ENGINE EXHAUST PARTICLE SIZER™ (EEPS™) SPECTROMETER
MODEL 3090/3090AK

OPERATION AND SERVICE MANUAL

P/N 1980494, REVISION J
MARCH 2015

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ENGINE EXHAUST PARTICLE SIZER (EEPS) SPECTROMETER
MODEL 3090/3090AK

OPERATION AND SERVICE MANUAL

Manual History

The following is a history of the Model 3090/3090AK Engine Exhaust Particle Sizer™ (EEPS™) Spectrometer Operation and Service Manual, P/N 1980494.

Revision	Date
A	January 2004
B	April 2004
C	March 2005
D	March 2006
E	August 2006
F	March 2009
G	October 2010
H	April 2011
J	March 2015

Warranty

Part Number 1980494 / Revision J / March 2015

Address TSI Incorporated / 500 Cardigan Road / Shoreview, MN 55126 / USA

Fax No. (651) 490-3824

E-mail Address particle@tsi.com

Limitation Of Warranty And Liability (effective February 2014)

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a. Hot-wire or hot-film sensors used with research anemometers, and certain other components when indicated in specifications, are warranted for 90 days from the date of shipment;

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(effective March 1999)

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TSI Patent

US Patent Number 7,230,431.

Safety

This section gives instructions to promote safe and proper operation of the Model 3090 Engine Exhaust Particle Sizer™ (EEPS™) Spectrometer. Samples of warnings and information on labels attached to the instrument chassis are also presented.

Description of Caution Symbol

The following symbol and an appropriate caution statement are used throughout the manual and on the EEPS spectrometer to draw attention to any steps that require you to take cautionary measures when working with the Model 3090:

Caution

Caution
Caution means ***be careful***. It means if you do not follow the procedures prescribed in this manual you may do something that might result in equipment damage, or you might have to take something apart and start over again. It also indicates that important information about the operation and maintenance of this instrument is included.

Warning

WARNING
Warning means that unsafe use of the instrument could result in serious injury to you or cause irrevocable damage to the instrument. Follow the procedures prescribed in this manual to use the instrument safely.

Caution or Warning Symbols

The following symbols may accompany cautions and warnings to indicate the nature and consequences of hazards:

	Warns you that uninsulated voltage within the instrument may have sufficient magnitude to cause electric shock. Therefore, it is dangerous to make any contact with any part inside the instrument.
	Warns you that the instrument is susceptible to electro-static dissipation (ESD) and ESD protection procedures should be followed to avoid damage.
	Indicates the connector is connected to earth ground and cabinet ground.

Electrical Safety

The EEPS spectrometer has high-voltage points within its cabinet. Only a qualified technician should perform service or maintenance.

WARNING
High voltage is accessible in several locations within these instruments. Make sure you unplug the power source before removing the cover or performing maintenance procedures.

Labels

The EEPS spectrometer has labels on the back of the instrument and on interior components. Labels are described below:

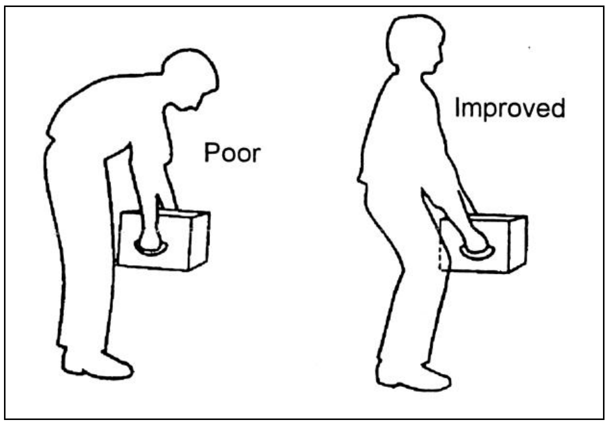
1 Serial Number Label (back of cabinet)	

2 Caution, No Serviceable Parts Label (back of cabinet)	 CAUTION No user serviceable parts inside. Refer service to qualified personnel. To avoid electrical shock, the power cord protective grounding conductor must be connected to earth ground.
3 Customer Service Label (back of cabinet)	**For Service and Information** **Contact TSI Customer Service** **www.tsi.com** **500 Cardigan Road** **Shoreview, MN 55126** **U.S.A.**
4 High-Voltage Symbol Label (interior, on power entry module) 5 Ground Symbol Label (interior, bottom, next to ground stud)	

Lifting Caution

The EEPS spectrometer weighs 32 kg (70 lbs). To protect your back when lifting:

- **Get help from another person to move the instrument**. The instrument is equipped with handles to allow for two people to safely lift it.
- Transport the instrument on a cart whenever possible.
- Lift with your legs while keeping your back straight.
- Keep the instrument close to your body as you lift.



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Tables

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About This Manual

Purpose

This is an operation and service manual for the Model 3090/3090AK Engine Exhaust Particle Sizer™ (EEPS™) Spectrometer.

Related Product Literature

The following TSI product manual may be of interest. Copies of these may be viewed on the TSI website, www.tsi.com.

- ***Model 3936 SMPS™ Scanning Mobility Particle Sizer™ Instruction Manual*** (part number 1933796) TSI Incorporated

Submitting Comments

TSI values your comments and suggestions on this manual. Please use the comment sheet on the last page of this manual to send us your opinion on the manual's usability, to suggest specific improvements, or to report any technical errors.

If the comment sheet has already been used, please mail, fax or email your comments on another sheet of paper to:

TSI Incorporated
500 Cardigan Road
Shoreview, MN 55126
USA

Fax: (651) 490-3824
Email: particle@tsi.com

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CHAPTER 1
Product Overview

This chapter contains an introduction to the Model 3090 Engine Exhaust Particle Sizer™ (EEPS™) Spectrometer (U.S. patent No. 7,230,431) and provides a brief explanation of how the system operates.

Product Description

The Model 3090 (Figure 1-1) is a high-performance instrument designed specifically for measuring particles emitted from internal combustion engines and vehicles. It measures particle size from 5.6 to 560 nanometers with a sizing resolution of 16 channels per decade (a total of 32 channels). Its unique design includes revolutionary features that allow fast distribution measurements.

Figure 1-1
Model 3090 Engine Exhaust Particle Sizer Spectrometer

Applications

The Model 3090 Engine Exhaust Particle Sizer spectrometer is ideal for analysis of a wide range of engine exhaust situations.

Engine tailpipe measurements

- Engine Dynamometer test cells
- Chassis Dynamometer test cells
- Old diesel engines with high emissions
- New generation diesels with active controls
- Measurements upstream and downstream of Diesel Particulate Filters or Particle Traps
- Spark Emission engine emissions—GDI Engines

Mobile Measurements
(Limited to 90 minute tests—not continuous monitoring.)

- Mobile test laboratories
- Electric vehicle measurement platforms
- Roadside measurements (in trailer or enclosure) to evaluate the effect of individual vehicles passing monitoring location

Instrument Description

Use the following information to familiarize yourself with the location and function of controls, indicators, and connectors on your Model 3090 Engine Exhaust Particle Sizer Spectrometer.

Front Panel

The main components of the front panel are the color LCD display and the control knob shown in Figure 1-2.

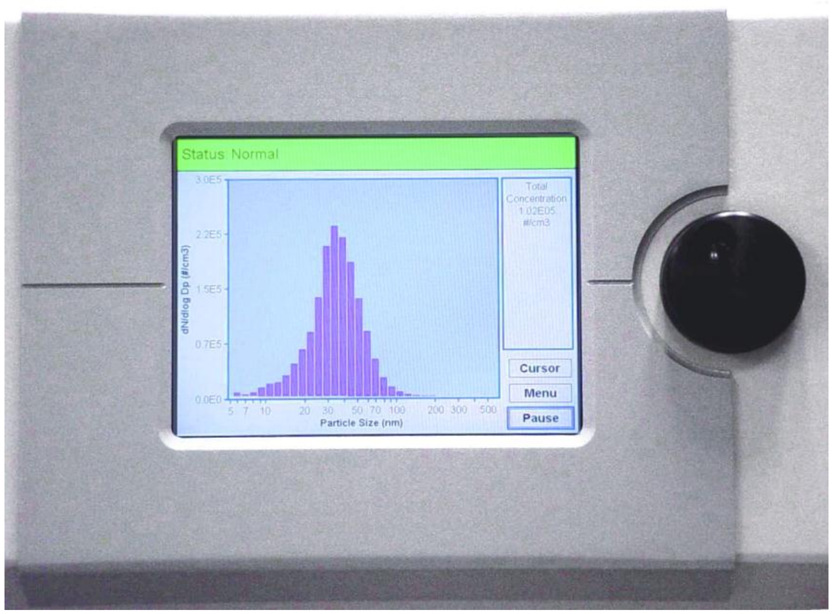

Figure 1-2
View of the EEPS Spectrometer LCD Display

LCD Display

The color 640 × 480 pixel LCD display provides continuous real-time display of sample data and is used in conjunction with the control knob to display options and instrument parameters. Refer to Chapter 4 for details of how to make selections and change values on the menu.

Instrument status is displayed at the top of the LCD display to indicate that required instrument voltages and flows have stabilized and the instrument is ready to use. Error status is also provided.

Control Knob

Turning the control knob highlights an item on the LCD display. Pressing the knob inward selects the option. To spin the knob quickly, place your finger in the indent on the knob surface.

Back Panel

As shown in Figure 1-3, the back panel of the Model 3090 has power and data connections, an analog and trigger input/output connection, an aerosol inlet, outlet, and a cooling fan.

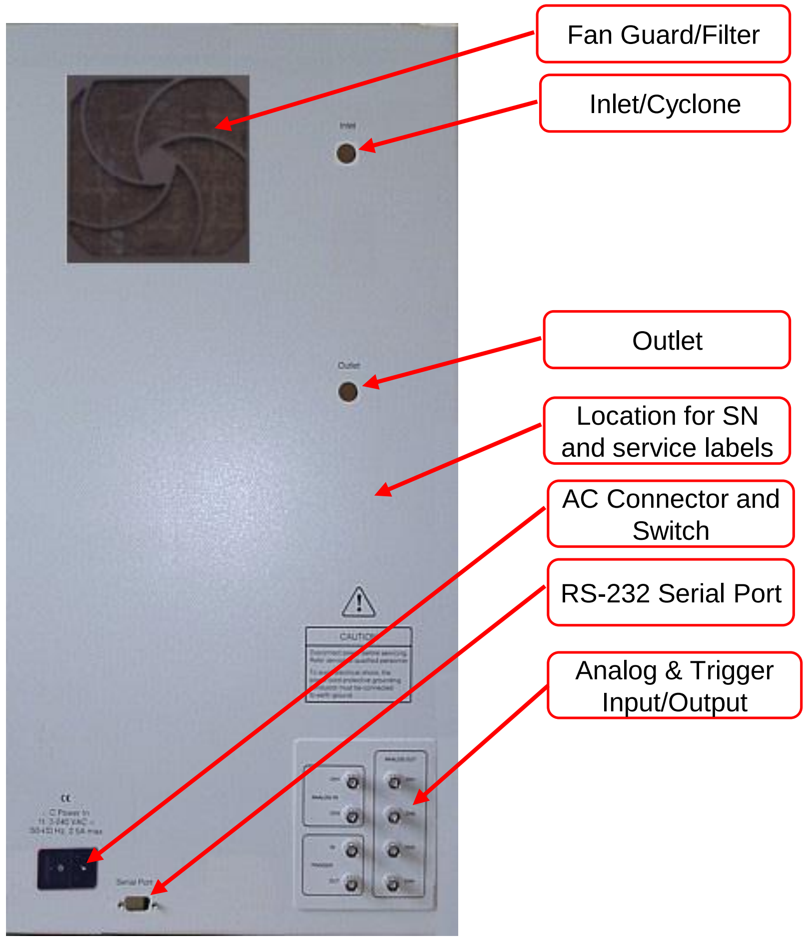

Figure 1-3
Back Panel of the EEPS Spectrometer

Heat Exchanger Fan

This fan keeps the sheath air temperature stable, near the ambient air temperature. It is provided with a guard and removable filter that should be cleaned periodically.

Aerosol Inlet/Cyclone

The aerosol inlet is designed for use with the supplied Cyclone (Model 1031083). The cyclone removes large particles outside the instrument measurement range that can cause counting errors. For remote sampling, tubing may be attached to the cyclone inlet. The cyclone is attached to the aerosol inlet using a Swagelok®-type union connector, which is supplied.

Aerosol Outlet

Sampled aerosol flow is filtered and exhausted at this port.

AC Connector and Switch

Plug the supplied AC cable into this receptacle. The instrument power switch is integrated into this AC connector at the top of the receptacle.

RS-232 Serial Connection

The data connection for the EEPS spectrometer is a standard RS-232 serial port connection that allows communications between the system computer and the Model 3090 for control by the EEPS software (Figure 1-4). Serial commands are sent to and from the computer to collect instrument status information and provide control functions.

Appendix D provides information that may be useful for developing custom software. The appendix provides a description of the basic serial data communication commands. (In some cases serial commands may be used for troubleshooting.) Appendix F provides information for communication via AK-Protocol (only available for the Model 3090 AK).

Figure 1-4
Detail of EEPS Spectrometer Back Panel

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Analog and Trigger Input/Output

The Analog and Trigger Input/Output connection is provided to allow the use of various triggers to synchronize the EEPS spectrometer data with another instrument or analog signal. These connections are fully *electrically isolated* from the rest of the instrument up to 500 volts. Details of the functions of each connection are listed in the table below:

Table 1-1
Analog and Trigger Input/Output

Connection	Description
Trigger In	A trigger input here will start a run if the run has already been initiated in software and **Enable External Trigger** is checked in the **Properties** dialog box. A trigger input consists of bringing the **+** input to a logic low, which can be done two ways. A potential-free contact closure can connect the **+** input to the **–** input which is at GND. Otherwise, a logic circuit can drive the + input low, provided the circuit's ground is connected to the – input. Logic thresholds are <0.5V for logic low and >2.5V for logic high. **Caution** The trigger **+** input should not exceed +12V or -8V with respect to the **–** input.
Trigger Out	A potential-free contact closes to connect the 2 outputs when a run starts, and opens when the run stops.
Analog Out CH1 to CH4	Four channels of 0–5 V or 0–10 V analog voltage output, 14-bit resolution. Updated each second (1 HZ). Channels are software configurable to represent concentration data. See paragraph below for details.
Analog In CH1 and CH2	0-10V analog voltage input, 12-bit resolution, sampled at 1 Hz (this input is displayed as a voltage at the bottom of the run view). **Caution** The analog **+** input should not exceed +17V or -4V with respect to the **–** input. Exceeding these values may damage the electronics.

Analog Voltage Out Channels 1–4

In addition to RS-232 serial communications for data transfer, particle concentration can be output by the EEPS spectrometer as analog voltages, to be readily integrated with other instruments on common laboratory data acquisition platforms requiring analog inputs. The EEPS spectrometer provides four *independently configurable* analog channels for this purpose. The four channels give the user the flexibility to select different particle size ranges and different concentration weightings (e.g., number, surface, mass) for conversion to a proportional voltage value.

Full scale analog voltage settings are available as 0–5 or 0–10 volts.

Entering parameters for the Analog Out feature are described in Chapter 5, Software Operation.

A further discussion of the application of the analog feature is described in Appendix E.

System Diagram and Operational Overview

A schematic of the EEPS spectrometer is shown in Figure 1-5.

Particles enter the instrument as part of the aerosol inlet flow through a cyclone with a 1 µm cut. This removes large particles that are above the instrument's size range. Next, the particles pass through an electrical diffusion charger in which ions are generated. These mix with the particles and electrically charge them to provide a predictable charge level based on particle size. The charger is mounted inline with the analyzer column and located at the top of the instrument.

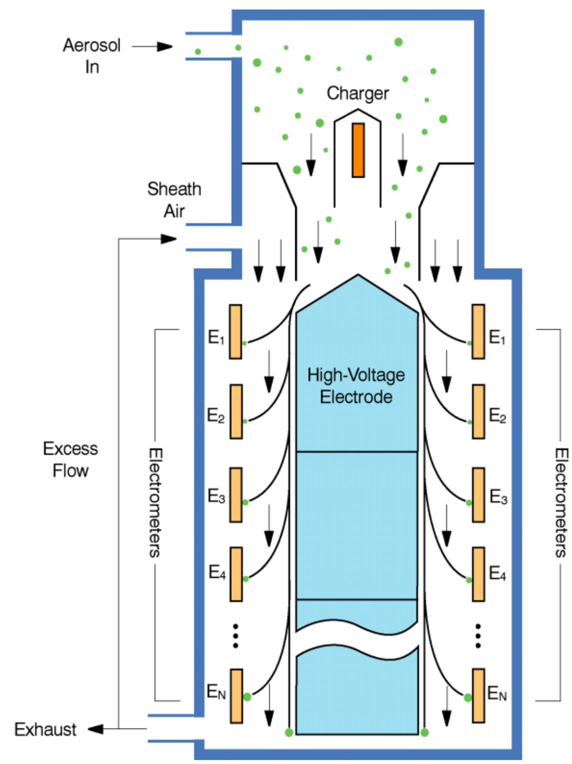

Figure 1-5
Schematic Diagram of the Model 3090 EEPS Spectrometer

Particles then enter the sizing region through an annular gap, where they meet a stream of particle free sheath air. The sizing region is formed by the space between two concentric cylinders. The outer cylinder is built from a stack of sensing electrode rings that are electrically insulated from each other. The electrodes are connected to a very sensitive charge amplifier, also called an electrometer, with an input near ground potential.

The inner cylinder is connected to a positive high voltage supply, which forms the high voltage electrode. This creates an electric field between the two cylinders. While the positive charged particles stream with the sheath air from the top to the bottom of the sizing region, they are also repelled from the high voltage electrode and travel towards the sensing electrodes.

Particles, which land on the sensing electrodes transfer their charge. The generated current is amplified by the electrometers, digitized, and read by a microcontroller. The data are processed in real time to obtain 10 particle size distributions per second. The entire system is automated and data analysis is performed using a computer system with customized EEPS software. The software collects and stores sample data. Data is displayed in graphs and tables and can be exported to other applications.

For information on the theory of instrument operation, refer to Appendix B.

CHAPTER 2

Unpacking and Setting Up

Use the information in this chapter to unpack your Model 3090 Engine Exhaust Particle Sizer™ (EEPS™) Spectrometer and set it up.

Packing List

Table 2-1 lists the components shipped with the EEPS spectrometer.

Table 2-1
Components of the EEPS System

Qty	Part Number	Description
1	962002	Computer RS-232 Serial Cable
1	1031083	Cyclone, 10 L/min, 1µm cut
1	1031252	Inlet Filter
1	1102125	USB to Serial Cable Adapter
1	1601501	Union Elbow Fitting 3/8-inch
2	1602051	HEPA Capsule Filter (spare)
1	1602071	Filter Media for Fan Guard (spare)
2	1602230	Filter, Balston DFU-BX (spare)
1	1980494	Operation and Service Manual, Model 3090 Engine Exhaust Particle Sizer Spectrometer
1	2900009	Assembly Cleaning Tool
1	3305070	Hex driver Set .050-3/8-inch, 13-piece
1	3900135	Model 3090 EEPS Software
1	2900008	Charger Needle Assemblies (Pack of 2, spare)
20		12 × 15 in. (30 × 38 cm) cleaning cloths*

*Available directly from Kimberly-Clark as *Kimtech Prep Scottpure® Wipers*, Product Code: 06121, www.kcprofessional.com

Unpacking

The Engine Exhaust Particle Sizer spectrometer comes assembled with protective coverings on the inlets and electrical connections. To prevent contamination, do ***not*** remove the protective covers until you are ready to use the instrument. In addition, the measurement column is shipped with a ratcheting tie-down strap to hold the column in place on its shock-absorbing mounts. For best measurement results, the strap should be removed for measurements.

Caution

The EEPS spectrometer is a heavy instrument weighing 70 pounds (32 kg). **Protect your back when lifting:**

- Get help from another person to move the instrument
- Transport the instrument on a cart whenever possible
- Lift with your legs while keeping your back straight
- Keep the instrument close to your body as you lift

Refer to Figure 2-1 and follow the steps below to remove the shipping strap.

1. Make sure the instrument is unplugged from power. Loosen the two screws on each side of the top panel (***Note****: They should not have to be removed*).
2. Squeeze the release mechanism as shown to allow the ratchet lever to be moved up.
3. While holding the release mechanism, swing the release lever through 180 degrees until it clicks and releases tension on the strap. While still holding the lever in release mode, pull the assembly away from the panel until all the strap has been removed.
4. Pull the strap up from the bottom of the cabinet to pull the strap out of the cabinet. Retighten the four screws that you loosened in step 1.

When shipping the instrument, the strap should be placed back on the column again. Take care to pad the ratchet mechanism with cardboard that is taped to the side panel to prevent damage to the painted panel. Save the shipping strap and ratchet in the accessory kit for future shipping needs. Save the original packaging materials for future use should the instrument need to be returned to TSI for service. See Chapter 6, "Returning the Engine Exhaust Particle Sizer Spectrometer for Service".

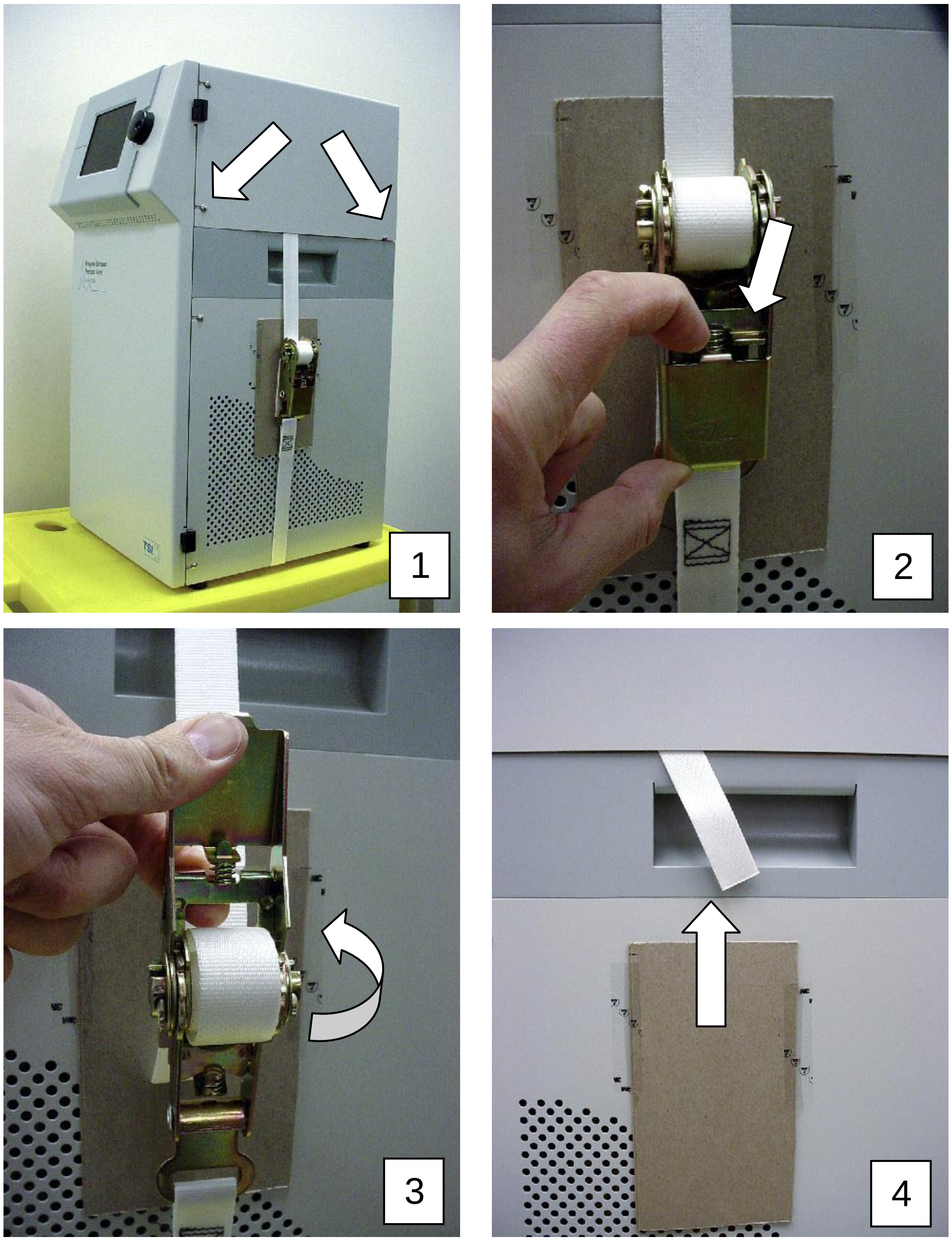

Figure 2-1
Removing the Shipping Strap

If anything is missing or appears to be damaged, contact your TSI representative, or contact TSI Customer Service at 1-800-874-2811 (USA) or 001-(651) 490-2811. Chapter 6 includes instructions on returning the EEPS spectrometer to TSI Incorporated.

Setting Up the Engine Exhaust Particle Sizer Spectrometer

The following provides information for setting up the Model 3090 Engine Exhaust Particle Sizer (EEPS) spectrometer.

Instrument Placement

The instrument cabinet is designed to be cooled by room air drawn in through a filter from the back of the cabinet and exhausted through the sides and front of the cabinet.

The cabinet should be installed with at least 3-inch (50-mm) clearance between the back panel and side panels and any other surface. The cabinet should be set on a flat, solid surface that isolates the instrument from outside vibration. Excessive vibration will produce artificial noise in the measurement.

When positioning the instrument, also allow adequate space at the back for access to the power switch and for the power cord.

Installing the Cyclone

The cyclone functions by removing large particles, preventing counting errors, and keeping the instrument clean. The cyclone is always used, and should only be removed when transporting or servicing the instrument. The cyclone will remove large particles and fibers that can cause excessive noise on one or more channels. Since cleaning the electrodes is a relatively involved procedure, it is much better to prevent contamination using the cyclone. The cyclone will be more effective in removing large fibers if the inside surfaces are lightly coated with a light oil.

Install the cyclone on the aerosol inlet using the union fitting shown in Figure 2-2. Make certain the components are tightly pushed together. Tighten the nuts on the union fitting finger tight and then ½-turn with a wrench (see Swagelok recommendations).

Caution
Be certain that the Cyclone is installed on the Aerosol Inlet in the orientation shown in Figure 2-1 prior to making particle size measurements. Make sure that the cyclone is cleaned regularly and that it is removed and cleaned before shipping.

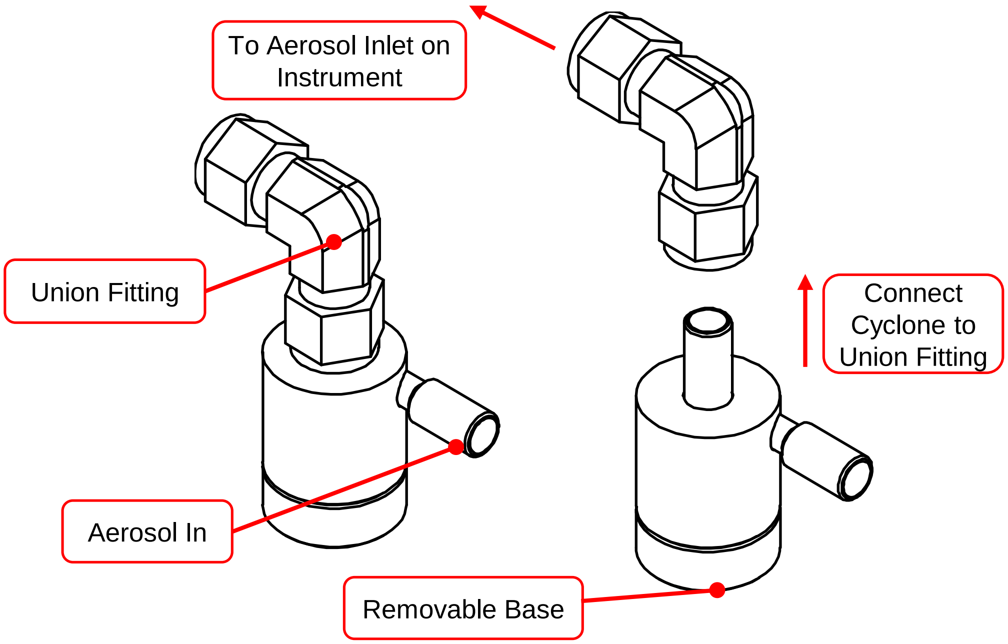

Figure 2-2
Cyclone Assembly

Connecting Power

1. Connect the supplied power cord to the receptacle at the back of the instrument. The cord has been supplied with the appropriate connector for your country. Supply voltage can be 100 to 240 VAC and 50 or 60 Hz.

2. The instrument on-off switch is located above the power cable connection on the instrument.

   ***Notes**: Make certain the line cord is plugged into a grounded (earth grounded) power outlet. Position the instrument so the power cord connector is not blocked and is easily accessible.*

   The internal power supply contains no user-serviceable parts. If the power supply is not operating correctly, use the information in the troubleshooting section to contact TSI. This instrument should not be used in a manner not specified by the manufacturer.

Connecting the Computer

1. Locate the serial cable supplied with the Model 3090. Connect one end of the cable to your computer's serial interface port (COM 1, COM2, or other if available). If you have a USB port only, use the adapter cable (1102125) supplied in the accessory kit.

2. Connect the other end of the cable to the serial connection at the back of the EEPS spectrometer.

Installing the Engine Exhaust Particle Sizer Software

Install the EEPS software as described below.

Computer Requirements

To use this software we recommend a personal computer with the following minimum features, components, and software:

- An SVGA color monitor.
- Windows® 7 operating system or newer.
- A hard drive large enough to accommodate Windows, the EEPS software, and data files.
- A CD-ROM drive.
- A mouse.
- An RS-232 serial interface port (in addition to the one that may be required for the mouse) or USB connection (use with supplied USB to Serial Cable Adapter).
- A Microsoft Windows-compatible printer is optional.

Program Installation

1. Shut down (exit) all programs/applications on the Windows desktop.
2. With the computer on and Windows running, insert the Model 3090 EEPS Software CD-ROM in your CD drive. To run the **setup.exe** from the CD:
    a. If AutoPlay is enabled on your PC, the setup program begins automatically and the introduction screen is displayed on the Windows desktop.
    b. If AutoPlay is not enabled, select **Run** from the **Start** menu and type: `D:\SETUP` in the Open box and press **OK**. (if D is the letter corresponding to your CD drive.)
3. Follow the instructions as the setup program runs. When the setup is complete, you may be asked if you want to view the readme.htm file. The readme.htm file contains important information that could not be included in this manual. If you decide not to view this file immediately, you may view the file later using a browser such as Internet Explorer.
4. When the installation program finishes, remove the CD-ROM and restart your computer. Store the CD-ROM in a safe place for later use.

The setup program creates a folder (directory) called “Engine Exhaust Particle Sizer” on your hard disk (assuming you accepted the default folder name). The folder contains the required program files and sample data files.

The setup program also creates a new item in the Start Menu called “TSI” and an icon on your desktop for the EEPS software.

Note: *Before creating a TSI menu item, the setup program checks for an existing one. If one is present, it adds the icon only.*

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CHAPTER 3
Quick Start

Ease of operation is a key feature of the Model 3090 Engine Exhaust Particle Sizer (EEPS) spectrometer. After you are familiar with the components identified in Chapter 1 and have performed the setup steps in Chapter 2, you are ready to begin taking measurements.

This chapter presents the very basics of operation. Detailed instrument and software operation instructions are in Chapters 4 and 5 and can be referenced as needed.

Turn the instrument on using the power switch at the back of the instrument, above the power cable connection. Once the instrument is turned on, the LCD display illuminates information as it appears in Figure 3-1. The instrument requires 10 minutes to warm up. When the warm up is finished the status will change to “Normal”.

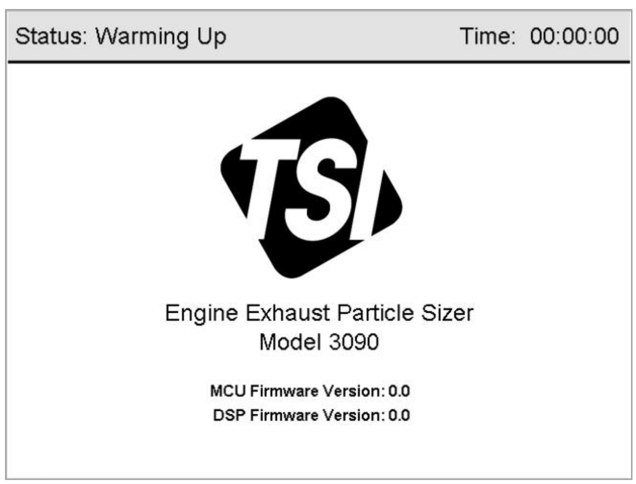


Figure 3-1
EEPS Warm-up Display Screen

While the instrument is warming up, start the EEPS software program (if it is not already running). To start the program, proceed as follows:

1. From the Windows desktop, press the **Start** button and select **Programs|TSI|Engine Exhaust Particle Sizer** or select the EEPS icon from the desktop.

The Engine Exhaust Particle Sizer desktop appears as shown in Figure 3-2.

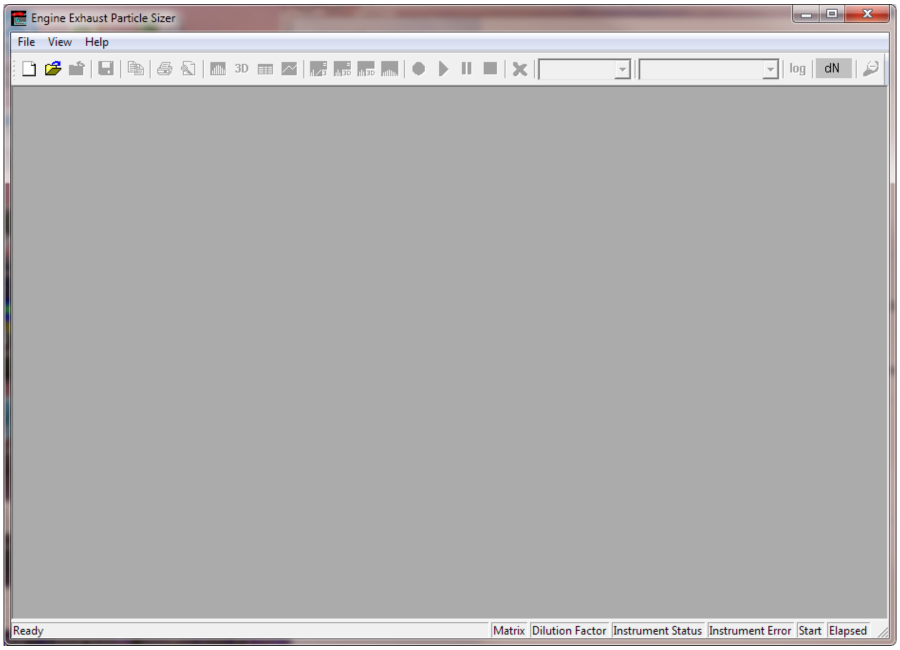


Figure 3-2
The Engine Exhaust Particle Sizer Desktop

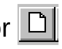
How To Perform a Sample Run

There are two steps to collecting sample data.

- Open a new file.
- Start data collection.

Before beginning, make certain the Model 3090 is connected to the computer, the instrument is warmed up, and the software is running.

Step 1—Open a New File

Select **File|New** or  or <**Ctrl**><**N**> on the toolbar. The dialog box shown in Figure 3-3 opens on your desktop.

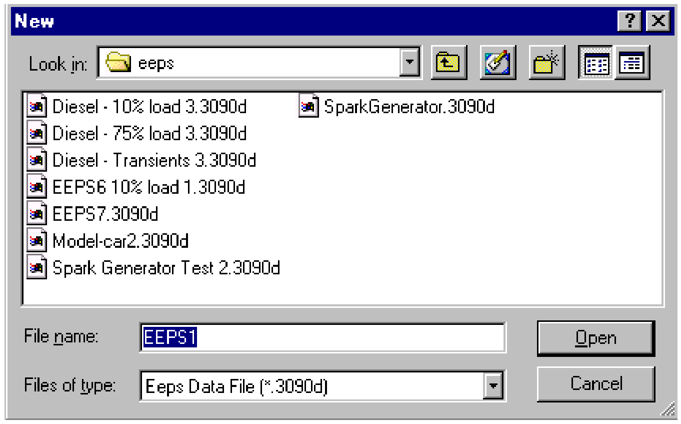


Figure 3-3
Open a New File

Select a filename (and, optionally, a location other than the EEPS folder). The default name is “EEPS1” for the first file you open, “EEPS2” for the second file you open and so on. Accept the default name or enter any name you choose. You do not need to enter an extension in the filename box. It will be assigned automatically (.3090d).

After you enter a filename (or if you accept the default name), press the **Open** button.

After you press the **Open** button, the computer attempts to connect to the instrument. When the connection is complete, the Run View window opens. Other windows that were open the last time the application was closed are also opened. All windows are initially empty.

Step 2—Start the Run

Start the run one of three ways:

- Select **Run|Start Data Collection**.
- Click on the toolbar.
- Press <**F10**>.

Each time you start a new run, you are shown the run properties you will use. The Run Properties dialog box shown in Figure 3-4 opens on the desktop.

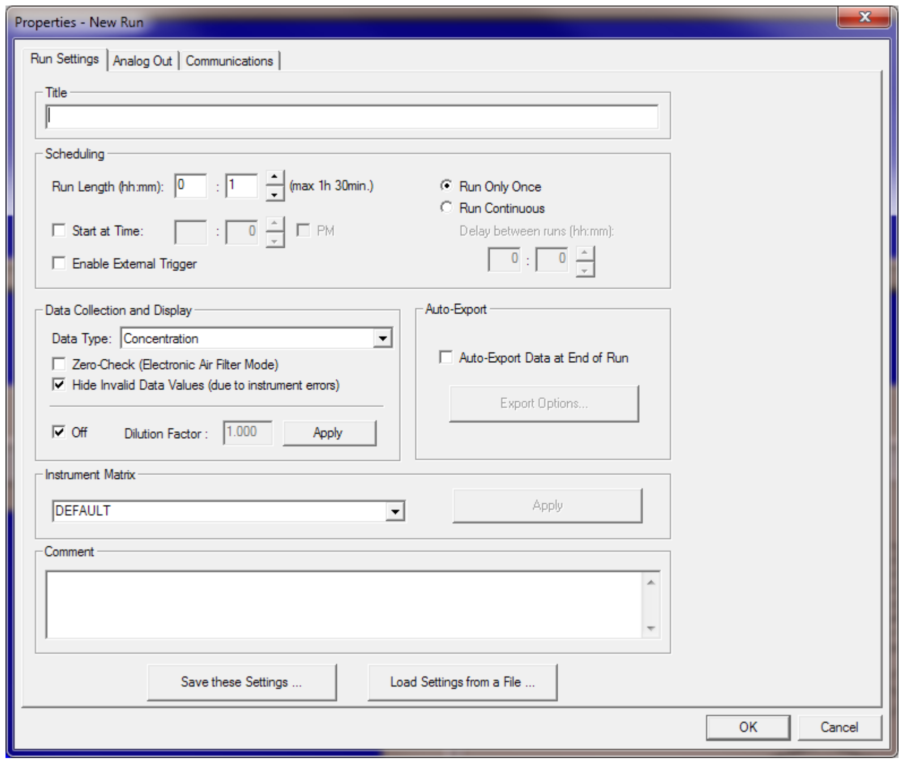


Figure 3-4
Properties Dialog Box

The parameters of the Properties dialog box are described below. For this “test” run, simply type a title and run length for the test and select **OK.**

Note: *To open the Properties dialog box prior to pressing the Start button on the toolbar, select **Run|Properties**. The values you enter in the properties dialog at this time will appear when the dialog box opens to start the run.*

After you have completed the properties dialog box, sampling begins at the Start Time you selected or immediately after you press the **OK** button.

As the program begins collecting sample data, it is displayed in the windows open on the desktop.

When the sample finishes, data for the sample is stored in the file, but the windows remain open.

To stop data collection before the selected run length time is complete, select **Run|Stop Data Collection** or ■ on the toolbar.

Communications Errors

If you get the following error message (Figure 3-5) when you try to start a new sample, there is a communications problem between the computer and instrument (i.e., the cable is not connected) or a connection is already open to the instrument, such as another run, and are attempting to open another connection.

Figure 3-5
Communications Error Dialog Box

Check the cable connection and close all files and then try to reconnect.

Note: *Most computers have only two active communications ports, COM1 and COM2. COM1 is most likely available for the EEPS connection.*

Run Properties

The Run Properties dialog box contains three tabs: Run Settings, Analog Out, and Communications.

If this is the first time you have accessed the Properties dialog, you need to set up the parameters before continuing. If you have set up the properties before, verify they are correct before pressing **OK**. The following paragraphs describe the settings of the Properties dialog box.

The Run Settings Tab

Use the Run Settings tab to enter information about the run and control variables for the run. Once the run settings are set, you can store them for later use by selecting the **Save Settings to File...** and **Load Settings from File...** buttons.

Title

Enter a descriptive title for the sample. This title will appear as a heading on various windows to identify this sample. The maximum number of characters allowed is 79.

Scheduling

Run Length (hh:mm).

Enter a run length by selecting the number of hours and minutes you want to collect data for this run. The maximum run length is 1 hour and 30 minutes. Remember, to stop the run at any time, use the ■ button on the toolbar or **Run|Stop Data Collection**.

Start at Time

If you do not want the run to start immediately, you can schedule the run to start at a specific time.

Run Only Once or Run Continuous

Sampling can be set to run once or to run continuously (specifying a delay time between runs of 1 minute to 24 hours). When sampling is set up to run continuous, a new filename is opened for each run. The new filename is based on the current filename. For example, if the original filename is ModelCar.3090d, the new filename will be ModelCar_0.3090d the first time the sample is repeated and ModelCar_1.3090d the second time it is repeated and so on.

Enable External Trigger

The checkbox for Enable External Trigger, lets you tell the software that you want to start sampling using an external trigger to start a run remotely. This can be useful when different instruments need to be started at the same time.

A trigger input (on the back of the instrument) consists of bringing the + input to a logic low. This can be done using:

- A potential-free contact closure (a toggle switch) that connects the + input to the – input, which is at ground (GND).
- A logic circuit to drive the + input low.

Data Collection and Display

Data Type

Select the type of data you would like to collect from the instrument. Select either Concentration data or Electrometer Current.

Zero-Check (Electronic Air Filter Mode)

Check this box if you would like to perform a run which has the same effect as a filter installed on the inlet. During a zero-check run the negative charger is set to its maximum current and the positive charger is turned off.

Note that this checkbox always defaults to “off”. If using it for consecutive runs, it must be checked each time.

Hide Invalid Values

Check this box to have the software hide any invalid data values in its graphs and tables. An invalid data value is one that is received by the instrument under a serious or fatal error condition. See Table 6-3 in Chapter 6 for a detailed list of fatal errors.

Dilution Factor

To correct for a dilution factor to match measurement conditions, you can add a dilution factor here and turn it on/off with the checkbox. For example, if you used a 100:1 diluter before sampling into the instrument, the concentration can be corrected back to the original concentration using a dilution factor of 100. This will multiply the concentrations measured by the instrument by a factor of 100 when shown on graphs and tables. The original data is not changed and the dilution factor can always be turned back off.

Auto-Export

Select the Export Data at End of Run checkbox to automatically export data when the run is complete. Refer to Chapter 5 for a complete description of how to export data.

Instrument Matrix

The software displays the currently configured matrix on the instrument in the combo box. To select an alternate matrix, use the drop-down arrow. DEFAULT refers to the factory default matrix; “SOOT” and “COMPACT” are other pre-defined matrices which are installed with the software. When you select a matrix other than the one currently configured on the instrument, that matrix is uploaded to the instrument by selecting the **Apply** or **OK** button (to close the dialog).

Comment

The Comment box allows you to store comments about the sample run. The maximum number of characters is 255.

This information is stored with the sample data in the file and may be displayed when the Properties dialog box is opened for this file. It is also included in the exported data.

Save Settings to File.../Load Settings to File...

Use these two buttons to save the run settings you have set up and recall them for later use.

To save the current settings, click the **Save These Settings...** button and enter a filename (and, if desired, a different directory/folder/drive) and then select **Save**.

To recall settings you have saved, click the **Load Settings from a File...** button, highlight the filename you want to recall (after navigating to the appropriate folder if necessary) and selecting **Open**.

Viewing Data

View data in a table or graphs while the data is being collected and change how data is viewed after sampling ends.

Note: *To view the data on the LCD panel of the EEPS spectrometer, refer to Chapter 4.*

Change scales, time resolution, weighting, and other parameters, as well as play back the entire run.

Data can be viewed in the graphs either logarithmically or linearly and at different time resolutions. The particle data in the 2-dimensional graph represents an individual histogram at a selected time.

The following procedure provides an example of how to change how data is viewed for an existing run. Refer to Chapter 5 for a complete description.

1. Open an existing run file using **File|Open** or by pressing  on the toolbar. Figure 3-6 shows sample data.

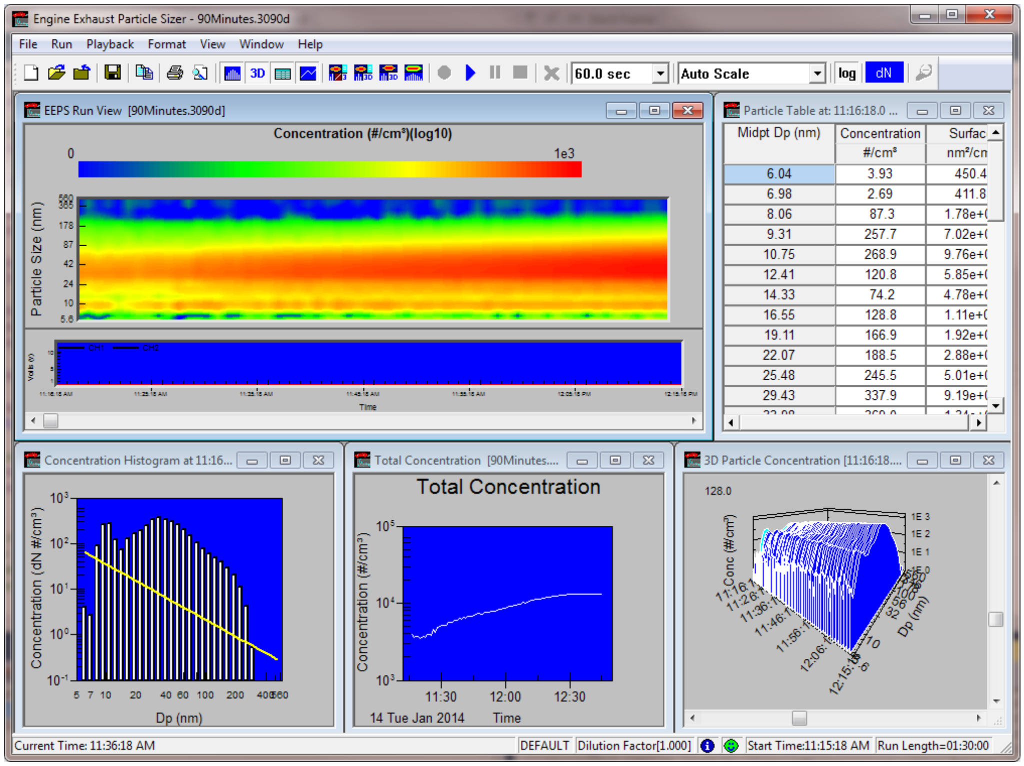


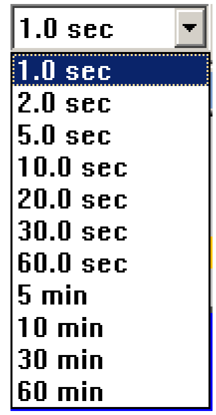
Figure 3-6
Sample Data

2. To toggle the graph scale between logarithmic and linear display modes, use the **log** and **lin** toolbar buttons.

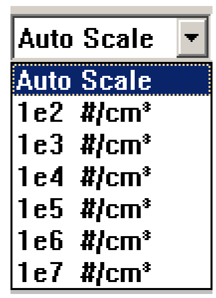
3. To toggle the display units between number concentration and dN/dlogDp, use the dN and dN/dlogDp toolbar buttons.

4. Using the mouse, point to a location in the Run View (contour graph) and click the left mouse button. This selects a *time window* during the run and this individual histogram of data is then displayed in the 2-dimensional Particle Histogram Graph window and in the Particle Table window. This subset of data is also highlighted in the 3D Graph window. Each time a new “time window” is selected, the histogram, table and 3D graph windows are updated. In the Total Concentration graph, the time window is identified with a crosshair annotation.

5. To view the data at a different time resolution, select a different averaging interval using the drop-down style selector on the toolbar (see figure). Depending on the length of the run, you can select an averaging interval from .1 second to 60 minutes.



6. To select a maximum value for the concentration range or have the software auto-scale the data, use the second drop-down style selector on the toolbar (see figure).



7. To display data other than concentration in the 2D particle histogram graph, click the right mouse button in that window to display the popup menu (Figure 3-7). Select **Weight|Mass**. Notice the change in how data is displayed. Use **Weight|Number** to change the graph to display the number weighting.

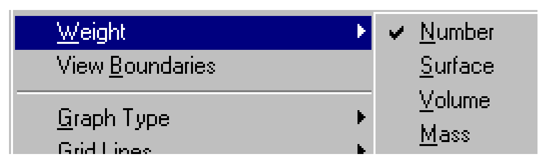


Figure 3-7
Popup Menu for the Histogram Window

CHAPTER 4

LCD Display Operation

This chapter provides information on the features and functions of the LCD display and the control knob. Refer to Chapter 5 for detailed operation information of the Engine Exhaust Particle Sizer (EEPS) software program

Use the control knob and LCD display to view instrument status, start and stop data display, read diagnostics, and view user settings.

To use the control knob, place your finger in the detent on the front of the knob and turn. Notice how items on the LCD display are highlighted (dark box around light text). To select a highlighted item, press the control knob in and release.

LCD Display Items

Figure 4-1 shows the LCD display while a sample is being taken. There are four unique regions of the display. Each is described below.

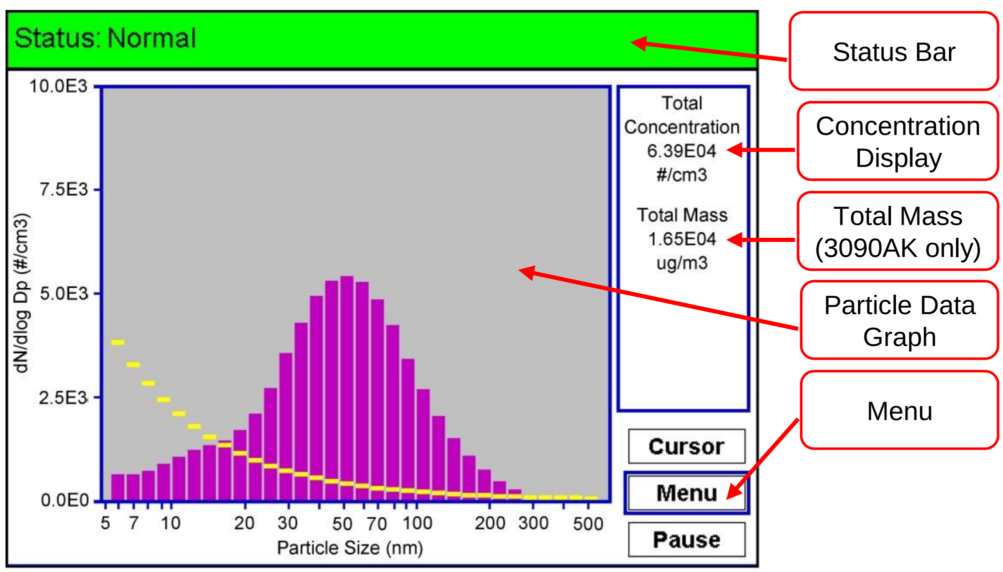


Figure 4-1
LCD Display Regions

Status Bar

The Status Bar indicates instrument status. Possible messages include: Warming Up, Normal, etc. Refer to Chapter 6 for a complete list of messages and actions you should take.

Menu Options

There are three menu options.

Menu Option	Description
Cursor	View individual particle channels.
Menu	View user settings and diagnostics.
Pause/Resume	Start and stop data display.

Cursor

Select **CURSOR** to view information about a particular particle size value in the graph. To view a specific value, use the control knob to highlight CURSOR then press the knob. A bar will appear on the graph and data for that size channel will be displayed in the concentration display region (see below). Rotate the control knob to view data to the left or right. To stop viewing data with the cursor, press the control knob again and turn the cursor to select another option from the display.

Menu

Select **MENU** to view user setting and diagnostics information. To view these items, highlight MENU with the control knob and press the knob. A menu appears for User Settings and Diagnostics. Use the control knob to highlight the item you want and press the control knob.

User Settings

The user settings (Table 4-1) let you change display settings and turn on/off the pumps or chargers and zero the electrometer. The pumps can be turned off to reduce noise and save power when the instrument is not being used, but still powered on.

Table 4-1
User Settings

Setting	Options	Description
Y-Axis Setting	Autoscale; 1E4 to 1E9	Use this option to select the maximum displayed scale for the Y-Axis. (1E4 can only be selected in Linear mode)
Y-Axis Scale	Linear/Log 10	Use this option to change the Y-Axis scale between Linear and Log 10 mode.
Flows	Off/On	Use this option to turn all flows on or off. When Off is selected, the status bar displays “Flows and Chargers Turned OFF.” There will be no draw at the sample inlet. The chargers are turned off to protect the electrodes from contamination.

Setting	Options	Description
Chargers	Off/On	Use this option to turn both chargers on or off. When Off is selected, the status bar displays "Chargers Turned OFF."
Column Heater	Off/On	Turns the column heater on or off. Turn the heater on when the instrument is in a cool (i.e., air conditioned) environment and sampling from a warm, humid environment to prevent condensation that could cause the electrometers to become noisy. Normally, it should be turned off unless needed.
Display Brightness	0-100	Use this option to change the panel brightness and improve display visibility. ***Note**: On recently built units this adjustment will have no effect.*
Zero Electrometer	None	Use this option to calibrate the electrometer offset (see "Troubleshooting, Baseline Noise" in Chapter 6)

The diagnostics information (Table 4-2) is read-only, and is available to let you quickly see if any of the important values are out of range.

Table 4-2
Diagnostics Information

Parameter	Nominal Value(s)	Description
Sheath, Sample Flow	39.4 L/min, 8 L/min	Sheath flow through column and sample flow (note that sample flow plus extraction flow equals the flow into the instrument inlet).
Extraction, Charger Flow	2 L/min, 0.6 L/min	Extraction pump flow and charger sheath flow.
Temperature, Pressure	25.0 C, 700 to 1034 mBar	Temperature of the sheath air flow, in degree Celsius and absolute pressure inside the sizing column.
Negative Charger	35 nA -1000 to -4200 V	Current of the negative charger, in nano ampere. Voltage level of the negative charger electrode, in volts.
Positive Charger	27 nA 1000 V to 4200 V	Current of the positive charger, in nano ampere. Voltage level of the positive charger electrode, in volts.
Column Voltages	85V, 470V, 1200V	Voltage on center electrode sections, top to bottom, in volts.
Analog Input Ch 1, Ch 2	0 to 10.0 V, 0 to 10.0 V	Voltage level on the analog input channel 1 and 2, in volts.
MCU Firmware Version	2.xx	Version of micro controller firmware.
DSP Firmware Version	2.xx	Version of digital signal processor firmware.
Error Message	None	Select with cursor to see a list with all error messages.

Pause/Resume

Select **Pause/Resume** to start and stop real-time data display. The button changes from Pause to Resume each time it is selected. You must select Pause, before you can use the Cursor menu item, see below.

Concentration Display

While running a sample, you can view particle size data using the CURSOR (see above). As you move the CURSOR, the information in the Concentration Display shows the particle size and concentration values for the CURSOR location.

Particle Data Graph

A histogram of sampled particle size data is presented in the graph window as normalized concentration dN/dlogDp (#/cc) to allow easy comparison to other instruments. This particle concentration is normalized to the bin width. In this case it is calculated by concentration multiplied by 16, the number of channels per decade. Particle size is presented on a log scale with 32 equally sized bins in the size range of 5.6 to 560 nanometers. Other weightings, such as particle mass or surface area as well as concentration that are not normalized can be viewed using the EEPS software.

A yellow curve is shown superimposed on the particle size distribution to show the RMS lower noise limit of the instrument. For best results, the concentration should be above the noise curve. In addition, when the concentration is too high, a red box will appear on the end of each size channel that has been over-ranged. When this happens, the concentration should be reduced using additional dilution air into the EEPS spectrometer. Running the instrument near the upper concentration limit will require more frequent cleaning of the column. See Maximum Concentration and Minimum Concentration in the Software chapter for more information.

CHAPTER 5

Software Operation

This chapter provides specific information for the Model 3090 Engine Exhaust Particle Sizer™ (EEPS™) software program including:

- Starting the program
- Opening an existing file
- Displaying particle histograms at different times during a run
- Changing how data is viewed
- Using a different matrix
- Playing back data collection
- Selecting a hotspot
- Deleting data
- Zooming in and out on data
- Printing information displayed on the desktop
- Exporting data
- Arranging open windows and changing the layout
- Quitting the program
- Description of all program menus and menu items

If you have read Chapter 3, you will already be familiar with some of this information.

Start the Engine Exhaust Particle Sizer Program

To start the program, proceed as follows:

From the Windows desktop, press the **Start** menu and select **Programs|TSI|Engine Exhaust Particle Sizer**.

The Engine Exhaust Particle Sizer desktop appears as shown in Figure 5-1.

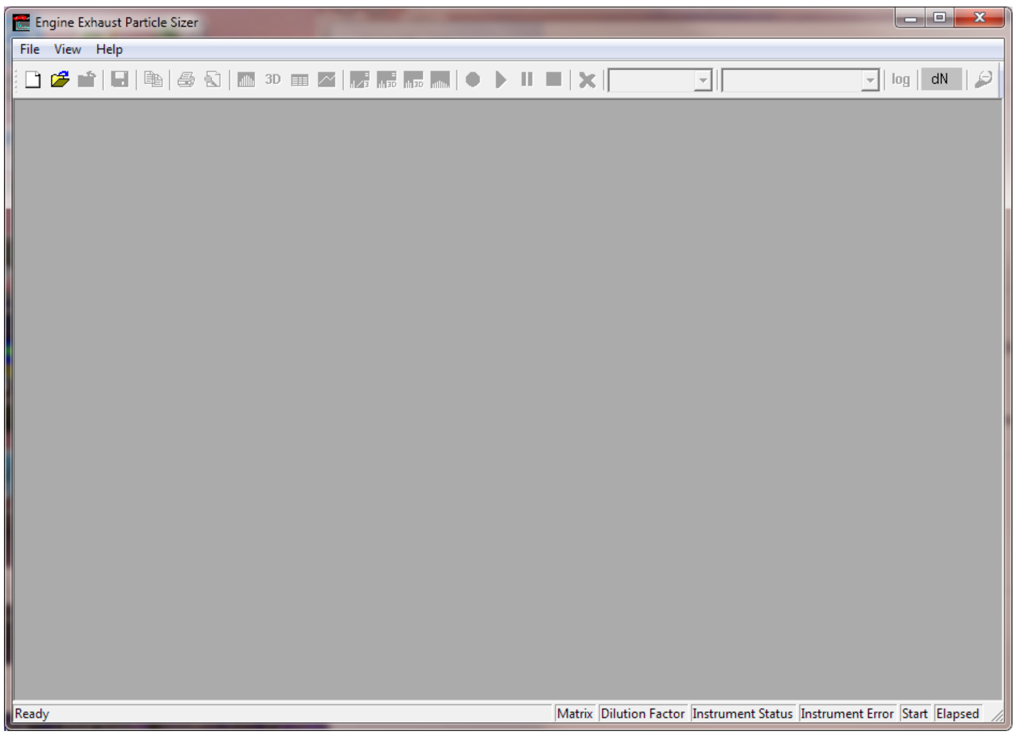


Figure 5-1
Engine Exhaust Particle Sizer Desktop

Open an Existing File

1. Select **File|Open** or  on the toolbar.
2. When the Open file dialog box appears, it shows the files available in the default file location. The default file location is Program Files/TSI/Engine Exhaust Particle Sizer. Example files are included with the program and are installed in the Engine Exhaust Particle Sizer software folder when the program is installed.

   Use the mouse to highlight the file you want to open. If you store data files in a location other than the default Engine Exhaust Particle Sizer folder, browse for the drive/directory where the data files are stored before you click **Open**.
3. Click **Open**. The program remembers the windows that were open on the desktop when you last closed the file and reopens them when you access the file again.

(continued on next page)

Selecting a Particle Histogram to Display

To select a time at which to display a particle histogram during a run, click on the “contour graph” or Run View window. The Run View window is the controlling view for the application and is always open on the desktop. Closing the Run View window closes the run file.

Use the mouse to click on a point in the Run View window. An annotation (see the dashed line in Figure 5-2) shows the selected time as time since the start of the run. The cursor corresponds to the Particle Histogram shown in the lower left corner.

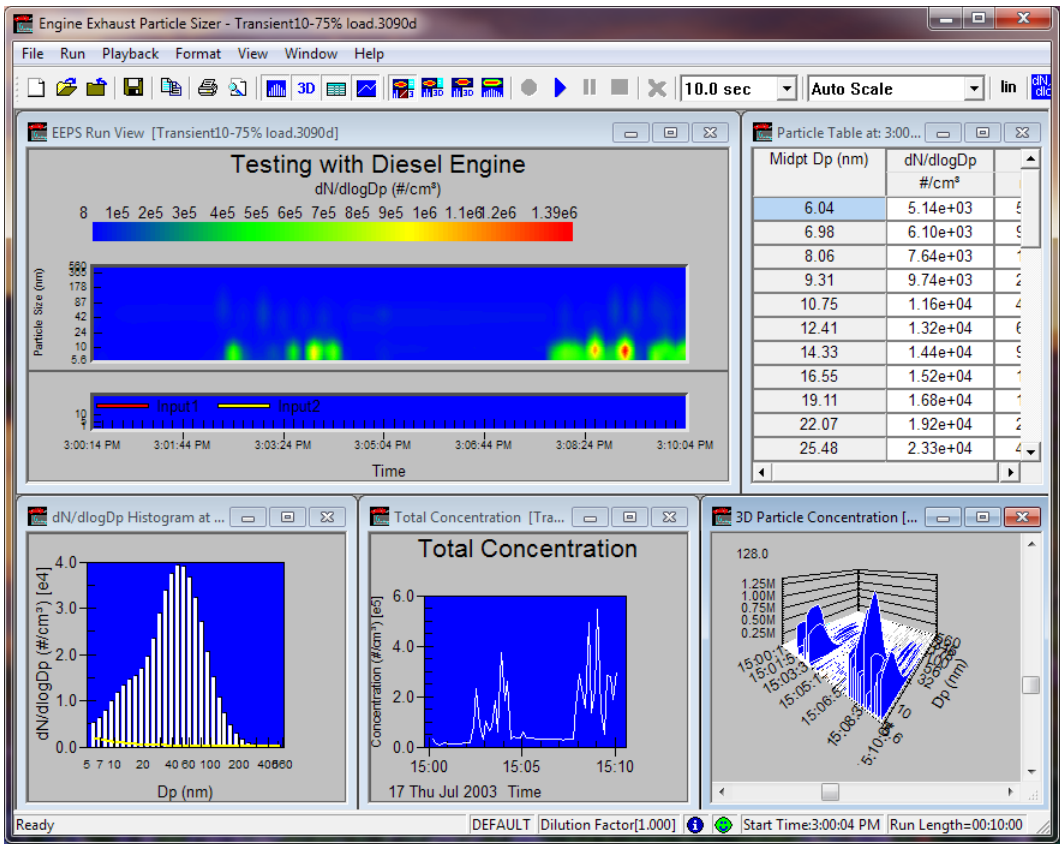


Figure 5-2
Selecting a Time Window

When you select a time window using the mouse, the corresponding histogram is displayed in the Concentration Histogram window and in the Particle Table window. The Total Concentration graph window draws an annotation at the selected time. The 3D Graph window displays the same data as in the Run View window with the selected time highlighted in a different color.

To continue, select an adjacent time window using the arrow keys on the keyboard or use the mouse to point and click at another location on the graph.

Maximum Concentration

The maximum concentration limits for each channel are plotted as a red line in the Concentration Histogram window. When the values for a given run reach the maximum concentration level defined for a given particle size or channel, an annotation is displayed on the graph. In the graph in Figure 5-3, the bars which are marked with the annotation indicate channels in which the concentration measured by the instrument (using the current averaging interval) reached or exceeded the defined maximum. The channels with a red box indicate channels where the concentration has been clipped. This affects the shape of the distribution considerably. If you see a graph with maximum concentration indicators, you should reduce the concentration sampled by the instrument. For a reference on the concentration limits see Figure B-4 in Appendix B.

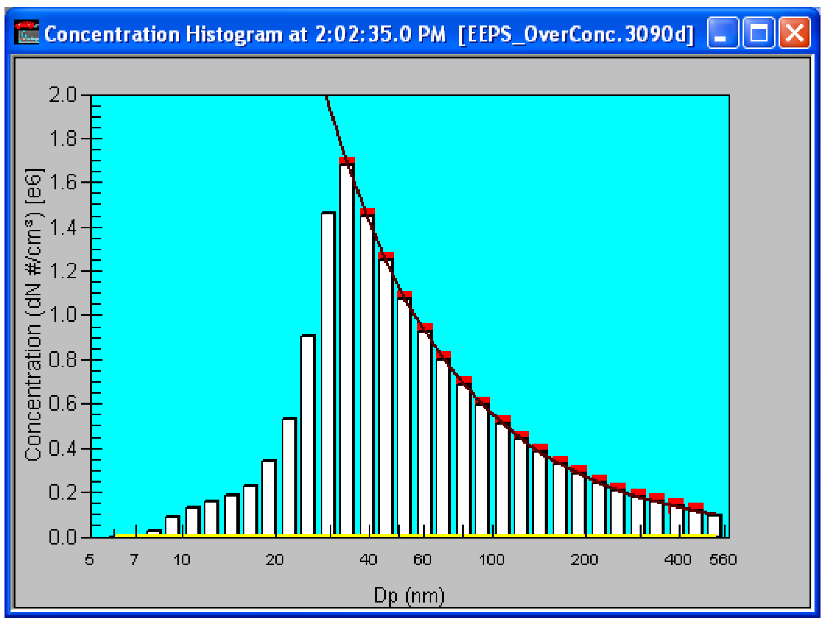


Figure 5-3
Histogram Showing Clipping Due to Exceeding Maximum Concentration

Minimum Concentration

Similarly, when the values shown in the Concentration Histogram window are small, it is useful to note the minimum concentration level defined for a given particle size or channel. The minimum concentration is shown for each channel in this graph as a yellow line. In the graph in Figure 5-4, this minimum concentration level is more apparent in a distribution where the concentration values measured by the instrument are relatively low. Note that this curve depends on the averaging time displayed—the longer the averaging time, the lower the concentration defined by the curve. This is because the electrometer noise is improved with longer averaging times. For a reference on the concentration limits see Figure B-4 in Appendix B.

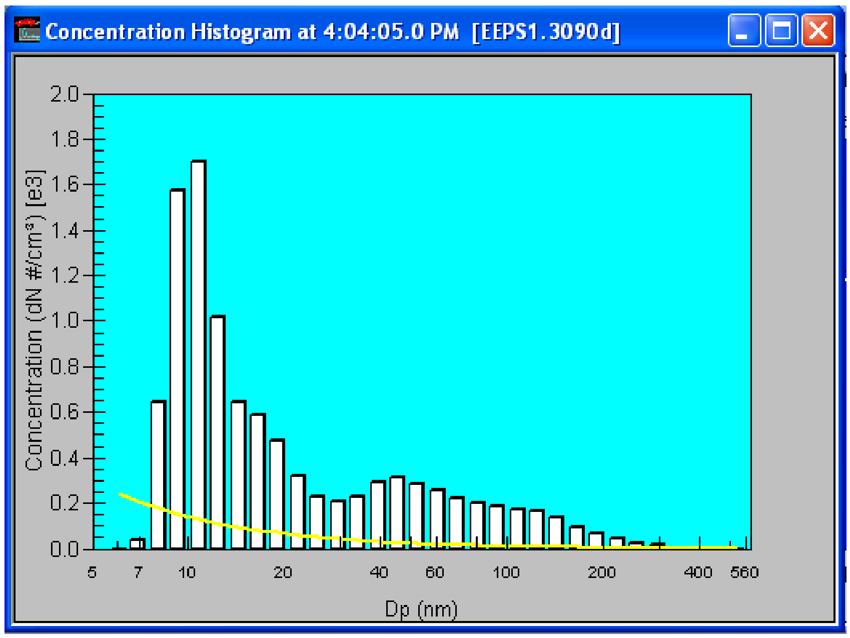


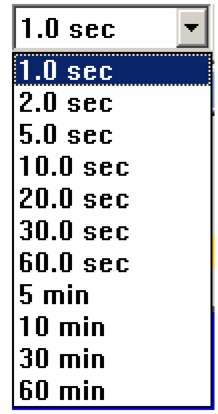
Figure 5-4
Concentration Histogram Showing Minimum Concentration

Change How Data is Viewed

The data can be viewed in the following ways:

- Changing the Time resolution
- Changing the Concentration scale
- Selecting a Weight (2D histogram)
- Selecting the Display units

Changing the Time Resolution



To view data at different time resolutions, select an averaging interval in the average interval drop-down selector on the toolbar (see figure). Depending on the length of the run, you may select averaging intervals from .1 second to 60 minutes.

Changing the Concentration Scale

To change the concentration scale of the data displayed in the graphs, open the Concentration Scale dialog (Figure 5-5) by selecting **Format|Concentration Scale**… or by selecting **Concentration Scale**… from the right-click popup menu on the Run View. This dialog lets you select linear or log scale and allows you to select the minimum and maximum concentration range for the data.

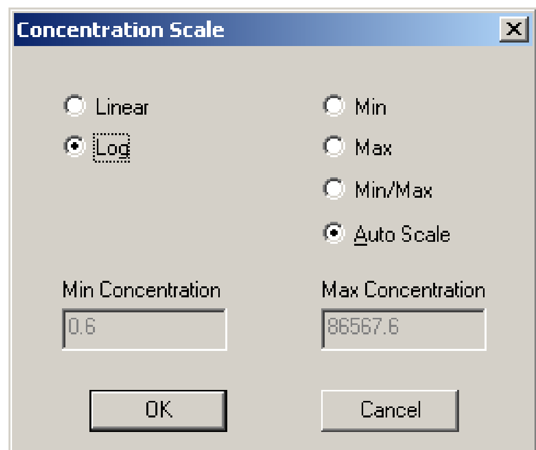
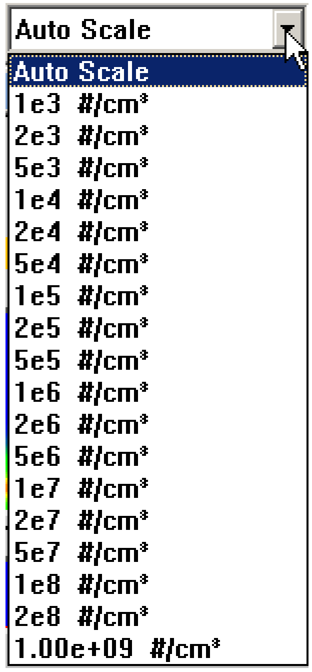


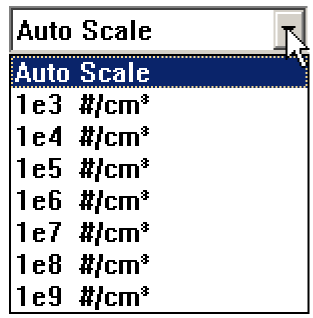
Figure 5-5
Concentration Dialog Box

If the concentration scale is set to "Auto Scale," the software determines the minimum and maximum concentration values for the current average interval. To select a concentration range, select either the "Min", "Max" or the "Min/Max" radio button. The box below "Min Concentration", "Max Concentration" or both will become enabled and you may enter a value, where the Minimum Concentration is equal to or greater than zero and less than the Maximum Concentration.

To change the scale between log and linear mode, press the **log** or **lin** buttons on the toolbar.

Finally, to select the maximum concentration value, use the drop-down Concentration Scale selector on the toolbar (see below examples for linear and log).





Changing the Weighting in the 2D Histogram

To view data in the 2D histogram graph using different weighting, proceed as follows.

1. Open a Model 3090 Engine Exhaust Particle Sizer data file.
2. Make the concentration histogram window active.
3. Right-click the mouse to display the popup menu (Figure 5-6).

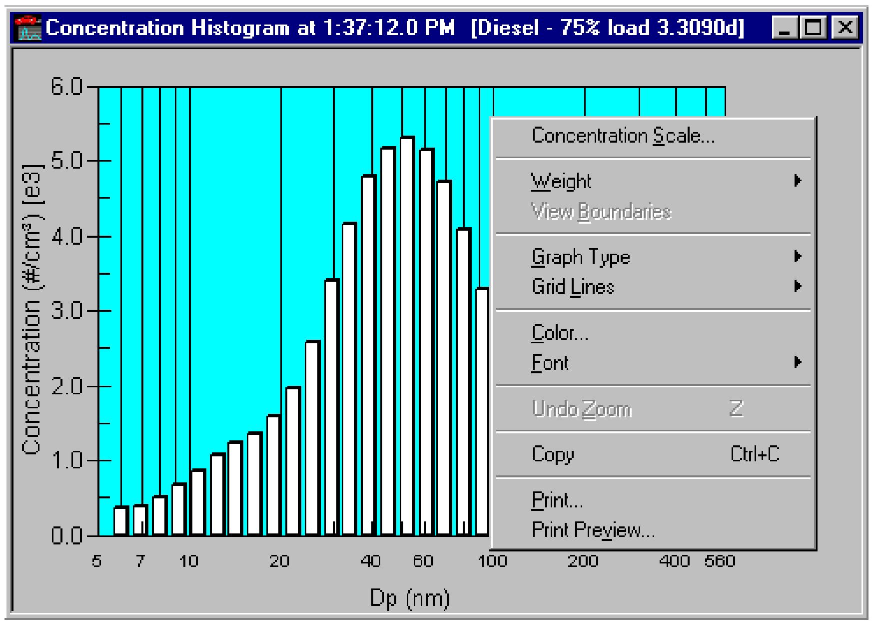


Figure 5-6
Popup Menu for the Concentration Histogram Window

4. Use the mouse to select **Weight|Mass**. Notice the change in how data is displayed. (A checkmark next to one of the menu items means that is the selected weight option.) The Y-axis title on the graph will display the current weighting also.

Note: *Important additional information on how data can be viewed is found later in this chapter "Software Menus."*

Changing the Display Units

To view data as number concentration or as dN/dlogDp, use the toolbar buttons dN or dN/dlogDp. Data in all graphs and tables will display in the selected units. Particle concentration is normalized to the bin width by multiplying by 16, the number of channels per decade.

Using an Alternative Inversion Matrix

Chapter 3 describes how to select an alternate matrix to upload to the instrument before starting a new run. You may also select a different matrix to apply to the raw data in an existing file.

Note: *If you have a data file which does not contain the raw data values this option is not available. The data file must have been created using EEPS Firmware version 3.05 or later and EEPS Software version 3.1.0 or later.*

Open the Run|Properties dialog for an existing data file. You may select a different matrix to apply to your raw data set using the combo box in the **Instrument Matrix** section. Select the **Apply** button to recalculate the number concentration values. The data in the graphs and tables will update. You may then save your file as a different file name or overwrite the file with these changes when you close the file.

The data inversion in the Model 3090 uses a matrix to convert the measured electrometer currents to size and concentration data. The DEFAULT matrix is based upon a combination of theoretical and experimental data. However, variation in particle shape can affect how the particles are charged within a unipolar charger which affects how they are sized. In general, agglomerates acquire a higher net charge than compact, near spherical particles.

To address differences in charging characteristics, two additional particle morphology-specific inversion matrices are included within EEPS software that result in better correlation between EEPS spectrometer and SMPS spectrometer data. Both matrices were developed by empirically calibrating the EEPS spectrometer to SMPS spectrometer measurements.

SOOT.matrix is designed to specifically change how soot particles, typically chain aggregates, in the accumulation mode (~>100nm) are sized. When measuring engine emissions (from constant volume sampling (CVS) tunnel or directly from the exhaust using partial flow dilution) it is recommended that the soot matrix be used.

COMPACT.matrix is designed to be used when measuring aerosols composed of compact, nearly spherical, particles. The compact matrix is useful for laboratory studies in which it is known (or assumed) that the sample aerosol is composed of compact particles such as atomized oil droplets, salt solution residue, or polystyrene latex spheres (PSL).

Matrix File Format

A matrix file is a file with the extension ".matrix" and consists of a header string followed by 22 rows x 33 columns of floating point values. The header string "TSI 3090/3091 Matrix" identifies it as a matrix file. Values are separated by either a comma or a tab character. In addition to the default matrix, TSI currently provides the matrix file "SOOT.matrix" and "COMPACT.matrix". You may use your own custom matrix file provided it conforms to this format.

Be aware that only the name of the matrix used is stored in the data file. The EEPS software will display all *.matrix files found in its installation directory in the instrument matrix combo box of the Run|Properties dialog. It is up to you to manage these files, and ensure that the file names are unique. The maximum length of a matrix name (filename only, excluding the .matrix extension) is 20 characters. The matrix name "Default" is reserved and refers to the factory default matrix already saved in the instrument memory.

Playback (Review) a Sample Run

Review data collection for the run (or portions of the run) as follows:

1. Select **Playback|Play or** ▶ **on the toolbar**. The Playback Options box shown in Figure 5-7 appears.

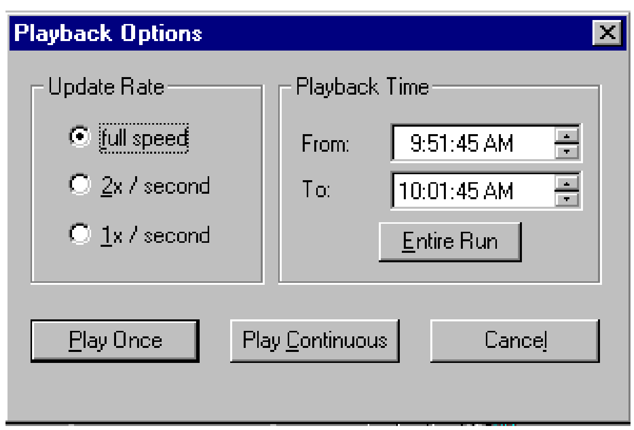
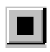


Figure 5-7
Playback Setup Dialog Box

2. Select the playback time, update rate, and whether you want the run playback displayed once or continuously. Playback begins immediately when you select Play Once or Play Continuous. For better viewing, it may be necessary to maximize the window of particular interest to you.

3. If you select Full Speed for Update Rate, the data is played back at full speed in the 3D graph view only. All other views are minimized until playback is complete or you stop playback.
4. If you select an update rate of 2x/second or 1x/second, all views are updated at that rate. An indicator arrow in the Run View window shows the current time of the playback.
5. Pause the playback at any time by selecting **Playback|Pause**. Select **Playback|Play** to continue playback where you left off. Stop playback at any time by selecting **Playback|Stop**. When you stop playback, you must restart it from the Playback dialog again. Use **Playback|Pause** and **Playback|Play** if you want to stop and start playback.

Control playback by using icons on the toolbar. The icons perform the following operations:

 **Stop**. Stop playback.

 **Pause**. Pause playback.

 **Start**. Start playback or restart playback.

Select a Data Hot Spot

When a concentration histogram window or the total concentration graph is active on the desktop, find the values of any data point as follows:

1. Position the pointer on the bar, line, or peak (depending on the type of graph that is active). The pointer becomes a pointing hand.
2. Press the left mouse button to display the corresponding values. Figure 5-8, shows how the data values would be displayed with the crosshair annotation at the selected data point**.**

   Tip: After you have a data hot spot selected, use the ">" and "<" or arrow keys to move the crosshair cursor right or left (from one value to the next), or grab the vertical crosshair annotation and drag it to another location. Refer to the end of this chapter for a list of other keys or key combinations for navigating and performing operations without using the mouse.

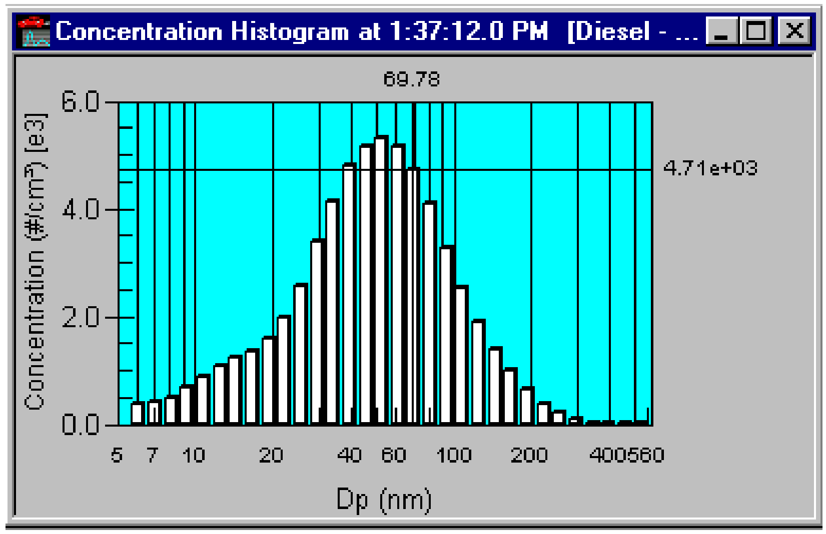


Figure 5-8
Use the Mouse to Directly View Data Values

Delete Data

To redo a run or delete data for a run just taken, on the toolbar select **Run|Delete** or . A verification message is displayed.

You can only delete data for the run you just collected. Once you close this file, you cannot delete the data from this file using this method the next time this file is opened using **File|Open** or . If you need to delete a saved file, use a tool such as Explorer to delete the file.

Zoom In and Out on Data in a Graph

Zoom in on data displayed in a graph as follows:

1. Use the mouse to position the cursor (pointer) on the graph surface, at one corner of the graph area you want enlarged.
2. Press down on the left mouse button and drag the mouse to the opposite corner of the data you want enlarged.
3. Release the left mouse button. The area you selected is enlarged.
4. Continue to zoom further by repeating steps 1 through 3.

To unzoom, select <**Z**> or **Format|Undo Zoom** or on the toolbar. The enlarged area is returned to normal view.

Print Information Displayed on the Desktop

Print the information displayed in the active window on the desktop as follows (a printer must be properly installed):

1. With a graph or table window active on the desktop, select **File|Print Preview** or on the toolbar.
2. Review that what you see in the print preview window is what you want to print (an example is shown in Figure 5-9) and select **Print** from the Preview box. The contents of the window are sent to your printer.
3. You can also select **Print** or **Print Preview** from the popup menu of each window.

To immediately print a window without previewing it, select **File|Print** or from the toolbar or press <**Ctrl**><**P**>.

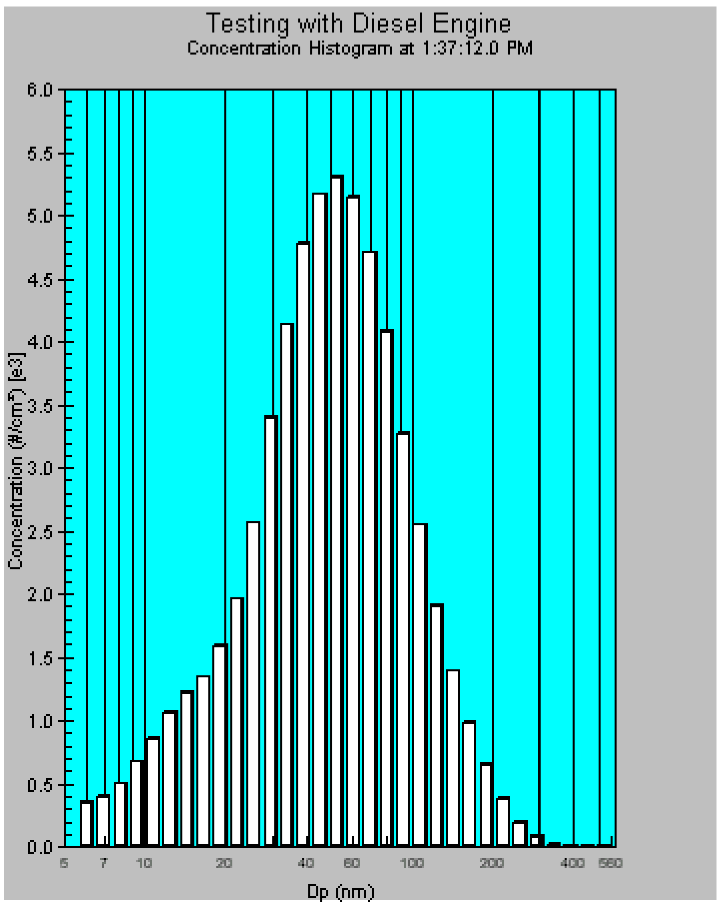


Figure 5-9
Print Preview

Export Data to a File

Data from a Model 3090 EEPS file can be exported for use in another program such as Microsoft Excel® or Microsoft Access® programs. Data can be exported either manually or automatically.

To Manually Export Data

To manually export data:

1. Open the data file by selecting **File|Open** or or <**Ctrl**><**O**>.
2. Select **File|Export**. An Export Data Options dialog box appears as shown in Figure 5-10.

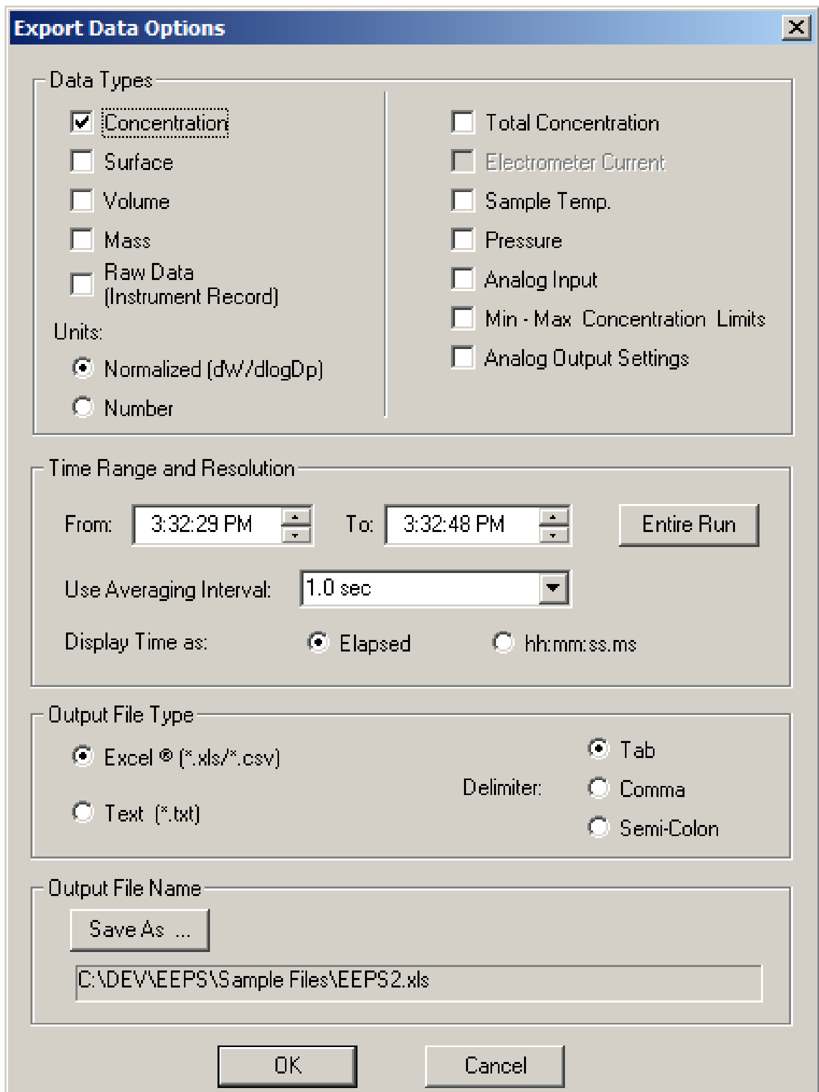


Figure 5-10
Export Data Options Dialog Box

®Excel and Access are trademarks of Microsoft Corporation.

3. Select the type of data you want to export, the data range, the type, averaging interval, and format of the file to which you want to export the data. Refer to Table 5-1 for a description of the parameters.

Table 5-1
Export Data Options

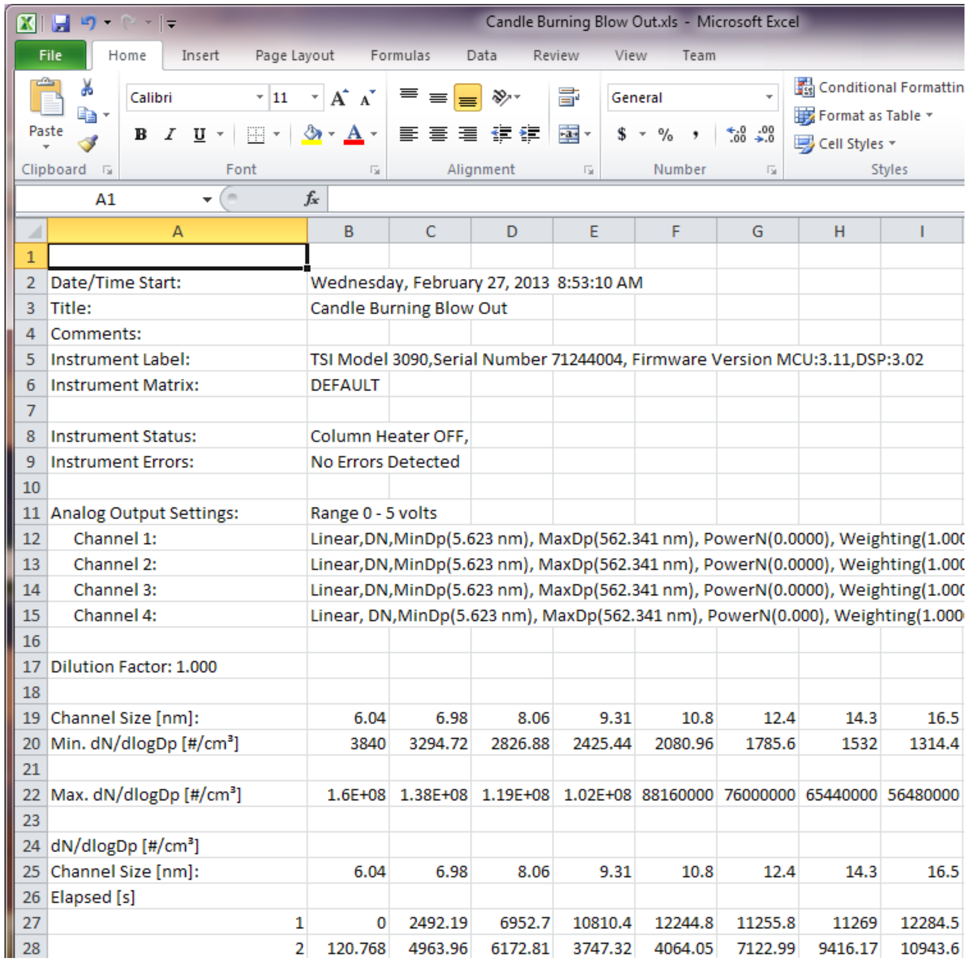
Parameter	Description
Data Types	
Concentration	The total number of particles per unit volume of air sampled (i.e., number concentration expressed as $\#/cm^3$). Concentration is the primary measurement of the Model 3090 EEPS system.
Volume	Volume represents the total volume of the particles per unit volume of air sampled (i.e., volume concentration expressed as nm^3/cm^3). The volume concentration calculation assumes that all the particles are perfect spheres.
Surface	Surface represents the total surface area of the particles per unit volume of air sampled (i.e., surface area concentration expressed as nm^2/cm^3). The surface area concentration calculation assumes that all the particles are perfect spheres.
Mass	Mass represents the total mass of the particles per unit volume of air sampled (i.e., mass concentration expressed as $\mu g/cm^3$). The mass concentration calculation assumes that all the particles are perfect spheres with the density defined in the particle table for each channel.
Raw Data (Instrument Record)	***Note:*** *Valid only with 3090 instruments with firmware newer than 3.05.* Each data set collected has attached to it the raw electrometer data. This data can be exported and reviewed.
Units	
Normalized (dW/dlogDp)	Concentration, surface, volume, mass values exported are normalized to 16 channels per decade.
Number	Actual (non-normalized) values are exported.
Total Concentration	Total concentration on all channels.
Electrometer Current	If the run file contains data which is electrometer current (see run settings), this option may be selected.
Analog Input	Input voltage for Analog Input Channel 1 and 2 in Volt.
Sample Temp	Sample temperature recorded during the run.
Pressure	Sample pressure recorded during the run.
Min-Max Concentration Limits	Export the minimum and maximum concentration limits for each channel. (Number or dN/dlogDp units apply.)
Analog Output	Exports the Model 3090 EEPS Analog Output settings that were in effect when the EEPS data was collected. Only valid for Model 3090 with Analog Out Option.

Parameter	Description
Time Range and Resolution	
From/To	Starting time in the run to begin exporting data.
Use Averaging Interval	Just as the averaging interval can be when viewing the data, it can be set for the exported data independently.
Display Time as:	Format of the time corresponding to each data point in the exported output.
File Type	
Excel	File extension will be either .xls or .csv (comma-separated-values) to be read by Excel®.
Text	Output will be written to a text (.txt) file.
Delimiter	Delimiter used in output.
Output Filename	Name of output file for exported data.

4. Verify the default file name (and path) or press the **Save As** button to change the filename and/or location if you want to save the file to another location or provide a new filename. The extension is automatically selected when you chose a file type for exporting.

5. Press **OK**.

Figure 5-11 illustrates how an exported *.xls file is formatted for a Model 3090 Engine Exhaust Particle Sizer (EEPS) spectrometer when Concentration is selected as Data Types for exporting.



	A	B	C	D	E	F	G	H	I
1									
2	Date/Time Start:	Wednesday, February 27, 2013 8:53:10 AM							
3	Title:	Candle Burning Blow Out							
4	Comments:								
5	Instrument Label:	TSI Model 3090,Serial Number 71244004, Firmware Version MCU:3.11,DSP:3.02							
6	Instrument Matrix:	DEFAULT							
7									
8	Instrument Status:	Column Heater OFF,							
9	Instrument Errors:	No Errors Detected							
10									
11	Analog Output Settings:	Range 0 - 5 volts							
12	Channel 1:	Linear,DN,MinDp(5.623 nm), MaxDp(562.341 nm), PowerN(0.0000), Weighting(1.000							
13	Channel 2:	Linear,DN,MinDp(5.623 nm), MaxDp(562.341 nm), PowerN(0.0000), Weighting(1.000							
14	Channel 3:	Linear,DN,MinDp(5.623 nm), MaxDp(562.341 nm), PowerN(0.0000), Weighting(1.000							
15	Channel 4:	Linear, DN,MinDp(5.623 nm), MaxDp(562.341 nm), PowerN(0.000), Weighting(1.000							
16									
17	Dilution Factor: 1.000								
18									
19	Channel Size [nm]:	6.04	6.98	8.06	9.31	10.8	12.4	14.3	16.5
20	Min. dN/dlogDp [#/cm³]	3840	3294.72	2826.88	2425.44	2080.96	1785.6	1532	1314.4
21									
22	Max. dN/dlogDp [#/cm³]	1.6E+08	1.38E+08	1.19E+08	1.02E+08	88160000	76000000	65440000	56480000
23									
24	dN/dlogDp [#/cm³]								
25	Channel Size [nm]:	6.04	6.98	8.06	9.31	10.8	12.4	14.3	16.5
26	Elapsed [s]								
27	1	0	2492.19	6952.7	10810.4	12244.8	11255.8	11269	12284.5
28	2	120.768	4963.96	6172.81	3747.32	4064.05	7122.99	9416.17	10943.6

Figure 5-11
Sample Export File

To Automatically Export Data

To export data automatically at the end of the run to a file for use in another program (such as Microsoft Excel® spreadsheet software):

1. When setting up the properties for the run, select **Auto-Export** on the Run Settings tab. This activates the Export Options button on the dialog. When you press the **Export Options** button, the Export Data Options dialog opens (see Figure 5-10 above).
2. Select the type of data you want to export, the data range, and the file format in which you want to export the data.
3. Verify the default file name (and path) or press the **Save As** button and change the filename and/or location if you want to save the file to another location or provide a new filename. The extension is automatically selected when you chose a file type for exporting.
4. Press **OK**. Data will be exported to the file at the end of the run.

Arrange Open Windows/Change Layout

When several windows are open on the desktop, it is helpful to arrange them for easier viewing.

There are two ways to arrange windows:

- The traditional Windows method.

  To arrange windows, select an item from the **Window** menu. Windows on your desktop can be arranged horizontally, vertically, or cascaded. Refer to your Windows documentation for examples and more information.

- Using the EEPS spectrometer layout function.

  Select one of the layout icons  (5-pane layout),  (4-pane layout),  (3-pane layout), or  (2-pane layout).

  Each icon changes the number and way in which windows are displayed on the desktop. (These layout functions can also be selected from the **Window** menu.)

All of the program windows that are currently open on the desktop are listed at the bottom of the **Window** menu under the **Close All** item. To make a window active (and bring it to the front of all windows), select the name of the window from the list of open windows.

Quit the Program

To end the program, select **File|Exit**. All windows and files open on the desktop are closed. If you have made changes to a file and have not yet saved it, you will be prompted to do so.

Software Menus

This section describes the software functions available for the EEPS spectrometer software. There are two types of menus: desktop menus and context-sensitive or popup menus.

- Desktop menus are those menus listed at the top of the Engine Exhaust Particle Sizer desktop. They include: **File, Run, Playback, Format, View, Window,** and **Help**.

- Popup menus are those menus that appear when you click the right mouse button when the cursor is positioned in an active window.

Nearly all menu items are available from both a desktop menu and a popup menu, though a few items are only available in one or the other. This section presents the items of the desktop menus first and then describes the menu items that are available only through the popup menus.

In addition to these menus, a toolbar, located just beneath the desktop menus, provides shortcuts to the most commonly used menu functions.

Shortcut keys (keyboard keystrokes that do not require the use of the mouse) are also available. They are described at the end of this section.

Desktop Menus

Note: *All menus and the menu items are described below. Depending on the operation you are currently performing and the window that is active on the desktop, the menu may appear different than shown; that is, some menu items may not be available.*

File Menu

The items of the **File** menu are used to open, save, and recall files and perform other program operations.

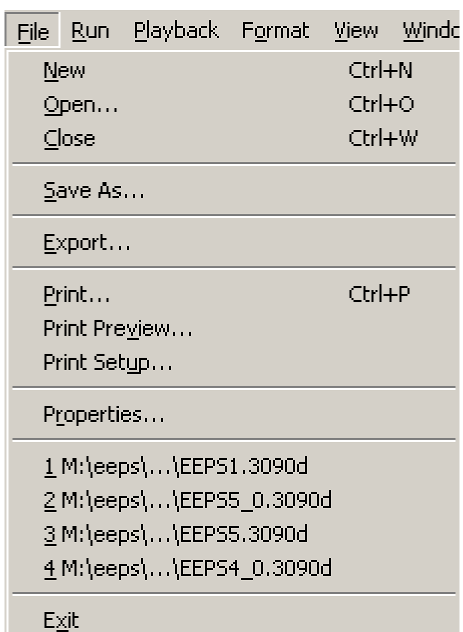


Figure 5-12
File Menu

New

Select **File|New** or or **<Ctrl><N>** to open a new file and prepare to collect sample data.

After you select **New**, you are prompted to enter a filename. Accept the default filename or enter any filename you chose then select **OK**.

A Run View window opens on the desktop with the filename you entered. If other windows were open at the time you last closed a file, these windows also open on the desktop. All graphs and tables are initially empty. You are ready to start collecting data. Refer to "How to Perform a Sample Run" for a complete description.

Open

Select **File|Open** or or **<Ctrl><O**> to open an existing file. By default, the program will look for files in the same directory location as the last file you opened or in the same directory as the EEPS program if this is the first time running the program. All files are automatically given the appropriate filename extension (.3090d). If you store data files in another directory or on another drive, you must first display the file pathname in the Open dialog box before you can select and open it.

When the file opens, a window (or windows) will open on the desktop displaying the data in this file.

Multiple files can be open on the desktop at the same time. Only one window, however, is the active window.

Close

Select **File|Close** or or <**Ctrl**><**W**> to close a file (and all the windows associated with it). If there are windows open on the desktop from more than one file, Close will close only those windows associated with the file whose window is currently active. If you attempt to close a file that has been changed but not saved, you will be prompted to save the changes before closing the file.

Since the Run View is the controlling view for a file, closing this window using the button in the upper right corner also closes the file.

Save As

Select **File|Save As** or to save data to a new filename. (The file contents are duplicated to the new filename. To delete the original filename later, use Windows® Explorer® to do so.)

After you select **Save As**, select a drive/directory in the file dialog box. The same filename can be used if you save the file to another drive/directory, but to save the file to the same directory, you must give it a new name.

Do ***not*** add the filename extension. It is added automatically when you select **Save As**.

Export

Select **File|Export** to export data for use in another program. Data is exported in a delimited text file. Refer to "Export Data to a File" earlier in this chapter for information.

Print

Select **File|Print** or or <**Ctrl**><**P**> to print the active window on the desktop in a report format. To preview the output before printing it, select **File|Print Preview**.

Refer to your Windows® documentation for information about the Print dialog box.

Print Preview

To avoid printing something you do not want, select **File|Print Preview** or to see what your printed output will look like before selecting **Print**.

Print Setup…

Select **File|Print Setup** to set up the printer for printing. Refer to your Windows® documentation and your printer's documentation for information about setting the printer parameters.

Properties…

Select **File|Properties** to see the run properties for the current run. The parameters that can be set in the Properties dialog for a new run are described earlier in this chapter. When viewing the properties for an existing run, only the title and comment fields may be modified and you may also select or de-select "Hide Invalid Data Values".

List of Recently Accessed Files

Between the Print Setup and Exit menu items is a list of the most recently accessed data files (a maximum of four files is displayed). These are accessed from the menu by selecting **File|1**, **2**, **3**, or **4**.

The list provides a shortcut to these files so you can bypass the Open command. To open one of the files listed, use the mouse to highlight it and click the left mouse button. The file opens on the desktop.

Exit

Select **File|Exit** to end the program.

Run Menu

The items available under the Run menu are used to start and stop data collection.

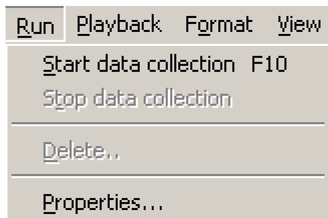


Figure 5-13
Run Menu

Start Data Collection

With a new file open on the desktop, select **Run|Start Data Collection** or or <**F10**> to begin collecting data. Data is collected according to the parameters set in the Properties dialog (see earlier in this chapter).

Once you select **Start Data Collection**, data collection begins immediately or at the time selected in the Parameters dialog box. As data is collected, it is displayed in the open windows.

Stop Data Collection

Select **Run|Stop Data Collection** or to stop collecting sample data immediately. When you select this item, sampling stops and data already collected is saved in the file.

Delete

Select **Run|Delete** or to delete data. This is useful if you need to stop and restart a run. You can only delete data for a new run. It cannot be used to delete data once the file is closed. To delete data for an existing run, use Explorer® or a similar tool to delete the file.

Properties…

This menu item provides a shortcut to the same Properties dialog box listed under the **File** menu. Refer to that description or see the description of the Properties dialog box earlier in this chapter.

Playback Menu

The Playback menu lets you display the sample data series, so that many timed samples can be viewed quickly, visually identifying trends or special events from a large list of samples.

The playback feature was described earlier in this chapter under "Playback (Review) a Sample Run." Refer to that description.

Figure 5-14
Playback Menu

Format Menu

The menu items of the Format menu let you control how information is presented in tables and graphs.

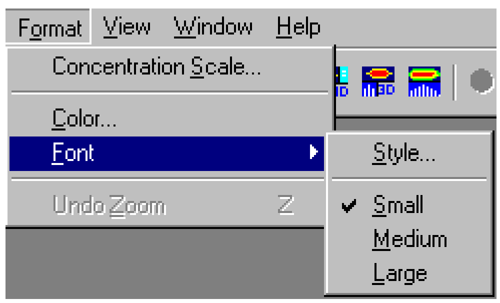


Figure 5-15
Format Menu

Concentration Scale

Select **Concentration Scale** to open the Scale dialog box (Figure 5-16).

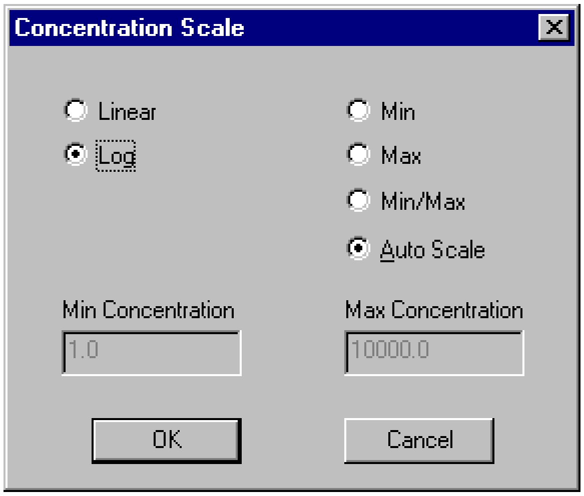
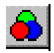


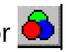
Figure 5-16
Concentration Scale Dialog Box

Use this dialog box to set options and parameters as described in Table 5-2. Make your changes and select **OK**.

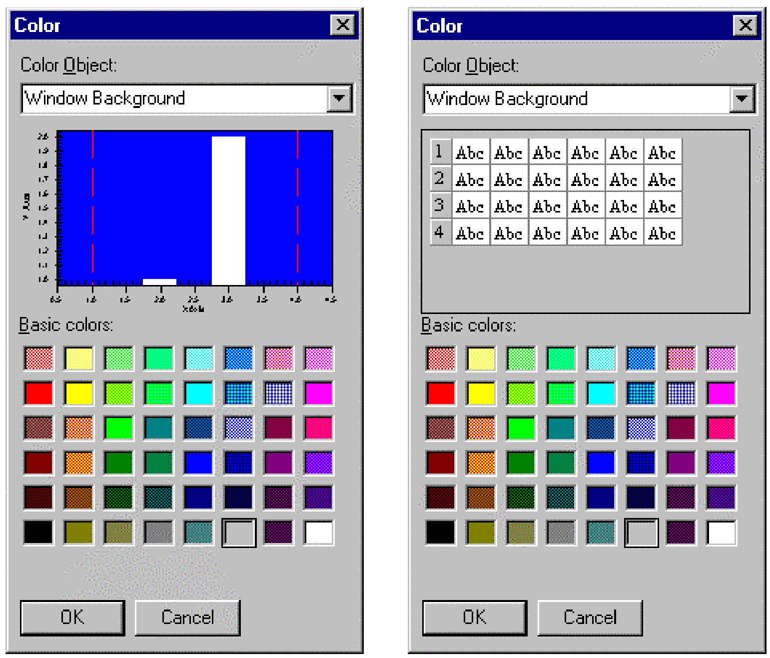
Table 5-2
Options/Parameters of the Concentration Scale Dialog Box

Option/Parameter	Description
Linear	Data plotted on a linear scale.
Log	Data plotted using a logarithmic scale.
Min	Select this radio button to specify a minimum value for the concentration range. When selected, enter a minimum value in the edit box below. This value must be greater than or equal to 0.
Max	Select this radio button to set a maximum value for the concentration range. When selected, enter a maximum value in the edit box below. Enter a value, *m*, such that 100 <= *m* <= 2e8.
Min/Max	Select this radio button to set both the minimum and maximum values for the concentration range.
Auto Scale	Select to let the software automatically determine the minimum and maximum concentration values. Auto-scale is the default.
Min Concentration	Enter the minimum concentration value here. When the graphs are auto-scaled, the value shown in this box (grayed) is the minimum value as calculated by the software.
Max Concentration	Enter the maximum concentration value here. When the graphs are auto-scaled, the value shown in this box (grayed) is the maximum value as calculated by the software.

Color 

Select **Format|Color** or  to change the colors used to display items in the active window.

When **Format|Color** is selected, the Graph Color or Table Color window opens depending on the active window on the desktop (Figure 5-17 shows both). These windows include a preview screen, a drop down list and a color palette. From the drop down list, select the name of the item you want to modify. The current color for that item is indicated in the color palette. Use the mouse to point to the new color for that item and click the left mouse button to select it. The preview screen then displays the item in the new color.



(A) **(B)**

Figure 5-17
(A) The Graph Color Dialog Box, (B) The Table Color Dialog Box

Select items from the drop down list and colors as desired. When finished press **OK**. The colors you selected will be used from that point on in all graphs and/or tables.

The items selectable for windows containing graphs are:

- Window Background
- Plot Area Background
- Labels
- Axis
- Data
- View Boundaries
- Data Hotspot Lines

The items selectable for windows containing tables are:

- Window Background
- Cell Text
- Grid Color
- Cell Background
- Fixed Area Text

The Color dialog box for the 3D graph is slightly different as shown in Figure 5-18.

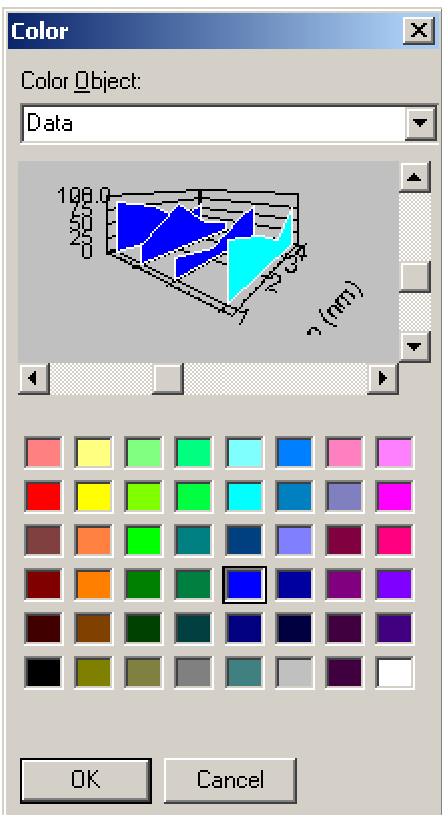


Figure 5-18
The Color Dialog Box for the 3D Graph

Use this dialog to change the color of the following items:

- Data
- Highlighted Data
- Window Background
- Graph Background
- Labels
- Axis

Font Style 

Select the **Format|Font|Style**… menu to change the style of the text in all graphs or tables. See Figure 5-19.

Select any font and font style available on your computer. The preview box displays what the text will look like before you implement it by selecting **OK**.

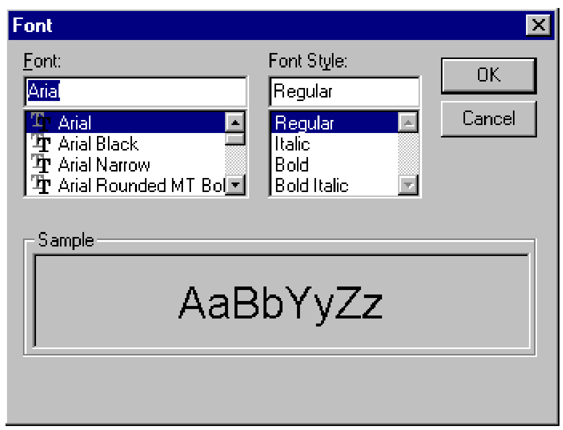


Figure 5-19
Font Dialog Box

Font Size 

To change the font size, select **Format|Font|Small**, **Medium**, or **Large** (the default is Medium). To change the text size without using the menus, select the  icon from the toolbar. Each time you select the icon the text size changes to the next text size. (Rotation is from small to medium to large.) The font size for text can be changed in all views except the Run View where only the font style can be changed.

Undo Zoom 

Select the **Format|Undo Zoom**, select the **Undo Zoom** icon  or type Z in the graph that is currently zoomed to return the graph to its normal viewing size. Refer to the section "Zoom In and Out on Data in a Graph" earlier in this chapter.

View Menu

The View menu lets you select the view windows you may open on the desktop. A checkmark next to an item indicates the item is already open. If it is not visible, look under the Windows menu to find the item and make it the active window.

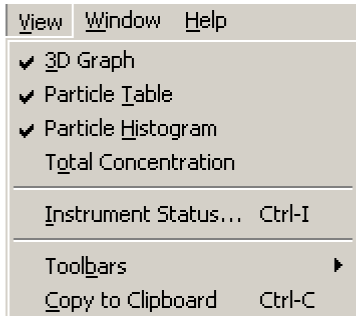


Figure 5-20
View Menu

3D Graph 3D

Select the 3D Graph menu item when you want the 3D graph window open on the desktop (Figure 5-21).

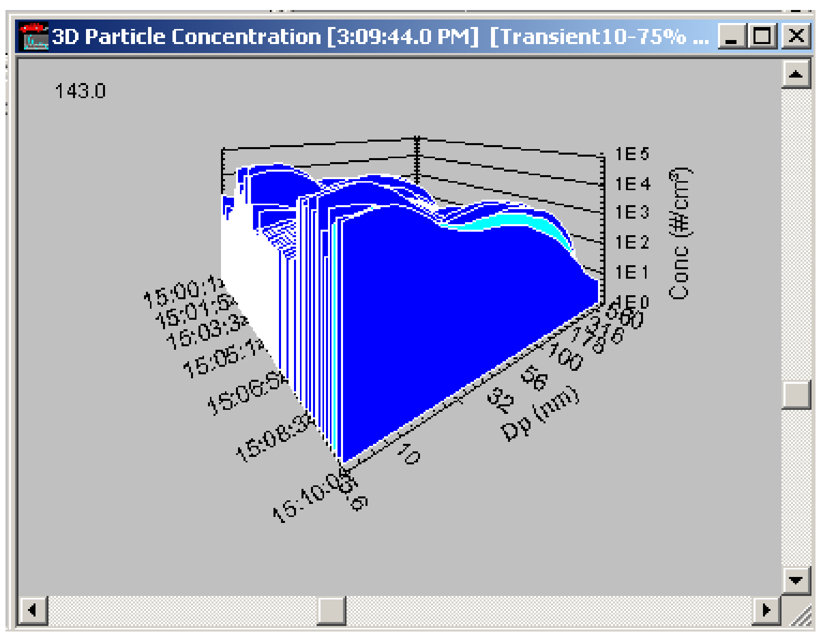
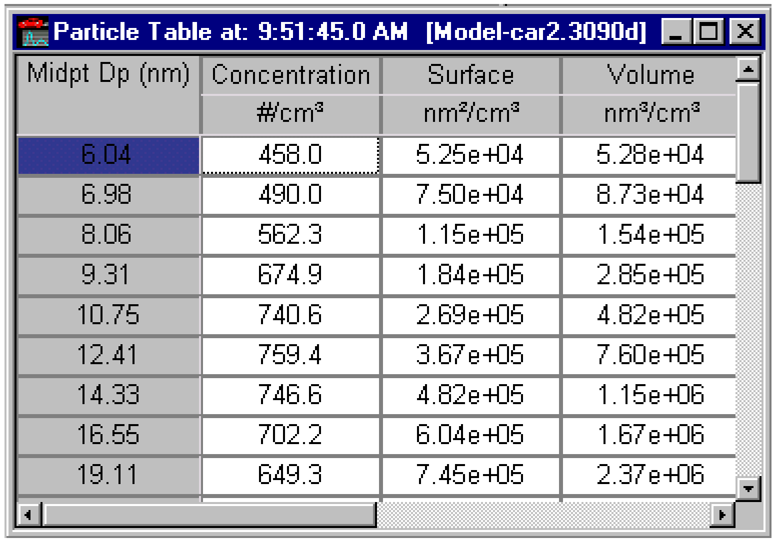


Figure 5-21
3D Graph View

Particle Table

Select the Particle Table menu item when you want the Particle Table window open on the desktop (Figure 5-22).



Midpt Dp (nm)	Concentration #/cm³	Surface nm²/cm³	Volume nm³/cm³
6.04	458.0	5.25e+04	5.28e+04
6.98	490.0	7.50e+04	8.73e+04
8.06	562.3	1.15e+05	1.54e+05
9.31	674.9	1.84e+05	2.85e+05
10.75	740.6	2.69e+05	4.82e+05
12.41	759.4	3.67e+05	7.60e+05
14.33	746.6	4.82e+05	1.15e+06
16.55	702.2	6.04e+05	1.67e+06
19.11	649.3	7.45e+05	2.37e+06

Figure 5-22
Particle Table Window

Particle Histogram

Select the Particle Histogram menu item when you want the Particle Histogram window open on the desktop (Figure 5-23).

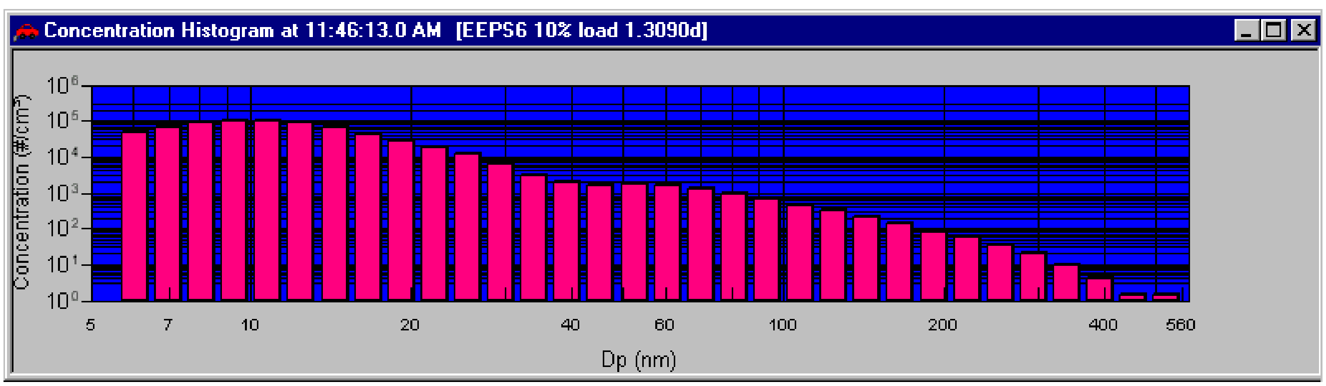


Figure 5-23
Particle Histogram Window

Total Concentration 

Select the Total Concentration menu item when you want the Total Concentration window open on the desktop (Figure 5-24).

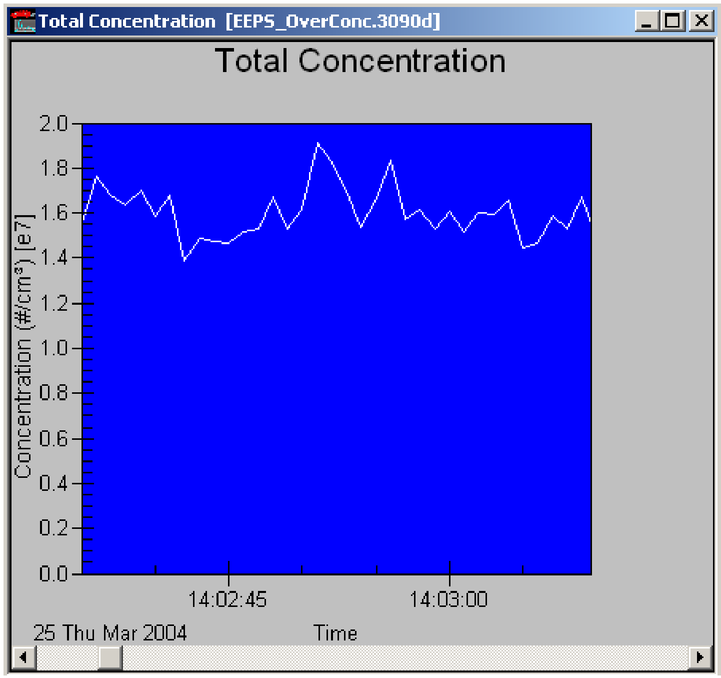


Figure 5-24
Total Concentration Window

Instrument Status <Ctrl><I>

This menu item is available at all times. You do not need to have a data file open in order to view instrument status. When you select the Instrument Status menu item, a dialog window opens detailing the status of the instrument as in Figure 5-25. This dialog will attempt to connect to the instrument if necessary. The Instrument Status dialog reads instrument status values once per second and updates the values for each item shown. Table 5-3 describes each of the parameters and buttons on this dialog.

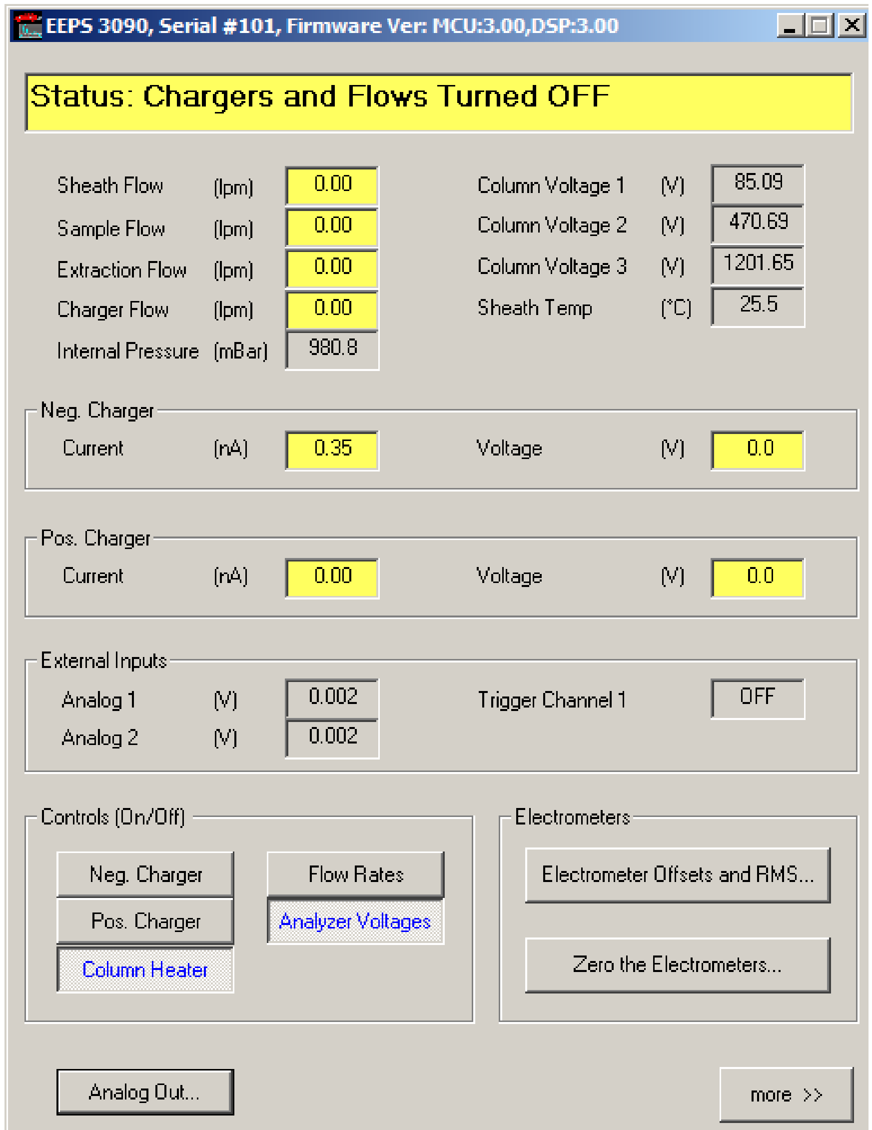
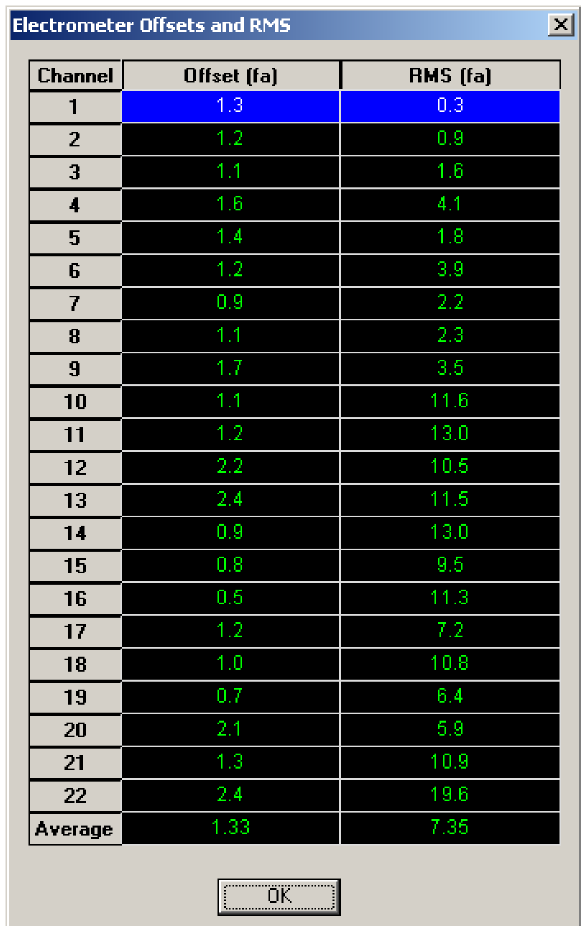


Figure 5-25
Instrument Status

Table 5-3
Instrument Status Parameters

Parameter	Description
Sheath Flow	Volumetric flow rate of the particle free sheath air flow in liter per minutes.
Sample Flow	Volumetric flow rate of the sample flow, in liter per minutes. Sample flow plus extraction flow equals the aerosol inlet flow.
Extraction Flow	Volumetric flow rate of the extraction flow in liter per minutes.
Charger Flow	Volumetric flow rate of the particle free charger sheath air in liter per minutes.
Internal Pressure	Absolute pressure in the sizing column in millibar. Used for the volumetric flow calculation.
Column Voltage 1-3.	Voltage on the center electrode sections in Volt. Column Voltage 1 = Top Section Column Voltage 2 = Middle Section Column Voltage 3 = Bottom Section
Sheath Temp.	Temperature of the particle free sheath air flow in degree Celsius before it enters the sizing column.
Neg. Charger Current and Voltage	Ion current of the negative charger in nano Ampere. Voltage at the charger needle in Volts.
Pos. Charger Current and Voltage	Ion current of the positive charger in nano Ampere. Voltage at the charger needle in Volts.
External Inputs	
Analog 1	Voltage of the external analog input Analog In CH1 in Volts.
Analog 2	Voltage of the external analog input Analog In CH2 in Volts.
Trigger channel 1	Status of the external Trigger IN (On or OFF)
External Outputs	
Analog Out	Activates the Analog Output Settings Dialog. The Analog Out button is only displayed if the Model 3090 EEPS spectrometer has the analog out option. ***Note:*** *The Instrument Status Dialog is inactive while the Analog Out dialog is displayed.*
Controls	
Neg. Charger	Use this push button to turn on/off the negative charger.
Pos. Charger	Use this push button to turn on/off the positive charger.
Column Heater	Use this push button to turn on/off the column heater. Turn the heater on when the instrument is in a cool (i.e., air conditioned) environment and sampling from a warm, humid environment to prevent condensation that could cause the electrometers to become noisy. Normally, the heater should be turned off unless needed.
Flow Control	Use this push button to turn on/off the flow control.
Analyzer Voltages	Use this push button to turn on/off the analyzer voltages.

Parameter	Description
Electrometers	
Electrometer Offsets and RMS	Press this button to open a window which will display the offsets and RMS values for each of the electrometer channels (see Figure 5-26).
Zero the Electrometers	Pressing this button will start the process of zeroing the electrometers on the instrument (see Figure 5-27 to Figure 5-29).
more >> or <<less	Press this button to expand or contract the dialog. See Figure 5-30.



Channel	Offset (fa)	RMS (fa)
1	1.3	0.3
2	1.2	0.9
3	1.1	1.6
4	1.6	4.1
5	1.4	1.8
6	1.2	3.9
7	0.9	2.2
8	1.1	2.3
9	1.7	3.5
10	1.1	11.6
11	1.2	13.0
12	2.2	10.5
13	2.4	11.5
14	0.9	13.0
15	0.8	9.5
16	0.5	11.3
17	1.2	7.2
18	1.0	10.8
19	0.7	6.4
20	2.1	5.9
21	1.3	10.9
22	2.4	19.6
Average	1.33	7.35

Figure 5-26
Electrometer Offsets and RMS Screen

When the **Zero the Electrometers...** button is pressed, the following message box is displayed (Figure 5-27). To continue with the zeroing procedure, select the **Yes** button. Refer to the "Troubleshooting" section in Chapter 6 which discusses this procedure and some possible reasons for doing a zero on the instrument.

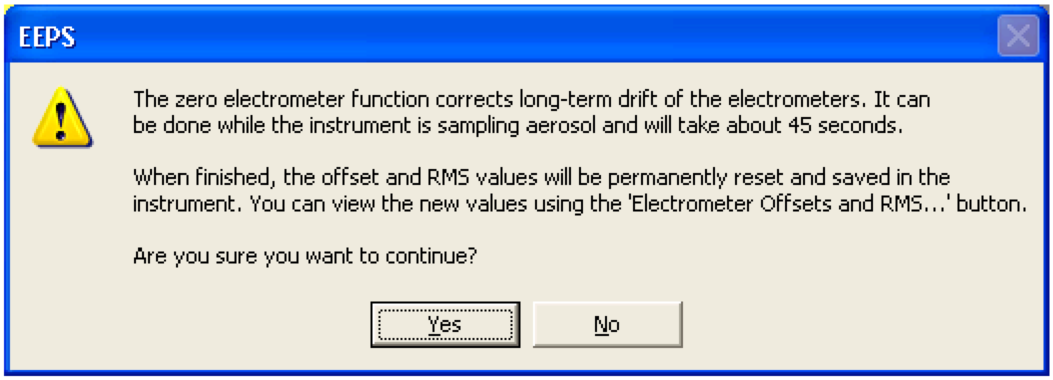


Figure 5-27
Zero Electrometer Function Dialog Box

If you answer "Yes" to continue, the zeroing procedure will start. A progress dialog will display while the zeroing is taking place. The zeroing takes approximately 45 seconds.

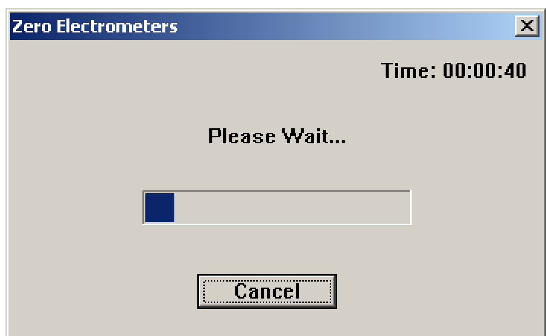


Figure 5-28
Zero Electrometers Progress Dialog Box

When the zeroing is complete, you will see a message window like this:

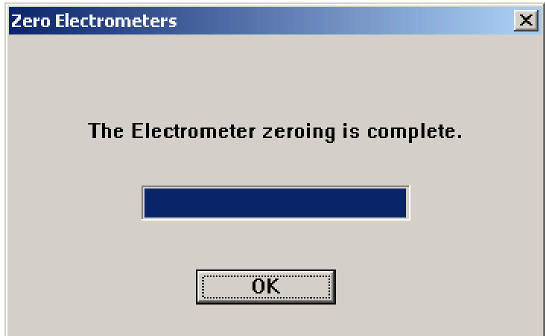


Figure 5-29
Zero Electrometers Zeroing Complete

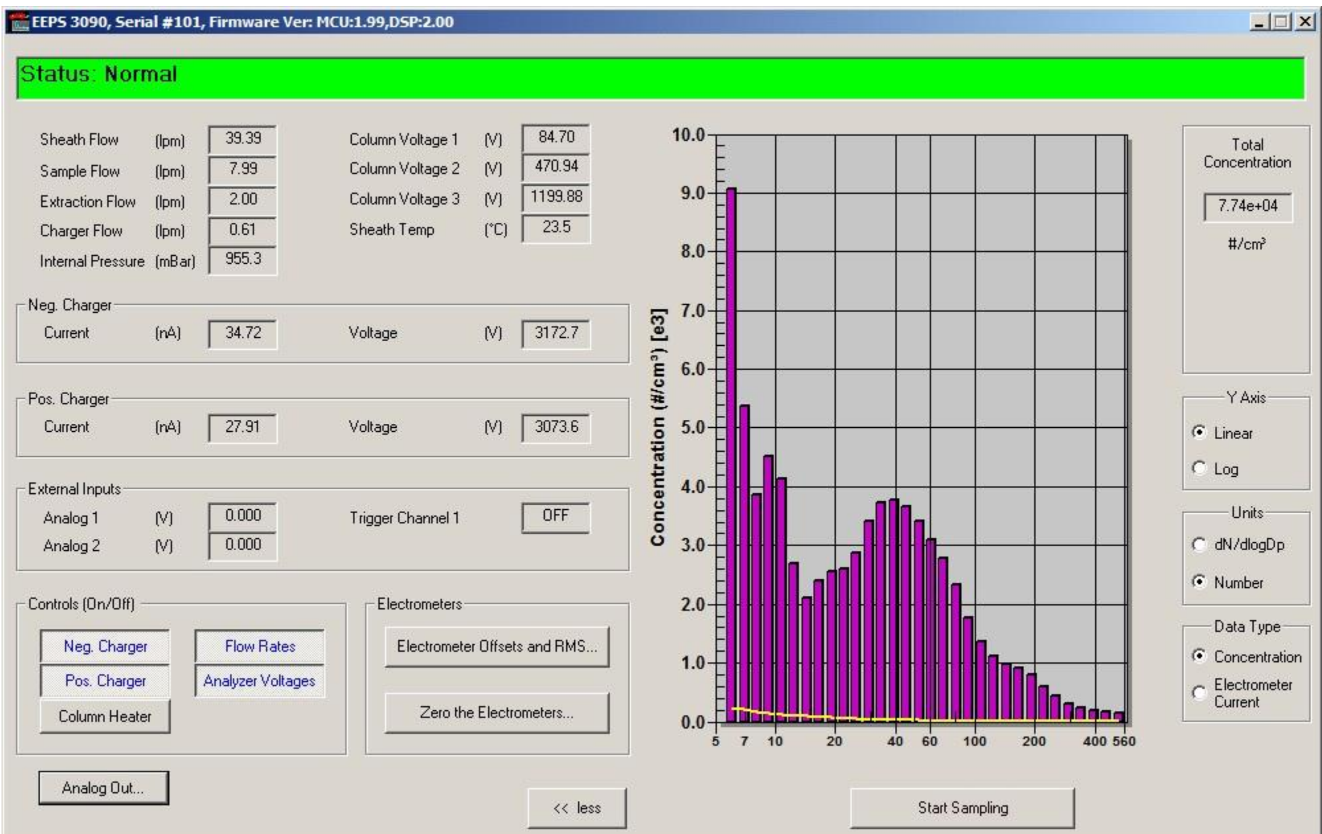


Figure 5-30
Instrument Status Expanded

When the instrument status dialog is expanded (**>>more** button is pressed), a graph showing current particle concentration similar to the instrument front panel is displayed. Control the data displayed in the graph in the following ways:

- Press the **Start Sampling** button to begin sampling. The graph will begin updates of current particle concentration once per second.
- **Linear** or **Log** button: Click on each of the buttons to toggle between the two y-axis scales.
- **dN/dlogDp** or **Number** button: Click on each of the buttons to toggle between the two display units.
- **Concentration** or **Electrometer Current** button: Click on each of the buttons to toggle between these data types sampled from the instrument.
- Press the **Stop Sampling** button to stop sampling and the instrument status display will resume updates to the status values on the left side of the dialog.
- Use the **<<less** button to contract the dialog back to its original size.

Analog Out

The Analog Output Setup dialog displays the output voltage and the EEPS Model 3090 Analog Out settings. If the dialog is active, it shows the current 3090 settings. If the current document is an old data file with Analog Data included, the **Properties | Analog Out Tab** will display the Model 3090 EEPS Analog Out settings state at the time the EEPS data file was created. If the Analog Out dialog is accessed from the Instrument Status dialog, it will always be active and display/adjust the current Model 3090 settings. If the Model 3090 does ***not*** have the **Analog Out** option or the data file was taken with a Model 3090 without the Analog Out feature, the Analog Out dialog will not be available. The information entered is immediately sent to the Model 3090 when data entry is completed. For direct entry, this is after the **Enter** key, **Esc** key, or **Tab** key is pressed. Invalid entries will leave the previous value for that field unchanged.

Note: *Cancel does **not** restore the Model 3090 EEPS spectrometer to any previous state. The Model 3090 Instrument Analog Out settings have already been updated by the time **Cancel** is pressed.*

- **Save these Settings…** button. Brings up a file dialog box where all of the values currently set will be saved in a Settings (*.set) file that can be used later to restore the Model 3090 settings back to the current settings.
- **Load Settings from a File…** button. Brings up a file dialog box where previous Model 3090 settings can be used to restore the Model 3090 settings back to a previous saved state. File type is *.set.

- **Weighting symbols**. These are used to represent three predefined values: Number(1), Surface(3.1416), and Volume(.5236).

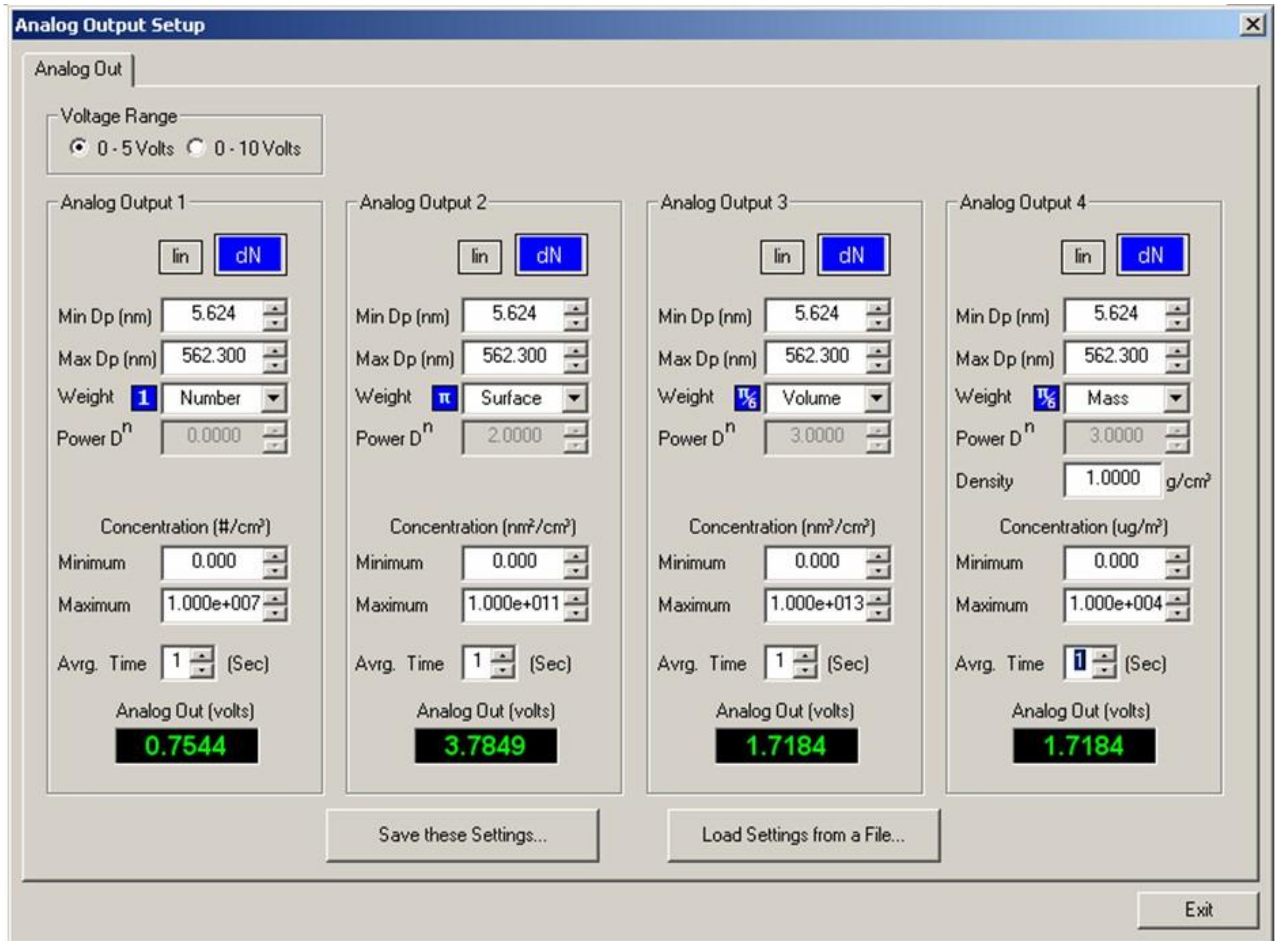


Figure 5-31
Analog Out Setup

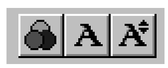
Voltage Range	Select the voltage range for analog outputs. Either 0–5 volts or 0-10 volts.
lin/log	Select whether the channel will display the analog voltage response linearly proportional to concentration (lin) or with a logarithmic (Log) response characteristic. $V(lin) = \frac{particleConc - MinConc}{MaxConc - MinConc} \times VoltageRangeSelection$ $V(Log) = \frac{LN(particleConc) - LN(MinConc)}{Log(MaxConc) - Log(MinConc)} \times VoltageRangeSelecion$
dN **dN/dlogDp**	Select whether the channel will display the analog voltage response “normalized” dN/dLog(Dp) or non-normalized (dN) over the selected particle size range. dLog(Dp) = Log(MaxConc) – Log(MinConc).
Min/Max Dp	Spin Control but values can be entered manually. The Maximum Value is 562.300, minimum is 5.624.
Power Dn	The Maximum Value is 10, minimum is 0.0000.

Weighting	The Maximum Value is 1e38, minimum is 0.0000. If 0.000, output will be 0.000.
Density	The Maximum Value is 1000, minimum is 0.0000. If 0.000, output will be 0.000.
Min/Max Conc.	Spin Control but values can be entered manually. The Maximum Value is 1e38, minimum is 0.000 lin or 0.001 log.
Avrg Time	Value is in integer seconds. The Maximum Value is 10, minimum is 1.
Analog Out (Volts)	Display of Scaled analog voltage out of the EEPS Model 3090 based on the selected channel settings.

Toolbars

Select **View|Toolbars** to display or hide the toolbars that appear on the desktop. Each toolbar is illustrated below:

Main Toolbar



Color and Font Toolbar

The Color and Font toolbar will be displayed if it was displayed the last time you ran the EEPS software. Select **View|Toolbars|Color and Font Toolbar** to display the color and font toolbar**.**

To view what each icon button does, position the cursor on the icon. A balloon appears to describe the function of the icon.

To move a toolbar, position the cursor on a gap between two icons and press and hold the left mouse button. As you move the mouse, the toolbar moves with it. When you release the mouse button, the toolbar remains where it is.

Window Menu

Use the Window menu items (Figure 5-32) to select your window layout, close all windows, and open, close and arrange the windows on your desktop. Refer to your Windows® documentation, if necessary, for an example of what the cascade, tile horizontal, and tile vertical commands do.

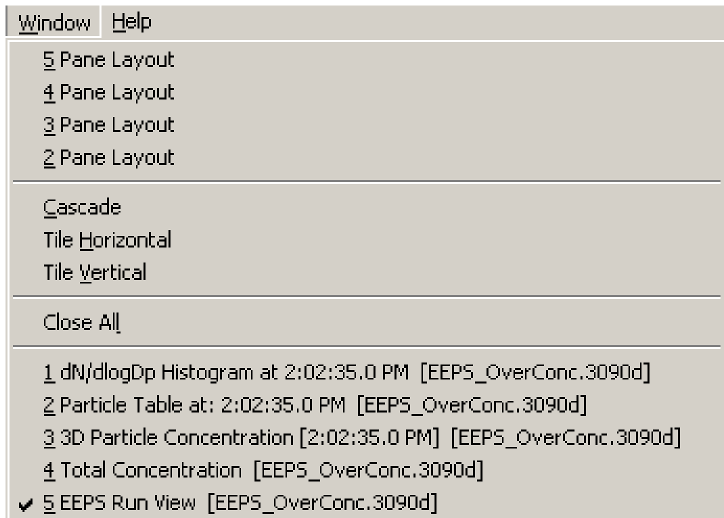


Figure 5-32
Window Menu

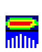
5, 4, 3, and 2 Pane Layout

These menu items and toolbar buttons are intended to provide a shortcut to viewing and sizing each of the windows within the bounds of the desktop in a convenient layout. Each of these window layout selections correspond to toolbar buttons:

 5 Pane Layout displays the Run View, Particle Table, Particle Histogram, Total Concentration Graph and the 3D graph. Each window is sized so that all five panes fit on the desktop.

 4 Pane Layout displays the Run View, Particle Table, Particle Histogram, and the 3D graph. Each window is sized so that all four panes fit on the desktop.

 3 Pane Layout displays the Run View, Particle Histogram, and 3D graph. Each window is sized so that all three panes fit on the desktop.

 2 Pane Layout displays the Run View and Particle Histogram. Each window is sized so that both panes fit on the desktop.

Close All

Closes all the windows on the desktop.

Help Menu

The Help menu (Figure 5-33) provides access to information about the program.

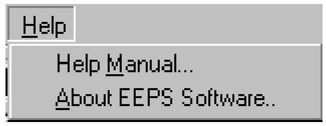


Figure 5-33
Help Menu

Help Manual

Select **Help Manual** to open a PDF file of this manual. Adobe® Acrobat® Reader must be installed on your computer to view the manual. The PDF file of the manual is searchable and printable.

About EEPS Software

Select **About EEPS Software** to see the copyright statement for the program and view the version number of the software.

Context-Sensitive Menus

To access context-sensitive menus, also called "popup menus," click the right mouse button when the cursor is in an active window. Each window has a popup menu as shown below. The table following each popup menu describes where to find a description of that menu item.

Run View Popup Menu

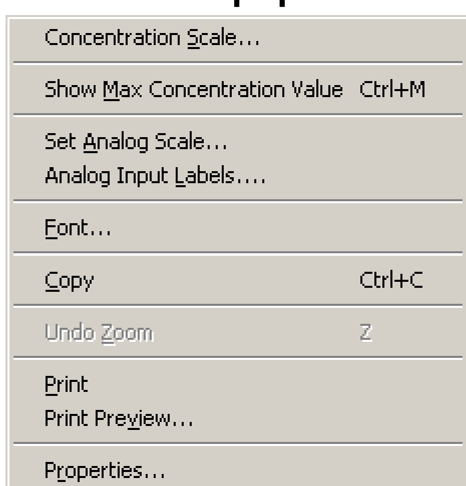


Figure 5-34
Run View Popup Menu

Menu Item	For a description, see ...
Concentration Scale ...	Format Menu
Show Max Concentration Value	Below
Set Analog Scale	Below
Analog Input Labels...	Below
Font...	Format Menu
Copy	View Menu
Undo Zoom	Format Menu
Print	File Menu
Print Preview	File Menu
Properties	File Menu

Show Max Concentration Value

Select this option or press <**Ctrl><M>** in the Run View and the software will select and display the time window corresponding to the maximum concentration value recorded for the current averaging interval.

Set Analog Scale

Select **Set Analog Scale** to open a dialog box (Figure 5-35) that lets you enter new values for the minimum and maximum Y values for the analog input data. You may enter a new value for the Min Y and or the Max Y.

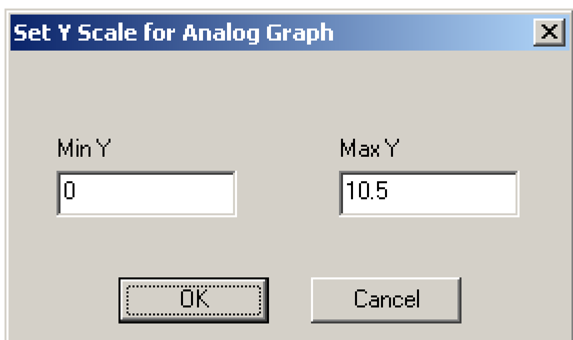


Figure 5-35
Set Y Scale for Analog Graph Dialog Box

Analog Input Labels

Select Analog **Input Labels** to open a dialog box (Figure 5-36) that lets you enter new labels for the analog inputs that are displayed in the analog graph in the lower section of the Run View window. Enter any text up to 47 characters.

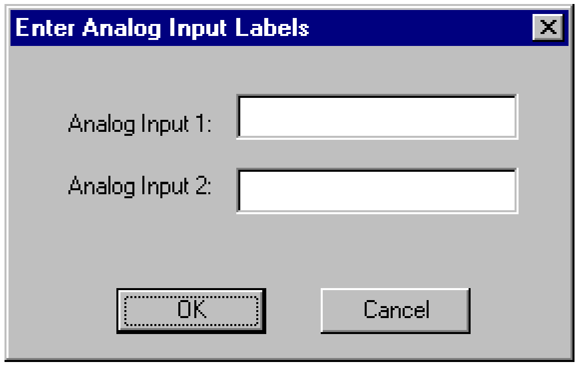


Figure 5-36
Enter Analog Input Labels Dialog Box

Particle Table Popup Menu

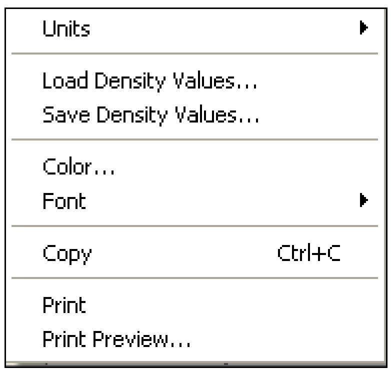


Figure 5-37
Particle Table Popup Menu

Menu Item	For a description, see ...
Units	Below
Load Density Values...	Below
Save Density Values...	Below
Color...	Format Menu
Font...	Format Menu
Copy	View Menu
Print	File Menu
Print Preview	File Menu

Units

dNdlogDp or **Concentration:** select either of these two display units.

Load Density Values...

Select **Load Density Values** to load previously saved density values from a text file. When you select this menu item, a Load Density File dialog box opens. Navigate to the file you want to use and select **Open**. The density values are read and displayed in the density column of the table. Density values are saved with the data file.

Save Density Values...

Select **Save Density Values** to save the current density values to a file for later use. When you select this menu item, a Save Density Values to a File dialog box opens. Enter a file name and select **Save**. The current values in the density column are written to this file.

Concentration Histogram and Total Concentration Popup Menus

The menu items for the popup menus for the Concentration Histogram and Total Concentration windows (Figure 5-38) are the same except Concentration Scale or View Boundaries cannot be selected from the Total Concentration Graph popup menu. This is because the data in the Total Concentration Graph window is always auto-scaled and represents totals for all channels. You can only change the scale type in the Total Concentration Graph window between logarithmic and linear using the toolbar button.

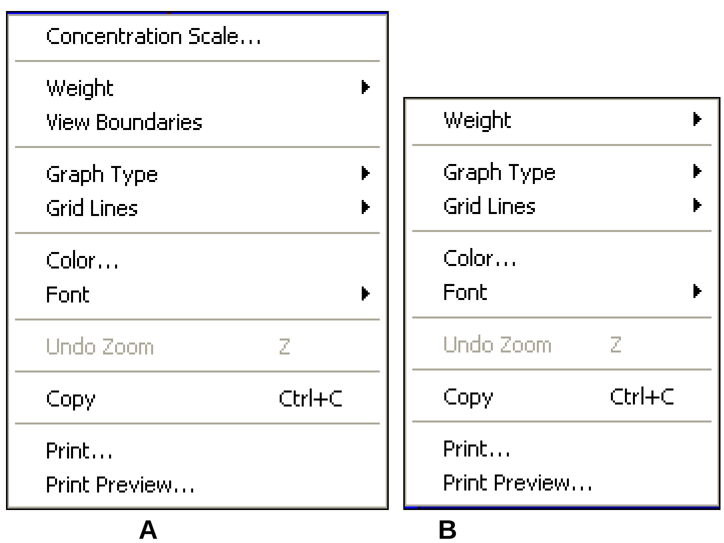


Figure 5-38
Concentration Histogram (A) and Total Concentration (B) Popup Menus

Menu Item	For a description, see ...
Concentration Scale...	Format Menu
Weight	Below
View Boundaries	Below
Graph Type	Below
Grid Lines	Below
Color...	Format Menu
Font...	Format Menu
Copy	View Menu
Print	File Menu
Print Preview	File Menu

Weight

Use the Weight menu to choose how to "weight" the units that are displayed.

The options are number, surface, volume, and mass.

Figure 5-39
Weight Menu

The currently selected weighting is marked with a checkmark. Table 5-4 gives a description of each unit.

Table 5-4
Weight Options

View Units	Description
Number	Number represents the total number of particles per unit volume of air sampled (i.e., number concentration expressed as $\#/cm^3$). Number concentration is the primary measurement of the Model 3090 EEPS system. The sensor is sensitive to the number of particles in the aerosol sample as opposed to the particle mass, color, shape, composition or other characteristic. The distributions of diameter, surface area, volume or mass concentrations of the particles are calculated based on the particle number distribution. The number concentration, dN, measured by the Model 3090 is the concentration of particles in a given channel. The normalized concentration dN/dlogDp is the number concentration of each channel multiplied by the number of channels per decade (16).
Surface	Surface represents the total surface area of the particles per unit volume of air sampled (i.e., surface area concentration expressed as nm^2/cm^3). The surface area concentration calculation assumes that all the particles are perfect spheres. Surface area concentration is calculated by: $dS = dN \cdot \pi D_p^2$, where D_p is the geometric midpoint of the particle size channel.

View Units	Description
Volume	Volume represents the total volume of the particles per unit volume of air sampled (i.e., volume concentration expressed as nm^3/cm^3). The volume concentration calculation assumes that all the particles are perfect spheres. Volume concentration is calculated by: $dV = dN \cdot (\pi/6)D_p^3$, where D_p is the geometric midpoint of the particle size channel.
Mass	Mass represents the total mass of the particles per unit volume of air sampled (i.e., mass concentration expressed as $\mu g/cm^3$). The mass concentration calculation assumes that all the particles are perfect spheres with the density defined in the density column of the Particle table for each channel. Mass concentration is calculated by: $dM = dN \cdot (\pi/6)D_p^3\rho$, where D_p is the geometric midpoint of the particle size channel and ρ is the density. This quantity is related to Volume concentration by the simple factor ρ.

In many of the tables, the values for all four weightings are supplied in tabular format.

Note: *Surface, Mass and Volume weighting calculations assume that all the particles are spherical. Mass calculations use the density defined in the particle table for each channel. However, comparisons to methods that measure particle surface, volume or mass directly may give results different from those calculated by the software.*

View Boundaries

Select **View Boundaries** to display the channel view boundaries in the graph window. After you select **View Boundaries**, drag view boundaries by positioning the cursor on the boundary, clicking the left mouse button, and dragging the boundary to a new location.

Graph Type

Select **Graph Type** to select the type of graph to display in the active window. The options are bar, line, or area.

Grid Lines

Select **Grid Lines** to select the lines for the graph in the active window. The options are horizontal, vertical, both or none.

3D Particle Concentration Popup Menu

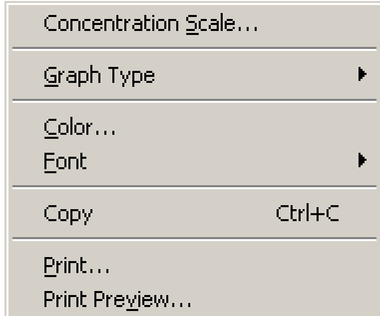


Figure 5-40
3D Particle Concentration Popup Menu

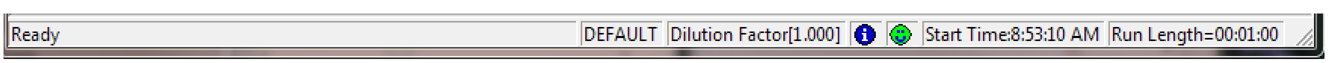
Menu Item	For a description, see ...
Concentration Scale...	Format Menu
Graph Type	Below
Color...	Format Menu
Font...	Format Menu
Copy	View Menu
Print	File Menu
Print Preview	File Menu

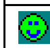
Graph Type

Select **Graph Type** to select the type of graph to display in the active window. The options are 3D Bar or Waterfall.

Status Bar Icons

A status bar at the bottom of the desktop displays information about the current run as described below.



Icon/Text	Description
Matrix Name	Name of the matrix currently configured on the instrument for new runs or, the name of the matrix used to calculate the concentration data for the current file. Refer to the description for the Run|Properties dialog.
Dilution Factor	The current dilution factor. This is set in the Run|Properties dialog.
	Attention. Errors conditions were detected during the run. Move the mouse over the icon to view the tool tip which displays the error text. See Chapter 6 for a complete description of instrument errors that may be reported here.
	Instrument status information. Move the mouse over the icon to view instrument status information saved for this run.
	The run completed without errors.

Shortcut Keys

Shortcut keys and key combinations can be used to perform operations using only the keyboard (no mouse required).

Key(s)	Action for EEPS Sensor
F1	Help; opens the help manual (PDF file)
F10	Start Data Collection
Ctrl C	Copy current view to clipboard
Ctrl I	Opens Instrument Status window
Ctrl N	Open a New document
Ctrl O	Open a document
Ctrl P	Print current view
P	Print current view
Ctrl S	Save As
Ctrl W	Close current file
Z	Undo Zoom in graph

CHAPTER 6
General Care, Troubleshooting and Service

This chapter is written for a service technician with skill in both electronics and mechanics. Static preventative measures should be observed when handling any printed circuit board connectors.

The Model 3090 Engine Exhaust Particle Sizer™ (EEPS™) spectrometer is designed for many hours of maintenance-free operation. This chapter describes basic care of the instrument, some troubleshooting suggestions, and provides information on where to go for service.

The Model 3090 is a complex instrument. Feel free to contact TSI prior to any maintenance procedure or for general questions regarding engine emission sampling. Read through the entire section and make sure all the tools necessary are available before starting to disassemble the instrument.

Basic Care of the Engine Exhaust Particle Sizer Spectrometer

Table 6-1 provides a general indication of the maintenance requirements. In applications where high concentrations may be generated, maintenance is required more often.

Caution
In general, if the instrument is functioning properly (sizing particles correctly compared to a standard, and without excessive noise), cleaning is not recommended—it can lead to leaks or damage if not done correctly.

Table 6-1
Maintenance Schedule

Maintenance	Frequency
Remove the cyclone cover and clean interior surfaces (especially the wall opposite the inlet nozzle).	100 hours of operation or as needed
Check/clean the charger electrodes.	100 hours of operation
Clean the column and outer electrode. Clean the high voltage column and sensing electrodes.	500 hours of operation
Replace the manifold filter cartridges.	>6000 hours of operation or as needed
Replace the pump filter cartridges.	>6000 hours of operation or as needed

Cleaning the Cyclone

To help maintain the instrument at peak performance, use the cyclone whenever you take measurements. The cyclone removes particles greater than those measured by the EEPS spectrometer and improves measurement accuracy by eliminating multiple charged particles behaving as smaller particles. The cyclone also reduces the particle load on filters and the accumulation of particles on interior surfaces of the charger column.

Clean the cyclone prior to the start of testing. When cleaning, refer to the illustration of the cyclone in Figure 2-2.

To clean the cyclone:

1. Separate the cyclone from the SS union fitting by loosening the hex nuts.
2. Remove the cyclone's removable base by turning it counterclockwise.
3. Use compressed air to blow out the interior surfaces and rinse it in isopropyl alcohol, acetone, or water.
4. Examine the interior inlet orifice to make sure it is clear.
5. Dry the parts thoroughly, and add a very light coating of oil or grease to the bottom sides of the cyclone. This will increase its collection efficiency especially for fibers.
6. Reassemble and reinstall the cyclone.

Cleaning and Replacing Charger Needles

If you receive an error code (Tables 6-2 and 6-3) identifying a problem with either the positive or negative charger current or voltage, you will need to clean or replace the electrode in the charger head.

The procedures for the negative and positive charger needles are very similar. To clean or replace the positive charger needle, follow the procedure for cleaning or replacing the negative charge needle, but read the short section below on the differences between the two procedures.

Note: *Protect your back. Because of the height of the EEPS spectrometer, these procedures are easier when the instrument is on the floor. Because of the instrument's weight, always have two people move the instrument.*

Cleaning the Negative Charger Needle

W A R N I N G
High voltage is accessible in several locations within this instrument. Make sure you unplug the power source to the instrument before performing maintenance procedures.

To clean the negative charger needle, proceed as follows:

1. Power off the equipment and wait 5 minutes for the internal capacitors to discharge.
2. Remove the top cover by:
   a. Loosen the three top-panel screws on each side of the instrument. (***Note:*** *Screws do* ***not*** *need to be removed. Panels are slotted to allow for removal without removing the screws.*)
   b. Loosening the two top-panel screws on the back of the instrument.
   c. Lift the back of the top panel up slightly, then pull it backward and lift it out (Figure 6-1).

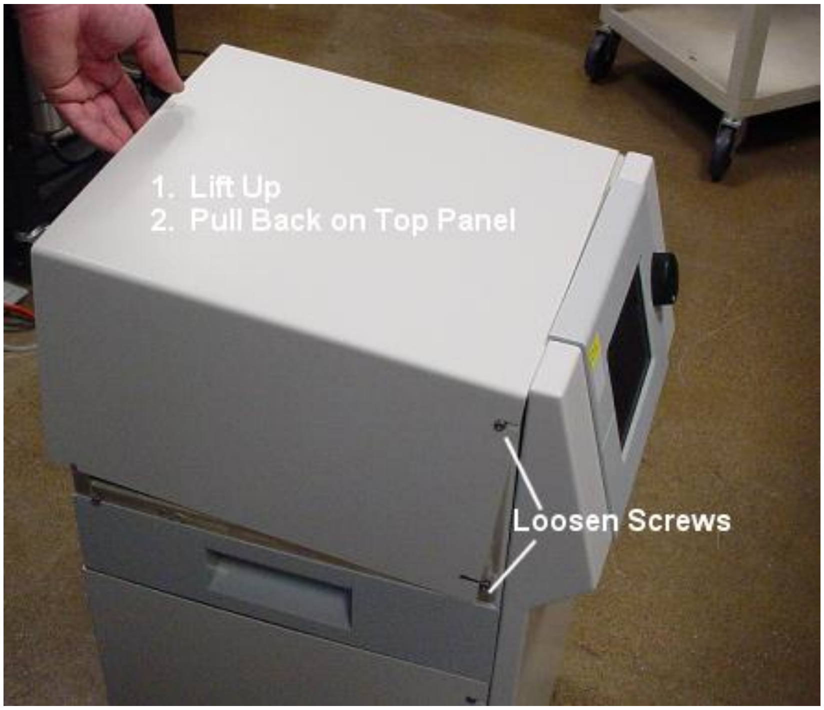


Figure 6-1
Remove Top Panel

3. Disconnect the sample inlet tube from the charger column (Figure 6-2).

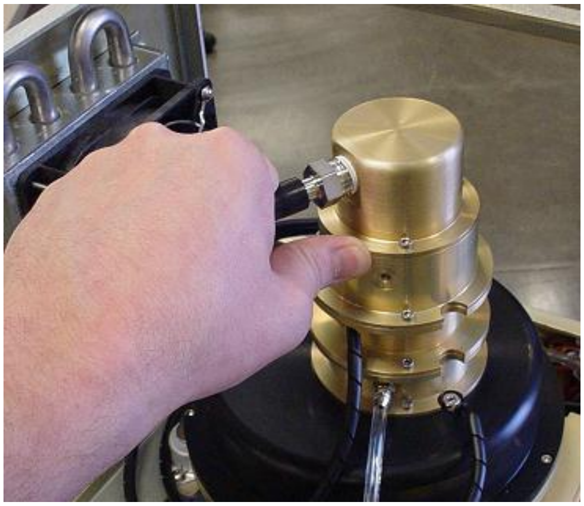


Figure 6-2
Disconnect Sample Inlet Tube

4. The negative charger is located closest to the top of the charger column (Figure 6-3). Remove the second set of screws (3) using an Allen wrench (provided in the accessory kit). Loosen all screws ½ turn, then remove each completely and put them aside for reassembly.

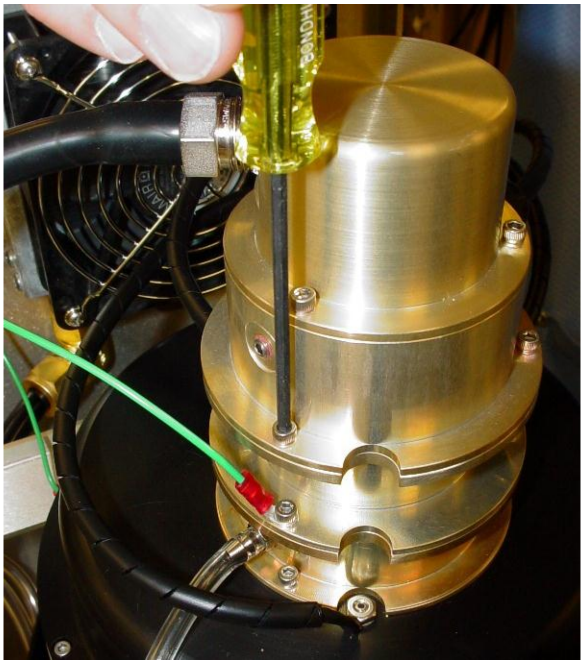


Figure 6-3
Remove the Screws of the Negative Charger Assembly

5. Carefully lift off the charger head (Figure 6-4).

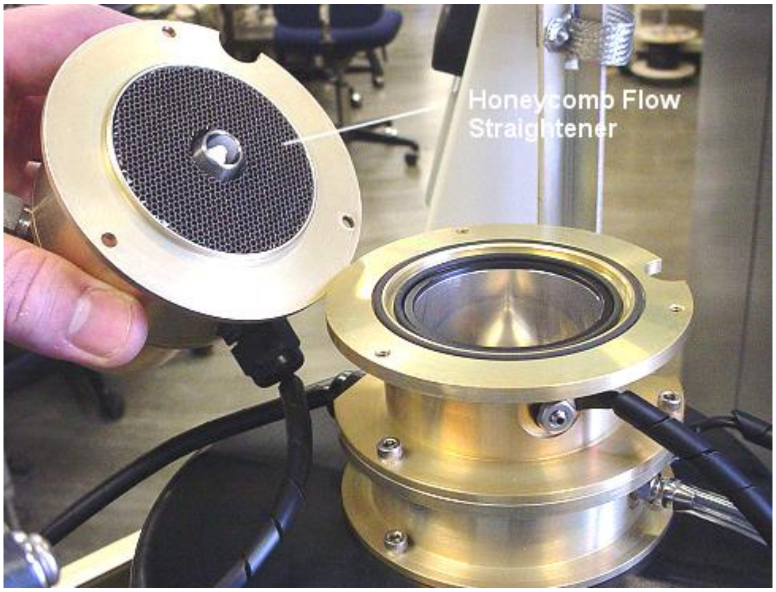


Figure 6-4
Lift off the Negative Charger Head

6. As you lift the charger head, note the honeycomb flow straightener. The “honeycomb” may be dislodged, it may stay inside the charger assembly, or it may stay inside the column. If the honeycomb remains in the charger assembly or inside the column, use a needle nose tweezers to remove it (Figure 6-5). Put the honeycomb aside for reassembly.

Figure 6-5
Remove the Honeycomb for Reassembly

7. With the charger head upside down on the charger column (as shown in Figure 6-5) and the honeycomb removed, inspect the charger needle.
8. The charger needle (Figure 6-6) is located on top of the white cone tip (insulator) and is nearly invisible to the naked eye. Use a magnifying glass (8x minimum), a jeweler's loop, or a microscope to view the fine charger wire. Generally, if you have a charger error, you will see a tiny bulb of contaminant (either white or black) collected on the charger needle.

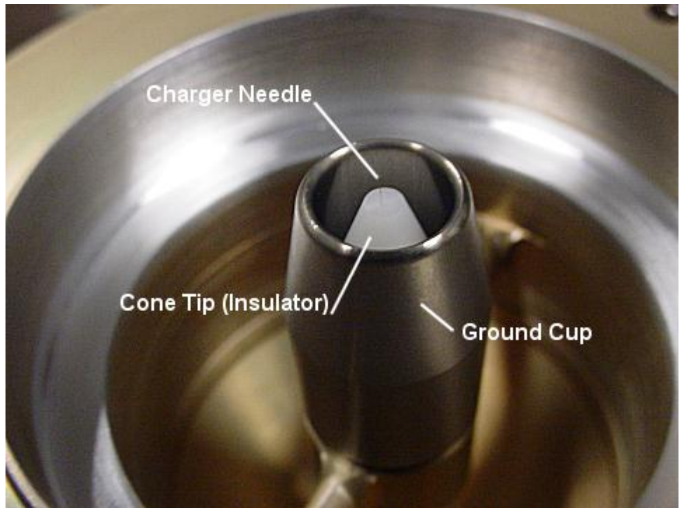


Figure 6-6
The Charger Needle

9. Use a fine-tipped pair of tweezers, to gently grab the contaminated needle and draw the tweezers up, using care not to bend the needle as you do so. **Do not use solvents to clean the needle.** If the needle bends, use the tweezers to straighten it. The needle must be as straight and centered in the ground cup as possible.
10. After you have removed the collected material, reassemble the instrument and run a test to check operation. If you get another error message (or if the needle breaks while cleaning it), replace the needle as described in the following section.

Replace the Negative Charger Needle

To replace the charger needle, proceed as follows:

Note: *Make sure your hands are clean so grease or oil does not get on the grounding cup or the insulator. You may want to wear examination gloves.*

1. Follow steps 1 through 6 of the cleaning procedure, then...
2. Unscrew the ground cup (Figure 6-6) and set it aside for cleaning and reassembly. No tools should be needed to remove it.
3. Unscrew the white cone tip (the insulator with the charger needle attached). A tweezers or pliers may be used to hold the flange with holes to keep it from turning (see Figure 6-7).

Figure 6-7
Hold the Flange with Tweezers

4. Screw a new charger wire/cone tip (provided in the accessories kit) onto the charger stem. A tweezers or pliers may be needed to hold the flange with holes to keep it from turning. Tighten the charger wire/cone tip so that it is bottomed-out and tight.
5. Use a swab and hot water or alcohol to clean the cone tip to remove any grease or oil from your hands. Be careful not to bend the charger needle.
6. Clean the ground cup with hot water or alcohol and blow it dry with compressed air.
7. Screw the ground cup back on (finger-tight).
8. Verify the charger wire is centered in the cone. Use a magnifying glass.
9. Carefully set the honeycomb on the charger column.
10. Flip the charger assembly back into position and line up the screw holes (the sample inlet tube should point to the back of the instrument).
11. Start each screw first then tighten each of them down firmly.
12. Do a final tightening of the screws to seal the O-ring.
13. Reconnect the sample inlet tube.
14. Replace the top panel and tighten the retaining screws.
15. Run a sample to verify the EEPS spectrometer is working properly.

Cleaning or Replacing the Positive Charger Needle

WARNING

High voltage is accessible in several locations within this instrument. Make sure you unplug the power source to the instrument before performing maintenance procedures.

The procedure for cleaning or replacing the positive charger needle is nearly identical to that for the negative charger needle, with the following exceptions:

- Before cleaning or replacing the positive charger needle, you must disconnect the charger sheath flow tubing (Figure 6-8). **You must push the retaining ring evenly into the connector before pulling the hose free. If you try to simply pull on the hose, it will become harder to remove.**
- The positive charger is the bottom set of screws (see Figure 6-9) on the charger head assembly.
- The positive charger does not have a honeycomb. Beneath the positive charger is a grid (screen) which you do not need to remove.
- When reassembling the positive charger, take care to protect the wire tip from bending over by coming in contact with the coarse wire mesh when inserting it through the hole in the center of the mesh.

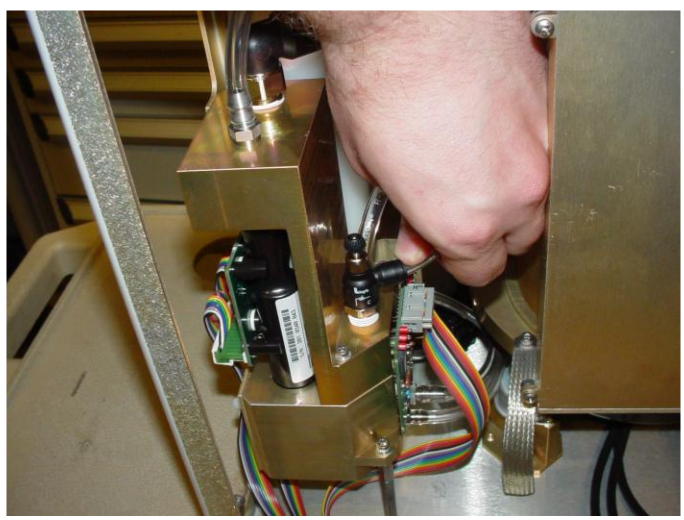


Figure 6-8
Disconnect the Charger Sheath Flow Tubing

Figure 6-9
Remove the Screws of the Positive Charger Assembly

Cleaning the Charger Column

The charger column should be cleaned according to Table 6-1 or when an error code indicates there is a problem. This section provides two procedures for cleaning the charger column: a basic procedure and a detailed procedure. Perform the basic procedure first. If that does not resolve the problem, perform the detailed procedure.

Note: *Make certain the cyclone is always mounted on the aerosol inlet. The cyclone removes lint and large particles from the air stream and will help keep the instrument clean.*

If you have questions regarding the need to clean the charger column, refer to "Technical Contacts" later in this chapter.

WARNING
High voltage is accessible in several locations within this instrument. Make sure you unplug the power source to the instrument before performing maintenance procedures.

Basic Charger Column Cleaning Procedure

Note: *Because of the height of the EEPS spectrometer, it is easiest to work on the instrument when it is on the floor. Protect your back—because of its weight, always use two people to move the instrument.*

Perform the basic charger column cleaning as follows:

1. Power off the equipment and wait 5 minutes for the internal high-voltage capacitors to discharge.
2. Remove the top panel (refer to "Cleaning and Replacing Charger Needles" and Figure 6-1).
3. Disconnect the sample inlet tube from the charger column (Figure 6-2).
4. Unscrew the charger head assembly screws (4) as shown in Figure 6-10.

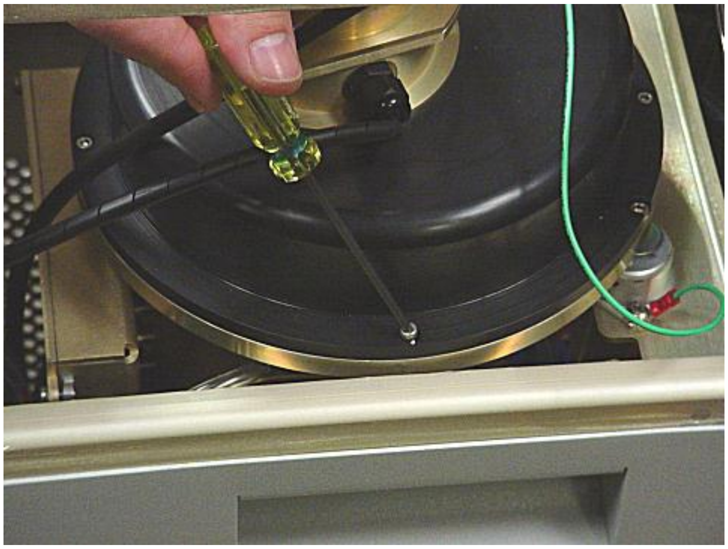


Figure 6-10
Unscrew Charger Head Assembly Screws

5. Unclip the wiring harness retainer using a flat-blade screwdriver, if needed (Figure 6-11). The charger wiring harness should now be free.

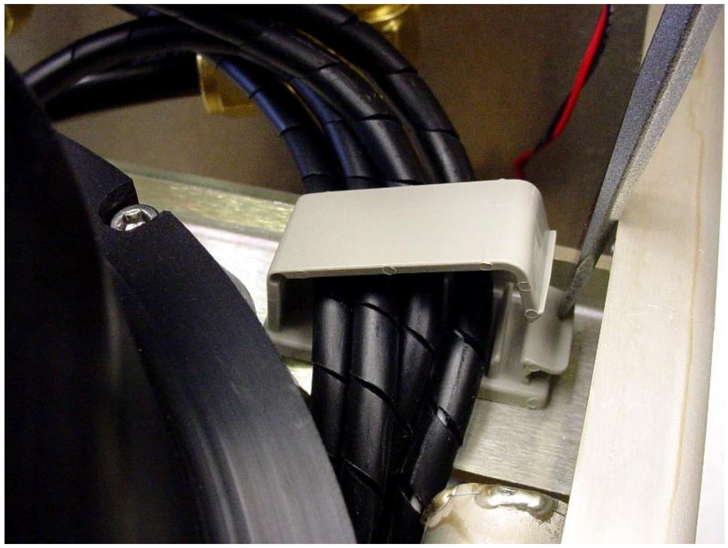


Figure 6-11
Unclip the Wiring Harness Retainer

6. Lift the charger head assembly off. It seals with an O-ring, so there will be some resistance as you lift the head assembly.
7. Turn the assembly over and set it off to one side, refer to Figure 6-12.
8. Locate the cleaning tool (TSI P/N 2900009—assembly cleaning tool) from the accessory kit and the 12 × 15 in. (30 × 38 cm) square cleaning cloths. The cloths should be lint-free and may be dampened with acetone if needed. Fold the cloth in the long direction to double up the cloth (if this is too thick, cut the cloth in half to get a 7.5 × 12 in. piece and try again).
9. Apply a cleaning cloth to the cylinder as shown in Figure 6-12. One edge should be attached to the loop fastener tape and the cloth wrapped around the cylinder until it overlaps.

Figure 6-12
Cleaning Tool

10. Using the cleaning tool with cloth, clean the inside of the cylinder by slowly inserting the tool into the space between the inner and outer column (Figure 6-13). Rotate the tool (in the direction which will not unwrap the cloth) and slowly push it down. Continue this motion until the cleaning tool has bottomed out at the bottom of the column.

    Note: *Generally, when the column gets "noisy," it is because a piece of lint has collected in the charger unit and it is shorting two of the rings. The purpose of wiping the cylinder sides is to remove any material on the outer cylinder. The inner cylinder will generally stay very clean due to the electric field.*

Figure 6-13
Cleaning the Charger Column

11. After cleaning, reassemble the charger column and after warm-up, zero the electrometers (see "Baseline Noise" in the following section, "Troubleshooting"). If the problem is still present, try zeroing the electrometers again from the front panel. If this still does not help, the detailed cleaning procedure described below must be performed.

Detailed Charger Column Cleaning Procedure

Note: *This procedure is easier to perform on a surface that is approximately waist high. Most of the steps in this procedure can be done by one person, but several steps may require assistance.*

W A R N I N G
High voltage is accessible in several locations within this instrument. Make sure you unplug the power source to the instrument before performing maintenance procedures. Use appropriate ESD precautions.

To perform the detailed charger column cleaning procedure, proceed as follows:

1. Power off the equipment and wait 5 minutes for the internal capacitors to discharge.
2. Remove the top cover and both side panels of the EEPS spectrometer. (Refer to Figure 6-1 and the previous cleaning procedures if necessary.)
3. Open the front panel (there are 3 screws on the inside left). Prop the door open using a binder clip or clamp.
4. Remove the sample inlet tube from the top of the charger column (Figure 6-2 above).
5. Remove the charger sheath flow tube from the charger column (Figure 6-14). **You must push the retaining ring evenly into the connector before pulling the hose free. If you try to simply pull on the hose, it will become harder to remove.**

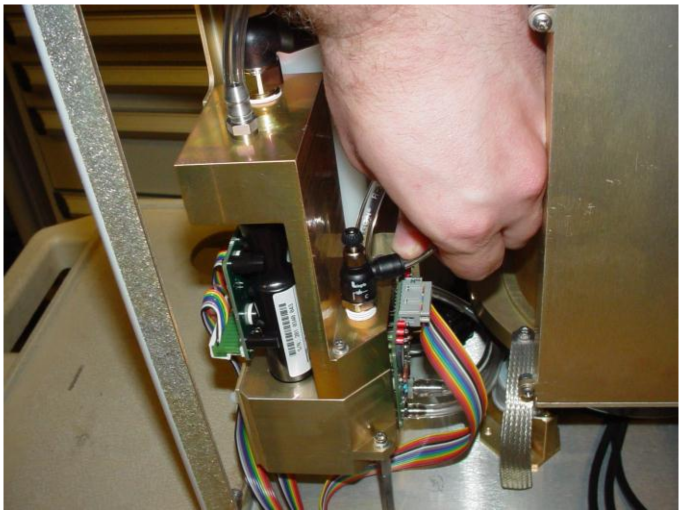


Figure 6-14
Remove the Charger Sheath Flow Tube from the Charger Column

6. Remove green ground cable from “damper” sitting on the frame.
7. Unscrew and remove the charger head assembly as you did for the Basic Cleaning Procedure, above.

8. Remove the two column retaining screws (Figure 6-15).

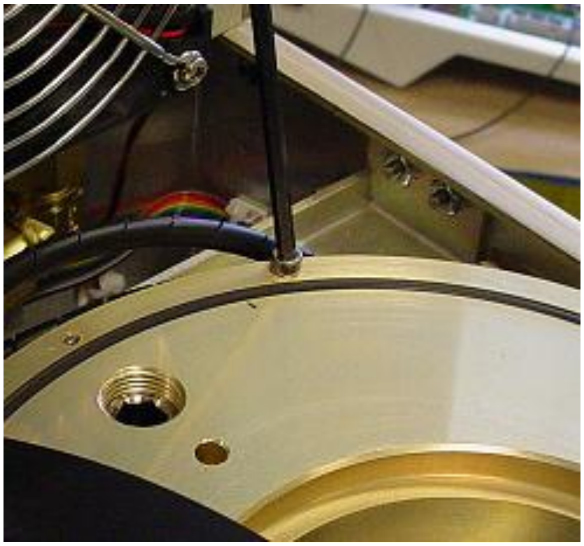


Figure 6-15
Remove the Column Retaining Screws

9. Disconnect the electrometer ribbon connector (Figure 6-16). Use caution. Pull the connector straight out so as not to damage the pin connectors (note the use of an ESD wrist strap).

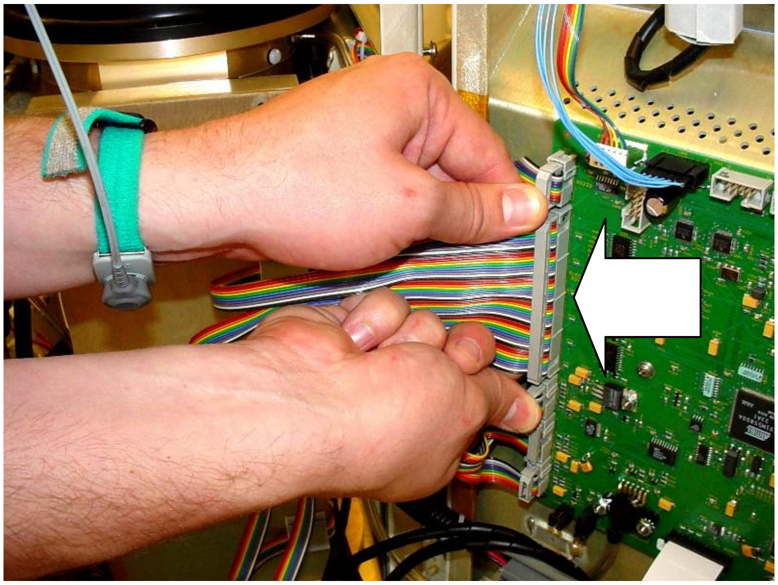


Figure 6-16
Disconnect the Electrometer Ribbon Connector

10. Disconnect the sheath air hose (Figure 6-17) from the fitting. **You must push the retaining ring evenly into the connector before pulling the hose free. If you try to simply pull on the hose, it will become harder to remove.**

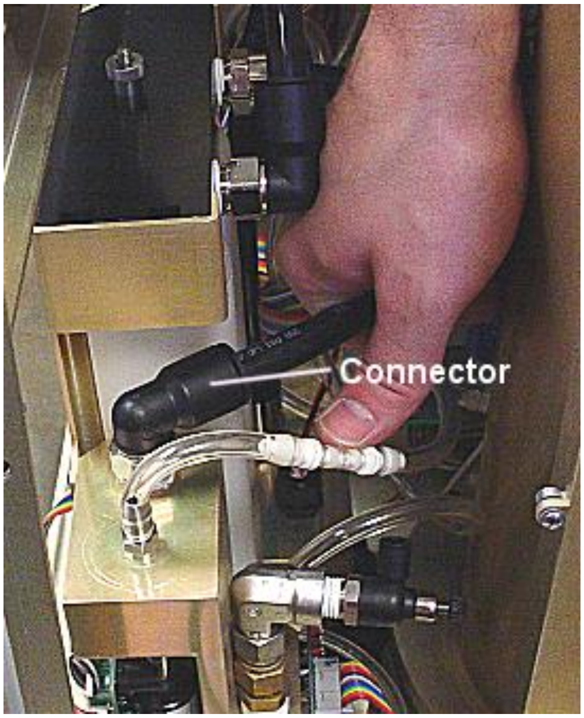


Figure 6-17
Disconnect the Sheath Air Hose

11. Disconnect the pressure transducer tube (Figure 6-18).

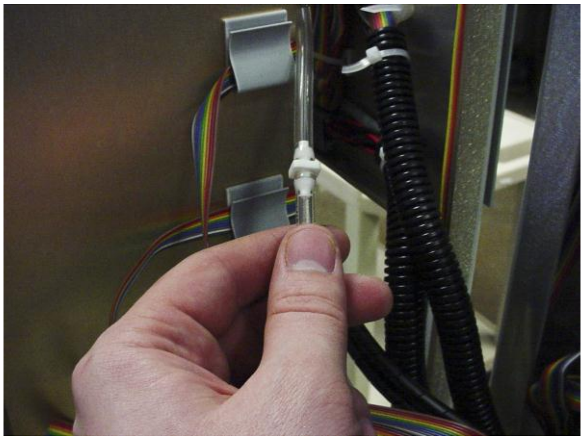


Figure 6-18
Disconnect the Pressure Transducer Tube at the Column

12. The four screws that hold the base of the outer column in place are covered by the heater wrapped around the outer column. Locate the screws, slightly remove the heater insulation from them, and remove the four screws shown in Figure 6-19 that hold the base of the outer column in place.

13. Unplug the heater cable connector (red cable) from the contact on the main board.

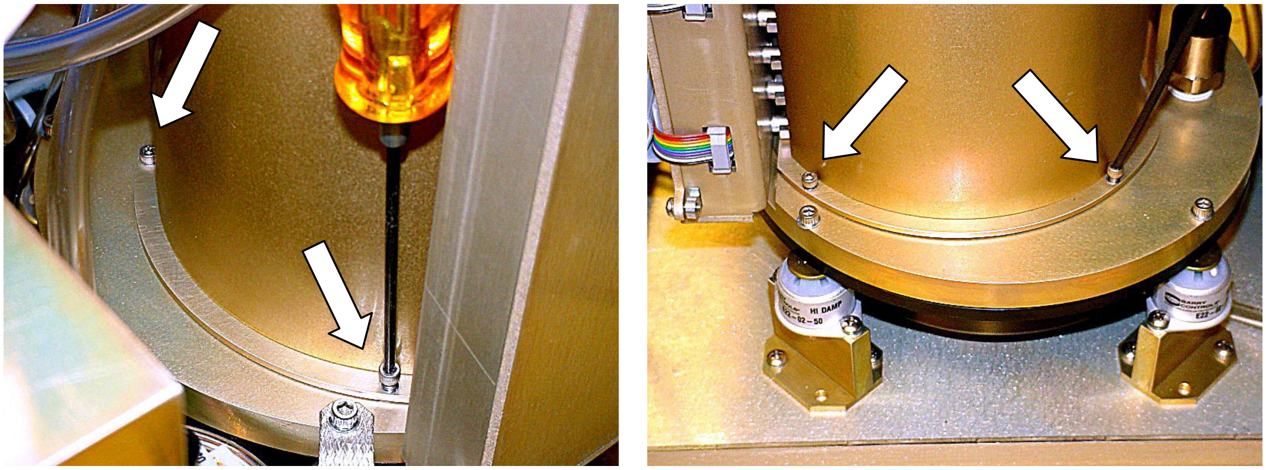


Figure 6-19
Column Assembly Base Screws

14. **Use assistance for this step. CAREFULLY** lift the outer column straight up and out of the instrument chassis. Take care **not** to scrape the inner and outer columns together.

Caution
Be careful to avoid scratching the rod and the inside of the tube as you remove it. A small scratch, nick, or burr can disrupt the electric field inside the mobility analyzer, severely affecting its performance.

Caution
As you move the assembly, check that all cables, hoses, and screws have been disconnected. Review above if something is still attached.

15. Move the column assembly to a clean work surface as in Figure 6-20.

Figure 6-20
Move the Outer Column Assembly to a Clean Work Surface

16. Although the inner column should not be dirty since the electric field repels all particles, the inner center column can now be cleaned using a soft, dry, lint-free cloth (Figure 6-21). Wipe the column using a clockwise motion, not up and down. If the accumulated particles cannot be removed with the cloth, try using a cloth dampened with acetone.

    Note: *Do **not** immerse the column in any solvent.*

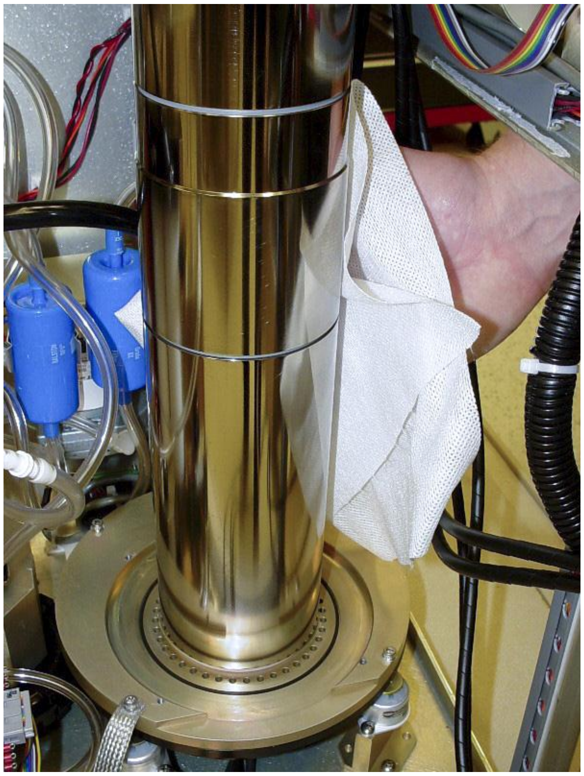


Figure 6-21
Clean the Center Column

17. Clean the inside rings of the electrometer assembly using a soft, dry, lint-free cloth (Figure 6-22). Wipe the rings using a clockwise motion, not up and down. If the accumulated particles cannot be removed with the cloth, try using a wet cloth (distilled water first; if that does not remove the particulates, try acetone). Depending on the size of your hand, it may be necessary to clean half the assembly from the top and then turn it over and clean the other half from the bottom.

    Note: *Do **not** immerse the column in any solvent.*

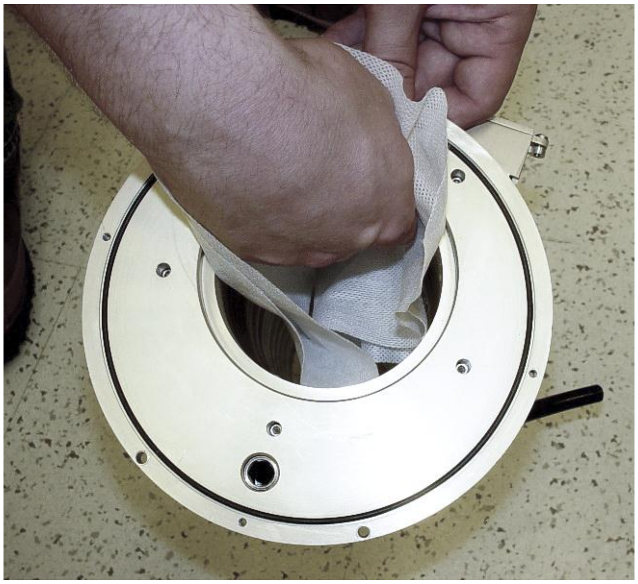


Figure 6-22
Clean the Rings of the Electrometer Assembly

18. Allow the column and assembly to air dry if necessary.

19. Reassemble the column in the reverse order of disassembly.

Caution
Be careful to avoid scratching the rod and the inside of the tube as you reassemble it. A small scratch, nick, or burr can disrupt the electric field inside the mobility analyzer, severely affecting its performance.

20. After cleaning, reassemble the charger column (pay particular attention that the O-rings are in place) and after warm-up, zero the electrometers (see "Baseline Noise" in the following section, "Troubleshooting"). If the problem is still present, try zeroing the electrometers again from the front panel. If this still does not help, you may have to clean the column again or contact a TSI representative for assistance.

Replacing the Filter Cartridges

WARNING

High voltage is accessible in several locations within this instrument. Make sure you unplug the power source before removing the cover or performing maintenance procedures.

There are four filters in the Model 3090 that may require changing at some time during the operational life of your Model 3090. To replace the filters, proceed as follows:

1. Obtain TSI Manifold filters: PN 1602051; TSI Pump filters: P/N 1602230.
2. Switch the instrument off and unplug the power cord.
3. Loosen the screws of the top panel and lift it off (Figure 6-1).
4. Face the left side of the instrument. Loosen the two screws on the side of the left panel and then loosen the two screws on the back of the left panel.
5. Remove the left panel.

Manifold Filters

To change the large Manifold filters proceed as follows:

1. Locate the manifold filters, refer to Figure 6-23.
2. Remove the thumbscrew from the top of the filter block.
3. Lift the filter block up.
4. If necessary, separate the tubing at the block fitting by pushing the fitting retaining collar IN while pulling the tube out of the fitting. The collar is located where the tube is inserted.
5. Install the new manifold filters making certain they are oriented with the flow arrows pointing DOWN.
6. Push the filter block back down over the filters and tighten the thumbnut.
7. If tubing has been removed, push the tubing back into the fittings, inserting fully so that the tubing is coming straight out of the fitting. If it comes out at a sharp angle, the fitting will not seal properly against the tubing.
8. Replace the instrument covers.

Pump Filters

To replace the pump filters, proceed as follows:

1. Locate the blue pump filters; refer to Figure 6-23.
2. Select one filter for removal and mark both ends of the tubing so you can install the new filter with flow in the proper direction. Note the orientation of the filters and direction of flow indicated on the filters.
3. Remove one filter at a time. Be careful when pulling the tubing from the filter end ports. Tubing may be very sticky and require twisting and flexing to facilitate removal.
4. Install the new filter in the correct orientation and insert the correct tubing.
5. Repeat steps 3 and 4, installing the other filters, one by one.

Figure 6-23
Replacing Filters

6. When all filters have been replaced, replace the instrument covers.

Replace the Extraction Pump

Remove the left side panel of the instrument (see above) and locate the extraction pump as shown in Figure 6-24.

Figure 6-24
Extraction Pump Location (inside back panel)

Replace the pump as follows:

1. Remove the pump from the retaining clip being careful not to pull on the wires or tubing.
2. Note the labels on the pump ports (P-Pressure and V-Vacuum). Mark both ends of the extraction pump tubing accordingly.
3. Remove the extraction pump tubing.
4. Remove the electrical connector.
5. Install the extraction tubing on the replacement pump. If the tubing does not fit tightly, trim ¼-inch (6mm) of tubing from the end and try again.
6. Slide the new pump into the holder.
7. Reconnect the electrical connector.
8. Reinstall the left side panel.

Baseline Noise

As the instrument becomes dirty, the noise level on all channels may gradually drift up. This can be seen when there is a considerable signal even when sampling filtered air. This can be corrected using the “Zero Electrometers” function from the EEPS spectrometer software application or from the front panel of the instrument.

Using the software, open the instrument status dialog from the View menu on the desktop or use the shortcut <**Ctrl**><**I**>. (You do not need to open a data file to open the instrument status dialog.)

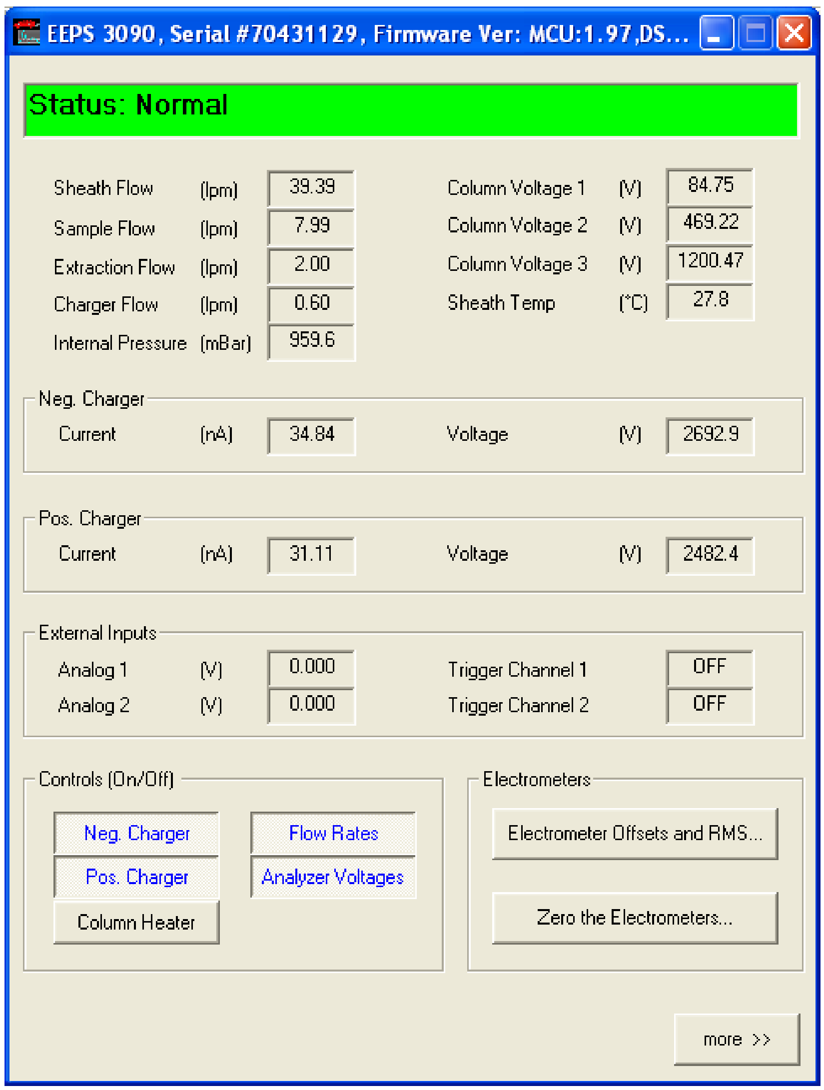


Figure 6-25
Instrument Status Dialog Box

In this dialog, press the **Zero the Electrometers** button to start the zeroing.

Or:

From the Front Panel of the instrument select **Menu|User Settings|Zero Electrometers**.

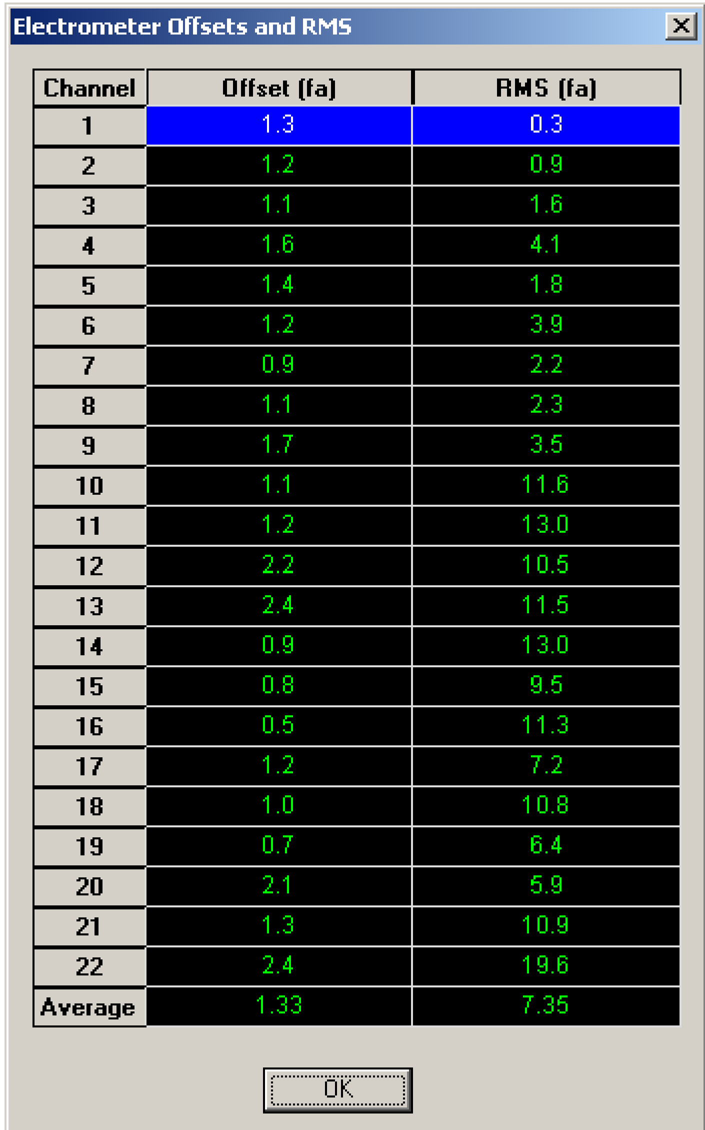
Preferably, this should be done with a filter on the inlet. However, during the zero measurement, the positive charger is turned off and the negative charger is turned on at full power which generally serves the same function if it is inconvenient to attach a filter inline.

Normally, the zero function should remove the baseline noise that has accumulated over time.

Note: *The following section is for advanced troubleshooting and should be used only by experienced users or with the help of a TSI representative.*

Especially after cleaning, it is important to zero the electrometers. It is also important to make sure that the electrometers are stable. You can check that the electrometer zero readings are stable after two repeated zero measurements. This is possible from the Instrument Status dialog in the software, shown above (Figure 6-25).

1. Press the **Electrometer Offsets and RMS** button. A window displays the offsets and RMS values for each of the 22 electrometer channels (Figure 6-26). To copy the values in this table to a clipboard, use **Copy Table** in the right-click popup menu for this table.
2. In general, these values should be below 1000. However, it is also important that the values are stable. When a zero is taken, the offset is completely compensated for. Frequently zeroing of the electrometers helps to reduce the effects of offset drift. If a channel's offset isn't changing over time, the frequency of zeroing can be reduced.
3. Close the window and repeat the zero procedure.
4. Press the **Electrometer Offsets and RMS** button again.
5. Compare the offset values from this reading to the last values from the previous zero. They should be similar. If they are not, allow the instrument to warm up for another 30 minutes and perform another zero. Repeat this until the readings are stable. If the reading does not become stable after repeated zero procedures, the column may need to be cleaned again.



Electrometer Offsets and RMS

Channel	Offset (fa)	RMS (fa)
1	1.3	0.3
2	1.2	0.9
3	1.1	1.6
4	1.6	4.1
5	1.4	1.8
6	1.2	3.9
7	0.9	2.2
8	1.1	2.3
9	1.7	3.5
10	1.1	11.6
11	1.2	13.0
12	2.2	10.5
13	2.4	11.5
14	0.9	13.0
15	0.8	9.5
16	0.5	11.3
17	1.2	7.2
18	1.0	10.8
19	0.7	6.4
20	2.1	5.9
21	1.3	10.9
22	2.4	19.6
Average	1.33	7.35

OK

Figure 6-26
Electrometer Offset Values

Noisy Channels

The most common problem with the EEPS spectrometer is that one or more electrometer channels become dirty or contaminated with material. This causes the channels to indicate a signal even when filtered air is sampled by the instrument. In this case, the recommended procedure is to clean the instrument (see sections above). However, it is also useful to know exactly how noisy each channel is and which channels are causing a problem. This can be done using the advanced features of the EEPS software.

***Note**: The top two electrometers rings are not actively measured. When referring to electrometer channel numbers, channel 1 is the third electrometer ring from the top.*

If the size distribution looks strange with filtered air, a good way to check if it is caused by a noisy channel is to collect the raw electrometer data. This can be done by selecting **View|Instrument Status** from the menu. This is a good screen to check on whether any instrument parameters are out of range (indicated by a yellow background for a reading).

Note: *The following section is for advanced troubleshooting and should be used only by experienced users or with the help of a TSI representative.*

Secure a filter to the inlet of the EEPS spectrometer (large white filter with fitting included in accessory kit). Using the EEPS software, open a new file. Start a run and from the Properties dialog select **Electrometer Current** using the drop-down control under the Data Collection and Display section (this is normally set to Concentration) as shown in Figure 6-27.

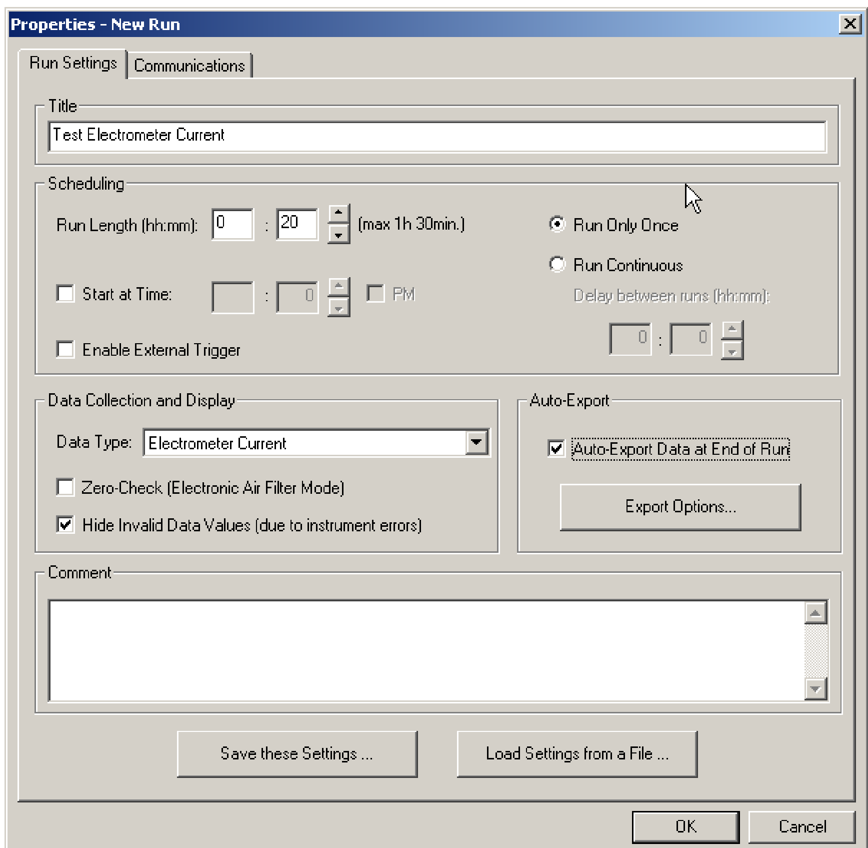


Figure 6-27
Advanced Run Settings

Collecting data in this mode will collect only the raw electrometer data. The graphs will update to display electrometer current instead of concentration. Figure 6-29 shows what a noisy channel might look like in this mode. Although you could try to zero out this noise, it may give errors since this channel is much higher than the others (indicating contamination). A bigger problem may be that this value will not be stable over time so even if it is reset to zero, it may drift over time.

***Note**: When the Data Type is changed from Concentration to Electrometer Current (and back), a command is sent to the instrument by the software to change this mode. The command takes approximately 5 seconds to complete. You may see the message shown in Figure 6-28.*

Figure 6-28
Changing Data Export Modes Dialog Box

The next step is to clean the column as indicated in the sections above.

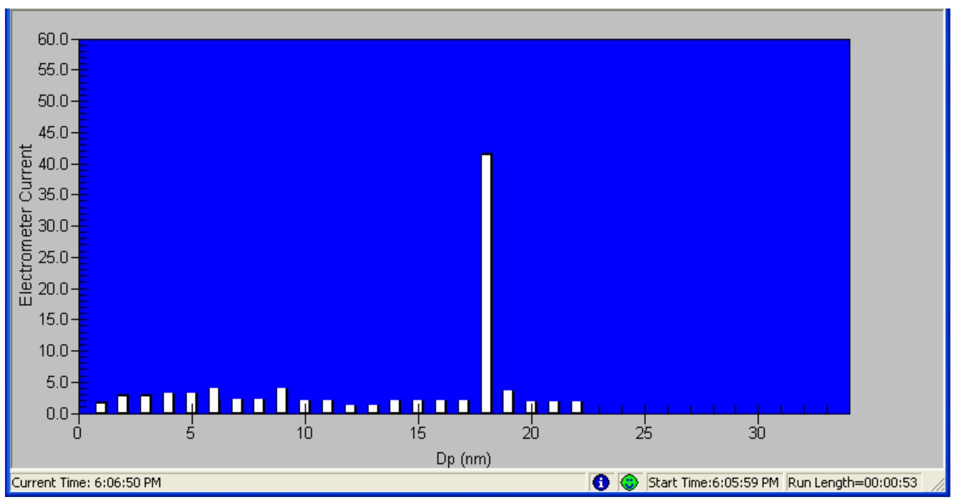


Figure 6-29
Software Showing Raw Electrometer Noisy Channel

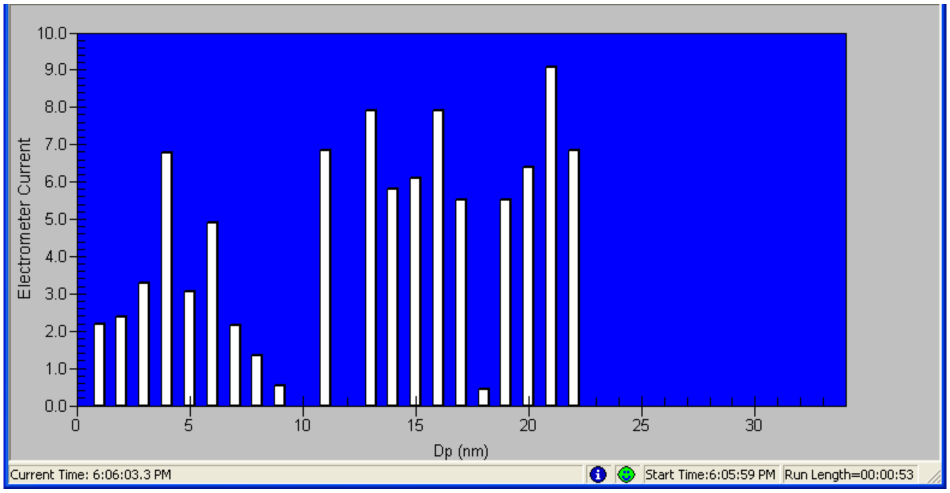


Figure 6-30
Raw Electrometer Data After Cleaning

Following cleaning, the raw electrometer channels should look more like Figure 6-30 (note different y-axis scale) with data fluctuating somewhere around 10 fA or less at 0.1 second resolution.

Another important consideration is that the instrument is properly warmed up for at least 10 minutes after being powered off and back on.

Errors

Instrument errors may be reported during a run by displaying a popup window describing each error encountered. This window appears above the status bar and will stay on your screen until you close it. A similar popup window also appears when an existing run file is opened in which there were instrument errors. An instrument error popup window looks something like the one shown in Figure 6-31.

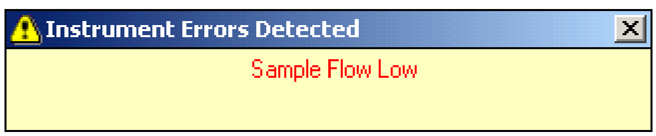


Figure 6-31
Instrument Errors Detected Dialog Box

Tables 6-2 and 6-3 describe non-fatal and fatal errors that may occur and suggested actions.

Error flags in Table 6-2 indicate **non-fatal errors** occurred but the associated data points may be still usable. The data points are shown in a graph as reported.

Error flags in Table 6-3 indicate **fatal errors** occurred and the associated data points *cannot* be used. The data points show zero (0) in a graph, but the actual data values are saved in the file. Exported data points for a given time period are set to exactly zero to indicate the invalidity of the data points.

Table 6-2
Non-Fatal Error Flags

<table>
<tr><th>Error Code</th><th>Error Message</th><th>Suggested Action</th></tr>
<tr><td>0</td><td>Sheath Flow Rate Too Low</td><td>• Check state of Flows in the instrument’s User Settings Window or view the Instrument Status window in the EEPS software.
• The sheath flow filters may be loaded. Try replacing the filters.</td></tr>
<tr><td>1</td><td>Sheath Flow Rate Too High</td><td>• Check that flowmeter connector did not come loose during shipping, or has a loose connection.
• Disconnect the instrument from any external air flow. The sheath pump may be off, but the flow is being forced through the flowmeter by an external source.</td></tr>
<tr><td>2</td><td>Sample Flow Rate Too Low</td><td>• Check state of Flows in the instrument’s User Settings Window or view the Instrument Status window in the EEPS software.
• Disconnect the instrument from any external flow—the external source may be at a high vacuum and the pump cannot maintain the correct flow. If the flow is still low, the filters before or after the sample pump may be clogged. Try replacing the filters.</td></tr>
<tr><td>3</td><td>Sample Flow Rate Too High</td><td>• Disconnect the instrument from any external air flow. The sample pump may be off, but the flow is being forced through the flowmeter by an external source.</td></tr>
<tr><td>4</td><td>Charger Flow Rate Too Low</td><td rowspan="2">• Check state of Flows in the instrument’s User Settings Window or view the Instrument Status window in the EEPS software.
• Check that flowmeter connector did not come loose during shipping.
• The charger flow is not actively controlled. The flow may have drifted for a number of reasons. Adjust the flow to the correct value using the charger flow valve (shown in Figure 6-8).</td></tr>
<tr><td>5</td><td>Charger Flow Rate Too High</td></tr>
<tr><td>6</td><td>Extraction Flow Rate Too Low</td><td>• Check state of Flows in the instrument’s User Settings Window or view the Instrument Status window in the EEPS software.
• The filter in front of the extraction pump may be clogged. Try replacing it—see above. The extraction pump uses a brush motor with a limited life. If the filter is new and the pump cannot maintain the correct flow, the pump should be replaced—see above.</td></tr>
<tr><td>7</td><td>Extraction Flow Rate Too High</td><td>• Check that flowmeter connector did not come loose during shipping.
• Disconnect the instrument from any external air flow. The extraction pump may be off, but the flow is being forced through the flowmeter by an external source.</td></tr>
</table>

Error Code	Error Message	Suggested Action
8	Sheath Flow Temperature Too Low	• Check that flowmeter connector did not come loose during shipping. • The flowmeter is reading outside its valid range of -10°C to 70°C. If the instrument is in a hot location, move it to a cooler location. If not, the flowmeter may be defective. • The flowmeter is reading outside its valid range of -10°C to 70°C. If the instrument is in a cold location, move it to a warmer location. If not, the flowmeter, its cable or connector may be defective.
9	Sheath Flow Temperature Too High	
10	Sample Flow Temperature Too Low	
11	Sample Flow Temperature Too High	
12	Charger Flow Temperature Too Low	
13	Charger Flow Temperature Too High	
14	Extraction Flow Temperature Too Low	
15	Extraction Flow Temperature Too High	
24	Positive Charger Current Too Low	• Check the state of the Chargers in the instrument's User Settings Window or view the Instrument Status window in the EEPS software. • Check state of Flows in the instrument's User Settings Window or view the Instrument Status window in the EEPS software. Chargers are turned off automatically when flows are turned off. • The charger current is not stable or has hit a voltage limit to meet the required current. Clean the charger assembly and clean or replace the charger corona wire.
25	Positive Charger Current Too High	
26	Positive Charger Voltage Too Low	
27	Positive Charger Voltage Too High	
28	Negative Charger Current Too Low	
29	Negative Charger Current Too High	
30	Negative Charger Voltage Too Low	
31	Negative Charger Voltage Too High	
34	Particle Concentration Too High	• The concentration on one or more channels has exceeded its upper limit. Lower the concentration of aerosol going into the instrument. This is indicated in the software by a red box on top of the column that is over-ranged in the 2D histogram.
34	Particle Concentration Too High	• The RMS noise for a single channel is much larger than the average of all the other channels. This could indicate that the column is dirty. Clean the column or contact TSI.
50	Electrometer Channel High Offset	• During instrument zeroing, the offset current for one or more channels was higher than normal. This could indicate that the column is dirty. View the last offset and RMS values to determine the channel causing the error. If the channel is not changing over time, the instrument may be okay to continue to use. Otherwise, clean the column or contact TSI.
54	Electrometer Channel Noisy	• During instrument zeroing, the RMS noise for one or more channels was higher than normal. This could indicate that the column is dirty. View the last offset and RMS values to determine the channel causing the error. If the channel is not changing over time, the instrument may be okay to continue to use. Otherwise, clean the column or contact TSI.

Table 6-3
Fatal Error Flags

Error Code	Error Message	Suggested Action
16	Column Voltage Section 1 Too Low	Contact TSI
17	Column Voltage Section 1 Too High	
18	Column Voltage Section 2 Too Low	
19	Column Voltage Section 2 Too High	
20	Column Voltage Section 3 Too Low	
21	Column Voltage Section 3 Too High	
32	Absolute Pressure Too Low	
33	Absolute Pressure Too High	
37	Instrument Matrix Readback Error	
38	ELM Covariance Readback Error	
39	ELM Offset Readback Error	
40	ELM Gain Readback Error	
41	Missed DSP Interrupt	
42	DSP Command Code Timeout Error	
43	DSP Reset Timeout Error	
44	COM1 Xmit Buffer Overflow Error	
45	Flowmeter EEPROM Error	• Check all connectors on main pc-board.
46	Serial Communication Error (Set by Software)	• If using a long cable, test with a standard length RS-232 cable. If used in an electrically noisy environment, remove instrument to a less noisy environment and try again.
48	DSP Timing Error	Contact TSI
49	DSP Command Code Error	
51	Electrometer Gain Error	Contact TSI
52	Electrometer Chan Above Noise Limit	• During instrument zeroing, the offset current and/or RMS noise for one or more channels was very high. Retake the zero with the instrument disconnected from any other equipment, in a vibration-free area, or with the filter provided in the accessory kit (1031252) on the inlet. Clean the column or contact TSI.
53	DSP Instrument Matrix Error	Contact TSI
55	DSP Data Not Valid	Contact TSI
56	DSP Checksum Error 1	
57	DSP Checksum Error 2	
58	Electrometer PCB 1 Error	There is a 60-conductor ribbon cable between the column and the large pc-board on the door of the cabinet. Make sure all six of the small connectors on the column and the large connector on the pc-board are plugged in and seated firmly. Power off the instrument and power it back on. If the error remains, contact TSI.
59	Electrometer PCB 2 Error	
60	Electrometer PCB 3 Error	
61	Electrometer PCB 4 Error	
62	Electrometer PCB 5 Error	
63	Electrometer PCB 6 Error	

Technical Contacts

- If you have difficulty setting up or operating the Model 3090 EEPS spectrometer, or if you have technical or application questions, contact an applications engineer at 1-800-874-2811 (USA) or 001 (651) 490-2811.
- If the EEPS spectrometer does not operate properly, or if you are returning the EEPS spectrometer for service, visit our website at http://rma.tsi.com or contact TSI at:

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Returning the Engine Exhaust Particle Sizer Spectrometer for Service

Before returning the EEPS spectrometer to TSI for service, visit our website at http://rma.tsi.com or call TSI at 1-800-874-2811 (USA) or 001 (651) 490-2811 for specific return instructions. Customer Service will need the following information when you call:

- The instrument model number
- The instrument serial number
- A purchase order number (unless under warranty)
- A billing address
- A shipping address

Use the original packing material to return the instrument to TSI. If you no longer have the original packing material, seal off any ports to prevent debris from entering the instrument and ensure that the display and the connectors on the instrument front and back panels are protected when shipping.

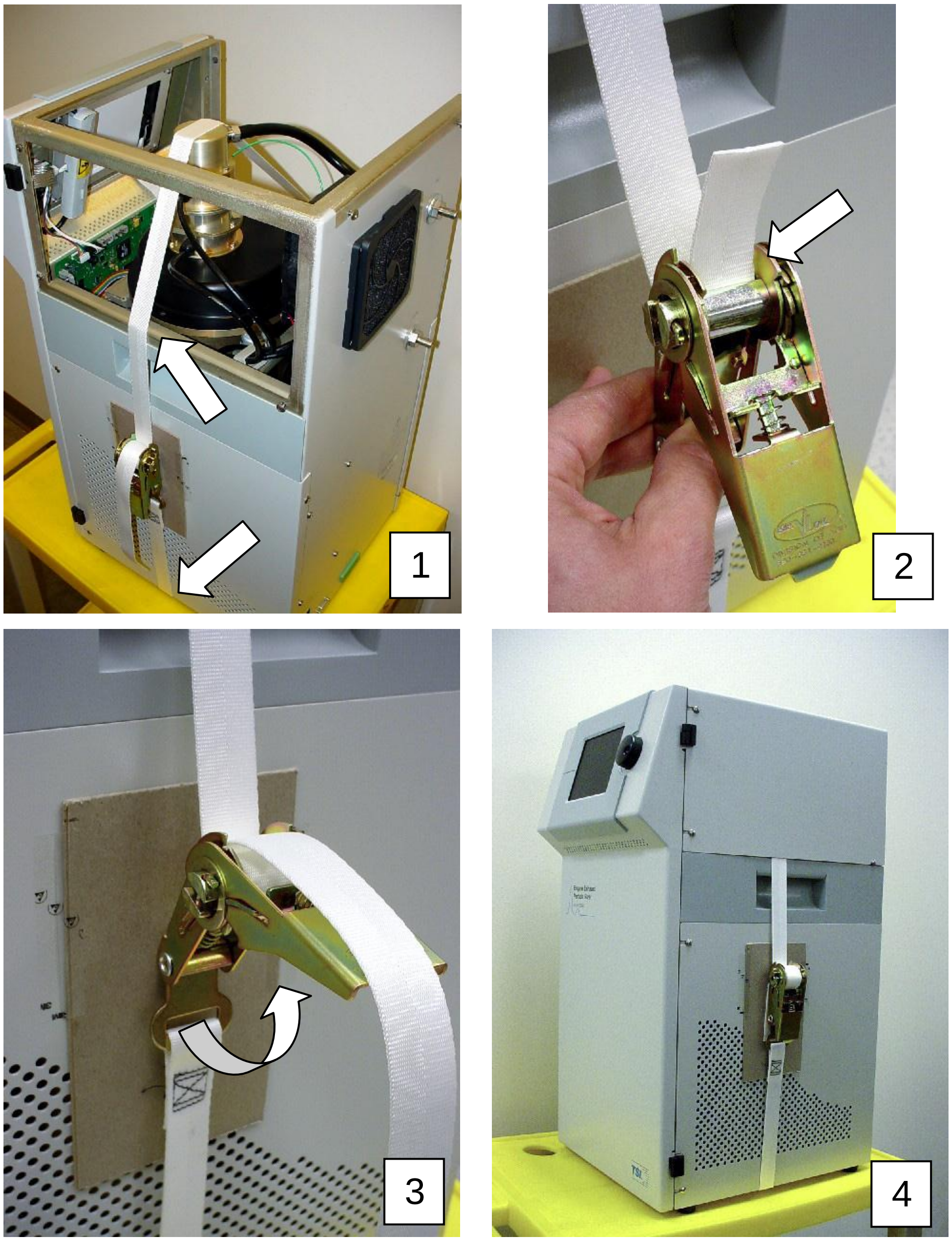

Figure 6-32
Installing the Shipping Strap

Follow the instructions below and use the shipping strap from the accessory kit to secure the column for shipping.

Refer to Figure 6-32 and follow the steps below to install the shipping strap.

1. Unplug the instrument from power. Loosen the three screws on each side and the two on the back of the top panel (they do not need to be removed). Loop the strap under the cabinet and over the top of the column as shown (the end of the strap without a buckle should be on top). Tape a piece of protective cardboard on the side panel to protect the finish.
2. Hook the end of the strap with a buckle to the bottom of the ratchet and thread the other end of the strap through the split cylinder as shown.
3. While holding the ratchet mechanism in place, swing the lever up and down to put tension on the strap. Use the ratchet to push the column down into its shock mounts until the column barely moves when pushed from side to side.
4. Replace the cover and tighten the screws loosened in step 1.

If you have any concerns regarding shipping the instrument, contact TSI service for assistance.

APPENDIX A

Specifications

Model 3090 Engine Exhaust Particle Sizer™ (EEPS™) spectrometer operating specifications are as follows (specifications are subject to change):

Particle Size Range	5.6 to 560 nanometers
Particle Size Resolution	16 channels per decade (32 total)
Electrometer Channels	22
Charger Mode of Operation	Unipolar diffusion charger
Inlet Cyclone 50% Cutpoint	1 µm
Maximum Data Rate	10 size distributions per second
Flow Rates	
Aerosol Inlet	10 L/min
Sheath Air	40 L/min
Inlet Aerosol Temperature	10 to 52°C
Storage Temperature	-20 to 50°C
Atmospheric Pressure Correction Range	700 to 1034 mbar
User Interface	Rotary knob and display/EEPS software
Front Panel Display	6.4-in. color VGA LCD
Data Averaging	0.1 to 60 sec
Computer Requirements	Pentium® 4 processor or better
Computer Operating System	Windows® 7 operating system or newer
Communications	9-pin RS-232
Analog Inputs	2 analog input ports, 0 to 10V, 12 bit Electrically isolated to 500V
Analog Outputs	4 analog output ports, 0-5V or 0-10V, 14 bit Electrically isolated to 500V
Trigger Input	Potential-free contact closure or 3.3 V pulled to GND Electrically isolated to 500V
Trigger Output	Potential-free contact closure Electrically isolated to 500V
Dimensions (LWH)	70.4 cm × 34.3 cm × 43.9 cm (27.7 in. × 13.5.0 in. × 17.3 in.)
Weight	32 kg (70 lb)
Aerosol Inlet	⅜-in. OD
Exhaust Outlet	⅜-in. OD
Cyclone Inlet	⅜-in. OD
Power Requirements	100 to 240 VAC, 50/60 Hz, 170 W maximum
Fuse (internal—not user replaceable)	~T 6.3A SB/250V

Environmental Conditions	Indoor use. Altitude: Up to 2000 m (6500 ft). Ambient Temperature: 0° to 40° C Ambient Humidity: 0 to 90% RH (non-condensing). Over-voltage Category II. Pollution Degree II.

APPENDIX B
Theory of Operation

The Model 3090 Engine Exhaust Particle Sizer™ (EEPS™) spectrometer builds on a tradition of TSI electrical-based measurements including the Electrical Aerosol Analyzer (EAA 3030) and Electrostatic Classifier (3071, 3080/3081/3085). The EEPS spectrometer extends this line of instruments based on a technique developed over the last two decades by the University of Tartu – Estonia. This chapter gives a brief description of the instrument and theory of operation.

Electrical Mobility History

The first electrical mobility instrument was the Whitby Aerosol Analyzer, developed in the late 1960's (1). This was followed a few years later by a similar but smaller version called the EAA (Electrical Aerosol Analyzer) (2). These instruments both used a unipolar charger assembly to place a positive charge on the particles. The level of charge depends on particle size and is correlated by the instrument calibration so that the instruments can report number concentrations.

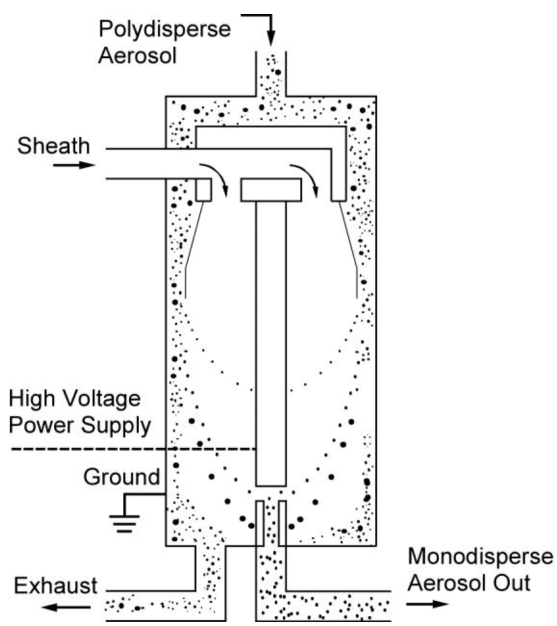

Figure B-1
Schematic of a Differential Mobility Analyzer

An improvement over the EAA was the development of the Differential Mobility Analyzer (DMA) column (Figure B-1).

Rather than using a unipolar charger, a very stable and predictable Krypton-85 radioactive bipolar charger was used (3,4). When combined with a Condensation Particle Counter (CPC), the DMA can be stepped through various voltages, to detect different particle sizes (5-9). Using a computer, the voltages can be automatically stepped to generate a particle size distribution. This was the basis for the Differential Mobility Particle Sizing (DMPS) systems. An improvement in resolution is obtained by continuously scanning the rod voltage with an exponential voltage ramp and counting to generate a size distribution (10,11). This is the basis for the current Scanning Mobility Particle Sizer (SMPS™) system that is commonly used to obtain high resolution size distributions of engine exhaust particles. Unfortunately, the SMPS™ method has a drawback in that it takes a significant amount of time (30 seconds minimum with 60 or 120 seconds being more commonly used) to obtain a single size distribution. This makes it unsuitable for measuring engine transients on a second-by-second basis. This led to designs for an improved sizing instrument that could give complete size distributions in one second or less. The EEPS spectrometer is such an instrument.

Size Distributions

The basic idea upon which the Model 3090 is based was developed at Tartu University in Estonia. The Tartu instrument, the Electrical Aerosol Spectrometer (EAS), was originally described in Russian Journals in the early 1980's (12) but was more recently published in English language journals (13, 14, 15). The EAS was developed for ambient monitoring and has 2 columns to cover a large size range. The EAS did not originally have a very fast time resolution because it wasn't needed for ambient measurement applications. However, it was modified for fast response (4 second time resolution) for fire detection research in the mid-1990s. (16, 17, 18). The EEPS spectrometer is based on this fast-response instrument. Conceptually these instruments are similar to a DMA. But, rather than particles being drawn to the center, as in a DMA, the particles are repelled outward to electrodes.

The EEPS spectrometer performs particle size classification based on differential electrical mobility classification (as with the SMPS). The charged aerosol enters the analyzer column near on-axis and above the central rod. The particles are deflected radially outward and collected on electrically isolated electrodes that are located at the outer wall (see Figure B-2). The particle number concentration is determined by measurement of the electrical current collected on a series of electrodes.

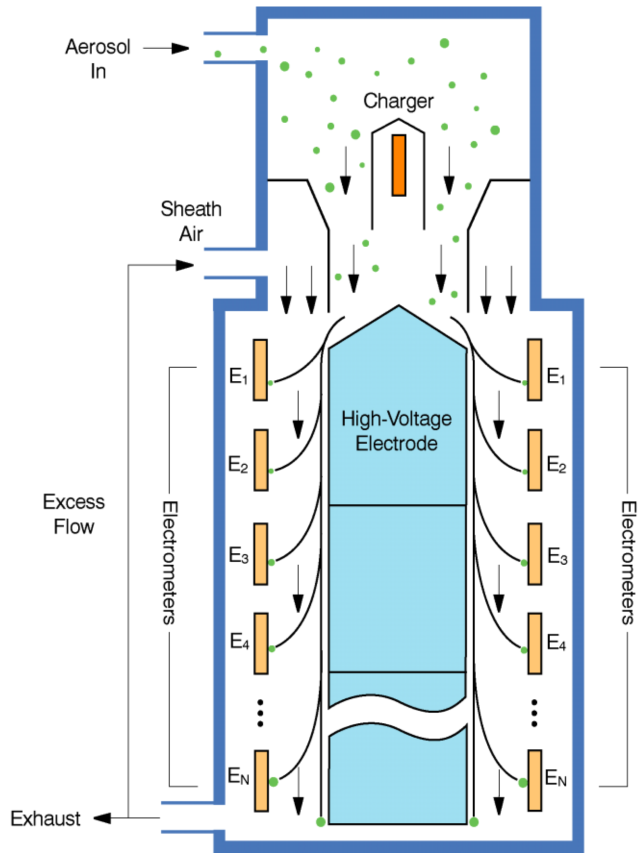

Figure B-2
Schematic of EEPS Measurement Column

Charger

The charging of the aerosol is accomplished through two unipolar diffusion chargers. First, a negative charger puts a negative net charge on the particles to reduce the number of highly positive charged particles and to prevent overcharging in the second charger. Then, a positive charger puts a predictable net positive charge on the particles.

Measurement Column

The electrical analyzer consists of an inner cylinder composed of multiple electrical sections with different voltages and column diameters. By stepping the voltage and changing the central column diameter, the required height of the column is reduced and the particles are more evenly distributed across 22 electrodes.

The electrode rings are made of a highly insulating plastic with metal rings molded into the inner diameter of the ring. Features in these parts provide a large electrical resistance between the electrometer rings while minimizing the gap between the rings. O-ring seals between the electrode rings ensure a leak-tight column. Custom electrometers are used to obtain low noise, fast response and high resolution.

Flow Path

After passing through a 1µm cut cyclone, the aerosol enters the charger at 10 L/min and close to atmospheric pressure (see Figure B-3). It then passes through the charging region where it receives a predictable charge. In the charger, 0.6 L/min of clean air is added to the flow to keep the charger electrode clean. After the charger, 2 L/min is removed from the center of the charging region, where charging is less uniform, and the rest of the aerosol passes near the center electrode. A recirculating flow of particle-free, laminar sheath air at 39.4 L/min joins the particle flow at the top of the center electrode for a total of 48 L/min through the column. Particles are then separated by electrical mobility as flow moves from the top to the bottom of the column. Particles with high electrical mobility (small particles) are deflected to the electrode rings near the top of the column, and those with low electrical mobility (large particles) are deflected further downstream. Air flow that is not filtered and recirculated is passed out of the exit of the instrument at 10 L/min.

Data Inversion

There are a number of parameters affecting the electrometer currents that need to be compensated if high time resolution is to be obtained. Particles that flow past the detection stages but don't contact the electrode rings can create image charges. In addition, there are time delays between when a small particle from an aerosol packet is detected on an upper stage of the column and when a large particle from the same aerosol packet is detected on a lower stage in the column.

An inversion algorithm is used to deconvolute the data and make corrections for the image charges and the time delays in the column. The algorithm also converts currents from the 22 electrometers into 32 size channels of output. This allows the maximum resolution of the instrument to be represented by output channels that are equally spaced on a log scale between 5.6 nm and 560 nm.

Concentration Limits

Unlike many instruments which have a single value as the lower detection limit, the EEPS spectrometer has a range of values depending on particle size and averaging time. This is due to the inherent noise in each electrometer as well as the particle charging probability vs. particle size. Figure B-4 gives a range of lower limits for several averaging intervals based on particle size. The EEPS software calculates a different detection limit based on each of the possible averaging intervals that can be selected in the software.

The upper limit of concentration is based on the fixed upper limit of current that can be detected by each electrometer channel. This limit is also plotted in Figure B-4. However, this limit does not change with averaging time. The EEPS software uses this limit to show maximum limit values (red boxes) at the top of any bar in the 2D histogram which has reached or exceeded this value. When a value is exceeded, the bar is clipped at the maximum value, affecting the shape of the distribution.

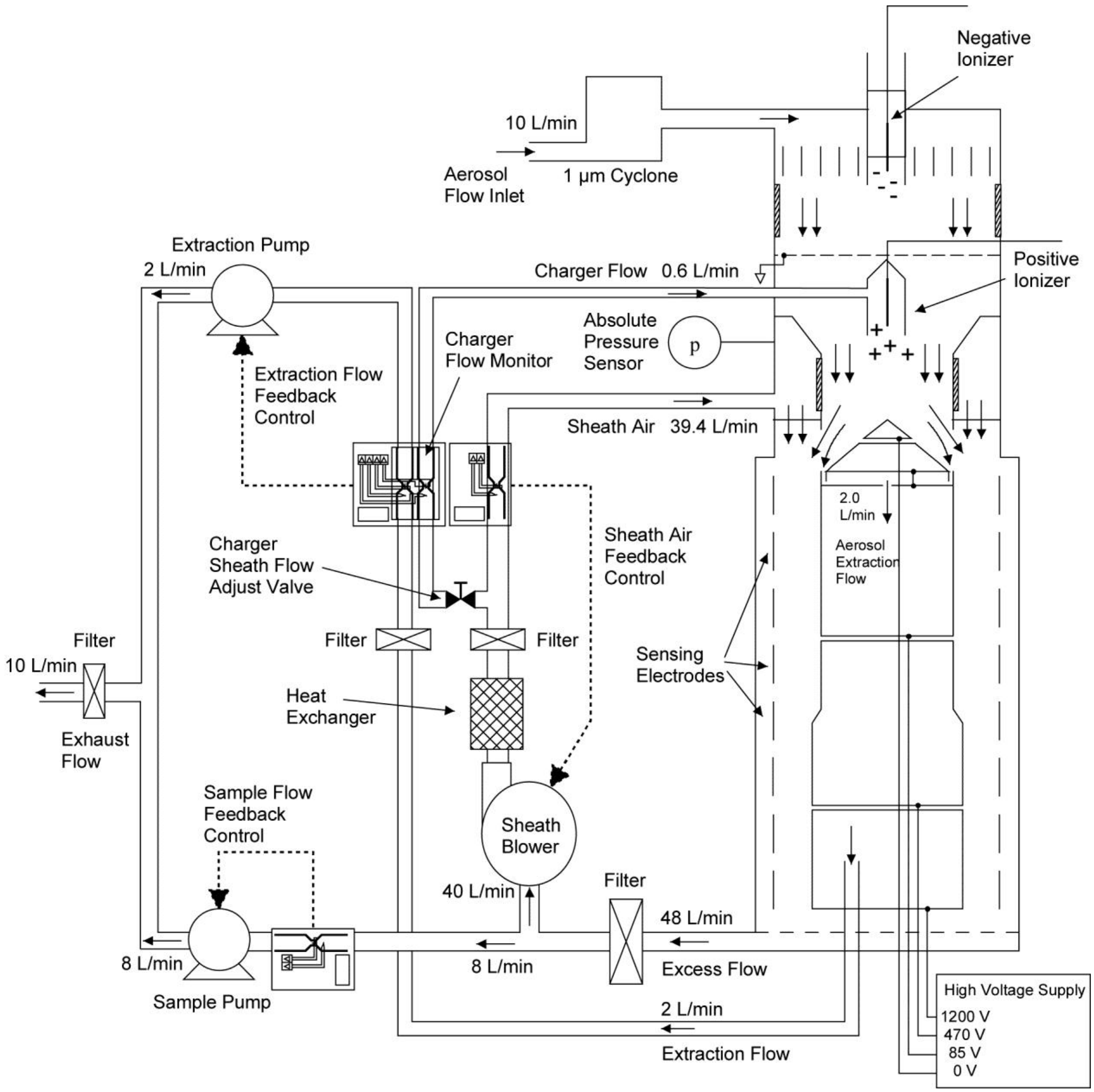

Figure B-3
Flow Schematic of the EEPS Spectrometer

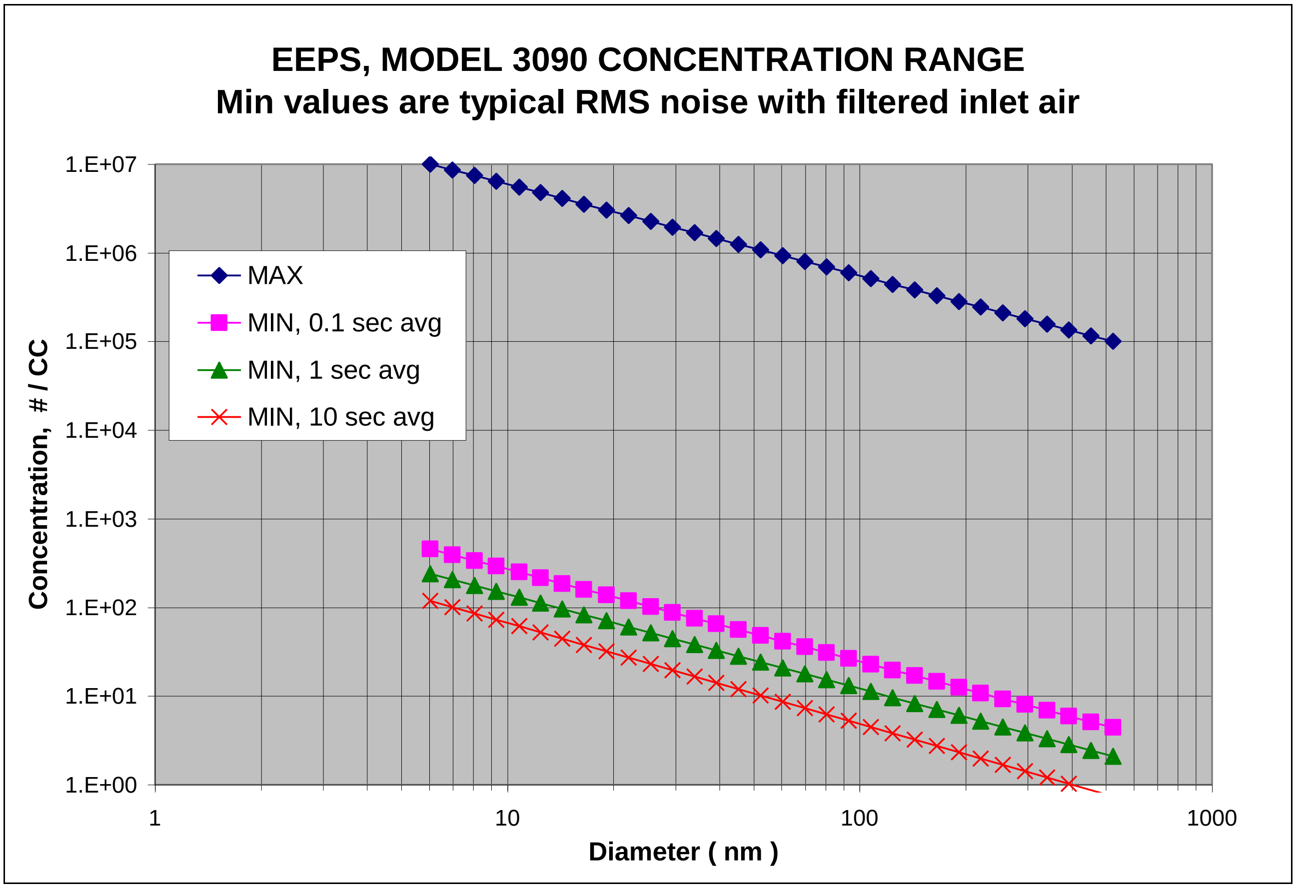

Figure B-4
Graph of Concentration Limits

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APPENDIX C

Particle Size Statistics

This appendix gives an explanation of the statistics calculations used by the Engine Exhaust Particle Sizer™ (EEPS™) software. The statistics are calculated for the interval defined by the upper and lower bounds selected from the graphs, which are not necessarily the entire size range of the instruments.

Statistic/Weight	Number	Surface Area	Volume	Mass
Concentration	$n = \frac{c}{tQ}\frac{\phi}{\eta}$	$s = \pi D_p^2 n$	$v = \frac{\pi D_p^3 n}{6}$	$m = \rho v$
Total Concentration	$N = \sum_l^u n$	$S = \sum_l^u s$	$V = \sum_l^u v$	$M = \sum_l^u m$
Mode	$D_p(n_{\max})$	$D_p(s_{\max})$	$D_p(v_{\max})$	$D_p(m_{\max})$
Median ($\tilde{x}$)	$D_p(N/2)$	$D_p(S/2)$	$D_p(V/2)$	$D_p(M/2)$
Mean ($\bar{x}$)	$\frac{\sum_l^u nD_p}{N}$	$\frac{\sum_l^u sD_p}{S}$	$\frac{\sum_l^u vD_p}{V}$	$\frac{\sum_l^u mD_p}{M}$
Geometric Mean ($\bar{x}_g$)	$\exp\left[\frac{\sum_l^u n \ln D_p}{N}\right]$		substitute *s*, *v*, *m* and *S*, *V*, *M* in place of *n* and *N* for other weightings	
Geometric Standard Deviation (σ_g)	$\exp\left[\frac{\sum_l^u n\left[\ln D_p - \ln \bar{x}_g\right]^2}{N}\right]^{1/2}$		substitute *s*, *v*, *m* and *S*, *V*, *M* in place of *n* and *N* for other weightings	

The symbols used in the formulas are defined as:

c = particle counts per channel
n = number weighted concentration per channel
s = surface area weighted concentration per channel
v = volume weighted concentration per channel
m = mass weighted concentration per channel
η = sample efficiency factor per channel
ϕ = sample dilution factor
D_p = particle diameter (channel midpoint)

C = total particle counts
N = total number concentration
S = total surface area concentration
V = total volume concentration
M = total mass concentration

Q = sample flow rate
t = sample time
ρ = particle density
ln = natural log
exp = base of natural log (*e*)
l = lower channel boundary
u = upper channel boundary

APPENDIX D
Serial Commands

This section is for advanced users that need to communicate with the Model 3090 for advanced calibration, troubleshooting or diagnostics. Due to the high data rate required, the actual particle count data from the instrument is sent as binary data, so it is not possible to use text-based serial commands to retrieve size distribution data from the instrument.

Caution

This section is written for technicians. Accessing or changing settings using serial commands can invalidate the calibration or possibly cause damage to the instrument.

Pin Connectors

The Model 3090 has a single 9-pin, D-subminiature connector port on the back panel. The communication port is configured at the factory to work with RS-232 type devices.

Table D-1 lists the signal connections.

Table D-1
Signal Connections for RS-232 Configurations

Pin Number	RS-232 Signal
1	—
2	Transmit Output
3	Receive Input
4	(Reserved)
5	GND
6	—
7	—
8	—
9	—

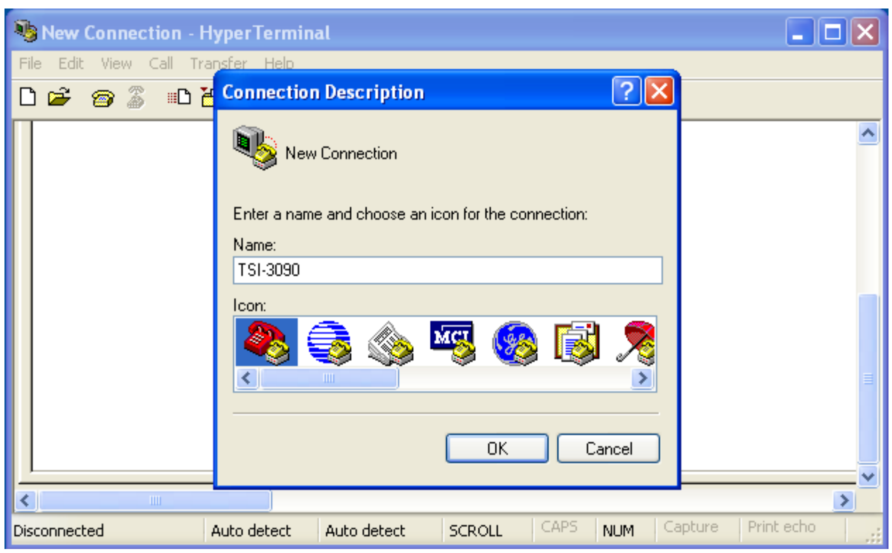
Serial Protocol

Baud Rate:	38,400
Data Bits:	8
Parity:	None
Stop Bits:	1
Handshaking:	None

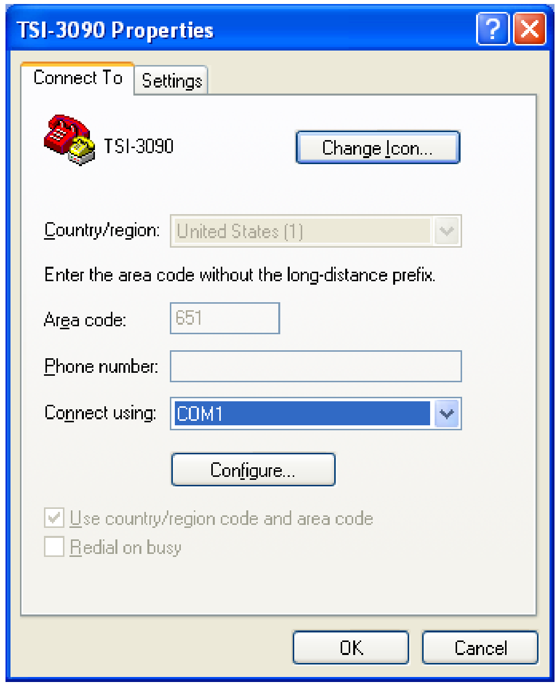
Serial Commands

To communicate with the Model 3090 requires a terminal program. The HyperTerminal program that is included as part of the Windows® operating system is satisfactory. Connect to the Model 3090 as follows:

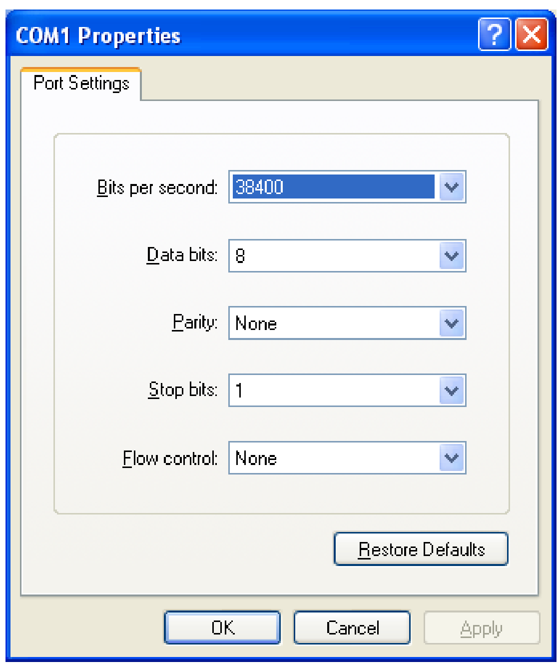
1. Open the HyperTerminal program by selecting: **Start|Programs|Accessories|Communications|HyperTerminal**.
2. Enter a name for the connection, for example, TSI-3090.



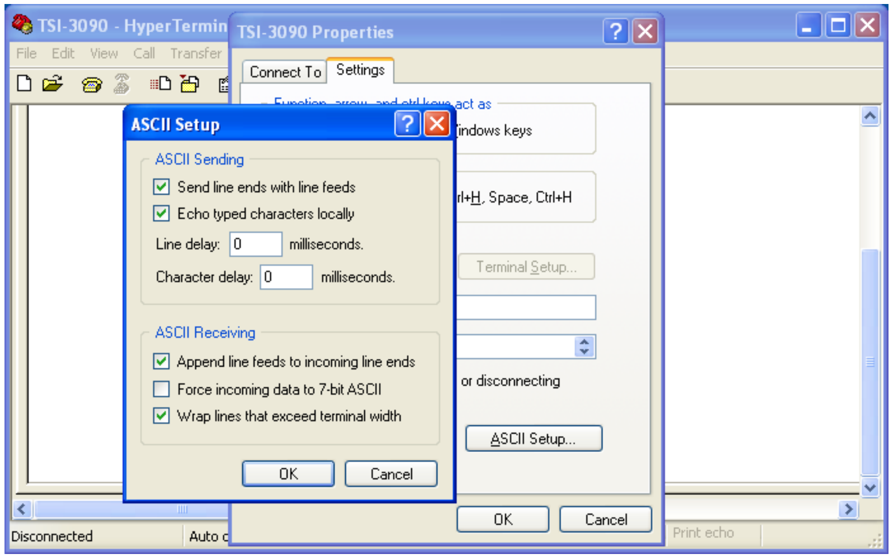
3. Enter the communications (COM) port.



4. Enter the port settings described below and click **OK**.



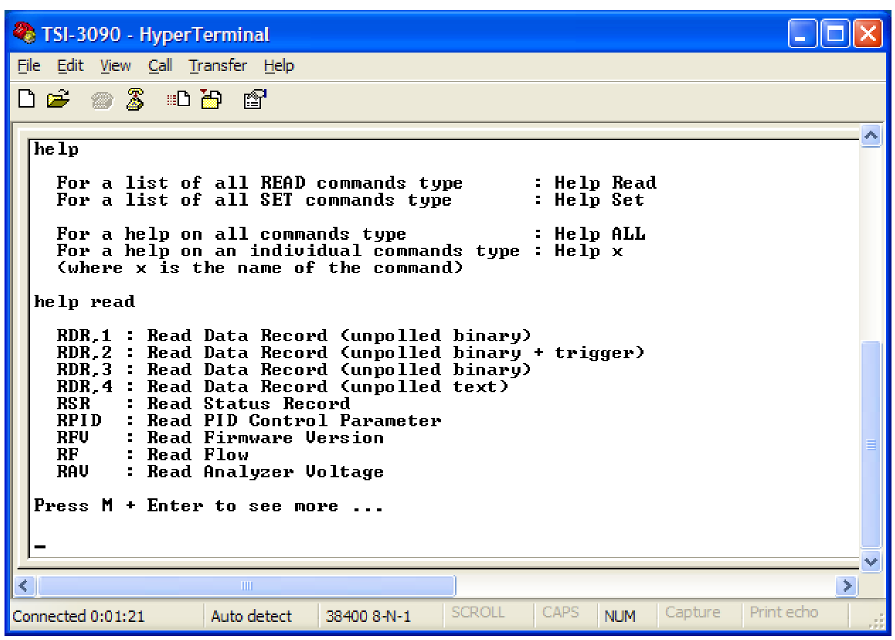
5. Under the settings tab, pick the **ASCII Setup** button and check the boxes shown below.



6. Now select **File|Save As** and save the file to the desktop for easy access.

7. Close the program and start it again from the desktop. It should automatically open a connection to the instrument.

8. Type **HELP** for a list of commands. Select **Transfer|Capture Text**… and then **HELP ALL** in the terminal window lets you capture all the help commands to a text file for easy reference.



Command Summary

The firmware commands are be divided into the following categories:

- READ Commands
- SET Commands
- HELP Commands

READ commands are used to read parameters from the instrument (flow rates, voltages, etc.). READ commands can be identified by a leading "R".

SET commands set an internal parameter to the value(s) supplied with the command. Supplied parameters are always delimited by a comma. SET commands can be identified by a leading "S". The instrument will reply to all set commands with the string “OK” <**CR**> if the command syntax is valid. Also, if no parameter is supplied, the command will return the current set value.

HELP commands. Type “HELP” in a HyperTerminal window or a similar program and it will explain how to use it. The detailed command descriptions shown below can be obtained using the help command.

The instrument will reply with a serial string of "ERROR", if a command was not understood.

READ Commands

RDR,1	Read Data Record (unpolled binary)
RDR,2	Read Data Record (unpolled binary + trigger)
RDR,3	Read Data Record (unpolled binary)
RDR,4	Read Data Record (unpolled text)
RSR	Read Status Record
RPID	Read PID Control Parameter
RFV	Read Firmware Version
RF	Read Flow
RAV	Read Analyzer Voltage
RC	Read Charger
RADC	Read Analog Digital Converter
RT	Read Temperature
RIE	Read Instrument Error
RIS	Read Instrument Status
RP	Read Pressure
RSN	Read Serial Number

RCH	Read Column Heater
RAI	Read Analog Input
RPCB	Read PCB Revision
RMN	Read Model Name
REE	Read EEPROM Default Settings
REM	Read Export Mode
RDS	Read Data Simulation
RIM	Read Instrument Matrix
RIN	Read Instrument Matrix Name
RAO,x	Read Analog Out, 8 cmd types
RDM	Read Debug Mode

SET Commands

SPID	Set PID Control Parameter
SF	Set Flow
SAV	Set Analyzer Voltage
SC	Set Charger
SDAC	Set Digital Analog Converter
SIE	Set Instrument Error
SSN	Set Serial Number
SCH	Set Column Heater
SPCB	Set PCB Revision
SEE	Set EEPROM Default Settings
SEM	Set Export Mode
SDS	Set Data Simulation
SELM	Set Electrometer
SAO,x	Set Analog Out, 8 cmd types
SDM	Set Debug Mode
SIM,x,y	Set Instrument Matrix
SIN,name	Set Instrument Matrix Name (20 chars max)

HELP Commands

Help	List help commands
Help Read	List read commands
Help Set	List set commands
Help ALL	List read and set commands
Help x	Describe command x

Detailed Command Description

READ Commands

RDR Read Data Record

RDR,0	Unpolled mode OFF (stop streaming binary data)
RDR,1	Unpolled mode ON (start streaming binary data)
RDR,2	Unpolled mode ON (start streaming binary data when instrument receives signal on trigger input)
RDR,3	Unpolled mode ON (start streaming binary data)
RDR,4	Unpolled mode ON (start streaming text data)

See TSI for more detailed information on data structure.

RSR Read Status Record

RSR	Read Status Record
RSR,#	Read Status Record (without comments)

Error Code	x2,x3; U_SHORT; [-]
Status Code	x1; U_SHORT; [-]
Sheath Flow	x4; FLOAT; [L/min]
Sample Flow	x5; FLOAT; [L/min]
Charger Flow	x6; FLOAT; [L/min]
Extraction Flow	x7; FLOAT; [L/min]
Absolute Pressure	x8; FLOAT; [mBAr]
Analyzer Voltage Top	x9; FLOAT; [V]
Analyzer Voltage Middle	x10; FLOAT; [V]
Analyzer Voltage Bottom	x11; FLOAT; [V]
Sheath Flow Temp.	x12; FLOAT; [C]
Neg. Charger Current	x13; FLOAT; [nA]
Pos. Charger Current	x14; FLOAT; [nA]
Neg. Charger Voltage	x15; FLOAT; [V]
Pos. Charger Voltage	x16; FLOAT; [V]
Analog Input 1	x17; U_SHORT; [V]
Analog Input 2	x18; U_SHORT; [V]

RPID Read PID Parameter

RPID	Read PID (numbers + text)

RFV Read Firmware Version

RFV	Firmware Version (text)

RF Read Flow

RF	Read Flow (numbers + text)
RF,#	Read Flow (numbers only)
RF,S	Read Flow Setpoint (numbers + text)
RF,S,#	Read Flow Setpoint (numbers only)

RAV Read Analyzer Voltage

RAV	Analyzer Voltage (numbers + text)
RAV,#	Analyzer Voltage (numbers only)

RC Read Charger

RC	Read Charger Current and Voltage (numbers + text) Return: 'CHx' [0<=CHx<=1023]
RC,#	Read Charger Current and Voltage (numbers only)
RC,S	Read Charger Current and Voltage Setpoint (numbers + text)
RC,S,1,#	Read Negative Charger Current Setpoint (numbers only)
RC,S,2,#	Read Positive Charger Current Setpoint (numbers only)

RADC Read Analog Digital Converter

RADC	Read all ADC Channels (numbers + text)
RADC,#	Read all ADC Channels (numbers only)
RADC,x	Read ADC Channel x [0<=x<=23] (numbers only)

RT Read Temperature

RT	Read Temperature (numbers + text)
RT,#	Read Temperature (numbers only)

RIE Read Instrument Error

RIE	Read Errors (numbers + text)
RIE,#	Read Errors (numbers)

Bit Position	Error Condition
0	Sheath Flow Rate low
1	Sheath Flow Rate high
2	Sample Flow Rate low
3	Sample Flow Rate high
4	Charger Flow Rate low
5	Charger Flow Rate high
6	Extraction Flow Rate low
7	Extraction Flow Rate high
8	Sheath Flow Temperature low
9	Sheath Flow Temperature high
10	Sample Flow Temperature low
11	Sample Flow Temperature high
12	Charger Flow Temperature low

13	Charger Flow Temperature high
14	Extraction Flow Temperature low
15	Extraction Flow Temperature high
16	Analyzer Voltage Upper Section low
17	Analyzer Voltage Upper Section high
18	Analyzer Voltage Middle Section low
19	Analyzer Voltage Middle Section high
20	Analyzer Voltage Lower Section low
21	Analyzer Voltage Lower Section high
22	Not used
23	Not used
24	Positive Charger Current low
25	Positive Charger Current high
26	Positive Charger Voltage low
27	Positive Charger Voltage high
28	Negative Charger Current low
29	Negative Charger Current high
30	Negative Charger Voltage high
31	Negative Charger Voltage high
32	Absolute Pressure low
33	Absolute Pressure high
34	Particle Concentration high
35	Not used
36	Not used
37	Instrument Matrix Readback Error
38	ELM Covariance Readback Error
39	ELM Offset Readback Error
40	ELM Gain Readback Error
41	Missed DSP Interrupt
42	DSP Command Code Timeout Error
43	DSP Reset Timeout Error
44	COM1 Xmit Buffer Overflow Error
45	Flowmeter EEPROM Error
46	Serial Communication error (set by Software)
47	Not used
48	DSP Timing Error
49	DSP Command Code Error
50	Electrometer Channel High Offset
51	Electrometer Gain Error
52	Electrometer Chan Above Noise Limit
53	DSP Instrument Matrix Error
54	Electrometer Channel Noisy
55	DSP Data Not Valid
56	DSP checksum error 1
57	DSP checksum error 2
58	Electrometer PCB 1
59	Electrometer PCB 2
60	Electrometer PCB 3
61	Electrometer PCB 4
62	Electrometer PCB 5
63	Electrometer PCB 6

RIS Read Instrument Status

RIS	Read Status (numbers + text)
RIS,#	Read Status (numbers)

Bit No.	Device
0	Positive_Charger
1	Negative_Charger
2	Analyzer high voltage
3	Analyzer high voltage offset
4	Sheath Flow
5	Sample Flow
6	Extraction Flow
7	Cabinet fan
8	Trigger Channel 1
9	Trigger Channel 2
10	Instrument in Warm-up Mode
11	Zero Electrometer Mode
12	not used
13	not used
14	not used
15	not used
16	not used
17	not used
18	not used
19	not used
20	not used
21	not used
22	not used
23	not used
24	not used
25	not used
26	not used
27	not used
28	not used
29	not used
30	not used
31	not used

RP Read Pressure

RP	Read Pressure (numbers + text)
RP,#	Read Pressure (numbers only)

RSN Read Serial Number

RSN	Read Serial Number (number only)

RCH Read Column Heater

RCH	Read Column Heater (numbers + text)
RCH,#	Read Column Heater (numbers only)

RAI Read Analog Input

RAI	Read all ADC Channels (numbers + text)
RAI,#	Read all ADC Channels (numbers only)

RPCB Read PCB Revision

RPCB	Main PCB Rev	x [-<=x<=Z]
	High Voltage PCB Rev	x [<<=x<=È]
	Electrometer PCB Rev	x [H<=x<=ƒ]
RPCB,#	Read PCB Revision (numbers only)	

RMN Read Model Number

RMN	Read Model Number

REE Read EEPROM

Read default values.

REM Read Export Mode

REM	Read Export Mode (numbers + text)
REM,#	Read Export Mode (numbers only)

Type HELP SEM to see a listing of the different export modes.

RDS Read Data Simulation

RDS	Read Data Simulation (numbers + text)
RDS,#	Read Data Simulation (numbers only) Return: 'x' [x=0: Simulation OFF, x=1: Simulation ON]

RELM,OFFSET	Read Electrometer Offset [fA] (text + data)
RELM,GAIN	Read Electrometer Gain (text + data)
RELM,COV	Read Electrometer Covariance [fA^2] (text + data)
RELM,RMS	Read Electrometer RMS [fA] (text + data)

RELM,OFFSET,#	Read Electrometer Offset [fA] (data only)
RELM,GAIN,#	Read Electrometer Gain (data only)
RELM,COV,#	Read Electrometer Covariance [fA^2] (data only)
RELM,RMS,#	Read Electrometer RMS [fA] (data only)

RIM Read Instrument Matrix

RIM	Read Instrument Matrix
Returns	Index, Number (Index = col + 33 x row) (col = 0-32, row = 0-21, index = 0-725)

RIN Read Instrument Matrix Name

Returns	“name” (text only)

RAO Read Analog Out

RAO,R	Read Voltage range [0=0-5V, 1=0-10V]
RAO,L,C	Read Lin/Log mode [0=Lin, 1=Log]
RAO,N,C	Read Normalize mode [0=Off, 1=On]
RAO,A,C	Read Averaging time, 1-10 [Sec]
RAO,D0,C	Read Minimum Diameter [nm]
RAO,D1,C	Read Maximum Diameter [nm]
RAO,D,C	Read Density, >= 0
RAO,M,C	Read Multiplier, >= 0
RAO,E,C	Read Exponent, 0-10
RAO,F0,C	Read Minimum Full Scale, >(=) 0 [dN/dlogdp]
RAO,F1,C	Read Maximum Full Scale, > 0 [dN/dlogdp]
RAO,V,C	Read Voltage, 0-5 or 10 [V]

C = chan, 1-4
Add ,# to any to read numbers only

RDM Read Debug Mode

RDM,x	Read Debug Mode [0<=x<=127]

SET Commands

SPID Set PID Parameter

Sheath Flow:

SPID,1,x	P Parameter [0 <= x <= 500]
SPID,2,x	I Parameter [0 <= x <= 500]
SPID,3,x	D Parameter [0 <= x <= 500]

Sample Flow:

SPID,4,x	P Parameter [0 <= x <= 500]
SPID,5,x	I Parameter [0 <= x <= 500]
SPID,6,x	D Parameter [0 <= x <= 500]

Sample Flow:

SPID,7,x	P Parameter [0 <= x <= 500]
SPID,8,x	I Parameter [0 <= x <= 500]
SPID,9,x	D Parameter [0 <= x <= 500]

SF Set Flow

SF,1,x	Sheath Flow Setpoint in L/min	[0<=x<=50]
SF,1,x	Sheath Flow Control	[ON, OFF, OPEN]
SF,2,x	Sample Flow Setpoint in L/min	[0<=x<=20]
SF,2,x	Sample Flow Control	[ON, OFF, OPEN]
SF,3,x	Charger Flow Setpoint in L/min	[0<=x<=2]
SF,3,x	Charger Flow Control	[ON, OFF, OPEN]
SF,4,x	Extraction Flow Setpoint in L/min	[0<=x<=5]
SF,4,x	Extraction Flow Control	[ON, OFF, OPEN]
SF,on	Turn all flows ON	
SF,off	Turn all flows OFF	

SAV Set Analyzer Voltage

SAV,x	Analyzer Voltage [ON, OFF]
SAV,OFFSET,x	Analyzer Voltage Offset [ON, OFF]

SC Set Charger

SC,1,x	Temporary Neg Charger Current Setpoint(nA) [0.00<=x<=50.00]
SC,1,x,PERM	Permanent Neg Charger Current Setpoint(nA) [0.00<=x<=50.00]
SC,1,x	Negative Charger Control [ON, OFF]
SC,2,x	Temporary Pos Charger Current Setpoint(nA) [0.00<=x<=50.00]
SC,2,x,PERM	Permanent Pos Charger Current Setpoint(nA) [0.00<=x<=50.00]
SC,2,x	Positive Charger Control [ON, OFF]

SDAC Set Digital Analog Converter

SDAC,x,y	Channel x [0<=x<=7]; Bitvalue y [0<=y<=1023]

SIE Set Instrument Error

SIE,x	This command turns error messages on front panel ON or OFF. [x = ON or OFF; default: ON]

SSN Set Serial Number

SSN,x	Set Serial Number [0<=x<=999999999]

SCH Set Column Heater

SCH,x	Set Column Heater [x = ON or OFF]

SPCB Set PCB Revision

SPCB,1,x	Main PCB Rev	[-<=x<=Z]
SPCB,2,x	High Voltage PCB Rev	[-<=x<=Z]
SPCB,3,x	Electrometer PCB Rev	[-<=x<=Z]

SEE Set EEPROM

SEE,DEFAULT	Write default values to Main PCB EEPROM.
SEE,CLEAR	Clear Main PCB EEPROM.

SEM Set Export Mode

SEM,x Set Export Mode [0<=x<=9]

SEM,0

```
NUMBER_DENSITY_IN_VARIABLE_NUM_CONCEN_XFR
STORE_RAW_ADC_BITS_IN_VARIABLE_RAW_DATA_XFR
```

SEM,1

```
INSTRUMENT_SPECTRUM_IN_VARIABLE_NUM_CONCEN_XFR
RAW_ADC_BITS_IN_VARIABLE_RAW_DATA_XFR
```

SEM,2

```
NUMBER_DENSITY_IN_VARIABLE_NUM_CONCEN_XFR
RAW_CURRENT_IN_VARIABLE_RAW_DATA_XFR
```

SEM,3

```
INSTRUMENT_SPECTRUM_IN_VARIABLE_NUM_CONCEN_XFR
RAW_CURRENT_IN_VARIABLE_RAW_DATA_XFR
```

SEM,4

```
NUMBER_DENSITY_IN_VARIABLE_NUM_CONCEN_XFR
INSTRUMENT_RECORD_IN_VARIABLE_RAW_DATA_XFR
```

SEM,5

```
INSTRUMENT_SPECTRUM_IN_VARIABLE_NUM_CONCEN_XFR
INSTRUMENT_RECORD_IN_VARIABLE_RAW_DATA_XFR
```

SEM,6

```
NUMBER_DENSITY_IN_VARIABLE_NUM_CONCEN_XFR
```

SEM,7

```
INSTRUMENT_SPECTRUM_IN_VARIABLE_NUM_CONCEN_XFR
```

SEM,8

```
RAW_CURRENT_IN_VARIABLE_RAW_DATA_XFR
```

SEM,9

```
INSTRUMENT_RECORD_IN_VARIABLE_RAW_DATA_XFR
```

SEM,10

```
NUMBER_CONCENTRATION_IN_VARIABLE_NUM_CONCEN_XFR
```

(Default setting for EEPS software)

SDS Set Data Simulation

SDS,x Set Data Simulation [x = ON or OFF; default: OFF]

SELM Set Electrometer Parameter

SELM,RESET	Reset all electrometers Wait 30 seconds after a reset to take data
SELM,ZERO	Initiate countdown to zero the electrometer. The countdown is updated every second and takes 45 seconds to complete. On completion the new offset and covariance values are written to the DSP and an OK will be returned
SELM,STOP	Stop the zeroing of electrometer

SAO Set Analog Out

SAO,R,x	Set Voltage range [x=0(0-5) x=1(0-10)]
SAO,L,C,x	Set Lin/Log mode [x=0(Lin) x=1(Log)
SAO,N,C,x	Set Normalize mode [x=0(Off) x=1(On)
SAO,A,C,x	Set Averaging time [1<=x<=10]
SAO,D0,C,x	Set Minimum Diameter [5.624<=x<=562.3]
SAO,D1,C,x	Set Maximum Diameter [5.624<=x<=562.3] Minimum Diameter must be < Maximum Diameter
SAO,D,C,x	Set Density [x>=0.0]
SAO,M,C,x	Set Multiplier [x>=0.0]
SAO,E,C,x	Set Exponent [0.0<=x<=10.0]
SAO,F0,C,x	Set Minimum Full Scale [x>(=)0.0]
SAO,F1,C,x	Set Maximum Full Scale [x>0.0] Min Full Scale must < Max Full Scale. Min can be 0 in lin mode only
SAO,V,C,x	Set Voltage [0.0<=x<=5.0 or 10.0] Sets Anout debug mode on. x=OFF sets debug mode off
	C = chan, 1-4

SDM Set Debug Mode

SDM,x	Set Debug Mode [0<=x<=127]
SDM,0	Stop Dumping Data
SDM,2	Dump Sheath Flowrate [L/min]
SDM,3	Dump Sample Flowrate [L/min]
SDM,4	Dump Charger Flowrate [L/min]
SDM,5	Dump Extraction Flowrate [L/min]
SDM,6	Dump Sheath Flow Temperature [C]
SDM,7	Dump Sample Flow Temperature [C]
SDM,8	Dump Charger Flow Temperature [C]
SDM,9	Dump Extraction Flow Temperature [C]
SDM,10	Dump Sheath Flowrate [Bit]
SDM,11	Dump Sample Flowrate [Bit]
SDM,12	Dump Charger Flowrate [Bit]
SDM,13	Dump Extraction Flowrate [Bit]

SDM,14	Dump Sheath Flow Temperature [Bit]
SDM,15	Dump Sample Flow Temperature [Bit]
SDM,16	Dump Charger Flow Temperature [Bit]
SDM,17	Dump Extraction Flow Temperature [Bit]
SDM,18	Dump Positive Charger Current [nA]
SDM,19	Dump Positive Charger Voltage [V]
SDM,20	Dump Negative Charger Current [nA]
SDM,21	Dump Negative Charger Voltage [V]
SDM,22	Dump Top Section Analyzer Voltage [V]
SDM,23	Dump Middle Section Analyzer Voltage [V]
SDM,24	Dump Bottom Section Analyzer Voltage [V]
SDM,25	Dump Absolute Pressure [mBar]
SDM,26	Dump All Flow PID Control Data
SDM,27	Dump Sheath Flow PID Control Data
SDM,28	Dump Sample Flow PID Control Data
SDM,29	Dump Extraction Flow PID Control Data
SDM,30	Dump ELM countdown during offset and covariance measurement
SDM,31	Dump ELM countdown and current during offset and covariance measurement
SDM,32	Dump simulated particle distribution
SDM,33	Dump analog channel 1
SDM,34	Dump analog channel 2

SIM Set Instrument Matrix

SIM,Index,Number

(Index = col + 33 x row)

(col = 0-32, row = 0-21, index = 0-725)

SIM,UPDATE

Send after all SIM,I,N cmds to update SIM,DEFAULT. Restore default instrument matrix (takes 4 sec.)

SIN Set Instrument Matrix Name

SIN,name

“name” is a string up to 20 characters, case-insensitive. Cannot be “Default”.

APPENDIX E
Analog Output

Engine Exhaust Particle Sizer™ (EEPS™) Model 3090 spectrometers (manufactured approximately August 2006 and later) come standard with four configurable analog outputs. These analog outputs offer users a convenient way to incorporate particle emission measurements into the dynamometer host data collection system. Configuration of the analog output parameters is performed using the Analog Out tab of the Properties window in the EEPS software.

Each analog output operates independently and is configurable for the size range, weighting, and concentration range. The size range for each output can be set for the full measurement range of the instrument (i.e., 5.624 to 562.3 nm), or any other size range, including down to less than the width of a single channel (one sixteenth of a decade). An example where a user might be interested to set a defined size range would be to output measurements of either the accumulation mode particles (i.e., soot) or the nucleation mode particles (SOF). Spin buttons in the software make it easy to select standard EEPS channel boundaries, or specific sizes can be entered within the size range of the instrument. The analog outputs can also be configured for linear or log outputs, as well as concentration (dN) or normalized concentration (dN/dlogDp).

The analog outputs have standard calculations for number concentration, surface area concentration, volume concentration and mass concentration (when a density value is entered) as shown in the table below. All standard calculations for surface area, volume and mass assume spherical particles. Since engine exhaust particles can be non-spherical there is a custom setting that allows a user to input any value for the weighting constant, power of diameter and density.

Weighting	Weighting Constant	Power of D (diameter)	Density	Units
Number	1	Zero	Not Applicable	$\#/cm^3$
Surface Area	π	Squared	Not Applicable	nm^2/cm^3
Volume	$\pi/6$	Cubed	Not Applicable	nm^3/cm^3
Mass	$\pi/6$	Cubed	Selectable	$\mu g/m^3$
Custom	Selectable	Selectable	Selectable	$\mu g/m^3$

An example of the setting screen is shown below.

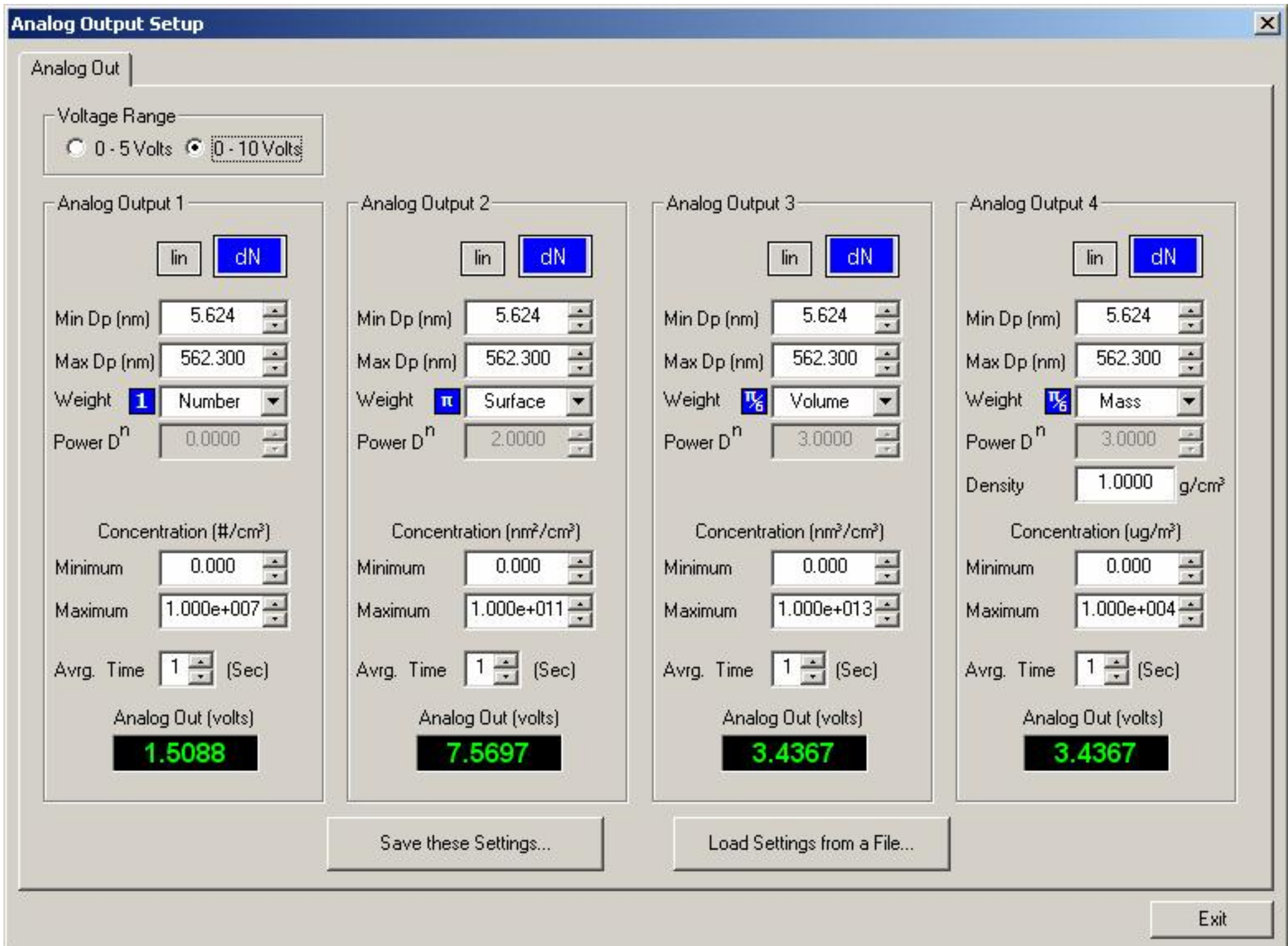


Figure E-1
Analog Out Screen

How Calculations are Made

The calculations for determining the output voltages for any choice of setting are based on the formulas shown below. The concentration calculation is based on summing concentrations in each EEPS spectrometer size channel (or portion of a size channel) to cover the total size range times a diameter weighting (diameter to some power) and times appropriate constants for the selected weighting and other settings:

Concentration signal:

$$C_S = \rho_e \cdot K \cdot \sum_{Dp,min}^{Dp,max} \left[\left(\frac{dN}{d\,logD_{pc}} \right) \cdot \left(d\,logD_{pw} \right) \cdot D_p{}^n \right] \cdot N_o$$

Where:

dN = Particle number concentration

ρ_e = Particle Density

K = Weighting Constant

$\sum_{Dp,min}^{Dp,max}$ = summation of channels or partial channels within the overall size limits specified

D_{pc} = Particle diameter size channel limits

D_{pw} = Particle diameter range (that can be less than one channel width)

$$d\,logD_{pc} = log\left(\frac{D_{upper}}{D_{lower}}\right)$$

where D_{upper} and D_{lower} are the upper and lower channel size boundaries, for the model 3090 $dlogD_{pc}$ is always 1/16

$$d\,logD_{pw} = log\left(\frac{D_{upper}}{D_{lower}}\right)$$

where D_{upper} and D_{lower} are the upper and lower size boundaries (may be less than one channel width)

$D_p^{\,n}$ = Particle diameter (midpoint of size range – channel or partial channel) to the n power

Normalizing Multiplier: $N_O = \dfrac{1}{log\left(D_{p_{max}} / D_{p_{min}}\right)}$ if Normalized mode is selected

$N_O = 1$ if Normalized mode is not selected

Output Voltage: $V_O = V_{fs} \cdot \dfrac{\left(C_s - C_{fs,min}\right)}{\left(C_{fs,max} - C_{fs,min}\right)}$ for linear mode

$V_O = V_{fs} \cdot \dfrac{\left(logC_s - logC_{fs,min}\right)}{\left(logC_{fs,max} - logC_{fs,min}\right)}$ for log mode

$C_{fs,\mathrm{min}}$ = Concentration minimum value (cannot be zero if log mode is used)

$C_{fs,\mathrm{max}}$ = Concentration maximum value

V_{fs} = Voltage full scale (5V or 10V)

Specifications

Analog Output	4 channels; 500 V isolation
Resolution	14 bit
Update rate	1 Hz
Output full scale	Configurable; 0-5 V and 0–10 V
Averaging time	Adjustable; 1–10 seconds
Connector type	BNC

APPENDIX F

AK-Protocol

Introduction

The AK-SAMT interface is a standardized communication interface for the integration of engine emissions testing equipment into automated emissions testing systems. The interface was defined by a working group if German automotive manufacturers to provide interoperability of equipment produced by different manufacturers. It is a de facto standard communication protocol for test bench application. The protocol was defined in 1991, but is not being actively developed anymore.

Interface Specifications

The serial interface is a RS 232C (V24) interface. At the back of the analyzer, a 9-pin D-sub female connector (see Figure F-1) serves for connecting a master computer.

Connector Pin Out

Pin Number	Signal Name
2	RxD (Input)
3	TxD (Output)
5	GND (Ground)

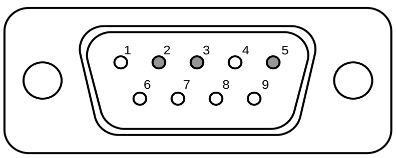


Figure F-1
9-pin D-sub Connector

Communication Parameter

Type	Response
Baud Rate	38.400
Data Bits:	8
Parity:	None
Stop Bits:	1
Handshaking:	None

Protocol Specifications

The AK-Protocol is a text-based only protocol. Each telegram begins with **STX** (Start of Text) in the first byte. The “don't care” byte can be any ASCII character. The next four bytes represent the command. A blank comes next, followed by K and the channel number. For delimiting the command parameters from the channel number another blank follows. This may be followed by command parameters with a variable length. Every telegram ends with the **ETX** (End of Text) character.

Instruction Telegram

Byte	Character	Hex Code	Description
1st Byte	STX	02	Start Byte
2nd Byte	Don’t Care	20	Any hex code, default blank
3rd Byte	Function Code 1		Function Code e.g.: ATEM
4th Byte	Function Code 2		
5th Byte	Function Code 3		
6th Byte	Function Code 4		
7th Byte	Blank	20	Blank
8th Byte	K	4B	K for channel (always 0)
9th Byte	Number		Channel Number
10th Byte	Blank	20	Blank
11th Byte	Data		Data sent with function
.	Data		
.	Data		
.	Data		
nth Byte	ETX	03	End Byte

Acknowledgement Telegram

Byte	Character	Hex Code	Description
1st Byte	STX	02	Start Byte
2nd Byte	Don’t Care	20	Any hex code, default blank
3rd Byte	Function Code 1		AK Instruction e.g.: ATEM
4th Byte	Function Code 2		
5th Byte	Function Code 3		
6th Byte	Function Code 4		
7th Byte	Blank	20	
8th Byte	Error Status		0 when no error, 1...9, +1 every error status change
9th Byte	Blank	20	
10th Byte	Data		AK instruction data, length is variable
.	Data		
.	Data		
.	Data		
nth Byte	ETX	03	End Byte

AK-Protocol Command Types

Code Type	AK-SAMT Definition	Type
EXXX	“**E**instellbefehle”	Write Command
AXXX	“**A**bfragen”	Read Command
SXXX	“**S**teuerbefehle“	Control Command

Acknowledgement Telegram

Acknowledgement	Description	AK-SAMT Definition
????	Analyzer does not understand the instruction sent	
XXXX E BS	Analyzer is busy with another function	“**B**usy”

XXXX = Function Code

(continued on next page)

AK Command Overview

This is an overview of the available AK commands for the instrument. Detailed descriptions of the individual commands follow on the next pages.

Control Commands – (S)

Code	Description
STBY	Set EEPS spectrometer to standby mode (turn pumps and chargers off)
SMEA	Set EEPS spectrometer into measurement mode (turn pumps and chargers on)

Write Commands – (E)

Set Command	Description
EPDV	Write Particle Size Density Vector
ECHM	Write Column Heater Mode
EDSM	Write Data Simulation Mode
EELM	Zero Electrometer

Read Commands – (A)

Read Command	Description
ASTZ	Read current instrument status and operational mode
AERR	Read instrument errors
APH1	Read Normalized Particle Size Histogram (dN/dlogDp); lower 16 particle size bins
APH2	Read Normalized Particle Size Histogram (dN/dlogDp); upper 16 particle size bins
APH3	Read Non-Normalized Particle Size Histogram (dN); lower 16 particle size bins
APH4	Read Non-Normalized Particle Size Histogram (dN); upper 16 particle size bins
ATPM	Read Total Particle Mass
ATPC	Read Total Particle Concentration
APDV	Read Particle Size Density Vector
AELO	Read Electrometer Offset
AELN	Read Electrometer Noise
ARSN	Read Serial Number
ARFV	Read Firmware Version

Command Details

Control Commands

Set Stand-by Mode

Command	Response	Description
STBY K0	STBY E	Set instrument to stand by-mode (turn pumps and chargers OFF)

Set Measurement Mode

Command	Response	Description
SMEA K0	SMEA E	Set instrument to measurement mode. (turn pumps and chargers ON)

Write Commands

Write Particle Density Vector

Command	Response	Description
EPDV K0 B1 B2 B3…B32	EPDV E	Write particle size density to instrument BX = Particle density for bin X Range: 0 to 10.00 [g/cm³.] Format: Float

Write Column Heater Mode

Command	Response	Description
ECHM K0 ON	ECHM E	Turn column heater ON
ECHM K0 OFF	ECHM E	Turn column heater OFF

Write Data Simulation Mode

Command	Response	Description
EDSM K0 ON	EDSM E	Turn data simulation mode ON
EDSM K0 OFF	EDSM E	Turn data simulation mode OFF

Zero Electrometer

Command	Response	Description
EELM K0 ZERO	EELM E	Initiate zeroing of electrometer. Instrument will respond with “BS” (busy) for 45 seconds. After completion, the new offset and covariance values are written to the DSP. ***Note****: The command is only executed if the instrument has finished the warm-up count.*
EELM K0 STOP	EELM E	Stop zeroing of electrometer.

Read Commands

Read Particle Size Histograms

Command	Response	Description
APH1 K0	APH1 E B1 B2 B3…B16	Normalized Particle Size Histogram (dN/dlogDp) Particle concentration for lower 16 particle size bins averaged over one second per size bin. BX = Particle concentration of size bin X Range: 0 to 9.9999E9 [#/cm^3] Format: Float Example: B1 = 1.2345E5
APH2 K0	APH2 E B17 B18 B19…B32	Normalized Particle Size Histogram (dN/dlogDp) Particle concentration for upper 16 particle size bins averaged over one second per size bin. BX = Particle concentration of size bin X Range: 0 to 9.9999E9 [#/cm^3] Format: Float Example: B32 = 1.2345E5
APH3 K0	APH3 E B1 B2 B3…B16	Non-Normalized Particle Size Histogram (dN) Particle concentration for lower 16 particle size bins averaged over one second per size bin. BX = Particle concentration of size bin X Range: 0 to 9.9999E9 [#/cm^3] Format: Float Example: B1 = 1.2345E5

Command	Response	Description
APH4 K0	APH4 E B17 B18 B19…B32	Non-Normalized Particle Size Histogram (dN) Particle concentration for upper 16 particle size bins averaged over one second per size bin. BX = Particle concentration of size bin X Range: 0 to 9.9999E9 [#/cm³] Format: Float Example: B32 = 1.2345E5

N o t e

The AK-SMAT Protocol was defined in 1991, and at that time not designed to manage large data sets. Due to the protocol limitations, two separate commands have to be issued to read the full particle size histogram. With each reading of the lower particle size bins (command APH1 or APH3), a new snapshot of the full particle size histogram, total particle concentration and total particle mass is stored in memory. These parameters can then be read subsequently to assure consistency within a data set and prevent that data from being overwritten between readings.

Data Read Sequence: Example 1	
APH1 K0	Read Normalized Particle Size Histogram (dN/dlogDp); **lower** 16 particle size bins
APH2 K0	Read Normalized Particle Size Histogram (dN/dlogDp); **upper** 16 particle size bins
ATPM K0	Read Total Particle Mass
ATPC K0	Read Total Particle Concentration
AERR K0	Read instrument errors

Data Read Sequence: Example 2	
APH3 K0	Read Non Normalized Particle Size Histogram (dN); **lower** 16 particle size bins
APH4 K0	Read Non Normalized Particle Size Histogram (dN); **upper** 16 particle size bins
ATPM K0	Read Total Particle Mass
ATPC K0	Read Total Particle Concentration
AERR K0	Read instrument errors

Read Total Mass and Particle Concentration

Command	Response	Description
ATPM K0	ATPM E PM	Total particle mass for all particle size bins measured over 1 second. PM = Particle Mass Range: 0 to 9.9999E9 [µg/m³] Format: Float Example: PM = 1.2345E6
ATPC K0	ATPC E PC	Total particle concentration for all particle size bins measured over 1 second. PC = Particle Concentration Range: 0 to 9.9999E9 [#/cm³] Format: Float Example: PC = 1.2345E5

Read Particle Density Vector

Command	Response	Description
APDV K0	APDV E B1 B2 B3…B32	Read particle size density from instrument BX = Particle density for bin X Range: 0.00 to 10.00 [g/cm³] Format: Float

Read Electrometer

Command	Response	Description
AELO K0	AELO E C1 C2 C3…C22	Read Electrometer Offset C = Electrometer offset current for channel X (C22: Bottom Electrometer) Range: -9.9999E9 to 9.9999E9 [fA] Format: Float
AELN K0	AELN E C1 C2 C3…C22	Read Electrometer RMS Noise C = Electrometer noise level for channel X (C22: Bottom Electrometer) Range: -9.9999E9 to 9.9999E9 [fA_{RMS}] Format: Float

Read Serial Number & Firmware Version

Command	Response	Description
ARSN K0	ARSN E XXXXXXXX	Read serial number XXXXXXXX [Serial Number] Format: Text
ARFV K0	ARFV E XXXX YYYY	Read firmware version XXXX [Main Firmware] YYYY [DSP Firmware] Format: Text

Read Instrument Status

Command	Response	Description
ASTZ K0	ASTZ E S0 S1 S2…S11	Read current instrument status SX = 0: Feature OFF SX = 1: Feature ON Format: Text S0 : Positive Charger S1 : Negative Charger S2 : Analyzer high voltage S3 : Analyzer high voltage offset S4 : Sheath Flow S5 : Sample Flow S6 : Extraction Flow S7 : Column Heater S8 : N/A S9 : N/A S10 : Instrument in Warm-up Mode S11 : Zero Electrometer Mode

Read Instrument Error

Command	Response	Description
AERR K0	AERR E S0 S1 S2…S63	Read current instrument error conditions. If no error is detected the command returns SX = 0: No Error SX = 1: Error Detected Format: Text **Possible Error Conditions** S0 : Sheath Flow Rate low S1 : Sheath Flow Rate high S2 : Sample Flow Rate low S3 : Sample Flow Rate high S4 : Charger Flow Rate low S5 : Charger Flow Rate high S6 : Extraction Flow Rate low S7 : Extraction Flow Rate high S8 : Sheath Flow Temperature low S9 : Sheath Flow Temperature high S10 : Sample Flow Temperature low S11 : Sample Flow Temperature high S12 : Charger Flow Temperature low S13 : Charger Flow Temperature high S14 : Extraction Flow Temperature low S15 : Extraction Flow Temperature high S16 : Analyzer Voltage Upper Section low S17 : Analyzer Voltage Upper Section high S18 : Analyzer Voltage Middle Section low S19 : Analyzer Voltage Middle Section high S20 : Analyzer Voltage Lower Section low S21 : Analyzer Voltage Lower Section high S22 : Not used S23 : Not used S24 : Positive Charger Current low S25 : Positive Charger Current high S26 : Positive Charger Voltage low S27 : Positive Charger Voltage high S28 : Negative Charger Current low S29 : Negative Charger Current high S30 : Negative Charger Voltage low S31 : Negative Charger Voltage high S32 : Absolute Pressure low S33 : Absolute Pressure high S34 : Particle Concentration high S35 : Not used S36 : Not used S37 : Instrument Matrix Readback Error S38 : ELM Covariance Readback Error S39 : ELM Offset Readback Error

Command	Response	Description
AERR K0 *(cont.)*	AERR E S0 S1 S2…S63	S40 : CELM Gain Readback Error S41 : Missed DSP Interrupt S42 : DSP Command Code Timeout Error S43 : DSP Reset Timeout Error S44 : COM1 Xmit Buffer Overflow Error S45 : Flowmeter EEPROM Error S46 : Not used S47 : Not used S48 : DSP Timing Error S49 : DSP Command Code Error S50 : Electrometer Channel High Offset S51 : Electrometer Gain Error S52 : Electrometer Chan Above Noise Limit S53 : DSP Instrument Matrix Error S54 : Electrometer Channel Noisy S55 : DSP Data Not Valid S56 : DSP checksum error 1 S57 : DSP checksum error 2 S58 : Electrometer PCB 1 S59 : Electrometer PCB 2 S60 : Electrometer PCB 3 S61 : Electrometer PCB 4 S62 : Electrometer PCB 5 S63 : Electrometer PCB 6

Particle Size Bin Numbers

Particle Size Bin Number	Particle Size Midpoints [nm]
B1	6.04
B2	6.98
B3	8.06
B4	9.31
B5	10.75
B6	12.41
B7	14.33
B8	16.55
B9	19.11
B10	22.07
B11	25.48
B12	29.43
B13	33.98
B14	39.24
B15	45.32
B16	52.33
B17	60.43
B18	69.78
B19	80.58
B20	93.06
B21	107.46
B22	124.09
B23	143.30
B24	165.48
B25	191.10
B26	220.67
B27	254.83
B28	294.27
B29	339.82
B30	392.42
B31	453.16
B32	523.30

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P/N 1980494 Rev. J Printed in U.S.A.

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