to a PC, a standard straight through 9 pin cable can be used, but only 3 wires are required.¹ The required signals are Transmit Data (TXD), Receive Data (RXD) and Ground (GND). The pinout is as follows:

Function	Pin
RXD	3
TXD	2
GND	5

¹ Systems with serial numbers lower than 10200 require a null modem cable or null modem adapter.

7.3. Communications port setup parameters

The port setup required by the InfraCal Soot Meter is:

- 9600 baud
- 8 data bits, 1 stop bit
- No parity

7.4. Operation

The Soot Meter accepts ASCII commands from the host and returns data as a response to certain commands or, in datalogging mode, on completion of a measurement cycle. All commands are two characters in length. Certain commands have parameters that follow the command. Parameters are separated by commas. All commands are terminated by a carriage return character. All data responses are comma separated ASCII fields, terminated by a carriage return character. The first field indicates the result type; the remaining fields are the result. Result types are 'B' for balance results, 'R' for run results or 'C' for calibration data. The result format is determined by the presentation mode and is identical to the LED display data. The Read Display Mode command returns a two character mode code. Alphabetic characters can be sent in upper or lower case. Response data is always upper case.

Command Set

Command	Description	Response Examples
RB	Read balance	B,1.025 B,0.865
RR	Read displayed result	R,27.5 R,315 R,1.873
RU	Run (same as RUN button)	None
RA	Run & display uncalibrated	result None
BA	Balance (same as Zero switch)	None
LR	Enable results datalogging	None
DR	Disable results datalogging	None
RM	Read display mode	MA, MP, MD or MR
MA	Set display mode to absolute	None
MP	Set display mode to percent	None

MD	Set display mode to decimal	None
MR	Set display mode to ratio	None
WB,<params.>	Set balance data	None
RC,<params.>	Read calibration table	See detailed description
WC,<params.>	Set calibration table	None
CM	Read Calibration Mode	CD, CE or CF
CD	Disable Calibration	None
CE	Enable User Calibration	None
CF	Enable Factory Calibration	None
ES	Return error status	E,0 E,2
RE	System reset	None
ID	Return firmware ID	2.02.06

7.5. Data logging

Data logging provides results output at the end of each RUN or BALANCE cycle. The results are output when datalogging is enabled both for functions initiated from the instrument control panel and functions initiated by the host. The format of the data returned after a RUN cycle is as shown for the RR command and is determined by the display mode. The format of the data returned after a BALANCE cycle is as shown for the RB command. The RA command allows the host to initiate a run cycle and datalog a result that is not adjusted by the calibration procedure. This can be used by an intelligent host resident calibration table generator.

7.6. Remote zero balance control

The instrument zero balance can be controlled via the communications port. The RB, WB and BA commands provide the necessary controls. This feature can be used to store multiple zero values for different operating conditions. This feature combined with the calibration controls described in the next section can be used to maintain multiple calibration curves when using the instrument for multiple applications.

The RB command will retrieve the current zero balance data. The WB command can then be used to reset the current zero balance to a previously recorded value. The WB data field is identical in format to the data returned in response to the RB command.

The BA command can be used to initiate a zero balance function under remote control. The operation is identical to initiating a zero balance from the instrument control panel. The user must insert the zero sample in the instrument prior to issuing this command. If datalogging is enabled the result will be returned on completion of the function. The data format is identical to the RB command response. The result can optionally be read with the RB command if datalogging mode is not used.

7.7. Remote calibration control

Calibration data can be retrieved or set under remote control. Due to the complexity of the calibration function (and the need to utilize multiple calibration standards) initial calibration can only be performed from the instrument panel. Another approach is to use the host to generate one or more calibration curves from uncorrected datalog results collected with the RA command. This technique is extremely useful if the user desires to generate a calibration curve based on an average result of several measurements from a lot of each calibration standard.

The RC command is used to retrieve the current calibration table. A Calibration table consists of zero to twenty entries. The RC command can take the following forms:

RC	Read entire calibration table
RC,0	Read calibration table size

RC,n Read a single calibration table entry, where n is the entry number.

The RC,0 command response is C,n where n is the number of calibration table entries from 0 to 20. If 0, the instrument is not calibrated. Otherwise, n is the number of calibration table entries.

The RC,n command response is C,n,x,y where n is the entry number as received, x is the raw measurement data as it appears on the display during calibration and y is the actual value as set by the user during calibration. The format is determined by the display mode (absolute, percent, or decimal). Calibration commands should not be used when in ratio mode since ratio mode does not use a calibration table. An RC command requesting data for a table entry number greater than the current table size returns erroneous data.

The RC command with no arguments returns the complete calibration table, one entry at a time starting with the table size information. The individual entries are then returned in numerical order up to the number of entries.

Read Calibration Table Example

Assume the instrument is calibrated in the absolute mode using three standards. Assume the calibration results were as follows:

<u>Entry</u>	<u>Measured</u>	<u>Actual</u>
1	15	30
2	26	50
3	33	70

The RC command will return the following:

```
C,0,3
C,1,15,30
C,2,26,50
C,3,33,70
```

The RC,0 command will return C,0,3

The RC,2 command will return C,2,26,50

The WC command can be used to download calibration table data based on previously uploaded data or as determined by a host program. The command format is WC,n,x,y where the parameters are identical in format to the RC command. The parameters must match the current display mode. When using the WC command the table size and all necessary table entries should always be downloaded. Once all table entries have been downloaded the table size should be set.

Write Calibration Table Example

To download the calibration table described in the previous example, send the following commands:

```
WC,1, 15,30
WC,2, 26,50
WC,3, 33,70
WC,0,3
```

7.8. Error status command

The Error Status (ES) command should return a value of 0. If a non-zero status is returned, a fatal error has occurred. The System Reset (RE) command can be used to restart the instrument in an attempt to clear the error condition. The host should then wait 30 seconds

and reissue the ES command. If the error condition persists, service is required. See Section VI for details. The error codes are mapped to displayed error messages as follows:

<u>Error Code</u>	<u>Display Message</u>
1	ErSA
2	ErEE
3	Er05
4	ErPA
5	Er-A

8. Service and Customer Support

Your InfraCal[®] Soot Meter may have been purchased either directly from Wilks Enterprise or from a local dealer or representative. In cases of any difficulties or problems associated with operation you are recommended to contact your local representative or dealer first. If the analyzer was purchased direct, or if there are problems that are unanswered by the local representative, or you have a technical question relative to the operation of the instrument or relative to the analysis, please contact Wilks Enterprise at the contact address provided below:

Customer Services Department

Wilks Enterprise, Inc.

140 Water Street

South Norwalk, CT 06854

USA

Telephone: (203) 855-9136

FAX: (203) 838-9868

E-mail: tech@WilksIR.com

Service and Repair

During the warranty period, Wilks Enterprise, Inc. offers free factory service for all failures that occur from normal instrument usage. The user is only required to cover the cost of shipping the instrument to the factory. After the warranty period, the user is required to cover the factory's cost of servicing plus all shipping charges. Normal one week turn around is offered for all InfraCal instruments that are returned to the factory for service. For users requiring faster service times, Wilks Enterprise also offers an advance replacement program that can respond to a user's needs with instrument replacement typically in less than 24 hours. For extended service contracts, advanced replacement programs, factory service charges or sample system installation procedures, please contact Wilks Enterprise, Inc. for details.

Appendix A: Alternate Data Presentation

The recommended format for the display is percent (*Pct*), which provides a single decimal place. This is adequate all soot measurements. Other formats are available, and these may be set for specific applications.

NOTE: The Soot Meter must be calibrated in the selected data presentation mode. Changing the data presentation mode requires re-calibration.

The following are the different data presentation modes available of the InfraCal analyzer:

Percent Mode (Pct): Calculated values are displayed to a single decimal place (0.0).

Decimal Mode (dEC): Calculated values are displayed to two decimal places (.00)

Absorption Mode (AbS): An arbitrary scale related to the raw absorption of the sample (00).

NOTE: Inserting a decimal point does not change the raw absorbance value displayed for a given sample. ie: an Abs reading of 25 becomes 2.5 (pct) or .25 (dec).

Ratio Mode (RAI): A threshold based scale where a value defining an acceptable limit for maximum or minimum acceptable concentration is set to the value of 1.000. All values less than 1.000 indicate that the concentration is less than the threshold, while all values greater than 1.000 indicate that the concentration is greater than the threshold.

The Soot Meter display format can be switched between modes by pressing and holding both the **CAL** and **ZERO** buttons for two seconds. Each time the **CAL** and **ZERO** buttons are pressed the display mode changes. Release both buttons and repeat until the desired mode is displayed. The display will read: **AbS** for absorption mode, **Pct** for percent mode, **dEC** for decimal mode, and **RAI** for ratio mode. Press **RUN** to exit the data presentation mode one the desired mode is displayed.