Particle Instruments

Model 3776
Ultrafine Condensation Particle Counter

Operation and Service Manual

P/N 1980522, Revision B
April 2006

TSI®

Model 3776
Ultrafine Condensation Particle Counter

Operation and Service Manual

Manual History

The following is a history of the Model 3776 Ultrafine Condensation Particle Counter Operation and Service Manual (Part Number 1980522).

Revision	**Date**
A	November 2005
B	April 2006

Warranty

Part Number
1980522 / Revision B / April 2006

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

Fax No.
651-490-3824

E-mail Address
particle@tsi.com

Limitation of Warranty and Liability
(effective July 2000)

Seller warrants the goods sold hereunder, under normal use and service as described in the operator's manual, shall be free from defects in workmanship and material for (12) months, or the length of time specified in the operator's manual, from the date of shipment to the customer. This warranty period is inclusive of any statutory warranty. This limited warranty is subject to the following exclusions:

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b. Parts repaired or replaced as a result of repair services are warranted to be free from defects in workmanship and material, under normal use, for 90 days from the date of shipment.

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Service Policy

Knowing that inoperative or defective instruments are as detrimental to TSI as they are to our customers, our service policy is designed to give prompt attention to any problems. If any malfunction is discovered, please contact your nearest sales office or representative, or call TSI’s Customer Service department at 1-800-874-2811 (USA) or (651) 490-2811.

Safety

This section provides instructions to ensure safe and proper operation and handling of the Model 3776 Ultrafine Condensation Particle Counter (UCPC).

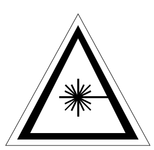
There are no user-serviceable parts inside the instrument. Refer all repair and maintenance to a qualified technician. All maintenance and repair information in this manual is included for use by a qualified technician.

Laser Safety

The Model 3776 UCPC is a Class I laser-based instrument. During normal operation, you will not be exposed to laser radiation. However, you must take certain precautions or you may expose yourself to hazardous radiation in the form of intense, focused visible light. Exposure to this light can cause blindness.

Take these precautions:

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



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

Chemical Safety

The Model 3776 UCPC uses n-butyl alcohol (butanol) as a working fluid. Butanol is flammable. Butanol is also toxic if inhaled. Refer to a Material Safety Data Sheet for butanol and take these precautions:

- ❑ Use butanol only in a well-ventilated area. Under normal operating conditions butanol is exhausted into the air at approximately 0.01 g per minute.

- ❑ Butanol vapor is identified by its characteristically strong odor and can easily be detected. If you smell butanol and develop a headache, or feel faint or nauseous, leave the area at once. Ventilate the area before returning.

C a u t i o n
Butanol is flammable. Butanol is also potentially toxic if inhaled. Use butanol only in a well-ventilated area. If you smell butanol and develop a headache, or feel faint or nauseous, leave the area at once. Ventilate the area before returning.

W A R N I N G
Although the UCPC is appropriate for monitoring inert process gases such as nitrogen or argon, it should not be used with hazardous gases such as hydrogen or oxygen. Using the UCPC with hazardous gases may cause injury to personnel and damage to equipment.

Description of Safety Labels

This section acquaints you with the advisory and identification labels on the instrument and used in this manual to reinforce the safety features built into the design of the instrument.

Caution

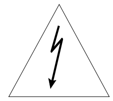
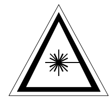
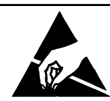
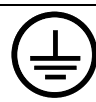
C a u t i o n
Caution means ***be careful***. It means if you do not follow the procedures prescribed in this manual you may do something that might result in equipment damage, or you might have to take something apart and start over again. It also indicates that important information about the operation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

Warning

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.

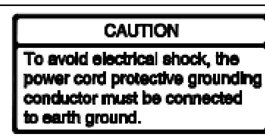
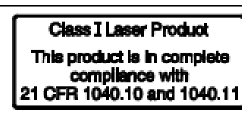
Caution or Warning Symbols

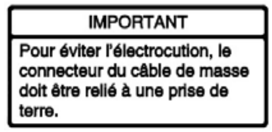
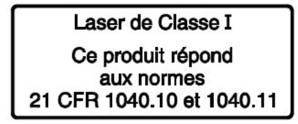
The following symbols may accompany cautions and warnings to indicate the nature and consequences of hazards:

	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 contains a laser and that important information about its safe operation and maintenance is included. Therefore, you should read the manual carefully to avoid any exposure to hazardous laser radiation.
	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.

Labels

Advisory labels and identification labels are attached to the outside of the UCPC housing and to the optics on the inside of the instrument. Labels for the Model 3776 UCPC are described below:

1. Serial Number Label (back panel)	
2. Laser Radiation Label (located internally on the optics housing)	
3.Electrical shock caution	
4. Laser device compliance label	
5. Caution	

6. WEEE Directive Label (Waste Electrical and Electronic Equipment). *(Item must be recycled properly.)*		
5. French language electrical safety and laser compliance labels		
8. ETL Label for safety certification.		
9. TSI Service Label		

Contents

Figures

Tables

About This Manual

Purpose

This is an operation and service manual for the Model 3776 Ultrafine Condensation Particle Counter (UCPC).

Organization

The following is a guide to the organization of this manual:

- **Chapter 1: Product Overview**
  This chapter gives as an introduction to the Model 3776 Ultrafine Condensation Particle Counter, a list of features, and a brief description of how the instrument works.
- **Chapter 2: Unpacking and Setting Up the UCPC**
  This chapter gives a packing list and the step-by-step procedure for getting the UCPC ready to operate.
- **Chapter 3: Instrument Description**
  This chapter describes features and controls that run the UCPC, including the components on the front-panel, back-panel, side-panel, and inside the instrument. It also covers the basic functions of the instrument.
- **Chapter 4: Instrument Operation**
  This chapter describes the operation of the instrument.
- **Chapter 5: Technical Description**
  This chapter details the principle of operation, theory, and performance of the condensation nucleus counter.
- **Chapter 6: Particle Counting**
  This chapter describes the particle counting modes.
- **Chapter 7: Computer Interface and Commands**
  This chapter describes the computer interface hardware, associated firmware commands, and flash memory card.
- **Chapter 8: Maintenance and Service**
  This chapter describes the recommended practices and schedule for routine cleaning, checking and calibration.

- **Appendix A: Specifications**
  This appendix lists the specifications of the Model 3776 Ultrafine Condensation Particle Counter.
- **Appendix B: Firmware Commands**
  This appendix lists all the serial commands for communications between the UCPC and the computer.
- **Appendix C: References**
  This chapter lists all of the references that have been used within the text of the manual. In addition, a general list of references pertaining to condensation nucleus counters is included.

Related Product Literature

- ***Model 3007 Condensation Particle Counter Operation and Service Manual*** (part number 1930035) TSI Incorporated
- ***Model 3010D Condensation Particle Counter Instruction Manual*** (part number 1900064) 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 3781 Water-based Condensation Particle Counter Operation and Service Manual*** (part number 1930111) TSI Incorporated
- ***Model 3782 Water-based Condensation Particle Counter Operation and Service Manual*** (part number 1930073) TSI Incorporated
- ***Model 3785 Water-based Condensation Particle Counter Operation and Service Manual*** (part number 1933001) TSI Incorporated
- ***Model 3786 Ultrafine Water-based Condensation Particle Counter Operation and Service Manual*** (part number 1930072) TSI Incorporated
- ***Aerosol Instrument Manager® Software for CPC and EAD Instruction Manual*** (part number 1930062) TSI Incorporated
  This manual contains operating instructions for Aerosol Instrument Manager Software for CPC and EAD, a software program that monitors, calculates, and displays particle concentration data collected by a CPC or an EAD.

Getting Help

To obtain assistance with the Model 3776 Ultrafine Condensation Particle Counter contact Customer Service:

TSI Incorporated
500 Cardigan Road
Shoreview, MN 55126 USA
Fax: (651) 490-3824
Telephone: 1-800-874-2811 (USA) or (651) 490-2811
E-mail Address: technical.service@tsi.com

Submitting Comments

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

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

TSI Incorporated
Particle Instruments
500 Cardigan Road
Shoreview, MN 55126
Fax: (651) 490-3824
E-mail Address: particle@tsi.com

CHAPTER 1
Product Overview

This chapter contains an introduction to the Model 3776 Ultrafine Condensation Particle Counter (UCPC) and provides a brief explanation of how the instrument operates.

Product Description

The Model 3776 Ultrafine Condensation Particle Counter (UCPC) is designed for researchers interested in airborne particles smaller than 20 nanometers. With sensitivity to particles down to 2.5 nanometers in diameter, this UCPC is ideally suited for atmospheric and climate research, particle formation and growth studies, combustion and engine exhaust research, and nanotechnology research. It is also compatible with TSI Scanning Mobility Particle Sizer™ (SMPS™) spectrometers for particle size distribution measurements.

The successor to the Model 3025A UCPC, the Model 3776 UCPC offers many new features and improvements:

- Detects particles down to 2.5 nanometers
- Fast response to rapid changes in aerosol concentration (T_{95} <0.8 second)
- Higher aerosol flow rate of 50 cm^3/min for improved counting statistics
- Extended single particle counting up to 300,000 particles/cm^3 with continuous, live-time coincidence correction for maximum accuracy
- Butanol friendly features, including anti-spill design, water-removal system, butanol odor absorber, and improved resistance to optics flooding
- Built-in data logging and storage capability with removable memory card
- Removable saturator wick for easy transport and maintenance
- USB and Ethernet available
- Built-in SMPS compatibility
- Auto recovery from power failure
- Particle concentration, plots of concentration versus time, total counts, instrument status and user settings shown on front-panel color LCD display

Figure 1-1
Model 3776 Ultrafine Condensation Particle Counter

How it Works

In the Model 3776 Ultrafine Condensation Particle Counter (UCPC), an aerosol sample is drawn continuously through a capillary and mixed with clean sheath air flow that passes through a heated saturator where butanol is vaporized and diffuses into the sheath flow stream. Together, the aerosol sample and butanol vapor pass into a cooled condenser where the butanol vapor becomes supersaturated and ready to condense. Particles present in the sample stream serve as condensation nuclei. Once condensation begins, particles that are larger than a threshold diameter quickly grow into larger droplets and pass through an optical detector where they are counted easily.

The Model 3776 UCPC detects particles as small as 2.5 nanometers in diameter, using a unique sheath air flow design that confines the aerosol flow path near the centerline of the condenser. Particles are exposed to the region of highest supersaturation and uniformity of butanol vapor. Particles that are larger than the threshold diameter are grown into large droplets for easy optical detection. This unique design greatly enhances measurement response time, produces a sharply defined lower size detection limit (counting efficiency curve) and minimizes diffusion losses of ultrafine and nanoparticles.

An internal vacuum pump draws the aerosol sample into the UCPC. The inlet flow can be configured for either high-flow mode operation (1.5 L/min) to improve response time and minimize particle transport loss, or low-flow mode operation (0.3 L/min) to provide flexibility when used as part of an SMPS system. In high-flow mode, 1.2 L/min of the inlet flow is diverted as a bypass flow. In the low-flow mode, 1.2 L/min clean air enters as makeup air through the back of the instrument. In both high- and low-flow modes, 0.3 L/min of the inlet flow passes through the saturator, condenser, and optics, comprising the sensor assembly. This flow is called sensor flow.

The 0.3 L/min sensor flow is controlled by a critical orifice. Sensor flow is split into a 0.25 L/min sheath flow and a 0.05 L/min aerosol flow just before the aerosol flow capillary. The sheath flow is cleaned by a HEPA filter and drawn through a heated, liquid-soaked wick where it becomes saturated with butanol vapor. The aerosol sample joins the filtered vapor-saturated sheath flow right before the inlet of the condenser. A short, heated section at this juncture allows vapor to diffuse into the aerosol before entering the cooled condenser.

The Model 3776 UCPC uses a laser-diode light source and diode photodetector to collect scattered light from particles. An internal microprocessor is used for instrument control and data processing.

A high resolution LCD display presents real-time graphs of number concentration, enables easy-to-use menus for control operation functions and presents instrument status and diagnostic information. A variety of communication options for computer data acquisition are available including an on-board data storage using a removable flash memory card.

The instrument offers a critical flow pump for high accuracy volumetric flows. It can also be used with an external vacuum pump with the necessary internal plumbing modifications.

CHAPTER 2

Unpacking and Setting up the UCPC

Use the information in this chapter to unpack the Model 3776 Ultrafine Condensation Particle Counter (UCPC) and set it up.

Packing List

Table 2-1 shows the components shipped with the Model 3776 UCPC.

Table 2-1
Model 3776 UCPC Packing List

Qty.	Description
1	Model 3776 UCPC and Operation Manual
1	Power cable
1	Aerosol Instrument Manager® Software
1	Fill Bottle
1	Drain Bottle
1	Bottle Bracket
1	RS-232 Cable (9-pin M/F, 12 ft)
1	USB I/O Cable A/B 6 ft
1	SanDisk ImageMate 5-in-1 Card Reader
1	Data Memory Card
1	Wick, Saturator UCPC 3776
1	Orifice, Critical Flow (⅛"NPT × ⅛" barb)
2	Variable Orifice, Bypass and Makeup Air (Ftg NY RSTR 0-0.025)
3	Insulation Plug .50 dia × .50 thk
3	Insulation Plug .75 dia × .50 thk
1	Filter, Charcoal
1	SS Elbow Fitting for Mounting Charcoal Filter
2	Micro Pump Filter (Filter Inline, 25 micron)
3	Fill/Drain/Makeup Air Filter (Filter Inline, 73 micron)
1	Sheath Air Filter (HEPA filter)
1	Bypass Air/Exhaust Filter (Filter, inline NY .6 um)
1	O-Ring for Reservoir Cover (FSI Ring 1-030)
1	Checkout Data Sheet
1	Certificate of Conformance

Note: *Some items above and those for future maintenance are available for purchase as kits from TSI. A complete list of* *replacement part kits is included in the maintenance section in [Chapter 8](#).*

Unpacking

The Model 3776 UCPC comes fully assembled with protective coverings on the inlet sample port, exit ports, and analog connectors. The UCPC comes packaged with the accessory kit. Use the packing list (Table 2-1) to make certain that there are no missing components.

The UCPC box contains special foam cutouts designed to protect the instrument during shipment. Save the original packaging materials for future use should you need to return the instrument to TSI for service.

To avoid contaminating the instrument or the environment the UCPC is monitoring, do *not* remove the protective covers until you are ready to install the instrument.

If anything is missing or appears to be damaged, contact your TSI representative or contact TSI Customer Service at 1-800-874-2811 (USA) or (651) 490-2811. Chapter 8, "Maintenance and Service," gives instructions for returning the UCPC to TSI Incorporated.

Setting Up

This section contains instructions for setting up the Model 3776 UCPC. Follow the instructions in the order given.

Remove Protective Caps

Remove all protective caps from the inlet sample port and exit flow ports at the back of the instrument, Also remove covers from the BNC connectors.

Mounting the Bracket and Fill Bottle

Mount the black anodized aluminum Bottle Bracket to the back panel using two 8-32 × ⅜-inch screws and two no. 8 lock-washers found in the mounting hole locations. Refer to the location of the bottle bracket shown in Figure 2-1.

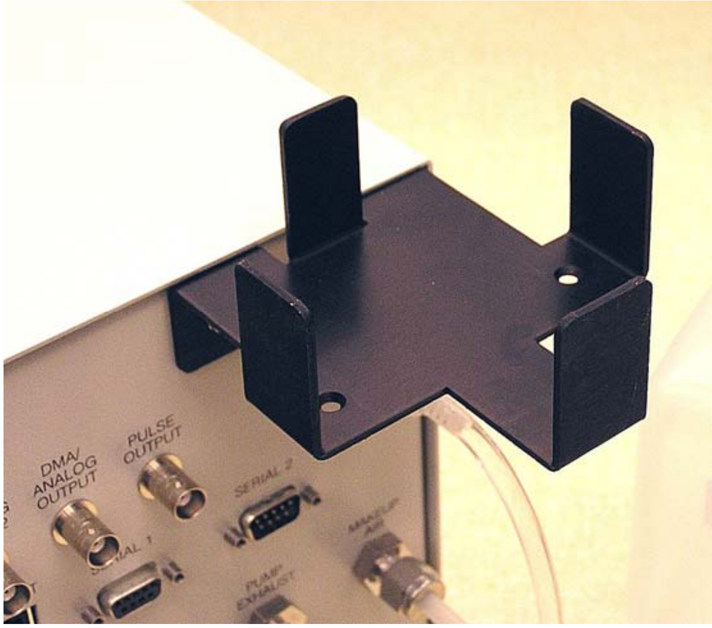


Figure 2-1
View of Fill Bottle Bracket Mounting

Find the Fill Bottle in the accessory kit. Connect the bottle tube fitting to the Butanol Fill port at the back panel of the instrument. Position the bottle with the fitting oriented for minimal stress on the tubing connector. Place the bottle in the bracket. Both mated fittings are leak-tight when disconnected.

Filling the Fill Bottle with Butanol

The UCPC uses reagent-grade n-butyl alcohol (butanol) as the working fluid for particle growth. Pour the butanol into the Fill Bottle to at least one-third full. Because of the leak-tight fittings and internal solenoid valve, liquid will not flow into the UCPC until the connections are made, the instrument is switched on, and warm-up cycle is complete.

Note: *Due to shipping regulations on flammable materials, n-butyl alcohol (butanol) is not supplied with the UCPC. Butanol may be purchased from scientific chemical supply houses. Reagent grade of butanol is required.*

Connecting the Butanol Drain Bottle

A drain bottle should be connected to the Liquid Drain port at the back panel of the UCPC. The drain bottle collects butanol drained from the UCPC prior to transport and holds condensed water and butanol removed from the condenser when the water removal system is turned on (see note below). Draining butanol is described in Chapter 8 "Maintenance and Service".

Note: *The water removal system will not work without a drain bottle connected to the drain port. Refer to* [*Chapter 4*] *for more details on water removal system.*

Caution
Butanol is flammable. Butanol is also potentially toxic if inhaled. Use butanol only in a well-ventilated area. If you smell butanol and develop a headache, or feel faint or nauseous, leave the area at once. Ventilate the area before returning.

Apply Power to the UCPC

Plug the power cord into the receptacle on the back panel of the UCPC and then plug it into the AC power source. The instrument uses a universal power supply that accepts a variety of input voltages identified below.

Power 100 – 240 VAC, 50/60 Hz, 335 W maximum

Note: *Make certain the power cord is plugged into a grounded power outlet. Position the UCPC so the power connector is easily accessible.*

Apply power to the UCPC by turning on the switch next to the power cord on the back panel.

The instrument begins a warm-up sequence. After warm-up, the fluid begins to fill the internal butanol reservoir in the saturator.

Positioning the UCPC

Place the UCPC on a level surface. Ensure the cooling fan on the back panel of the UCPC is exposed to ambient air.

Note: *If the UCPC has n-butyl alcohol (butanol) in the reservoir, be very careful when moving the UCPC. See "Moving and Shipping the UCPC" section for details.*

CHAPTER 3

Instrument Description

Use the information in this chapter to become familiar with the location and function of controls, indicator, and connectors on the Model 3776 Ultrafine Condensation Particle Counter (UCPC).

Front Panel

The main components of the front panel include the color LCD display, rotate/select control knob, aerosol inlet, particle indicator light, and flash memory card slot. These are identified in Figure 3-1 and described below.*

LCD Display

The quarter VGA color LCD display provides continuous real-time display of sample data and is used in conjunction with the control knob to display user menus and instrument status information. Refer to Chapter 4 for details on how to make selections and change options on the menus.

Rotate/Select Control Knob

Turning the control knob highlights items on the LCD display. Depressing the knob inward selects the option. To spin the knob quickly, place your finger in the indent on the knob surface and rotate the knob.

*A black cap is located at the bottom left of the front panel to cover a hole. Do *not* remove it from the instrument.

Figure 3-1
View of the Model 3776 UCPC LCD Display and Control Knob

Aerosol Inlet

The Aerosol Inlet is located on the front panel. The inlet consists of a ¼” OD tube suitable for use with common tube fittings. Permanent fittings with metal locking ferrules should be avoided since this may inhibit removal of the front panel in the event service is required. Aerosol inlet flows of 0.3 or 1.5 L/min can be set as needed.

Particle Light

The particle light flashes each time a particle is detected. At high particle counting levels (>10 counts per second) the light appears continuously on.

Flash Memory Card Slot

The Model 3776 UCPC provides storage of particle concentration data using a standard flash memory card. A flash memory card is included. Refer to Using the Flash Memory Card in Chapter 4 for more on how to use the Flash Memory Card. Technical information is also found in Chapter 7.

Back Panel

As shown in Figure 3-2, the back panel of the Model 3776 UCPC has power and data connections, analog input/output connections, pump exhaust port, makeup air port, butanol fill and drain ports, and cooling fan. The function of the ports and connectors are clearly labeled.

AC Connector and Switch

Plug the supplied AC power cable into this receptacle. The instrument power switch is integrated into above the AC receptacle.

USB Communication Port

The Model 3776 UCPC provides a USB port for use with the TSI Aerosol Instrument Manager® software included with the instrument. When USB communications are used with the software, the computer automatically recognizes the UCPC as a TSI instrument. Additional information on USB communications is found in Chapter 7 and also in the Aerosol Instrument Manager software manual.

***Note**: Up to three CPCs can be simultaneously connected to one computer running Aerosol Instrument Manager software with USB connections.*

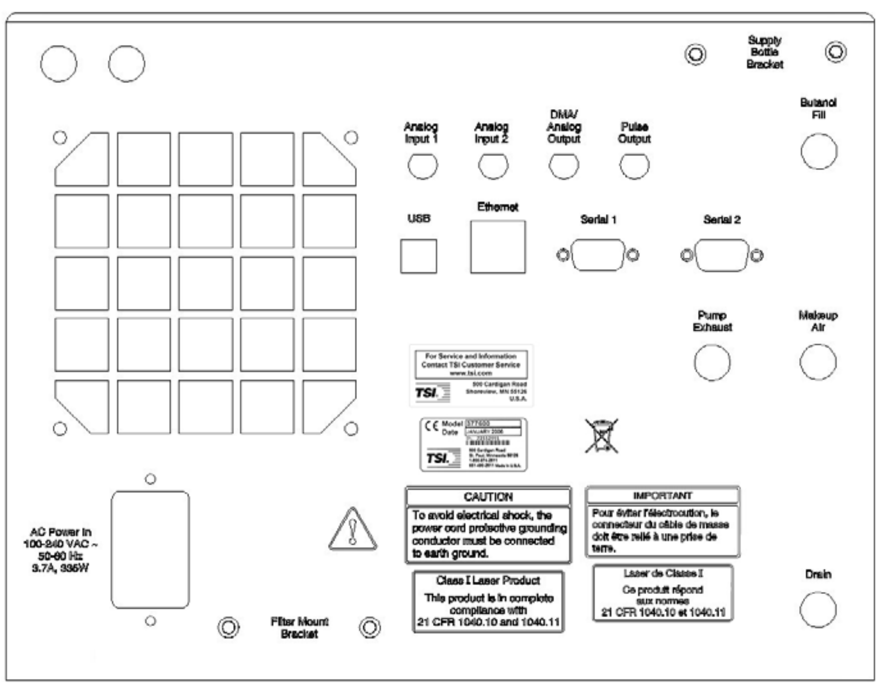


Figure 3-2
Back Panel of the Model 3776 UCPC

RS-232 Serial Connections

The Model 3776 UCPC provides two standard 9-pin RS-232 serial ports that allow communication between a computer and the UCPC. Serial commands are sent to and from the computer to monitor instrument status information, to retrieve and monitor data, and to provide a variety of control functions such as turning the pump on and off (Serial 1 only). Aerosol Instrument Manager software may be used with Serial 1 as well as USB. Information on RS-232 communications can be found in Chapter 7, "Computer Interfaces and Commands".

Analog Inputs

The UCPC can monitor the analog voltages from two external sources via the analog input BNC connectors on the back panel, labeled Analog Input 1 and Analog Input 2. The input voltage range for these ports is 0 to 10 volts. Analog voltages can be displayed together with concentration data on the LCD display and saved to the removable Flash Memory Card or a computer. Voltages from pressure, flow, or temperature transducers can be correlated to particle concentration in real time.

Amplification must be supplied by the user to bring low voltage signals to the appropriate 0 to 10 volt range for best resolution.

DMA/Analog Output and Pulse Output

DMA/Analog Output is configured by the Aerosol Instrument Manager software to provide the ramped voltage signal needed when the UCPC is used as part of the Scanning Mobility Particle Sizer™ (SMPS™) spectrometer. During normal operation of the UCPC (standalone, not used as part of an SMPS), this port provides an analog 0–10 V signal proportional (linear or log) to particle concentration. This particle concentration is corrected for coincidence and equals the displayed concentration. See more details in Chapter 4.

Pulse Output provides a 5-volt (50-ohm termination) digital pulse for each particle detected. This enables you to use your own counting electronics hardware and provides a particle trigger for special applications. The width of the pulse depends on both the shape of the photodetector pulse and the trigger-level of the pulse threshold. Typical (nominal) pulse widths are 400 nanoseconds (see Figure 3-3) for the 3776 UCPC. To provide accurate pulse counts, use a counter that is capable of counting pulses with a width of 50 nanoseconds or less.

Particle concentrations calculated based on the particle counts from the counting electronics hardware are not corrected for particle coincidence. Thus, the concentration obtained this way might be lower than the displayed concentration when particle concentration is high. Appropriate coincidence correction needs to be applied when pulse output is used for high concentration measurements.

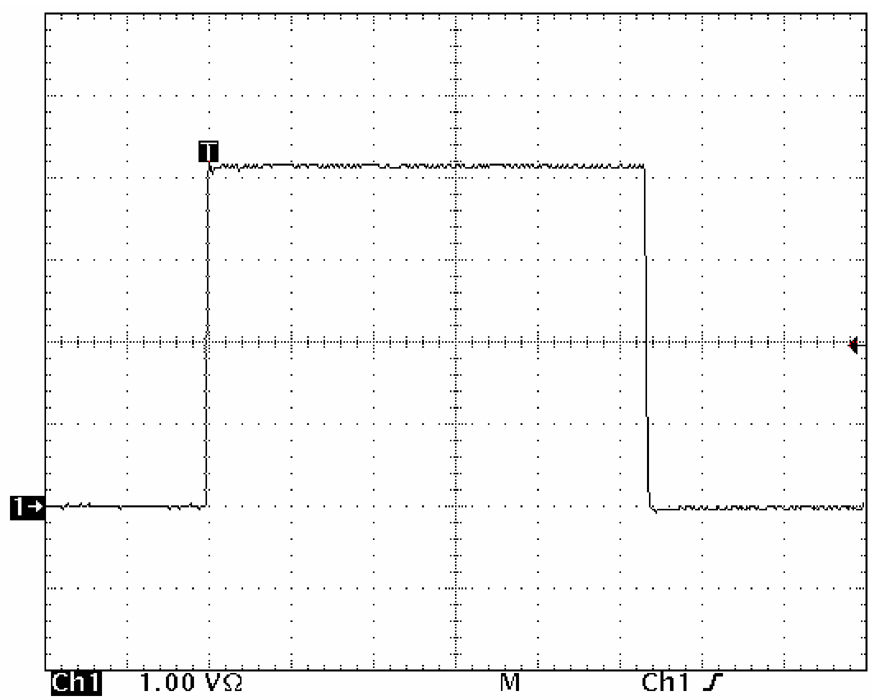


Figure 3-3
Sample Digital Pulse from Pulse Output Port at the Back Panel of the UCPC

Ethernet Communication Port

Instrument status including particle concentration of the Model 3776 UCPC can be monitored remotely from a local area network or over the internet using the Ethernet communication port. Ethernet communications are described further in Chapter 7, "Computer Interfaces and Commands".

Butanol Fill Port

Butanol is supplied from the butanol fill bottle to the instrument at the Butanol Fill port quick connect fitting.

Pump Exhaust Port

The air flow containing butanol vapor exhausts from this fitting at the back panel of the UCPC. Pump exhaust should be directed away from the work area using a piece of tubing connected to this port. A supplied charcoal filter can be used on a temporary basis to capture butanol vapor from the exhaust. Care must be taken that the exhaust port is not blocked. More charcoal filters can be ordered through TSI (P/N 1031492 and P/N 1031493). See Chapter 8 "Maintenance and Service."

Makeup Air Port

The UCPC samples at a rate of 1.5 L/min through the aerosol inlet during high-flow mode and 0.3 L/min during low-flow mode. To maintain a consistent pump operation flow during high flow and low flow operation modes, makeup air (1.2 L/min) is added through the Makeup Air port during low flow mode operation. The 1.2 L/min makeup air flow is combined with the 0.3 L/min sensor flow prior to the internal vacuum pump.

Drain Port

This port is used to drain the working fluid (butanol) from the 30 cm^3 liquid reservoir and is used when collecting water extracted using the Water Removal system. See Chapters 3 and 4 for more on the water removal feature.

Instrument Cooling Fan

This fan cools internal electronics and dissipates heat generated during cooling of the condenser. The fan is provided with a guard and a removable filter that should be cleaned of dust periodically.

Cover

The cover refers to the removable section of the chassis covering the top and sides of the UCPC. It is secured to the chassis with six screws on the bottom. The six screws can be loosened to remove the cover and access to the interior of the Model 3776 UCPC.

Left Side Panel

The left side panel refers to the side panel on the left when facing the front panel of the instrument. As shown in Figure 3-4, it includes a clear removable butanol reservoir cover plate that is used to view the liquid level in the saturator and to access the saturator wick for easy removal before instrument shipment. Also shown in the figure are the cover screws that can be loosened to take off the instrument cover.

Clear Reservoir Cover Plate

The clear reservoir cover plate provides a view of the butanol level in the liquid reservoir and access to the saturator wick for removal, prior to instrument transport or maintenance.

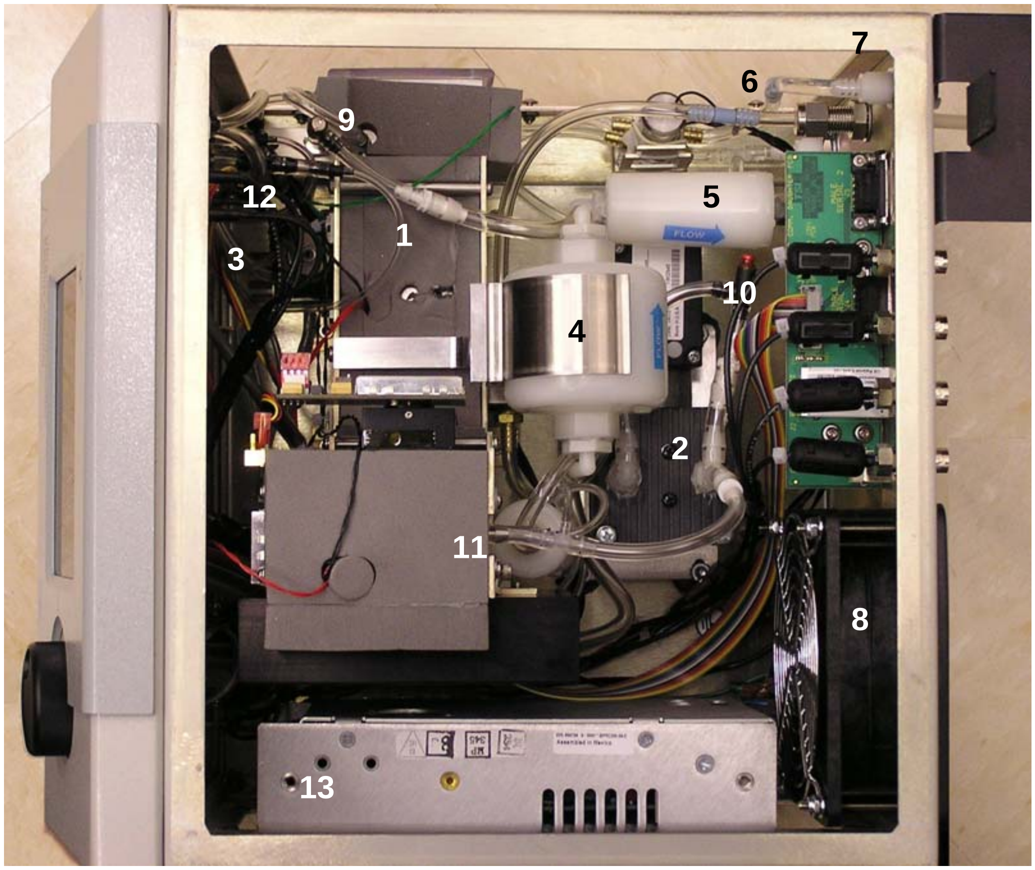
The 30 cm^3 butanol reservoir, white cylindrical wick, and blue sealing gasket are all visible through the clear cover.

Four screws are used to mount the cover plate. Instructions for wick access and replacement are provided in Chapter 8.

Figure 3-4
Left Side Panel Showing Butanol Reservoir and Saturator Wick

Internal Instrument Components

Internal components are described in this section and identified in Figure 3-5 and Figure 3-6.



1. Sensor assembly
2. High vacuum pump
3. Water removal pump
4. Sheath filter
5. Exhaust filter
6. Makeup air filter
7. Butanol fill filter
8. Cooling Fan
9. Sheath variable orifice
10. Bypass / makeup air variable orifice
11 Critical orifice
12. Pressure transducers
13. Power supply

Figure 3-5
Internal Components of the Model 3776 UCPC

Sensor Assembly

The sensor assembly consists of the heated saturator, liquid wick, sheath filter and variable orifice, cooled condenser, and optics. In this assembly, sample particles serve as condensation nuclei and are grown in a supersaturated atmosphere of butanol. The large droplets are easily detectable using a conventional focused laser and solid-state detector.

Pumps

The Model 3776 UCPC uses a High Vacuum Pump for inlet sample flow (aerosol and bypass) and makeup flow. A micro-flow Water Removal Pump removes condensate from the condenser.

The High Vacuum Pump draws the inlet sample flow through the UCPC. This flow is a stable *volumetric* flow, maintained using a critical orifice and a bypass/makeup air variable orifice. Both orifices are operated at a critical pressure.

The Water Removal Pump draws condensed butanol and water from the condensate collection reservoir. Water removal prevents contamination of the butanol during operation in a high humidity environment. When activated, the pump runs continuously. A drain bottle must be connected for water removal to occur. For information on operating the water removal pump refer to Chapter 4, "User Settings."

Filters

The Model 3776 UCPC uses four particulate air filters. The high efficiency Sheath Filter removes particles from the sheath flow before the flow enters the saturator. The Exhaust Filter removes particles in the exhaust air flow. The Makeup Air Filter removes particles from the makeup air when the instrument operates in low flow mode. The Bypass Air Filter removes particles from the bypass flow when the instrument operates in the high flow mode.

Two liquid filters are used to filter butanol supplied from the fill bottle, and condensed water and butanol before it passes through the water removal pump.

Valves and Variable Orifices

The Model 3776 UCPC uses valves and variable orifices for air flow control and butanol filling and draining. A three-way solenoid valve controls the inlet flow rate, switching between high and low inlet sample flow modes.

A variable orifice is used to control the 0.25 L/min sheath flow. Another variable orifice operating under critical pressure controls the 1.2 L/min bypass or makeup air flow.

Solenoid fill and drain valves enable butanol to be added or removed from the liquid reservoir. The fill valve is actuated when the Auto-Fill is turned ON and the level sensor indicates a low butanol level in the liquid reservoir. When the butanol fill bottle is connected, butanol flows into the reservoir until the level sensor indicates a full state. The drain valve is activated through the front panel. Butanol is drained prior to shipment or removal of the saturator wick. See "User Settings" in Chapter 4 and "Maintenance" in Chapter 8.

Pressure Transducers

The Model 3776 UCPC uses four pressure transducers for monitoring instrument flows. The differential pressure across the Critical Orifice is measured to verify that a critical pressure is maintained across the orifice. Differential pressure across the aerosol capillary is measured to obtain actual aerosol flow rate. Differential pressure across the nozzle is measured and verifies the nozzle in the optics block is free from obstruction. The ambient pressure is also measured. These pressure transducers are mounted to the main PC board. Pressure information is provided on the Status screen except the differential pressure across the aerosol capillary. The actual aerosol flow rate is displayed instead.

Electronics Boards

Five electronics boards identified in Figure 3-6, are used in the Model 3776. The boards include Main PC board, laser board, detector board, communication connector board, and flash memory board.

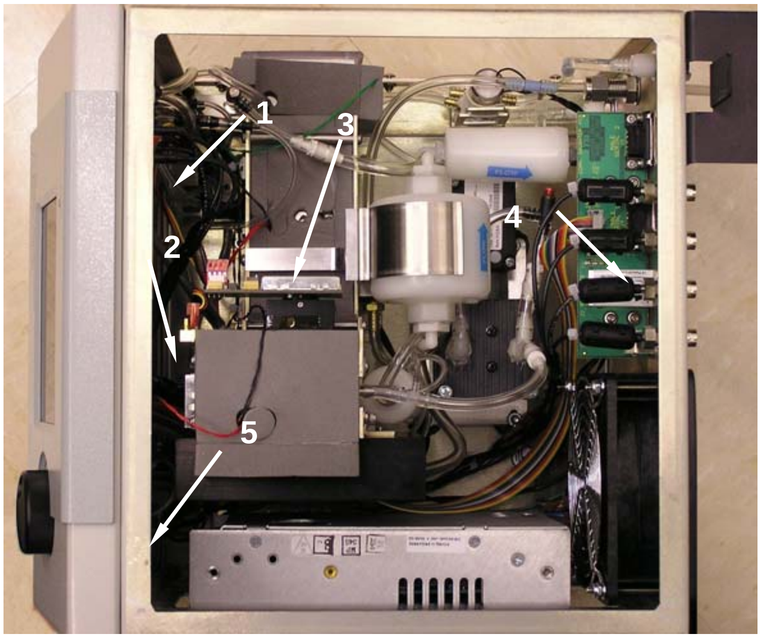


Figure 3-6
Electronics Boards Inside the Model 3776 UCPC

1. Main PC board
2. Detector board
3. Laser board
4. Communication connector board
5. Flash memory board

Basic Instrument Functions

This section describes basic instrument functions.

Concentration Measurement

Particle concentration is presented as particles per cubic centimeter (p/cc), and displayed on the front panel LCD both in numeric form and in graphic form. Particle concentration is determined from the count rate (particles counted per tenth of a second) and the actual aerosol flow rate measured. This flow rate is very close to its nominal value of 50 cubic centimeters per minute (cm^3/min). It is monitored from the pressure drop across the aerosol capillary, which is calibrated at the factory. Particle concentration is live-time corrected for coincidence. Refer to Chapter 6, "Live-time Counting" for more information.

Totalizer Mode

Totalizer mode counts number of particles in a given time period. This mode is used to improve counting resolution at very low particle concentrations. Time, number of counts, and concentration are shown on the front panel display.

High and Low Flow Modes

The Model 3776 UCPC has user-selectable high and low inlet sample flow modes. The high inlet sample flow mode, 1.5 L/min, is preferred for smaller particles because particles are transported more quickly through sampling lines, reducing particle diffusion losses. The low flow mode, 0.3 L/min, is primarily used with the Scanning Mobility Particle Sizer™ Spectrometer (TSI Model 3936 SMPS™) to measure size distributions for wider particle size range.

Water Removal

When the aerosol sample has a dew point above the condenser temperature of 10 °C, water vapor may condense on the walls of the condenser and run back into the saturator, contaminating the butanol over time. Unlike its predecessor, the Model 3025A, the Model 3776 UCPC is able to capture condensed water vapor and remove it, significantly reducing butanol contamination. The water removal process increases the butanol consumption. For additional information refer to Chapter 4.

Internal Data Logging

A removable Flash Memory Card can be inserted in the slot on the front panel to store particle concentration data and analog input data. Data can then be transferred to a computer for further data processing. Refer to Chapter 4 for more details. It is not recommended you use a Flash Memory Card and Aerosol Instrument Manager software or terminal program to collect data simultaneously to avoid data transfer interference.

Remote Access of Instrument

The Model 3776 UCPC provides an Ethernet port to connect the instrument to a network for monitoring status information. Status information includes saturator, condenser, optics temperatures, laser power, and particle concentration. The data is updated once every five seconds. Refer to Chapter 7 for more details.

Optional External Pump

It is possible to use an external pump to provide sample flow for the instrument. The pump must provide sufficient vacuum to maintain a critical pressure across the sensor flow critical orifice and bypass/makeup air variable orifice, while providing a flow of 1.5 L/min (total instrument flow). At an atmospheric pressure of 100 kPa (1 atm), an external pump must provide at least 50 kPa (15 in. Hg) of vacuum and 1.5 L/min inlet volumetric flow for each CPC supported. This option requires changing of the internal tubing connections and routing. Procedures for use of an external pump are provided in the maintenance section in Chapter 8.

Flow Rate Control

The Model 3776 UCPC uses a critical orifice and two variable orifices to accurately control the air flows in the instrument. The critical orifice operates at or below a critical pressure to control the 0.3 L/min (nominal) volumetric sensor flow. The bypass/makeup air variable orifice is also operated at a critical pressure for a flow of 1.2 L/min. The sheath air variable orifice is adjusted to provide 0.25 L/min air flow through the saturator. More is found in Chapter 5 "Technical Description."

Problems with the sensor flow can be detected by monitoring the pressure drop across the nozzle, and verifying that the critical orifice pressure is maintained.

Temperature Control

The temperatures of the condenser, saturator, and optics are maintained at 10°C, 39°C, and 40°C, respectively, with specified ambient temperatures in the operating range of 10 to 35°C. Temperatures are controlled through feedback circuits on the main electronics board, and are displayed in the Status menu on the front panel. For ambient temperatures outside the instrument operating range, the instrument temperature performance may not be maintained. Moderate increases in saturator temperature and optics are tolerated in some instances, depending on measurement requirements.

Inlet Pressure Measurement

With the built-in high vacuum pump, the instrument is capable of operating at inlet pressures in the range of 75 to 105 kPa. The inlet pressure is measured by an absolute pressure sensor, and is essentially the barometric pressure if no inlet restriction is present. The Inlet Pressure reading is found on Status screen of the front panel display. Refer to Chapter 4 for more details.

CHAPTER 4

Instrument Operation

This chapter describes the basic operation of the Model 3776 Ultrafine Condensation Particle Counter (UCPC) and provides information on the use of controls, indicators, and connectors found on the front and back panels.

Operating Precautions

Read the following before applying power to the 3776 UCPC:

- Review the operating specifications for the UCPC in Appendix A.
- Do **not** operate the UCPC outside the range of 10 to 35 °C. If the UCPC is operated outside this range, the displayed concentration may be inaccurate.
- If the UCPC reservoir contains butanol, be very careful when moving the UCPC. Refer to "Moving and Shipping the UCPC" for more details.

WARNING
Although the UCPC is appropriate for monitoring inert process gases such as nitrogen or argon, it should not be used with hazardous gases such as hydrogen or oxygen. Using the UCPC with hazardous gases may cause injury to personnel and damage to equipment.

Power Switch

The power switch is found on the back panel of the UCPC. The switch is combined with the power cord receptacle.

Control Knob and LCD Display

The 3776 UCPC measurement data is presented on a 3.5" × 4.5" quarter VGA color LCD display. Instrument functions are accessed on the display using the rotate/select control knob. The display and control knob are shown in Figure 4-1 below.

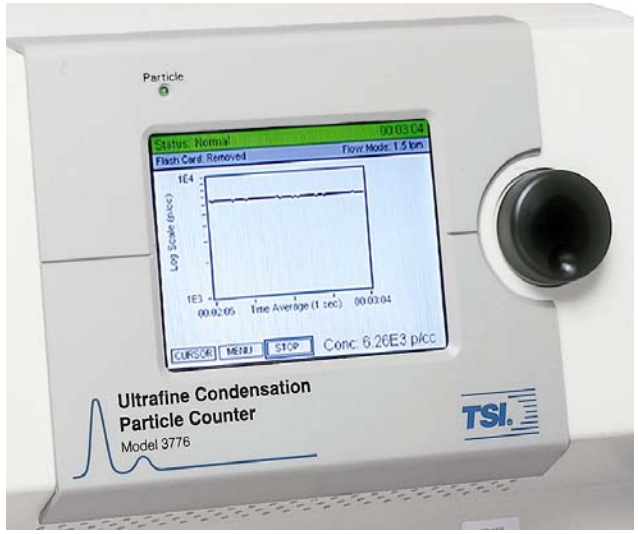


Figure 4-1
UCPC Front Panel LCD Display and Control Knob

Turn the control knob clockwise or counterclockwise to highlight items on the LCD display. Highlighting is indicated as a box around the text. Depress the knob momentarily to select the option. To spin the knob quickly, place your finger in the indentation on the knob surface and turn.

Warm-up

When the instrument is turned on, the saturator, condenser and optics have to reach set operating temperatures. This "warm-up interval" takes about 10 minutes during which the start-up screen is displayed as shown in Figure 4-1. The status bar at the top of the LCD display is yellow when the instrument status is "Warming up". When the warm-up is complete, the Main Data Presentation Screen is automatically displayed (see "Main Data Presentation Screen" section in this chapter) and the vacuum pump is turned on automatically. The Main Data Presentation Screen may be displayed and the pump may be turned on before the warm-up is complete by depressing the knob at any time from the warm-up screen. In the Main Data Presentation Screen, a *Status: Multiple Errors* is indicated in red on the status bar during warm-up rather than yellow. When warm-up is complete, a green *Status: Normal* bar appears. Under extremes in ambient temperature, it may take considerably longer than ten minutes for the instrument to warm-up.

Main Data Presentation Screen

The Main Data Presentation Screen is shown in Figure 4-2. This screen appears automatically once the warm-up is complete or can be displayed prior to the completion of the warm-up by depressing the control knob. The top bar on the Main Data Presentation Screen shows instrument status and current time. The second line shows the status of the Flash Memory Card (Ready, Removed, or Logging) and the inlet sample flow setting (high or low flow).

The Main Data Presentation Screen shows a graph of the number concentration, in particles per cubic centimeter (p/cc) versus time, and presents real-time number concentration at the lower right corner of the display. A menu of three primary instrument functions (CURSOR, MENU, and START/STOP) are presented at the bottom of the screen.

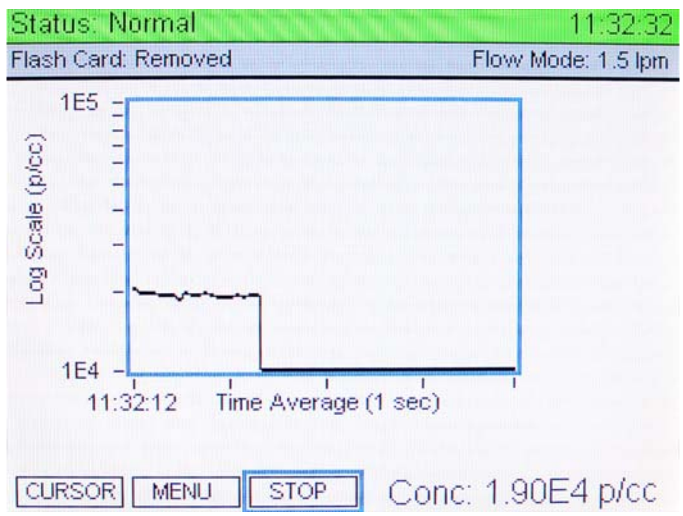


Figure 4-2
UCPC Main Data Presentation Screen During Operation.

Primary Functions in the Main Data Presentation Screen

Primary functions are accessed directly through the use of the control knob by highlighting a function and pressing the knob inward to select. A highlighted function will have a blue box surrounding the text. The display in Figure 4-2 has the STOP function highlighted for example.

Number concentration data is presented graphically in real time once the START button is selected. When START is selected, the function label changes to STOP as shown in Figure 4-2. Depressing the knob again stops the graph from updating, and START reappears. The display is updated once per data average period.

Figure 4-2 shows a concentration of approximately 2×10^4 p/cc. The graph was updated each second over an interval of 24 seconds.

***Note**: At concentrations between 3×10^5 and 10^6 particles/cm^3, particle concentration data and the top status bar on the front panel are in red. If this occurs, the number of particles shown on the display could be lower than the actual concentration. The aerosol needs to be diluted or the CPC needs to be calibrated versus electrometer in this concentration range for it to be used up to 10^6 particles/cm^3.*

If a Flash Memory Card is inserted in the slot on the front panel of the instrument, data is saved to the card when START is selected. In this case, the Flash Card status on the front panel display shows Logging. Left unattended, a new data file is created each hour, with the number of data points determined by the data average period. Data Average Period is described later in this chapter. If the data collection is stopped using the STOP option, the current data file is saved with less than one hour of data. If the data collection is not properly stopped, such as instrument is turned off or the card is removed, data from the current hour's file will be lost.

The primary selectable functions are summarized below.

CURSOR	Displays a vertical cursor on the graph (Figure 4-3). Turning the knob moves the cursor within the graph boundary, and presents the time data was taken and number concentration at the bottom of the display.
MENU	Displays menus for User Settings and Instrument Status. See Figure 4-4.
STOP	Stops the real-time graphical update of the particle number concentration and properly closes the data file on the Flash Memory Card.
START	START is displayed once STOP is pressed. Press START to initiate update of the graphical display, and to save to the Flash Memory Card.

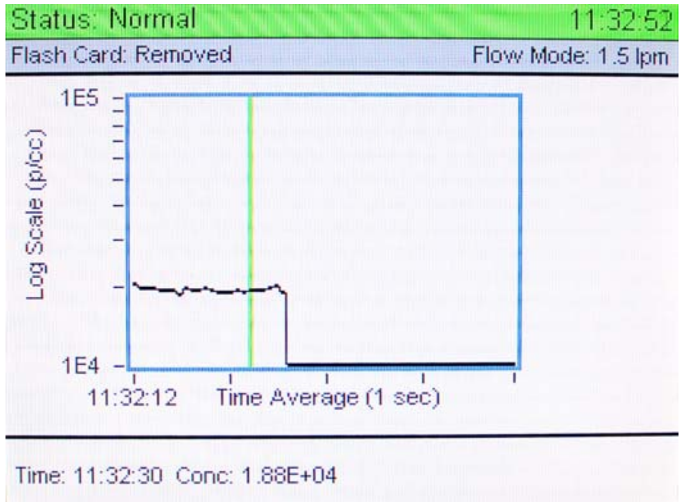


Figure 4-3
Display Showing Cursor

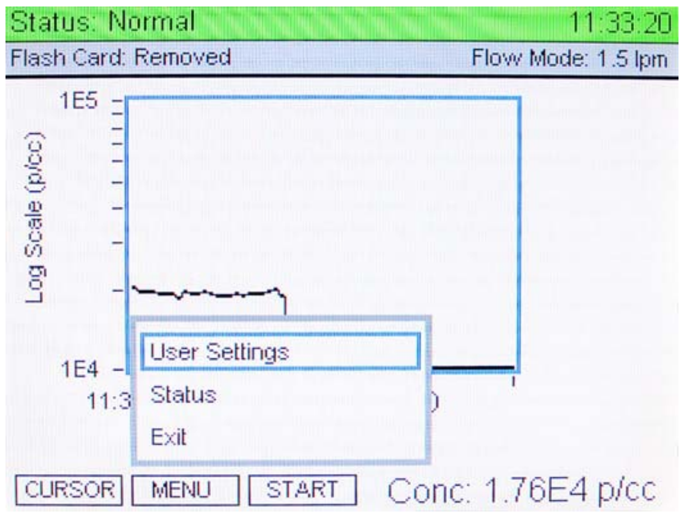


Figure 4-4
Display After the MENU Function is Selected

Display Header

Two bars are present at the top of the display screen to provide information on instrument operation.

Status Bar Color	The status bar background changes from red to green as the instrument reaches normal operating conditions (Status: Normal). Deviations from normal operating parameters will cause the bar to appear red. During warm-up, the bar is yellow in the Start-up screen.
Status	Normal status indicates that the instrument is warmed up and temperatures are in the correct range, flow rates are correct, laser power is correct, etc.

Flash Card	Indicates if the Flash Memory Card is ready, logging, or removed.
Time	Current time appears in the upper right corner of the screen in the format of hh:mm:ss, 24 hour clock.
Flow Mode	Indicates which aerosol inlet flow mode is selected: high (1.5 L/min) or low (0.3 L/min).

User Settings

The screen display shown in Figure 4-4 appears when MENU is selected in the Main Data Presentation Screen. User Settings are accessible by highlighting the User Settings option and depressing the control knob.

Figure 4-5 shows the User Settings menu that appears once User Settings option is selected. Once in the User Settings menu, select options by rotating and depressing the knob. User settings in the menu are described under individual headings below, beginning with the EXIT option.

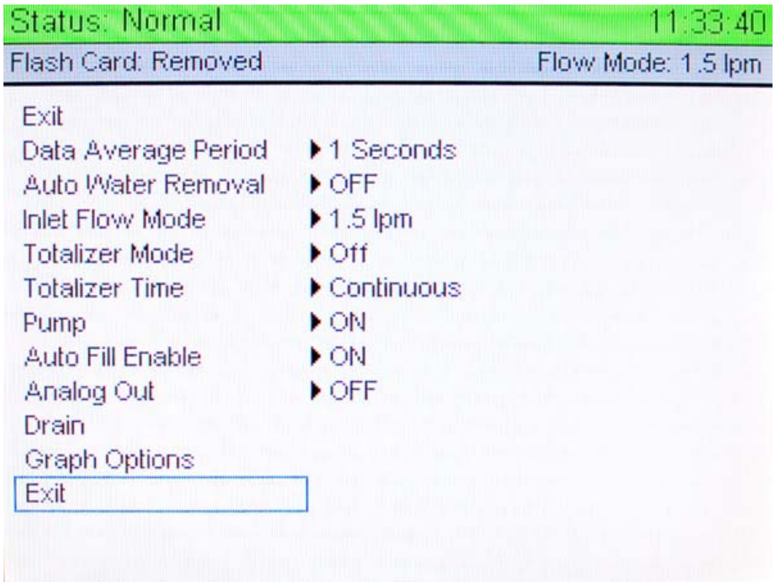


Figure 4-5
User Settings Display

Exit (top and bottom)

This option exits the User Settings menu and returns the display to the previous screen.

Data Average Period

Data is collected at a frequency of 10 times per second and is averaged over selected Data Average Period for display on the graph and for saving to the flash memory card. To set the Data Average Period from the instrument, highlight the Data Average Period option using the control knob and depress the knob. Rotate the knob to select from the following periods: 1, 2, 3, 4, 5, 6, 10, 12, 15, 20, 30, or 60 seconds. The particle concentration graph is updated once per Data Average Period. The graph x-axis scale is determined by the selected average period as described in the table below. This option is deactivated while data is logging into the flash memory card.

Graph Display	The selection of Data Average Period determines the total time interval shown on the graph with 60 data bins providing 60 data samples. Each data sample is averaged over the selected period. When the average period is one second, one minute (60 seconds) of data is displayed, i.e., one second of data per bin. If the average period is 60 seconds, one hour (3600 seconds) of data is displayed, i.e., one minute of data per bin. After START is selected, data fills bins from left to right. When all 60 bins are full, bins scroll to the left as each new concentration value appears in the rightmost bin. This continues until STOP is selected. Reselection of START clears the current graph display and puts the first new concentration value in the leftmost bin.
Flash Logging	If a Flash Memory Card is inserted in the slot on the front panel, data is saved once per Data Average Period. Details on the use of the Flash Memory Card are presented later in this chapter and in Chapter 7.

Data is transferred to the computer running Aerosol Instrument Manager software at a rate of once per second. Each data transfer contains 10 data points. The software provides more flexibility in data averaging and improved time resolution. Check the software manual for details.

Auto Water Removal

This option provides ON/OFF control for the automatic water removal feature of the Model 3776 UCPC. This feature is used in hot/humid environments to eliminate contamination of the butanol working fluid by condensed water vapor. Water removal keeps the UCPC operating at peak performance.

Water removal is achieved by collecting all condensate from the cooled condenser before it has a chance to return and remix with the butanol in the heated saturator. The collected condensate is pumped to the Drain port and flows to the supplied Drain Bottle.

Important Note: The Drain Bottle must be connected for the water removal system to work properly.

Butanol Consumption	The water removal feature removes condensed butanol as well as water, increasing butanol consumption. The operator may elect not to use water removal in cool/dry environments, to preserve butanol. When water removal is not used, butanol is recycled. A full bottle of butanol (1 liter) lasts about three weeks (35°C, 90% RH) with the water removal system ON, about ten weeks (room condition) when water removal system is OFF.

Inlet Flow Mode

Select this option and turn the knob to select between High and Low aerosol inlet flow modes. High inlet flow is used to reduce diffusion particle losses which occur in the sample tubing. Low inlet flow is preferred when the UCPC is used as part of an SMPS system to measure particles in a wider size range. The nominal flow rate is 1.5 L/min for high flow mode and 0.3 L/min for low flow mode.

Totalizer Mode

This operation mode allows particle counts to be accumulated and displayed as shown in Figure 4-6. Totalizer mode is generally useful for tests at very low particle concentrations, such as evaluation of high efficiency filters. Depress the control knob to turn on the Totalizer Mode. Totalizer Mode Screen is displayed as shown in Figure 4-6. The UCPC will count time and particles once the START button is selected. Concentration is calculated from the time and count data.

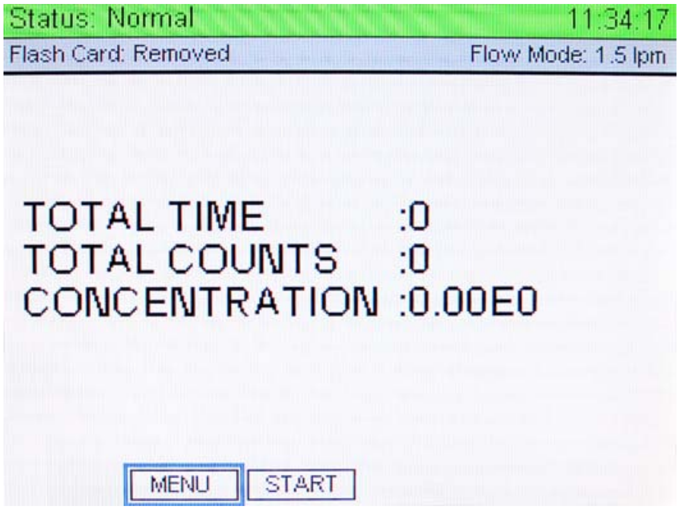


Figure 4-6
Totalizer Mode Data Screen

Totalizer Time

Use this option with the Totalizer Mode to select the time period for accumulating counts. Three options are available; 60 seconds, 60 minutes and Continuous. Sampling stops once the time is complete. Sampling can be ended manually prior to the end of a sampling period by selecting STOP.

Pump

The critical flow vacuum pump can be turned on or off by selecting the Pump option. When idle for long periods of time, the pump should be turned off to reduce maintenance requirements and reduce butanol consumption. If the instrument is to be left idle continuously, it is recommended that a filter be placed on the aerosol inlet. See below.

Caution
In a dirty environment with high or unknown aerosol concentration, turn the pump off when possible or provide filter protection at the inlet. This reduces the likelihood of large fibers clogging the delicate aerosol capillary tube. If the instrument is used in a monitoring application over long periods of time, an impactor or cyclone should be used upstream of the UCPC to keep large particles and debris from clogging the capillary tube.

Auto Fill Enable

When the Auto-Fill Enable is ON, the instrument fills with butanol automatically when the liquid level indicator in the butanol reservoir detects a low butanol level condition. A fill bottle with butanol needs to be connected to the Butanol Fill port to fill the instrument. Selecting Auto-Fill OFF prevents the fill valve from opening despite a low butanol level. The Auto-Fill option is turned on each time the instrument is turned on.

Caution
Auto-Fill is automatically turned on each time the UCPC is turned on. Make sure the UCPC is not operated with the reservoir cover plate removed. This will prevent butanol from spilling out of the instrument as filling takes place.

Analog Out

When the UCPC is used as a standalone CPC, the voltage output from the DMA/Analog Output port at the back panel of the instrument is proportional (linear or log) to the particle concentration. There are nine options: OFF, 1E+1, 1E+2, 1E+3, 1E+4, 1E+5, 1E+6, 1E+7, and LOG. The relationship between voltage output and particle concentration with the options selected is listed below.

Option	Concentration Range for Analog Output 0–10 V	Relation
OFF	0 V independent of concentration	-
1E+1	0 to 10 particles/cm^3	linear
1E+2	0 to 100 particles/cm^3	linear
1E+3	0 to 1,000 particles/cm^3	linear
1E+4	0 to 10,000 particles/cm^3	linear
1E+5	0 to 100,000 particles/cm^3	linear
1E+6	0 to 1,000,000 particles/cm^3	linear
1E+7	0 to 10,000,000 particles/cm^3	linear
LOG	10 V = 10,000,000 particles/cm^3 9 V = 1,000,000 8 V = 100,000 7 V = 10,000 6 V = 1,000 5 V = 100 4 V = 10 3 V = 1 2 V = 0.1 1 V = 0.01 0 V = <0.01	log

Drain

For specific instructions on draining butanol, refer to the section "Draining Butanol from the Butanol Reservoir" in Chapter 8.

During draining, the Auto-Fill mode and the high vacuum pump operation are automatically turned off. When draining is stopped, the pump restarts but the Auto-Fill must be turned on again by selecting this option from the User Settings menu. Whenever the instrument is turned on, the Auto-Fill is activated. Refer to the previous caution note.

Graph Options

Refer to Figure 4-2 depicting the graph while reading this section.

Figure 4-7 shows the options possible when Graph Options is selected from the User Settings Menu. A description of these options is provided below:

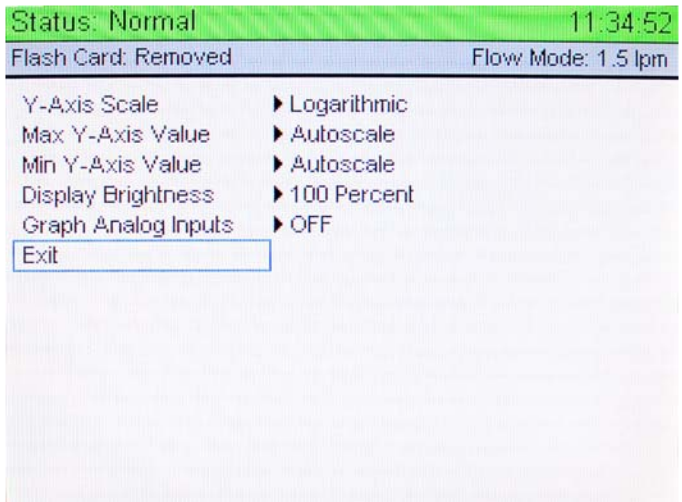


Figure 4-7
Graph Options Menu

Y-Axis Scale	Select from Log or Linear concentration display.
Max Y-Axis Value	Use this option to pick the upper limit for concentration display on the graph. Concentration is presented in particles per cubic centimeters (p/cc). Autoscale automatically scales the graph based on the highest concentration. Fixed upper limits are provided by factors of 10. 1E–1 0.1 1E+0 1 1E+1 10 1E+2 100 1E+3 1,000 1E+4 10,000 1E+5 100,000 1E+6 1,000,000 1E+7 10,000,000

Min Y-Axis Value	Use this option to pick the lower limit for concentration display on your graph. Autoscale automatically scales the graph based on the lowest concentration. Fixed lower limits are provided by factors of 10. The options include 1E-2, 1E-1, 1E+0, 1E+1, 1E+2, 1E+3, 1E+4, 1E+5, and 1E+6. The lower limit is at least one order of magnitude lower than the upper limit. Selecting fixed values for upper and lower concentration limits provides the best resolution in the concentration range of interest. The concentration line will not be displayed if it is outside the boundaries defined by the upper and lower limits.
Display Brightness	Adjust the brightness of the front panel display as a percentage of maximum brightness.
Graph Analog Inputs	Select to include analog input data on the graph display during display of particle concentration. Analog input scale is fixed between 0 and 10 volts. Transducer voltages having a different range may need to be amplified or reduced to achieve suitable resolution for display. Analog data is recorded to the Flash Memory Card and output through the communication ports. This is true even if the analog data is not displayed on the graph. While data is logging into the memory card, this option is deactivated.

Status

Statuses are accessed by selecting MENU, then the Status option shown in Figure 4-8. Information presented in the Status screen (Figure 4-9) provides data from instrument sensors useful to confirm basic performance and for troubleshooting. If the top bar is in red and the Status shows Multiple Errors, statuses that deviate from normal operating parameters are in red color. The Status menu can be used as a diagnostic tool.

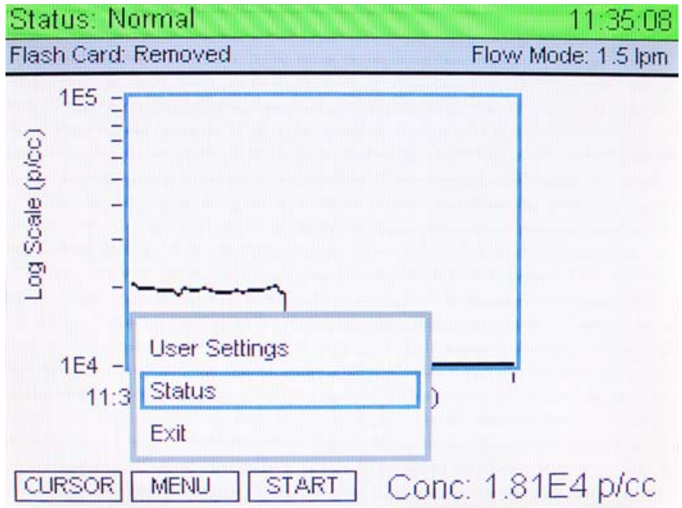


Figure 4-8
Status MENU Option Highlighted

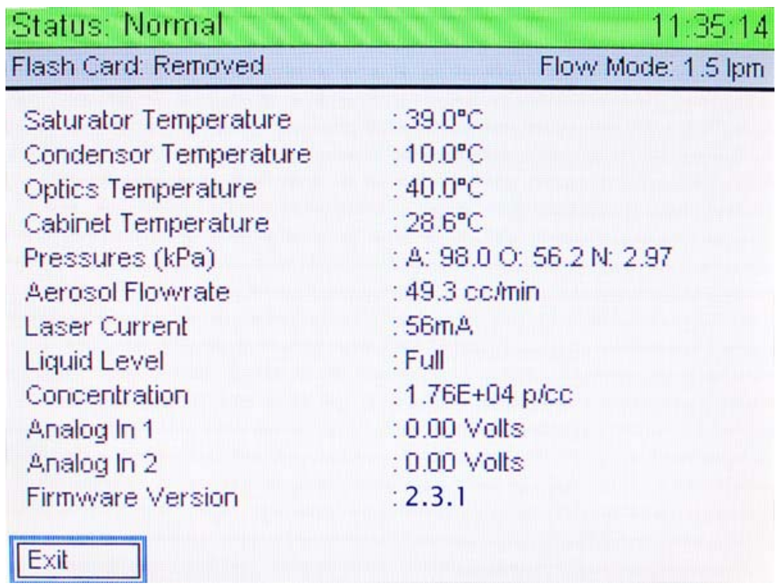


Figure 4-9
Status Screen

Information provided in the Status screen is described below.

Saturator Temperature

Saturator temperature is 39 °C when the instrument warm up is complete and the instrument has stabilized. The saturator provides saturated butanol vapor that mixes with aerosol particles in the condenser.

Condenser Temperature

Particle growth occurs in the condenser as butanol vapor from the saturator is cooled and condenses on sampled aerosol particles. The condenser temperature is maintained at 10°C.

Optics Temperature

The optics temperature is maintained at 40°C. This is higher than the saturation temperature and prevents butanol from condensing on the lenses and other internal components in the particle detection optics.

Pressures (kPa)

Pressures from three transducers are labeled A, O, N and displayed on the Status Screen. **A:** is the barometric air pressure in kPa. Inlet air pressure is very close to the barometric pressure when sampling directly from the ambient environment. A restriction at the inlet will change the inlet air pressure. The instrument is designed to operate with an inlet pressure between 75 and 105 kPa. **O:** is the differential pressure across the sensor flow critical orifice. **N:** is the differential pressure across the nozzle. Identification of the orifice and nozzle are found in the flow schematic Figure 5-1 in Chapter 5.

Aerosol Flow Rate

Aerosol flow is monitored using the differential pressure reading across the aerosol capillary. The aerosol flow is nominally 50 cm^3/min but varies with inlet resistance. The actual aerosol flow rate is determined by the differential pressure across the capillary and is used in the calculation of particle concentration. If the capillary flow falls far outside a prescribed range (<30 or >70 cc/min), an error is indicated on the front panel display. The instrument capillary is calibrated at the factory.

Laser Current

Laser power is monitored by an internal detector in the laser diode package. If laser light energy drops below 35 mA, an Error is indicated.

Liquid Level

Full is indicated if adequate butanol is present in the liquid reservoir. Liquid level is detected by a heated RTD (Resistance

Temperature Detector) level detector. If the liquid level is low, Not Full is indicated.

Concentration

Measured particle concentration is displayed in particles per cubic centimeter (p/cc).

Analog Inputs

Analog Input 1 and 2 display voltages supplied to the BNC connectors at the back panel of the instrument. These analog data inputs have a range of 0 to 10 volts. Voltages can come from a variety of sources at the operator's discretion. Signals should be gained up or down so the outputs fall into the 0-to-10-volt window with maximum resolution. Analog input data can be displayed together with particle concentration on the front panel LCD display and saved to the Flash Memory Card during data logging. The analog input data can also be displayed along with particle concentration in the Aerosol Instrument Manager® software.

Using the Flash Memory Card

Particle concentration data and analog input data can be saved to a Flash Memory Card inserted in the slot at the lower right of the front panel. Insert the card label up.

Data saving is initiated from the Main Data Presentation Screen when the START option is selected. A file having a .DAT extension is created and will sample one hour of UCPC data. Additional files will be created automatically each hour, i.e., having one hour of data. A shorter file is created if the test is stopped using the STOP option. Data is lost if an open file is improperly closed, by turning the instrument off or removing the flash memory card.

To read saved data to computer, connect the supplied card reader to your computer using the USB cable. Insert the flash card in the reader. Your computer will recognize the card reader and display a window showing several options. Select the option **Open folder to view files** to access the test files on the installed memory card. Files are named based on the date and time the test was initiated. Files can be moved from the flash memory card to the computer using file management methods.

The Aerosol Instrument Manager® software described below retrieves files from the flash memory card for data display. Refer to your Aerosol Instrument Manager software instruction manual for information on importing DAT, data files.

Additional technical information on the flash memory card is found in Chapter 7.

***Notes**: Data cannot be saved to the flash memory card and to the computer through Aerosol Instrument Manager software simultaneously.*

Keep the amount of data stored in the flash memory card under 64 MB to avoid long overhead time before generating a new data file each hour in the card.

Caution

Remove the flash memory card following the correct procedures:

1. Use *Safely Remove Hardware* option in Windows to disconnect the card reader from the computer—stop USB Mass Storage Device.
2. After the message *Safe To Remove Hardware: The "USB Mass Storage Device" device can now be safely removed from the system* appears, physically remove the flash memory card from the card reader.

Failure to follow these procedures may result in failure to log data with the flash memory card.

Aerosol Instrument Manager® Software

Aerosol Instrument Manager® software is supplied with the Model 3776 UCPC. This program provides many useful data acquisition, display, processing and download functions used in particle measurement. Review the supplied Aerosol Instrument Manager software manual for complete information on software functions.

Moving and Shipping the UCPC

Make sure the Model 3776 UCPC is turned off and remains upright when moving the instrument. There is no need to drain the UCPC before moving. Prior to shipping, however, it is necessary to drain butanol from the instrument and dry the instrument. Refer to "Draining Butanol from the Butanol Reservoir" in Chapter 8 to drain the UCPC. Remove the saturator wick to expedite the drying process. The Model 3776 UCPC was designed so that the wick is easily removed. Refer to the "Wick Removal" section in Chapter 8. To dry the instrument without taking the wick out, run the CPC continuously with the pump on for a period of at least 12 hours. During drying place a HEPA filter at the inlet. It may take up to 60 hours to completely dry the instrument so the particle concentration reads zero.

TSI recommends that you keep the original packaging (carton and foam inserts) of the UCPC for use whenever the UCPC is shipped, including when it is returned to TSI for service. Always seal off the sampling inlet to prevent debris from entering the instrument and drain and dry the UCPC before shipping.

Caution
While the pump is on, do ***not*** tip the UCPC more than 10° to any direction with the water removal system ON. Do not tip the UCPC more than 10° to the front (to avoid overfilling the butanol reservoir) or 20° to other directions with the water removal system OFF. It is recommended to turn off the UCPC and disconnect the butanol fill bottle before the UCPC is being moved or tilted for longer than a few seconds to prevent flooding of the sensor.

Sheath Air Drying Accessory

The Model 3776 provides the Auto Water Removal option to prevent contamination of the butanol working fluid. This very effective technique extends the useful sampling life of the instrument tremendously in humid environments; however, it is limited to removing condensate and does not remove water vapor which diffuses to the wick surface as it passes through the saturator along with the sheath air. For some critical applications, a more complete drying may be assured by passing the sheath air through desiccant prior to having it enter the saturator. For this purpose, TSI provides a kit (P/N 1031483) consisting of a desiccant dryer, accessory parts, and instructions necessary for this application.

CHAPTER 5
Technical Description

The Model 3776 UCPC is a continuous-flow condensation particle counter that detects particles as small as 2.5 nanometers (50% detection efficiency) in diameter. This section describes the function of the UCPC, its subsystems and its components. A discussion of operation theory and history is given first.

Theory

The UCPC acts very much like an optical particle counter. However, the particles are first enlarged by a condensing vapor to form easily detectable droplets. The science behind the counter, therefore, is focused on how to condense the vapor onto the particles. Portions of the following discussion are taken from a paper by Keady, et al. [1986].

When the vapor surrounding particles reaches a certain degree of supersaturation, the vapor begins to condense onto the particles. This is called *heterogeneous* condensation. If supersaturation is too high, condensation can take place even if no particles are present. This is referred to as *homogeneous nucleation* or *self-nucleation*, whereby molecules of the vapor form clusters due to the natural motion of the gas and attractive van der Waals forces to form nucleation sites. This condition is avoided by accurately controlling operating temperatures. The UCPC operates below the supersaturation ratio to avoid homogenous nucleation.

The degree of supersaturation is measured as a saturation ratio (P/P_s), which is defined as the actual vapor partial-pressure divided by the saturation vapor pressure for a given temperature:

$$\text{supersaturation} = \frac{P}{P_s}$$

For a given saturation ratio, the vapor can condense onto particles only if they are large enough. The minimum particle size capable of acting as a condensation nucleus is called the *Kelvin diameter* and is evaluated from the following relationship:

$$\text{saturation ratio} = \frac{P}{P_s} = \exp\frac{(4\gamma M)}{\rho RTd}$$

where γ = surface tension of the condensing fluid
M = molecular weight of the condensing fluid
ρ = density of the condensing fluid
R = universal gas constant
T = absolute temperature
d = Kelvin diameter

The higher the saturation ratio, the smaller the Kelvin diameter.

The saturation vapor pressure P_s is defined for a flat liquid surface. For a round liquid surface, such as the surface of a droplet, the actual saturation vapor pressure is greater. In other words, the smaller the droplet, the easier it is for the vapor molecules to escape the liquid surface. The Kelvin diameter defines the critical equilibrium diameter at which a pure droplet is stable—there is neither condensation nor evaporation. Smaller liquid particles will evaporate and larger particles grow even larger by condensation. The larger particle will grow until the vapor is depleted, causing the saturation ratio to fall until it is in equilibrium with the particle droplet.

If the saturation ratio is controlled to a level below the critical saturation ratio—the point at which homogeneous nucleation takes place—condensation will not take place in a particle-free environment.

The lower size sensitivity of the counter is determined by the operating saturation ratio. For the counter this ratio is several hundred percent, whereas in the atmosphere, this ratio is only a few percent for water.

History

Historically, the counter has been called a condensation nucleus counter (CNC). CNC technology uses three techniques to cool and supersaturate the condensing vapor: adiabatic expansion, two-flow mixing, and diffusional thermal cooling. The UCPC uses the latter.

Adiabatic Expansion CNC

The first CNC was developed over a century ago by John Aitken [1888]. His simple and completely mechanical device cooled water-saturated air by adiabatic expansion using a pump. The droplets were counted as they fell onto a counting grid and a calculation was made to determine the concentration of dust particles in the sample volume. He made several improvements to his invention and his portable dust counter was used for many years (Aitken [1890–91]).

Other significant developments in adiabatic-expansion CNCs include the use of electrical photodetectors to measure the light attenuation from cloud formation (Bradbury and Meuron [1938], Nolan and Pollak [1946], Rich [1955], Pollak and Metneiks [1959]); the use of under- and overpressure systems; and automation using electrically controlled valves and flow systems. The amount of light attenuated from the droplet cloud is monotonically related to the concentration of particles and is calibrated either by manual counting techniques, calculated from theory of particle light-scattering, or by using an electrical classification and counting method (Liu and Pui [1974]). A historical review of the expansion CNCs is given by Nolan [1972], Hogan [1979], and Miller and Bodhaine [1982].

Two-Flow Mixing CNC

Another cooling method turbulently mixes two vapor-saturated flows, one hot and one cold, to rapidly cool and supersaturate the vapor (Kousaka et al. [1982]). The condensation and droplet growth are fairly rapid and uniform. The flows can be passed continuously (that is, non-pulsating) through the mixing chamber onto a single-particle-counting optical detector.

Diffusional Thermal CNC

A continuous-flow, diffusional, alcohol-based, thermal-cooling CNC (Bricard et al. [1976], Sinclair and Hoopes [1975], Agarwal and Sem [1980]) first saturates the air sample with alcohol vapor as the sample passes over a heated pool of liquid alcohol. The vapor-saturated air stream flows into a cold condenser tube where the air is cooled by thermal diffusion. The alcohol condenses onto the particles and the droplets grow to about 10 to 12 micrometers. The droplets are counted by a single-particle-counting optical detector.

Continuous-flow, diffusional, water-based CPCs (TSI Model 3781, 3782, 3785, and 3786 WCPCs) were developed in between 2003 and 2006. Using a patented technique (Technology from Aerosol Dynamic Inc., U.S. Patent No. 6,712,881), an aerosol sample is drawn continuously through a cooled saturator and then into a heated condenser, where water vapor diffuses to the centerline of the condenser faster than heat is transferred from the warm walls, producing supersaturated conditions for water vapor condensing onto the particles.

The Model 3760, 3762, and 3010 were introduced in early 90s and was replaced by Model 3772/3771 in 2005. Both the 3772/3771 CPCs and the 3782 WCPC work only in the single count mode at relatively high aerosol flow rates of 1.0 and 0.6 L/min, respectively.

The 3772/3771 CPC uses n-butyl alcohol as the working fluid and an external vacuum pump or source to drive the 1 L/min aerosol flow rate. The 3782 WCPC uses water as the working fluid and uses an internal vacuum pump to drive the 0.6 L/min aerosol flow. Both 3772/3771 and 3782 can detect 10 nm particles at 50% detection efficiency. The 3782 can also be set to have a D_{50} of 20 nm.

For high-concentration measurements, a classical photometric light-scattering technique is used. The first commercial version of this type of CNC (TSI Model 3020) used n-butyl alcohol as the condensing fluid and has a flow rate of 0.3 L/min. TSI's Model 3020 CNC was replaced in 1988 by the Model 3022A which was replaced in 2005 by the Model 3775 CPC. Both the Model 3775 CPC and the 3785 WCPC use the photometric mode of operation to monitor high particle concentrations up to 10^7 particles/cm^3. These CPCs are general-purpose instruments suitable for a wide variety of applications.

The Model 3025 Ultrafine Condensation Particle Counter (UCPC) was developed in 1989 and was replaced by the Model 3776 UCPC in 2005. The 3776 has a lower size detection limit and a higher aerosol flow rate compared to the 3025A. Both the 3776 UCPC and 3786 UWCPC utilize sheath-air-flow design to lower the size detection limit. When growing the particles in the condenser chamber, the highest saturation ratio occurs on the centerline of the flow stream at some distance down the condensing tube (Stolzenburg [1988]). Although the saturation ratio is not uniform across the flow profile due to thermal gradients, the lower size-sensitivity can still be predicted and measured. Using sheath air, the UCPC confines the aerosol to the centerline of the condenser tube where level of supersaturation is the highest. The result is very high detection efficiency for small particles. The high sensitivity of the Model 3776 UCPC and the Model 3786 UWCPC makes them the only instruments of their kind that can detect particulates down to 2.5 nm. This makes them useful for atmospheric studies, nucleation, cleanroom monitoring, and basic aerosol research, etc. The sheath-air-flow design of the two CPCs also significantly reduces the response time for particle detection and particle diffusion losses. This occurs because aerosol particles are routed directly from the inlet to the condenser and optics, not through the saturator.

The Model 3781 WCPC is a small size and light weight instrument that detects particles down to 6 nm and operates in single count mode for concentrations up to 5×10^5 particles/cm^3.

The Model 3007 CPC was developed in 2001. It is a hand-held, battery powered instrument with a size detection limit of 10 nm. It uses isopropyl alcohol as the working fluid.

Currently, six CPCs (Models 3772, 3775, 3776, 3782, 3785, and 3786) are also commonly used with submicron size-distribution measurement systems such as the Scanning Mobility Particle Sizer™ (SMPS™) Spectrometers (TSI Model 3936).

Design of the UCPC

The basic instrument consists of three major subsystems: the sensor, the microprocessor-based signal-processing electronics, and the flow system. The sensor and the flow system are described below.

Sensor

The sensor is made up of saturator, condenser, and optical detector, shown schematically in Figure 5-1. The sensor grows the sampled aerosol particles into larger droplets and detects them optically. In the Low Flow mode, the aerosol entering the instrument is split to form the aerosol sample flow and sheath flow. In the High Flow mode, additional flow is drawn through the inlet to reduce particle diffusion losses. This additional flow bypasses the sensor. (See "High Flow" below for information on the bypass flow.)

The sheath flow is filtered and enters the saturator section where it passes through a heated, liquid-soaked cylindrical wick. To remain wetted, the wick dips into the liquid reservoir and continually absorbs liquid. The liquid butanol evaporates and saturates the sheath air stream with butanol vapor. Butanol is replenished from a reservoir and a fill bottle.

The aerosol sample flow passes through a capillary tube and is injected into the centerline of a vertical condenser tube and rejoined with the vapor-saturated sheath air as a laminar flow. The combined sheath and aerosol flows are then cooled using a thermoelectric device (TED) in the condenser. The vapor becomes supersaturated and condenses onto the aerosol particles (condensation nuclei) to form larger droplets. The droplets pass from the condenser tube through a nozzle into the optical detector. Liquid that condenses on the walls of the condenser tube runs back down and is removed by the water removal system into the drain bottle when the system is ON. Otherwise, the liquid goes back into the saturator and is absorbed into the wick for reuse.

The sensor's optical detector is comprised of a laser diode, collimating lens, cylindrical lens, collection lenses, and photodiode detector. The laser and collimating lens form a horizontal ribbon of laser light above the aerosol exit nozzle. The collection lenses and detector incorporate a pair of aspheric lenses that collect the light scattered by the droplets at a 90° angle (side scatter) and focus the light onto a low-noise photodiode. The main beam is blocked by a light-stop in the rear of the sensing chamber. A reference photodiode is used to maintain constant laser power output. The surface temperature of the optics housing is maintained at a higher level than the saturator to avoid condensation on the lens surfaces.

The Model 3776 UCPC operates in single particle count mode up to 3×10^5 particles/cm^3. Rather than simply counting individual electrical pulses generated by light scattered from individual droplets, the UCPC uses a continuous, live-time coincidence correction to improve counting accuracy at high particle concentrations. Coincidence occurs when the presence of one particle obscures the presence of another particle creating an undercounting error. "Live-Time Counting" is discussed in Chapter 6.

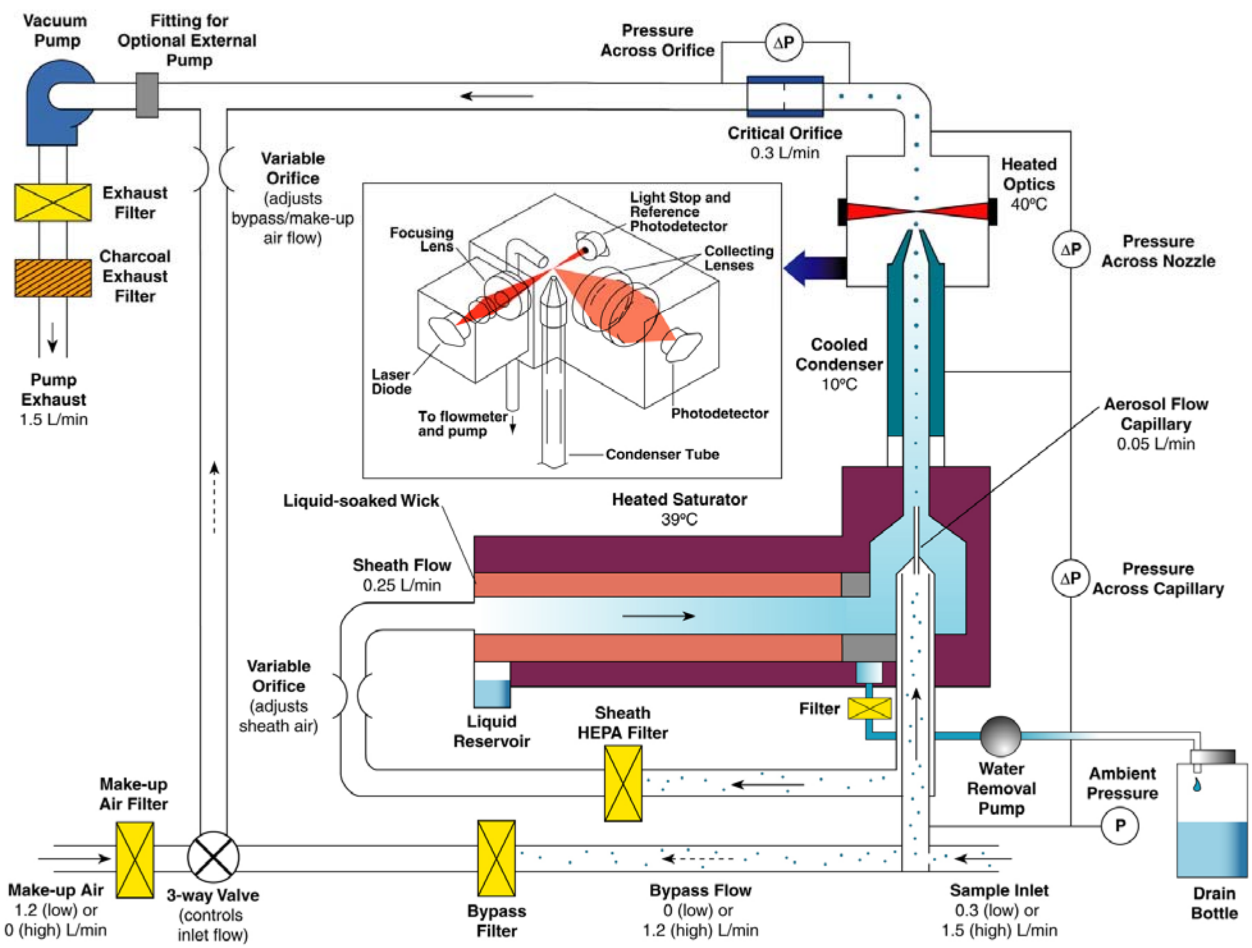


Figure 5-1
Flow Schematic of the Model 3776 UCPC

Flow System

Refer to Figure 5-1 while reviewing information on instrument flow provided in this section.

The UCPC relies on an on-board high-vacuum pump to maintain constant flows through a critical orifice and two variable orifices. The UCPC has two inlet flow options: high flow mode, nominally 1.5 L/min (1500 cm^3/min) and low flow mode, nominally 0.3 L/min (300 cm^3/min). The flow rate through the sensor is always 0.3 L/min, independent of the inlet flow rate setting. More information on instrument flows is provided below.

Critical Flow

To achieve the 0.3 L/min nominal sensor flow through the sensor, an orifice is used, operated at the *critical pressure ratio* to provide a *critical flow*. Critical flow is very stable and is a constant volumetric flow, assuring accurate concentration measurements despite varied inlet pressure.

The critical pressure ratio is found by dividing the absolute pressure downstream of the orifice P_D, by the absolute pressure upstream of the orifice P_U. This ratio must be below 0.528 for air.

$$\text{Critical pressure} = \frac{P_D}{P_U} \leq 0.528$$

Values for pressures impacting UCPC flow are found on the Status screen shown in Figure 4-9. These pressures are identified as A, O and N. Pressure **A** is the inlet pressure, typically the ambient barometric pressure. Pressure **O** is the differential pressure across the sensor flow orifice. Pressure **N** is the differential pressure across the nozzle. Figure 5-1 identifies the location of the pressure transducer sample ports.

To verify that critical pressure (therefore critical flow) is achieved under extremes in inlet resistance, determine the orifice upstream pressure from **(A – N)**. The downstream pressure is the upstream pressure minus the orifice differential pressure **(A – N – O)**.

The differential pressure across the capillary, **S**, does not appear on the Status screen, and is ignored for the calculation below because it is very small compared to the other pressures. This differential pressure is important however, as it is used to determine the actual aerosol capillary flow which is used to calculate particle concentration. Refer to the section "Aerosol Flow Capillary" later in this chapter.

Flow is critical if the following is true:

$$\frac{A - N - O}{A - N} \leq 0.528 \qquad (5\text{-}1)$$

Control of the aerosol inlet flow requires a variable orifice for *bypass* and *makeup* flow. This orifice is also operated at a critical pressure ratio.

High Flow

The high-flow option allows the aerosol sample to be brought to the UCPC faster to minimize response time and reduce particle diffusion losses. In the high-flow mode, the three-way solenoid valve (see Figure 5-1) is opened to the bypass flow, closing the makeup air path. A total of 1.5 L/min is drawn into the UCPC, 0.3 L/min flows through the sensor as the aerosol flow and 1.2 L/min flows as bypass flow. For information on how to select the high flow mode, see "Inlet Flow Mode" section in the "User Settings" section in Chapter 4.

Low Flow

An inlet flow rate of 0.3 L/min is used when using the UCPC in a Scanning Mobility Particle Sizer spectrometer to measure wider particle size range. In the low-flow mode, the three-way valve (see Figure 5-1) is open to the makeup air path, and the bypass flow is shut off. Only the sensor flow of 0.3 L/min is drawn into the inlet and enters the sensor directly. 1.2 L/min makeup air enters the makeup air port at the back panel of the instrument and mixes with the aerosol flow before entering the vacuum pump to make up the 1.5 L/min total flow. For information on how to select the low flow mode, see "Inlet Flow Mode" section in the "User Settings" section in Chapter 4.

Aerosol Flow Capillary

The aerosol capillary depicted in Figure 5-1 also functions as a capillary flowmeter for monitoring and determining the volumetric flow of the aerosol passing through the optics. Each capillary is calibrated at TSI for volumetric flow versus differential pressure. A sensitive pressure transducer on-board the UCPC measures the differential pressure continuously during instrument operation.

The capillary flow calibration is maintained over the operation specification inlet pressure range (75–105 kPa). Capillary temperature is constant so environmental temperature effects on the flow are eliminated.

Aerosol flow rate through the capillary is displayed in the Status screen on the front panel. This value is used in the calculation of aerosol concentration to provide highly accurate readings.

Pump

A high-vacuum diaphragm pump is used to maintain a critical sensor flow and bypass/makeup air flow. The pump uses a brushless DC motor with an anticipated life of more than 15,000 hours.

Counting Efficiency and Response Time of the UCPC

The 3776 UCPC has a sharp lower detection curve with a D_{50} of 2.5 nm. D_{50} is defined as the particle diameter at which 50% of particles are detected. The curve fit shown in Figure 5-2 is based on testing of three 3776 UCPCs using sucrose particles generated by TSI Model 3480 Electrospray Aerosol Generator and size classified with TSI Model 3080 Electrostatic Classifier and Model 3085 Nano Differential Mobility Analyzer (DMA). The counting efficiency is calculated by comparing the CPC readings to TSI Model 3068A Aerosol Electrometer readings.

Note the particle concentration measured by the UCPC is the total number concentration of all particles that a UCPC can detect. This measurement provides no size differentiation and it is not corrected using the UCPC counting efficiency curve. When the UCPC is used as part of a Scanning Mobility Particle Sizer (TSI Model 3936 SMPS), the counting efficiency curve is used to correct particle count data to provide particle size distribution.

The 3776 UCPC has a fast response time. T_{95}, defined as the time it takes for the UCPC reading to reach 95% of a concentration step change, is less than 0.8 sec in high flow mode and less than 5 sec in low flow mode for the 3776 UCPC. Figure 5-3 shows the response time curves in both flow modes. The curves are based on averaging of three UCPCs.

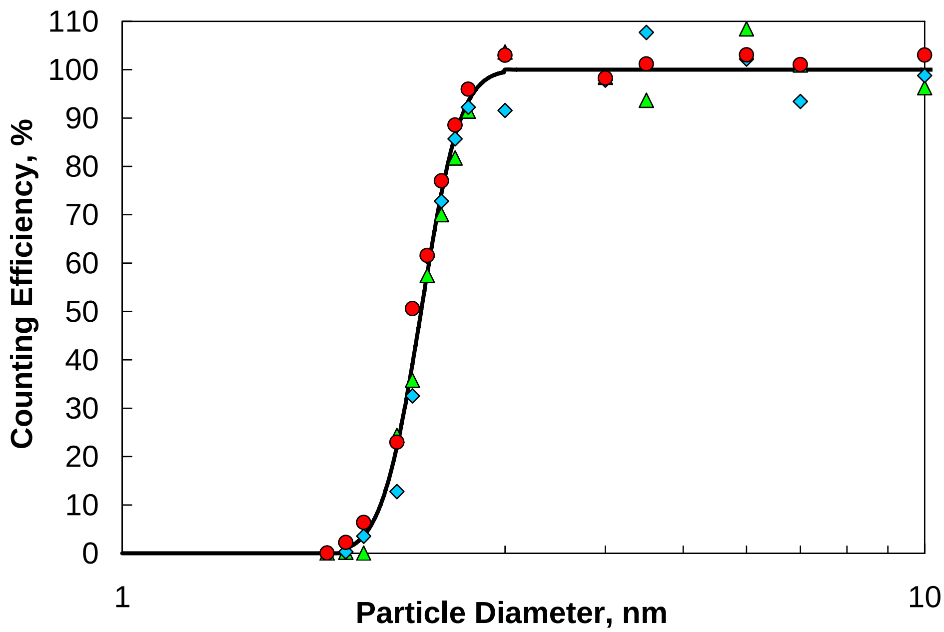


Figure 5-2
Counting Efficiency Curve of 3776 UCPC

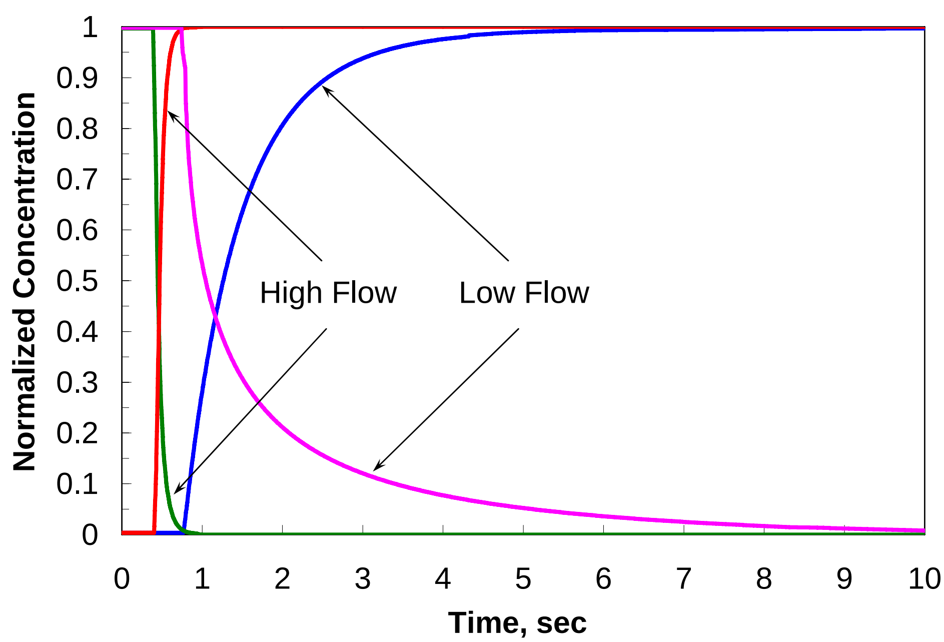


Figure 5-3
Response Time of 3776 UCPC

CHAPTER 6

Particle Counting

This chapter discusses specific aspects of particle counting and particle count measurements performed using the Model 3776 Ultrafine Condensation Particle Counter (UCPC).

The Model 3776 UCPC has two modes for particle counting:

- Concentration mode, where data is presented as particle concentration in p/cc, updated each second on the display (the maximum time resolution is tenth of a second).
- Totalizer mode, where total particle counts are accumulated and presented each second.

Concentration mode is commonly used for most applications. Totalizer mode is used at very low particle concentrations. Particles can be accumulated until a desired statistical accuracy is achieved. Refer to the section below discussing total count accuracy.

In the concentration mode, the UCPC operates in the single count mode with continuous, live-time coincidence correction over the range between 0 and 3×10^5 particles per cubic centimeter.

The instrument can display up to 10^6 particles/cm^3. However, because of the high coincidence level between 3×10^5 and 10^6 particles/cm^3, the concentration measurement error may be outside the specification of ±10%. The UCPC needs to be calibrated against a concentration reference (e.g., an aerosol electrometer or another CPC with a dilution bridge with a known dilution ratio) in the range from 3×10^5 to 10^6 particles/cm^3 in order to provide accurate concentration measurements.

Optical Detection

Submicrometer particles are drawn into the counter and enlarged by condensation of a supersaturated vapor into droplets that measure several micrometers in diameter. The droplets pass through a lighted viewing volume where they scatter light. The scattered-light pulses are collected by a photodetector and converted into electrical pulses. The electrical pulses are then counted and their rate (live-time corrected) is a measure of particle concentration.

Total Count Accuracy

At very low concentrations, the accuracy of the measurement in the single-particle-counting mode is limited by statistical error. If the total number of particles counted in each time interval is very small, the uncertainty in the count is large. The relative statistical error of the count σ_r is related to the total count n by

$$\sigma_r = \frac{\sqrt{n}}{n}.$$

In totalizer mode, the accuracy of the concentration is increased by sampling for a longer period and counting more particles. The concentration is displayed on the front panel in totalizer mode and is calculated by:

$$\text{concentration} = \frac{\text{total counts}}{\text{volume of aerosol flow in the sensor}} = \frac{n}{Q \times t}$$

where
Q = Real-time aerosol flow rate displayed on the Status Screen; this value is determined from the differential pressure across the aerosol capillary based on factory calibration. It is very close to its nominal value of 0.05 L/min (0.83 cm^3/sec)
t = sample time in sec.

Live-Time Counting

Coincidence occurs when more than one particle occupies the optical sensing region simultaneously. The optical detector cannot discriminate between the particles and multiple particles are counted as a single particle. At higher particle concentrations, particle coincidence begins to significantly impact the measured concentration.

The UCPC corrects for coincidence continuously with the instrument electronics performing a "live-time" correction. Live-time refers to the time between electrical pulses. This is the total measurement time interval minus the time during which the counter is disabled with one or multiple particles in the optical sensing volume (the Dead Time). The dead time should not be included in the sample time since particles can't be counted during this time interval except the ones that are already in the viewing volume. The actual particle concentration therefore equals the number of counted particles divided by the live-time and the aerosol flow rate.

To measure live-time, a high-speed clock and accumulator are used. The accumulator adds up the live time and the counter adds up pulse counts. The particle concentration is then calculated by

$$C_a = \frac{\text{number of counted particles}}{\text{accumulated live-time}} \times \frac{1}{\text{aerosol flow rate}}$$

Note: *At concentrations between 3×10^5 and 10^6 particles/cm^3, particle concentration data and the top status bar on the front panel are in red. If this occurs, the number of particles shown on the display could be lower than the actual concentration. The aerosol needs to be diluted or the CPC needs to be calibrated versus electrometer in this concentration range for it to be used up to 10^6 particles/cm^3.*

CHAPTER 7

Computer Interface and Commands

This chapter provides computer interface and communications information for the Model 3776 Ultrafine Condensation Particle Counter (UCPC). Information on the Flash Memory Card is also provided.

Computer Interface

This section includes descriptions on USB, Ethernet connections, RS-232, and the Flash Memory Card.

USB

USB communications are provided with the UCPC, for use with the supplied Aerosol Instrument Manager® software. Simply connect the supplied USB cable to the instrument and computer having Windows®-based operating system and the Aerosol Instrument Manager software. Refer to the Aerosol Instrument Manager manual for specific system requirements, including operating system version.

Ethernet

The Ethernet port on the UCPC can provide system status information over the internet and is updated every five seconds. Your web browser must support java plug-ins.

Network Setup

1. Connect the UCPC to the network using an Ethernet cable and turn the instrument on.
2. On the computer that is connected to the same network using another Ethernet cable, run the device discovery program **Discovery.exe** found on the supplied Aerosol Instrument Manager Software CD or in the folder where the Aerosol Instrument Manager software is installed. The **Discovery.exe** program will find CPC devices on the network.

Note: *This program will only find CPCs that are on the same subnet. Example: If the computer is at IP address 10.1.3.1, the device discovery program will find all CPCs on 10.1.3.x. Also, if the windows firewall is enabled (on by default in service pack 2), the device discovery will not find any CPCs. Once the IP address is known, you can access the Ethernet port on the UCPC from another subnet.*

3. Select the device and choose **Configure network settings**.

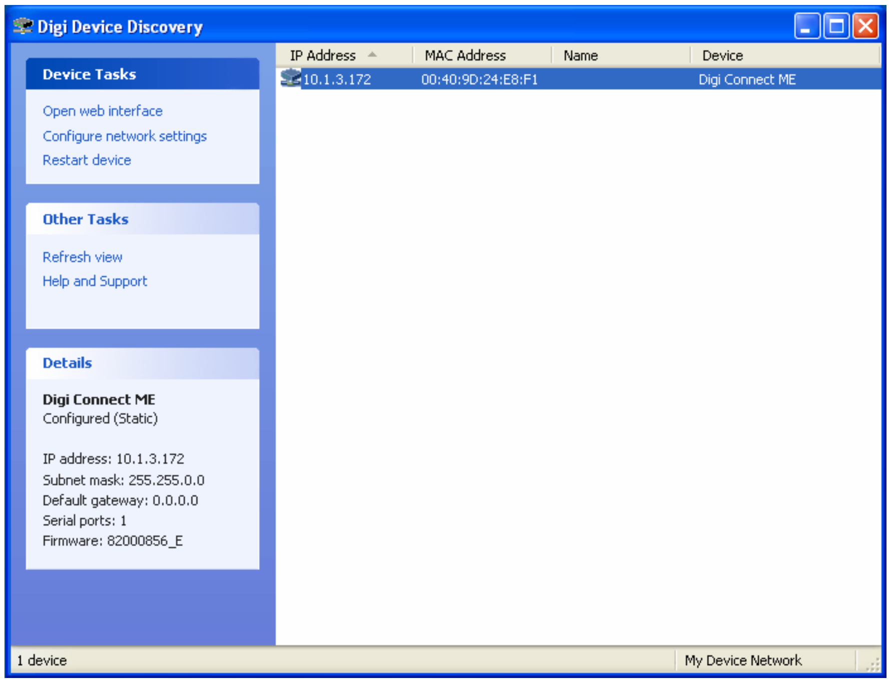


Figure 7-1
Digi Device Discovery Screen

4. Talk with your network administrator to verify the correct network settings this device should operate at. If needed, the MAC address can be located on the back of the instrument or in this pop-up window. Fill in the appropriate information and click **Save**.

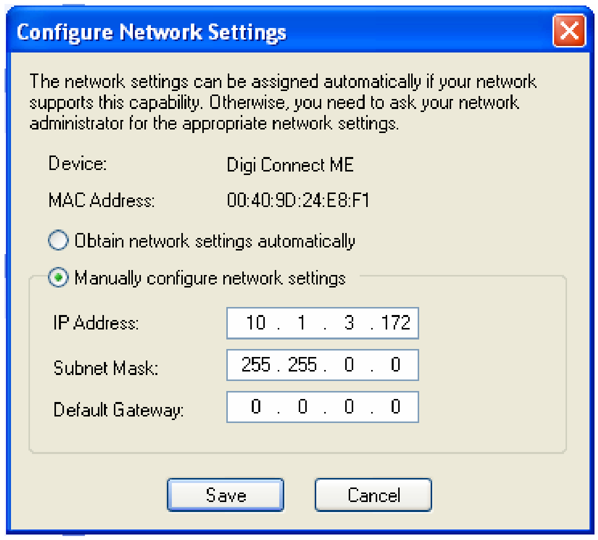


Figure 7-2
Configure Network Settings Screen

5. Close the device discovery program and restart the UCPC. It takes about a minute for the Ethernet to initialize.

6. If the UCPC is in the same subnet as the computer, start the device discovery program **Discovery.exe** and click on **Open web interface**. The username and password are "**tsicpc**" as shown below in Figure 7-3. If the UCPC is not in the same subnet as the computer, type in the IP address in your web browser. Work with your network administrator to make sure the IP address is accessible from the network your computer is in.

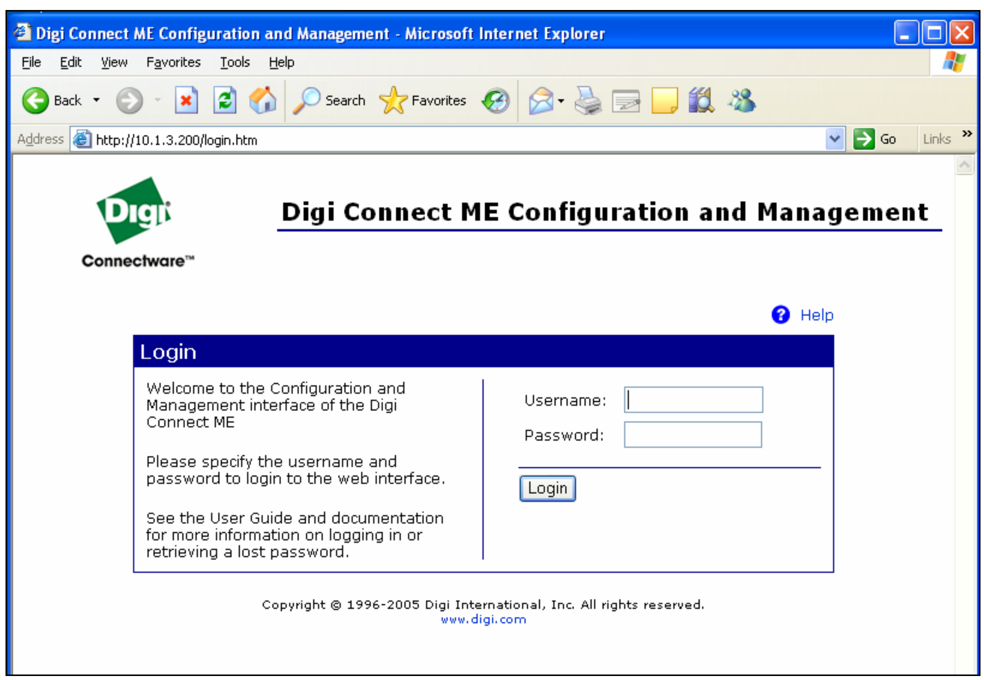


Figure 7-3
Digi Connect ME Configuration and Management Screen

7. From the web interface of the device discovery program or the web browser, you can monitor the status of the UCPC.

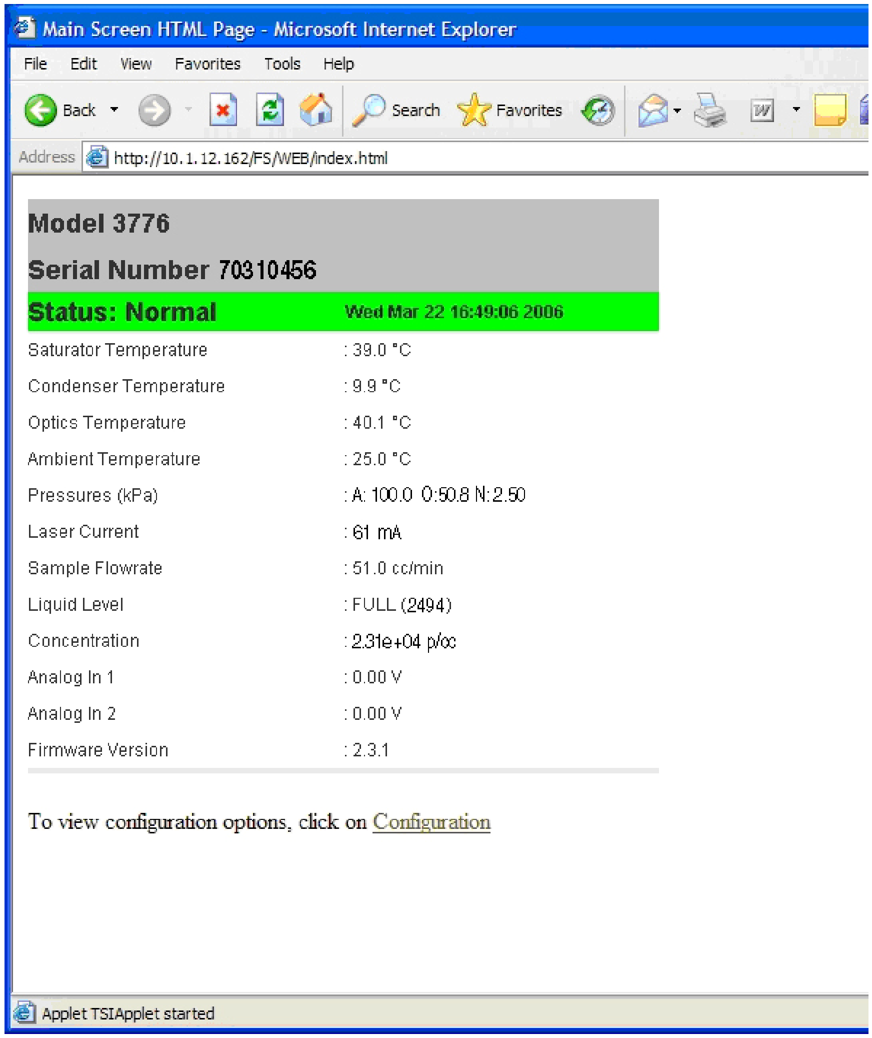


Figure 7-4
Main Screen HTML Page

Flash Memory Card Specification

A file is created on the Flash Memory Card when the START option is selected in the Main Data Presentation screen. Each file will contain one hour of data, unless if the run is stopped early with the STOP option. See Chapter 4.

Each file has this format:

LINE 1: "TSI CPC DATA VERSION 1"
LINE 2: start time of this file (the first number is the total number of seconds elapsed from midnight Jan. 1, 1970)

LINE 3: data average interval in seconds
LINE 4: Instrument model number, firmware version number, instrument serial number (result of the "RV" command)
LINE 5: first data set
LINE 6: second data set
LINE X: last data set

The data sets are defined as counts, concentration, analog input 1, analog input 2, status. These data sets are saved every average interval so if the average interval was one minute, the counts would be total counts (coincidence-corrected) over the last minute, etc. Instrument operates in normal condition if the status bit shows zero. A nonzero status indicates that some operating parameters deviate from normal conditions. See RIE command in Appendix B.

Every time you begin a new run, a unique file will be created with the date and time as the file name.

Www_Mmm_dd_hh_mm_ss_yyyy

Where Www is the weekday, Mmm the month in letters, dd the day of the month, hh_mm_ss the time, and yyyy the year.

Disclaimer: Due to the fact that the FAT file systems are by design not power fail-safe, if power is lost, part or all of the file system may be lost.

Note: *Keep the amount of data stored in the flash memory card under 64 MB to avoid long overhead time before generating a new data file each hour in the card.*

Caution

Remove the flash memory card following the correct procedures:

1. Use *Safely Remove Hardware* option in Windows to disconnect the card reader from the computer—stop USB Mass Storage Device.
2. After *the* message *Safe To Remove Hardware: The "USB Mass Storage Device" device can now be safely removed from the system* appears, physically remove the flash memory card from the card reader.

Failure to follow these procedures may result in failure to log data with the flash memory card.

RS-232 Serial Communications

The communications ports are configured at the factory to work with RS-232-type devices. RS-232 is a popular communications standard supported by many mainframe computers and most personal computers. The Model 3776 UCPC has two 9-pin, D-type subminiature connectors on the back panel labeled Serial 1 and Serial 2. Figure 7-5 shows the connector pins on the serial ports; Table 7-1 lists the signal connections.

Note: *This pin configuration is compatible with the standard IBM PC serial cables.*

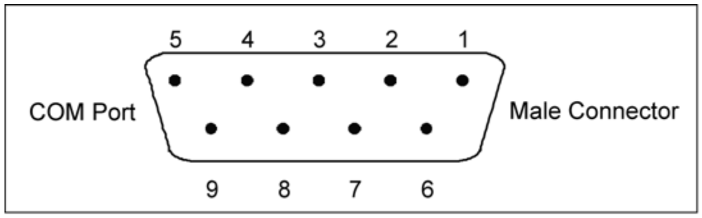


Figure 7-5
RS-232 Connector Pin Designations

Table 7-1
Signal Connections for RS-232 Configurations

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

An external computer is connected to Serial 1 for basic instrument communications and when Aerosol Instrument Manager software is used. Serial 2 is used for attaching another instrument. Read and write commands are sent and received from Serial 2 by the computer connected to Serial 1. Serial 1 and Serial 2 can have different baud rates and communications protocols. Normally, only Serial 1 is used.

Commands

All commands and responses, unless specified as binary-encoded, are sent or received as ASCII characters. All messages are terminated with a <CR> (0x0D) character. All linefeeds (0x0A) characters are ignored and none are transmitted. Commands are case insensitive. Backspace character (0x08) will delete previous characters in buffer.

In this specification, values enclosed by "<>" indicate ASCII characters/values sent/received. For example, <,> indicates the comma was sent or received via the communications channel.

Integers are 32-bit values. Floating point are IEEE() 32-bit values.

Integer and floating point values are 'C' string compatible ASCII-encoded. For example, an integer value of <11011100101110101001100001110110> binary, would be sent as <3703216246>.

When char, integer or hex-decimal data is sent with more than one digit, leading zeros should always be left off. If the value of the data is zero, then one zero must be sent. An exception is the value zero in real format, it should be sent as 00000E0.

The firmware commands are divided into the following categories:

- READ Commands
- SET Commands
- MISC (MISCELLANEOUS) Commands
- HELP Commands

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

SET commands set an internal parameter to the value(s) supplied with the command. Supplied parameters are always delimited by a "<,>". SET commands can be identified by a leading "S". The instrument will reply to all set commands with the string "OK" <CR>.

MISC (MISCELLANEOUS) commands will be used for calibration and SMPS mostly.

HELP commands. A list of firmware commands are accessible using the HELP command sent to Serial 1 of the UCPC. The firmware commands are also listed in Appendix B. The commands can be used to read UCPC data, instrument statuses, set instrument operating parameters, and send and receive data from another instrument attached to the Serial 2 port.

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

To use the HELP commands and the firmware commands, a program capable of sending and receiving ASCII text commands can be used. A terminal program such as "HyperTerminal" (supplied with Windows®) is appropriate.

Connect to Serial 1 of the Model 3776 UCPC and perform the following steps:

1. Open the HyperTerminal program by selecting: **Start | Programs | Accessories | Communications | HyperTerminal**.
2. Enter a name for the connection, for example, TSI-3776.

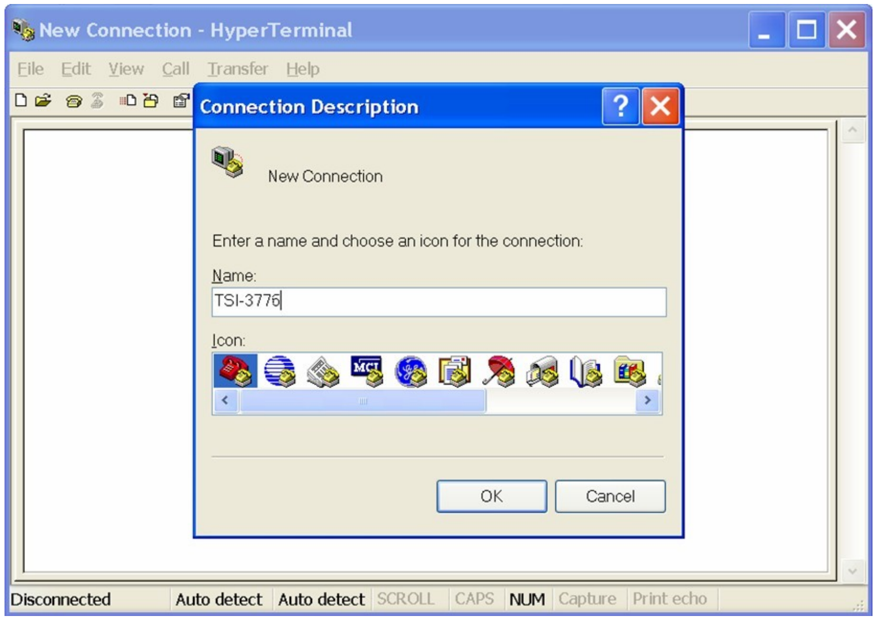


Figure 7-6
Connection Description Screen

3. Enter the communications (COM) port.

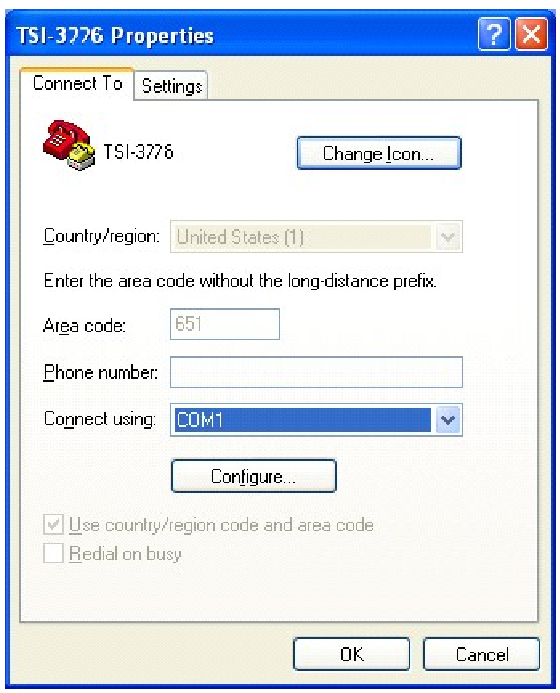


Figure 7-7
Connect To Dialog Box

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

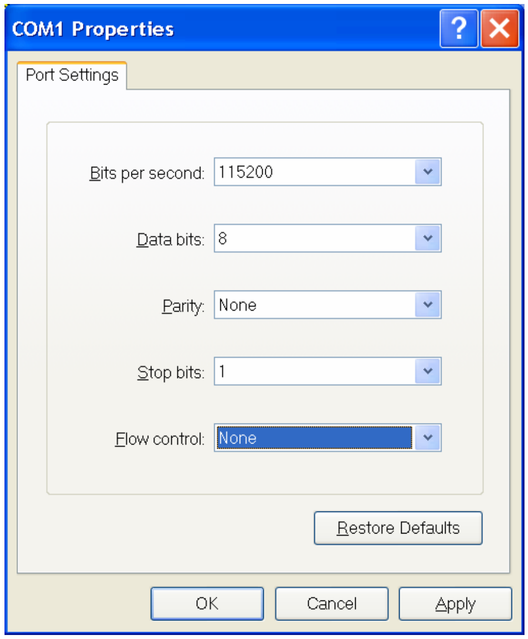


Figure 7-8
Port Settings Dialog Box

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

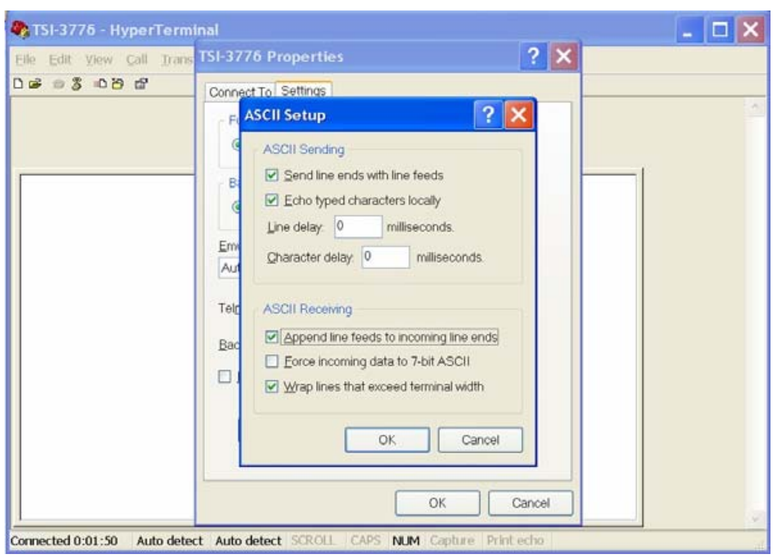


Figure 7-9
ASCII Setup Dialog Box

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

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

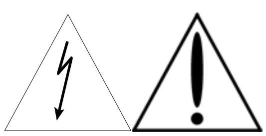
8. Type in firmware commands to communicate with the UCPC. A list of firmware commands can be obtained using the HELP command or from Appendix B. To obtain the list from HELP command, select **Transfer|Capture Text**..and then **HELP ALL** in the terminal window lets you capture all the help commands to a text file for easy reference.

CHAPTER 8
Maintenance and Service

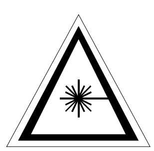
This chapter is written for a service technician with skills in both electronics and mechanics. Static preventative measures should be observed when handling any printed circuit board connectors.

Regular maintenance of the Model 3776 Ultrafine Condensation Particle Counter (UCPC) will help ensure years of useful operation. The frequency of service depends on the frequency of use and the cleanliness of the air measured. This section describes how to check and service some components of the UCPC.

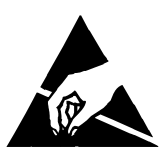
You are encouraged to call TSI for assistance in performing special maintenance. It may also be helpful to have the technician, tools, and the UCPC close to the telephone when discussing the problem with a TSI technician. Refer to this chapter for directions on contacting a technical resource at TSI.



W A R N I N G
Procedures described below may require removal of the instrument cover. The instrument must be unplugged prior to service to prevent possible electrical shock hazard.



W A R N I N G
Unplug the instrument prior to removing the cover to avoid potential of exposure to laser radiation.

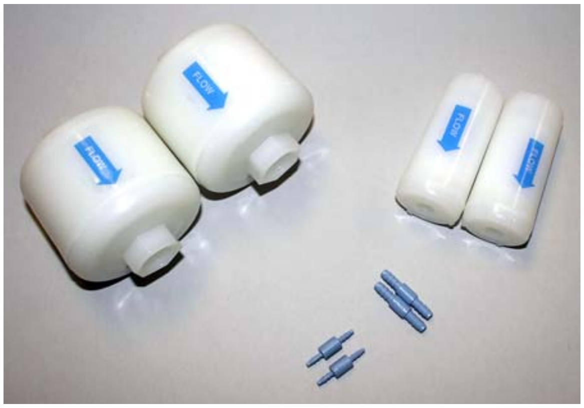


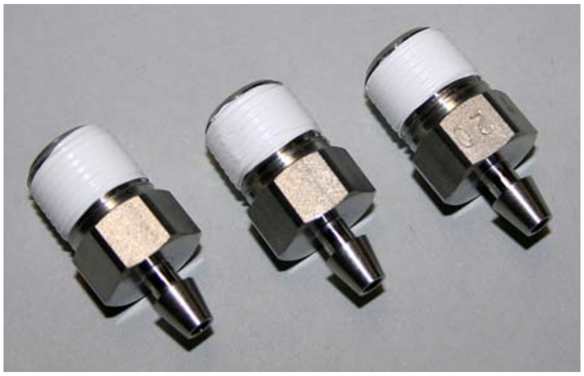
C a u t i o n
Whenever performing service on internal components avoid damage to the UCPC circuitry by not stressing internal wiring, through bumping, snagging or pulling. Also use electrostatic discharge (ESD) precautions: ❑ Use only a table top with a grounded conducting surface. ❑ Wear a grounded, static-discharging wrist strap

Replacement Parts Kits

In addition to replacement parts found in your supplied accessory kit, additional replacement items are available from TSI to keep your UCPC operating for many years. Parts are available in kits listed below in Table 8-1. Please contact your TSI representative for details and purchase of these items.

Table 8-1
3776 UCPC Maintenance and Replacement Kits

TSI Part No.		Name	Description
1031484		Reservoir Cover Replacement Kit	Replacement clear cover and O-rings for the butanol reservoir
1031487		Insulation Plug supplies	Insulation plugs for insulating the RTD thermocouples used for temperature control
1031489		Replacement Filter Kit 3776	Kit of all filters used within the Model 3776 UCPC

TSI Part No.		Name	Description
1031491		Orifice Flow Control Kit 3776	Replacement critical orifices
1031492		Kit, Charcoal Filter, large, CPC	Five (5) large charcoal filters used to remove butanol from exhaust (~ten-day effectiveness for each filter)
1031493		Kit, Charcoal Filter, small, CPC	Five (5) small charcoal filters used to remove butanol from exhaust (~two-day effectiveness for each filter)

TSI Part No.		Name	Description
1031495		Replacement Saturator Wicks, UCPC 3776	Two (2) replacement wicks
1031498		Maintenance Kit UCPC 3776	Includes 1031484, 1031487, 1031489, 1031491, 1031493, and 1031495
1031483	Contact TSI for more information about this kit.	Dryer Assembly Kit for UCPC 3776	Kit to provide drying capability for saturator sheath flow
1031486		Fill/Drain Bottle Replacement Kit	Fill and drain bottles, bracket, tubing and fittings

Draining Butanol from the Butanol Reservoir

Butanol must be drained from the reservoir prior to removing the clear plastic butanol reservoir plate on the side panel of the instrument and wick. To drain the butanol reservoir:

1. Connect butanol drain bottle (from the accessories) to the drain fitting on the back of the UCPC using the mating quick-connect fitting.
2. Place the drain bottle on the floor.
3. Select the Manual Drain option from the User Settings menu, and depress the control knob, (see Chapter 4, "User Settings").
4. Select **Continue** from the options in the window that appears. The butanol drain valve will open. Often there is not a significant column of liquid in the butanol drain line to initial flow from the butanol reservoir. Tipping the instrument toward the drain port and squeezing the butanol drain bottle will sometimes help start flow.
5. Confirm that butanol has drained by checking the butanol level through the clear reservoir cover plate. During draining, Auto-Fill and the vacuum pump are automatically turned off.

   ***Note**: When draining is stopped, the pump restarts but the Auto-Fill must be turned on again by selecting this option from the User Settings menu or by restarting the instrument.*

Caution
Whenever the instrument is turned on, the Auto-Fill is activated. Do *not* run the instrument with the butanol reservoir cover plate removed to prevent spilling butanol from the butanol reservoir.

Changing the Filters

The Model 3776 UCPC use four particulate filters and two liquid filters. The particulate filters are for the sheath flow, exhaust flow, bypass flow, and makeup air flow. The liquid filters are for butanol fill and water removal system. The filter in the water removal system is called Micro-pump filter. These filters may be replaced at regular intervals depending on use.

Filter Replacement Schedule

Table 8-2 provides some guidance on how often filters should be changed. Filters may require replacement sooner, or may last significantly longer depending upon the sampled aerosol concentration level or aerosol type. Changes in the nozzle differential pressure and inlet sample flow rate may indicate that a filter requires replacement. Capillary flow will change depending on changes in barometric pressure or inlet resistance. This is normal. Capillary flow is not a reliable indicator of the need for filter replacement.

Replacement filters are supplied in the accessories kit and are available from TSI as maintenance kits. Refer to the earlier section Replacement Parts Kits.

Table 8-2
Filter Replacement Schedule

Filter Name (TSI Part Number)	Replacement Schedule (Operation Time)
Exhaust Filter (1602094)*	2000 hours
Sheath Filter (1602300)	1500 hours
Bypass Filter (1602094)	>2000 hours
Makeup Air Filter (1602088)	1500 hours
Butanol Fill (1602088)	2000 hours
Micro-pump Filter (1500192)	As necessary

*Part numbers are listed for reference only. Replacement filters are ordered from TSI as Replacement Filter Kit P/N 1031489.

Sheath Flow Filter

The high efficiency Sheath Filter collects particles from a large portion of the sample flow (nominally 250 cm^3/min) before the flow combines with the remaining portion (nominally 50 cm^3/min aerosol flow). The sheath filter cleans the sheath air used to confine the aerosol flow to the centerline of the condenser. The Sheath Flow filter is replaced at regular intervals depending on use. Six months to one year is recommended. The Sheath flow filter is shown in Figure 8-1.

1. Read warnings and cautions at the beginning of this chapter.

2. Unplug the instrument and remove the instrument cover by loosening the six side panel screws (they don't have to be fully removed). Lift the cover up. Do **not** remove the screws holding the clear butanol reservoir cover.

3. Before removing the old filter, note the direction of the arrow on the filter and the corresponding tubing connections. The sheath flow control variable orifice is located downstream of the filter.

4. Remove the tubing from the barbed fittings at both ends of the filter shown in Figure 8-1.
5. Discard the old filter and fittings.
6. Find a new filter with fittings (P/N 1602300) in the accessory kit.
7. Reinstall the new sheath flow filter by reinserting the tubing over the barbed fittings. The Arrow on the filter should face to the left, oriented as shown in the figure.

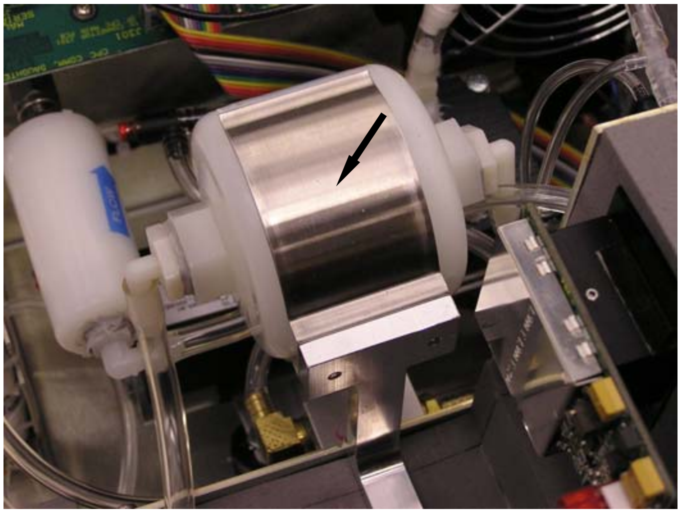


Figure 8-1
Replacing the Sheath Flow Filter

(continued on next page)

Exhaust Filter

The Exhaust Filter is mounted at the back panel as shown in Figure 8-2. This filter removes particles in the air stream exhausting the instrument from the internal vacuum pump. This filter does not require replacement unless instrument sample flow is compromised as the filter loads. A drop in the nozzle differential pressure or reduction in inlet sample flow may indicate a plugged exhaust filter.

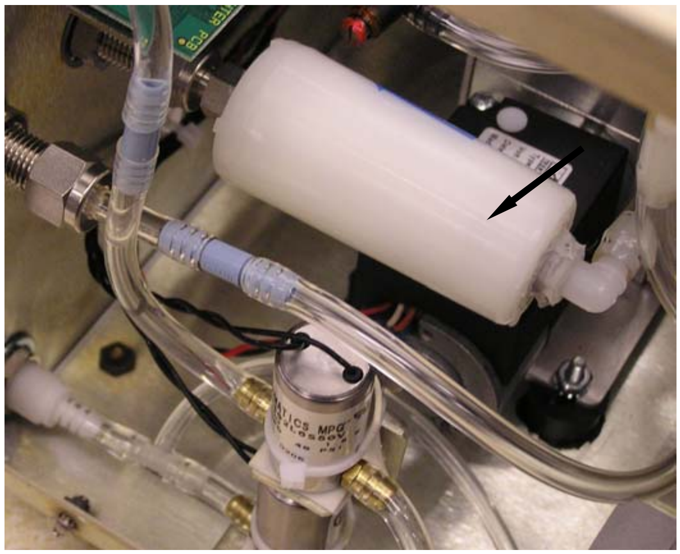


Figure 8-2
Replacing the Exhaust Filter

1. Read warnings and cautions at the beginning of this chapter.
2. Unplug the instrument and remove the instrument cover by loosening the six side panel screws (they don't have to be fully removed). Lift the cover up. Do **not** remove the screws holding the clear butanol reservoir cover.
3. Before replacing the filter, note the direction arrow on the filter that points to the back of the instrument.
4. Remove the tubing from the barbed fitting at the back of the filter.
5. Unscrew the filter and separate it from the threaded bulkhead panel fitting. Discard the old filter after removing fittings at both ends.
6. Find in the accessory kit the new exhaust filter (P/N 1602094) with the stainless steel fitting and the elbow plastic fitting.
7. Reinstall the new exhaust filter, by screwing the filter housing onto the bulkhead fitting and connect the barbed fitting with the corresponding tubing.

Bypass Filter

The Bypass air filter is identified in Figure 8-3 and is referenced in the schematic, Figure 5-1. This filter is used to protect a variable orifice controlling flow at a nominal 1.2 L/min. The Bypass filter is used during the high-flow operation mode. This filter is generally not replaced unless the instrument sample flow is compromised as the filter loads.

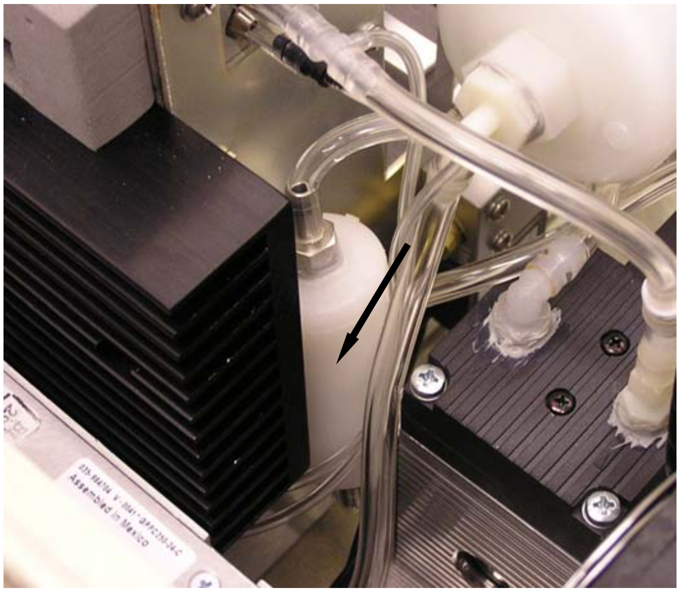


Figure 8-3
Replacing the Bypass Air Filter

1. Read warnings and cautions at the beginning of this chapter.
2. Unplug the instrument and remove the instrument cover by loosening the six side panel screws (they don't have to be fully removed). Lift the cover up. Do **not** remove the screws holding the clear butanol reservoir cover.
3. Locate the filter in Figure 8-3. Before replacing the filter note the direction arrow on the filter. It points to the 3-way solenoid valve that controls the inlet flow operation mode.
4. Remove the tubing from both ends of the filter.
5. Replace the filter with the one in the accessory kit (P/N 1602094), orienting the directional arrow and tubing correctly. Flow arrow should point to the three-way solenoid valve.

Makeup Air Filter

The Makeup air filter is identified in Figure 8-4 and is referenced in the flow schematic, Figure 5-1. This filter is used to protect the variable orifice controlling flow at a nominal 1.2 L/min. The Makeup Air Filter is used during the low-flow operation mode. This filter is generally not replaced unless the instrument sample flow is compromised as the filter loads. Makeup air is sampled from ambient environment.

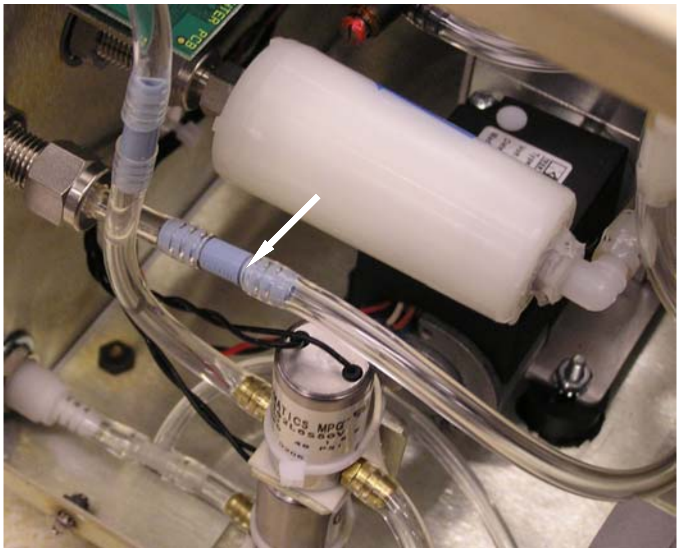


Figure 8-4
Replacing the Makeup Air Filter

1. Read warnings and cautions at the beginning of this chapter.
2. Unplug the instrument and remove the instrument cover by loosening the six side panel screws (they don't have to be fully removed). Lift the cover up. Do **not** remove the screws holding the clear butanol reservoir cover.
3. Locate the filter in Figure 8-4.
4. Remove the tubing from both ends of the filter.
5. Replace the filter with the one in the accessory kit (P/N 1602088). This filter has no preferred direction.

Butanol Fill Filter

The butanol fill filter is found in the fill line leading from the butanol bottle (Figure 8-5).

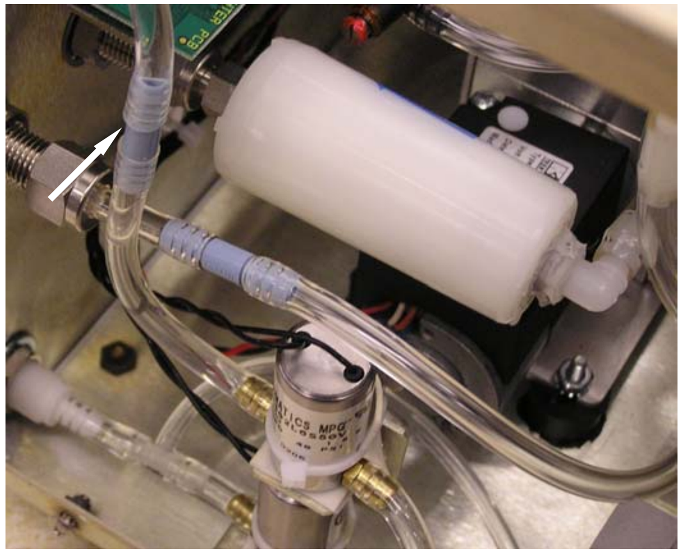


Figure 8-5
Replacing the Butanol Fill Filter

1. Read warnings and cautions at the beginning of this chapter.
2. Unplug the instrument and remove the instrument cover by loosening the six side panel screws (they don't have to be fully removed). Lift the cover up. Do **not** remove the screws holding the clear butanol reservoir cover. .
3. Remove the tubing from the barbed fittings at the ends of the filter.
4. Replace the filter with the appropriate filer found in the accessory kit (P/N 1602088). This filter has no preferred direction.

Micro Pump Filter

The Micro-pump is used to remove condensed water vapor before it contaminates butanol in the saturator. The micro-pump filter protects the pump from contamination which could impede its performance. The micro-pump filter should generally be replaced only if it becomes blocked as it requires front panel removal. A blocked micro-pump filter prevents condensate from being extracted.

When using the water removal feature it is advisable to check the drain tubing to the drain bottle to verify liquid movement. The liquid column will pulse a small amount toward the drain bottle, approximately once per second as the micro-pump actuates. If no pulsing occurs, first verify that the water removal feature is on (see User Settings in Chapter 4).

1. Read warnings and cautions at the beginning of this chapter.
2. Unplug the instrument and remove the instrument cover by loosening the six side panel screws (they don't have to be fully removed). Lift the cover up. Do **not** remove the screws holding the clear butanol reservoir cover.
3. The micro-pump filter is accessed from the front of the instrument. Remove the three screws (see arrows) at the top of the front panel as shown in Figure 8-6. Carefully, tip the panel back, being careful not to bend the sampling inlet.
4. Find the filter shown in Figure 8-7.
5. Remove the micro-pump filter by carefully working the tubing at the ends of the filter barbs. Be careful not to pull the tubing off the pump fitting or fitting in the saturator.
6. Install a new filter (P/N 1500192) from the accessory kit. This filter has no preferred direction.

Figure 8-6
Front Panel Screw Removal

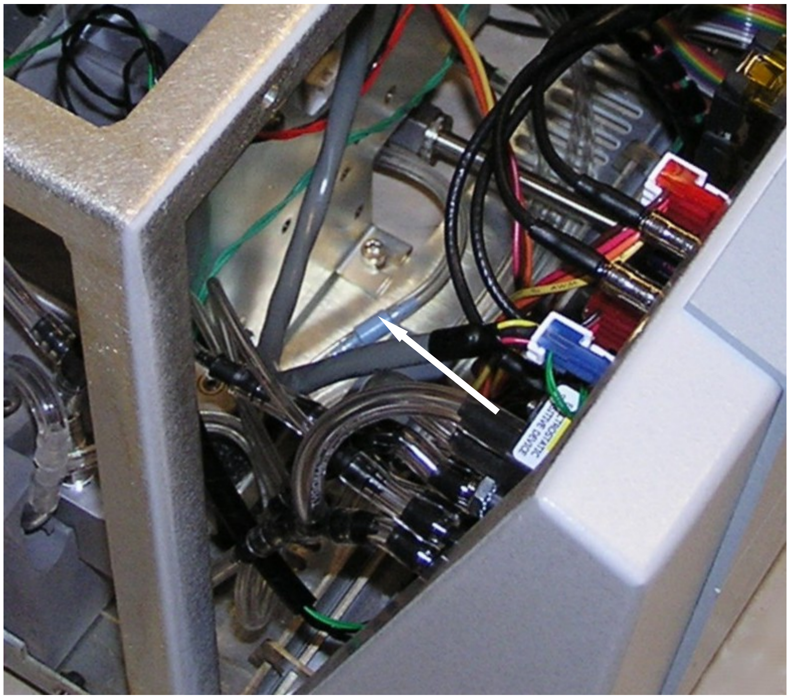


Figure 8-7
Micro-Pump Filter, Shown Behind the Opened Front Panel

Removing and Installing the Saturator Wick

Saturator wick needs to be removed prior to shipping the instrument. It is no longer necessary to wait overnight to let the saturator wick dry out as for the predecessor Model 3025A UCPC.

Caution
Removing the saturator wick will cause butanol (butyl-alcohol) vapors to diffuse into the work space. Wick replacement operations must be performed in a well ventilated area, ideally under a fume hood. If unfamiliar with butanol, refer to the Chemical Safety information at the front of this manual.

Caution
Whenever the instrument is turned on, the Auto-Fill is activated. Do not run the instrument with the clear butanol reservoir cover plate removed to prevent spilling butanol from the butanol reservoir.

Tools Needed

8" plastic bag with seal, Philips-head screwdriver, small flat-blade screwdriver, needle nose pliers, and paper towels. Refer to figures that follow.

To remove and reinstall the saturator wick, follow the instructions below.

1. Find a plastic bag with seal, (P/N 2300027 in accessory kit) suitable to hold the 8" × 1" saturator wick. The wick will likely be wet with butanol when removed and needs to be placed in the bag immediately to reduce release of butanol vapors.
2. Connect the Drain Bottle to the drain port at the back of the instrument.
3. Select the Manual Drain option from the User Settings menu as described in Chapter 4.
4. The drain bottle should be placed on the floor, well below the instrument. To facilitate draining, tilt the instrument to the side of the clear reservoir plate and/or to the side of the back panel. The bottle can also be squeezed to initiate movement of the liquid column in the drain tube.
5. Once drained, remove the clear plastic reservoir cover plate by removing the four retaining screws as shown in Figure 8-8. Make sure the blue O-ring gasket seal is retained if it becomes unseated. Put paper towels on the table under the reservoir to absorb any butanol that spills out.

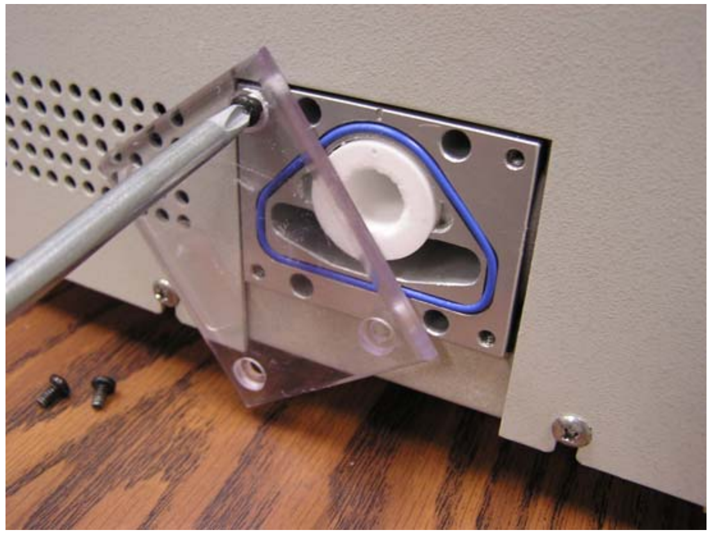


Figure 8-8
Saturator Wick Removal

6. Insert a small flat-blade screwdriver in the notch at the side of the wick and pry the wick out as shown in Figure 8-9. You may need to use pliers if the wick is soaked with butanol (see Figure 8-10). Be sure to use as minimal force as possible. Place the wick in the plastic bag included in the accessories and seal the bag. This wick can be dried by putting it in a vacuum for three hours. However, it is not necessary to dry the wick before putting it back into the saturator block after the shipment.
7. To install a wick back into the saturator, insert the wick into the saturator block, orienting it as shown in Figure 8-11 with the metal orientation pin at the side of the wick positioned in the notch to the right.
8. Replace the gasket seal, if necessary, by reinserting it into the grove and applying vacuum grease on the gasket.
9. Replace the clear plastic plate, making sure the O-ring is properly seated and not pinched.
10. Tighten the screws with modest torque.
11. Use the Auto-Fill option to refill the reservoir with Butanol. See "User Settings" in Chapter 4.

Figure 8-9
Prying the Saturator Wick Out

Figure 8-10
Pulling the Saturator Wick Out Using Pliers with Minimal Force

Figure 8-11
Installing a Saturator Wick

Aerosol Flow Adjustment

Refer to the flow schematic in Figure 5-1.

The flow which determines the aerosol concentration is the “aerosol” flow through a capillary, nominally 0.05 L/min. Aerosol flow through the capillary is combined with the “sheath” flow, nominally 0.25 L/min which gives a 0.3 L/min total “sensor” flow. Total sensor flow is maintained by an orifice operated at critical pressure. Refer to the technical discussion on critical flow in Chapter 5.

Adjustment of the aerosol flow is made using a variable orifice in the sheath flow path. As the variable orifice is opened there is more sheath flow and less aerosol flow. As the variable orifice is closed, more aerosol is directed through the capillary increasing the aerosol flow and reducing the sheath flow.

The capillary has been calibrated at the factory for flow versus differential pressure. Pressure across the capillary is continually monitored during UCPC operation. Over time as the sheath filter loads, more flow will pass through the capillary. This increase in aerosol flow can be seen on the UCPC Status screen. If the variable orifice becomes contaminated, more flow will be directed through the sheath path, and a reduction in the aerosol flow results. In both cases the aerosol flow and particle concentration will be correctly calculated and displayed based on the actual measured capillary pressure.

Adjustments to the orifice can be made if the flow becomes too high or low.

Caution

Whenever performing service on internal components avoid damage to the UCPC circuitry by not stressing internal wiring, through bumping, snagging, or pulling. Also use electrostatic discharge (ESD) precautions:

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

WARNING

Procedures described below require removal of the instrument cover with the instrument powered. Keep hands away from electronic components to avoid possible electrical shock hazard**.**

1. Read warnings and cautions at the beginning of this chapter.
2. Unplug the instrument and remove the instrument cover by loosening the six side panel screws (they don't have to be fully removed). Lift the cover up. Do **not** remove the screws holding the clear butanol reservoir cover.
3. With the cover removed, locate the small sheath air variable orifice, item number 9 in Figure 3-5. The variable orifice has a screw that is adjustable with a flat-blade screwdriver.
4. Remove the bulk of the red material used to prevent the screw on the variable orifice from turning due to vibration.
5. Because the instrument is powered, pay special attention to the caution and warning above.
6. Using a flat-blade screwdriver adjust the orifice screw while watching the instrument Aerosol Flow value on the Status screen.
7. Adjust to the desired value of 50 cc/min.

Bypass/Makeup Air Flow Adjustment

Refer to the flow schematic in Figure 5-1.

High inlet flow is adjustable using the bypass/makeup air variable orifice. The bypass/makeup air is nominally 1.2 L/min. Together with nominally 0.3 L/min sensor flow, 1.5 L/min inlet sample flow is produced.

To make adjustments to the bypass/makeup air flow, you must have a suitable flowmeter as a reference. Choose an external flowmeter that has a low pressure drop and measure the actual volumetric flow e.g., a *bubble meter or a TSI flowmeter*. If you use a mass flowmeter (one referenced to standard conditions), convert the standard flow to actual (volumetric) flow with the following equation:

$$\text{Actual flow}\,(cm^3/s) = \text{std flow}\,(scm^3/s) \times \left(\frac{T}{293} \times \frac{101.35}{P}\right)$$

where T = °K
P = kPa

Inlet flow in the high flow mode may be reduced if the bypass filter is loaded. The bypass filter is shown in Figure 8-3. Prior to adjusting the bypass/makeup air variable orifice, replace the bypass filter. To adjust the bypass/makeup air flow, perform the following operations.

C a u t i o n

Whenever performing service on internal components avoid damage to the UCPC circuitry by not stressing internal wiring, through bumping, snagging, or pulling. Also use electrostatic discharge (ESD) precautions:

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

W A R N I N G

Procedures described below require removal of the instrument cover with the instrument powered. Keep hands away from electronic components to avoid possible electrical shock hazard.

1. Read warnings and cautions at the beginning of this chapter.

2. Unplug the instrument and remove the instrument cover by loosening the six side panel screws (they don't have to be fully removed). Lift the cover up. Do **not** remove the screws holding the clear butanol reservoir cover.

3. With the cover removed, locate the small bypass/makeup variable orifice, item number 10 in Figure 3-5. This orifice has a screw adjustment for a flat blade screwdriver.

4. Remove the bulk of the red material used to prevent the screw on the variable orifice from turning due to vibration.

5. Because the instrument is powered, pay special attention to the caution and warning above.

6. Using a flat blade screwdriver, adjust the orifice screw while monitoring the flow using your flowmeter.

7. Adjust the flow to the desired value.

Maintenance of the Critical Orifice

If the differential pressure across the Nozzle decreases significantly from its initial value, a low aerosol flow may be indicated on the front panel display, meaning a possible contaminated or plugged critical orifice (see note next page). The initial value of nozzle pressure is found on the checkout data sheet supplied with the instrument. Current nozzle differential pressure and orifice differential pressure are both displayed on the Status screen shown in Figure 4-9, Chapter 4. Note that the orifice differential pressure can indicate there is sufficient vacuum pressure even when the orifice itself is clogged because the vacuum pump may pull less air flow through the sensor.

A plugged orifice is best determined by measuring the inlet flow while the instrument is in the low flow operation mode. Inlet flow measurement is made using a volumetric flowmeter capable of accurately measuring 0.3 L/min flow. A "bubble meter" or a TSI flowmeter is an accurate meter for this purpose. Connect the flowmeter to the instrument inlet and operate the instrument in the low flow operation mode. Orifice replacement or cleaning is not necessary if your UCPC flow rate is measured about 0.3 L/min. If a low inlet flow is observed using the flowmeter, maintenance of the orifice is recommended.

***Note**: Low nozzle pressure can indicate other problems too, such as plugged nozzle pressure tubing. This can occur if butanol collects in the tubing. Butanol in the nozzle pressure tubing may indicate a more serious flooding problem. Contact TSI service personnel if this problem occurs. A leak in the pump sampling tubing or diminished pump performance will also cause reduced flow through the critical flow orifice and lowered nozzle pressure. This will be accompanied by a reduced orifice pressure as well as nozzle pressure reduction. Reference the discussion in Chapter 5, "Technical Description," on critical flow for a better understanding of UCPC flow.*

To remove the critical orifice for cleaning or replacement, use the following instructions.

1. Read warnings and cautions at the beginning of this chapter.
2. Unplug the instrument and remove the instrument cover by loosening the six side panel screws (they don't have to be fully removed). Lift the cover up. Do **not** remove the screws holding the clear butanol reservoir cover.
3. Identify the stainless steel barbed orifice fitting from Figure 8-12 indicated by the arrow.
4. When performing any operations within the cabinet, take great care to avoid stressing any electrical wiring. Damage to this

wiring may necessitate the return of the instrument to the factory for repair.

5. Carefully separate the clear tubing from the orifice barb, prying carefully between the end of the tube and fitting with a flat blade screwdriver to facilitate tubing removal

6. Use a $\frac{7}{16}$" socket wrench or nut driver to remove the fitting.

7. Clean or replace the fitting. Cleaning may require the use of an ultrasonic bath or use of appropriate solvent depending upon source of contamination. The orifice fitting is constructed of 316 SS with an imbedded Sapphire orifice. Orifice replacement (one orifice supplied) may be required if the blockage cannot be removed.

Note: *TSI replacement orifices have excellent repeatability, and calibration is unnecessary to maintain the basic instrument flow specification when an orifice is replaced.*

8. Apply thread sealing tape or compound and re-install the orifice.

9. Reconnect the plastic tubing.

10. Verify flow as described earlier.

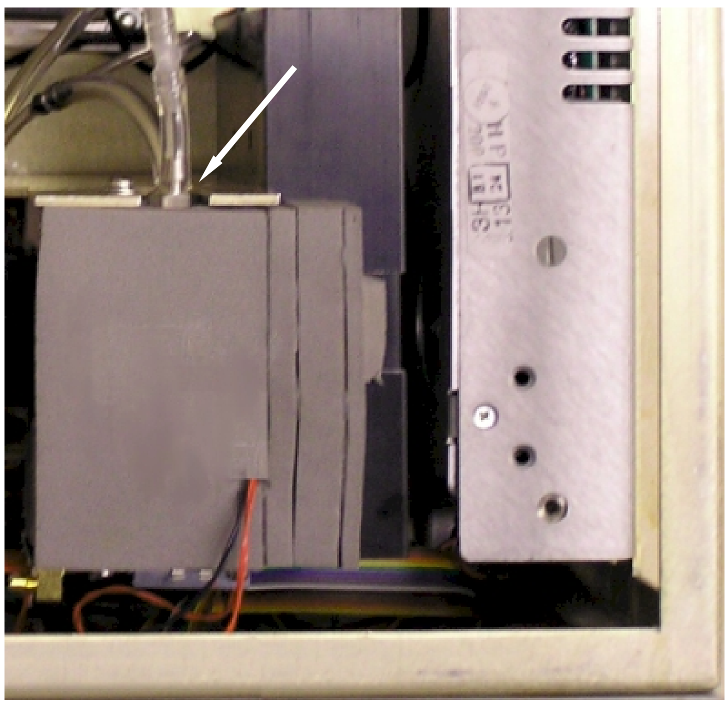


Figure 8-12
Top View of Instrument Showing Critical Orifice in Optics Block

Installation of an External Vacuum Pump

It is possible to use an external pump with your UCPC. The pump must provide sufficient vacuum to maintain a critical pressure across the sensor flow critical orifice and bypass/makeup air variable orifice, while providing adequate inlet flow for instrument operation.

The external vacuum pump must maintain at least 50 kPa (15 in. Hg) of vacuum pressure at 100 kPa (1 standard atmosphere) to achieve critical flow of 1.5 L/min volumetric flow at the inlet. If multiple CPCs are connected to the same pump, the inlet flow specification must be increased accordingly.

Install an external vacuum pump by following the instructions below:

1. Read warnings and cautions at the beginning of this chapter.
2. Unplug the instrument and remove the instrument cover by loosening the six side panel screws (they do not have to be fully removed). Do **not** remove the screws holding the clear butanol reservoir cover. Lift the cover up.
3. Locate the top of the internal vacuum pump shown in Figure 8-13.
4. Disconnect tubing from the barbed fittings identified by arrows in Figure 8-13.

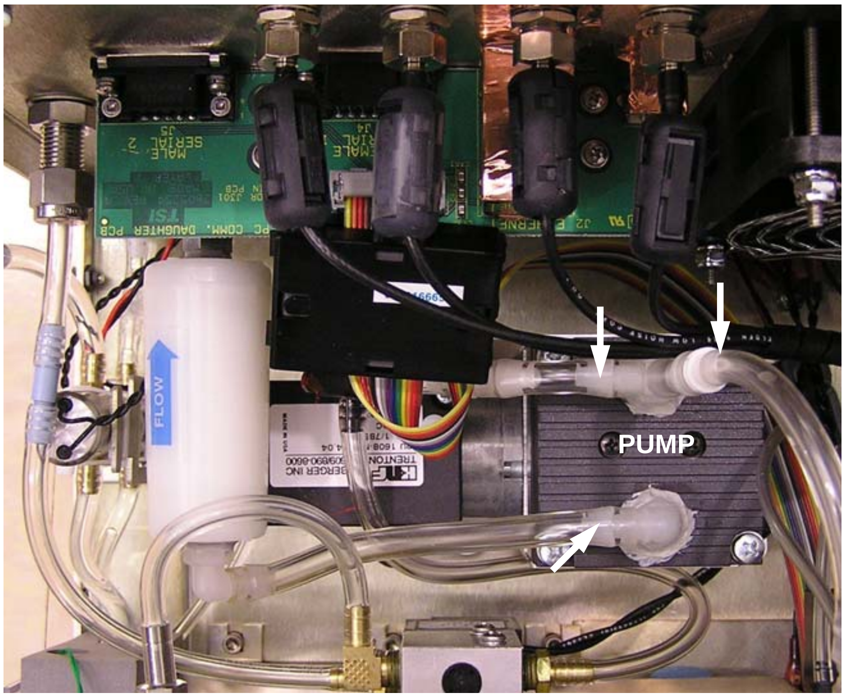


Figure 8-13
Top View of Instrument Showing Pump Top and Pump Inlet and Exhaust Fittings and Tubing

5. Use a polyethylene tee having $^{3}/_{16}$" tube barbs to connect the tubes as shown in Figure 8-14.
6. Connect your external vacuum pump to the **Makeup** air fitting at the back of the UCPC using plastic tubing capable of providing high vacuum without collapsing under the vacuum load.
7. Replace the cover and tighten the cover screws.
8. When operating the instrument, turn the internal vacuum pump off.

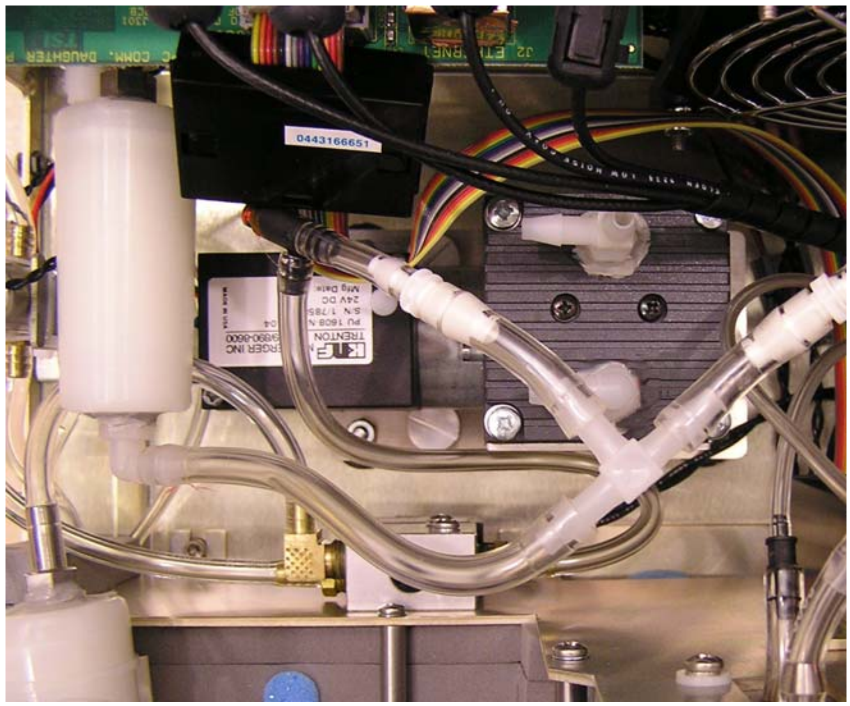


Figure 8-14
View of Instrument Interior Showing Tee Connection for External Pump

False Count Check

If you find that the UCPC is continually counting a lot of particles even with a high efficiency (HEPA or ULPA) filter on the inlet, the UCPC may have developed a leak or the aerosol flow path may have become contaminated with butanol.

To eliminate the possibility of butanol contamination, follow the directions in the following section for "Flooded Instrument." If the false count problem continues, it is most likely due to a leak. Contact TSI for assistance.

Error Messages and Troubleshooting

The table below provides basic information on the errors generated by the Model 3776 UCPC, and suggestions for corrective action.

When an error occurs, the status bar at the top of the screen turns red and the error is displayed e.g., "Saturator temp out of range". When multiple errors are present "Multiple Errors" is indicated. To help determine the type of errors, refer to the Status Screen (see Figure 4-9). The number presented in the right column appears red if out of range. Refer to Table 8-3 to help in identifying the problem.

When the pump is turned off in User Settings (Figure 4-5), the error bar turns yellow and "Pump off" is indicated.

When called upon to remove the cover for service in the troubleshooting table, follow instructions below:

1. Read warnings and cautions at the beginning of this chapter.
2. Unplug the instrument and remove the instrument cover by loosening the six side panel screws (they don't have to be fully removed). Lift the cover up. Do **not** remove the screws holding the clear butanol reservoir cover.

Table 8-3
Troubleshooting

Problem	Description	Problems/Suggestions
Status: Concentration out of range	Concentration exceeds the specification of 3×10^5 particles/cm^3.	Concentration entering the UCPC is too high. Dilute the aerosol before it enters the UCPC; calibrate the UCPC against an aerosol concentration standard such as an aerosol electrometer for the range between 3×10^5 and 10^6 particles/cm^3 for the UCPC to be used up to 10^6 particles/cm^3.
Status: Saturator temp out of range	Saturator temperature out of range ~±0.5 degree C.	Warm up is not complete, instrument is operating in an environment outside its specified operating range (10 to 35°C), or instrument was removed recently from a temperature extreme. Place instrument in an appropriate environment, allow temperature to stabilize.
Status: Condenser temp out of range	Condenser temperature out of range ~±0.5 degree C.	Warm up is not complete, instrument is operating in an environment outside its specified operating range (10 to 35°C), instrument was removed recently from a temperature extreme, or fan flow is impaired. Place instrument in an appropriate environment, allow temperature to stabilize. Clean or replace fan filter, remove object blocking fan flow.

Problem	Description	Problems/Suggestions
Status: Optics temp out of range	Optics temperature out of range ±2 degrees C	Warm up is not complete, instrument is operating in an environment outside its specified operating range (10 to 35 °C), or instrument was removed recently from a temperature extreme. Place instrument in appropriate environment, allow temperature to stabilize.
Status: Inlet flow out of range	The pump is turned off.	Turn the pump on.
Status: Aerosol flow out of range	The aerosol capillary flow is out of range. This error is triggered if the capillary flow is below 30 cm^3/min or above 70 cm^3/min.	Immediately remove any blockages at the instrument inlet. From the Status Screen (Figure 4-9) check the Pressures (kPa). If **N:** is <1 or >6, the nozzle pressure is out of range and is displayed as red in the Status Screen. If the orifice pressure **O:** is <10 or >90, the orifice pressure is out of range and is displayed as red in the Status Screen. Refer to the earlier section, "Maintenance of the Critical Orifice" and confirm that you have appropriate inlet flow using a flowmeter. If the aerosol flow (with inlet flow in low flow mode – 0.3 L/min) is incorrect, check to make sure the pump is operating, listen for pump noise. Remove the instrument cover following warnings and cautions presented at the beginning of this chapter. Check for loose or disconnected tubing from the pump. Check for disconnected pressure tubes to the pressure transducers. Check for signs of liquid in the pressure lines. This will defeat the pressure readings and may indicate a flooded instrument (see below).
Flooded instrument	Butanol liquid is present in the instrument optics causing a variety of problems including erratic or very low concentration readings, changes in aerosol flow rate, and/or changes in transducer pressure measurements.	Although the 3776 UCPC has been designed to resist flooding, it can occur if the instrument is shipped without properly drying or removing a wet wick. Flooding can also occur if the inlet is blocked or the instrument is tipped during operation. Once the instrument cover is removed, evidence of flooding is seen by examining air tubing for the presence of liquid. Start by looking at tubing downstream of an optics. Carefully **remove** and dry out wet tubing then replace. ***Note****: Don't dry the tubing in place to avoid damaging other parts in the UCPC.* If flooding has occurred, it will be necessary to dry the optics block.* Begin by draining the butanol and removing the wick as described earlier. Replace the reservoir cover without replacing the wick. Turn the instrument on and make sure the pump is on. Allow the instrument to operate for at least 24 hours.
Status: Laser power low	Detector in the laser indicates low laser power.	Contact a TSI service technician.

Problem	Description	Problems/Suggestions
Status: Liquid level low	Liquid level sensor in the reservoir does not detect the presence of butanol.	Verify that no liquid is present in the reservoir by looking through the reservoir window. If no liquid level line is seen, check carefully to confirm that it is not overfilled, indicating a problem in the butanol level detection circuitry. Add butanol to the fill bottle and connect the bottle at the quick connect fitting. Make sure the Auto Fill Enable is selected ON in the User Settings menu (Figure 4-5). Watch the reservoir to confirm that it fills then stops. If filling does not occur, the fill filter may need to be replaced. Refer to "Changing the Filters" presented earlier.

*Flooding can contaminate the lens surfaces in the optics block reducing signal strength and instrument sensitivity. Lens cleaning is performed at the factory if flooding occurs. A noticeable change in instrument performance characteristics (e.g., lowered detected concentration) can indicate the need to return the instrument to TSI for maintenance.

Technical Contacts

- If you have any difficulty installing the UCPC, or if you have technical or application questions about this instrument, contact an applications engineer at TSI Incorporated, (651) 490-2811.
- If the UCPC fails, or if you are returning it for service, visit our website at http://rma.tsi.com or contact TSI at:

TSI Incorporated
500 Cardigan Road
Shoreview, MN 55126 USA
Phone: 1-800-874-2811 (USA) or 001 (651) 490-2811
E-mail: technical.service@tsi.com
Website: http://service.tsi.com

Returning the UCPC for Service

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

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

TSI recommends that you keep the original packaging (carton and foam inserts) of the CPC for use whenever the CPC is shipped, including when it is returned to TSI for service. Always seal off the sampling inlet to prevent debris from entering the instrument and drain and dry the CPC before shipping. If you no longer have the original packing material, first protect the CPC by placing it inside a plastic bag. Then package the unit with at least 5" (13 cm) of shock absorbing/packaging material around all six sides of the CPC. The packaging material must be sufficient to completely protect the integrity of the CPC when dropped from a height of 30 inches (76 cm). See "Moving and Shipping the CPC" in Chapter 4 for detailed instructions.

APPENDIX A

Specifications

Table A-1 contains the operating specifications for the Model 3776 Ultrafine Condensation Particle Counter (UCPC). These specifications are subject to change without notice.

Table A-1
Model 3776 CPC Specifications

Particle size range	
Min. detectable particle (D_{50}) .	2.5 nm, verified with DMA-classified sucrose particles
Max. detectable particle	>3 µm
Particle concentration range..	0 to 3 × 10^5 particles/cm^3, single particle counting with continuous, live-time coincidence correction; display concentrations up to 10^6 particles/cm^3 (custom calibration versus concentration reference needed for concentrations higher than 3×10^5 particles/cm^3)
Particle concentration accuracy	±10% at <3 × 10^5 particles/cm^3
Response time	
High flow mode	<0.8 sec to 95% in response to concentration step change
Low flow mode	<5 sec to 95% in response to concentration step change
Flow rate	
Aerosol	50 ± 5 cm^3/min (0.05 ± 0.005 L/min)
Sensor flow	300 ± 15 cm^3/min (0.3 ± 0.015 L/min)
Inlet, high-flow	1500 ± 50 cm^3/min (1.5 ± 0.05 L/min)
Inlet, low-flow	300 ± 15 cm^3/min (0.3 ± 0.015 L/min)
Flow source..........................	Internal high vacuum diaphragm pump with brushless DC motor (15,000 hours rated lifetime); option to use external vacuum source (requires change to internal plumbing)
Flow control	Volumetric flow control of sensor flow by critical orifice, aerosol flow is monitored through differential pressure across capillary
Operating temperatures	
Saturator	39°C ±0.2°C
Condenser	10°C ±0.2°C
Optics	40°C ±0.2°C
False background counts	<0.01 particle/cm^3, based on 12-hr average; No false counts incurred during butanol fill
Aerosol medium	Recommended for use with air; safe for use with inert gases such as nitrogen, argon, and helium (performance specifications are for air)

Table A-1
Model 3776 CPC Specifications

Environmental operating conditions	Indoor use
	Altitude up to 2000 m (6500 ft)
	Inlet pressure 75 to 105 kPa (0.75 to 1.05 atm)
	Operating temperature range 10 to 35°C
	Safe temperature range 5 to 40°C
	Storage temperature range -20 to 50°C
	Ambient humidity 0–90% RH noncondensing
	Pollution degree II
	Overvoltage degree II
Condensing liquid	
Working fluid	Reagent-grade n-butyl alcohol (butanol, not included)
Filling system	Electronic liquid-level sensor initiates automatic filling as needed, requires connection to fill bottle
Water removal	All condensate is collected and removed automatically by a constant-flow-rate micropump, may be switched on for use in humid environments
Communications	
Protocol	Command set based on ASCII characters
Interface	RS-232, 9-pin, “D” subminiature connector, pinouts compatible with standard IBM-style serial cables and interfaces
	USB, type B connector, USB 2.0 compatible at 12 MB
	Ethernet, 8-wire RJ-45 jack, 10/100 BASE-T, TCP/IP
Data Logging and Storage	SD/MMC flash memory card
Averaging interval	1, 2, 3, 4, 5, 6, 10, 12, 15, 20, 30, or 60 seconds (set from front panel), software provides more averaging options
Inputs	
Analog	Two BNC connectors, 0 to 10 volts (data recording for external sensors)
Outputs	
Digital display	Graph of concentration vs. time, concentration, time and total counts, status (temperatures, pressures, laser power, aerosol flow, etc.), and user settings
Analog	BNC connector, 0 to 10 volts, user-selectable function output (linear or log concentration or DMA voltage control)
Pulse	BNC connector, TTL level pulse, 50-ohm termination, nominally 400 nanoseconds wide
Software	Aerosol Instrument Manager® software (RS-232 and USB compatible)
Calibration	Recommended annually
Power requirements	100 to 240 VAC, 50/60 Hz., 335 W maximum

Table A-1
Model 3776 CPC Specifications

Physical features	
Front panel	LCD TFT QVGA (320 ×240 pixel) 5.7-inch color display, aerosol inlet, LED particle indicator light, rotate/select control knob, flash memory card slot
Back panel	Power connector, USB, Ethernet, two 9-pin D-sub serial connectors, two BNC inputs, two BNC outputs, fan, butanol-fill connector, butanol-drain connector, makeup-air port, pump-exhaust port, fill bottle and bracket
Back panel	Butanol-level viewing window
Dimensions (HWD) (nominal)	25 cm × 32 cm × 37 cm (10 in. × 13 in. × 15 in.), not including fill bottle and bracket
Weight	9.9 kg (22 lb)
Fuse	2-~ F 6.3A FB/250V (internal—not replaceable by operator)

APPENDIX B

Firmware Commands

The firmware commands are be divided into the following categories:

- READ Commands
- SET Commands
- MISC (MISCELLANEOUS) Commands
- HELP Commands

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

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

MISC (MISCELLANEOUS) commands will be used for calibration and SMPS mostly.

HELP commands. Type "HELP" in a HyperTerminal window or a similar program and it will explain how to use it. All the command descriptions that follow can be obtained using the help command.

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

READ Commands

RFV Read the firmware version number

Returns: A string in the format of X.X.X where X are numbers from 0–9

Example: 2.3.1

RSF Read the aerosol flow rate in cc/min

Returns: A floating point number from 0.0 to 9999.9

Example: 50.0

RIF Read the inlet flow rate setting in liters per minute

Returns: A floating point number from 0.0 to 9999.9

Example: 0.3

RTS Read the saturator temperature in degrees Celsius

Returns: A floating point number from 0.0 to 50.0

Example: 39.0

RTC Read the condenser temperature in degrees Celsius

Returns: A floating point number from 0.0 to 50.0

Example: 10.0

RTO Read the optics temperature in degrees Celsius

Returns: A floating point number from 0.0 to 50.0

Example: 40.0

RTA Read the cabinet temperature in degrees Celsius

Returns A floating point number from 0.0 to 50.0

Example 23.8

RCT Read the current time

Returns: Www Mmm dd hh:mm:ss yyyy
where
Www is the weekday
Mmm is the month in letters
dd is the day of the month
hh:mm:ss is the time
yyyy is the year

Example: Mon Jun 11 11:05:08 2006

RIE Read the instrument errors

Returns: 16-bit integer in hexadecimal format.
The parameter is in error if the bit is set.
Bit 0x0001 => Saturator Temp
Bit 0x0002 => Condenser Temp
Bit 0x0004 => Optics Temp
Bit 0x0008 => Inlet Flow Rate
Bit 0x0010 => Aerosol Flow Rate
Bit 0x0020 => Laser Power
Bit 0x0040 => Liquid Level
Bit 0x0080 => Concentration
Bit 0x0100 => Unused
Bit 0x0200 => Unused
Bit 0x0400 => Unused
Bit 0x0800 => Unused
Bit 0x1000 => Unused
Bit 0x2000 => Unused
Bit 0x4000 => Unused
Bit 0x8000 => Unused

RPA Read the absolute pressure transducer in kPa

Returns: A floating point number from 15.0 to 115.0

Example: 100.1

RPO Read the orifice pressure transducer. Units are in kPa

Returns: A floating point number from 0.0 to 99.9

Example: 50.8

RPN Read the nozzle pressure transducer. Units are in kPa

Returns: A floating point number from 0.000 to 10.000

Example: 2.50

RPS Read the aerosol pressure transducer (3776 only)
Units are in inches of water

Returns: A floating point number from 0.000 to 1.000

Example: 0.746

RSN Read the serial number

Returns: A string of up to 20 characters

Example: 70514396

RAI Read the analog input voltages

Returns: X,Y where X is analog input 1 and Y is analog input 2.
X and Y are floating point numbers from 0.00 to 10.00

Example: 5.22,3.65

RLP Reads the laser current in milliamps

Returns: An integer from 0 to 150

Example: 61

RLL Reads the liquid level

Returns: FULL or NOTFULL and the corresponding ADC reading. The ADC reading is an integer from 0 to 4095

Example: FULL (2471)

RMN Read the model number

Returns: An integer from 3771 to 3776

Example: 3776

R0 Legacy command to read the liquid level

Returns: FULL or NOTFULL

R1 Legacy command to read the condenser temperature in degrees Celsius

R2 Legacy command to read the saturator temperature in degrees Celsius

R3 Legacy command to read the optics temperature in degrees Celsius

R5 Legacy command to read the instrument status.

Returns: READY or NOTREADY

R7 Legacy command to read the photometric voltage (3775 only)

Returns: 0.000–2.500 volts

Example: 2.013

RD Legacy command to read the concentration in p/cc

RV Read the version string.

Returns: Model 377x Ver B.B.B S/N AAAAAAAA

SET Commands

SSTART Start a new sample

Params: 0 – Stop
1 - Start

Example: SSTART,1 (starts a new sample)

This command will return every second

UX,D,D,D,D,D,D,D,D,D,D,C,C,C,C,C,C,C,C,C,C,AN1,AN2,RIE

UX => integer that counts the elapse time

D => integers of the tenth second counts from the last second

C => floating point numbers of the tenth second concentration

AN1 => floating point number of analog input 1

AN2 => floating point number of analog input 2

RIE => See the help command for RIE

SCM Set the operating mode

Params: 0 => Concentration
1 => Totalizer
2 => SMPS

Example: SCM,0 (sets operating mode to concentration)

STS Set saturator temperature

Params: c => 0.0–50.0

Example: STS,39.0 (changes the saturator set point to 39.0 degrees C)

STC Set condenser temperature

Params: c => 0.0–50.0

Example: STC,10.0 (changes the condenser set point to 10.0 degrees C)

STO Set optics temperature

Params: c => 0.0–50.0

Example: STO,40.0 (changes the optics set point to 40.0 degrees C)

SAWR Set the auto water removal function on/off

Params: 0–Off
1–On

Example: SAWR,1 (turns on water removal)

SVO Set analog output voltage

Params: v => 0.000–10.000

Example: SVO,4.482 (sets the output voltage at 4.482 volts)

SCOM Setup auxiliary comport

Params: Port => 2
Baud => 2400,4800,9600,14400,19200,28800,38400,57600,115200
Bits => 6,7,8
Parity => E, O, N
Stop => 1, 1.5, 2

Example: SCOM,2,9600,7,E,1 (sets the second serial port to 9600, Even Parity, 1 Stop bit)

SHOUR Set the Real Time Clock Hours (24 hour mode)

Params: hour => 0–23

Example: SHOUR,13 (sets the hour to 13)

SMINUTE Set the Real Time Clock Minutes

Params: min => 0–59

Example: SMINUTE,45 (sets minutes to 45)

SSECOND Set the Real Time Clock Seconds

Params: sec => 0–59

Example: SSECOND,0 (sets seconds to zero)

SYEAR Set the Real Time Clock Year

Params: year => 0–99

Example: SYEAR,6 (sets the year to 2006)

SDAY Set the Real Time Clock Day of the Month

Params: day => 1–31

Example: SDAY,23 (sets the day to the 23rd of the month)

SMONTH Set the Real Time Clock current Month

Params: month => 1–12

Example: SMONTH,2 (sets the month to February)

S3776FLOW

Set the 3776 flow calibration parameters (3776 only)

Params: A => Floating point number
B => Floating point number
where flow rate = A * (sample pressure) + B

Example: S3776FLOW,2.58e-2,8.37e1

SFILL Turn on/off auto fill

Params: 0 => Off
1 => On

Example: SFILL,1 (turns on auto fill)

SDRAIN Turn drain on/off (3771 only)

Params: 0 => Off
1 => On

Example: SDRAIN,1 (turns drain on)

SCC Turn coincidence correction on/off (3772 and 3771 only)

Params: 0 => Off
1 => On

Example: SCC,1 (turns coincidence correction on)

SAF Set the 3775 aerosol flow rate in cc/min (3775 only)

Params: Q => 200–400 cc/min

Example: SAF,300 (changes the aerosol flow rate to 300 cc/min)

MISC (MISCELLANEOUS)

ZB Begin SMPS scan based on the ZT, ZV and ZU parameters (except 3771)

ZE End SMPS scan (except 3771)

ZT Set the scan time in tenth second increments (except 3771)

Params:	delay	=> 0–255 (0–25.5 seconds)
	up	=> 10–6000 (1–600 seconds)
	down	=> 10–6000 (1–600 seconds)

Example: ZT0,600,100

Note: *This command does not need a comma separating the first parameter from the command*

ZU Scan using up direction instead of down (except 3771)

ZV Set the scan voltages (except 3771)

Params:	start	=> 10–10000 Volts
	end	=> 10–10000 Volts

Example: ZV10,10000

Note: *This command does not need a comma separating the first parameter from the command*

COM2 Data after the ":" will be transmitted to serial port 2

Example: COM2:RFV ("RFV" will be transmitted to com port 2)

X2 Legacy command to turn the pump off

X3 Legacy command to turn the pump on

X7 Legacy command to set the inlet flow to 0.3 L/min (3775 and 3776 only)

X8 Legacy command to set the inlet flow to 1.5 L/min (3775 and 3776 only)

D Legacy command to read accumulative time (sec) and accumulative counts since the last time this command was sent.

DEL Delete Flash File, path\filename (except 3771)

FORMAT Format the flash drive. This will also erase all the data stored on the drive (except 3771).

DIR Read the flash card directory (except 3771)

CD Change the active flash card directory (except 3771)

CAL3775 Set the 3775 Photometric calibration table (3775 only).

Format: CAL3775,x,y

Where x => photometric voltage * 100 in volts
y => concentration in p/cc

Example: CAL3775,101,2.03e5 (a photometric voltage of 1.01 V will result in a concentration of 2.03e5 p/cc)

HELP Commands

Help,Read

Help,Set

Help,Misc

Help,x where x=Command Name

APPENDIX C
References

The following sources have been used in the text of this manual.

Agarwal, J.K. and G.J. Sem [1980]
"Continuous Flow Single-Particle-Counting Condensation Nuclei Counter"
J. Aerosol Sci., Vol. **11**, No. 4, pp. 343–357

Aitken, J. [1888]
"On the Number of Dust Particles in the Atmosphere"
Proc. Royal Soc. Edinburgh, **35**

Aitken, J. [1890-1891]
"On a Simple Pocket Dust Counter"
Proc. Royal Soc. Edinburgh, Vol. XVIII

Bradbury, N.E. and H.J. Meuron [1938]
'The Diurnal Variation of Atmospheric Condensation Nuclei"
Terr. Magn., **43**, pp. 231–240

Bricard, J., P. Delattre, G. Madelaine, and M. Pourprix [1976]
"Detection of Ultrafine Particles by Means of a Continuous Flux Condensation Nucleus Counter"
in *Fine Particles*, B.Y.H. Liu, ed., Academic Press, New York, pp. 565-580

Caldow, R. and P.B. Keady [1990]
"Performance of an Ultrafine Condensation Particle Counter."
Aerosols Science, Industry, Health and Environment - Proceedings of the 3rd International Aerosol Conference, Kyoto Japan, (S. Masuda and K. Takahashi, ed.) 1, 503-506

Hogan, A.W. [1979]
"Aerosol Detection by Condensation Nucleus Counting Techniques"
in *Aerosol Measurement*, D.A. Lundgren, ed., Univ. Presses of Florida, Gainesville, Florida, pp. 497–514

Keady, P.B., F.R. Quant and G.J. Sem [1986]
"'A Condensation Nucleus Counter for Clean Rooms"
Proc. Institute of Environmental Sci., Annual Technical Mtg, pp. 445-451

Keady, P.B., F.R. Quant and G.J. Sem [1988]
Two New Condensation Particle Counters: Design and Performance
Presented as a poster at the AAAR Annual Meeting, Chapel Hill, NC, U.S.A.

Keady, P.B., V.L. Denler, G.J. Sem [1988]
A Condensation Nucleus Counter Designed for Ultrafine Particle Detection Above 3-nm Diameter,
Presented at the 12th International Conference on Atmospheric Aerosols and Nucleation, Vienna, Austria.

Keston, J., Reineking, A. and J. Porstendorfer (1991)
"Calibration of a TSI Model 3025 Ultrafine Condensation Particle Counter." *Aerosol Science and Technology,* **15**, 107-111, 1991 (TSI paper A77).

Kousaka, Y. T. Nida, K. Okuyama and H., Tanaka [1982]
"'Development of a Mixing-Type Condensation Nucleus Counter"
J. Aerosol Sci., Vol. **13**, No. 3, pp. 231–240

Liu, B.Y.H. and D.Y.H. Pui [1974]
"A Submicron Aerosol Standard and the Primary Absolute Calibration of the Condensation Nucleus Counter"
J. Coll. Int. Sci., Vol. **47**, pp. 155–171

Miller, S.W. and B.A. Bodhaine [1982]
"Supersaturation and Expansion Ratios in Condensation Nucleus Counters: an Historical Perspective"
J. Aerosol Sci., Vol. **13**, No. 6, pp. 481–490

Nolan, P.J. and L.W. Pollack [1946]
"The Calibration of a Photoelectric Nucleus Counter"
Proc. Royal Irish Acad., **A9**, pp. 9–31

Nolan, P.J. [1972]
"The Photoelectric Nucleus Counter"
Sci. Proc. Royal Dublin Soc., Series A, Vol. **4**, pp. 161–180

Pollak, L.W. and A.L. Metnieks [1959]
"New Calibration of Photoelectric Nucleus Counters"
Geofis. Pura Appl., Vol. **43**, pp. 285–301

Quant, F. R., R. Caldow, G.J. Sem, T.J. Addison [1992]
"Performance of Condensation Particle Counters with Three Continuous-Flow Designs," presented as a poster paper at the European Aerosol Conference, Oxford England, Sept. 7-11, 1992.

Rich, T.A. [1955]
"A Photoelectric Nucleus Counter with Size Discrimination"
Geofis. Pura Appl., Vol. **31**, pp. 60–65

Scheibel, H.G., and J. Porstendorfer [1983]
"Generation of Monodisperse Ag- and BaCl- Aerosols with Particle Diameters Between 2 and 300 nm. *Journal of Aerosol Science*, **14**, 113-126

Schlichting [1955]
Boundary Layer Theory, 6th ed., McGraw-Hill, New York

Sem, G.J.
"Design and Performance Characteristics of Three Continuous-Flow Condensation Particle Counters: a Summary." *Atmospheric Research* **62**: 267-294, 2002

Sem, G.J., J.K. Agarwal and C.E. McManus [1980]
"New Automated Diffusion Battery/Condensation Nucleus Counter Submicron Sizing System: Description and Comparison with an Electrical Aerosol Analyzer"
Proc. 2nd Symp. Advances in Particulate Sampling and Measurement, U.S. Environ. Protection Agency, Research Triangle Park, North Carolina

Shi, Q, H.S. Han, S.W. Kerrigan, and E.M. Johnson [2005]
"Characterization of Two New Butanol-based Condensation Particle Counters."
Poster #IPC17, American Association for Aerosol Research annual conference, Austin, Texas, October 2005.

Shi, Q, H.S. Han, S.W. Kerrigan, and E.M. Johnson [2005]
"Characterization of A New Butanol-based Ultrafine Condensation Particle Counter,"
Oral presentation #086 at European Aerosol Conference 2005, Ghent, Belgium.

Sinclair, D. and G.S. Hoopes [1975]
"A Continuous Flow Nucleus Counter"
J. Aerosol Sci., Vol. **6**, pp. 1–7

Stolzenburg, M.R., and P. H. McMurry [1991]
"An Ultrafine Aerosol Condensation Nucleus Counter." *Aerosol Science and Technology*, **14**, 48-65, 1991 (TSI paper A82)

Stolzenburg, M.R. [1988]
"An Ultrafine Aerosol Size Distribution Measuring System"
Ph.D. Thesis, University of Minnesota, Minneapolis, Minnesota, July

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Manual Title __Model 3776 Ultrafine Condensation Particle Counter__ P/N __1980522__ Rev __B__

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