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PARTICLE INSTRUMENTS

Aerosol Neutralizers

Series 3080

Electrostatic Classifiers

Operation and Service Manual

P/N 1933792, Revision J
March 2009



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Series 3080

Electrostatic Classifiers

Operation and Service Manual

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Manual History

The following is a manual history of the Series 3080 Electrostatic Classifiers operation and service manual (Part Number 1933792).

Revision	Date
Original Version	March 1999
Final	April 1999
A	June 2000
B	July 2000
C	October 2000
D	July 2002
E	September 2002
F	March 2005
G	April 2006
H	April 2008
J	March 2009

- In revision A, changes were made to: Chapters 3, 5, and 6; Appendix B, “Particle Mobility Theory” section and Tables B-1 and B-2; Appendix D; and Appendix E schematics.
- In Revision B, TSI’s Limitation of Warranty and Liability was updated.
- In Revision C, Appendixes B, C, and E were updated.
- In Revision D, TSI phone numbers were updated and changes were made in Chapter 4 and Appendix B.
- In Revision E, all mentions of the Model 3083 Radial DMA were removed from manual.
- In Revision F, Figure 1-1 was updated, a minor error was fixed in Appendix B, and Model 3080-Series was changed to Series 3080.
- In Revision G, the word polynominal was changed to polynomial. TSI customer service and technical telephone numbers were changed to 1-800-874-2811 and 490-2811. Figure 6-8 was corrected. Numerous other updates were made to entire manual.
- In Revision H, the Model 3077 was changed to be optional with 3077A becoming the default. The manual was also reformatted with the new TSI logo.
- In Revision J, Product Registration page was added to front of manual.

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Warranty

Part Number 1933792 / Revision J / March 2009

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Safety

This section gives instructions to promote safe and proper handling of Series 3080 Electrostatic Classifiers.

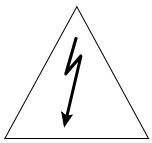
There are no user-serviceable parts inside the instrument. Refer all repair and maintenance to a qualified technician. All maintenance and repair information in this manual is included for use by a qualified technician.

To prevent problems, take these precautions:

- Do ***not*** remove any parts from the instrument unless you are specifically told to do so in this manual.
- Do ***not*** remove the instrument housing or covers while power is supplied to the instrument.



Caution
If the Model 3080 is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.



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

Labels

The Classifier Platform has the ten labels shown in Figure S-1. They are described below starting from the upper-left and moving counter-clockwise.

1 Danger, High Voltage Label (interior, on the high-voltage feedback module)

2 High Voltage Symbol Label (above the high-voltage output connector, side of cabinet)

3 Serial Number Label (back of cabinet)

4 Caution, No Serviceable Parts Label (back of cabinet)

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5 Customer Service Label (back of cabinet)

6 High-Voltage Symbol Label (interior, on power entry module)

7 Ground Symbol Label (interior, bottom, next to ground stud)

8 High-Voltage Symbol Label (interior, on high-voltage inverter for display)

9 Flag up Label (top, outside cover)

10 High Voltage Symbol Label (interior, on high-voltage power supply)

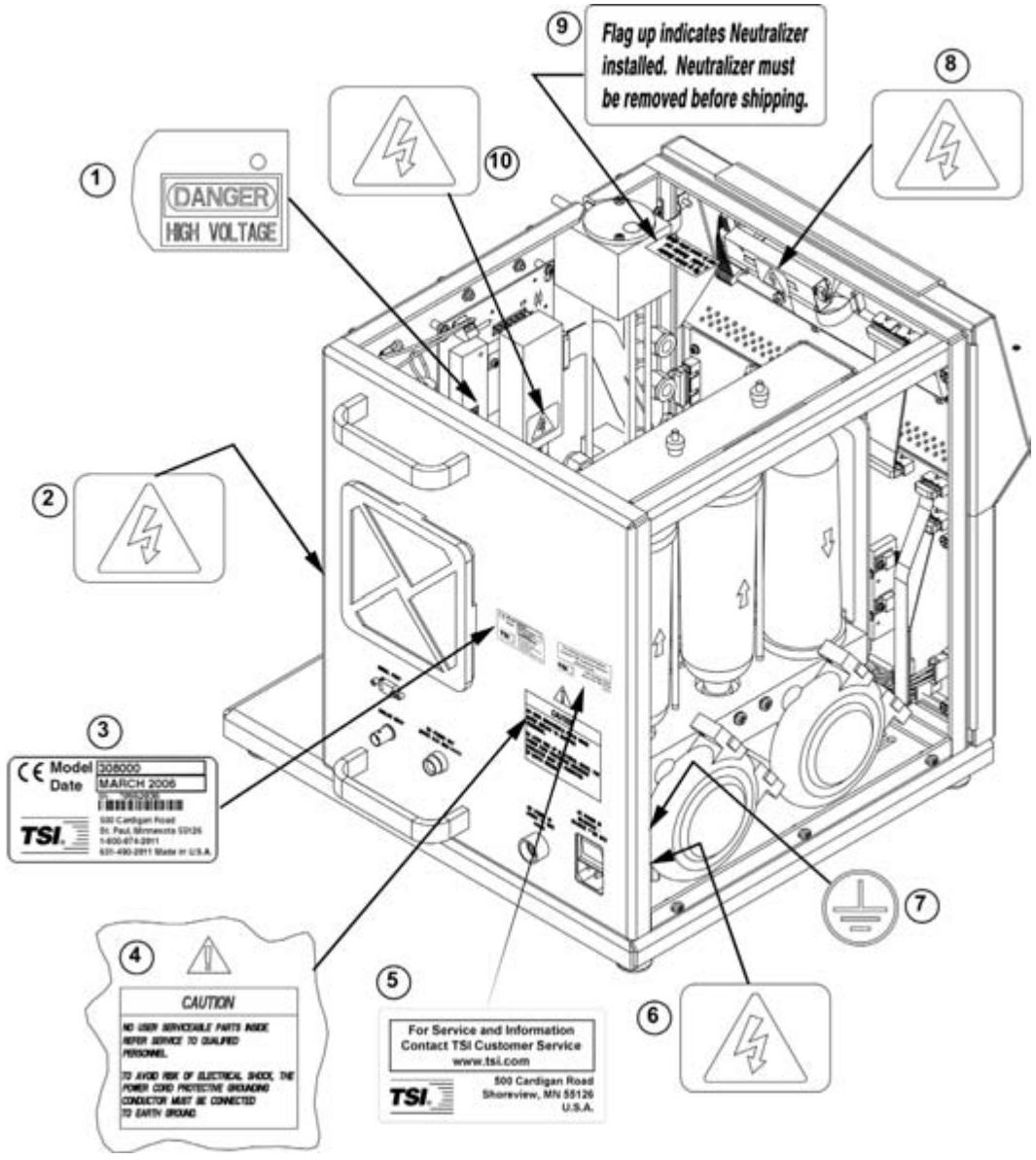


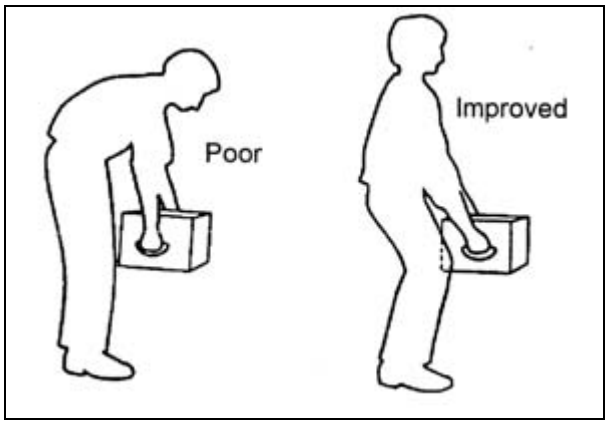
Figure S-1
Location of Warning and Information Labels

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Lifting Caution

The Model 3080 Electrostatic Classifier is a heavy instrument. The Classifier alone weighs 17.6 kg (38.9 lbs) and with a DMA attached can weigh as much as 23.2 kg (51.2 lbs). The weight can be unbalanced, especially with a DMA attached. To protect your back when lifting:

- Get help from another person to move the instrument.
- Transport the instrument on a cart whenever possible.
- Carry the DMA and Classifier separately.
- Lift with your legs while keeping your back straight.
- Keep the instrument close to your body as you lift.
- Use the handles built into the left and right undersides of the base or the black handles attached to the back panel.



Description of Caution Symbols

The following symbols and appropriate caution statements are used throughout the manual and on the Model 3080 to draw attention to any steps that require you to take cautionary measures when working with the Model 3080:

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.

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Warning



W A R N I N G
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.
	Warns you that the Model 3077A/3077 Aerosol Neutralizer, which is installed inside the Model 3080 Electrostatic Classifier, contains radioactive material that is subject to the regulations of the U.S. Nuclear Regulatory Commission and local regulations. Carefully read the enclosed Model 3077A/3077 Aerosol Neutralizers Instruction Manual to determine your legal responsibilities regarding the neutralizer.

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About This Manual

Purpose

This is an instruction manual for the operation and handling of Series 3080 Electrostatic Classifiers.

Related Product Literature

- ***Model 3077/3077A Aerosol Neutralizers Instruction Manual*** (part number 1933077 TSI Incorporated)
- ***Model 3936 Scanning Mobility Particle Sizer™ (SMPS™) Spectrometer Operation and Service Manual*** (part number 1933796 TSI Incorporated)
- ***Model 3480 Electrospray Aerosol Generator Operation and Service Manual*** (part number 1933793 TSI Incorporated)
- ***Model 3772/3771 Condensation Particle Counter Operation and Service Manual*** (part number 1980529 TSI Incorporated)
- ***Model 3775 Condensation Particle Counter Operation and Service Manual*** (part number 1980527 TSI Incorporated)
- ***Model 3776 Ultrafine Condensation Particle Counter Operation and Service Manual*** (part number 1980522 TSI Incorporated)
- ***Model 3782 Water-based Condensation Particle Counter Operation and Service Manual*** (part number 1930073 TSI Incorporated)
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- ***Model 3010 Condensation Particle Counter Instruction Manual*** (part number 1933010 TSI Incorporated)
- ***Model 3022A Condensation Particle Counter Instruction Manual*** (part number 1933763 TSI Incorporated)

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- ***Model 3025A Ultrafine Condensation Particle Counter Instruction Manual*** (part number 1933762 TSI Incorporated)

Getting Help

To obtain assistance with this product or to submit suggestions, please contact:

TSI Incorporated
Particle Instruments
500 Cardigan Road
Shoreview, MN 55126 USA
Fax: (651) 490-3824
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CHAPTER 1

Product Overview

This chapter describes the Model 3080 Electrostatic Classifier, shown in Figure 1-1, and gives an overview of how the Classifier works.

Product Description

The Model 3080 Electrostatic Classifier can be used with either Differential Mobility Analyzer (DMA): *Long* or *Nano*, as the main component for generating or sizing aerosols. Given a polydisperse input aerosol, the instrument output can be a stream of monodisperse aerosol of known particle size (particle electrical mobility).



Figure 1-1
Model 3080 Electrostatic Classifier shown with Model 3081 Long DMA and Model 3085 Nano DMA

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Collectively, the family of Electrostatic Classifiers size-classifies highly monodisperse, submicrometer aerosols in the range from 2 to 1000 nanometers in particle diameter. The Electrostatic Classifier is most often used as an integral part of a monodisperse-aerosol generation system or a submicrometer-particle sizing system.

In an aerosol generation system, the Electrostatic Classifier selects aerosol particles of uniform size from a polydisperse source, resulting in a highly monodisperse aerosol. The *Long DMA* offers classification in the range from 10 to 1000 nanometers in diameter. The *Nano DMA* offers classification from 2 to 150 nanometers in diameter.

In a particle sizing system, the Electrostatic Classifier separates particles by size for high-resolution measurements of particle size distribution. When used in TSI Scanning Mobility Particle Sizer (SMPS) spectrometers, for example, monodisperse aerosol exiting the Electrostatic Classifier passes to a Condensation Particle Counter (CPC), which measures particle number concentration. By scanning quickly through a portion of the size range from 2 to 1000 nanometers (size range varies by SMPS configuration), the SMPS measures the size distribution of the aerosol precisely.

Some advantages of the 3080 Electrostatic Classifiers include:

- Choice of two interchangeable DMAs and flexibility to use other custom DMAs
- Minimal diffusional broadening and particle loss for Nano DMA due to its short length and bypass inlet flow design
- Recirculating flow for precise match of sheath and excess flows
- Accurate microprocessor-controlled volumetric flow
- Precision dynamic high-voltage supply for fast, accurate scanning
- Optional easy-to-install positive high-voltage supply (negative supply is standard)
- Convenient front-panel design with control knob and built-in display
- Electronic control of flow, voltage, particle-size, gas type, and instrument functions

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Applications

When used in an aerosol generation system to produce highly monodisperse particles:

- Aerosol research, including studies of particle transport, diffusion, coagulation, nucleation, and condensation
- Particle-charge and electrical-mobility studies
- Filter-media tests for filter efficiency
- Calibration of particle instruments such as optical particle counters—enhancing the monodispersity of polystyrene latex (PSL) or other aerosols by removing residue particles and multiplets

When used in a TSI SMPS spectrometer to offer high-resolution sizing of submicrometer particles:

- Aerosol research, including nucleation and condensation studies
- Atmospheric and climate studies
- Nanotechnology research and materials synthesis
- Combustion and engine exhaust studies
- Characterization of sprays, powders, and other generated aerosols

and much more…

When used in tandem: Measuring small and large changes in particle size due to coagulation, evaporation, condensation, humidification, and chemical reactions.

When used with a TSI Model 3068B Aerosol Electrometer: Primary size and concentration calibration of Condensation Particle Counters and other aerosol instruments.

How the Classifier Operates

The Model 3080 Electrostatic Classifier consists primarily of a Kr-85 bipolar charger to neutralize the charges on particles, a controller to control flows and high-voltage, and a Differential Mobility Analyzer (DMA) which separates particles based on their electrical mobility.

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Polydisperse, submicrometer aerosol passes through a radioactive bipolar charger, establishing a bipolar equilibrium charge level on the particles. Particles receive either positive, negative, or zero charge(s). The particles then enter the DMA and are separated according to their electrical mobility. This parameter is inversely related to particle size and proportional to number of charges on the particles.

In the particle-generation mode, the particle size of the monodisperse aerosol exiting the Electrostatic Classifier is selected simply by using the control knob on the front panel. When using the Classifier for particle sizing, it can be operated in two modes: underpressure mode, during which the flow rate of the polydisperse aerosol is set by the CPC, and overpressure mode, in which the flow rate of the polydisperse aerosol is set by the aerosol source entering the Classifier. In underpressure operation, air is drawn through the DMA, a useful practice when sampling from aerosol at or near atmospheric pressure. In overpressure mode, the aerosol is pushed through the DMA. Overpressure operation is best when generating aerosols from pneumatic nebulizers or other pressurized systems.

System History

The first Electrostatic Classifier manufactured by TSI was designated as the Model 3071. It consisted of a manually-adjusted high-voltage controller and manually-adjusted valves with mass-flowmeters to measure flows. The cabinet incorporated a Kr-85 radioactive neutralizer and a long DMA. This version was in production from September 1976 to November 1992.

In 1993, the Model 3071 Classifier received cosmetic updates and some minor engineering changes. This brought the instrument up-to-date in terms of electrical compliance and replaced obsolete parts. A new color scheme brought the Classifier inline with the family of TSI scientific particle instruments as the 3071A. The Model 3071A was replaced by the newer Model 3080.

The Model 3080 is a complete redesign of earlier Classifier models and began shipping in January of 1999. The modular instrument has two interchangeable DMAs with recirculating flow for precise match of sheath and excess flows. It uses electronics to control volumetric flow, voltage, and particle size. Instrument can be conveniently controlled using control knob and display on the front panel.

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CHAPTER 2

Unpacking and Setting Up the System

Use the information in this chapter to unpack and setup the Model 3080 Electrostatic Classifier.

Packing List

As you unpack the shipping container, make certain the shipment is complete. Table 2-1 gives a packing list for the Classifier.

Table 2-1
Classifier Packing List

Qty	Description	Part No.
1	Model 3080 Electrostatic Classifier	3080
1	Electrostatic Classifier Accessory Kit Including:	
1	Support Bracket for Long DMA w/screws	1035991
1	Fitting Adapter, ⅜ to ¼	1035992
1	⅜-in cap fitting	1602304
1	Cable, Power Supply	
1	Cable, RS-232 Serial	962002
1	Serial Cable Adapter, 25F to 9M	962003
1	3080 Manual	1933792
10 ft [3.0 m]	Tubing, Silicone Conductive, fits ¼-in barb fitting (⅜-in OD × 0.19-in ID)	3001903
10 ft [3.0 m]	Tubing, Silicone Conductive, fits ⅜-in barb fitting (½-in OD × 0.31-in ID)	3001904
10 ft [3.0 m]	Tubing, Tygon Clear ¼-in OD × ⅜-in ID	3001220

Unpacking Instructions

The Model 3080 is not shipped fully assembled. A Model 3077A (or the optional Model 3077) Aerosol Neutralizer must be installed for the Classifier to operate properly. Use the instructions given later in this chapter to install the Neutralizer. If you ordered the Model 3080 with a DMA, the DMA must be installed and properly plumbed. See the sections later in this chapter for instructions.

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Moving the Instrument

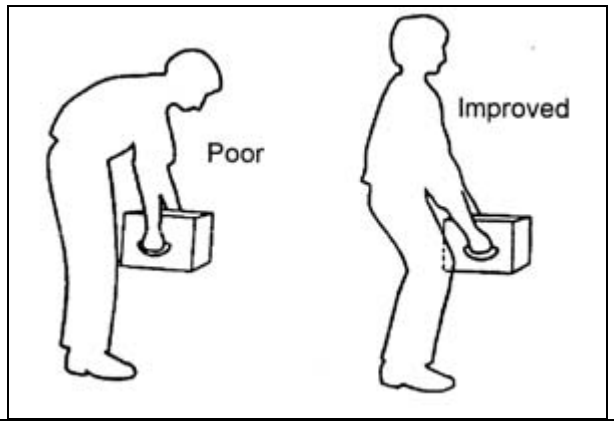
Use the handles built into the left and right undersides of the base or the black handles attached to the back panel while moving the instrument.



Caution

The Model 3080 Classifier is a heavy instrument. The Classifier alone weighs 17.6 kg (38.9 lbs) and with a DMA attached can weigh as much as 23.2 kg (51.2 lbs). The weight can be unbalanced, especially with a DMA attached. **Protect your back when lifting:**

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



Mounting the Instrument

The Classifier has no special mounting requirements other than providing good ventilation (see below). The cabinet has four non-marking rubber feet that give the instrument a good grip on clean, level surfaces. The rubber feet (Figure 2-1) are installed in the cabinet using integrated ¼-20 UNC threaded fasteners and can be removed (by unscrewing) to allow other mounting fasteners to be used.

***Note**: If the cabinet is mounted to a plate, drill holes in the plate to match the ventilation holes in the bottom of the cabinet or use standoffs to raise the bottom of the cabinet at least ½ inch (1.2 cm) above the mounting plate.*

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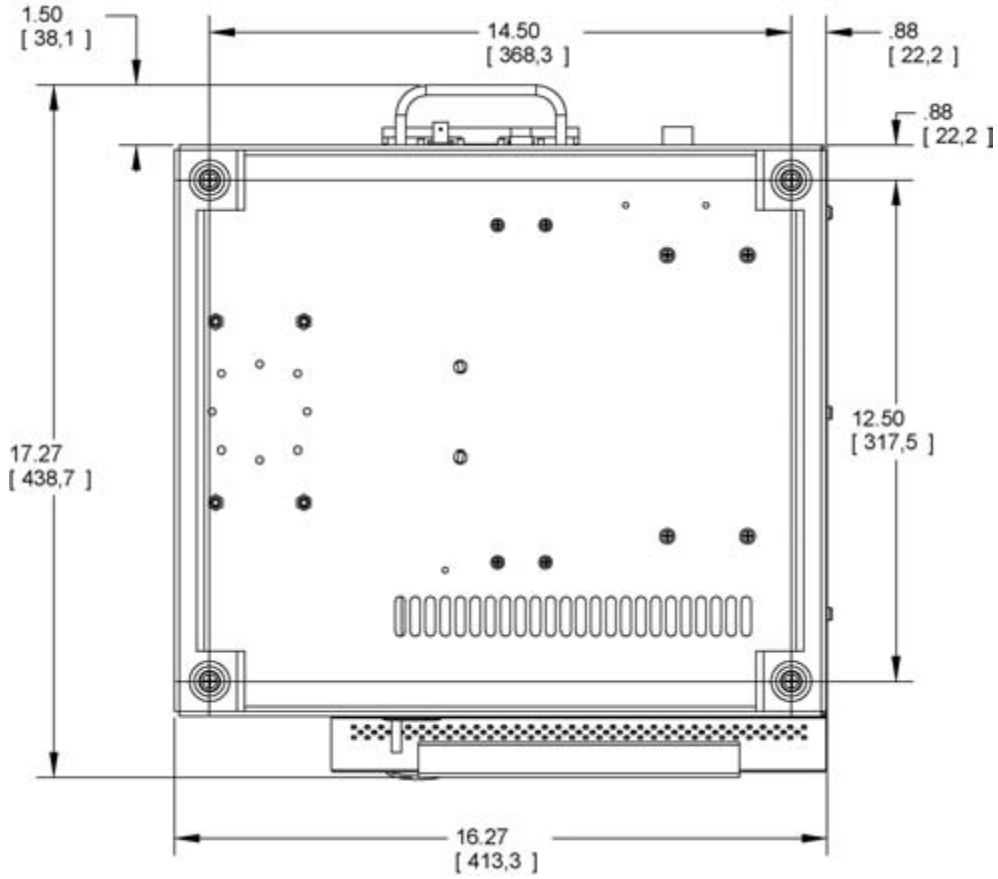


Figure 2-1
Bottom View of Electrostatic Classifier Showing Location of Rubber Feet. Feet can be removed to provide mounting points on cabinet. Dimensions are in inches [mm].

Ventilation Requirements

The Classifier cabinet is designed to be cooled by room air drawn in through a filter from the back of the cabinet and exhausted through holes at the side, front, and bottom of the cabinet.

The cabinet should be installed with at least 2-inch (50-mm) clearance between the back panel and left-side panel and any other surface. Also, the cabinet should be set on a clean, hard surface so that the exhaust air can move freely from the base of the cabinet.

Power Connection

Connect the AC power cord (supplied) to the AC POWER IN connection on the back of the Classifier and then into an available power outlet. It is not necessary to select the correct voltage because the instrument accepts line voltage of 100 to 240 VAC,

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50-60 Hz, 200 W max., single phase. The connector has a built-in on/off switch.

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

The Classifier power supply contains no user-serviceable parts. If the power supply is not operating correctly, use the information in Chapter 6, "Technical Contacts" to contact TSI. This instrument should not be used in a manner not specified by the manufacturer.

Toggle the on/off switch at the AC POWER IN connection on the back panel to the on position to verify the instrument has power.

Alternately, connect 24 VDC to the DC POWER IN connection. Contact TSI to order the necessary connector (TSI part number 1035551).

Analog Input

There is an Analog Input connector on the Classifier (located just below the Serial Port on the back panel) for analog control of the High-Voltage supplied to the DMA. Usually, this is used for input of the control signal from a Condensation Particle Counter in a Scanning Mobility Particle Sizer™ (SMPS™) system.

Connecting a Computer

Although normally only necessary for instrument calibration at the factory, it is possible to communicate directly with the Classifier using a computer. Refer to Appendix C for detailed information on communicating with the instrument.

Installing the Kr-85 Bipolar Charger

The Kr-85 neutralizer is shipped separately because of regulations that govern packaging requirements for radioactive materials.

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WARNING

The Model 3077A/3077 Aerosol Neutralizer, which is installed inside the Model 3080 Electrostatic Classifier, contains radioactive material that is subject to the regulations of the U.S. Nuclear Regulatory Commission and local regulations. Carefully read the enclosed Model 3077/3077A Aerosol Neutralizers Instruction Manual to determine your legal responsibilities regarding the neutralizer.

Before the Classifier will operate, the neutralizer must be installed according to the following steps:

1. Remove the two screws securing the neutralizer outlet block on the top of the instrument, and remove the block by lifting it up using the ¼-in exit tube.

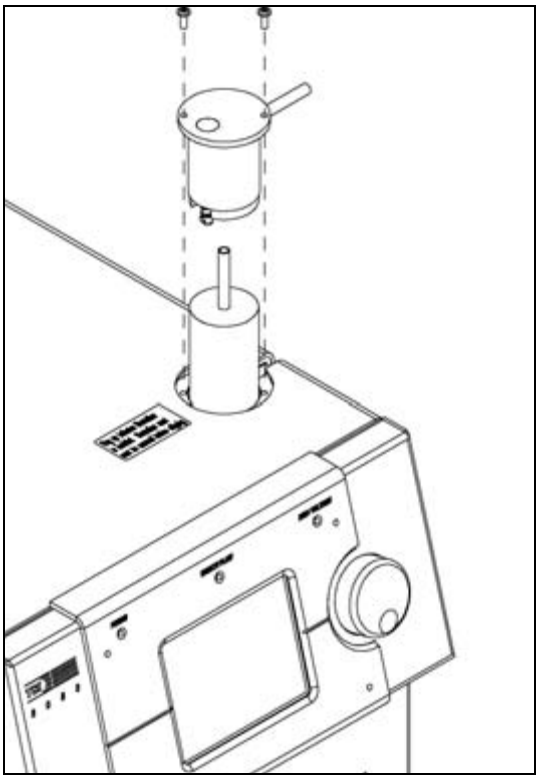


Figure 2-2
Installation of Model 3077A/3077 Kr-85 Neutralizer

2. Inspect the ¼-in tubes on the neutralizer to make sure that the ends do not have sharp edges. If the outer edges of the ends are sharp, they will cut the O-ring seals in the Classifier and cause a leak. Remove any sharp edges using a fine file or fine grit sandpaper suitable for stainless steel.
3. Put a light coating of grease on the outer diameter of the ¼-in tubes on the neutralizer.

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4. Insert the neutralizer with the long tube up and the screws in the side of the neutralizer aligned with the slots in the neutralizer mounting block as shown in Figure 2-2.

5. Replace the outlet block in the Classifier and push down. If the block does not fit over the neutralizer tubes easily, do ***not*** force it—you will damage the O-rings and cause a leak—try steps 2 and 3 again.

6. Replace the screws in the outlet block. The outlet block should be flush with the cabinet top and the pop-up flag indicating that the neutralizer is installed should be visible as shown in Figure 2-3.

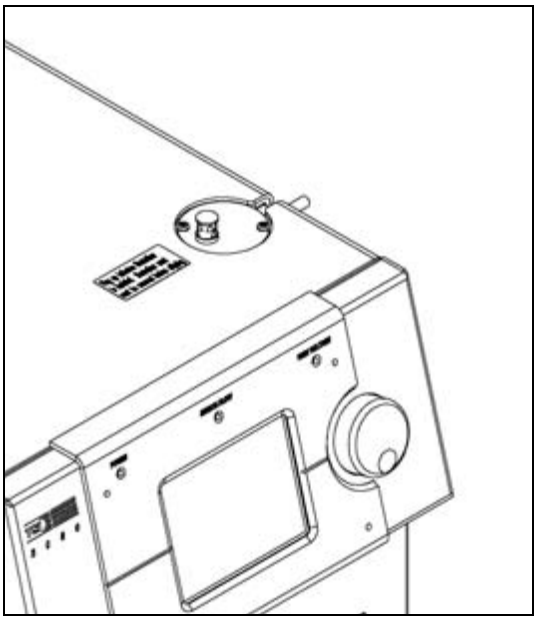


Figure 2-3
Model 3077A/3077 Kr-85 Neutralizer Installed (showing pop-up-flag indicator)

Installing an Impactor

Depending on the Classifier package you ordered, an impactor will be shipped as an accessory. The primary function of the impactor is to remove larger particles that carry more than a single charge. However, the impactor is also used as a flowmeter, since the pressure drop across the impactor is proportional to the square of the flow rate.

The impactor assembly is attached to the aerosol inlet of the Classifier using a Swagelok® fitting. Make sure the downstream

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side of the impactor (fitting with low pressure tap) is attached to the aerosol inlet of Classifier (Figure 2-4).

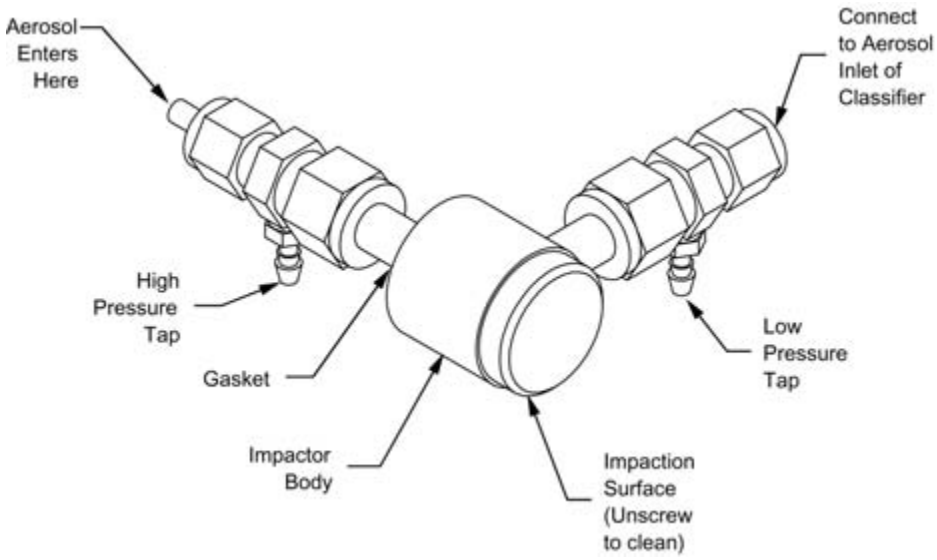


Figure 2-4
Impactor Inlet

There are three nozzle sizes to choose from. The nozzle size and flow rate determine the largest particle size that can be sampled within each SMPS measuring size range. For best results, use Table 2-2 to determine the correct nozzle to use for the flow you set. Each nozzle is interchangeable and can be screwed into the impactor body with a gasket to seal the thread. Using the Classifier display, you can view the flow rate directly from the pressure drop measured across the impactor. The Classifier stores an internal calibration curve for each impactor size and serial number. Only use the impactor nozzles that come with the Classifier because the calibration curves stored in the Classifier are unique for the nozzles.

Table 2-2
Typical Flow Range for Each Impactor Nozzle

Aerosol Inlet Flow Range (L/min)	Nozzle Size (cm)
0.2 to 0.8	0.0457
0.3 to 1.0	0.0508
0.6 to 2.1	0.071

When you have selected a nozzle size you need to physically install it in the impactor body and then set the corresponding nozzle size on the front panel of the Classifier.

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To install the impactor assembly, use the following steps:

1. Refer to Figure 2-4 and Figure 2-5. The impactor can be oriented in any direction that is convenient. Simply rotate the pressure tap fittings as needed.

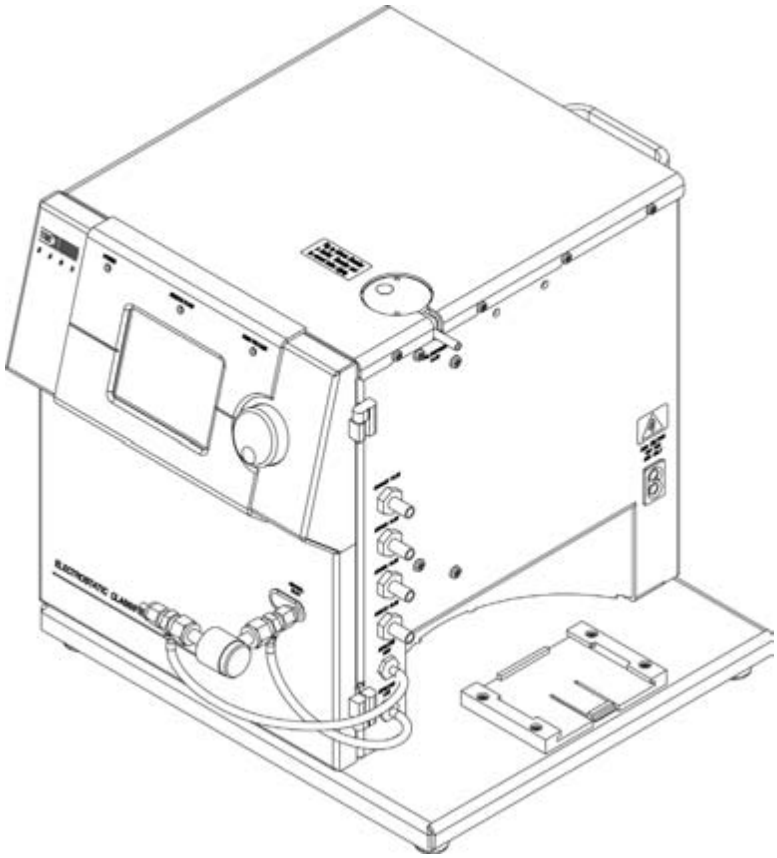


Figure 2-5
Impactor Inlet Installed on Classifier

2. Loosen the nut on the low pressure fitting side of the Impactor assembly and push the Swagelok® fitting onto the aerosol inlet of the Classifier. Tighten the nut with a wrench.
3. Using clear Tygon® tubing provided in the accessory kit (part number 3001220), cut a 12-inch [30 cm] length and connect the high pressure tap from the impactor assembly to the *impactor high* fitting on the side of the Classifier.
4. With the same tubing, cut an 8-inch [20 cm] length and connect the low pressure tap from the impactor assembly to the *impactor low* fitting on the side of the Classifier.

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5. The inlet for the impactor is the fitting that attaches to the end of the impactor cylinder body. The exit fitting attaches to the side wall of the cylinder body.
6. Turn on the Classifier and rotate the control knob to highlight the *Menu* pane on the display.
7. Click the control knob by pushing in. This should bring up the menu.
8. Scroll by rotating the control knob until *Impactor* is highlighted and then click the selection.
9. Select the impactor size corresponding to the impactor physically installed and click the selection
10. Scroll the menu up to *Exit* and click to exit the menu.

Installing Model 3081 Long DMA

If your order included a Long DMA, it will be shipped separately from the Classifier and must be assembled to the Classifier before use. The following section describes how to mount the Long DMA and install plumbing.

Long DMA Mounting

The Classifier uses a quick-connect bracket to mount any of the two TSI DMAs. This mount provides physical support for the DMA as well as electrical grounding for safety.



Caution
If, for any reason, you operate the Classifier with a DMA that is not installed in the mounting bracket, you must connect the base of the DMA to the chassis of the Classifier with a ground strap or provide independent earth grounding to the DMA for safety.

The mounting bracket has a spring-loaded locking mechanism that holds the base of the DMA securely. To install the DMA use the following steps:

1. Place the base of the DMA down into the middle of the mounting plate on the Classifier as shown in Figure 2-6.
2. Slide the base toward the cabinet of the Classifier until you hear a click. If you have trouble getting the plates to slide, try wiggling the DMA plate from side to side slightly as you push or try a little grease on intersecting parts of the plates.

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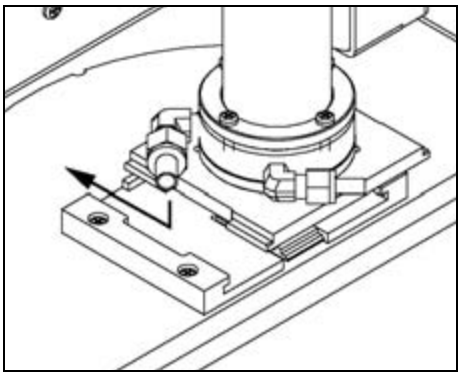


Figure 2-6
Installing Long DMA in Mounting Bracket. Push down and toward cabinet until spring locks in place.

To remove the DMA refer to Figure 2-7 and use the following steps:

1. Place a flat-bladed screwdriver between the DMA base plate and the mounting plate locking spring.
2. Push the screwdriver in about ⅛-inch [3-mm] and twist the screwdriver to unlock the spring.
3. Pull the DMA away from the cabinet and then up to release it.

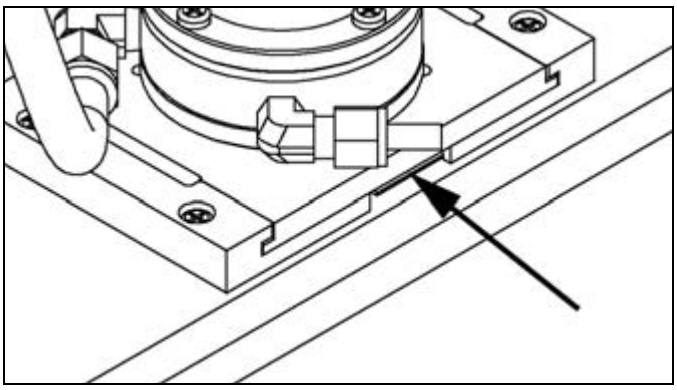


Figure 2-7
Releasing the Long DMA Base Bracket

Side-Support Bracket

Although the locking base is acceptable for most mounting applications, if the Classifier is to be transported or used in an environment with vibration (such as an aircraft), the side-support bracket from the accessory kit should be used to further mount the Long DMA. Refer to Figure 2-8 and follow the steps below to install the side-support bracket:

1. Insert the two 6-32 × ¾-inch screws in the holes of the V-shaped bracket.

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2. Install the bracket on the side of the cabinet. If the DMA is already mounted at the base, simply pull the DMA column away from the side of the cabinet enough to install the bracket (the cabinet base is somewhat flexible).

3. Install the DMA with the clamp and two 6-32 × 1-inch screws (the high-voltage cord should be routed between the clamp and bracket—but, do ***not*** pinch the cable—it should move freely).

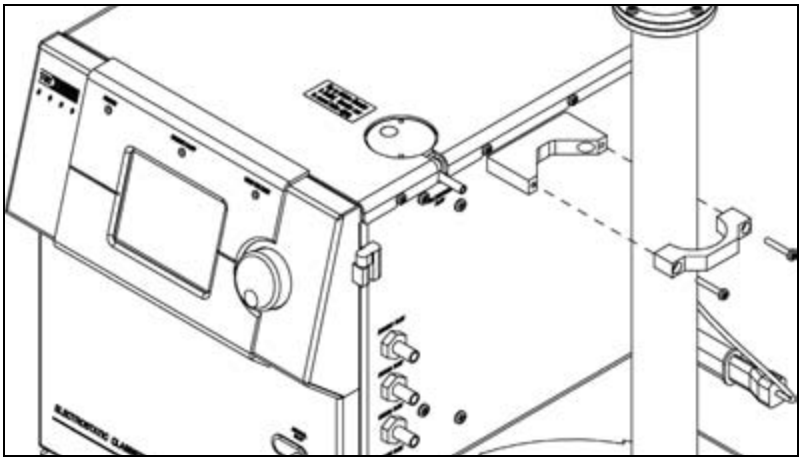


Figure 2-8
Installing the Long DMA Side-Support Bracket

Tubing

The Long DMA requires tubing to carry aerosol and sheath air between the Classifier and the DMA. For the Long DMA, two internal blowers are connected in series to provide clean sheath air up to 15 L/min (See Chapter 5 for more details). Refer to Figure 2-9 and Table 2-3 as you follow the steps listed below to install the DMA tubing:

1. The accessory kit contains flexible, conductive tubing that allows you to quickly configure the Classifier for use. Cut appropriate lengths of tubing as listed in Table 2-3.

2. Connect tube #1 from the Classifier port marked POLYDISPERSE FLOW to the DMA port marked POLYDISPERSE FLOW.

3. Connect tube #2 from the Classifier port marked SHEATH FLOW to the DMA port marked SHEATH FLOW.

4. Connect tube #3 from the Classifier port marked BYPASS FLOW to the DMA port marked EXCESS FLOW.

5. Connect tube #4 from the Classifier port marked EXHAUST FLOW to the Classifier port marked EXCESS FLOW.

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Table 2-3
Tubing Connections for Model 3081 Long DMA

Tube #	Length	Description	Part No.
1	13-in [330-mm]	Black, fits ¼-in [6.35-mm] fitting	3001903
2	23-in [584-mm]	Black, fits ⅜-in [9.5-mm] fitting	3001904
3	10.5-in [267-mm]	Black, fits ⅜-in [9.5-mm] fitting	3001904
4	6.5-in [165-mm]	Black, fits ⅜-in [9.5-mm] fitting	3001904

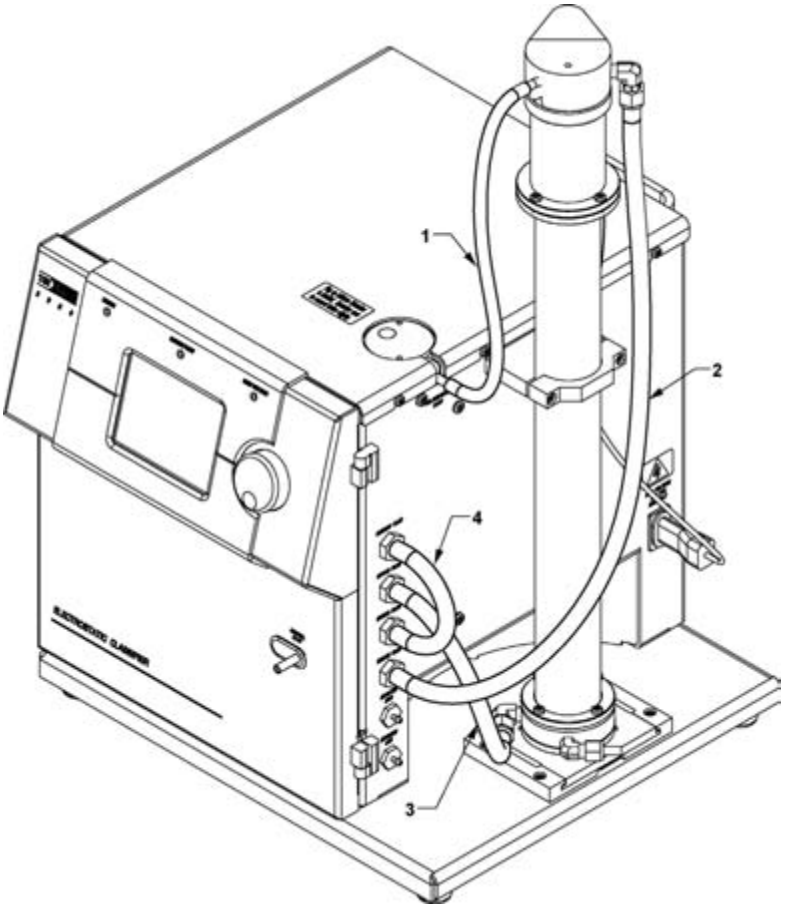


Figure 2-9
Tubing Configuration for the Model 3081 Long DMA

Installing Model 3085 Nano DMA

If your order included a Nano DMA, it will be shipped separately from the Classifier and must be assembled to the Classifier before use. The following section describes how to mount the Nano DMA, install plumbing and connect the high-voltage line.

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Nano DMA Mounting

The Classifier uses a quick-connect bracket to mount any of the two TSI DMAs. This mount provides physical support for the DMA as well as electrical grounding for safety.



Caution
If, for any reason, you operate the Classifier with a DMA that is not installed in the mounting bracket, you must connect the base of the DMA to the chassis of the Classifier with a ground strap or provide independent earth grounding to the DMA for safety.

The mounting bracket has a spring-loaded locking mechanism that holds the base of the DMA securely. To install the DMA use the following steps:

1. Place the base of the DMA down into the middle of the mounting plate on the Classifier as shown in Figure 2-10.
2. Slide the base toward the cabinet of the Classifier until you hear a click. If you have trouble getting the plates to slide, try wiggling the DMA plate from side to side slightly as you push or try a little grease on intersecting parts of the plates.

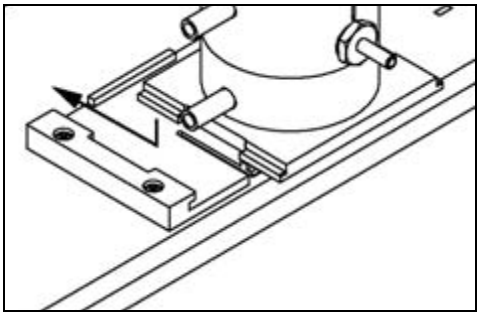


Figure 2-10
Installing Nano DMA in Mounting Bracket. Push down and toward cabinet until spring locks in place.

To remove the DMA refer to Figure 2-11 and use the following steps:

1. Place a flat-bladed screwdriver between the DMA baseplate and the mounting plate locking spring.
2. Push the screwdriver in about ⅛ inch [3 mm] and twist the screwdriver to unlock the spring.
3. Pull the DMA away from the cabinet and then up to release it.

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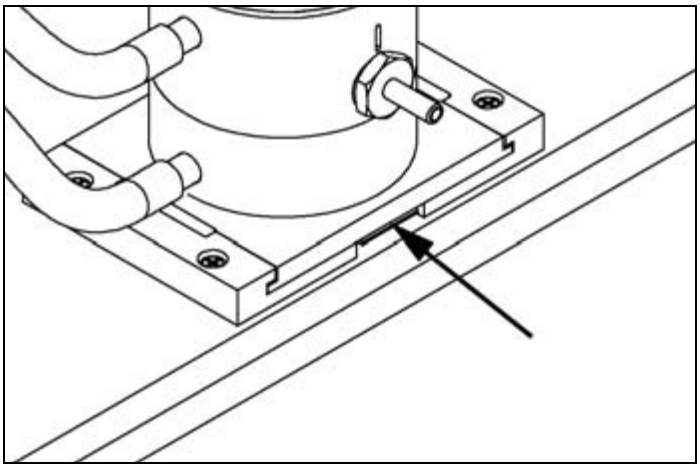


Figure 2-11
Releasing the Nano DMA Base Bracket

Tubing

The Nano DMA requires tubing to carry aerosol and sheath air between the Classifier and the DMA. There are two different modes to connect the Nano DMA to the Classifier: the Single Blower mode and the Dual Blower mode. The Single Blower mode uses one internal blower for the clean sheath air and the other for bypass flow to minimize the diffusion loss at the DMA inlet. The Dual Blower mode connects two internal blowers in series to drive the clean sheath air up to 20 L/min to reduce diffusion loss and narrow down the DMA transfer function. No bypass flow is used in this mode. See Chapter 5 for more details.

Single Blower Mode

For Single Blower mode, refer to Figure 2-12 and Table 2-4 as you follow the steps listed below to install the DMA tubing:

1. The accessory kit contains flexible, conductive tubing that allows you to quickly configure the Classifier for use. Cut appropriate lengths of tubing as listed in Table 2-4.
2. Attach the ⅜ to ¼-inch tubing adapter from the accessory kit to the Polydisperse Flow inlet on the Nano DMA.
3. Connect tube #1 from the Classifier port marked POLYDISPERSE FLOW to the DMA port marked POLYDISPERSE FLOW.
4. Connect tube #2 from the Classifier port marked SHEATH FLOW to the DMA port marked SHEATH FLOW.
5. Connect tube #3 from the Classifier port marked EXCESS FLOW to the DMA port marked EXCESS FLOW.

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6. When using the bypass flow, connect tube #4 from the Classifier port marked BYPASS FLOW to the DMA port marked BYPASS FLOW. Leave the EXHAUST FLOW port on the Classifier open without the cap (#6 in Figure 2-12).

   Note: *Impactor inlet has to be removed when using the bypass flow because the pressure drop across the impactor inlet is too large for the pump with the 10 to 15 L/min bypass flow.*

7. When the bypass flow is *not* used, remove tube #4 between the Classifier and the DMA. Add the cap to the BYPASS FLOW port on the DMA.

Table 2-4
Tubing Connections for Model 3085 Nano DMA in Single Blower Mode

Tube #	Length	Description	Part No.
1	8-in [203-mm]	Black, fits ¼-in [6.35-mm] tubing	3001903
2	7-in [178-mm]	Black, fits ⅜-in [9.5-mm] tubing	3001904
3	7-in [178-mm]	Black, fits ⅜-in [9.5-mm] tubing	3001904
4	7-in [178-mm]	Black, fits ⅜-in [9.5-mm] tubing	3001904
5		⅜ to ¼-in tubing adapter	1035992
6		⅜-in cap fitting	1611270

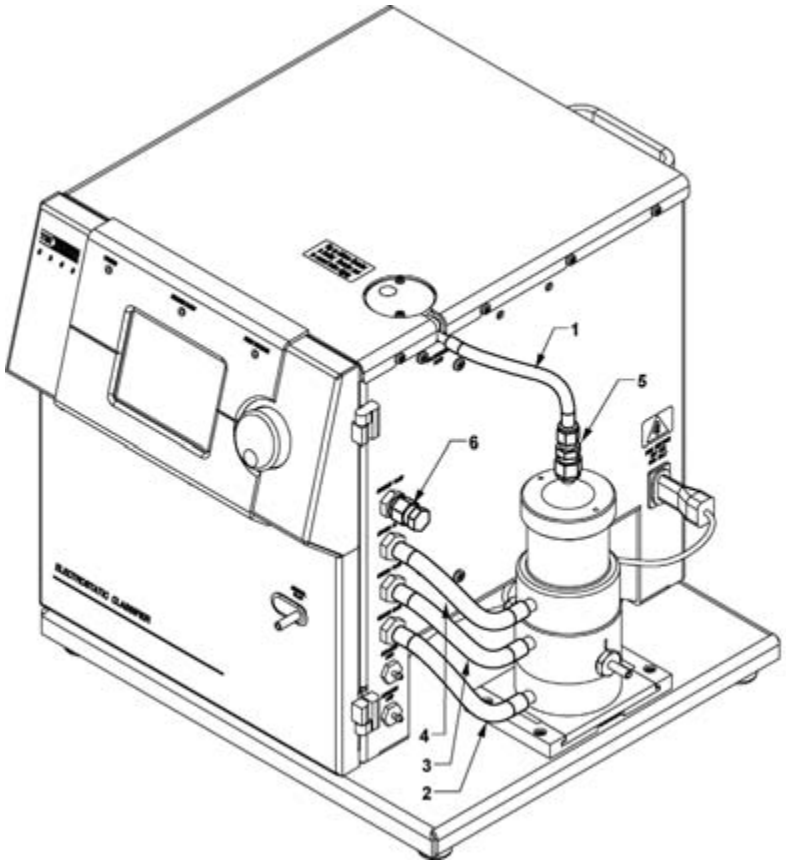


Figure 2-12
Tubing Configuration for the Model 3085 Nano DMA in Single Blower Mode

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Dual Blower Mode

For Dual Blower mode, refer to Figure 2-13 and Table 2-5 as you follow the steps listed below to install the DMA tubing:

1. The accessory kit contains flexible, conductive tubing that allows you to quickly configure the Classifier for use. Cut appropriate lengths of tubing as listed in Table 2-5.
2. Attach the ⅜ to ¼-inch tubing adapter from the accessory kit to the Polydisperse Flow inlet on the Nano DMA.
3. Connect tube #1 from the Classifier port marked POLYDISPERSE FLOW to the DMA port marked POLYDISPERSE FLOW.
4. Connect tube #2 from the Classifier port marked SHEATH FLOW to the DMA port marked SHEATH FLOW.
5. Connect tube #3 from the Classifier port marked BYPASS FLOW to the DMA port marked EXCESS FLOW.

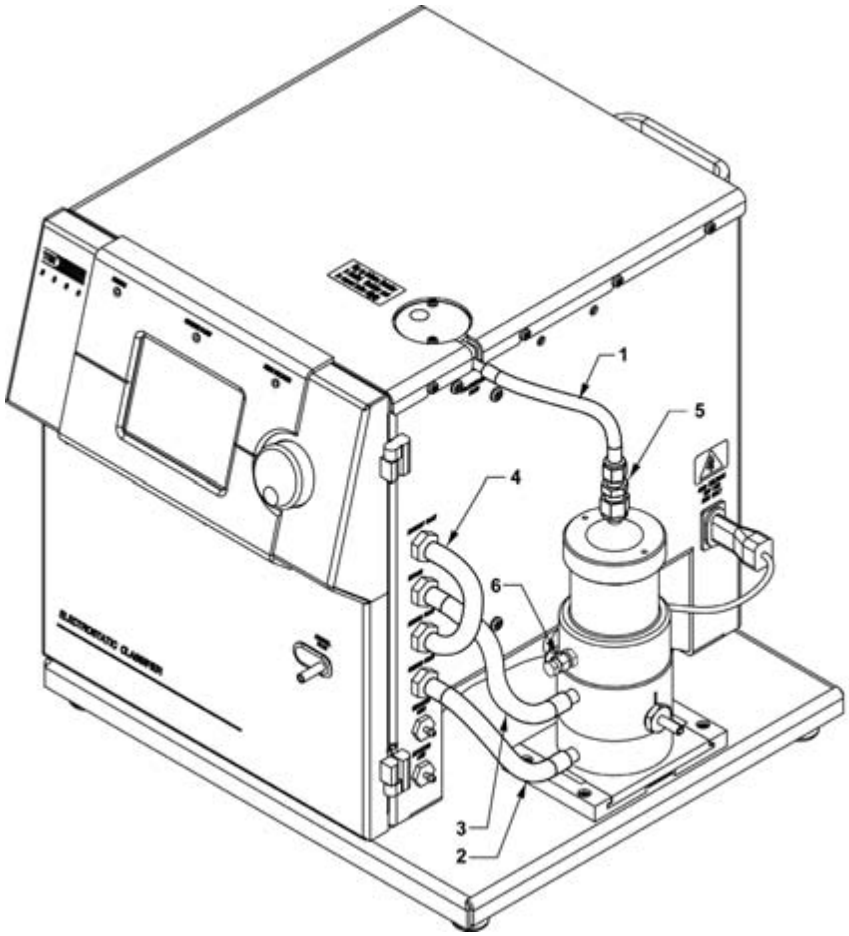


Figure 2-13
Tubing Configuration for the Model 3085 Nano DMA in Dual Blower Mode

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6. Connect tube #4 from the Classifier port marked EXHAUST FLOW to the Classifier port marked EXCESS FLOW.

7. In this setup, the bypass flow is ***not*** used. Add the cap to the DMA port marked BYPASS FLOW.

Table 2-5
Tubing Connections for Model 3085 Nano DMA in Dual Blower mode

Tube #	Length	Description	Part No.
1	8-in [203-mm]	Black, fits ¼-in [6.35-mm] fitting	3001903
2	7-in [178-mm]	Black, fits ⅜-in [9.5-mm] fitting	3001904
3	9.5-in [241-mm]	Black, fits ⅜-in [9.5-mm] fitting	3001904
4	6.5-in [165-mm]	Black, fits ⅜-in [9.5-mm] fitting	3001904
5		⅜ to ¼-in tubing adapter	1035992
6		⅜-in cap fitting	1611270

High-Voltage Connection

Each DMA has a high-voltage cable and connector specially designed to connect to the Electrostatic Classifier cabinet.



Caution

You should never pull or tug on the high-voltage cable—always grip the plug to disconnect the cable. You should never use the cable to carry or move the instrument. If the cable breaks, you could be exposed to dangerous high voltage. A cut or damaged cable should be replaced immediately. Always switch the instrument off before connecting or disconnecting the high-voltage connector.

1. When the Long or Nano DMA is secure, plug the high-voltage cord into the socket marked: HIGH VOLTAGE OUT FOR DMA ONLY on the side of the Classifier. The connector simply pushes together.

2. To remove the high-voltage connector, grip the connector and pull straight out.

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CHAPTER 3

Controls, Indicators, and Connectors

Use the information in this chapter to familiarize yourself with the location and function of controls, indicators, and connectors on the Model 3080 Electrostatic Classifier.

This chapter is organized into four sections describing aspects of the instrument: Front Panel, Back Panel, Side Panel, and Internal Components.

Front Panel

The main components of the front panel are the LCD display, the control knob, the three status LEDs, the aerosol inlet and neutralizer chamber as shown in Figure 3-1.

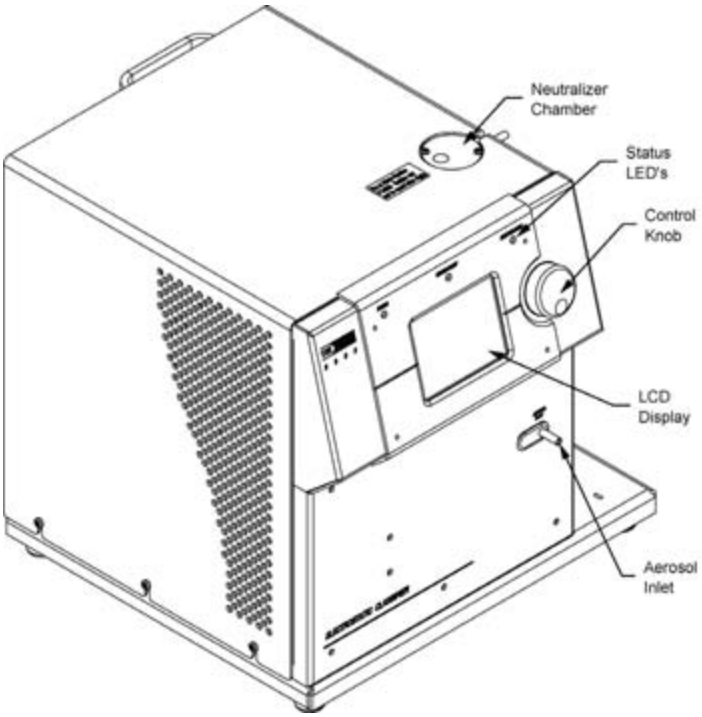


Figure 3-1
Front of the Model 3080 Electrostatic Classifier

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The LCD display is used in conjunction with the control knob to adjust the various flows, high voltage, particle size settings and many menu items. The 320 × 240 pixel LCD display provides continuous real-time display of settings.

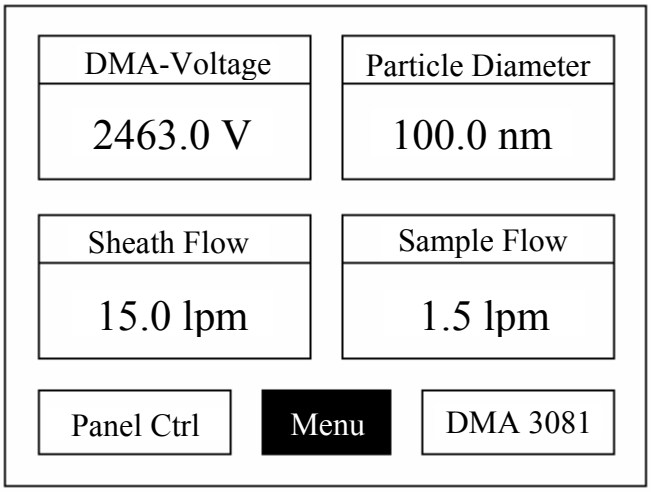


Figure 3-2
Classifier LCD Display

There are several operations you can perform using the control knob with the display. Refer to Chapter 5, "Operating the Classifier," for a description of how to make selections and change values on the menu.

Aerosol Inlet

The aerosol inlet on the front of the Classifier is designed for use with the impactor. Tubing can be attached to the inlet to sample directly when necessary. The inlet is 0.25 inch (6.35 mm) in diameter for use with ¼-inch Swagelok®-type connectors or with flexible tubing with a slightly smaller inner diameter.

Note: *Conductive tubing is recommended for use with the Classifier to minimize particle loss due to electrostatic charge. Suitable tubing is available from TSI.*

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Indicators

There are three status LEDs on the Classifier: Power, Sheath Flow, and High Voltage.

- The green Power LED indicates that power is supplied to the instrument.
- The Sheath Flow LED indicates that the sheath flow is within ±0.05 L/min of its set point.
- The High Voltage LED indicates that the High-Voltage module is operating correctly. If the LED is blinking, this indicates that the high-voltage module has been installed incorrectly.

Neutralizer Chamber

The Neutralizer Chamber allows a TSI Model 3077A/3077 Aerosol Neutralizer to be installed in the cabinet to meet safety requirements for radiation exposure. The neutralizer provides an equilibrium charge on aerosols that enter the DMA.

Back Panel

As shown in Figure 3-3, the back panel has a variety of power and data connections as well as a cooling fan.

AC Power Connector

The AC Power Connector accepts the line cord (supplied) to provide AC power to the instrument. See “Power Connection” in Chapter 2 for more information.

DC Power Input

The DC power connector is a quarter-turn quick-connect entry point that allows the Classifier to be powered by a 22–26 VDC (24 VDC nominal) 7A max. power source. This power could be supplied by aircraft power or two 12 VDC automotive batteries in series. Refer to Figure 3-4 for pin designations for this 24 VDC power input port. Contact TSI for the adapter cable (TSI part number 1035551) and instructions on using this power method.

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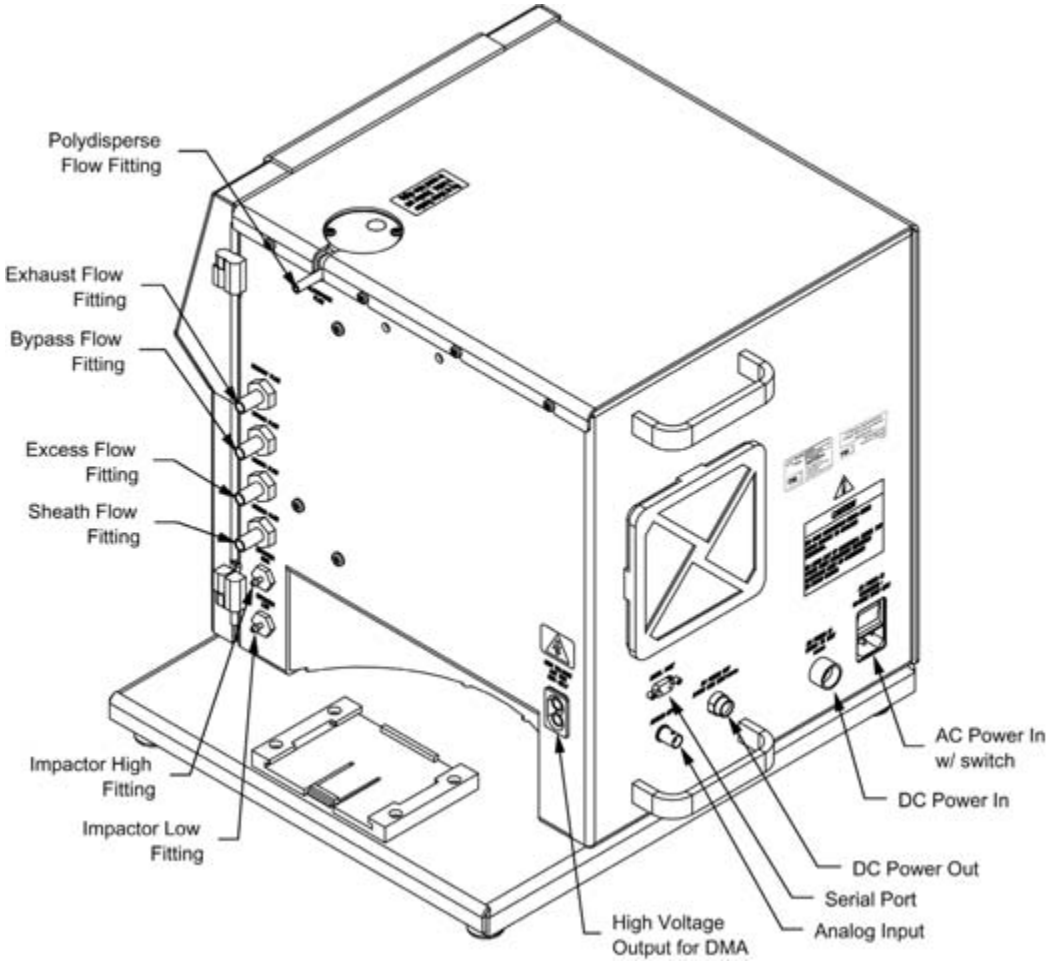
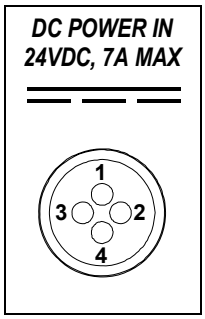


Figure 3-3
Back Panel and Side Panel of the Model 3080 Electrostatic Classifier



Pin Number	Signal	
1	GND Chassis	Green
2	+24V	Blue
3	GND	Brown Shield
4	Not Used	

Figure 3-4
24V DC Power Input Pin Designations

Serial Port

The Serial Port is a standard RS-232 serial connection that allows communications between the system computer and the Classifier. Serial commands are sent to and from the computer to collect instrument status and provide control information.

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Note
If the Classifier is part of an SMPS system, when connecting the serial cable, make sure you connect the cable from the computer to the CPC. It should not be connected to the Model 3080 Electrostatic Classifier. The SMPS system requires the synchronization between DMA voltage and particle counts that the CPC provides.

If you are developing specialized software for the Classifier or performing troubleshooting, refer to Appendix C. This appendix provides a complete description of the serial data commands, as well as signal connections.

DC Power Out

The DC power connector is a quarter-turn quick-connect power connector. It is intended to be used to power an external auxiliary device using 24 VDC at no more than 0.2 Amps. Contact TSI for more information on using this connector to power an external device.

Analog Input

This BNC connector is used to control the high-voltage setting for the DMA using an external analog signal. This signal is typically provided by a Condensation Particle Counter (CPC) in a Scanning Mobility Particle Sizer (SMPS) system. A 0-10V signal corresponds to a high-voltage setting of 0–10,000V when the front panel is set for **Analog Control**.

Side Panel

The side panel shown in Figure 3-3 includes plumbing connections for the sheath and bypass air flows, impactor pressure tap connections, aerosol neutralizer output, and high-voltage connector for a DMA.

Polydisperse Flow Fitting

The Polydisperse Flow fitting provides a ¼-in tube connection from the exit of the neutralizer chamber. This is where aerosol exits the neutralizer and is usually connected to the inlet of the DMA. The connection can be made with flexible conductive tubing or with Swagelok-type connections and rigid conductive tubing.

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Exhaust Flow Fitting

The Exhaust Flow fitting is a ⅜-in straight fitting that allows connections for the bypass air exiting the Classifier for the Nano DMA or for the sheath air flow for all DMAs. This fitting is left open in Single Blower mode, or it is connected to the Excess Flow fitting on the Classifier in Dual Blower mode. The connection can be made with flexible conductive tubing or with Swagelok-type connections and rigid tubing.

Bypass Flow Fittings

The Bypass Flow fittings are ⅜-in straight fittings that allow connections for bypass flow if available with your DMA. Typically, the Model 3085 Nano DMA uses the bypass flow to bring aerosol to the inlet slit faster to minimize ultrafine particle losses due to diffusion. The Exhaust Flow port on the Classifier is usually left open to exhaust the filtered bypass flow. The Bypass Flow fitting on the Classifier can be connected to the Bypass Flow fitting on the Nano DMA with flexible conductive tubing or with Swagelok-type connections and rigid tubing. This bypass flow is up to 15 L/min. This bypass flow normally is set between 10 and 15 L/min. The BYPASS FLOW port on the Nano DMA is capped when bypass flow is not used.

A second use of the bypass flow is to provide added flow for the Model 3081 long DMA to reach flows up to 15 L/min or for Model 3085 Nano DMA to reach flows up to 20 L/min. The bypass can be connected in series with the sheath flow to increase the sheath flow rate.

Excess Flow Fitting

The Excess Flow fitting is a ⅜-in straight fitting that allows connections for the excess air exiting all DMAs. This fitting is either connected to the Excess Flow fitting on the DMA in Single Blower mode or to the Exhaust Flow fitting on the Classifier in Dual Blower mode. The connection can be made with flexible conductive tubing or with Swagelok-type connections and rigid tubing.

Sheath Flow Fitting

The Sheath Flow fitting is a ⅜-in straight fitting that allows connections for the sheath air used in all DMAs. This fitting is connected to the Sheath Flow fitting on the DMA. The connection can be made with flexible conductive tubing or with Swagelok-type connections and rigid tubing.

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Impactor High/Low

The impactor fittings are used to connect an internal pressure transducer to the tubes connected to the impactor on the inlet of the Classifier. This allows you to display the aerosol flow rate on the front panel (based on a calibration stored in the Classifier for each impactor nozzle).

High Voltage Out for DMA Only

This is a specialized high-voltage connector for use with all TSI DMAs to connect the high-voltage supply in the Classifier to the DMA.

Internal Components

The main internal components are shown in Figure 3-5. For a more detailed explanation of these components refer to Chapter 5.

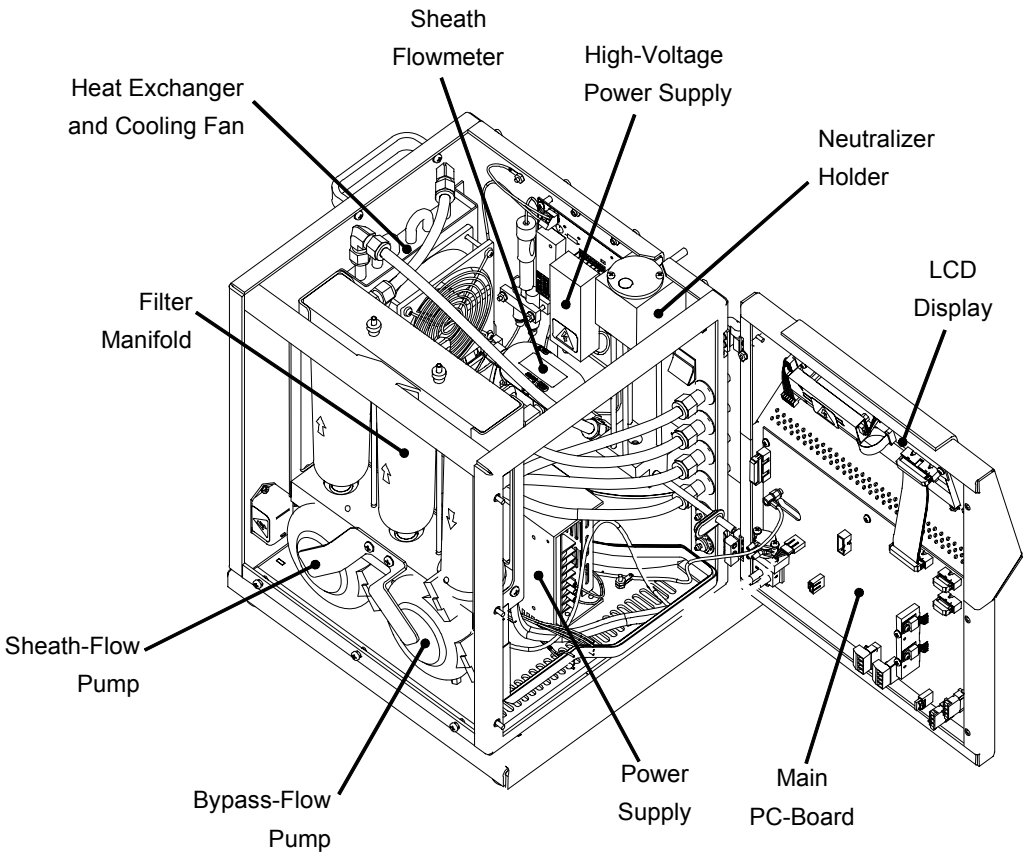


Figure 3-5
Main Internal Components

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System Description

The Classifier consists of several subsystems that are needed in addition to the DMA to process a polydisperse aerosol and provide a monodisperse output. The main subsystems include: impactor, sheath-air flow controller, neutralizer, high-voltage controller, and DMA. All control can be performed using the front-panel interface, or using a computer and serial port. In addition, a CPC in an SMPS configuration can provide voltage control for the system. Figure 3-6 shows how the systems are configured with the Classifier. The subsystems are described in more detail below.

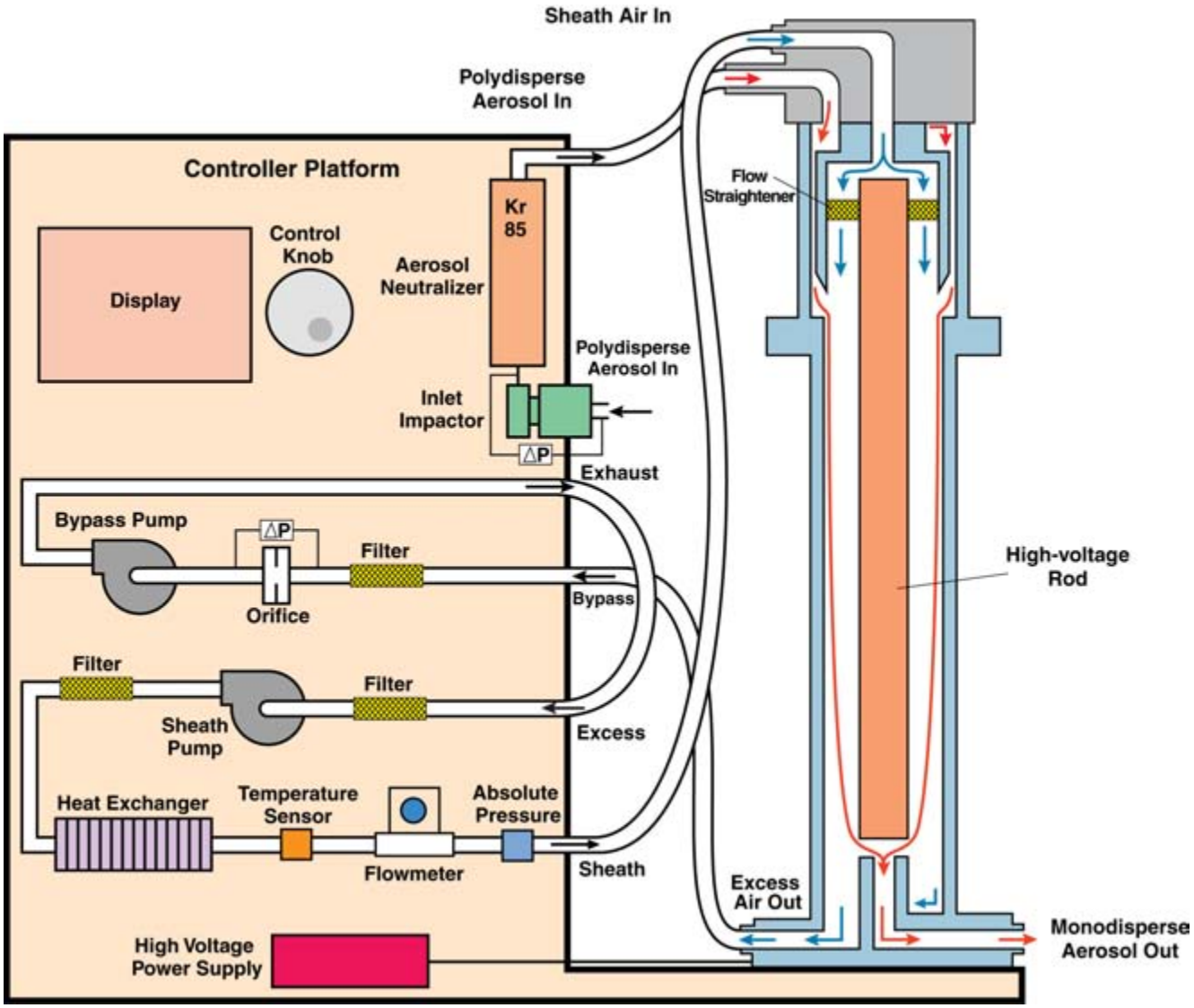


Figure 3-6
Schematic Diagram of the Classifier

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Impactor

An impactor may be mounted on the outside of the Electrostatic Classifier (see Figure 2-5). The aerosol first enters an impactor, which removes particles above a known particle size by inertial impaction. For more information on impactor theory, see Appendix B, "Impaction Theory and Operation."

Sheath Flow Controller

The sheath flow controller maintains a constant flow through the sheath flow loop. The loop consists of a filter, pump (blower), filter, heat exchanger, and flowmeter (see Figure 3-6). The flowmeter has built-in temperature sensor and pressure sensor which are shown separately in Figure 3-6. The flow is monitored by the microprocessor and used to control the pump based on the desired flow rate set from the front panel. The heat exchanger is used to remove heat added to the flow loop by the pump. Readings from the temperature and pressure sensors are used to update the particle mobility and size displayed on the front panel display.

Bypass Flow Controller

The bypass flow controller maintains a constant flow through the bypass flow path. The flow path consists of a filter, an orifice, and a pump (blower). The pressure drop across the orifice is monitored to control the pump and maintain a constant flow.

For both Model 3081 Long DMA and Model 3085 Nano DMA, the bypass flow loop can be connected in series with the sheath flow loop to provide higher sheath flow rate. The flowmeter in the sheath flow controller loop is used for the feedback control of the total flow rate when two blowers are connected in series.

Neutralizer

The neutralizer provides a known charge distribution on the aerosol entering the DMA. The Classifier is made to accommodate a Model 3077A/3077 Krypton-85 neutralizer without having to remove the cabinet cover. For more information on the neutralizer/charger, see "Charging Theory" in Appendix B.

The Model 3077A is a default neutralizer for the Model 3080 Electrostatic Classifier. For aerosol at low concentrations, an optional Model 3077 Krypton-85 neutralizer can be used to neutralize the aerosol. The Model 3077 has exactly the same dimensions as the Model 3077A so it fits in the neutralizer chamber as well. The Model 3077 has five times less intensity (2 millicurie

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instead of 10 millicurie) as that of the 3077A so it is sufficient enough to achieve charge equilibrium for low concentration aerosols for example ambient aerosols.

High-Voltage Controller

The High-Voltage controller provides a charge on the center rod of the DMA. This high voltage is controlled by the microprocessor based on the desired setting from the front panel and monitored by a sensitive high-voltage divider. The default High Voltage controller is with negative polarity so positive particles are selected by the DMA. An optional positive polarity High Voltage controller is available through TSI (part number 1030354) for selecting negative particles. Refer to Chapter 6, "Replace Negative High-Voltage Controller with Positive High-Voltage Controller," for details.

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CHAPTER 4

DMAs: Using Different Models with the Classifier

This chapter describes the Differential Mobility Analyzers (DMA) that can be used with the Electrostatic Classifier. These DMAs consist of the Model 3081 Long DMA and Model 3085 Nano DMA. Custom DMAs can also be used with the 3080 Electrostatic Classifier but they are not described here.

Model 3081 Long DMA

The Long DMA, as shown in Figure 4-1, is the traditional length DMA used in the TSI Model 3071 Classifier for many years. The Long DMA provides the widest size range (10-1000 nm) available of any of the DMAs.

A cross-sectional view of the Long DMA is shown in Figure 4-2. The mobility analyzer consists of two cylindrical electrodes made of polished stainless steel and insulated from each other by a Teflon® spacer at the top and an acetyl-plastic (Black Delrin®) spacer at the bottom. The lower spacer allows enough high-voltage leakage to prevent static charge build up near the exit slit. This gives better particle transport for small particles than the traditional TSI Model 3071 Classifier with Long DMA which had Teflon insulators at both the top and bottom.

The center electrode has an outer radius of 0.369 in. (0.937 cm) and is coaxial with the outer electrode which has an inner radius of 0.772 in. (1.961 cm). The characteristic length of a DMA is defined as the length between middle of inlet slit to middle of outlet slit. However, as the inlet slit is formed by a sharp edge and a radius, the middle of shortest distance between the edge and the radius, projected to vertical line is used as the mid point of the inlet slit. The characteristic length for the long DMA is 17.468 in. (44.369 cm).

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Figure 4-1
Model 3081 Long Differential Mobility Analyzer

Particle-free (filtered) air enters the Sheath Flow inlet of the DMA and passes to an annular chamber at the top of the DMA. The flow then goes through a double screen of fine nylon (Dacron®) mesh to straighten the flow. The air flows downward axially through the classifier region. The Polydisperse Flow enters the DMA though an inlet pipe from the top and flows in an axial direction between two narrow concentric cylinders to evenly distribute the concentric flow and concentration distribution. This thin annular flow is introduced into the classifier region and smoothly merged with the laminar sheath-air flow.

Particles with negative charge stick to the outer electrode, whereas, noncharged (neutral) particles are removed unaffected with the Excess Flow. Positively charged particles are carried axially downward with the sheath airflow while also being attracted radially toward the center electrode due to the electric field. Particles with a narrow range of electrical mobility reach a circumferential slit with twelve holes in the center electrode and exit the DMA through the lower insulator as the Monodisperse Flow. If the optional positive polarity High Voltage controller is used, negatively charged particles with the narrow range of electrical mobility exit the DMA through the circumferential slit.

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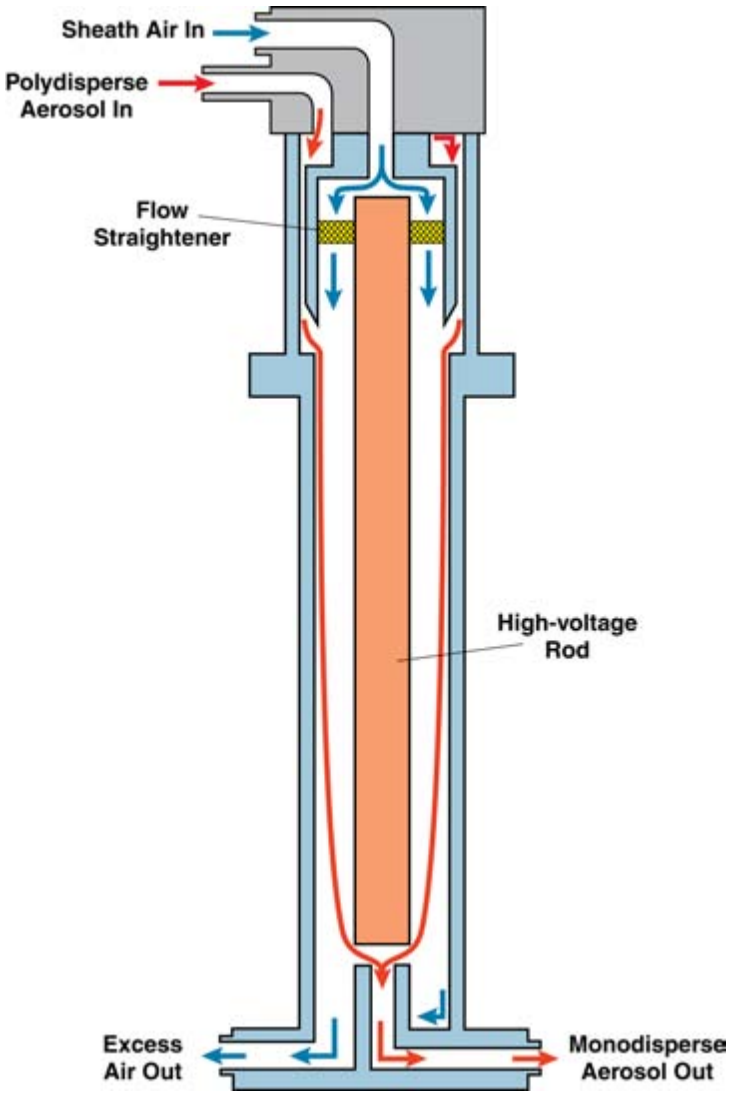


Figure 4-2
Schematic Diagram of Long DMA (*drawing not to scale*)

Model 3085 Nano DMA

The Nano DMA, as shown in Figure 4-3, is optimized for the size range below 20 nm. However, it covers a broad range of particle diameters from 2 to 150 nm.

The Nano-DMA is an extensive modification of the Long-DMA to optimize its performance with small particles. Although the Nano DMA is similar to the Long DMA, it has many important differences explained below (refer to Figure 4-4).

For the Nano DMA. the center electrode has an outer radius of 0.369 in. (0.937 cm) and the grounded outer electrode has an inner

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radius of 0.75 in. (1.905 cm). To reduce the effects of diffusion (by reducing the residence time of particles in the classification zone), the characteristic length has been reduced to 1.963 in. (4.987 cm). The characteristic length is defined as the length between middle of inlet slit to middle of outlet slit.



Figure 4-3
3085 Nano Differential Mobility Analyzer

The inlet to the Nano DMA is an axial ⅜-inch port. The aerosol flows through a short connecting tube that quickly widens in a conical section to reach a narrow annular channel. The inner cone is fixed by four narrow supports at the top of the outer cylinder. This design promotes axisymmetric aerosol flow and reduces distortions of the flow field. To accommodate the axial aerosol inlet, the sheath air flow is routed through the center electrode from the bottom before it is turned 180 degrees and passed through the same style Dacron screen flow-straightener (P/N 1030389) as the Long DMA.

The Nano DMA has an extra concentric cylinder below the inlet slit that allows an increased polydisperse aerosol flow up to the inlet slit. This increased flow reduces the particle transport time and therefore, reduces diffusion losses up to the inlet slit. The extra inlet flow exits the DMA as bypass flow. In addition, to match the velocity of sheath air and aerosol flow, and to reduce electric field penetration into the slit, the slit gap has been reduced to 0.26 in. [0.66 mm]. The extra flow passes through a perforated ring to provide enough pressure drop to assure a uniform and undisturbed aerosol flow at the inlet slit.

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To improve the flow field at the sample slit (in the center electrode), the exit design for the Nano DMA is four thin supports instead of twelve holes for the Long DMA. The lower section of the center electrode also contains concentric cylinders. The inner cylinder allows the sheath air to pass up to the top of the DMA while the outer cylinder carries the monodisperse sample flow from the exit slit to the exit port.

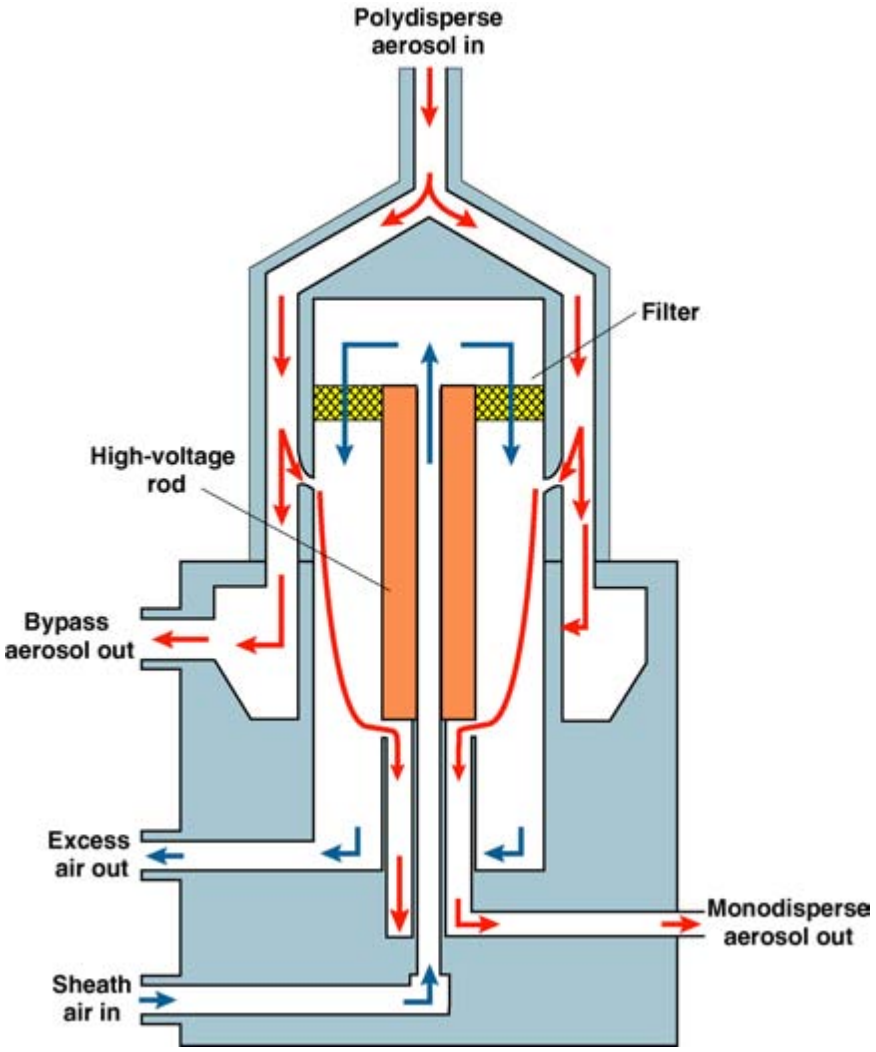


Figure 4-4
Schematic Diagram of the Model 3085 Nano DMA

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CHAPTER 5

Operating the Classifier

This chapter describes how to operate the Classifier using the control knob and LCD display.

Display and Menus

The Classifier is controlled primarily through the multifunction control knob and the display on the front of the instrument. Refer to Table 5-1 to experiment with the control knob.

Table 5-1
Control Knob Functions

To move the cursor around	Turn the control knob until the item you wish to change has been highlighted. Press the control knob into the panel to select that item. Turn the knob again to modify the item and then press the knob again to store the setting.
To choose menu items	Select the menu item in the bottom center of the screen using the method described above. Items with a ▶ symbol on the right indicate further options. Pushing the control knob will allow you to change those items by rotating the knob. Push again to store the setting. Scroll to the very bottom or top and choose Exit to leave the menu.
Knob Adjustment	Fine adjustment of the control knob (that is, moving from one selection to the next) is best accomplished using the outer edge of the knob. Faster movement (that is, setting a voltage) is best accomplished using your index finger and the dimple in the knob.

Rotating the knob after the instrument has first been powered up highlights the various panes in the display window. The panes are rotated from Menu to Panel or Analog Ctrl, to Sheath Flow Rate, to DMA-Voltage, to Particle Diameter, to the Multifunction Pane and then back to Menu in a clockwise fashion.

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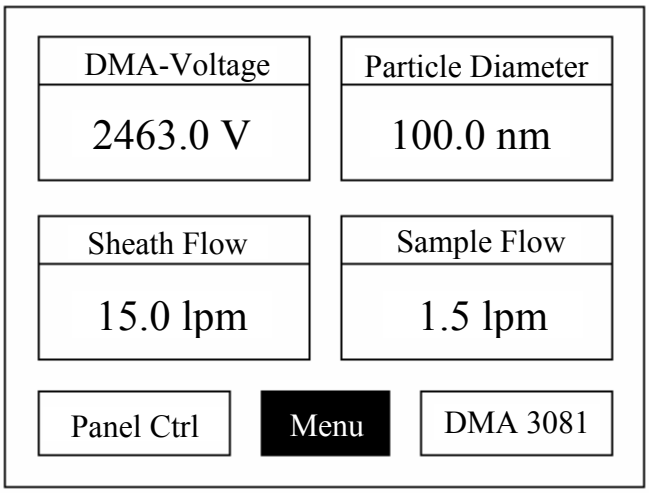


Figure 5-1
Classifier LCD Display

For most of the panes, you can access the function in the pane by pushing the center of the control knob into the panel. The functions of each pane are listed below.

Menu

The Menu pane is highlighted when you first power-up the instrument. This item allows you to set all aspects of the Classifier. The menu items are summarized in Table 5-2 and addressed in detail below.

Exit	This allows you to exit from the menu commands. It is located at the extreme top and bottom of the menu list for convenience.
Sheath Flow Mode	This selection toggles between *Single Blower* and *Dual Blower*. The Single Blower mode is used with the Model 3085 Nano DMA. In this mode the sheath air blower and bypass blower are controlled independently. In the Dual Blower mode the sheath and bypass blowers are connected in series (by connecting tubing from the Excess Flow port to the Exhaust Flow port on the Classifier). This mode is used with the Model 3081 DMA to boost the sheath air flow up to 15 L/min. This is necessary due to the higher pressure drop through the Model 3081. For the Model 3085, Dual Blower mode can also be used to boost the sheath flow rate up to 20 L/min to narrow down DMA transfer function and reduce diffusion losses. The maximum sheath flow rate is 15 L/min in Single Blower mode for the Model 3085 Nano DMA.

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Sheath Flow Rate	This selection (also available from the main screen) allows you to set the sheath flow rate from 0 (off) to 15 L/min in Single Blower mode and from 0 (off) to 20 L/min in Dual Blower mode. Note that it requires operating in Dual Blower mode to reach 15 L/min with the Model 3081 Long DMA and 20 L/min with the Model 3085 Nano DMA (see above).
Bypass Flow Rate	The bypass flow rate (also viewable from the main screen) is disabled in Dual Blower mode (see above). In Single Blower mode the range of bypass flows is from 0 (off) to 15 L/min. This flow is most useful with the Model 3085 Nano DMA for providing higher flow to the inlet of the DMA to reduce diffusion losses.
DMA Model	The DMA models available from this menu include the standard TSI models: Model 3081 Long DMA and Model 3085 Nano DMA. Selection of these models corresponds to parameters that are included in the calculation of particle size vs. flow rate and voltage. Three other DMA models can be selected: Custom DMA 1, Custom DMA 2, and Custom DMA 3. Parameters for these custom DMAs must be downloaded using the serial commands described in Appendix C. The pane at the lower right corner of the front panel display shows the current DMA selected: DMA 3081, DMA 3085, DMA No. 1, DMA No. 2, and DMA No. 3.
Impactor	The impactor nozzle mounted on the inlet of the Classifier is selected with this menu item. If no impactor is used, *Pressure Drop* should be selected. In this case the multipurpose pane in the main window will only show Impactor Pressure in cmH_2O. The value shown here is close to zero because no impactor is installed. For the selections: .0457 cm, .0508 cm, and .0710 cm the calibrated flow rate will be displayed in the multipurpose pane under Sample Flow Rate. The serial numbers (SN) of the nozzles calibrated are also shown in the selection menu.
Cabinet Temperature	This temperature is an indication of the internal cabinet temperature. This is useful for troubleshooting issues like clearance space around the fan inlet and exhaust holes in the cabinet. If this temperature reads consistently 10°C above ambient temperature, check for a dirty fan filter and proper clearance around the cabinet.
Power-Up With	This menu controls any settings that are enabled during power-up. For example, if the sheath flow is set to 6.0 L/min and “current settings” is selected, the instrument will start up with the sheath flow set to 6.0 L/min. Selecting “default settings” will restore factory defaults.

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Display Brightness	This allows you to adjust the brightness of the LCD display for best viewing. The brightness may have to be adjusted if you alter the lighting in the room dramatically (that is, nighttime lighting vs. bright daylight). The setting varies from 1 to 10 and the display is immediately updated. The brightness may also be reduced to increase the lifetime of the fluorescent backlight.
Flow Calibration	This menu accesses further menus to aid in calibrating the Sheath Flow, Bypass Flow, and Impactor Flows. This menu is addressed further in Appendix D, "Classifier Calibration."
Diagnostic	The Diagnostic menu item toggles between normal display operation and a diagnostic display which shows additional troubleshooting information such as digital-to-analog converter values. It is normally used only for troubleshooting and produces a cluttered main screen.
Firmware Version	This read-only item shows the current firmware version installed in the Classifier.

(continued on next page)

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Table 5-2
Classifier Menu Structure Quick Reference

Exit
Sheath Flow Mode
Single Blower
Dual Blower
Sheath Flow Rate
0 (off) to 15.0 L/min (in Single Blower mode)
0 (off) to 20.0 L/min (in Dual Blower mode)
Bypass Flow Rate
Disabled (in Dual Blower mode)
0 (off) to 15.0 L/min (in Single Blower mode)
DMA Model
Model 3081
Model 3085
Custom DMA 1
Custom DMA 2
Custom DMA 3
Impactor
Pressure Drop
.0457 cm; SN: 103
.0508 cm; SN: 125
.0710 cm; SN: 118
Cabinet Temperature (read only)
Power-Up With
Exit
Current Settings
Default Settings
Display Brightness
0 to 10
Flow Calibration
Exit
Sheath Flow
Bypass Flow
Impactor Flow
Diagnostic
On
Off
Firmware Version (read only)
Exit

Sheath Flow Rate

The Sheath Flow Rate is displayed in this pane and can be set by pressing and turning the control knob. When you do this the Multifunction Pane will change to show the Particle Size Range that can be selected based on the full range of voltage setting (0 to 10,000 volts), the type of DMA, temperature, pressure and the flow setting. When you have finished setting the sheath flow, the multifunction pane will return to its previous setting.

The sheath flow can be set to a maximum of 15 L/min in Single Blower mode and 20 L/min in Dual Blower mode. The blower mode is set using the Menu as explained above. However, the Long DMA

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is only able to reach 15 L/min in Dual Blower mode due to the high pressure drop across it.

DMA-Voltage

The rod voltage is the primary setting that controls the particle size exiting the DMA. This control can be set from 0 to 10,000 volts for any of the DMAs. As you change the voltage setting, the Particle Diameter pane is updated to reflect the calculated particle size based on voltage, DMA type, flow rate, temperature and pressure. The smallest internal digital voltage step possible is:

10,000/65535 = 0.1526 volt

Particle Diameter

The Particle Diameter is calculated based on voltage, DMA type, flow rate, temperature, pressure and a single charge assumption. However, a powerful feature of the Classifier controller is that you can directly enter a particle diameter and the nearest voltage setting will be appeared in the voltage pane and the DMA voltage will be controlled to this setting. This allows you to easily set particle size without consulting curves or tables.

Multifunction Pane

The multifunction pane, as the name suggests, provides a variety of read-only secondary information. By pressing on the control knob in this pane you can rotate through six different selections of information. The information displayed can be locked by pressing on the control knob again. The choices available are:

- Bypass Flow Rate
- Absolute Pressure (based on an internal pressure tap near Sheath Flow port)
- Sample Flow Rate (Impactor Pressure is displayed if *Pressure Drop* is selected from the menu)
- Electrical Mobility
- Particle Size Range
- Sheath Flow Temperature

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Impactor

The primary function of the impactor is to remove larger particles that carry more than a single charge. However, the impactor is also used as a flowmeter, since the pressure drop across the impactor is proportional to the square of the flow rate.

Table 5-3
Flow Range for Each Impactor Nozzle

Flow Range (L/min)	Nozzle Size (cm)
0.2 to 0.8	0.0457
0.3 to 1.0	0.0508
0.6 to 2.1	0.071

The nozzle size and flow rate determine the largest particle size that can be sampled within each SMPS measuring size range. For best results, use Table 5-3 to determine the correct nozzle to use for the flow you set. Each nozzle is interchangeable and can be screwed into the impactor body with a gasket to seal the thread. Using the Multifunction pane in the display, you can view the sample flow rate directly from the pressure drop measured across the impactor. The Classifier stores an internal calibration curve for each impactor size and serial number. To change the impactor, follow the steps below:

1. Turn on the Classifier and rotate the control knob to highlight the **Menu** pane on the display.
2. Click the control knob by pushing in. This should bring up the menu.
3. Scroll by rotating the control knob until **Impactor** is highlighted and then click the selection.
4. Select the impactor size and serial number corresponding to the impactor physically installed and click the selection.
5. Scroll the menu up or down to **Exit** and click.

When you have selected a nozzle size you need to physically install it (see Chapter 2).

Sheath Air Flow Controller

Traditionally, most DMAs have been set up with four flows: polydisperse, sheath, excess, and monodisperse. Managing all of these flows can be a daunting task requiring several vacuum or pressure sources and complex plumbing. Although the Model 3080

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Classifier can be set up this way, the complexity of the system can be reduced dramatically if the sheath and excess flows are connected into a recirculating flow arrangement.

In this case, the excess air flow is fed back into the DMA as sheath air. The recirculating flow arrangement requires a pump to move the air, filters to clean the air entering and leaving the pump, a heat exchanger to remove heat added by the pump, and a flowmeter to control the flow. In a sealed system the sheath and excess flows are equal, therefore, the aerosol flow and monodisperse flows are also equal. Thus, when the sheath/excess flow is set, the remaining two flows are set by either the aerosol source or the particle detector. This greatly simplifies setup and also allows the flows to be set more precisely.

Setting the sheath flow is simply a matter of dialing a flow from the front panel. Generally, you should set the sheath flow to a 10:1 ratio with the aerosol flow. So, if you are using a CPC with a 1 L/min sampling flow, you can connect the inlet of the CPC directly to the Monodisperse Flow fitting of the DMA. This will give a polydisperse flow of 1 L/min and you can set a sheath flow rate of 10 L/min from the front panel. To set the sheath flow:

1. Turn on the Classifier and rotate the control knob to highlight the Sheath Flow Rate pane on the display.
2. Click the control knob by pushing in.
3. Scroll by rotating the control knob with your index finger until the correct flow is indicated and then click the selection.
4. The flow will then update with the actual flow. When it stabilizes at the set flow, the green Sheath Flow LED will light up.

Neutralizer

The TSI Model 3077A/3077 Kr-85 Neutralizer is usually required in a system to provide known charge on the particles going into the Classifier. This allows calculation of actual particle concentration based on particle size and number concentration of particles exiting the DMA. This also allows the correlation of particle mobility with particle size to correct for multiple-charged particles. In some cases, however, such as when using an Electrospray Aerosol Generator (TSI Model 3480) to generate ultrafine particles, the 3077A/3077 Kr-85 neutralizer can be bypassed because the 3480 has a Po-210 neutralizer. If you have not yet installed a neutralizer, refer to "Installing the Kr-85 Bipolar Charger" in Chapter 2. The

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Model 3077 Aerosol Neutralizer is an optional part that is recommended to be used for low concentration aerosol.

High-Voltage Controller

An integral part of the Classifier is the precise control of high voltage. This is accomplished using a precision high-voltage supply with an external feedback reference module. The voltage is set from the front panel, through the **Analog Input** on the back panel, or using a computer and the serial port. From the front panel the voltage is set by following these steps:

1. Turn on the Classifier and rotate the control knob to highlight the DMA-Voltage pane on the display.
2. Click the control knob by pushing in.
3. Scroll by rotating the control knob with your index finger until the correct voltage is indicated and then click the selection.

Traditionally, a voltage was set to select a particle size for the output of the DMA. The voltage was then converted to a particle size based on the voltage, flow rate and other parameters (see Chapter 5). However, with the microprocessor in the Classifier, the Particle Diameter can be set directly. Simply set the particle diameter in the same way that DMA-Voltage is set. The corresponding voltage is calculated and set automatically. Note that a sheath flow must be set before a particle diameter can be entered. Otherwise, an error message “no flowrate selected” comes up in the Particle Diameter pane. This method is suitable for both the default negative HV controller and the optional positive HV controller. See Chapter 3, “High-Voltage Controller,” for more information.

Differential Mobility Analyzer

The Model 3080 Classifier can accommodate two different models of DMAs as well as three custom units. Once the DMA has been mounted and the tubing and high-voltage connections made, the model has to be entered using the front panel display. To select the appropriate model, follow the steps below:

1. Turn on the Classifier and rotate the control knob to highlight the **Menu** pane on the display.
2. Click the control knob by pushing in. This should bring up the menu.

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3. Scroll by rotating the control knob until **DMA Model** is highlighted and then click the selection.
4. Select the DMA model number corresponding to the DMA physically installed and click the selection.
5. Scroll the menu up or down to **Exit** and click.

Note: *The correct DMA must be entered for the Particle Size calculations to be performed correctly on the front panel.*

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CHAPTER 6

Maintenance and Service

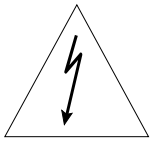
This chapter gives maintenance and service procedures for the Classifier.

Periodic Maintenance

Periodic cleaning of several parts of the Classifier is necessary to ensure proper performance. If aerosol deposits accumulate in the differential mobility analyzer, they may cause an electrical breakdown of the high voltage. The service intervals depend on the aerosol concentration entering the Classifier. When the instrument is used as an aerosol generator, the input aerosol concentration is usually high and the Classifier requires more frequent cleaning. The following maintenance schedule is suggested for the system when it is used as an aerosol generator. For a Classifier used in an SMPS system measuring room-air levels of aerosol, multiply the hours of operation by 2-3 times.

Table 6-1
Maintenance Schedule

Maintenance Task	Hours of Operation
Cleaning the impactor	5–50
Clean the collector rod and outer tube of the DMA	4000
Clean the Dacron screen of the DMA	8000
Clean the bipolar charger	8000
Replace the filter cartridges	8000



WARNING

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

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Cleaning the Impactor

The impactor's function is to remove particles above a certain cut size. Over time, particle loading on the impaction plate influences the pressure drop across the nozzle and, therefore, particle measurements due to particle re-entrainment. Follow the steps below for cleaning of impactor inlet.

1. Remove tubing connected to the pressure tap connectors from the impactor and then refer to Figure 6-1.
2. Remove the impactor screw by hand by gripping the knurled surface and unscrewing.
3. Clean the impaction surface with a soft cloth soaked with alcohol.

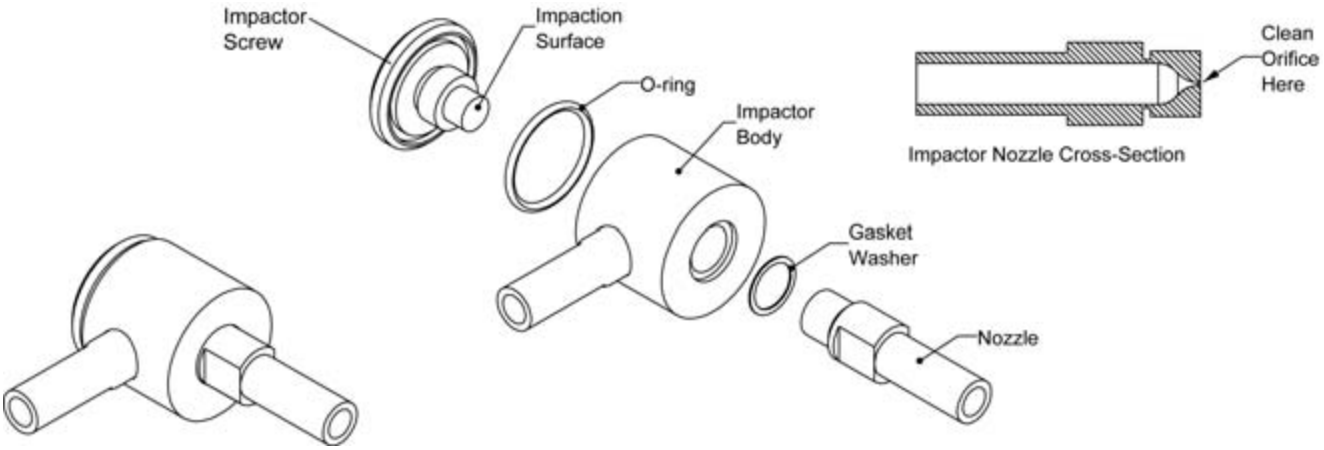
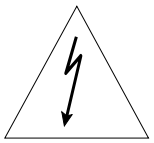


Figure 6-1
Cleaning the Impactor

4. Apply a very small amount of vacuum grease to the impaction surface. Apply grease sparingly, since this will alter the pressure drop across the nozzle.
5. Examine the nozzle orifice under a microscope or powerful magnifying glass. If the nozzle needs to be cleaned, squirt alcohol through the nozzle hole until clean. Repeat this for all nozzles.
6. Reassemble the impactor making sure that the gasket washer is properly in place between the impactor nozzle and body.

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Cleaning the Long DMA Electrodes



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 Classifier and unplug the high-voltage cable from the Classifier to the DMA before disassembling the DMA or performing maintenance procedures.

To clean the inner rod and inside of the outer tube, follow these steps and refer to Figure 6-2:

1. Switch the Classifier off and unplug the power cord.
2. Disconnect the high-voltage connector marked HIGH VOLTAGE OUT FOR DMA ONLY on the side of the Classifier.

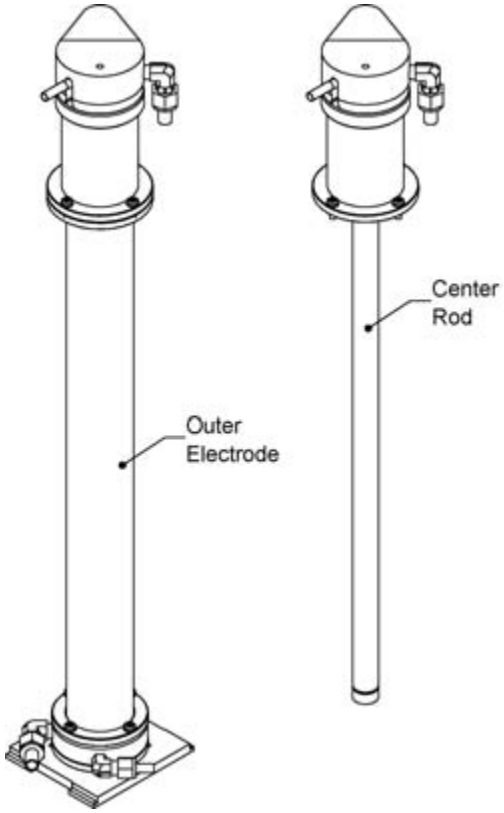


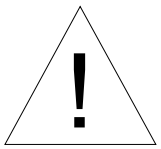
Figure 6-2
Unscrew Middle Flange to Split Long DMA for Cleaning

3. Disconnect the polydisperse flow tube at the top of the differential mobility analyzer (DMA) assembly.
4. Disconnect the sheath-air inlet tube at the top of the DMA assembly.
5. Loosen the four screws (see Figure 6-2) on the top of the flange about 10 centimeters below the top of the DMA assembly, leaving them one turn from complete removal.

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6. Carefully pull up on the assembly above the flange. (You may need to work the assembly back and forth to loosen the O-ring seal.) Remove the four screws completely. (To avoid the possibility of disastrous damage, leave the four flange screws about one turn short of complete removal before pulling up the assembly; this stops the assembly from suddenly breaking loose.)

7. Remove the DMA's center collector rod by continuing to lift the top of the center rod assembly out of the long outer tube.



Caution

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

8. Visually inspect the center rod for contamination. If the rod is visually quite dirty, clean it and the inside of the mobility analyzer's outer tube. Continue with steps **9** through **11**.
9. To remove the DMA outer tube:
   a. Remove the two screws in the side-support bracket (if installed).
   b. Remove the four screws that attach the outer tube to the baseplate.
   c. Lift the tube up, off of the base.
10. Wash the collector rod and the inside of the outer tube with a soft cloth soaked in alcohol or a mild solvent.



Caution

Avoid scratching or otherwise damaging the critical collector-rod surface and the inside of the outer tube.

Also, take care not to dent the cone edge near the top of the collector rod or the Dacron screen inside the cone. If you dent, scratch, or otherwise damage the mobility analyzer assembly, contact TSI to discuss repairs.

11. Carefully reassemble the center rod and outer tube and leak-test the unit (see "Testing for Leaks" in Chapter 7).

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Cleaning the Long DMA Dacron Screen

The Dacron screen (P/N 1030389) located at the top of the annulus assembly can become contaminated and contribute to arcing. An extra Dacron screen is included in the accessory kit for cases where the Dacron screen has been burned out from extensive contamination, which interferes with high voltage. For this reason, TSI recommends the Dacron screen be thoroughly cleaned. However, it is only necessary to clean or replace the screen if you have an arcing problem. Arcing may happen at high voltages near 10,000 V. If there is an arcing problem, a particle size distribution from an SMPS shows particles at the upper size limit of a scan with a HEPA filter in front of the 3080 Classifier.

1. To remove the collector rod, follow the steps in "Cleaning the Long DMA Electrodes".
2. Hold the center collector rod at the top and the bottom and unscrew the collector rod from the top portion (Figure 6-3). Carefully separate the collector rod from the top.
3. Remove the black top of the upper assembly by loosening the set screw in the top and then loosening knurled retaining ring.
4. Remove the sheath assembly from the other components.
5. *Carefully* pull the upper insulator from the sheath core and then unscrew the sheath *cone* from the sheath *core*.
6. The Dacron screen is located inside the lower portion of the sheath cone, and is easily removed for cleaning.
7. To clean the Dacron screen, use tweezers to dip the screen into a clean beaker filled with isopropyl alcohol. Repeat three times.
8. The screen must be dry before the Electrostatic Classifier will operate correctly. You can air-dry the screen or use a very light flow of filtered, compressed air.
9. Reassemble unit.

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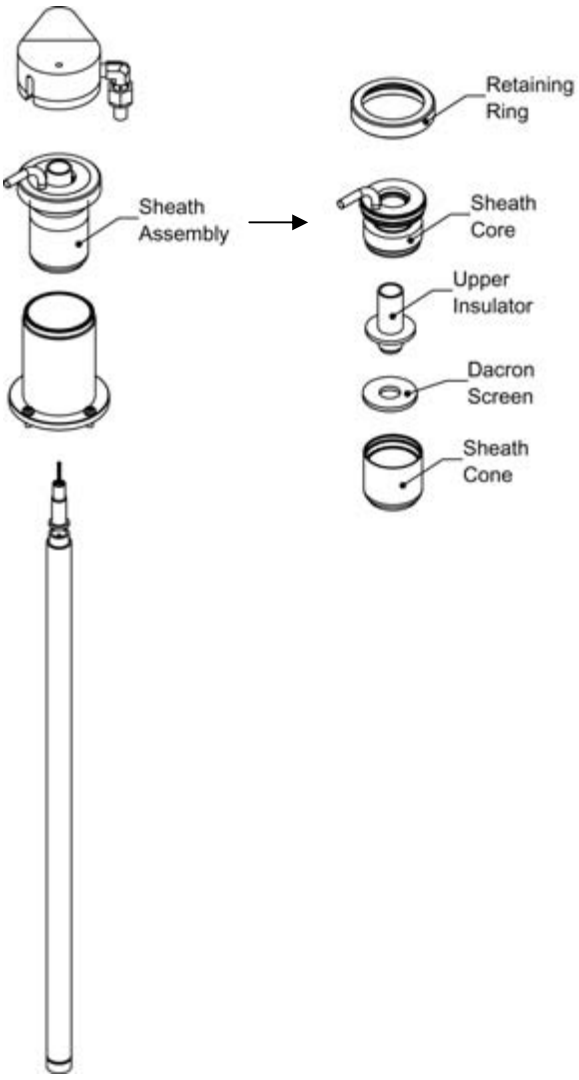
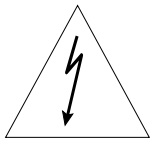


Figure 6-3
Cleaning/Replacing Model 3081 Dacron Screen

Cleaning the Nano DMA Electrodes



WARNING
High voltage is accessible in several locations within this instrument. Make sure you unplug the power source to the Classifier and unplug the high-voltage cable from the Classifier to the DMA before disassembling the DMA or performing maintenance procedures.

To clean the inner rod and inside of the outer tube, follow these steps and refer to Figure 6-4:

1. Switch the Classifier off and unplug the power cord.

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2. Disconnect the high-voltage connector marked HIGH VOLTAGE OUT FOR DMA ONLY on the side of the Classifier.

3. Disconnect all of the tubing between the Classifier and the DMA.

4. Remove the DMA from the Classifier Platform (see "DMA Mounting" under "Installing Model 3085 Nano DMA" in Chapter 2).

5. Mark the location of the sheath flow fitting on the baseplate for easy re-assembly. Loosen the two screws in the baseplate of the DMA and remove the base.

6. Using a 0.050 inch Allen-wrench, loosen the grounding set screw located above the high-voltage cable connector (see Figure 6-4).

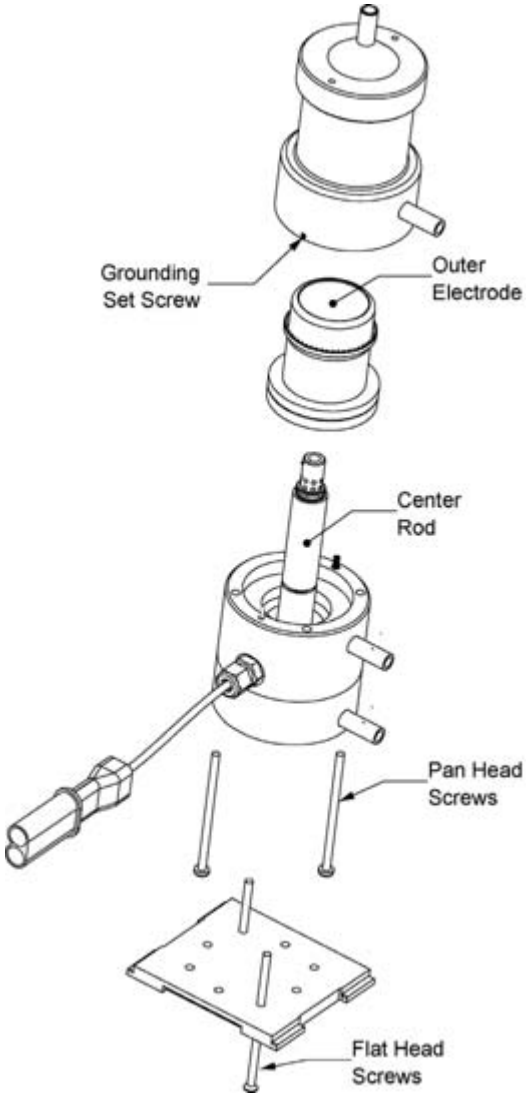


Figure 6-4
Disassembly of Model 3085 Nano DMA for Cleaning

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7. Loosen the two screws in the white plastic base of the DMA and support the parts so they don't fall apart.

8. Place the DMA back on its base and separate the sections between the stainless steel body and white plastic base (between the Bypass and Excess Flow fittings).

9. Lift up on the stainless steel housing being careful not to make contact between the outer case and the center rod.



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 completely disrupt the electric field inside the mobility analyzer, severely affecting its performance.

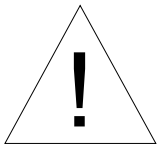
10. Visually inspect the center rod for contamination. If the rod is visually quite dirty, clean it and the inside of the DMA's outer tube. Continue with steps **11** through **13**.

11. To remove the DMA outer electrode:

    a. Place your fingers inside the outer tube or use a soft rubber sheet, to grip the polished surface (do ***not*** scratch the inner finish).

    b. Pull the outer tube from the outside case.

12. Wash the collector rod and the inside of the outer tube with a soft cloth soaked in alcohol or a mild solvent.



Caution

Avoid scratching or otherwise damaging the critical collector-rod surface and the inside of the outer tube.

Also, take care not to dent the cone edge near the top of the collector rod or the Dacron screen inside the cone. If you dent, scratch, or otherwise damage the mobility analyzer assembly, contact TSI to discuss repairs.

13. Carefully reassemble the center rod and outer tube and leak-test the unit (see "Testing for Leaks" in Chapter 7).

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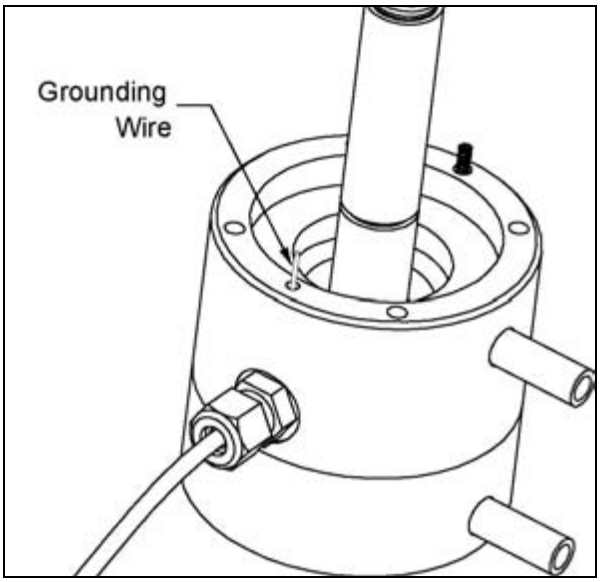


Figure 6-5
Location of Ground Wire

Caution
Make sure when you re-assemble the base of the Nano DMA that the ground wire (Figure 6-5) is secured by the ground set screw (Figure 6-4). Use the 0.050 inch Allen-wrench to tighten the set screw. Failure to do this will result in improper grounding and can produce unpredictable measurements.

Cleaning the Nano DMA Dacron Screen

The Dacron screen (P/N 1030389) located at the top of the annulus assembly can become contaminated and contribute to arcing. An extra Dacron screen is included in the accessory kit for cases where the Dacron screen has been burned out from extensive contamination, which interferes with high voltage. For this reason, TSI recommends the Dacron screen be thoroughly cleaned. It is only necessary to clean or replace the screen if you have an arcing problem. Arcing may happen at high voltages near 10,000 V. If there is an arcing problem, a particle size distribution shows particles at the upper size limit of a scan with a HEPA filter in front of the 3080 Classifier.

1. To remove the collector rod, follow the steps in "Cleaning the Nano DMA Electrodes."
2. Loosen the retaining ring with the tool provided in the Nano DMA accessory kit and separate the inlet cone, sheath

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assembly, and outer housing (Figure 6-6). Be careful not to damage the sharp edge at the bottom of the sheath assembly.

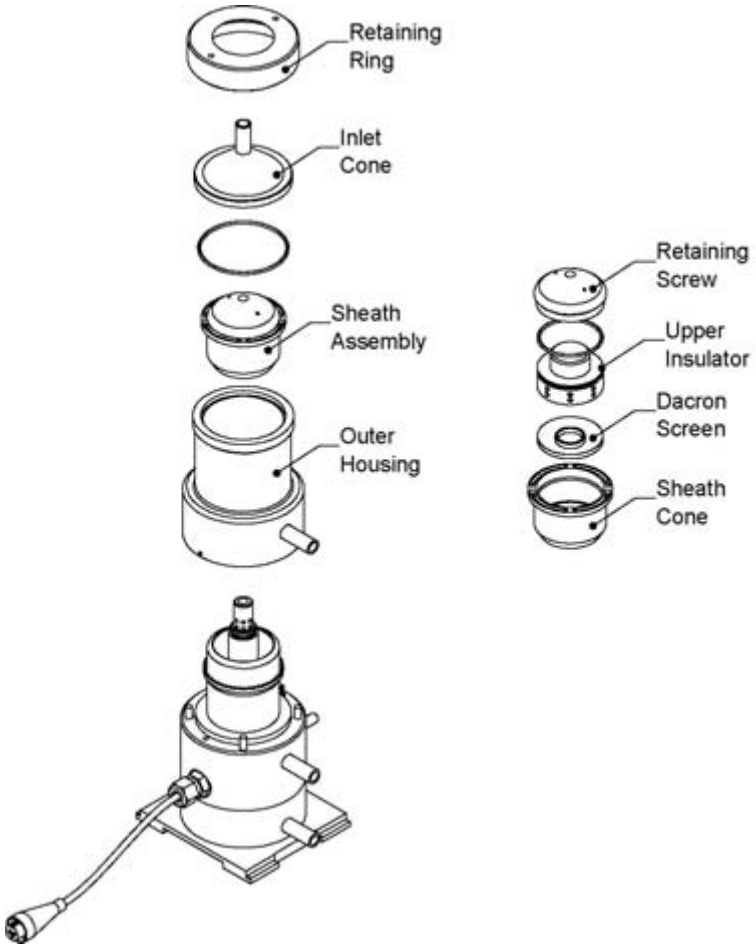


Figure 6-6
Replacing/Cleaning the Dacron Screen

3. The sheath assembly must be separated to remove the Dacron screen. Remove the retaining screw from the sheath cone using the opposite side of the same tool used in step 2.
4. The upper insulator is pressed into the sheath cone to maintain good alignment of the center rod. This means that the insulator has to be pressed out from below by pushing on the Dacron screen.
5. Orient the sheath cone so that the sharp edge is pointed upward. Place the cone in a press and support it by the outer edges. Using a plastic dowel slightly smaller than the inner diameter of the cone, push with a press on the Dacron screen until the upper insulator comes free (about 0.25 inches).
6. Remove the Dacron screen for cleaning and check it for damage. If the screen has been damaged in the removal

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process, it should be replaced with the spare screen from the accessory kit.

7. To clean the Dacron screen, use tweezers to dip the screen into a clean beaker filled with isopropyl alcohol. Repeat three times.
8. The screen must be dry before the Electrostatic Classifier will operate correctly. You can air-dry the screen or use a very light flow of filtered, compressed air.
9. Reassemble unit.

Cleaning Kr-85 Bipolar Charger/Neutralizer



Caution

Do ***not*** use solvents that might corrode stainless-steel or epoxy. See the separately bound Model 3077A/3077 Aerosol Neutralizers Instruction Manual for very important U.S. Nuclear regulatory commission limitations and regulations; also, consult your local radioactivity regulations.



W A R N I N G

The use of controls, adjustments, or procedures other than those specified in this manual may result in exposure to hazardous radiation.

- Do *not* use water above 50°C. Temperatures above 50°C can degrade materials that are a part of the Neutralizer (303, 304, or 316 stainless steel, copper, silver solder, or epoxy), causing the Neutralizer to leak radioactive contamination.
- Do *not* fill the Neutralizer with water and then shake it. This could cause sufficient mechanical shock to damage the krypton source, causing it to leak. Instead, allow water to flow through the Neutralizer.

To clean the Model 3077A/3077 Neutralizer, refer to Figure 6-7 and follow the steps below:

1. Switch the Classifier off and unplug the power cord.
2. Remove the two screws securing the neutralizer outlet block, and remove the block by lifting it up using the ¼-in Polydisperse Flow tube.

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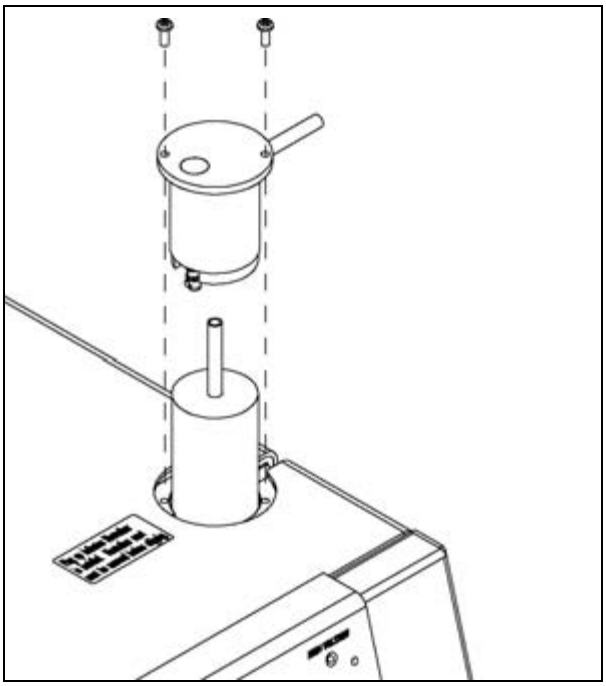


Figure 6-7
Removal of Model 3077A/3077 Kr-85 Neutralizer

3. Remove the neutralizer by pulling up on the Polydisperse Flow (neutralizer exit) tube. If the neutralizer does not move easily, remove the cover on the Classifier (loosen seven screws on the side panels) and grip the Neutralizer body to remove it. ***Never*** use pliers on the tube.

4. Pour clean alcohol or water and detergent into the charger/neutralizer. Shake it gently.

5. Drain the liquid from the end with the longest exterior tube.

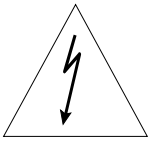
6. Repeat steps **4** and **5** several times as necessary.

7. Thoroughly rinse the inside with clean alcohol.

8. Thoroughly air-dry the neutralizer by blowing through it with clean, dry air.

9. Finally reinstall it into the electrostatic Classifier (see "Installing the Kr-85 Bipolar Neutralizer" in Chapter 2).

Replacing the Filter Cartridges



W A R N I N G
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.

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There are three filters in the Classifier: two in the Sheath Air line (before and after the pump) and one in the Bypass Air line (before the pump). The cartridges in both filters require periodic replacement (see "Periodic Maintenance" earlier in this chapter).

To replace the filter cartridges, refer to Figure 6-8 and follow the steps below:

1. Disconnect the electric power cable and remove the cabinet cover by loosening the seven (7) screws on the side panels securing the cover (the screws do ***not*** have to be removed).
2. Remove the filter assembly support screw from the upper-left strut in the cabinet.
3. Loosen the two thumb nuts on the top of the filter assembly.
4. Raise the upper assembly about ½-inch (12 mm).
5. Replace the filter cartridges making sure that the O-rings are in place on the top and bottom filter manifolds. Observe the correct filter orientation (arrows as shown in Figure 6-8).

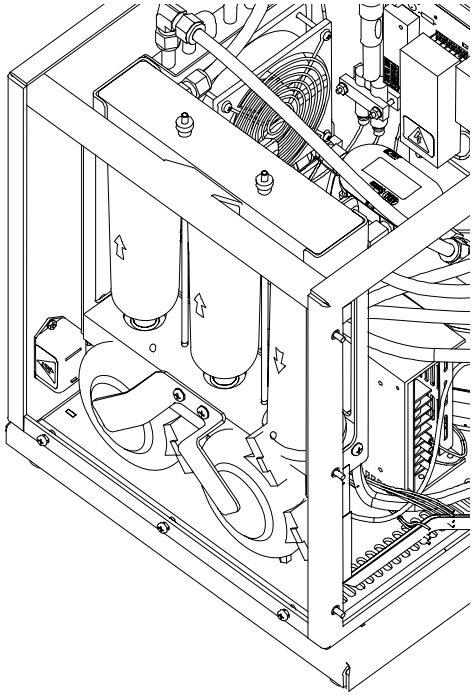


Figure 6-8
Replacing Classifier Filters

6. Push the top manifold back down over the filters and tighten the thumbnuts evenly.
7. Replace the filter assembly support screw in the upper-left strut in the cabinet.
8. Replace the instrument cover.

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9. Leak-test the instrument (see "Testing for Leaks" in Chapter 7).

Replacement filter cartridges can be reordered under TSI P/N 1602051 or directly from the manufacturer (see filter case for current part number).

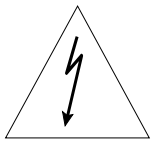
Flowmeters

The flowmeter in the sheath-air loop is protected by a HEPA filter at all times. Therefore, it does not require cleaning. In the event the flowmeter becomes contaminated, please contact TSI for service. The flowmeter may require recalibration periodically. See Appendix D for calibration instructions.

The Bypass flowmeter (orifice) also does not normally require maintenance. It can be cleaned, if necessary. However, this requires removing the filter assembly and is beyond the scope of this manual. Please contact TSI for assistance. The bypass orifice flowmeter also may require recalibration periodically. See Appendix D for calibration instructions.

Replacing the EPROM

Normally the EPROM should not need to be replaced. However, updates may be required to add functions/features or to correct bugs in the firmware. In this case, EPROM replacement may be required. This service should only be performed by a qualified electronics technician observing ESD precautions.



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.



Caution

The electronic circuits within this instrument are susceptible to electro-static discharge (ESD) damage. Use ESD precautions to avoid damage.

- ❑ Use only a table top with a grounded conducting surface
- ❑ Wear a grounded, static-discharging wrist strap

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To replace the EPROM, proceed as follows:

1. Switch the Classifier off and unplug the power cord.
2. Remove the cabinet cover by loosening the seven (7) screws on the side panels securing the cover (the screws do ***not*** have to be removed).
3. Remove the small bezel around the aerosol inlet on the front panel. Pry the left-hand side up with a small flat-bladed screwdriver and pull straight off the inlet tube.
4. Release the front panel door with the three captive screws on the inside-left of the front panel.
5. Swing the front panel open (only 90 degrees) to gain access to the main pc-board as shown in Figure 6-9. Have someone else support the door as you work on the pc-board.

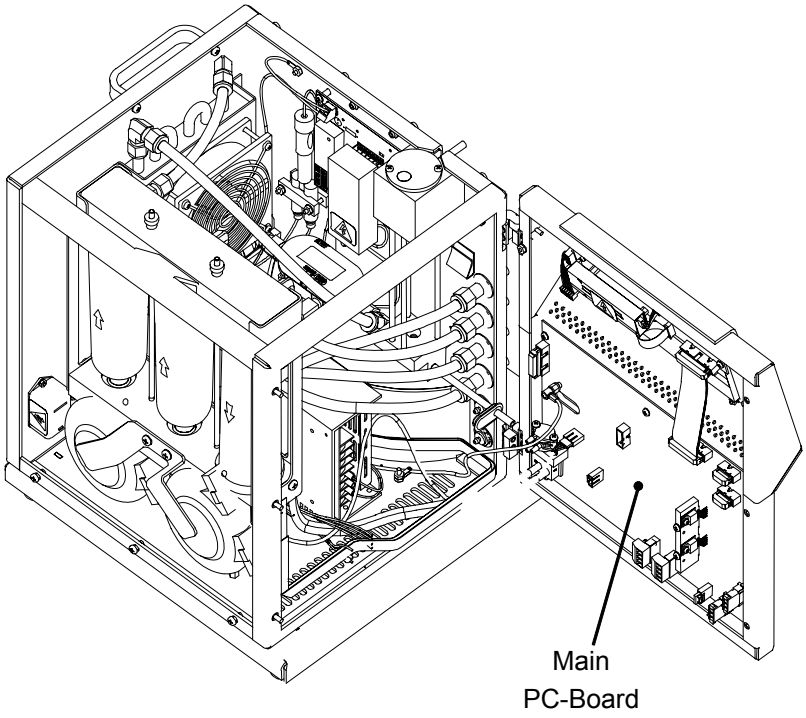


Figure 6-9
Location of Main PC-Board

6. The Classifier uses a single EPROM chip. It should be labeled with a seven-digit part number. It is important that it goes in the correct socket with the correct orientation.
7. Locate the EPROM socket on the main pc-board attached to the front panel of the instrument and refer to Figure 6-10.
8. Use the EPROM removal tool provided with the new EPROM chips to remove the old chip.
9. Remove the new EPROM from its static protection bag.

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10. Install the new chip into the vacant socket by aligning the notch on the top center of the chip with the notch shown on the silkscreen.
11. Slightly insert one row of pins, then push the chip sideways to insert the other row.
12. Once both rows of pins are slightly inserted, press the EPROM firmly the rest of the way into the socket.
13. Inspect the socket to make sure that all pins are inserted into the socket.

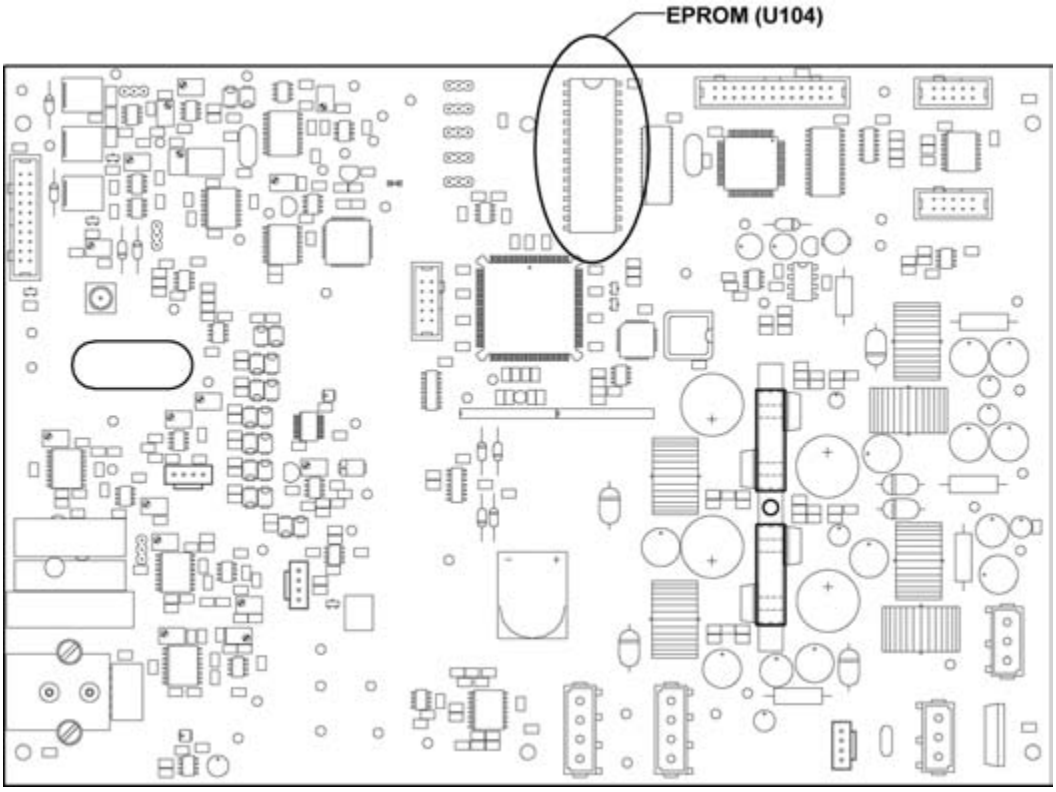


Figure 6-10
Location of the EPROM on the Main PC-Board

14. Swing the front panel shut making sure that no cables or tubing are pinched.
15. Tighten the three captive screws on the inside left of the front panel (you may have to move the panel up or down slightly to get the screws to engage).
16. Replace the cover on the instrument.
17. Tighten the seven screws holding the cover in place.
18. Insert the power cord into the power entry connector on the back of the instrument.

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19. Apply power to the instrument with the switch on the back panel.
20. Check that the version shown under the menu screen (near the bottom of the list) matches the new version of the EPROM.
21. Insert the small black bezel back to the hole around the sample inlet on the front panel.

Replace Negative High-Voltage Controller with Positive High-Voltage Controller

The Model 3080 Electrostatic Classifier has a negative polarity high-voltage (HV) controller by default for the Long or Nano DMA to select positively-charged particles. Researchers that are interested in negatively charged particles can order an optional positive HV controller (P/N 1030354) from TSI to size classify negatively charged particles. The location of the HV controller in the Classifier is shown in Figure 6-11 and the optional positive HV controller is shown in Figure 6-12.

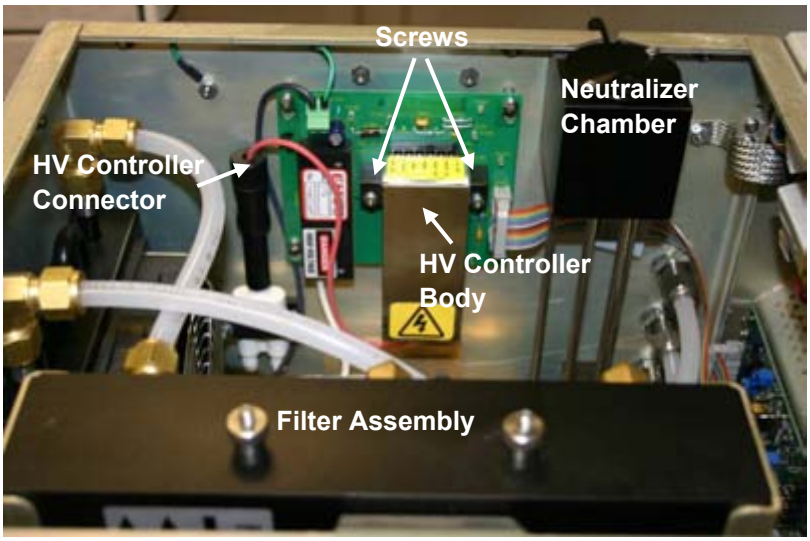


Figure 6-11
Location of High-Voltage Controller in 3080 Electrostatic Classifier

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Figure 6-12
Positive High-Voltage Controller

The two different polarity HV controllers can be identified by their different model numbers:

Negative polarity HV controller: 10A12-N4-M (Default)

Positive polarity HV controller: 10A12-P4-M (Optional)

Follow the steps below to replace the negative HV controller with the positive HV controller physically in the 3080 Electrostatic Classifier:

1. Turn off the power of the 3080 and disconnect the electrical power cable.
2. Remove the cabinet cover of the 3080 by loosening the seven (7) screws securing the cover (the screws do *not* have to be removed)
3. Disconnect the long black HV controller connector by pulling it up and then loosen the two screws on the sides of the HV controller body from the mounting bracket as shown in Figure 6-11 and Figure 6-13.

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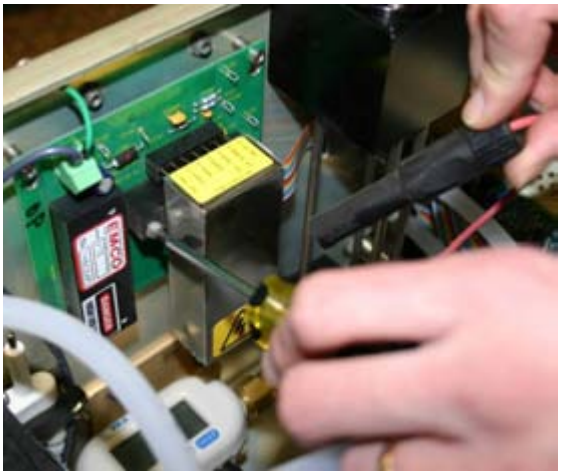


Figure 6-13
Removing High-Voltage Controller

4. Grab the sides of the HV controller body and pull it slowly away from the electrical board until it is fully removed. Figure 6-14 shows the electrical board after the HV controller is removed.

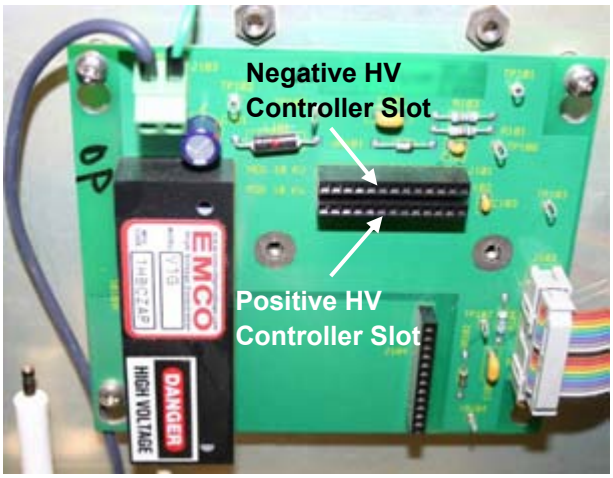


Figure 6-14
Electrical Board After High-Voltage Controller is Removed

5. Push in the positive HV controller onto the electrical board with the line of seven pins seat in the bottom horizontal slot on the board and two side pins seat in the vertical slot on the board.

   Note: *The default negative HV controller seats into the top horizontal slot while the optional positive HV controller seats into the bottom horizontal slot.*

6. Fix the HV controller onto the electrical board by fastening the two screws back into the mounting bracket.

7. Connect the HV controller connector onto the white post on the left side of the electrical board. Figure 6-15 shows the positive HV controller after it is installed.

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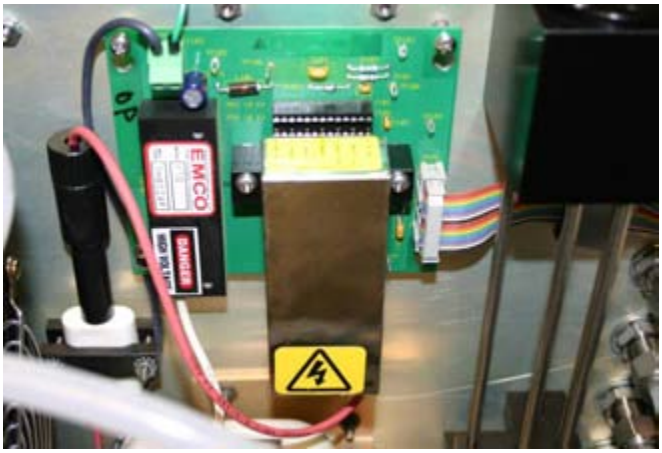


Figure 6-15
Optional Positive High-Voltage Controller Installed

8. Put the instrument cover back on and tighten the seven (7) screws to fix the cover.

9. Plug in the power cable and turn on the instrument.

10. When the instrument is first powered, the bottom line of the front panel display shows High Voltage Check: In process. The 3080 first looks for the default negative HV controller and a relay click indicates the 3080 is not able to find the negative HV controller and start to look for the positive HV controller. After the 3080 finds and checks the positive HV controller, the front panel display shows High Voltage Check: Passed.

11. Now the 3080 Classifier is ready to be used to size-classify negatively-charged particles.

    ***Note**: When 3080 Classifier is used as part of a TSI Scanning Mobility Particle Sizer™ (SMPS™) spectrometer and the Aerosol Instrument Manager® software is used to collect particle size distribution data, the corresponding HV controller should be selected in the properties tab in the software in order to use the correct charge efficiency file for the size distribution. See the software manual for details.*

12. The same procedures can be followed to install the default negative HV controller back to the 3080 Electrostatic Classifier. Be sure to use the top slot on the electrical board and select the right HV controller in the software for the negative HV controller.

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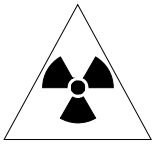
Technical Contacts

- If you have any difficulty setting up or operating the Classifier, or if you have technical or application questions about this system, contact an applications engineer at TSI Incorporated, 1-800-874-2811 (USA) or (651) 490-2811 or e-mail technical.service@tsi.com.
- If the Classifier does not operate properly, or if you are returning the instrument for service, visit our website at http://rma.tsi.com, or contact TSI Customer Service at 1-800-874-2811 (USA) or (651) 490-2811.

Returning the Classifier for Service

Visit our website at http://rma.tsi.com or call TSI at 1-800-874-2811 (USA) or (651) 490-2811 for specific return instructions. Customer Service will need this 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



WARNING

The Model 3077A/3077 Aerosol Neutralizer must be removed from the Classifier prior to shipping. See the section titled "Cleaning Kr-85 Bipolar Charger/Neutralizer" in this chapter, for instructions on how to remove the neutralizer.

The neutralizer must be shipped in the original shipping container. If you no longer have the original shipping container, contact TSI before shipping so we can send you a suitable carton.

Use the original packing material to return the instrument to TSI. For the Classifier or DMAs: if you no longer have the original packing material, before packing the instrument, seal off any ports to prevent debris from entering the instrument and ensure that the indicator lights and the connectors on the instrument front and back panels are protected.

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CHAPTER 7

Troubleshooting

This chapter tells how to troubleshoot the Classifier.

Detecting Particles When the Collector-Rod Voltage is Not Switched *on*

When the collector-rod voltage is not *on*, the airstream flowing out of the Monodisperse Flow connector should be particle-free. If particles are detected in the airstream, the Classifier may have one or more of the following problems:

Problem	Solution
The ratio of aerosol to clean-sheath air flow is too high	The imbalance ratio can occur if the ratio of aerosol to clean-sheath-airflow exceeds 1:10. Change flows so that ratio is below 1:10.
The sheath-air filter has a leak	Replace the sheath-air filter cartridge (see "Replacing the Filter Cartridges" in Chapter 6).
Turbulent flow has developed in the differential mobility analyzer	If particles still appear after these checks, decrease sheath and polydisperse flows so that the total flow rate inside the analyzer is less than 10 liters per minute. If particles disappear using these steps, it suggests that turbulent flow has developed in the analyzer at normal flow rates. Contact TSI for repair information.

Testing for Leaks

Whenever an air leak is suspected or a significant part of the airflow system has been reassembled, perform a leak test to assure proper performance. Begin by isolating the DMA from the Classifier using these steps:

1. Disconnect all tubing from the DMA.

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2. Plug all ports on the DMA except for the Monodisperse Flow port.
3. Connect a pressure gauge or manometer between the Monodisperse Flow port and a leak-tight valve. The valve should be closed.
4. Connect the valve to a vacuum source or a vacuum pump capable of drawing 18 in. Hg vacuum.
5. Turn on the vacuum pump or vacuum system and slowly open the valve. Allow the vacuum gauge reading to become stable and then close the valve.
6. Observe the gauge reading. The reading should not change by more than 0.1 in. Hg in 5 minutes.
7. If the DMA does leak, follow the steps below under "Isolating Leaks."

It is much easier to leak-check the Model 3080 Classifier by breaking the process down into three subsystems: Sheath flow path, the Bypass flow path, and the aerosol flow path.

To leak-check the Sheath flow path, follow these steps:

1. Plug the EXCESS FLOW port on the Classifier.
2. Connect a pressure gauge or manometer between the SHEATH FLOW port and a leak-tight valve. The valve should be closed.
3. Connect the valve to a vacuum source or a vacuum pump capable of drawing 18 in. Hg vacuum.
4. Turn on the vacuum pump or vacuum system and slowly open the valve. Allow the vacuum gauge reading to become stable and then close the valve.
5. Observe the gauge reading. The reading should not change by more than 0.1 in. Hg in 5 minutes.
6. If the Sheath-air plumbing does leak, follow the steps below under "Isolating Leaks."

To leak-check the Bypass flow path, follow these steps:

1. Plug the EXHAUST FLOW port on the Classifier.
2. Connect a pressure gauge or manometer between the BYPASS FLOW port and a leak-tight valve. The valve should be closed.
3. Connect the valve to a vacuum source or a vacuum pump capable of drawing 18 in. Hg vacuum.
4. Turn on the vacuum pump or vacuum system and slowly open the valve. Allow the vacuum gauge reading to become stable and then close the valve.

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5. Observe the gauge reading. The reading should not change by more than 0.1 in. Hg in 5 minutes.
6. If the Bypass flow plumbing does leak, follow the steps below under "Isolating Leaks."

To leak-check the Aerosol flow path, follow these steps:

1. A neutralizer must be installed. If an impactor is installed, the pressure taps should be connected to the ports on the side of the Classifier or connected together (or plugged).
2. Plug the AEROSOL INLET port on the front of the Classifier or the Inlet to the Impactor if you have one installed.
3. Connect a pressure gauge or manometer between the POLYDISPERSE FLOW port and a leak-tight valve. The valve should be closed.
4. Connect the valve to a vacuum source or a vacuum pump capable of drawing 18 in. Hg vacuum.
5. Turn on the vacuum pump or vacuum system and slowly open the valve. Allow the vacuum gauge reading to become stable and then close the valve.
6. Observe the gauge reading. The reading should not change by more than 0.1 in. Hg in 5 minutes.
7. If the Aerosol flow path plumbing does leak, follow the steps below under "Isolating Leaks."

Isolating Leaks

1. Isolate the leak by wetting suspected joints with clean isopropyl alcohol while the system is under vacuum. The alcohol will be drawn into a leaky joint and evaporate.
2. After isolating the leak, repair it (usually by greasing or replacing an O-ring, or by sealing a fitting).
3. Blow clean, dry air through the repaired section to evaporate and remove any leftover alcohol.
4. If you cannot find the leak, or cannot repair the leak, please contact TSI for assistance.

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APPENDIX A

Model 3080 Specifications

The following specifications—which are subject to change—list the most important features of the Model 3080 Electrostatic Classifier and each of the DMAs.

Table A-1
Specifications of the 3080 Controller Platform

Mode of operation	Bipolar charge neutralization and differential mobility analysis (requires installation of DMA)
Flow rates	
Aerosol	0 to 3 L/min, determined by external pressure or vacuum
Sheath flow	0 to 15 L/min (Single Blower mode) 0 to 20 L/min (Dual Blower mode)
Bypass flow	0 to 15 L/min (Single Blower mode) None (Dual Blower mode)
Aerosol temperature range	10 to 40°C
Charger/Neutralizer (Model 3077A Aerosol Neutralizer* supplied with instrument) (Optional Model 3077 Aerosol Neutralizer)	Bipolar, Kr-85, 10 millicurie, half-life of 10.7 years Bipolar, Kr-85, 2 millicurie, half-life of 10.7 years
Aerosol pressure range	70 to 120 kPa [0.7 to 1.2 atm]
Front panel display	Backlit, alphanumeric, 320 × 240-pixel LCD
Calibration	NIST-traceable voltage and flow standards
Dimensions (LWH)	45.7 cm × 41.4 cm × 40.6 cm (18 in. × 16.3 in. × 16 in.)
Weight	17.6 kg (38.9 lb)
Ports	
Polydisperse Flow	¼-in. OD
Sheath Flow	⅜-in. OD
Excess Flow	⅜-in. OD
Bypass Flow	⅜-in. OD
Exhaust Flow	⅜-in. OD
Power requirements	100 to 240 VAC, 50-60 Hz, 200 W maximum
Fuse (***not*** replaceable by user)	~F 7A FB/250V (internal—***not*** replaceable by operator)

(continued on next page)

*TSI is authorized by the United States Nuclear Regulatory Commission to distribute these Aerosol Neutralizers. If your location is within the United States, no other federal license is required. Check local regulations for your own protection. Neutralizers are shipped separately from other system components. End-user name and address is required.

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Table A-2
Specifications of the 3080 Controller Platform *(continued)*

Environmental Conditions	Indoor use Altitude up to 3000 m (10,000 ft) Ambient temperature 10°-40°C Ambient humidity 0-90% RH non-condensing Over-voltage category II Pollution degree II

Table A-3
Specifications of the 3080L Electrostatic Classifier

DMA included	Long (Model 3081)
Particle type	Solids and nonvolatile liquids
Particle size range (generation mode)	Adjustable from 10 to 1000 nm
Maximum input concentration	10^8 particles/cm^3 at 10 nm
Voltage	10 to 10,000 VDC
Flow rates	
Sheath air	2 to 15 L/min (Dual Blower mode)
Aerosol	0.2 to 1.5 L/min
Bypass	None
Physical measurements	Long DMA
Height	61 cm (24 in.)
Outside diameter	7.6 cm (3 in.) excluding ports
Weight	5.4 kg (11.8 lb)
Monodisperse and polydisperse aerosol ports	¼-in. OD
Sheath and excess air ports	⅜-in. OD
Complete instrument	
Dimensions (LWH)	45.7 cm × 41.4 cm × 64.3 cm (18 in. × 16.3 in. × 25.3 in.)
Weight	23.2 kg (51.2 lbs)

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Table A-4
Specifications of the 3080N Electrostatic Classifier

DMA included	Nano (Model 3085)
Particle type	Solids and nonvolatile liquids
Particle size range (generation mode)	Adjustable from 2 to 150 nm
Maximum input concentration	10^8 particles/cm^3 at 10 nm
Voltage	10 to 10,000 VDC
Flow rates	
Sheath air	2 to 15 L/min (Single Blower mode) 2 to 20 L/min (Dual Blower mode)
Aerosol	0.1 to 2 L/min
Bypass	0 to 15 L/min (Single Blower mode with impactor inlet removed) None (Dual Blower mode)
Physical measurements	Nano DMA
Height	20.3 cm (8 in.)
Outside diameter	7.9 cm (3.1 in.) excluding ports
Weight	2.2 kg (4.9 lb)
Polydisperse aerosol inlet	⅜-in. OD
Monodisperse aerosol outlet	¼-in. OD
Sheath, excess, and bypass ports	⅜-in. OD
Complete instrument	
Dimensions (LWH)	45.7 cm × 41.4 cm × 40.6 cm (18 in. × 16.3 in. × 16 in.)
Weight	20.1 kg (44.3 lb)

Specifications are subject to change without notice. TSI and the TSI logo are registered trademarks of TSI Incorporated.

The design of the Model 3085 Nano DMA is covered under US patent No. 6,230,572.

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APPENDIX B

Theory of Operation

The principle of the Model 3080 Electrostatic Classifier with any DMA is based on the monotonic relationship between electrical mobility and particle size with singly charged particles. To ensure a fixed percentage of particles carrying one unit of charge, the particles are introduced to a bipolar charge (in a Model 3077A/3077 Neutralizer) where they undergo frequent collisions with bipolar ions. This process is known as bipolar charging or "neutralization." As a result, an equilibrium charge state is obtained, with known percentages of particles carrying no charge, a single charge, or multiple charges of both positive and negative polarities. These aerosol particles are then classified with the differential mobility analyzer and measured by a Condensation Particle Counter or an Aerosol Electrometer. The mobility distribution, and hence size distribution, can be determined from the measurement.

History

Electrical mobility techniques have been used to measure the size distribution of aerosols since the work of Rohmann [1923]. The differential mobility analyzer (DMA) was developed and used initially for electrical mobility measurements of submicrometer particles [Hewitt, 1957].

Liu and Pui [1974] used the differential mobility analyzer with a bipolar charger to produce monodisperse aerosols of known size. Their design was used to develop the first commercial DMA, the TSI Model 3071 Electrostatic Classifier. Not long after the development of the DMA, Knutson and Whitby [1975] incorporated the DMA into a particle-sizing system. The commercial system is known as the Model 3932 Differential Mobility Particle Sizer (DMPS).

The interface hardware was developed by TSI Incorporated. Knutson [1976] developed a data inversion technique for obtaining the initial aerosol size distribution based on the measured particle mobility distribution. A data inversion technique similar to Knutson's was used in the commercial DMPS/C data reduction. The data inversion technique is based on the work of Plomp, et al.

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[1982] and Hoppel [1978], and the data reduction technique was developed by Fissan et al. [1982]. The approximation of the bipolar charge distribution on submicrometer particles has been taken from the work of Wiedensohler [1986, 1987] and Wiedensohler and Fissan [1988].

In 1989, Wang and Flagan improved upon the system by using a dynamically scanned DMA voltage. This system, called SEMS (Scanning Electrical Mobility Spectrometer), provided rapid aerosol distribution measurements. Instead of requiring several intervals of ten minutes each to measure a size distribution, the SEMS could provide results in less than one minute.

In 1993, TSI commercialized the scanning system as the SMPS.

In January of 1999 TSI began shipping a complete redesign of earlier Classifier models as the Model 3080 with modular DMAs. The instrument includes improvements such as:

- Choice of two interchangeable DMAs and flexibility to use custom DMAs
- Recirculating flow for precise match of sheath and excess flows
- Accurate microprocessor-controlled volumetric flow
- Convenient front-panel design with control knob and built-in display
- Precision dynamic high-voltage supply for fast, accurate scanning
- Optional easy-to-install positive high-voltage supply (negative supply is standard)
- Electronic control of flow, voltage, particle-size, and instrument functions

Impaction Theory and Operation

An impactor may be mounted on the outside of the Electrostatic Classifier (see Figure B-1). The aerosol first enters an impactor, which removes particles above a known particle size by inertial impaction. The aerosol flow is accelerated through a nozzle directed at a flat plate, as shown in Figure B-2.

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Figure B-1
Classifier Shown with Impactor Installed on Inlet

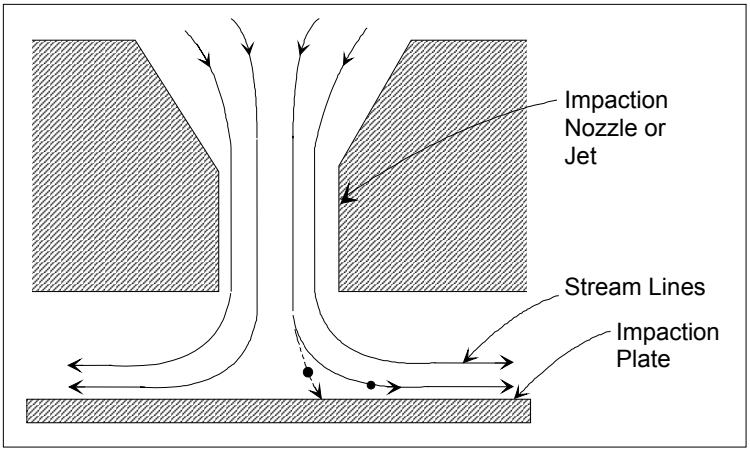


Figure B-2
Cross-Sectional View of an Inertial Impactor [Hinds, 1982]

The impaction plate deflects the flow to form a 90° bend in the streamlines. Particles with sufficient inertia are unable to follow the streamlines and impact on the plate. Smaller particles follow the streamlines, avoid contact with the plate and exit the impactor. The impactor is used in the SMPS system to remove particles larger than a known aerodynamic size due to their contribution to multiply charged aerosols. The aerodynamic particle size at which the particles are separated is called the cut-point diameter. The

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cut-point diameter is a function of the impactor flow rate and nozzle diameter.

Equation B-1 is used to calculate the cut-point diameter.

$$D_{50} = \sqrt{\frac{9\pi Stk\mu W^3}{4\rho_p CQ}}$$ Equation B-1

where:

D_{50} = particle cut-point diameter (centimeter, 50% cut efficiency)
Stk = Stokes number = 0.23
ρ_p = particle density (g/cm^3)
Q = volumetric flow rate (cm^3/s)
C = Cunningham Slip Correction
= 1 + Kn [α + β exp(-γ/Kn)]
(where Kn is the Knudsen number: Kn = 2 λ/Dp)
(α = 1.142, β = 0.558, γ = 0.999)
λ = gas mean free path
μ = gas viscosity (dyne·s/cm^2 or g/(cm·s))
W = nozzle diameter (cm)

The Stokes number is a dimensionless parameter that characterizes impaction.

Electrostatic Classifier

The purpose of the Electrostatic Classifier is to extract a known size fraction of submicrometer particles from the incoming polydisperse aerosol.

In the Electrostatic Classifier, the aerosol enters a Kr-85 Bipolar Charger (or neutralizer), which exposes the aerosol particles to high concentrations of bipolar ions. The particles and ions undergo frequent collisions due to the random thermal motion of the ions. The particles quickly reach a state of charge equilibrium, in which the particles carry a known bipolar charge distribution.

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The charged aerosol passes from the neutralizer into the main portion of the Differential Mobility Analyzer (DMA), shown in Figure B-3 and Figure B-4. The DMA contains two concentric metal cylinders. The polydisperse aerosol (q_a) and sheath air (q_{sh}) are introduced at the top of the Classifier and flow down the annular space between the cylinders. The aerosol surrounds the inner core of sheath air, and both flows pass down the annulus with no mixing of the two laminar streams. The inner cylinder, the collector rod, is maintained at a controlled negative voltage, while the outer cylinder is electrically grounded. This creates an electric field between the two cylinders.

The electric field causes positively charged particles to be attracted through the sheath air to the negatively charged collector rod. Particles are precipitated along the length of the collector rod (see Figure B-3 and Figure B-4). The location of the precipitating particles depends on the particle electrical mobility (Z_p), the Classifier flow rates, and the Classifier geometry. Particles with a high electrical mobility are precipitated along the upper portion of the rod; particles with a low electrical mobility are collected on the lower portion of the rod. Particles within a narrow range of electrical mobility exit with the monodisperse air flow (q_m) through a small slit located at the bottom of the collector rod. These particles are transferred to a particle sensor to determine the particle concentration. The remaining particles are removed from the Classifier via the excess air flow (q_e).

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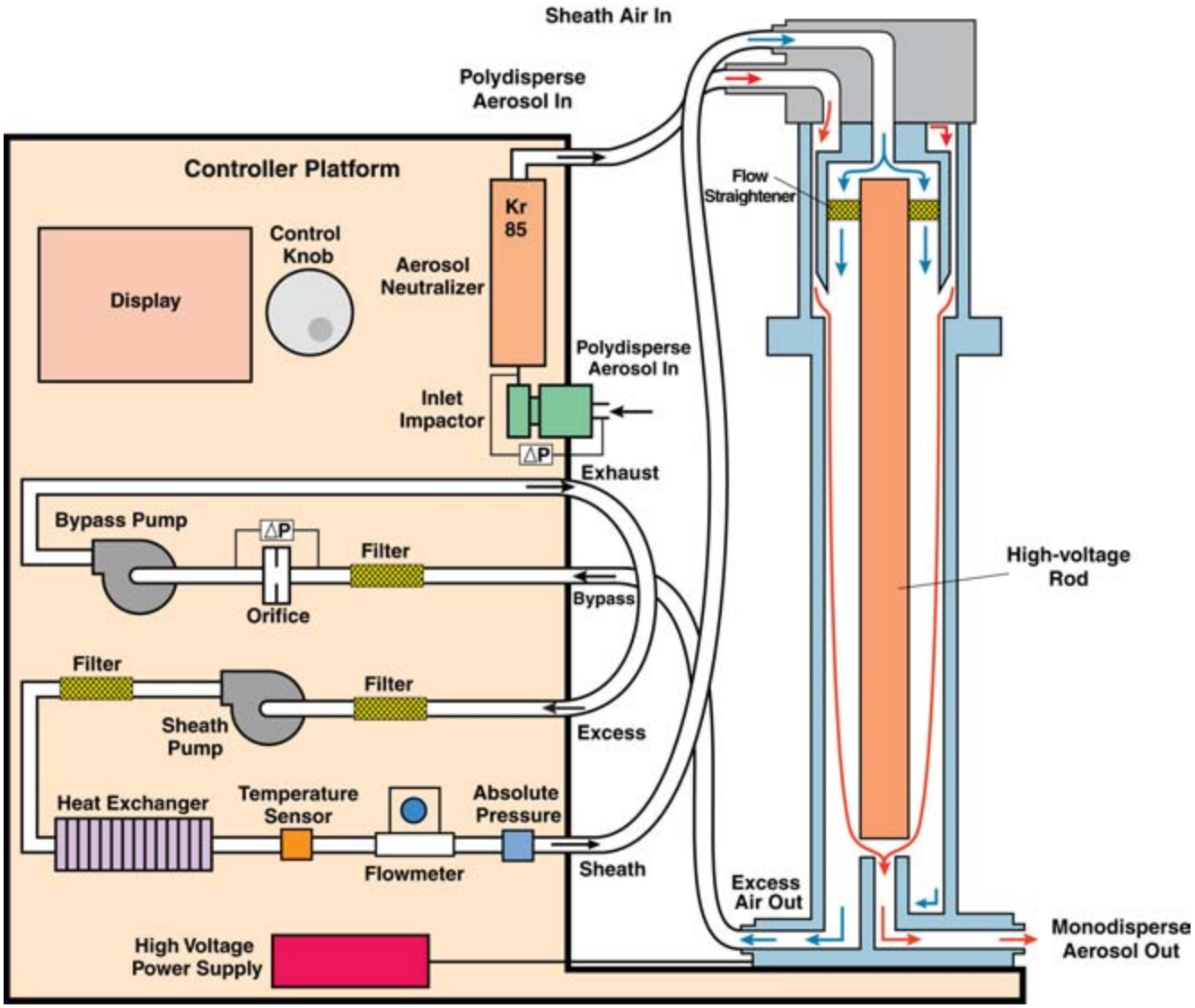


Figure B-3
Flow Schematic for the Electrostatic Classifier with Long DMA

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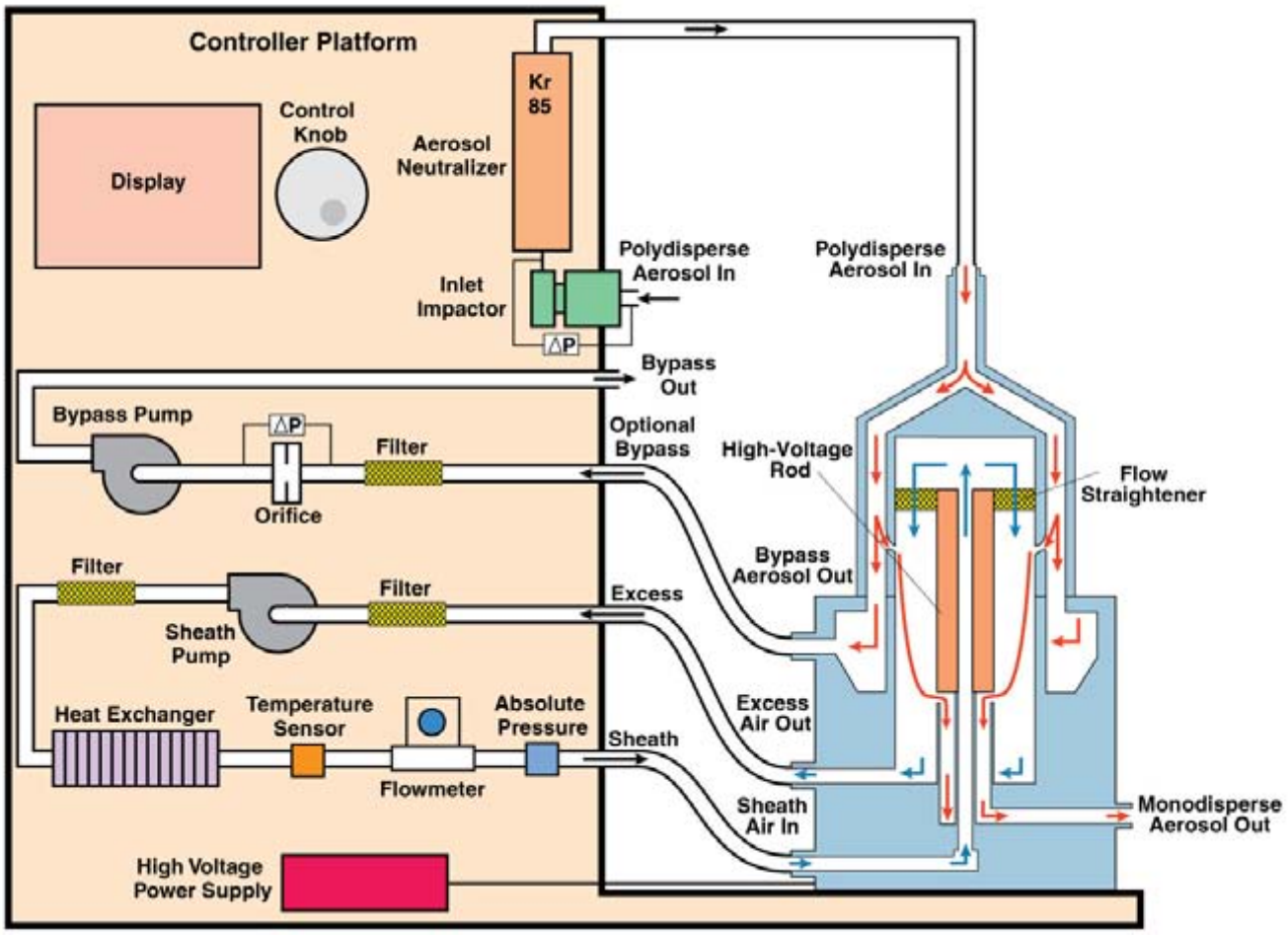


Figure B-4
Flow Schematic for the Electrostatic Classifier with Nano DMA in Single Blower Mode

(continued on next page)

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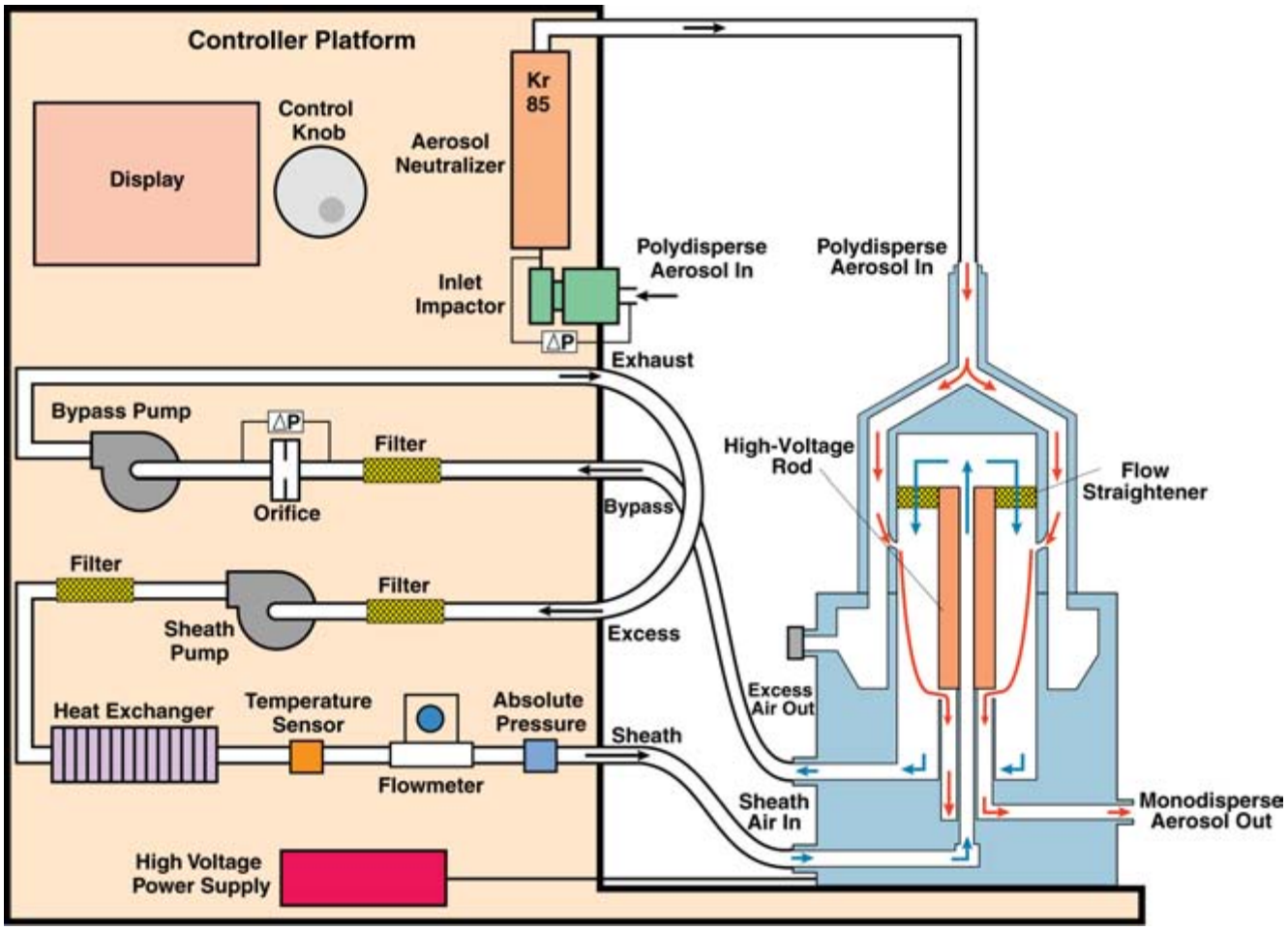


Figure B-5
Flow Schematic for the Electrostatic Classifier with Nano DMA in Dual Blower Mode

Charging Theory

The particle charge distribution used in the data reduction for the SMPS is based on a theoretical model developed by Wiedensohler [1986] and is an approximation of the Fuchs [1963] diffusion theory for particle sizes in the submicrometer range.

Figure B-6 shows the measured data of Wiedensohler [1986] and theoretical curves based on the theory of Fuchs [1963] and calculated by Wiedensohler [1988]. The theoretically determined charge distribution agrees well with experimental data. It can be seen from the figure that the fraction of positively charged particles is different from the fraction of negatively charged particles. Table B-1 lists the fractions of particles in air that carry -6, -5, -4, -3, -2, -1, 0, +1, +2, +3, +4, +5, and +6 charge units. This table was calculated based on Wiedensohler [1988] and Kim et al. [2005].

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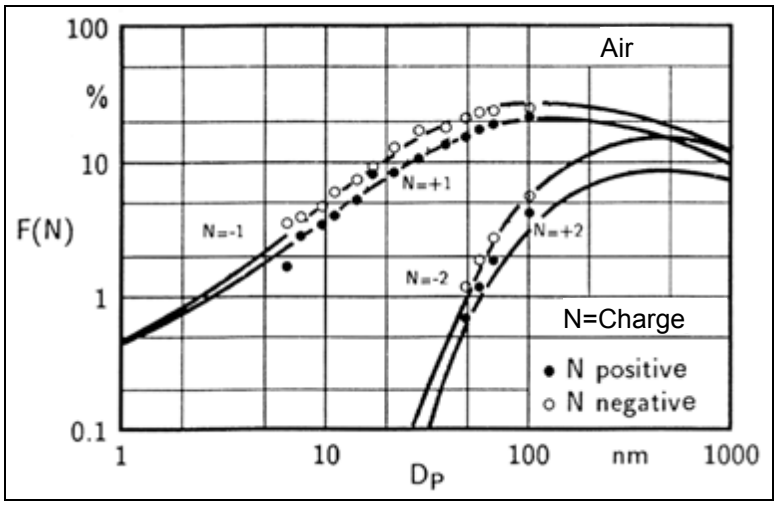


Figure B-6
Bipolar Particle Charge Distribution in Air [Wiedensohler and Fissan, 1988]

(continued on next page)

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Table B-1
Midpoint Mobilities, Midpoint Particle Diameters, and Fraction of Total Particle Concentration that Carries –6 to +6 Elementary Charges as a Function of Mobility

Particle Diameter Midpoint, nm	Mobility Midpoint $cm^2/v\text{-}s$	Fraction of Total Particle Concentration That Carries This Number (-6 to +6) of Charges												
		-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6
2.21	4.216E-01	0	0	0	0	0	0.0091	0.98268	0.0082	0	0	0	0	0
2.55	3.164E-01	0	0	0	0	0	0.0105	0.98007	0.0094	0	0	0	0	0
2.94	2.375E-01	0	0	0	0	0	0.0123	0.97691	0.0108	0	0	0	0	0
3.40	1.783E-01	0	0	0	0	0	0.0144	0.9731	0.0125	0	0	0	0	0
3.92	1.339E-01	0	0	0	0	0	0.0169	0.9685	0.0146	0	0	0	0	0
4.53	1.005E-01	0	0	0	0	0	0.0200	0.96297	0.0170	0	0	0	0	0
5.23	7.553E-02	0	0	0	0	0	0.0237	0.95634	0.0199	0	0	0	0	0
6.04	5.675E-02	0	0	0	0	0	0.0282	0.94842	0.0234	0	0	0	0	0
6.98	4.265E-02	0	0	0	0	0	0.0335	0.939	0.0275	0	0	0	0	0
8.06	3.207E-02	0	0	0	0	0	0.0398	0.92787	0.0323	0	0	0	0	0
9.31	2.412E-02	0	0	0	0	0	0.0472	0.9148	0.0380	0	0	0	0	0
10.75	1.815E-02	0	0	0	0	0	0.0559	0.89958	0.0445	0	0	0	0	0
12.41	1.367E-02	0	0	0	0	0	0.0659	0.88202	0.0520	0	0	0	0	0
14.33	1.030E-02	0	0	0	0	0	0.0774	0.86198	0.0606	0	0	0	0	0
16.55	7.767E-03	0	0	0	0	0	0.0903	0.83938	0.0703	0	0	0	0	0
19.11	5.862E-03	0	0	0	0	0	0.1047	0.81425	0.0810	0	0	0	0	0
22.07	4.429E-03	0	0	0	0	0.0004	0.1205	0.78618	0.0928	0.0002	0	0	0	0
25.48	3.351E-03	0	0	0	0	0.0008	0.1375	0.75588	0.1054	0.0004	0	0	0	0
29.43	2.539E-03	0	0	0	0	0.0015	0.1554	0.72334	0.1188	0.0009	0	0	0	0
33.98	1.927E-03	0	0	0	0	0.0029	0.1739	0.68883	0.1327	0.0017	0	0	0	0
39.24	1.465E-03	0	0	0	0	0.0051	0.1926	0.65272	0.1467	0.0029	0	0	0	0
45.32	1.116E-03	0	0	0	0	0.0084	0.2109	0.61545	0.1605	0.0048	0	0	0	0
52.33	8.532E-04	0	0	0	0	0.0131	0.2282	0.57755	0.1737	0.0075	0	0	0	0
60.43	6.539E-04	0	0	0	0	0.0195	0.2440	0.53969	0.1857	0.0111	0	0	0	0
69.78	5.030E-04	0	0	0	0	0.0278	0.2576	0.5026	0.1963	0.0157	0	0	0	0
80.58	3.885E-04	0	0	0	0.0012	0.0379	0.2686	0.46539	0.2050	0.0213	0.0005	0	0	0
93.06	3.014E-04	0	0	0	0.0026	0.0497	0.2766	0.4304	0.2115	0.0280	0.0012	0	0	0
107.46	2.350E-04	0	0	0.0001	0.0051	0.0628	0.2812	0.39728	0.2155	0.0356	0.0023	0	0	0
124.09	1.843E-04	0	0	0.0004	0.0091	0.0767	0.2825	0.36632	0.2169	0.0439	0.0041	0.0001	0	0
143.30	1.454E-04	0	0	0.0010	0.0146	0.0909	0.2804	0.33774	0.2158	0.0525	0.0066	0.0004	0	0
165.48	1.154E-04	0	0.0001	0.0023	0.0220	0.1047	0.2751	0.31172	0.2122	0.0612	0.0099	0.0008	0	0
191.10	9.227E-05	0	0.0003	0.0044	0.0309	0.1174	0.2671	0.28841	0.2065	0.0694	0.0139	0.0015	0.0001	0
220.67	7.428E-05	0.0001	0.0009	0.0077	0.0411	0.1285	0.2568	0.26786	0.1989	0.0768	0.0185	0.0026	0.0002	0
254.83	6.021E-05	0.0002	0.0019	0.0125	0.0522	0.1376	0.2448	0.25006	0.1898	0.0829	0.0234	0.0043	0.0005	0
294.27	4.914E-05	0.0005	0.0037	0.0187	0.0634	0.1443	0.2316	0.23483	0.1797	0.0873	0.0284	0.0064	0.0010	0.0001
339.82	4.036E-05	0.0012	0.0066	0.0262	0.0742	0.1486	0.2178	0.22184	0.1690	0.0901	0.0333	0.0090	0.0017	0.0002
392.42	3.336E-05	0.0025	0.0108	0.0348	0.0842	0.1505	0.2039	0.21058	0.1581	0.0910	0.0378	0.0120	0.0028	0.0005
453.16	2.772E-05	0.0046	0.0162	0.0440	0.0929	0.1503	0.1904	0.20035	0.1474	0.0903	0.0417	0.0151	0.0043	0.0009
523.30	2.315E-05	0.0079	0.0229	0.0534	0.1001	0.1481	0.1777	0.19035	0.1372	0.0883	0.0449	0.0183	0.0060	0.0016
604.30	1.941E-05	0.0123	0.0305	0.0623	0.1056	0.1445	0.1661	0.1797	0.1278	0.0854	0.0474	0.0214	0.0080	0.0025
697.83	1.634E-05	0.0180	0.0386	0.0705	0.1093	0.1398	0.1560	0.16748	0.1194	0.0821	0.0490	0.0242	0.0102	0.0036
805.84	1.380E-05	0.0246	0.0469	0.0775	0.1113	0.1345	0.1475	0.15282	0.1121	0.0789	0.0499	0.0266	0.0123	0.0050
930.57	1.169E-05	0.0319	0.0547	0.0831	0.1117	0.1289	0.1410	0.13491	0.1063	0.0763	0.0501	0.0286	0.0144	0.0064

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The formulas used to calculate Table B-1 are shown below. They are taken from Wiedensohler [1988]. The mean free path is taken from Kim et al. [2005]. To calculate the fraction of particles carrying zero, one or two charges, use Equation B-2 which is an approximation of the Fuchs model. Equation B-2 is valid for size ranges:

$$1\ \text{nm} \le D_p \le 1000\ \text{nm for } N = -1,\ 0,\ 1$$
$$20\ \text{nm} \le D_p \le 1000\ \text{nm for } N = -2,\ 2$$

$$f(N) = 10^{\left[\sum_{i=0}^{5} a_i(N)\left(\log\frac{D_p}{nm}\right)^i\right]} \qquad \text{Equation B-2}$$

Table B-2
Coefficients for Equation B-2

$a_i(N)$	N=-2	N=-1	N=0	N=1	N=2
a_0	-26.3328	-2.3197	-0.0003	-2.3484	-44.4756
a_1	35.9044	0.6175	-0.1014	0.6044	79.3772
a_2	-21.4608	0.6201	0.3073	0.4800	-62.8900
a_3	7.0867	-0.1105	-0.3372	0.0013	26.4492
a_4	-1.3088	-0.1260	0.1023	-0.1553	-5.7480
a_5	0.1051	0.0297	-0.0105	0.0320	0.5049

For the fraction of particles carrying three or more charges, use Equation B-3 which is based on a derivation by Gunn from 1956.

$$f(N) = \frac{e}{\sqrt{4\pi^2 \varepsilon_0 D_p kT}} \exp \frac{-\left[N - \frac{2\pi\varepsilon_0 D_p kT}{e^2} \ln\left(\frac{Z_{i+}}{Z_{i-}}\right)\right]^2}{2\frac{2\pi\varepsilon_0 D_p kT}{e^2}} \qquad \text{Equation B-3}$$

where:

e = elementary charge
= 1.60217733E-19 coulomb
ε_0 = dielectric constant
= 8.854187817E-12 farad/m (for air)
D_p = particle diameter [m]
k = Boltzmann's constant
= 1.380658E-23 joule/K (for air)
T = Temperature [K]
N = number of elementary charge units
Z_{i+}/Z_{i-} = ion mobility ratio
= 0.875 (Wiedensohler)

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Particle Mobility Theory

As mentioned previously, only particles with a narrow range of electrical mobilities are extracted by the DMA to be measured by a particle sensor. To determine the particle size associated with this range of mobilities, the definition of particle electrical mobility must be examined.

An aerosol particle in an electric field, E, carrying *n* electric charges experiences an electrical force, causing it to move through the gas in which it is suspended. It very quickly reaches its terminal velocity, v. The resulting drag force on the particle is given by Stokes law and can be equated to the electrical force to determine the electrical mobility of a particle. The electrical mobility, then, is a measure of the particle's ability to move in an electric field. The electrical mobility, Z_p, is defined by Equation B-4:

$$Z_p = \frac{neC}{3\pi\mu D_p}$$ Equation B-4

where:

n = number of elementary charges on the particle

e = elementary charge (1.6×10^{-19} Coulomb)

C = Cunningham slip correction =
$1+Kn[\alpha+\beta \exp(-\gamma/Kn)]$
$\alpha = 1.142$, $\beta = 0.558$, $\gamma = 0.999$ (Allen & Raabe, 1985)
Kn = Knudsen Number = $2\lambda/Dp$

λ = gas mean free path = $\lambda_r \left(\frac{P_r}{P}\right)\left(\frac{T}{T_r}\right)\left(\frac{1+S/T_r}{1+S/T}\right)$

S = Sutherland constant [K]
T = temperature [K]
T_r = reference temperature [K]

μ = gas viscosity (dyne·s/cm^2) poise = $\mu_r \left(\frac{T_r+S}{T+S}\right)\left(\frac{T}{T_r}\right)^{\frac{3}{2}}$

D_p = particle diameter (cm)

Note that in Equation B-4, the gas mean free path and gas viscosity parameters are based on values for *S* and *T*. It is important to use consistent values (that is, you may use different values for *S* and *T* to calculate μ than to calculate λ as long as the values are consistent for each equation). Values for common gases can be found in Radar (1990). An explanation of the gas equations can be found in Willeke & Baron (1993).

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The range of particle diameters removed from the Electrostatic Classifier not only depends on particle electrical mobility. Knutson [1975] determined the relationship between the particle electrical mobility and the Classifier parameters. The relationship is given in equation B-5.

$$Z^{*}_{p} = \frac{q_{sh}}{2\pi VL} \ln\left(\frac{r_2}{r_1}\right)$$ Equation B-5

and the mobility bandwidth, ΔZ_p, is:

$$\Delta Z_{p} = \frac{q_a}{q_{sh}} Z^{*}_{p}$$ Equation B-6

where:

Z_p^* = set mobility (if $q_a = q_{sh}$ then $Z_p = Z_p^*$)
q_a = aerosol flow rate through the Classifier ($q_s + q_p$: monodisperse flow rate and the polydisperse flow rate)
q_{sh} = sheath air flow rate (equal to excess air flow rate)
r_2 = outer radius of annular space
= 1.961 cm (for Long DMA)
= 1.905 cm (for Nano DMA)
r_1 = inner radius of annular space
= 0.937 cm (for Long DMA)
= 0.937 cm (for Nano DMA)
$\overline{V}$ = average voltage on the inner collector rod (volts)
L = length between exit slit and polydisperse aerosol inlet
= 44.369 cm (for Long DMA†)
= 4.987 cm (for Nano DMA)
b = gap spacing between plates

Equations B-4 and B-5 can be combined to give an equation that relates the particle diameter to collector rod voltage, number of charges on the particle, Classifier flow rate, and geometry for the Long DMA or Nano DMA:

$$\frac{Dp}{C} = \frac{2ne\overline{V}L}{3\mu q_{sh} \ln\frac{r_2}{r_1}}$$ Equation B-7

†The length measurement is based on the geometrical value of the distance between the vertical midpoint of the inlet slit and the midpoint of the exit slit. Traditionally, a value of 44.44 cm has been used. Kinney, et. al. [1991] suggests using a value of 43.6 cm as an “effective length” to account for entrance and exit effects. TSI firmware and software uses the value of 44.369 since this is a physically verifiable number.

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Figure B-7 allows calculation of the particle diameters that pass through the exit slit of the Electrostatic Classifier, if the number of charges on the particle is known. Table B-1 shows that the majority of the aerosol in charge equilibrium exists as singly charged particles. However, a fraction of the particles exist as multiply charged particles.

A particle with a certain mobility may exist as a small particle with a single charge or as a larger particle with multiple charges. Either has the same mobility and is removed by the system with the monodisperse airflow. Refer to Wang and Flagan [1990] for the effect of multiply charged particles on the data analysis. Figure B-7 shows the relationship between the diameter of particles with a single charge and collector rod voltage for a Model 3081 Long DMA.

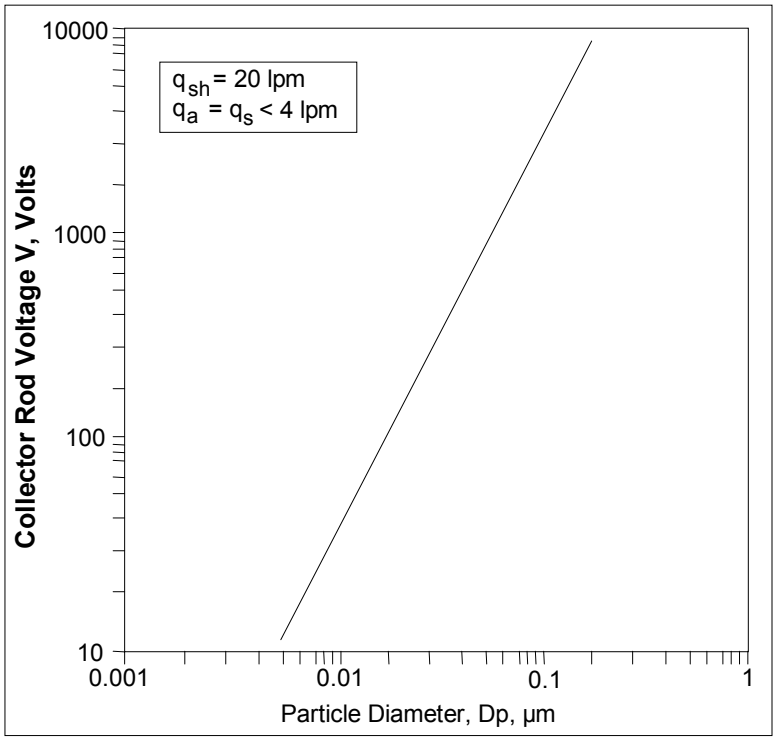


Figure B-7
Collector Rod Voltage as a Function of Particle Diameter for Normal Operating Conditions of the Long DMA [Agarwal and Sem, 1978]

The Equations listed above do not account for diffusion broadening. This is an important factor in particles below 50 nm. For the more comprehensive formulas, refer to work by Stoltzenburg [1988].

Once the particles are classified according to electrical mobility, their concentration is measured by a CPC or Electrometer.

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APPENDIX C

Using Serial Data Commands

This chapter contains information you need if you are writing your own software for a computer or data acquisition system. Information includes:

- Pin connectors
- Baud rate
- Parity
- Command definitions and syntax.
- Examples, as well as input and troubleshooting directions are also provided.

Making Connection

Connect the serial port of an IBM-compatible computer to the SERIAL PORT connector on the back of the Classifier (Figure 2-2). Use the 3-meter cable provided. If you need a longer cable, use a standard IBM 9-pin, serial extension cable. The computer should be configured for communications settings of 9600 Baud, 7 bits, Even Parity, and 1 stop bit (7-E-1).

Pin Connectors

The Classifier has a single 9-pin, D-subminiature connector port on the back panel labeled SERIAL PORT (See Figure C-1 and Figure C-2). This communication port is configured at the factory to work with RS-232 type devices. Table C-1 provides the signal connections.

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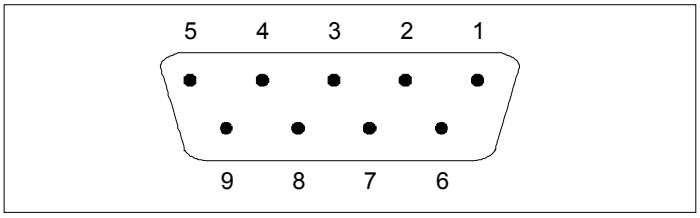


Figure C-1
Serial Port Pin Designations

Table C-1
Signal Connections for RS-232 Configurations

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

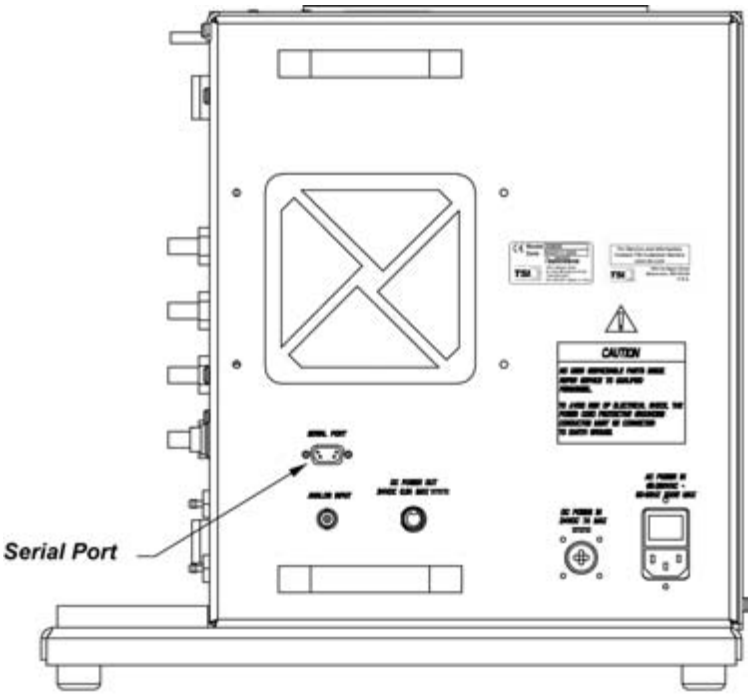


Figure C-2
Serial Port Connector on the Back of the Classifier

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Baud Rate

The baud-rate setting is the rate of communication in terms of bits per second (baud). The Classifier uses a baud rate setting of 9600. For proper communications, make sure that all software used with the instrument is set at the appropriate rate.

Parity (7-Bits Even)

Parity is the additional bit that accompanies the seven data bits to confirm that they are transmitted correctly. It is set so that the number of “1” bits (high) in a transmitted character is always an even number. The Classifier uses even parity as the only setting.

Commands

The Classifier uses an ASCII-based communications protocol that uses the RS-232 port of a computer to transmit commands in the form of strings.

The two types of commands are:

- Read commands, in which the Classifier sends data in response to a specific request from the computer
- Set commands, which set all the operating parameters for the Classifier

Some things to keep in mind if you are writing your own interface software to communicate with the Classifier:

- No line-feed characters are transmitted.
- A “Set” command with no parameter echoes the current parameter setting.
- A “Set” command with parameters echoes "OK" if the parameter is accepted.
- A “Read” command returns the requested value.
- All other commands will return an "OK" if executed unless otherwise noted. The response "ERROR" will be returned if the command is not understood or has an invalid parameter.
- Commands returning multiple parameter are separated with “,”.

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Command Quick Reference

The following tables provide a quick reference to all the serial commands. Command definitions, syntax, and examples begin after the tables. Directions for issuing commands and troubleshooting commands are provided at the end of this section.

Read Commands

RP	**R**ead **P**ressure	RFV	**R**ead **F**irmware **V**ersion
RQ	**R**ead Flow Rate	RMN	**R**ead **M**odel **N**ame
RT	**R**ead **T**emperature	ROT	**R**ead **O**n **T**ime
RUS	**R**ead **U**ser **S**etting	RFL	**R**ead **F**lags
RMV	**R**ead **M**easured **V**alue		

Set Commands

SPDx	**S**et **P**article **D**iameter
SVMx	**S**et **V**oltage **M**ode
SHVx	**S**et **H**igh **V**oltage
SFMx	**S**et **F**low **M**ode
SQSx	**S**et **S**heath Flow Rate
SQBx	**S**et **B**ypass Flow Rate
SCSAx	**S**et **C**al **S**heath Parameter **A**
SCSBx	**S**et **C**al **S**heath Parameter **B**
SCBAx	**S**et **C**al **B**ypass Parameter **A**
SCBBx	**S**et **C**al **B**ypass Parameter **B**
SCI1Ax	**S**et **C**al **I**mpactor **1** Parameter **A**
SCI1Bx	**S**et **C**al **I**mpactor **1** Parameter **B**
SCI2Ax	**S**et **C**al **I**mpactor **2** Parameter **A**
SCI2Bx	**S**et **C**al **I**mpactor **2** Parameter **B**
SCI3Ax	**S**et **C**al **I**mpactor **3** Parameter **A**
SCI3Bx	**S**et **C**al **I**mpactor **3** Parameter **B**
SAOx	**S**et **A**uxiliary **O**utput
SFCx	**S**et **F**low **C**alibration Algorithm
SCTw,x,y,z	**S**et **C**alibration **T**able
SCTCx	**S**et **C**alibration **T**able **C**orrect
SDMAx,y,z	**S**et **DMA** Parameter
SISx,y	**S**et **I**mpactor **S**erial Number
SOVx	**S**et **O**ffset **V**alues

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Troubleshooting Input

Use Table C-2 as a troubleshooting guide.

Table C-2
Troubleshooting Serial Commands

Symptom	Possible Problem	Refer to
"Error" message after pressing <**Enter**>	An invalid command; command does not exist. An invalid parameter, which includes too many parameters or a parameter that is out-of-range. Incorrect syntax	Detailed description of the commands in this section. The command description shows the range and an example.
No response after pressing <**Enter**>	Serial cable	Check the cable and the cable connection. See Chapter 2, "Unpacking and Setting Up the System."
	Incorrect COM port	Check the COM port specified in the software.
	Incorrect baud rate	Software must be set at 9600 Baud, 7E1. Also check computer hardware.
	RS-232 chip on the Classifier	Contact TSI. Refer to "Technical Contacts," in Chapter 6.
	Classifier is locked up	Remove power from the Classifier, then apply power to the instrument. If the problem continues, contact TSI.

Definitions of Read Commands

Read Pressure

RP (**R**ead **P**ressure)
Returns the following pressures:

Return: Absolute pressure [mBar],
pressure drop across the impactor nozzle [cmH_20]
pressure drop across the bypass orifice [mmH_20]

Read Flow Rates

RQ (**R**ead Flow Rate)
Returns the following flow rates:
Return: Impactor flow rate [in L/min],
Sheath flow rate [in L/min],
Bypass flow rate [in L/min]

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Read Temperature

RT (**R**ead **T**emperature)
Returns the following temperatures:

Return: Sheath flow temperature [in °C],
Cabinet temperature [in °C]

Read User Settings

RUS (**R**ead **U**ser **S**etting)
Returns values selected on front panel:

Return: Selected DMA voltage [in Volt]
Selected particle diameter [in nm]
Selected flow mode [D or S (D = Dual, S = Single)]
Selected electrical mobility [in $cm^2/(Vs)$]
Selected sheath flow rate [in L/min]
Selected bypass flow rate [in L/min]
Voltage control mode [P or A (P= Panel, A= Analog)]

Read Measured Values

RMV (**R**ead **M**easured **V**alue)
Returns measured values:

Return: Selected Particle Diameter [in nm]
Measured DMA voltage [in Volt]
Measured sheath flow rate [in L/min]
Measured bypass flow rate [in L/min]
Measured absolute pressure [in mBar]
Measured sheath flow temperature [in °C]
Measured cabinet temperature [in °C]
Measured impactor flow rate [in L/min]
Selected electrical mobility [in $cm^2/(Vs)$]
Voltage control mode [P or A (P= Panel, A= Analog)]
Selected flow mode [D or S (D = Dual, S = Single)]
Sheath flow status [0 or 1 (0 = not stable, 1 = stable)]
Bypass flow status [0 or 1 (0 = not stable, 1 = stable)]
High voltage status [0 or 1 (0 = error, 1 = OK)]
Measured impactor pressure drop [in cm H_2O]
Selected DMA model [4-0]
Selected gas type [5-0]
Selected impactor [3-0]
Actual particle diameter [in nm]
Adjustable minimum particle diameter [in nm]
Adjustable maximum particle diameter [in nm]

Read Firmware Version

RFV (**R**ead **F**irmware **V**ersion)
Returns the version of the firmware:
Return: Firmware version

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Read Model Name

RMN (**R**ead **M**odel **N**ame)
Returns the current model name and number as displayed on the power on screen:
Return: "Electrostatic Classifier 3080"

Read On Time

ROT (**R**ead **O**n **T**ime)
Returns the accumulated On Time hours of instrument, sheath blower and bypass blower. (updated every minute) stored in the EEPROM.
Return: Classifier On Time HH:MM
Sheath Blower On Time HH:MM
Bypass Blower On Time HH:MM

Read Flags

RFL (**R**ead **F**lags)
Returns the status of the following flags:
Return: Sheath flow led status [0 or 1 (0 = not stable, 1 = stable)],
Bypass flow stable [0 or 1.],
High-voltage ok [0 or 1 (0 = not ok, 1 = ok)]

Definitions of Combined Set Commands

Set Particle Diameter

SPDx (**S**et **P**article **D**iameter)
Set particle diameter:

SPD6.4	*Set:*	particle diameter = 6.4 nm
SPD	*Return:*	particle diameter [in nm]

Set Voltage Mode

SVMx (**S**et **V**oltage **M**ode)
Set bypass flow rate:

SVMP	*Set:*	panel control
SVMA	*Set:*	analog control
SVM	*Return:*	P or A

Set High Voltage

SHVx (**S**et **H**igh **V**oltage)
Set DMA high-voltage:

SHV80.6	*Set:*	dma voltage = 80.6 Volt
SHV	*Return:*	dma voltage [in Volt]

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Set Flow Mode

SFMx (**S**et **F**low **M**ode)
Set sheath blower mode:

SFMS	*Set:*	Single Blower
SFMD	*Set:*	dual blower
SFM	*Return:*	S or D

Set Sheath Flow Rate

SQSx (**S**et **S**heath Flow Rate)
Set sheath flow rate:

SQS10.0	*Set:*	sheath flow rate = 10.0 L/min
SQS	*Return:*	sheath flow rate [in L/min]

Set Bypass Flow Rate

SQBx (**S**et **B**ypass Flow Rate)
Set bypass flow rate:

SQB15.0	*Set:*	bypass flow rate = 15.0 L/min
SQB	*Return:*	bypass flow rate [in L/min]

Set Flow Calibration Algorithm

SFCw (**S**et **F**low **C**alibration Algorithm)

SFCS	*Set:*	Stepwise Linear Flow Calibration Algorithm
SFCP	*Set:*	Polynomial Flow Calibration Algorithm
SFC	*Return:*	P: Polynomial Flow Calibration Algorithm S: Stepwise Linear Flow Calibration Algorithm

Set Flow Calibration Table (Stepwise Linear Flow Calibration Algorithm)

SCTw,x,y,z (**S**et **C**alibration **T**able)

SCTw,x,y,z *Set:*

w = 0: sheath flow calibration
x = row of calibration table ($1 \leq x \leq 50$)
y = raw sheath flow rate in (100 * L/min)
z = calibrated sheath flow rate in (100 * L/min)

w = 1: bypass flow calibration
x = row of calibration table ($1 \leq x \leq 50$)
y = raw bypass pressure in (100 * mmH_2O)
z = calibrated bypass flow rate in (100 * L/min)

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w = 2: impactor 1 flow calibration
x = row of calibration table (1 ≤ x ≤ 50)
y = raw impactor 1 pressure in (100 * mmH_2O)
z = calibrated impactor 1 flow rate in (100 * L/min)

w = 3: impactor 2 flow calibration
x = row of calibration table (1 ≤ x ≤ 50)
y = raw impactor 2 pressure in (100 * mmH_2O)
z = calibrated impactor 2 flow rate in (100 * L/min)

w = 4: impactor 3 flow calibration
x = row of calibration table (1 ≤ x ≤ 50)
y = raw impactor 3 pressure in (100 * mmH_2O)
z = calibrated impactor 3 flow rate in (100 * L/min)

SCTw *Return:* w = 0: Sheath Flow Calibration
w = 1: Bypass Flow Calibration
w = 2: Impactor 1 Flow Calibration
w = 3: Impactor 2 Flow Calibration
w = 4: Impactor 3 Flow Calibration

Set Flow Calibration Table Correct (Stepwise Linear Flow Calibration Algorithm)

SCTCw (**S**et **C**alibration **T**able **C**orrect)

SCTCw *Set:* w = 0: Sheath flow calibration table is correct
w = 1: Bypass flow calibration table is correct
w = 2: Impactor 1 flow calibration table is correct
w = 3: Impactor 2 flow calibration table is correct
w = 4: Impactor 3 flow calibration table is correct

Set or Read Impactor Serial Number

SISx,y (**S**et **I**mpactor **S**erial Numbers)

SISx,y *Set:* serial number y of impactor x
x = 1: 0.0710 cm impactor nozzle
x = 2: 0.0508 cm impactor nozzle
x = 3: 0.0457 cm impactor nozzle

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SIS	*Return:*	read serial number of all impactor example: 0457 cm; SN: 320 0508 cm; SN: 120 0710 cm; SN: 173

Set Offset Bit Value of Flow Sensor

SOVx (**S**et **O**ffset **V**alues of pressure transducer and flowmeter)

SOVx	*Set:*	measure offset bit values the following sensors and stores values in EEPROM: x = B: Bypass Pressure Transducer x = I: Impactor Pressure Transducer x = L: Flowmeter
SOV	*Return:*	offset of Bypass Pressure Transducer (in bit), offset of Impactor Pressure Transducer (in bit), offset of Flowmeter (in bit)

Set Sheath Flow Calibration Parameter A (Polynomial Flow Calibration Algorithm)

SCSAx (**S**et **C**alibration **S**heath Parameter **A**)
Set sheath flow calibration parameter A:

SCSA1.234567e-12	*Set:*	sheath flow calibration parameter A
SCSA	*Return:*	sheath flow calibration parameter A

Set Sheath Flow Calibration Parameter B (Polynomial Flow Calibration Algorithm)

SCSBx (**S**et **C**alibration **S**heath Parameter **B**)
Set bypass flow calibration parameter B:

SCSB1.234567e-12	*Set:*	sheath flow calibration parameter B
SCSB	*Return:*	sheath flow calibration parameter B

Set Calibration Bypass Parameter A (Polynomial Flow Calibration Algorithm)

SCBAx (**S**et **C**alibration **B**ypass **A** Parameter)
Set sheath flow calibration parameter:

SCBA1.234567e-12	*Set:*	bypass flow calibration parameter
SCBA	*Return:*	bypass flow calibration parameter

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Set Calibration Bypass Parameter B (Polynomial Flow Calibration Algorithm)

SCBBx (**S**et **C**alibration **B**ypass **B** Parameter)
Set sheath flow calibration parameter:

SCBB1.234567e-12	*Set:*	bypass flow calibration parameter
SCBB	*Return:*	bypass flow calibration parameter

Set Calibration Impactor Parameter A (Polynomial Flow Calibration Algorithm)

SCIxAy (**S**et **C**alibration **I**mpactor Parameter **A**)
Set impactor flow calibration parameter A (x can be 1, 2, or 3; corresponding to 0.457, 0.508 and 0.071 nozzles):

SCI1A1.234567e-12	*Set:*	impactor flow calibration parameter 1 A
SCI1A	*Return:*	impactor flow calibration parameter 1 A

Set Calibration Impactor Parameter B (Polynomial Flow Calibration Algorithm)

SCIxBy (**S**et **C**alibration **I**mpactor Parameter **B**)
Set impactor flow calibration parameter B (x can be 1, 2, or 3; corresponding to 0.457, 0.508 and 0.071 nozzles):

SCI1B1.234567e-12	*Set:*	impactor flow calibration parameter 1 B
SCI1B	*Return:*	impactor flow calibration parameter 1 B

Set Auxiliary Output

SAOx (**S**et **A**uxiliary **O**utput)

SAO0	*Set:*	auxiliary output to [*x* = 0: 0 volt, x = 1: 5 volt
SAO	*Return:*	auxiliary input status (0: 0 volt, 1: 5 volt)

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Set DMA Parameter

SDMAxyz	(**S**et **DMA** parameter)	
SDMAxSz	*Set:*	style z for DMA x ($1 \leq x \leq 5$) z = 0: DMA data not available, z = 1: cylindrical DMA,]
SDMAxIz	*Set:*	inner diameter for DMA x (in mm)
SDMAxOz	*Set:*	outer diameter for DMA x (in mm)
SDMAxL*z*	*Set:*	characteristic length for DMA x (in mm)
SDMAx	*Return:*	inner diameter of DMA x (in mm), outer diameter of DMA x (in mm), characteristic length of DMA x (in mm), style of DMA x (0=DMA data not available, 1=cylindrical DMA)

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APPENDIX D

Classifier Calibration

This appendix contains sections on calibrating the Model 3080 Classifier. There are three main aspects of the instrument that can be calibrated by the user: sheath flowmeter, bypass flowmeter, and impactor inlets. To assist in the calibration, there are settings on the main menu from the front panel and custom software that interfaces to the Classifier through the serial port on the back panel. In addition, this chapter covers some features of the Classifier that should only be done by a qualified technician.

Calibration Software Setup

The calibration software is designed for Windows® 2000 or Windows® XP operating system. To install the software, follow the steps below.

1. With the computer on and Windows running, insert the 3080 Calibration Software CD into your CD drive to run the **autorun.exe** from the CD.
2. If AutoPlay is enabled on your PC, the setup program will begin automatically and the introduction screen is displayed on the Windows desktop.
3. If AutoPlay is not enabled, select Run from the Start menu and type `D:\SETUP` (where D is the letter corresponding to your CD drive) in the Open box and press OK.
4. Follow the instructions as the setup program runs. When setup is complete, you should read the readme.htm file. The readme.htm file contains information that could not be included in this manual. If you decide not to read this file immediately, you can access the file later using a browser such as Windows Explorer.
5. When the installation program finishes, remove the CD-ROM.

The calibration software requires that an unused serial port from your computer be connected to the Model 3080 Classifier using the serial cable (and adapter, if needed) provided in the accessory kit. Connect the cable, power up the Classifier and then run the

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software by double-clicking on the Electrostatic Classifier software icon.

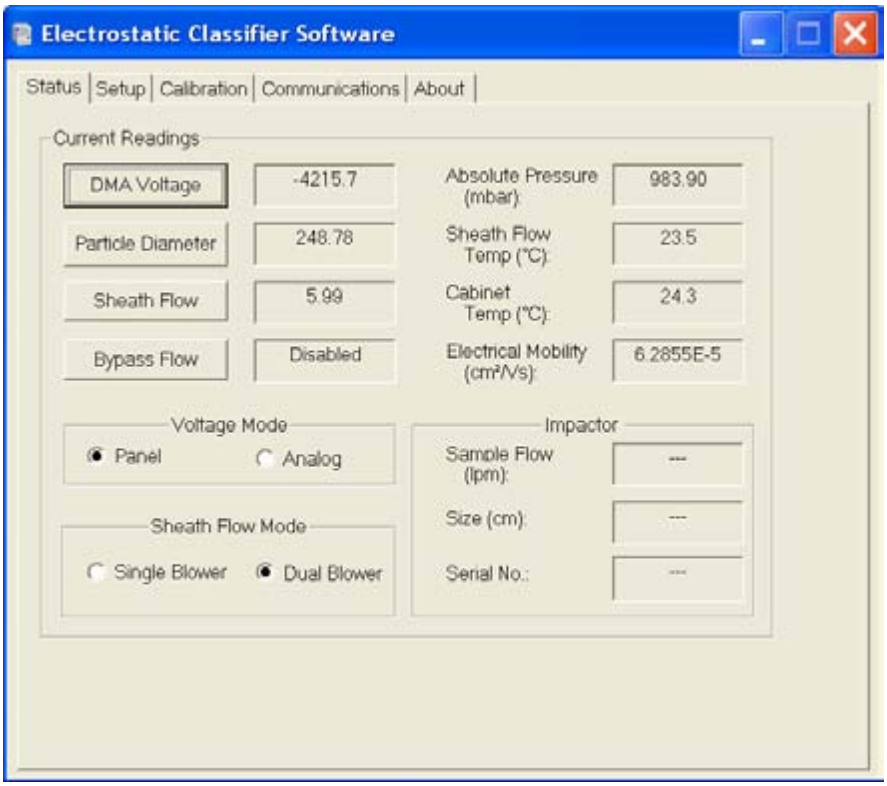


Figure D-1
Electrostatic Classifier Calibration Software Startup Screen

When the software starts, you should see a screen similar to that shown in Figure D-1. If you get an error message like that shown in Figure D-2, check the serial cable connection or try setting the software to another available serial port using the tab shown in Figure D-3.



Figure D-2
Connection Error

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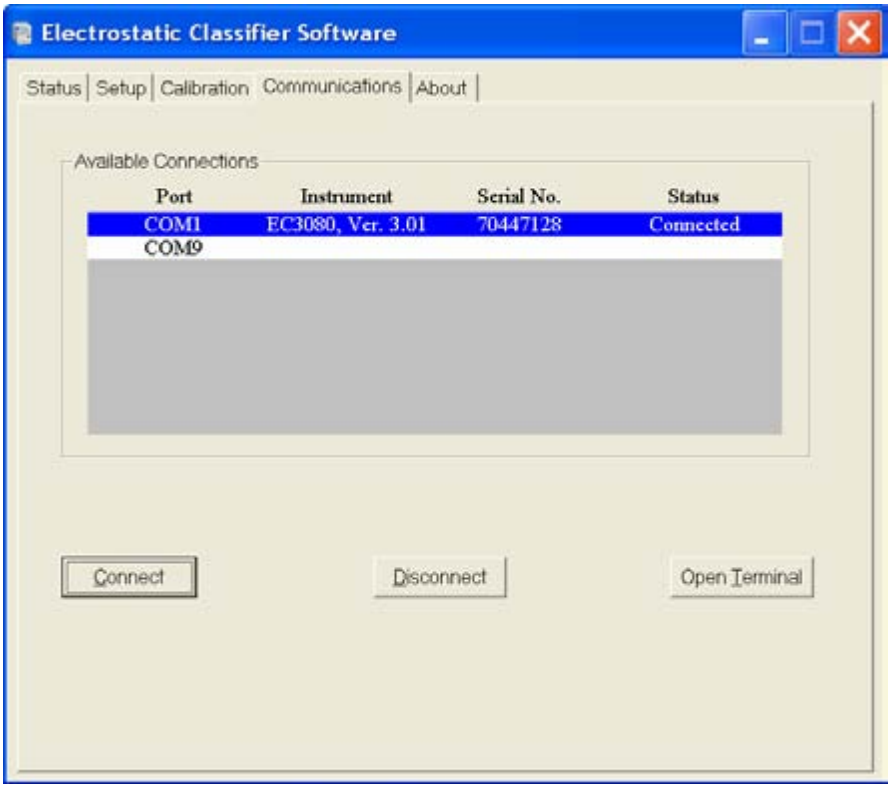


Figure D-3
Communications Settings for Serial Port

Using the Calibration Software

The first tab in the calibration software, shown in Figure D-4, gives instrument status information. This can be used to remotely monitor the instrument or even to set some parameters. It can be useful for troubleshooting and checking on calibration settings. When the program is first started, all the settings are read from the instrument and the fields are updated regularly (once per second). The leftmost fields have buttons next to them allowing you to enter a value by clicking on the button. Press **Enter** after the value is input. For DMA voltage, input a positive value and the software converts it into negative voltage automatically.

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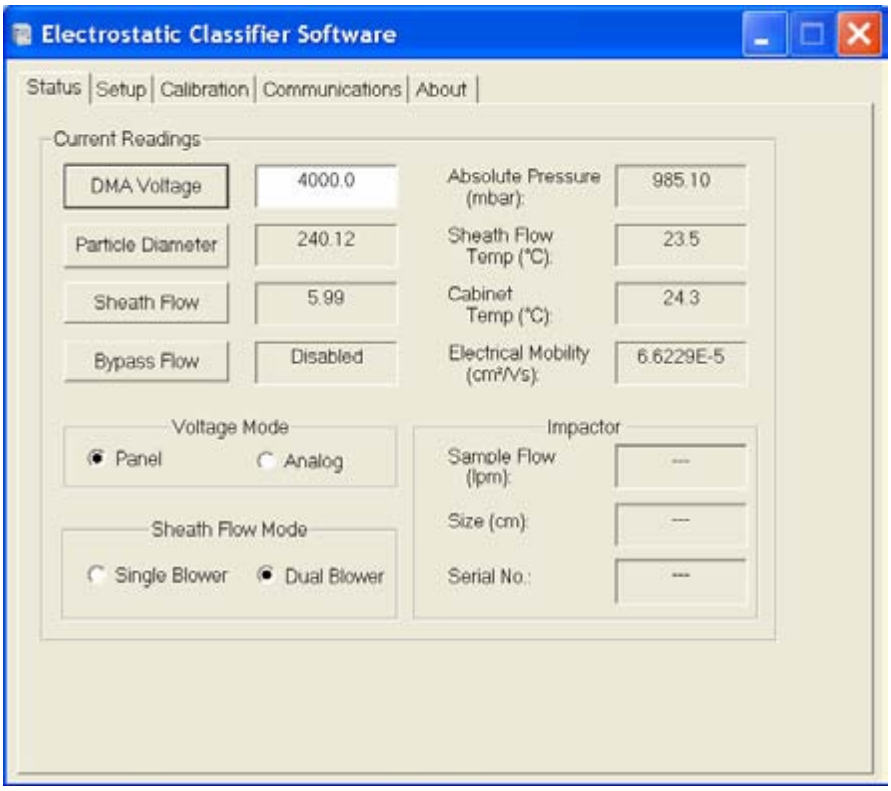


Figure D-4
Status Settings

The setup tab allows you to view the gas properties used by the Classifier.

Note: *You cannot change any of the gas parameters.*

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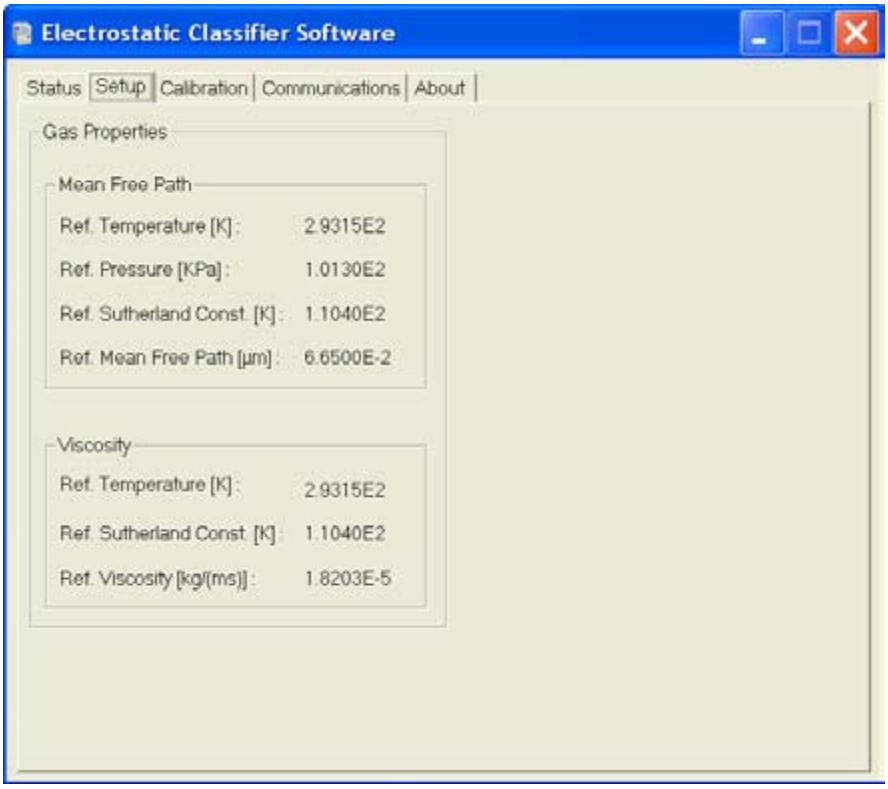


Figure D-5
Setup Tab

Sheath-Air Calibration

The flows described below are calibrated at TSI and normally do not need to be recalibrated. These instructions are intended for the advanced user that may wish to perform a field calibration.

It is best to calibrate the flows in the order described in this section. A primary standard flowmeter such as an electronic bubble flowmeter is required. The Classifier is calibrated at TSI using a Gilman Gilibrator Electronic Bubble Flowmeter. Contact your TSI representative to order a calibration flowmeter.

Equipment needed:

- ❑ Volumetric Flowmeter Standard
- ❑ ⅜ to ¼ adapter
- ❑ Computer with EC software loaded and connected to Serial port of Classifier

1. Select **MENU** from the main screen on the front panel display of the 3080 Electrostatic Classifier.

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2. Select **Flow Calibration**.

3. Select **Sheath Flow**.

4. Set **Raw Sheath Flow** to OFF (0.00) LPM using the dial knob on the front panel of the Classifier and wait 60 seconds until flow has completely stopped.

5. Make sure that **Exhaust Flow** and **Excess Flow** port fittings are connected by a tube on the outside of the Classifier.

6. Connect the Flowmeter Standard to the **Sheath Flow** port fitting on the Classifier.

7. Set **Raw Sheath Flow** on the Classifier front panel screen to 2 L/min and wait for the flow to stabilize. Take 5 samples and average them. Record the raw flow (Qraw) and flowmeter (Qcal) readings.

8. Repeat step **7** for 4, 6, 8, 10, 12, 14, 16, 18 L/min.

9. Repeat step **7** for 20 L/min, if possible. If this flow cannot be reached, use 19 L/min instead for a total of 10 data points.

10. Enter the data into the EC program (Figure D-6) under **Sheath Flow Calibration** tab and click on the **Set Calibration** button, which calibrates the instrument.

11. Exit the Sheath Calibration Screen on the Classifier and close the software window.

12. Recheck the sheath flow dialed in on the main Classifier display screen with an external flowmeter.

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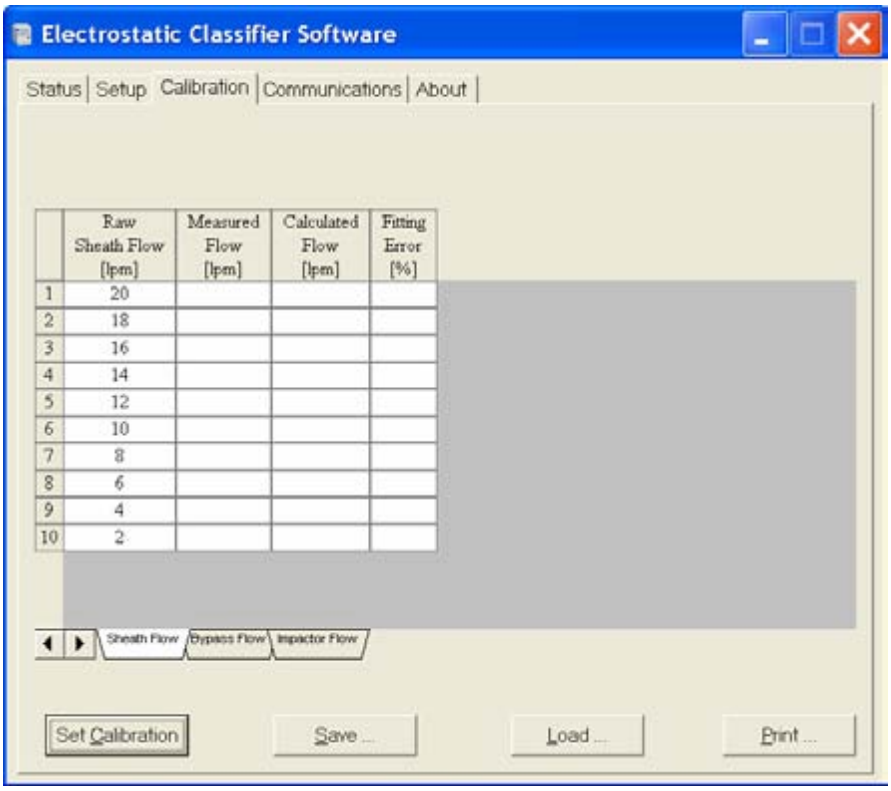


Figure D-6
Sheath Flow Calibration

Bypass-Air Calibration

1. Select **MENU** from the main screen on the front panel display of the 3080 Electrostatic Classifier.
2. Select **Flow Calibration**.
3. Select **Bypass Flow**.
4. Set **Raw Bypass Flow** to OFF (0.00) LPM and wait 60 seconds until flow has completely stopped.
5. Make sure that **Exhaust Flow** and **Excess Flow** port fittings are connected by a tube on the outside of the Classifier.
6. Connect the Flowmeter Standard to the **Sheath Flow** port fitting on the Classifier.
7. Set **Bypass Flow** to 2 L/min and wait for the flow to stabilize. Take five (5) samples and average them. Record the Pressure drop (dP) and flowmeter (Qcal) readings.
8. Repeat step **7** for 4, 6, 8, 10, 12, 14, and 16 L/min for a total of 8 data points.

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9. Enter the data into the EC program under Bypass Flow Calibration tab (Figure D-7) and click on the **Set Calibration** button.

10. Exit the Bypass Calibration Screen on the Classifier and close the software window.

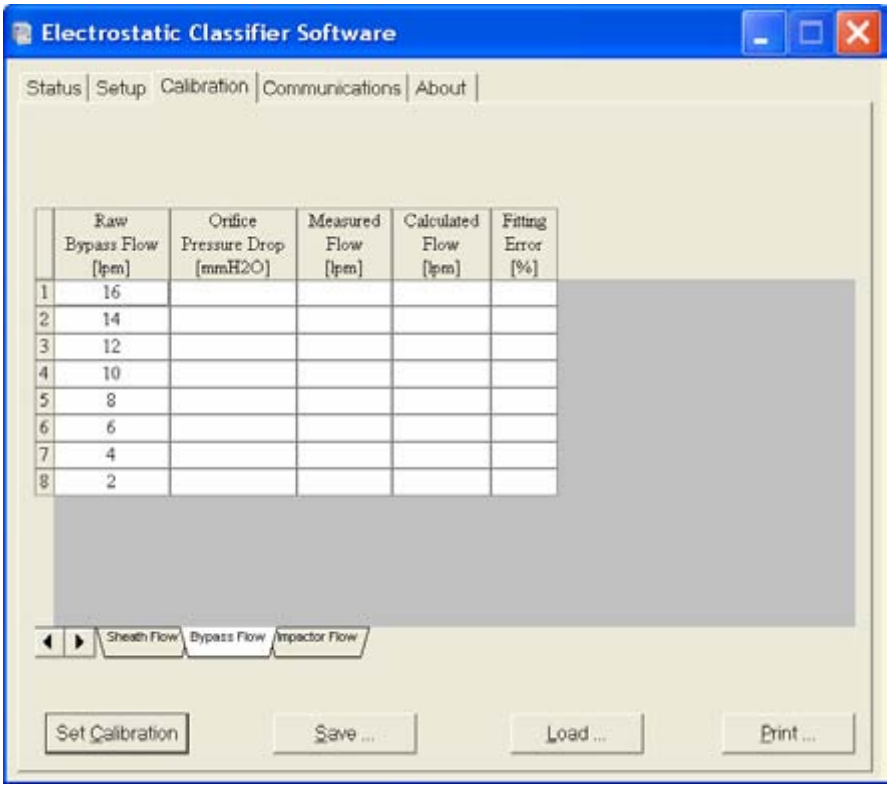


Figure D-7
Bypass Flow Calibration Tab

Impactor Calibration

1. Select **MENU** from the main screen on the front panel display of the 3080 Electrostatic Classifier.

2. Select **Flow Calibration**.

3. Select **Impactor Flow**.

4. Set **Pressure Drop** to .0 cmH_2O and wait 60 seconds until flow has completely stopped.

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5. Make sure that **Exhaust Flow** and **Excess Flow** port fittings are connected by a tube on the outside of the Classifier. Put a ⅜ to ¼ inch adapter on the **Bypass Flow** port fitting. Connect the **Bypass Flow** port fitting to the **Polydisperse Flow** port fitting with a tube.
6. Install the 0.0457 impactor nozzle.
7. Connect the Flowmeter Standard to the **Impactor Inlet** fitting.
8. Set **Pressure Drop** to 5 cmH_20 and wait for the flow to stabilize. Take 5 samples and average them. Record the **Pressure Drop** (dP) and flowmeter (Qcal) readings.
9. Repeat step **8** for 10, 20, 30, 40, 50, and 60 cmH_20.
10. In the Electrostatic Classifier software, select the **Calibration** tab and then select **Impactor Flow** tab.
11. Select the size of the impactor nozzle (.0457/.0508/.0710 cm) using the **Impactor Type** drop-down box. Enter the serial number of the corresponding impactor.
12. Enter the measured flows from steps **8** and **9** into the Measured Flow column and click on the **Set Calibration** button.

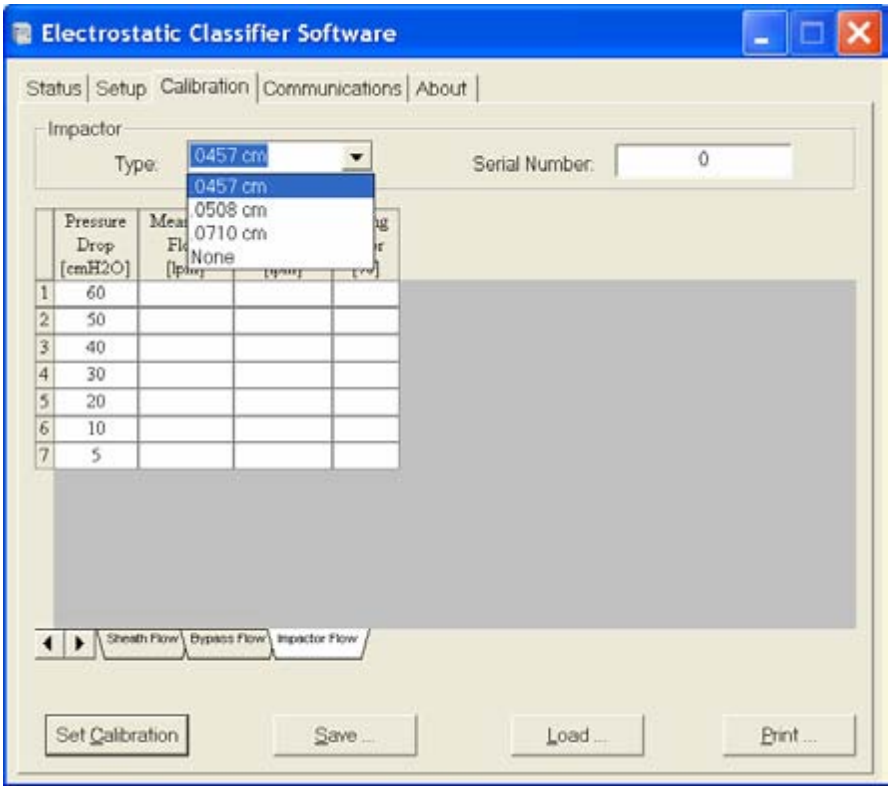


Figure D-8
Impactor Calibration Tab

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13. Repeat steps **6** to **12** for the 0.0508 and 0.071 cm nozzles by selecting those sizes from the **Impactor Nozzle Type** drop-down box.

14. The calibration file can be saved by pressing the **Save** button; But saving the file is not required for this calibration procedure.

15. Exit the Sheath Calibration Screen on the Classifier and close the software window.

Working with Calibration Files

In the calibration screen there are four buttons that are used to work with the calibration files: Set Calibration, Save, Load, and Print. The buttons are used as follows:

Set Calibration	Use the Set Calibration button to send the calibration settings to the Classifier as discussed previously in this appendix.
Save ...	Use the Save button to write out all of the calibration values for the Sheath, Bypass or Impactor flows into a file.
Load ...	Use the Load button to load a previously saved calibration from a file into the program.
Print ...	Use the Print button to print the calibration tables on a single page, in landscape mode.

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