CONDENSATION PARTICLE COUNTER MODEL 3772/3771

OPERATION AND SERVICE MANUAL

P/N 1980529, REVISION F
APRIL 2015

Model 3772

Model 3771
(discontinued)

START SEEING THE BENEFITS OF REGISTERING TODAY!

Thank you for your TSI instrument purchase. Occasionally, TSI releases information on software updates, product enhancements and new products. By registering your instrument, TSI will be able to send this important information to you.

http://register.tsi.com

As part of the registration process, you will be asked for your comments on TSI products and services. TSI's customer feedback program gives customers like you a way to tell us how we are doing.

UNDERSTANDING, ACCELERATED

TSI Incorporated - Visit our website **www.tsi.com** for more information.

USA	**Tel:** +1 800 874 2811	**India**	**Tel:** +91 80 67877200
UK	**Tel:** +44 149 4 459200	**China**	**Tel:** +86 10 8219 7688
France	**Tel:** +33 1 41 19 21 99	**Singapore**	**Tel:** +65 6595 6388
Germany	**Tel:** +49 241 523030		

CONDENSATION PARTICLE COUNTER MODEL 3772/3771

OPERATION AND SERVICE MANUAL

Manual History

The following is a history of the Model 3772/3771 Condensation Particle Counter Operation and Service Manual (Part Number 1980529).

Revision	Date
A	February 2006
B	April 2006
C	April 2007
D	December 2009
E	July 2011
F	April 2015

Warranty

Part Number 1980529 / Revision F / April 2015

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

Fax No. 651-490-3824

E-mail Address particle@tsi.com

Limitation of Warranty and Liability
(effective February 2015)

Seller warrants the goods, excluding software, sold hereunder, under normal use and service as described in the operator's manual, to be free from defects in workmanship and material for **12 months**, or if less, 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 and exceptions:

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

b. Pumps are warranted for hours of operation as set forth in product or operator's manuals;

c. 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;

d. Seller does not provide any warranty on finished goods manufactured by others or on any fuses, batteries or other consumable materials. Only the original manufacturer's warranty applies;

e. This warranty does not cover calibration requirements, and seller warrants only that the instrument or product is properly calibrated at the time of its manufacture. Instruments returned for calibration are not covered by this warranty;

f. This warranty is **VOID** if the instrument is opened by anyone other than a factory authorized service center with the one exception where requirements set forth in the manual allow an operator to replace consumables or perform recommended cleaning;

g. This warranty is **VOID** if the product has been misused, neglected, subjected to accidental or intentional damage, or is not properly installed, maintained, or cleaned according to the requirements of the manual. Unless specifically authorized in a separate writing by Seller, Seller makes no warranty with respect to, and shall have no liability in connection with, goods which are incorporated into other products or equipment, or which are modified by any person other than Seller.

The foregoing is **IN LIEU OF** all other warranties and is subject to the **LIMITATIONS** stated herein. **NO OTHER EXPRESS OR IMPLIED WARRANTY OF FITNESS FOR PARTICULAR PURPOSE OR MERCHANTABILITY IS MADE**. **WITH RESPECT TO SELLER'S BREACH OF THE IMPLIED WARRANTY AGAINST INFRINGEMENT, SAID WARRANTY IS LIMITED TO CLAIMS OF DIRECT INFRINGEMENT AND EXCLUDES CLAIMS OF CONTRIBUTORY OR INDUCED INFRINGEMENTS. BUYER'S EXCLUSIVE REMEDY SHALL BE THE RETURN OF THE PURCHASE PRICE DISCOUNTED FOR REASONABLE WEAR AND TEAR OR AT SELLER'S OPTION REPLACEMENT OF THE GOODS WITH NON-INFRINGING GOODS.**

TO THE EXTENT PERMITTED BY LAW, THE EXCLUSIVE REMEDY OF THE USER OR BUYER, AND THE LIMIT OF SELLER'S LIABILITY FOR ANY AND ALL LOSSES, INJURIES, OR DAMAGES CONCERNING THE GOODS (INCLUDING CLAIMS BASED ON CONTRACT, NEGLIGENCE, TORT, STRICT LIABILITY OR OTHERWISE) SHALL BE THE RETURN OF GOODS TO SELLER AND THE REFUND OF THE PURCHASE PRICE, OR, AT THE OPTION OF SELLER, THE REPAIR OR REPLACEMENT OF THE GOODS. IN THE CASE OF SOFTWARE, SELLER WILL REPAIR OR REPLACE DEFECTIVE SOFTWARE OR IF UNABLE TO DO SO, WILL REFUND THE PURCHASE PRICE OF THE SOFTWARE. IN NO EVENT SHALL SELLER BE LIABLE FOR LOST PROFITS, BUSINESS INTERRUPTION, OR ANY SPECIAL, INDIRECT, CONSEQUENTIAL OR INCIDENTAL DAMAGES. SELLER SHALL NOT BE RESPONSIBLE FOR INSTALLATION, DISMANTLING OR REINSTALLATION COSTS OR CHARGES. No Action, regardless of form, may be brought against Seller more than 12 months after a cause of action has accrued. The goods returned under warranty to Seller's factory shall be at Buyer's risk of loss, and will be returned, if at all, at Seller's risk of loss.

Buyer and all users are deemed to have accepted this LIMITATION OF WARRANTY AND LIABILITY, which contains the complete and exclusive limited warranty of Seller. This LIMITATION OF WARRANTY AND LIABILITY may not be amended, modified or its terms waived, except by writing signed by an Officer of Seller.

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.

Trademarks

Safety

This section provides instructions to ensure safe and proper operation and handling of the Model 3772/3771 Condensation Particle Counter (CPC).

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 3772/3771 CPC 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 CPC unless you are specifically told to do so in this manual.
- Do ***not*** remove the CPC housings or covers while power is supplied to the instrument.

W A R N I N G
The use of controls, adjustments, or procedures other than those specified in this manual may result in exposure to hazardous optical radiation.

Chemical Safety

The Model 3772/3771 CPC 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 0.015 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 CPC 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 CPC 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.

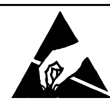
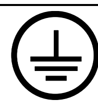
Warning

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.

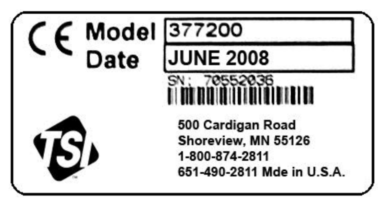
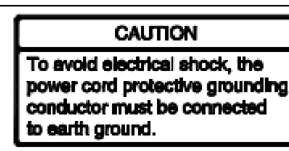
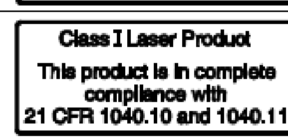
Caution or Warning Symbols

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 CPC housing and to the optics on the inside of the instrument. Labels for the Model 3772/3771 CPC are described below:

1. **Serial Number label** – displayed on the back panel	
2. **Laser Radiation label** – located internally on the optics housing	
3. **Electrical shock caution label** – displayed on back panel	
4. **Laser device compliance label** – displayed on back panel	

5. **Caution label**	
6. **European Recycling Label** – displayed on the back panel (indicates item is non-disposable and must be recycled).	
7. **French language electrical safety and laser compliance labels** – displayed on the back panel	IMPORTANT Pour éviter l'électrocution, le connecteur du câble de masse doit être relié à une prise de terre. Laser de Classe I Ce produit répond aux normes 21 CFR 1040.10 et 1040.11
8. **NRTL TÜV SÜD Mark** – displayed on the back panel. This mark identifies the product as meeting safety regulations in the US, Canada and Europe and further identifies the product as one for which ongoing production is monitored for quality.	
9. **TSI Address and Service Label** – displayed on the back panel	For Service and Information Contact TSI Customer Service www.tsi.com 500 Cardigan Road Shoreview, MN 55126 U.S.A.
10. **Saturator Wick Removal caution label** – displayed on the bottom of the enclosure	CAUTION Pull out inlet tube prior to removing saturator wick

Contents

Figures

Tables

(This page intentionally left blank)

About This Manual

Purpose

This is an operation and service manual for the Model 3772/3771 Condensation Particle Counter (CPC).

Organization

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

- **Chapter 1: Product Overview**
  This chapter gives an introduction to the Model 3772/3771 Condensation Particle Counter, a list of features, and a brief description of how the instrument works.
- **Chapter 2: Unpacking and Setting Up the CPC**
  This chapter gives a packing list and the step-by-step procedure for getting the CPC ready to operate.
- **Chapter 3: Instrument Description**
  This chapter describes features and controls that run the CPC, including the components on the front-panel, back-panel, bottom-panel, cover and inside the instrument. It also covers the basic functions of the instrument.
- **Chapter 4: Instrument Operation**
  This chapter describes the operation of the instruments.
- **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 3772/3771 Condensation Particle Counter.

- **Appendix B: Firmware Commands**
  This appendix lists all the serial commands for communications between the CPC 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 3775 Condensation Particle Counter Operation and Service Manual*** (part number 1980527) TSI Incorporated
- ***Model 3776 Ultrafine Condensation Particle Counter Operation and Service Manual*** (part number 1980522) TSI Incorporated
- ***Model 3783 EPC™ Environmental Particle Counter™ Monitor Operation and Service Manual*** (part number 6003653) 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
- ***Model 3787 General Purpose Water-based Condensation Particle Counter Operation and Service Manual*** (part number 6003712) TSI Incorporated
- ***Model 3788 Nano Water-based Condensation Particle Counter Operation and Service Manual*** (part number 6003713) TSI Incorporated
- ***Model 376060 Particle Size Selector Instruction Manual*** (part number 1930013) TSI Incorporated
  This manual contains operating instructions for the Model 376060 Particle Size Selector, an accessory for the Model 3772, 3771, and 3781 CPCs. The Model 376060 is a separating device that removes small particles from an aerosol while passing larger particles.
- ***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.

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

(This page intentionally left blank)

CHAPTER 1
Product Overview

This chapter contains an introduction to the Model 3772/3771 Condensation Particle Counter (CPC) and provides a brief explanation of how the instrument operates.

Product Description

The Model 3772/3771 Condensation Particle Counter is a compact, rugged, and full-featured instrument that detects airborne particles down to 10 nanometers in diameter at an aerosol flow rate of 1.0 liter per minute, over a concentration range from 0 to 10^4 particles per cubic centimeter. These CPCs are ideally suited for applications that do not require measurement of high concentrations, such as basic aerosol research, filter and air-cleaner testing, particle counter calibration, environmental monitoring, mobile aerosol studies, particle shedding and component testing, and atmospheric and climate studies. The Model 3772 CPC is also compatible with TSI Scanning Mobility Particle Sizer™ (SMPS™) spectrometers for particle size distribution measurements.

The successor to the Model 3010, 3760A, and 3762 CPCs, the Model 3772 and 3771 CPCs offer many new features and improvements:

- Fast response to rapid changes in aerosol concentration ($T_{95} \cong 3$ seconds)
- Butanol-friendly features, including anti-spill design, water-removal system, and improved resistance to optics flooding
- Removable saturator wick for easy transport and maintenance
- USB and Ethernet available
- Auto recovery from power failure

The Model 3772 CPC offers the following additional features:

- Built-in SMPS™ spectrometer compatibility
- Particle concentration, total counts, instrument status or user settings shown on enhanced front panel LCD display
- Built-in data logging and storage capability with removable memory card

Figure 1-1
Model 3772 Condensation Particle Counter

Figure 1-2
Model 3771 Condensation Particle Counter
(discontinued)

How it Works

In the Model 3772/3771 Condensation Particle Counter (CPC), an aerosol sample is drawn continuously through a heated saturator in which butanol is vaporized and diffuses into the sample 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 3772/3771 CPC detects particles as small as 10 nanometer in diameter and employs single-particle-count-mode operation to measure concentrations up to 10^4 particles per cubic centimeter. The detector counts individual pulses produced as each particle (droplet) passes through the sensing zone. A high signal-to-noise ratio and continuous, live-time coincidence correction provide great measurement accuracy, even at very low concentrations. An external vacuum pump is required to draw the aerosol sample into the CPC. The 1.0 L/min aerosol flow rate is controlled accurately and reliably using an internal critical orifice.

The CPCs use 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.

Model 3772 CPC has a two-line LCD display which presents real-time number concentration, totalizer function, and enables easy-to-use menus for control operation functions and presents instrument status information and user settings. A variety of communication options for computer data acquisition are available. The 3772 CPC also includes on-board data logging and storage using a removable flash memory card. Model 3771 has no display and no memory card.

(This page intentionally left blank)

CHAPTER 2

Unpacking and Setting up the CPC

Use the information in this chapter to unpack the Model 3772/3771 Condensation Particle Counter (CPC) and set it up.

Packing List

Tables 2-1 and 2-2 show the components shipped with the Model 3772 and 3771 CPCs.

Table 2-1
Model 3772 CPC Packing List

Qty.	Description	Model/ Part Number
1	Model 3772 CPC and Operation Manual	1980529
1	Power cable	(based on destination)
1	Aerosol Instrument Manager® Software	390065
1	Fill Bottle	1035590
1	Drain Bottle	1035591
1	Bottle Bracket	1503475
1	Vacuum Drain Bottle Cap	1031526
1	RS-232 Cable (A-pin M/F, 12 ft)	962002
1	USB I/O Cable A/B 6 ft	1303740
1	SanDisk ImageMate 5-in-1 Card Reader	1500208
1	Data Memory Card	1500108
1	Saturator Wick CPC 3772	1600047
2	Water Removal Filter Inline, 25 micron 1⁄16" barb	1500192
3	Butanol Fill/Drain Filter Inline, 73 micron 1⁄8" barb	1602088
2	Saturator Base O-Ring FVMQ 1-010	2500021
1	Saturator Base O-Ring FVMQ 1-030	2501172
2	Saturator Base O-Ring EPDM 1-027	2501569
1	Krytox® O-ring Grease	1701154
1	Checkout Data Sheet	N/A
1	Certificate of Conformance	N/A

Krytox® is a registered trademark of DuPont.

Table 2-2
Model 3771 CPC Packing List

Qty.	Description	Model/ Part Number
1	Model 3771 CPC and Operation Manual	1980529
1	Power cable	(based on destination)
1	Aerosol Instrument Manager® Software	390065
1	Fill Bottle	1035590
1	Drain Bottle	1035591
1	Bottle Bracket	1503475
1	Vacuum Drain Bottle Cap	1031526
1	RS-232 Cable (A-pin M/F, 12 ft)	962002
1	USB I/O Cable A/B 6 ft	1303740
1	Saturator Wick CPC 3771	1600047
2	Water Removal Filter Inline, 25 micron 1⁄16" barb	1500192
3	Butanol Fill/Drain Filter Inline, 73 micron 1⁄8" barb	1602088
2	Saturator Base O-Ring FVMQ 1-010	2500021
1	Saturator Base O-Ring FVMQ 1-030	2501172
2	Saturator Base O-Ring EPDM 1-027	2501569
1	Krytox® O-ring Grease	1701154
1	Checkout Data Sheet	N/A
1	Certificate of Conformance	N/A

Note: *Some items in the lists 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 3772/3771 CPC comes fully assembled with protective coverings on the inlet sample port, exit ports, and analog connectors. The CPC comes packaged with the accessory kit. Use the packing list (Table 2-1 or Table 2-2) to make certain that there are no missing components.

The CPC box contains special foam cutouts designed to protect the instrument during shipment. Save the original packaging materials for future use should you need to ship the instrument or return the instrument to TSI for service. Also keep the protective coverings for ports for shipping.

To avoid contaminating the instrument or the environment the CPC 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 CPC to TSI Incorporated.

Setting Up

This section contains instructions for setting up the Model 3772/3771 CPC. 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.

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 on the back panel and place the bottle in the bracket. Both mated fittings are leak-tight when disconnected.

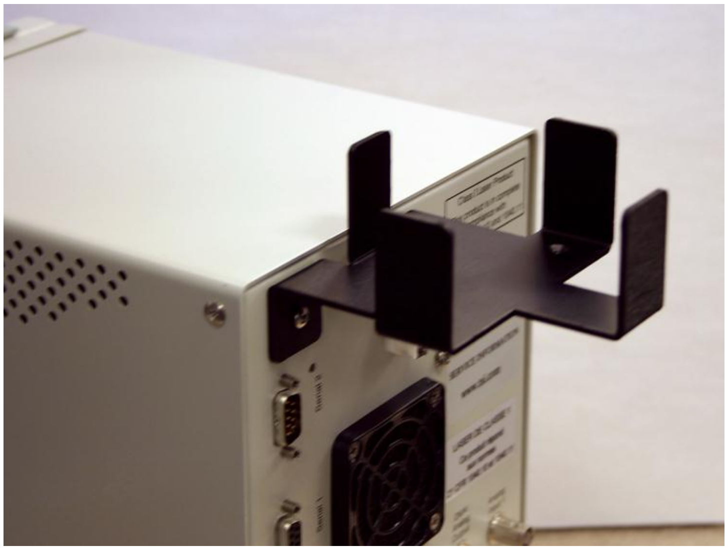


Figure 2-1
View of Fill Bottle Bracket Mounting

Filling the Fill Bottle with Butanol

The Model 3772/3771 CPC 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 CPC 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 CPC. 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 CPC. The drain bottle collects butanol drained from the CPC 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 CPC

Plug the power cord into the receptacle on the back panel of the CPC 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, 200 W maximum

Note: *Make certain the power cord is plugged into a grounded power outlet. Position the CPC so the power connector and switch are easily accessible in case an emergency disconnect is required.*

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

The instrument begins a warm-up sequence which typically lasts ten minutes at room temperature. On the 3772, a ten-minute countdown is displayed on the front panel. Particle concentration will not be accurately measured during warm-up. After warm-up completes, the fluid begins to fill the internal butanol reservoir in the saturator.

Supply External Vacuum to the CPC

An external vacuum port is located in the lower right-hand corner of the CPC back panel. An external vacuum must be connected to this port before the CPC can count particles. Vacuum source, either a central building vacuum or a stand-alone vacuum source (e.g., TSI Model 3032 Vacuum Pump), should provide at least 60 kPa (18 in. Hg) vacuum and 1.0 L/min critical flow at the inlet of each CPC. Details of vacuum specifications are given in Chapter 5.

Positioning the CPC

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

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

(This page intentionally left blank)

CHAPTER 3

Instrument Description

Use the information in this chapter to become familiar with the location and function of controls, indicators, and connectors on the Model 3772 and 3771 Condensation Particle Counters (CPC).

Model 3772 Front Panel

The main components of the 3772 front panel include the two-line LCD display, six-key push button keypad, flash memory card slot, aerosol inlet, two LED indicator lights (particle and status). These are identified in Figure 3-1 and described below.

LCD Display and Keypad

The two-line backlit LCD provides continuous real-time display of sample data and is used in conjunction with the keypad to display option menus, instrument status information, and user settings. Refer to Chapter 4 for details on how to make selections and change options on the menus.

Figure 3-1
View of the Model 3772 Front Panel

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 can deform the tube when overtightened, leading to leaks.

Status Light

The status light indicates the working status of the CPC. It will light only when the key performance parameters of the CPC fall within an acceptable range. More information on the status light is provided in Chapter 4.

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 3772 CPC 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.

Model 3771 Front Panel

The main components of the 3771 front panel include the aerosol inlet and two LED indicator lights (particle and status). These are identified in Figure 3-2 and operate the same as described above for the 3772.

Figure 3-2
View of the Model 3771 Front Panel

Model 3772/3771 Back Panel

As shown in Figure 3-3, the back panel of the 3772/3771 CPC has power and data connections, analog input/output connections, external vacuum 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 this AC receptacle at the top.

USB Communication Port

The Model 3772/3771 CPC 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 CPC 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.*

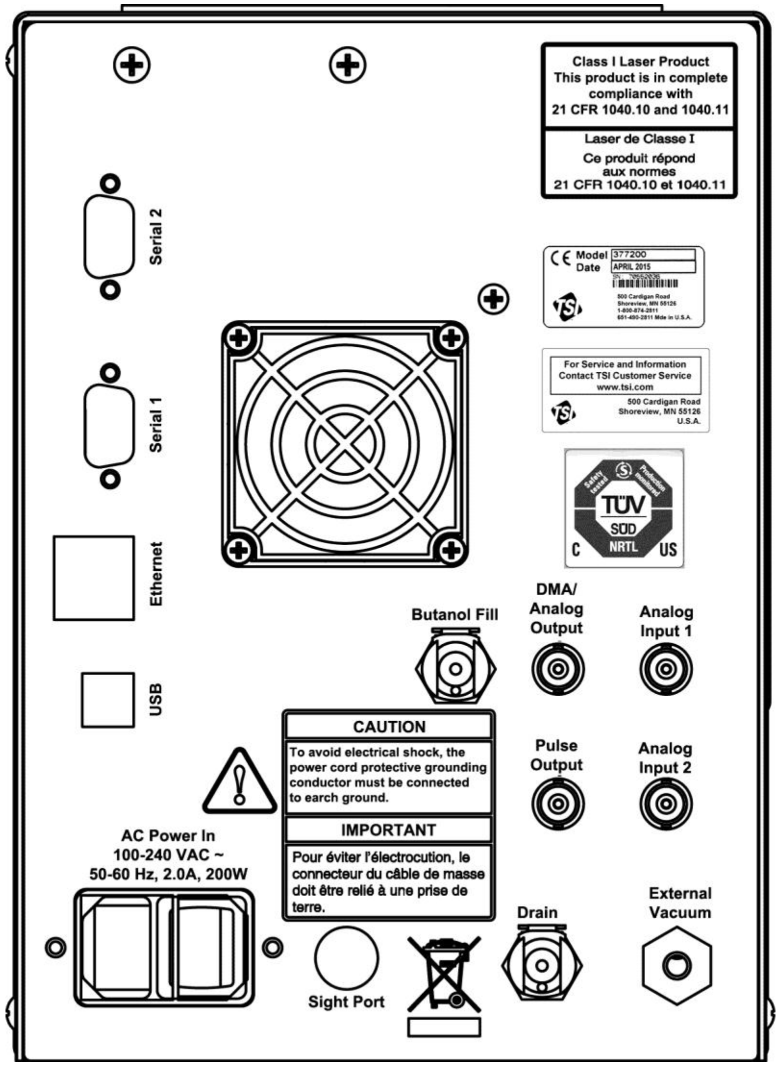


Figure 3-3
Back Panel of the Model 3772/3771 CPC

RS-232 Serial Connections

The Model 3772/3771 CPC provides two standard A-pin RS-232 serial ports that allow communication between a computer and the CPC. 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 water removal system 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 CPC 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. On the 3772 the analog voltages can be displayed on the LCD display and saved to the removable Flash Memory Card or a computer. Voltages from external 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

The DMA/Analog Output port provides an analog 0–10 V signal linearly proportional to particle concentration. This particle concentration is corrected for coincidence and equals the concentration displayed on the front panel of the CPC and the concentration saved to the Flash Memory Card or computer. Refer to Chapter 4 for details. In addition, on the 3772 this port can be configured by the Aerosol Instrument Manager® software to provide the ramped voltage signal needed when the 3772 CPC is used as part of the Scanning Mobility Particle Sizer™ (SMPS™) spectrometer. Although this port on the 3771 is also labeled DMA/Analog Output, the DMA function is not available for the 3771.

Pulse Output port provides a 5-volt (50-ohm termination) digital pulse for each particle detected. This enables you to use your own counting electronics hardware or 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 350 nanoseconds (see Figure 3-4) for the 3772/3771 CPC. 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 slightly lower than the displayed concentration when particle concentration is high. Refer to Chapter 6 "Particle Counting" for coincidence correction for pulse output.

The Pulse Output is a way to get raw particle count information. This information is also available through serial command. Using the SSTART,2 command, described in Appendix B, you can read raw, uncorrected, particle counts. TSI recommends using the SSTART,2 command for raw counts as then all the information is shipped which is used to calculate the corrected concentration, and there are no issues with the counters ability to accurately count the pulses.

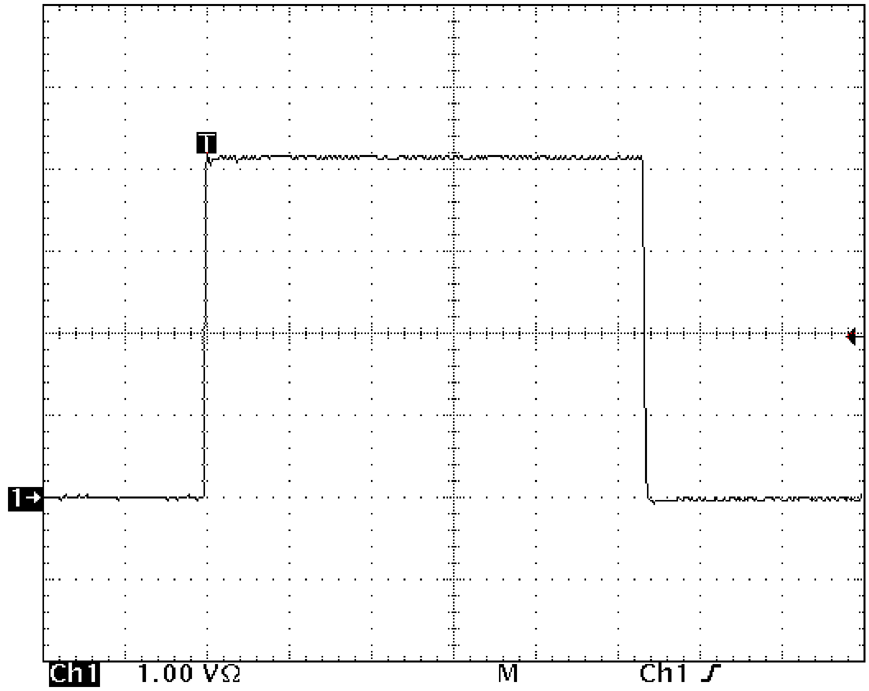


Figure 3-4
Sample Digital Pulse from Pulse Output Port at the Back Panel of the CPC

Ethernet Communication Port

Instrument status including particle concentration of the Model 3772/3771 CPC 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.

External Vacuum Port

By attaching an external vacuum to this port, critical flow is established through the critical orifice described in Chapter 5. The flow through this port contains butanol vapor so the external vacuum must be properly vented away from work areas or use charcoal filter to absorb the butanol vapor. Charcoal filters can be ordered through TSI (P/N 1031492 and P/N 1031493). See Chapter 8 "Maintenance and Service."

Drain Port

This port is used to drain the working fluid (butanol) from the 5 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 CPC. It is secured to the chassis with four screws on the bottom and two on the top and it can be removed for access to the interior of the Model 3772/3771 CPC. Refer to Chapter 8 for details.

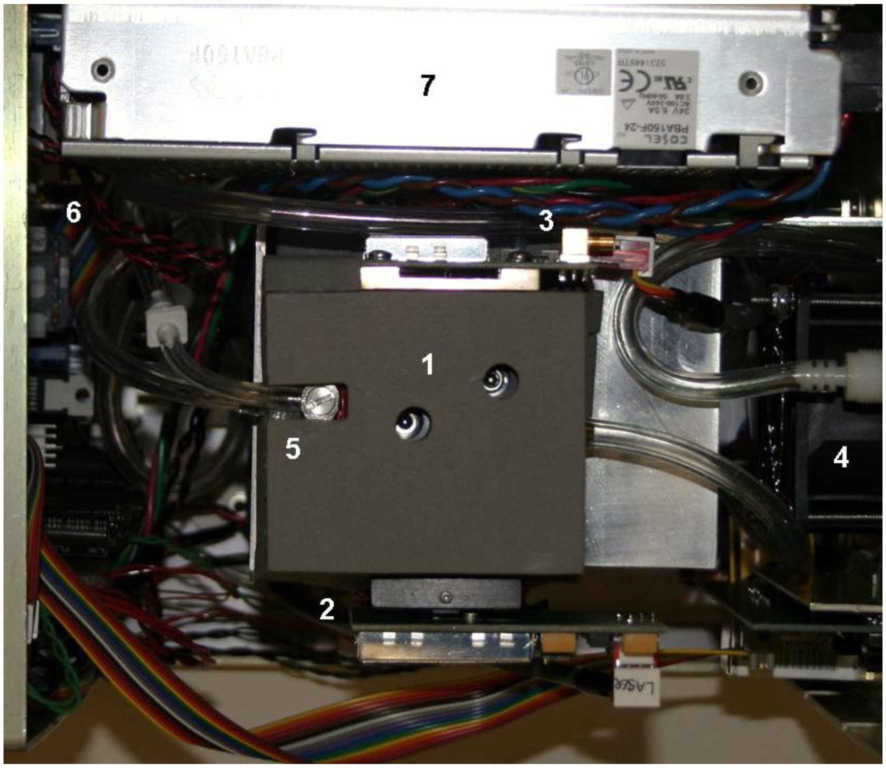
Bottom Panel

The bottom portion of the chassis provides access to the saturator wick. As shown in Figure 3-5, the saturator base, which is attached to the wick, is visible above the centrally located 2.5-inch diameter hole on the bottom panel. The base and wick can be removed for maintenance, as described in Chapter 8.

Figure 3-5
Bottom Panel Showing Removable Saturator Base

Internal Instrument Components

Internal components are described in this section and identified in Figure 3-6 and Figure 3-7.



1. Sensor assembly
2. Water removal pump
3. Butanol fill filter
4. Fan
5. Critical orifice
6. Pressure transducers
7. Power supply

Figure 3-6
Internal Components of the Model 3772/3771 CPC

Water Removal Pump

The Model 3772/3771 CPC uses a micro-flow Water Removal Pump to remove condensate from the condenser. 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 CPCs use three liquid filters. One liquid filter is used to filter butanol supplied from the fill bottle while a second filters the butanol drain line. The third is used to filter the condensed water and butanol mixture before it passes through the Water Removal Pump.

Valves

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. On the 3772, the drain valve is activated through the front panel or through serial command. On the 3771, the drain valve is activated through serial command. Butanol is drained prior to shipment or removal of the saturator wick. See "User Settings" in Chapter 4 and "Maintenance and Service" in Chapter 8.

Pressure Transducers

The Model 3772/3771 CPC uses three 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 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. On the 3772, pressure information is viewable via the front panel display. On both 3772 and 3771 CPCs, pressure information is available through serial commands.

Electronics Boards

Four electronics boards identified in Figure 3-7, are used in Model 3772/3771 CPC. The boards include main PC board, laser board, detector board, and communication connector board. The 3772 also includes a fifth board—flash memory board.

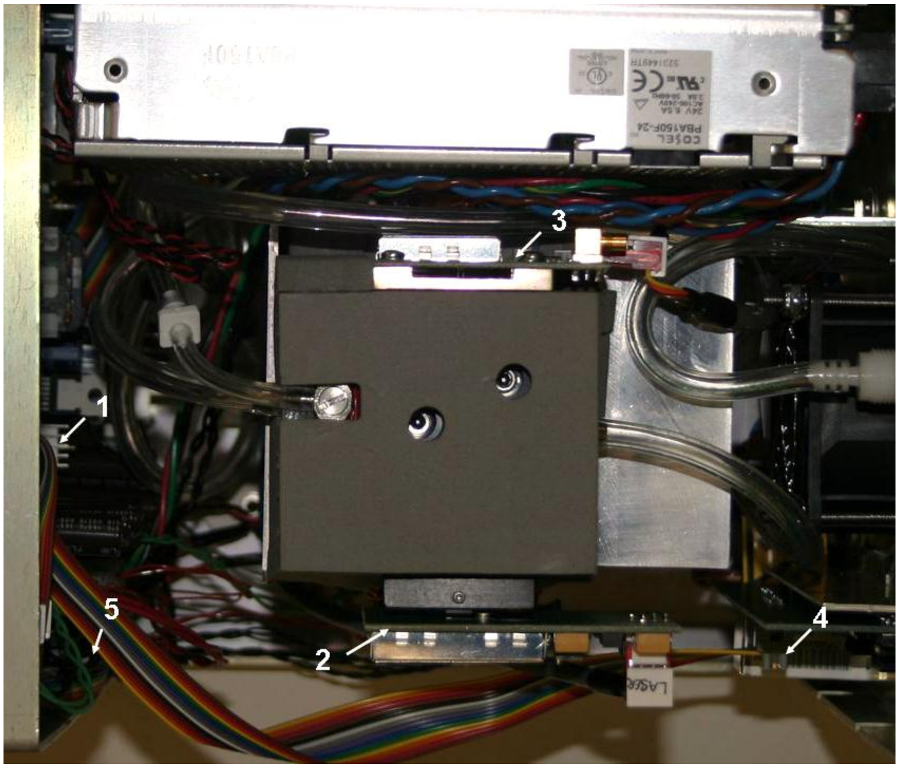


Figure 3-7
Electronics Boards inside the Model 3772/3771 CPC

1. Main PC board
2. Laser board
3. Detector board
4. Communication connector board
5. Flash memory board (3772 only)

Basic Instrument Functions

This section describes basic instrument functions.

Concentration Measurement

Particle concentration is presented as particles per cubic centimeter (p/cc). For the 3772, the particle concentration is displayed on the front panel LCD in numeric form. For both CPCs, data is collected using the Aerosol Instrument Manager® software or other terminal program (such as HyperTerminal). Particle concentration is determined from the count rate (particles counted per tenth of a second) and the aerosol flow rate, nominally 1000 cubic centimeters per minute (cm^3/min). The concentration is also live-time corrected for coincidence. Refer to Chapter 6 "Live-Time Counting" for more information.

Total Count Mode (3772 only)

Total Count Mode (also called 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 and number of counts are shown on the front panel display of the 3772.

Water Removal

When the aerosol sample has a dew point above the condenser temperature of 22°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 3010, 3760A, or 3762 CPC, the Model 3772/3771 CPC is able to capture condensed water vapor and remove it, significantly reducing butanol contamination in high humidity environment. The water removal process increases the butanol consumption. For additional information refer to Chapter 4.

Internal Data Logging (3772 only)

A removable Flash Memory Card can be inserted in the slot on the 3772 front panel to store data including particle concentration 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 3772/3771 CPC 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, etc. The data is updated once every five seconds. Refer to Chapter 7 for more details.

External Vacuum Pump or Source

The external vacuum pump or source must provide sufficient vacuum to maintain a critical pressure across the critical orifice, while providing an aerosol flow of 1.0 L/min. At an atmospheric pressure of 100 kPa (1 atm), an external pump or other vacuum source must provide at least 60 kPa (18 in. Hg) of vacuum and 1.0 L/min inlet volumetric flow for each CPC supported. TSI offers Model 3032 Vacuum Pump for one CPC and Model 3033 Vacuum Pump for multiple CPCs. Contact TSI technical support for more information on use of an external vacuum pump.

Flow Rate Control

The Model 3772/3771 CPC uses a critical orifice to accurately control the air flow in the instrument. The critical orifice operates at or below a critical pressure to control the 1.0 L/min volumetric aerosol flow. More is found in Chapter 5 "Technical Description."

Problems with the aerosol 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 22 °C, 39 °C, and 40 °C, respectively, with specified ambient temperatures in the operating range of 10 to 35 °C. The temperatures are controlled through feedback circuits on the main electronics board and are viewable via firmware commands. For the 3772, the temperatures are also viewable with the Status display screen. If the temperatures are out of range on either CPC, the status indicator LED on the front panel will be off. 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 adequate external vacuum, 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. Inlet Pressure is accessible through firmware commands on both 3772 and 3771 CPCs and it is also viewable via the Status display screen for the 3772. Refer to Chapter 4 for more details.

CHAPTER 4

Instrument Operation

This chapter describes the basic operation of the Model 3772/3771 Condensation Particle Counter (CPC) 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 3772/3771 CPC:

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

WARNING
Although the Condensation Particle Counter 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 CPC 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 CPC. The switch is combined with the power cord receptacle.

Warm-up

When the CPC is turned on, the saturator, condenser, and optics have to reach set operating temperatures. This "warm-up interval" takes about 10 minutes at room temperature. The Status LED indicator on the front panel will remain unlit during this time. Under extremes in ambient temperature, it may take considerably longer for the instrument to warm-up.

On the 3772 front panel display, a countdown is also displayed during the warm-up time, as shown in Figure 4-1.

Figure 4-1
Model 3772 Display During Warm-Up

When warm-up is complete, the concentration is automatically displayed for the 3772 as shown in Figure 4-2. The concentration can also be displayed before the warm-up is complete by pressing the **ESC** key ESC at any time.

Figure 4-2
Model 3772 Display After Warm-Up is Completed

Status Indicator

A status LED indicator on the front panel of the Model 3772/3771 CPC indicates the overall status of the CPC. It will remain unlit if a key parameter falls outside of the acceptable operating range. Parameters monitored include instrument temperatures, pressures, and liquid level. Generally it will light after warm-up time is complete, an external vacuum is applied, and butanol has filled the reservoir. See Chapter 8 for troubleshooting instructions if the Status indicator LED does not turn on.

Particle Indicator

A particle LED indicator light on the front panel of the CPCs indicates particle counts.

Communication

CPC measurement data, instrument status, and user settings are available through firmware communication for both Models 3771 and 3772 and also viewable through the front panel for Model 3772. For more information on firmware communication, see Chapter 7 and Appendix B.

Model 3772 LCD Display and Keypad

In addition to firmware communication, Model 3772 presents measurement data, instrument status, and user settings on a 2-line, 16-character, alphanumeric LCD display. You can navigate the menu options using the six-button keypad. The display and keypad are shown in Figure 4-3.

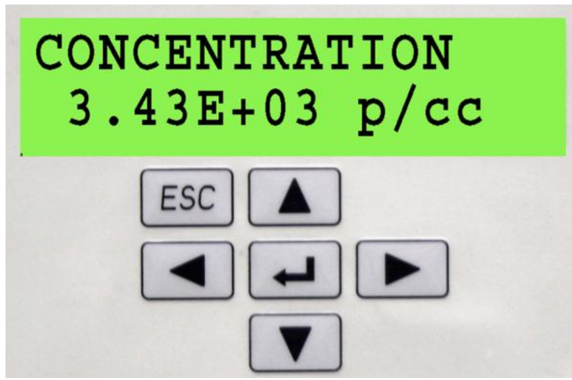


Figure 4-3
Model 3772 Front Panel LCD Display and Keypad

Model 3772 Keypad Navigation

As shown in Figure 4-3, the keypad has six keys: scroll left ◄, scroll right ►, scroll up ▲, scroll down ▼, **Enter** ↵, and **ESC** ESC. Detailed navigation instructions are described below. Generally,

- The up and down arrows are used to scroll through a given menu.
- The left and right arrows are used to configure user settings. The new setting becomes active immediately after the setting is selected.
- The **Enter** ↵ key displays submenus.
- The **ESC** ESC key returns the display out of a submenu.

The control menu has a two-tier hierarchy. There are four primary functions: Concentration, User Settings, Status, and Total Count Mode. By pressing the up ▲ or down ▼ arrow, the display will scroll through these four functions.

Two of the primary functions, User Settings and Status, have submenus. A submenu can be accessed by pressing the **Enter** ↵ key. Once inside a submenu, the up ▲ or down ▼ arrow can be used to scroll through the features. The submenu for User Settings contains all the options for configuring the CPC. The submenu for Status contains all the parameters for monitoring the CPC. The primary functions are summarized below along with their submenus. These are described in detail in the following sections.

Primary Function	Secondary Submenu
Concentration *Aerosol concentration measured in [p/cc]*	No submenu available.
User Settings *Displays features available for configuration*	Data Logging, Water Removal, Totalizer Time, Auto Fill, Analog Out, Data Averaging, and Drain.
Status *Displays operating parameters and status of CPC*	Saturator Temperature, Condenser Temperature, Optics Temperature, Cabinet Temperature, Ambient Pressure, Orifice Pressure, Nozzle Pressure, Laser Current, Liquid Level, Analog Input 1, Analog Input 2, Flash Status, USB status, Firmware Version
Total Count Mode *Accumulates particle counts and clock time*	No submenu available.

Concentration

The CPC measures aerosol concentration in particles per cubic centimeter. The 3772 displays a Concentration screen as shown in Figure 4-3. This is the default display. Pressing **ESC** ESC twice from any other screen returns the display to Concentration screen. The LCD is updated once per second. For both 3771 and 3772, concentration data can be accessed through firmware communication using "RD" command. Refer to Chapter 7 and Appendix B for more information on firmware commands. The maximum concentration limit for the 3772/3771 is 10,000 particles/cm^3.

When concentration exceeds 10,000 particles/cm^3 for a 3772, two exclamation marks appear on the LCD main display, one in front of the concentration value and one after. For both 3772 and 3771 CPCs, measurements with concentrations that exceed 10,000 are flagged and the status LED will be turned off.

Total Count Mode (3772 only)

Total Count Mode allows particle counts to be accumulated and displayed as shown in Figure 4-4. Total Count Mode is generally useful for tests at very low particle concentrations (e.g., below 10.0 particles/cm^3), such as evaluation of high efficiency filters.

To access Total Count Mode from the default Concentration screen, press the down ▼ arrow once. When first accessed, the display appears as shown in Figure 4-5. By pressing **Enter** ↵, the screen changes to Figure 4-5. Pressing **Enter** ↵ again at this screen will cycle between Start, Stop, and Reset. The CPC will count time and total particles once Start is set. The sample automatically stops when the time is equal to the Totalizer Time. Totalizer Time can be set in the User Setting submenu.

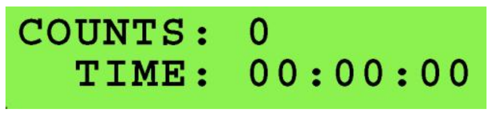


Figure 4-4
Total Count Mode Data Screen

Figure 4-5
Initial Total Count Mode Data Screen

User Settings

User settings can be configured through firmware commands on both 3772 and 3771. Refer to Chapter 7 and Appendix B for information on firmware commands. On the 3772, User Settings is also accessible from the front panel display. It is a primary function accessible from the default Concentration screen by pressing the up arrow ▲ once. The screen appears as in Figure 4-6. Pressing **Enter** ↵ once brings up the submenu. Once inside the submenu, the up ▲ or down ▼ arrow can be used to scroll through a list of configurable settings. To change a setting, use the left ◄ or right ► arrow. The setting takes effect immediately after it is selected. Pressing **ESC** ESC once returns the display to User Settings as shown in Figure 4-6. User settings in the menu are described under individual headings below, beginning with the Data Logging.

Figure 4-6
User Settings Display

Data Logging (3772 only)

Data can be saved on a Flash memory card on the 3772. By default Data Logging is "OFF." To initiate data logging, switch the Data Logging user setting to "ON" by pressing the left ◄ or right ► arrow once. Logging will begin immediately. Press the arrow again to toggle Data Logging to "OFF" to stop. More information on data logging is provided under "Using the Flash Memory Card." Use the Data Averaging option in User Settings to set the data averaging interval for data collection.

Water Removal

The Water Removal option provides ON/OFF control for the water removal feature of the CPC. The default setting is "OFF." On the 3772 it can be set from the Water Removal option in the submenu of User Settings. Pressing the left ◄ or right ► arrow toggles Water Removal system on or off. On either 3772 or 3771 CPC, it can be turned on using the "SAWR" firmware command. See Chapter 7 and Appendix B for information on firmware commands.

Water Removal system is used in hot/humid environments to eliminate contamination of the butanol working fluid by condensed water vapor. Water removal keeps the CPC 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 into 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 approximately 7 days with the water removal system ON and last 15 days with the water removal system OFF.

Totalizer Time (3772 only)

The Totalizer Time feature is available from the User Settings submenu. Use this feature with the Total Count Mode function to select the time period for accumulating counts. Three options are available: 1 minute, 60 minutes, and Continuous. The default setting is "Continuous." Pressing the left ◄ or right ► arrow will cycle through these three options. Time and count accumulation stops once the time is complete. The accumulation can also be ended manually prior to the end of a sampling period from the Total Count Mode display.

Auto Fill

When the Auto-Fill option is ON, the instrument fills with butanol automatically when the liquid level indicator in the butanol reservoir detects a low butanol level condition. Selecting Auto-Fill OFF prevents the fill valve from opening despite a low butanol level. **Note that a Drain command will turn Auto-Fill to OFF.** Auto-Fill can be turned back on by using the Auto-Fill setting or by restarting the CPC.

On the 3772, an Auto Fill option is available in the User Setting submenu. Pressing the left ◄ or right ► arrow will toggle Auto-Fill ON or OFF. On both 3771 and 3772, Auto-Fill can be set ON or OFF with the "SFILL" firmware command. See Chapter 7 and Appendix B for more information on firmware commands.

Analog Out

The Analog Out setting configures the signal from the "DMA/Analog Output" port on the back panel. This analog signal is from 0 to 10 V. There are five options available to select: OFF, 1E+1, 1E+2, 1E+3, 1E+4. The analog signal is linearly proportional to particle concentration when it is turned on. The relationship between voltage output and particle concentration 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
OFF	0 V independent of concentration	-

On the 3772, the Analog Out option is available in the User Settings submenu. Pressing the left ◄ or right ► arrow will cycle through the options. The scaling and OFF options are available to the 3771 and 3772 through the "SAO" firmware command. See Chapter 7 and Appendix B for more information on firmware commands.

Data Averaging (3772 only)

When Data Logging is set to “ON”, data is averaged over selected Data Averaging Period for saving to the flash memory card. The Data Average Periods available are 1, 2, 3, 4, 5, 6, 10, 12, 15, 20, 30, or 60 seconds. By default the Data Average Period is 1 second.

To change the Data Average Period, the Data Logging option first must be set to “OFF.” Then in the Data Average Period display, press the right ► or left ◄ arrow to cycle through the available Data Average Periods. When the desired period is displayed, press **ESC** ESC to return to the User Settings screen.

The Aerosol Instrument Manager® software provides more choices for data average period. See the software manual for 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.

Drain

The Drain feature is used as part of the process to drain butanol from the reservoir. It opens the drain valve and turns Auto-Fill mode OFF. When the drain is complete, Auto-Fill must be turned back on by using Auto-Fill setting or by restarting the CPC. For specific instructions on draining butanol, refer to the section “Draining Butanol from the Butanol Reservoir” in Chapter 8.

On the 3772 the Drain feature is available from the User Settings submenu. Pressing the left ◄ or right ► arrow toggles Drain ON or OFF. On the 3771 the Drain feature is controlled through the “SDRAIN” firmware command. Refer to Chapter 7 and Appendix B for further information on firmware commands.

Status

Status information provides data from instrument sensors useful to confirm basic performance and for troubleshooting. The Status parameters are described below, beginning with Saturator Temperature.

Status parameters are accessible through firmware commands for both CPCs. Refer to Chapter 7 and Appendix B for further information on firmware commands.

On the 3772, the parameters are also available from the Status menu. To access the Status menu on 3772, start at the default Concentration screen and press the up ▲ arrow twice. The Status screen appears as shown in Figure 4-7. Press the **Enter** ↵ key to view the submenus for Status. Toggle through submenus (status parameters) with the up ▲ or down ▼ arrow. Pressing **ESC** ESC once returns the display to the Status screen as shown in Figure 4-7. If any of the status parameters deviates from the normal condition, the status light is off and there are two exclamation marks around the parameter: one before and one after, as shown in Figure 4-8.

Figure 4-7
Status Display

Figure 4-8
Status Parameter Display for Diagnostics

Saturator Temp (Temperature)

Saturator temperature is 39.0 °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 Temp (Temperature)

Particle growth occurs in the condenser as butanol vapor from the saturator is cooled, supersaturated, and condenses on sampled aerosol particles. The condenser temperature is maintained at 22.0 °C.

Optics Temp (Temperature)

The optics temperature is maintained at 40.0 °C. This is above the saturation temperature and prevents butanol from condensing on the lenses and other internal components in the particle detection optics.

Cabinet Temp (Temperature)

The cabinet temperature measures the temperature inside the CPC.

Ambient Pressure

Ambient pressure 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.

Orifice Pressure

Orifice pressure is the differential pressure across the aerosol flow critical orifice in kPa. Identification of the orifice is found in the flow schematic Figure 5-1.

Nozzle Pressure

Nozzle pressure is the differential pressure across the nozzle between the condenser and the optics chamber in kPa. Identification of the nozzle is found in the flow schematic
Figure 5-1.

Laser Current

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

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.

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-B-volt window with maximum resolution. On both 3772 and 3771 CPCs, analog input data is saved along with concentration data through firmware commands or to a computer running Aerosol Instrument Manager® software. On the 3772 analog input data can also be saved to the Flash Memory Card when a card is present and data logging is ON.

Flash Status (3772 only)

When a flash memory card is present, READY is indicated. When a flash memory card is present and data logging is ON, LOGGING is indicated. When there is not a flash memory card, REMOVED is indicated. See more details below.

USB Status

When the USB port on the back panel of the 3772/3771 CPC is connected, the status indicates CONNECTED. The status indicates DISCONNECTED when there is no connection to the USB port.

Firmware Version

This option shows the current firmware version of the instrument.

Using the Flash Memory Card (3772 only)

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

Data logging is initiated (turned ON) from the front panel under the User Settings Menu. A file having a .DAT extension is created and will sample one hour of CPC 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 by turning Data Logging OFF. 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. The file names are based on the date and time when the test was initiated.

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.

Flash Memory Card Format

The data card supplied with Model 3772 CPC is formatted as per **FAT32** file system. This ensures data is logged and saved properly. Should you use another external data card, make sure that you reformat the card to the **FAT32** file system before logging data.

Note: *Recording data on memory cards not formatted to **FAT32** file system can result in malfunctioning of the data logging system. This may cause the CPC to freeze at the end of a run and loss of previously recorded data files.*

Follow the steps below to reformat your card:

1. Connect the supplied card reader to your computer using the USB cable.
2. Insert the flash card in the reader. The flash memory card will appear as a separate disk drive in Microsoft® Internet Explorer® browser.
3. If you have any data on the flash memory card you want to save, you must copy it to a temporary directory on your computer, because the reformat will erase it from the flash card.
4. Put your cursor on the flash memory card's drive letter in Microsoft® Internet Explorer® browser and right click. Select **Format**.
5. Under File System, make sure "FAT32" is selected. Click on **Start**.
6. When it is done reformatting, copy any files you saved back onto the flash memory card.
7. You can check the format type of the flash memory card at any time by right clicking on the drive letter in Microsoft® Internet Explorer® browser. Select **Format** and look under File System.

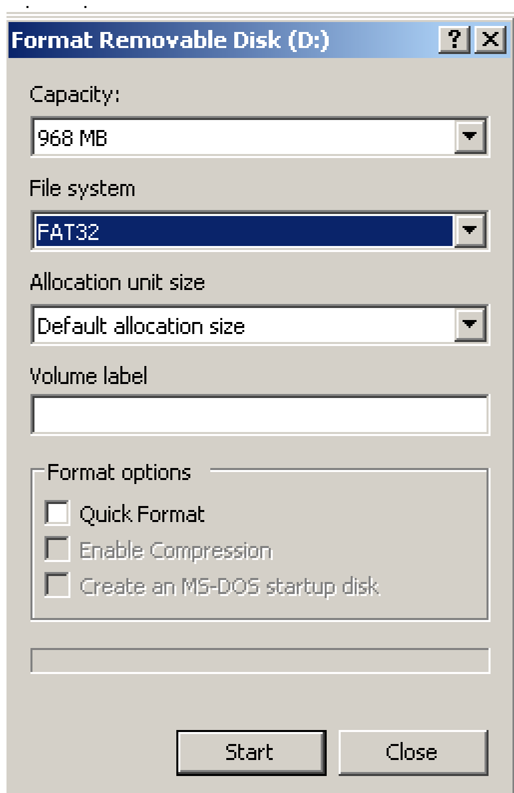


Figure 4-9
Reformatting the Flash Memory Card

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 3772/3771 CPCs. This program provides many useful data acquisition, display, processing, and download functions used in particle measurements. Review the supplied Aerosol Instrument Manager® software manual for complete information on software functions.

Moving and Shipping the CPC

Make sure the Model 3772/3771 CPC is turned off and remains upright while moving the instrument. There is no need to drain the CPC before moving it. Prior to shipping, however, it is necessary to drain butanol from the instrument. Refer to “Draining Butanol from the Butanol Reservoir” in Chapter 8 to drain the CPC.

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.

Caution

With the vacuum on and butanol in the reservoir, do **not** tip the counter more than 10° in any direction. It is recommended to turn off the CPC and disconnect the butanol fill bottle before the CPC is being moved or tilted for longer than a few seconds to prevent flooding the sensor.

(This page intentionally left blank)

CHAPTER 5
Technical Description

The Model 3772/3771 CPC is a continuous-flow condensation particle counter that detects particles as small as 10 nanometers (50% detection efficiency) in diameter. This section describes the function of the CPC, its subsystems and its components. A discussion of operation theory and history is given first.

Theory

The CPC 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 CPC 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 Model 3772/3771 CPC 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, 3785, and 3786 WCPCs) were developed 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.

Model 3760, 3762, and 3010 was introduced in early 90s and was replaced by Model 3772/3771 in 2005. The 3772/3771 CPC works 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 3772/3771 can detect 10 nm particles at 50% detection efficiency.

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 again in 2005 by the Model 3775 CPC. Both the Model 3775 CPC and the 3785 Water-based Condensation Particle Counter 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, five CPCs (Models 3772, 3775, 3776, 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 CPC

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. The laminar aerosol flow enters the saturator section where it passes through a heated, liquid-soaked cylindrical wick. The liquid evaporates and saturates the air flow with butanol vapor. Butanol is replenished from a reservoir and a fill bottle.

The flow of combined aerosol and butanol vapor is then cooled using a thermoelectric device (TED) in the condenser. The vapor becomes supersaturated and condenses on 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 and focus the light onto a low-noise photodiode. 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 3772/3771 CPC operates in single particle count mode up to 10^4 particles/cm^3. Rather than simply counting individual electrical pulses generated by light scattered from individual droplets, the CPC 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 later in Chapter 6. This option can be turned OFF by firmware command "SCC,0".

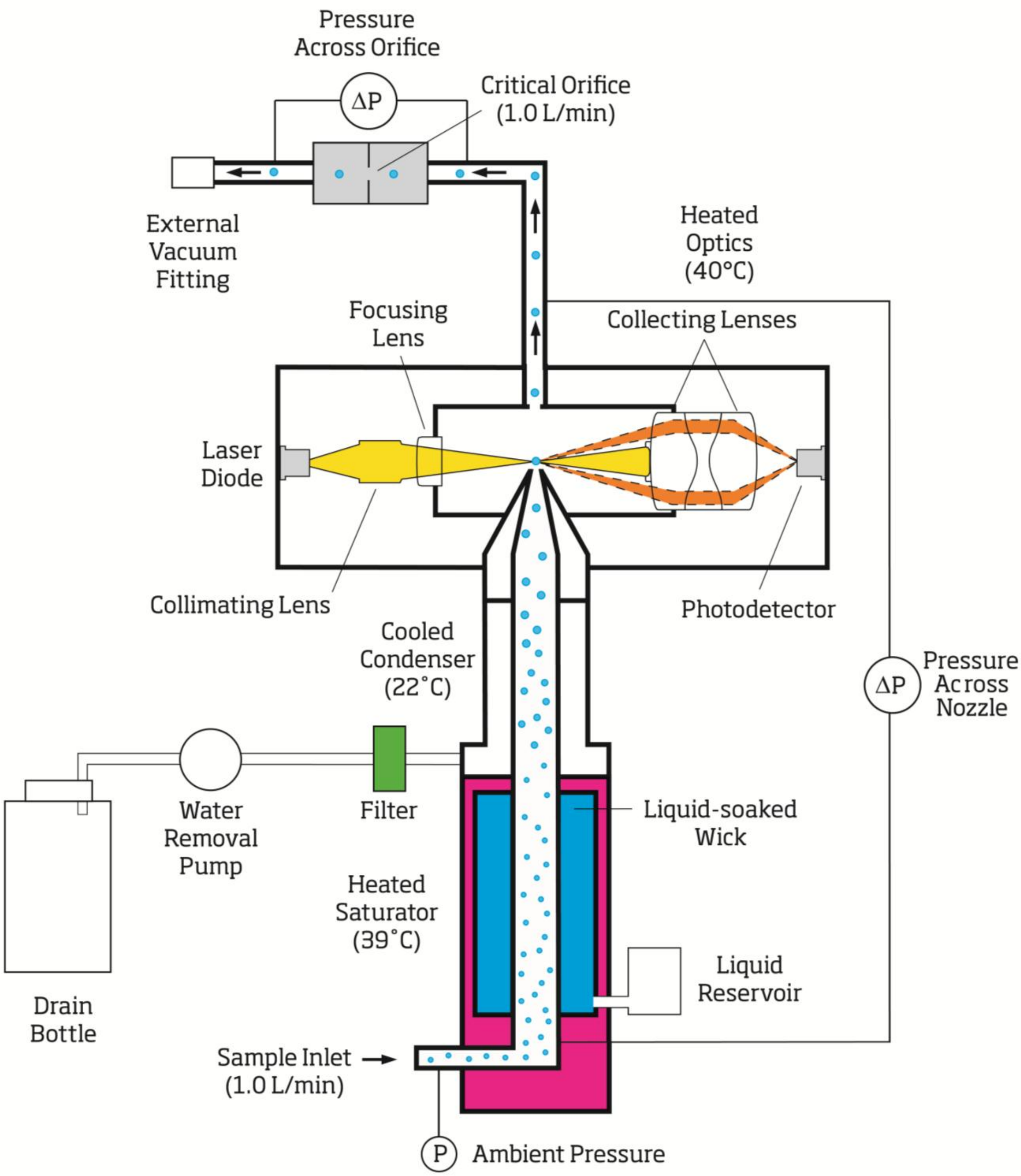


Figure 5-1
Flow Schematic of the Model 3772/3771 CPC

Critical Flow

To achieve the 1.0 L/min critical aerosol 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 CPC flow can be obtained using firmware commands for both 3772 and 3771 CPCs. They are also found on the Status menu on the front panel display for 3772. These pressures are identified as the Ambient pressure, the Orifice pressure, and the Nozzle pressure. The ambient pressure is typically the barometric pressure at the inlet. The orifice pressure is the differential pressure across the aerosol flow orifice. The nozzle pressure 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)**.

Flow is critical if the following is true:

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

Vacuum source, either a central building vacuum or a stand-alone vacuum source (e.g., TSI Model 3032 Vacuum Pump), should provide at least 60 kPa (18 in. Hg) vacuum and 1.0 L/min critical volumetric flow at the inlet of each CPC supported. The flow in the CPC is regulated by a critical orifice. Changes in the inlet pressure will not affect the flow rate through the instrument. A vacuum source that can provide a higher volumetric flow (e.g., TSI Model 3033 Vacuum Pump) is needed when running multiple CPCs.

Counting Efficiency and Response Time of the 3772/3771 CPC

The 3772/3771 CPC has a D_{50} of 10 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 3772/3771 CPCs 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 CPC is the total number concentration of all particles that a CPC can detect. This measurement provides no size differentiation and it is not corrected using the CPC counting efficiency curve. When the 3772 CPC 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 3772/3771 CPC has a fast response time. T_{95}, defined as the time it takes for the CPC reading to reach 95% of a concentration step change, is about 3 sec for the 3772/3771 CPC. Figure 5-3 shows the response time curves. The curves are based on averaging of three CPCs.

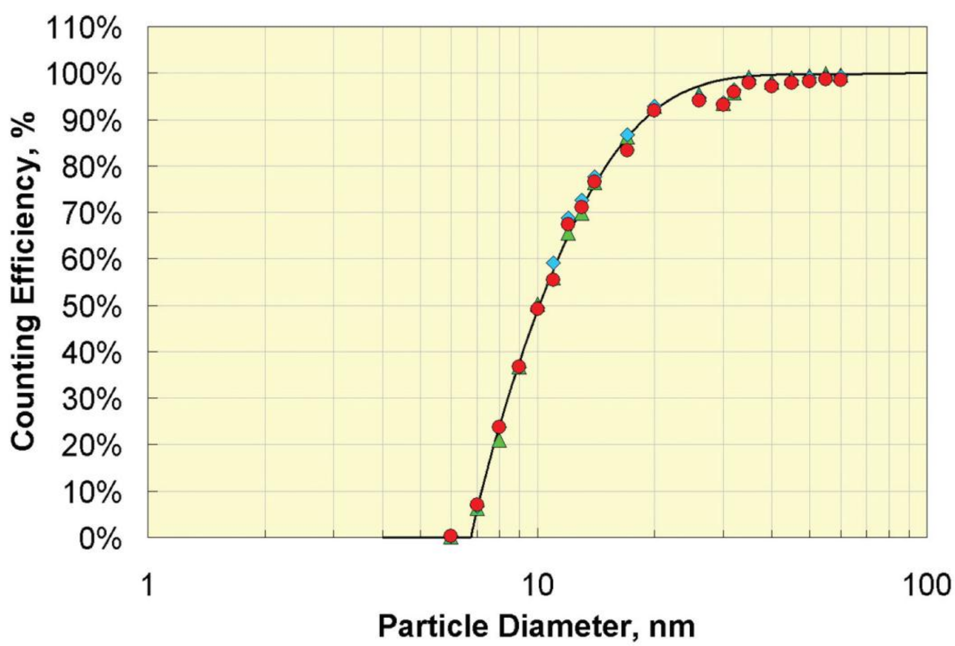


Figure 5-2
Counting Efficiency Curve of 3772/3771 CPC

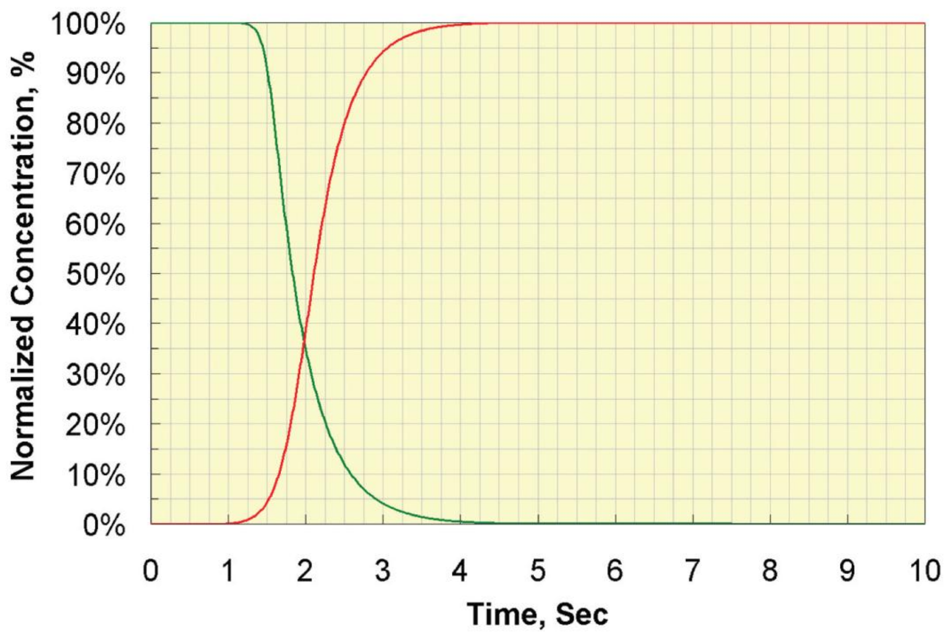


Figure 5-3
Response Time of 3772/3771 CPC

(This page intentionally left blank)

CHAPTER 6
Particle Counting

This chapter discusses specific aspects of particle counting and particle count measurements performed using the Model 3772/3771 Condensation Particle Counter (CPC).

The Model 3772 CPC 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).
- Total Count Mode (Totalizer Mode), where total particle counts are accumulated and presented each second.

The Model 3771 CPC has the Concentration mode and is capable of Total Count Mode using the Aerosol Instrument Manager® software. Concentration mode is commonly used for most applications. Total Count 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 CPC operates in the single count mode with continuous, live-time coincidence correction over the range between 0 and 10^4 particles per cubic centimeter.

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

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

In total count mode (or totalizer mode), the accuracy of the concentration is increased by sampling for a longer period and counting more particles. The concentration is calculated by:

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

where
Q = Aerosol flow rate, nominally 1000 cm^3/min (16.7 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 CPC 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

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

This option can be turned off by firmware command "SCC,0".

Coincidence Correction for Pulse Output

Live-time coincidence correction is not available if you are using the pulse output from the CPC which only provides raw counts of the particles. Concentration can be calculated using raw counts and the aerosol flow rate of the CPC. This concentration is only accurate for low particle concentrations when coincidence level is low, e.g., in clean air or after a filter. If the pulse output is used for higher concentration up to 10^4 particles/cm^3, the following calculation improves the accuracy of the particle concentration obtained from pulse output:

$$N_a = N_i \exp(N_a Q \tau_p)$$

where N_a = the actual concentration (particles/cm^3)
N_i = the indicated concentration (particles/cm^3)
Q = 16.67 cm^3/s
τ_p = 0.35 microsecond is the nominal effective time each particle resides in the viewing volume

The N_a in the exponent can be approximated by *Ni*.

Table 6-1 shows the calculated coincidence for several concentrations. Coincidence is 1-*Na*/*Ni*.

Table 6-1
Coincidence Levels Based on 0.35 µsec Pulse Width

Concentration Calculated (particles/cm^3)	**Coincidence (%)**
10	>.01
100	.06
1000	.59
5000	3.05
10000	6.4

Concentrations obtained from pulse width and coincidence-corrected with the above equation are slightly different from the live-time corrected concentrations on the front panel display. The former concentration is corrected based on nominal pulse width but the latter is corrected based on the actual pulse widths for particles. For concentrations above those in Table 6-1, contact TSI Incorporated for a more suitable particle counter.

C a u t i o n

At concentrations above 10,000, two exclamation marks appear at the sides of the concentration reading on the front panel of the 3772. If this occurs, the number of particles shown on the display could be lower than the actual concentration.

Particle Size Selector

The particle size selector (Model 376060 PSS) is an accessory (not included) to the Model 3772/3771 CPC to let you choose any of 11 cutoff sizes between 0.010 and 0.122 micrometer. The PSS uses a series of fine-mesh screens to remove small particles by diffusional capture. An additional set of diffusion screens (available separately, Model 376061) lets you select cutoff diameters up to 0.25 micrometer. The cutoff sizes listed below are calculated using efficiencies for 3772/3771 CPC and diffusion screens.

Diffusion screens	**Particle size cut, µm (50%)**
0	0.010
1	0.020
2	0.031
3	0.041
4	0.052
5	0.062
6	0.072
7	0.083
8	0.092
9	0.102
10	0.112
11	0.122

CHAPTER 7

Computer Interface and Commands

This chapter provides computer interface and communications information for the Model 3772/3771 Condensation Particle Counter (CPC). Information on the Flash Memory Card for the 3772 is also provided.

Computer Interface

This section includes descriptions on USB, Ethernet connections, RS-232, and the Flash Memory Card (3772 only).

USB

USB communications are provided with the 3772/3771 CPC, 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 CPC 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 CPC 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. This **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 CPC from another subnet.

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

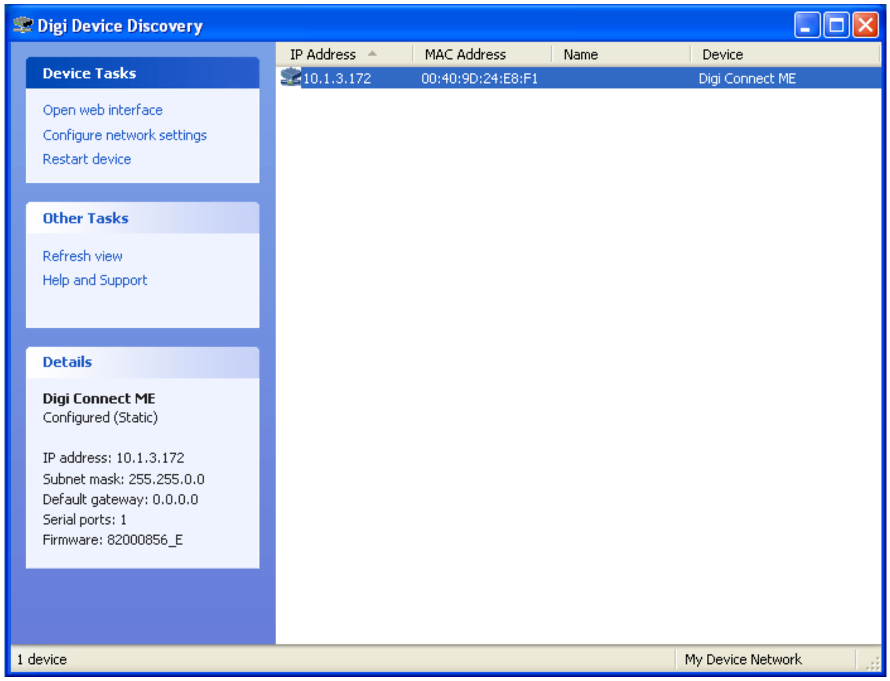


Figure 7-1
Digi Device Discovery Screen

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**.

®Windows is a registered trademark of Microsoft Corporation.

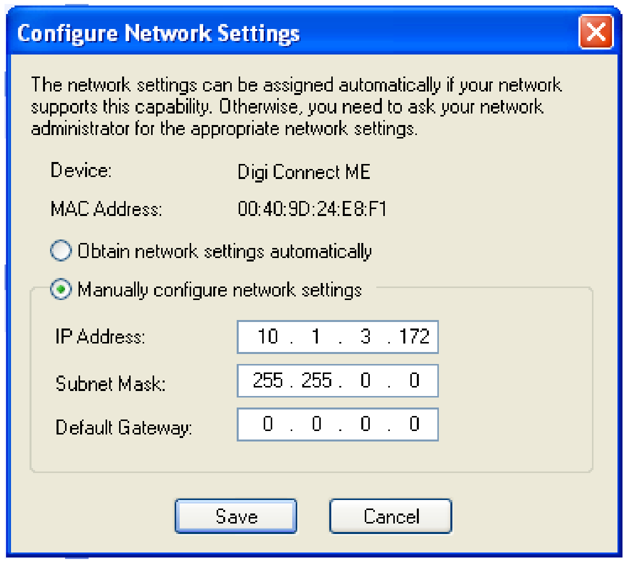


Figure 7-2
Configure Network Settings Screen

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

6. If the CPC 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 CPC 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.

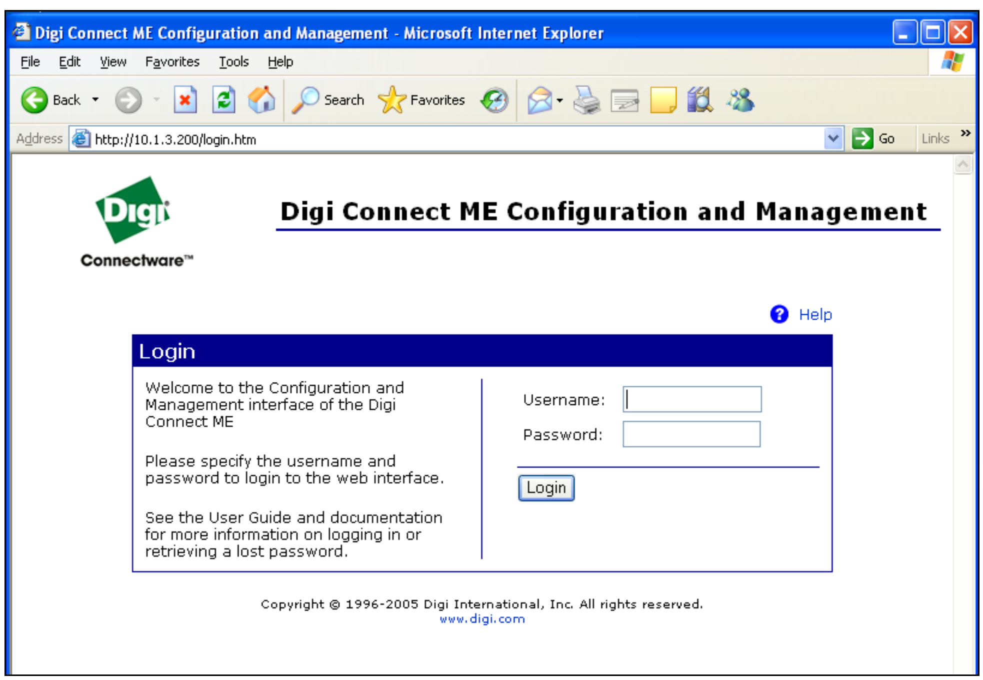


Figure 7-3
Digi Connect ME Configuration and Management Screen

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

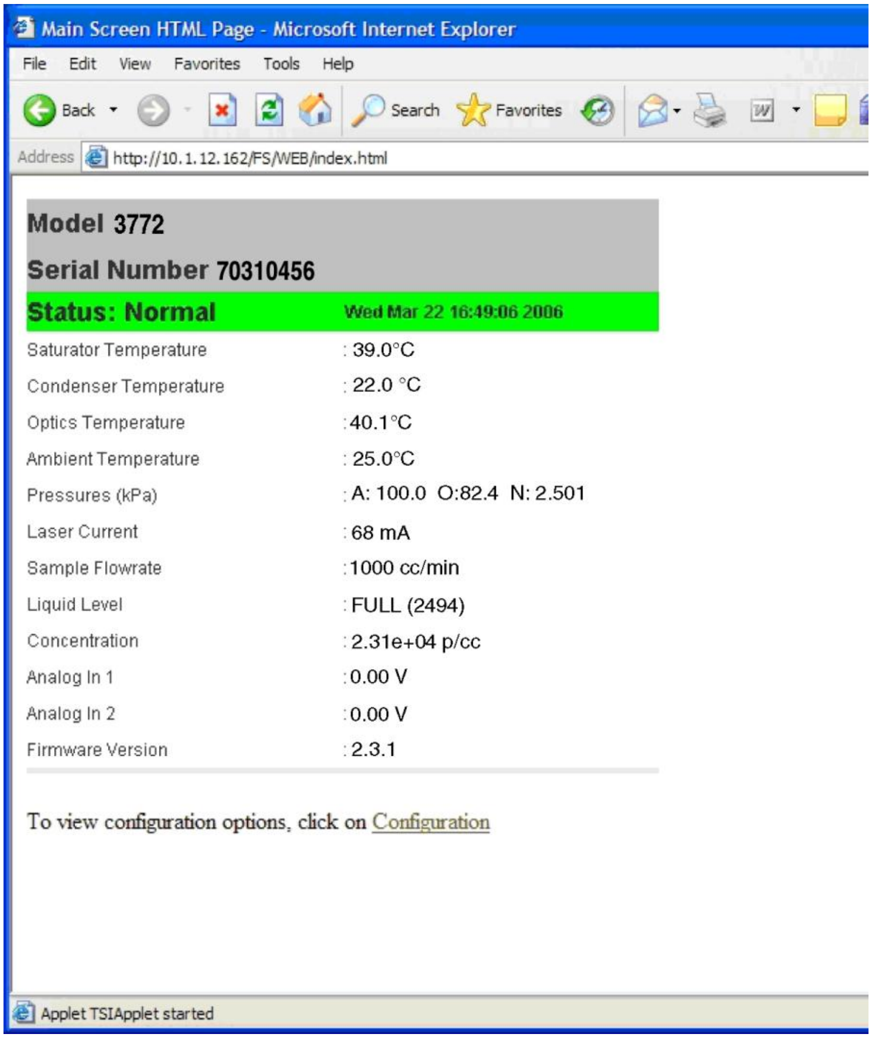


Figure 7-4
Main Screen HTML Page

Flash Memory Card Specification (3772 only)

A file is created on the Flash Memory Card when the Data Logging option is turned ON from the front panel of the 3772. Each file will contain one hour of data, unless 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 a user begins 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.*

Flash Memory Card Formatting Issue

On Model 3772 CPCs shipped before January 2008, the unit's internal flash memory card had a formatting issue. This caused the card to appear full when the number of logged data files got much above 100, which resulted in the unit freezing up at the end of taking run data. To solve this issue, follow the steps below to reformat the card.

1. Power on the instrument and connect a USB cable to it from your computer. The flash memory card will appear as a separate disk drive in Microsoft® Internet Explorer® browser.

2. If you have any data on the flash memory card you want to save, you must copy it to a temporary directory on your computer, because the reformat will erase it from the flash card.
3. Put your cursor on the flash memory card's drive letter in Microsoft® Internet Explorer® browser and right click. Select **Format**.
4. Under File System, make sure "FAT32" is selected. Click on **Start**.
5. When it is done reformatting, copy any files you saved back onto the flash memory card.
6. You can check the format type of the flash memory card at any time by right clicking on the drive letter in Microsoft® Internet Explorer® browser. Select **Properties** and look under File System.

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 3772/3771 CPC has two A-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.*

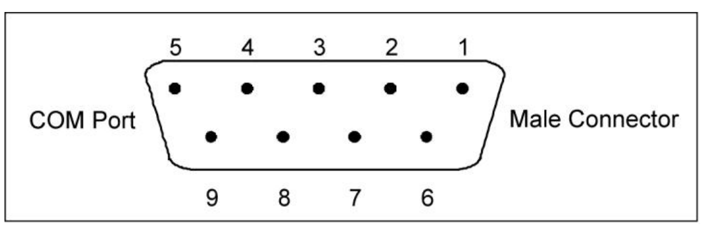


Figure 7-5
RS-232 Connector Pin Designations

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 CPC. The firmware commands are also listed in Appendix B. The commands can be used to read CPC 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 3772/3771 CPC 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-3772.

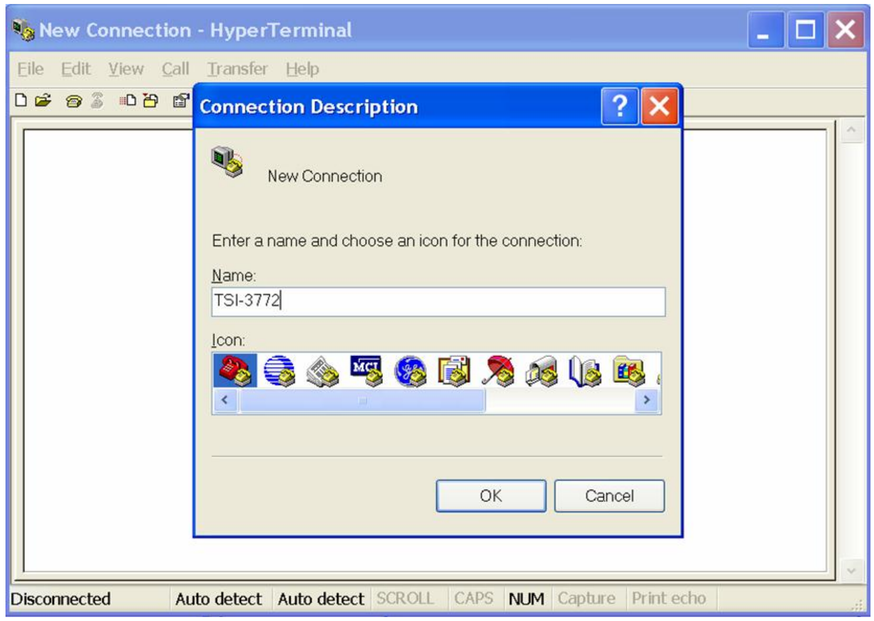


Figure 7-6
Connection Description Screen

3. Enter the communications (COM) port.

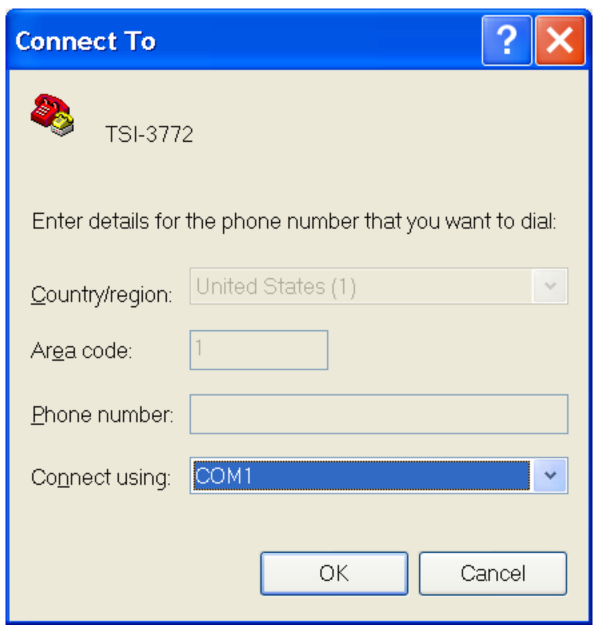


Figure 7-7
Connect To Dialog Box

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

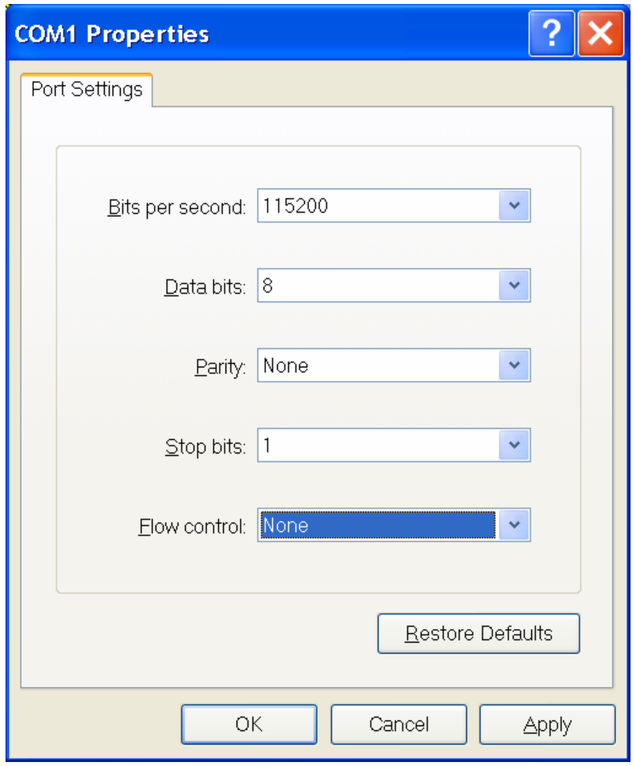


Figure 7-8
Port Settings Dialog Box

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

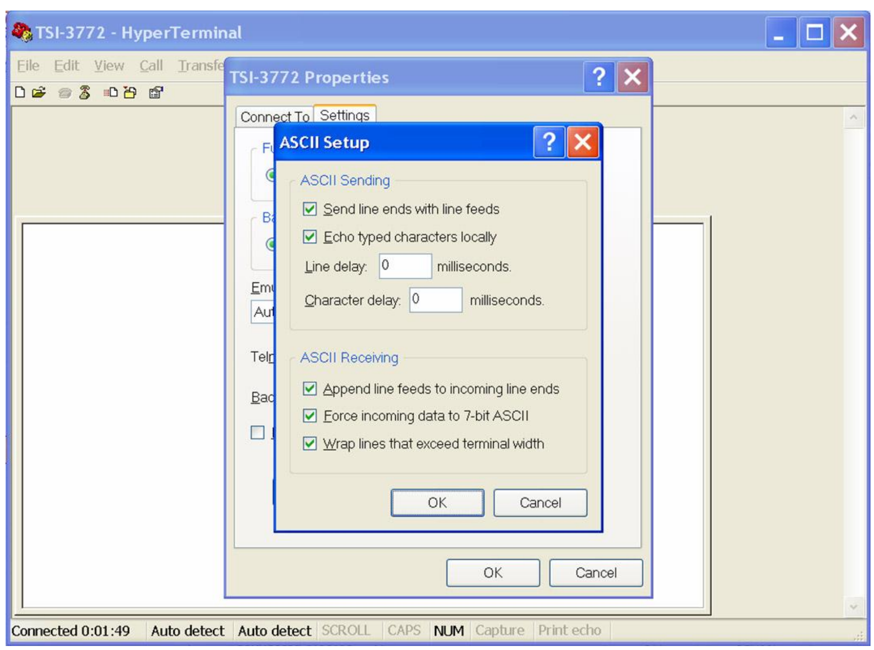


Figure 7-9
ASCII Setup Dialog Box

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 CPC. A list of firmware commands can be obtained using the HELP commands 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.

(This page intentionally left blank)

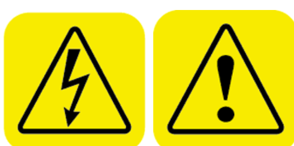
CHAPTER 8

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 3772/3771 Condensation Particle Counter (CPC) 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 CPC.

You are encouraged to call TSI for assistance in performing special maintenance. It may also be helpful to have the technician, tools, and the CPC 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.

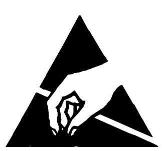


W A R N I N G

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

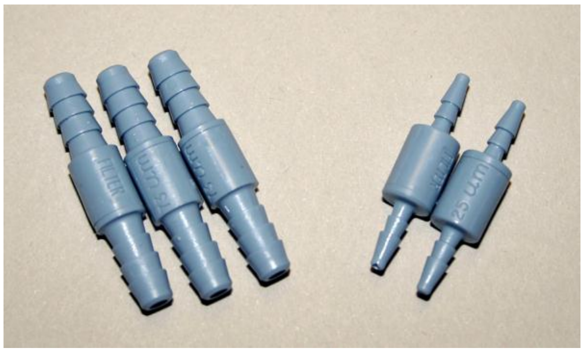
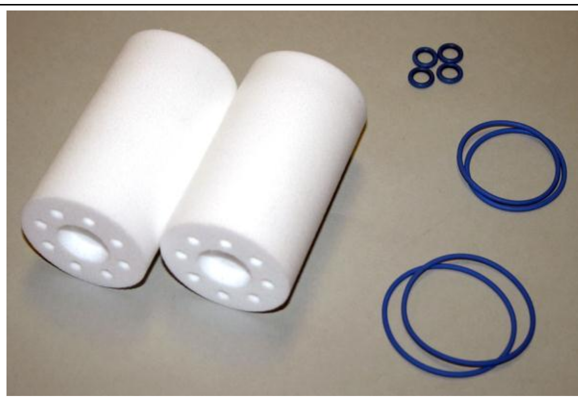
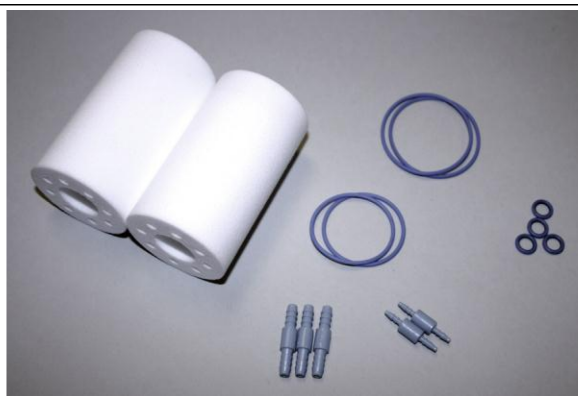
Whenever performing service on internal components avoid damage to the EECPC circuitry by not stressing internal wiring, through bumping, snagging or pulling. Also use electrostatic discharge (ESD) precautions:

- 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, replacement items are also available from TSI to keep your CPC operating for many years. Parts are available in kits listed below. Please contact your TSI representative for details and purchase of these items.

Table 8-1
3772/3771 CPC Maintenance and Replacement Kits

TSI Part No.		Name	Description
1031513		Replacement Filter Kit, CPC 3772 and 3771	Kit of all filters used within the CPC.
1031514		Replacement saturator wick kit, CPC 3772 and 3771	Two (2) replacement wicks and O-rings for the removable saturator base.
1031515		Maintenance Kit Model, CPC 3772 and 3771.	All items listed above.

TSI Part No.		Name	Description
1031548		Fill/Drain Bottle Kit, CPC 3772 and 3771	Fill and drain bottles, bracket, vacuum drain cap, tubing and fittings.
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).

Draining Butanol from the Butanol Reservoir

Butanol must be drained from the butanol reservoir prior to removing the saturator base and wick from the bottom of the CPC. To drain the butanol reservoir:

1. Connect butanol drain bottle (from the accessories) to the drain fitting on the back of the CPC using the mating quick-connect fitting.
2. Place the drain bottle on the floor.
3. The Drain can be initiated by using the “SDRAIN” firmware command on 3771 or by using the User Settings menu on the 3772. Detailed instructions for initiating the manual Drain for the 3772 are provided in Chapter 4.
4. The butanol drain valve will open. Often there is not a significant column of liquid in the butanol drain line to initiate flow from the butanol reservoir. Tipping the instrument toward the drain port and squeezing the butanol drain bottle will sometimes help start flow. When releasing the squeezed drain bottle, plug the hole on the bottle cap to create a vacuum and to initiate draining.
5. A special vacuum drain bottle cap is provided in the accessory kit to facilitate butanol draining using a vacuum source. Figure 8-1 shows the special cap, which consists of a vacuum port and a Balston filter. The Balston filter provides a bypass flow path. Connect the external vacuum source to the vacuum port. Connect the drain line to the Drain port on the CPC. When drain valve is open and vacuum is applied, the vacuum helps to pull excess butanol from the internal butanol reservoir and the wick. Exhaust from the external vacuum source contains butanol vapor and must be directed away from work spaces.
6. The butanol reservoir in the 3772 and 3771 CPCs is much smaller than the reservoir in predecessor models 3010, 3760, or 3762. The total volume drained from the reservoir and tubing is typically less than 7 ml. During draining, Auto-Fill is automatically turned off.

Figure 8-1
Vacuum Drain Cap Assembly

***Note**: When draining is stopped, the Auto-Fill must be turned on again by selecting this option from the User Settings menu for 3772 or through “SFill” firmware command for 3772 and 3771. Restarting the CPC can also turn Auto-Fill on.*

Caution

Whenever the instrument is turned on, the Auto-Fill is activated. Do **not** run the instrument with the saturator base and wick removed to prevent spilling butanol from the butanol reservoir.

Changing the Filters

The CPCs use three liquid filters. The liquid filters are for butanol fill, butanol drain, and the water removal system. The filter in the water removal system is called Micro-pump filter. These filters may require replacement at intervals that depend on usage. As a general estimate the butanol fill filter needs to be replaced after every 2000 hours of usage, while the other two are replaced only as needed. Replacement filters are supplied in the accessory kit and are available from TSI as maintenance kits. Refer to the earlier section Replacement Parts Kits.

Butanol Fill and Drain Filters

The butanol fill filter is found in the fill line leading from the butanol fill bottle to the fill solenoid valve. The butanol drain filter is found in the line between the reservoir and the drain solenoid valve (Figure 8-2).

1. Read warnings and cautions at the beginning of this chapter.
2. Unplug the instrument and lift off the cover by first removing the cover screws.
3. Find the filter shown in Figure 8-2.
4. Remove the tubing from the barbed fittings at the back and front of the filter.
5. Replace the filter with the 73 μm filter (P/N 1602088) found in the accessory kit. This filter has no preferred direction.

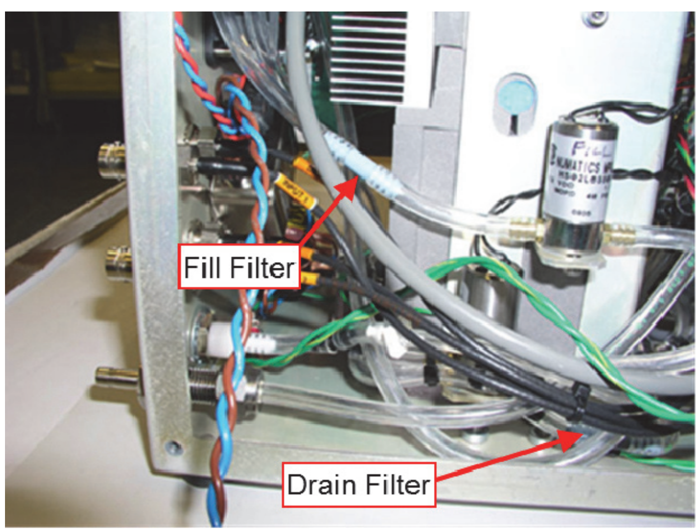


Figure 8-2
Replacing the Butanol Fill and Drain Filters

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. This filter should generally be replaced only if it becomes blocked. 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). If the feature is on and no liquid flows in the liquid column, the micro-pump filter needs to be changed.

1. Read the warnings and cautions at the beginning of this chapter.
2. Unplug the instrument and lift off the cover by first removing the cover screws.
3. Find the filter shown in Figure 8-3.
4. Remove the tubing from the barbed fittings at the back and front of the filter.
5. Replace the filter with the 25 µm filter (P/N 1500192) found in the accessory kit. This filter has no preferred direction.

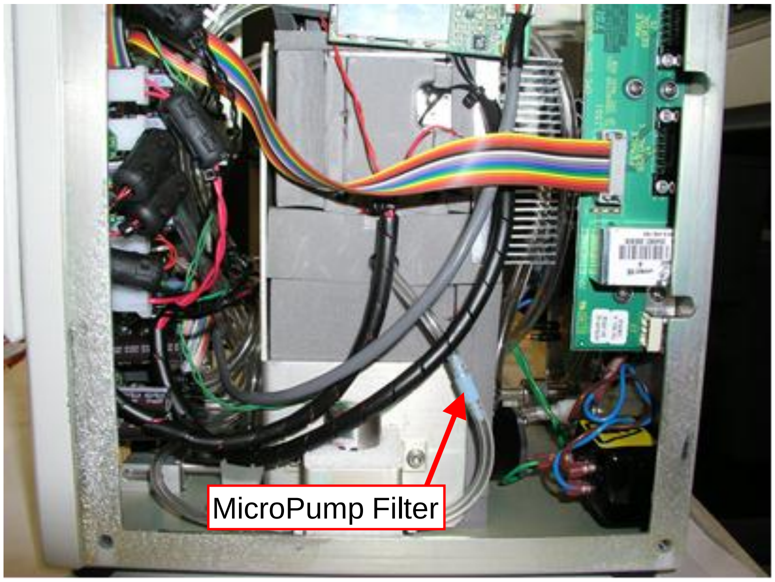


Figure 8-3
Replacing the Micro Pump Filter

Removing and Installing the Saturator Wick

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 saturator assembly removed to prevent spilling butanol from the butanol reservoir.

Tools Needed

Plastic bag with seal, Phillips-head screwdriver, 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, suitable to hold the 3” × 1.75” 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. Initiate the Manual Drain option as described in “Draining Butanol from the Butanol Reservoir” section.
4. Once drained, turn the CPC off and remove the vacuum source from the external vacuum port.
5. Remove the inlet screw indicated in Figure 8-4 on the front panel and pull out the inlet tube. The inlet tube will not pull all the way out. It will stop when it has cleared the saturator block, approximately half an inch.

Figure 8-4
Inlet Tube

6. To access the saturator base on the bottom panel, tilt the CPC on its side so it is lying on the table. Place paper towels on the table under the saturator base to absorb any butanol that spills out. Do ***not*** turn it upside down.

7. Remove the three screws which hold the base in the saturator block as shown in Figure 8-5. Release the handle in the base by loosening the thumbscrew.

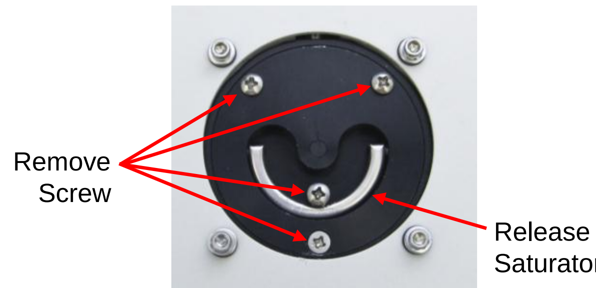


Figure 8-5
Wick Removal

8. Using the saturator handle, pull the saturator base straight out. The wick is attached and will be removed with the base. It will be snug but avoid using a twisting motion.

9. Remove the 2-inch screw securing the wick to the base as indicated in Figure 8-6. Pull the wick straight off the base. **Avoid using a twisting motion** because the wick is keyed onto the base with dowel pins and the soft wick material can rip.

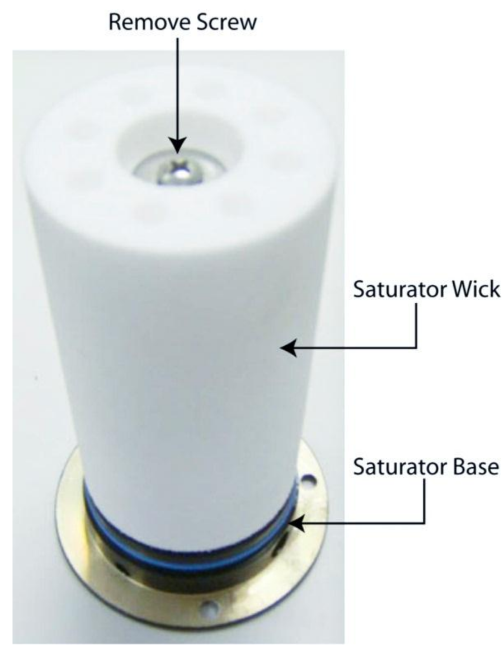


Figure 8-6
Removing the Wick from the Saturator Base

10. Place the wick in the plastic bag and seal the bag. Replace the saturator base in the CPC prior to shipping. This will prevent the aerosol path from becoming contaminated. Re-secure the inlet tube. The 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.

11. To install a wick back into the CPC, confirm that four O-rings on the saturator base are in place and undamaged. Replacement O-rings are provided in the accessory kit if an O-ring on the saturator base becomes lost or damaged. Figure 8-7 shows the two outer O-rings (P/N 2501172, 2501569) and Figure 8-8 shows the two inner O-rings (P/N 2500021).

Figure 8-7
O-Rings on Saturator Base (P/N 2501172 and 2501569)

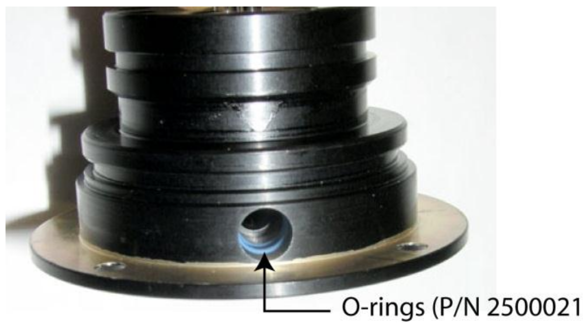


Figure 8-8
O-Rings on Saturator Base (P/N 2500021)

12. Slide the wick back onto the saturator base using the two dowel pins to key it. This will keep the holes aligned as the wick is replaced in the CPC. Replace the 2-inch screw and washer.
13. Keep the CPC turned off and the vacuum supply disconnected from the external vacuum port on the back panel. Tilt the CPC on its side to access the bottom panel. The CPC can lie flat on its side but do ***not*** turn it upside down.
14. Reinsert the wick and base and secure to CPC using the three screws indicated in Figure 8-5. In case the wick does not insert easily, follow these tips:
    i. If the CPC has recently been turned off, the saturator may still be warm. Let the saturator cool down to room temperature before inserting the wick.
    ii. Apply Krytox O-ring grease (accessory kit) to the bottom O-ring only. Do ***not*** use silicon-based O-ring grease.
15. Reinsert the inlet tube and secure the sleeve with the screw indicated in Figure 8-4.

16. Turn on the instrument and use the Auto-Fill option to refill the reservoir with butanol. See "User Settings" in Chapter 4.

Verifying Flow Rate

To measure the instrument sample flow rate, connect a low pressure-drop flowmeter to the CPC inlet. A bubble flowmeter or a thermal flowmeter works best. A TSI mass flowmeter also works because it is corrected for atmospheric pressure to give volumetric flow. The flow rate should be 1.0 L/min (0.035 cfm) ±5 percent. If the flow rate is too low, the orifice or nozzle may be plugged, the vacuum may be less than 18 inches of mercury, or the pressure drop of the test flowmeter may be too high. A clogged orifice or nozzle can be further verified by the pressure drop across the orifice or nozzle which can be read on the front panel display for the 3772 or through serial command for both 3772 and 3771. If you suspect a clogged orifice or nozzle, contact TSI for instructions.

Calibration

Aside from the optics alignment, the initial factory checkout of the electronics, and the periodic flow verification, the CPC requires no calibration. The flow is controlled by a critical orifice, and thus, no adjustments are needed. The minimum detectable particle size is controlled by the supersaturation ratio of the fluid vapor in the condenser. Since the fluid droplets grow to nearly the same size, there is no particle size discrimination by electrical pulse-height. Finally, the CPC is a single-particle counter, there is no photometric calibration for concentration.

Correcting Flooded Optics

Due to the nature of the reservoir in the CPC, the inlet tube must not be plugged for more than a couple seconds when the instrument is in operation. In addition, the instrument should not be tilted more than 10º when it is in operation. In these events the vacuum flow can draw fluid from the reservoir through the entire flow path, including the optics.

Usually the first sign of flooding is the particle concentration decreases or changes erratically. In addition, the vacuum may have trouble functioning, you may see fluid in the vacuum lines, or you may hear a slurping sound coming from the CPC.

If you suspect the CPC is flooded, shut off the vacuum pump or disconnect the vacuum system. Follow these steps to dry out the instrument:

1. Drain the reservoir following the steps in the "Draining Butanol from the Butanol Reservoir" section in this chapter.
2. Remove the cover from the CPC.
3. Inspect all tubing to make sure that no fluid is in the lines. If there is, **remove the tubing** and blow out any fluid with clean, compressed air. Tubing needs to be removed prior to cleaning to avoid other parts, e.g., pressure transducer, that could be damaged by compressed air.
4. With fill bottle disconnected, run the CPC for 48 hours with vacuum to thoroughly dry out the optics.
5. Refill the CPC with clean working fluid.
6. While sampling room air, use an oscilloscope to check the pulse height of the analog pulses from the CPC. See the "Viewing Analog Pulses" procedure next in this chapter.
7. If the pulse height is not within a normal range, the CPC should be returned to TSI to have the optics cleaned. Refer to "Returning the CPC for Service" later in this chapter for directions on returning the CPC to TSI.

Viewing Analog Pulses

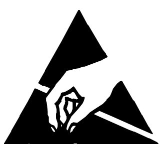
You may want to observe the pulse shape of droplets passing through the CPC optics by looking at the electronic signal produced in the photodetector. This signal is produced when detecting scattered light from the droplets passing through the laser beam. In general, the pulses will be fairly uniform in shape and size regardless of the initial size of the particles detected.

Notes:

- ❑ *Viewing analog pulses should only be attempted by someone who is familiar with the operation of the CPC and who is technically qualified.*
- ❑ *When removing the cover of the CPC, observe the laser warning label on the inside of the instrument.*

W A R N I N G

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



C a u t i o n

Whenever performing service on internal components avoid damage to the CPC 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

Using an oscilloscope, observe the analog electrical pulses from the photodetector by following these steps:

1. Remove power from the CPC.
2. Remove the CPC cover.
3. Connect a “SMC Plug to BNC male” cable (not included) from J101 on the detector board to an oscilloscope as shown in Figure 8-9. The oscilloscope should be 50-ohm terminated. When viewing the signal on the scope, the signal height should be scaled down by a factor of 10. For a typical pulse of 3 volts, the scope will read only 300 mV.

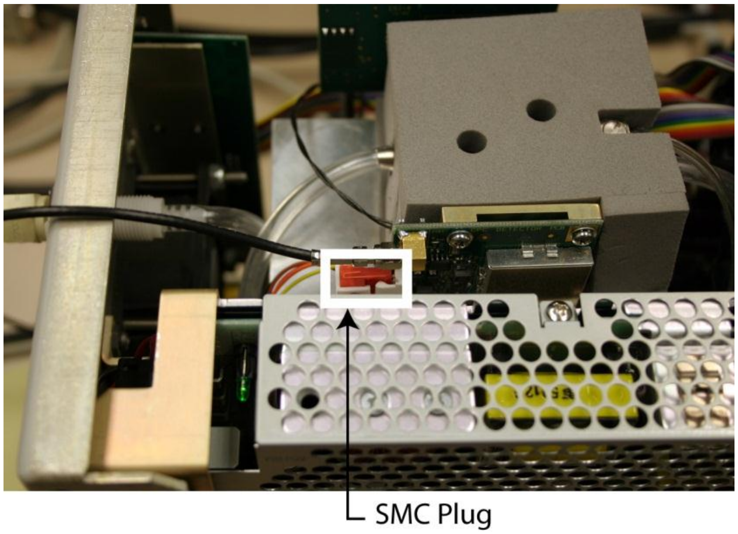


Figure 8-9
Connecting SMC Plug to Detector Board

4. Apply power to the CPC.

   A typical analog pulse trace for 3772/3771 CPC is shown in Figure 8-10. The minimum pulse amplitude is about 1 volt (100 mV on the oscilloscope) and the pulse width is about 0.30 microseconds. The pulse amplitude may range as high as 3.5 volts (350 mV on the oscilloscope).

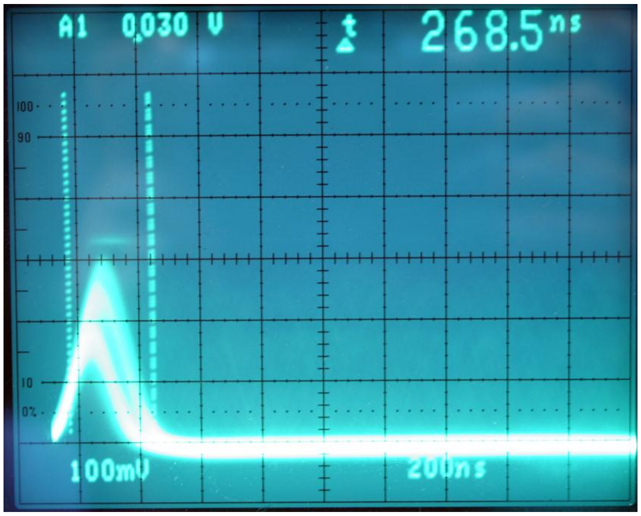


Figure 8-10
Typical Analog Pulse Trace

Calibration Reminder

TSI recommends yearly calibrations for your CPC. Ten months after the instrument's last calibration, a series of periodic reminders are generated to notify the user that a yearly recalibration is due soon. These reminders come in two forms: a message appears on the screen (3772 only) and an error bit is set which is seen with the RIE firmware command. The message and bit will remain until cleared by either of these two methods: pressing a front panel key (3772 only), or sending the SCCR firmware command. After this, the reminder remains cleared until either another one is generated in several days, or the last reminder is given, or the unit is recalibrated. Be aware this is only a reminder and will not affect the operation of your instrument in any way, even if it is not recalibrated. Although not necessary, if you wish to check the instrument's last calibration date or reminder status, use the SCD firmware command, which is explained in the appendix.

False Count Check

If you find that the CPC is continually counting a lot of particles even with a high efficiency (HEPA or ULPA) filter on the inlet, the CPC 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 for "Correcting Flooded Optics" in this chapter. If the false count problem continues, it is most likely due to a leak. If the wick has recently been replaced, confirm that the aerosol inlet is secured on the front panel.

If the false count problem continues, return the CPC to TSI for service.

Error Messages and Troubleshooting

The table below provides basic information on the errors generated by the Model 3772/3771 CPC, and suggestions for corrective action.

When an error occurs, the status LED on the front panel of the CPC turns off. Status parameters can provide information for troubleshooting the error. On the 3772/3771, the RIE firmware command will list instrument errors. On the 3772, in addition, refer to the Status Screen for status errors (see Figure 4-8). An exclamation mark will appear next to the parameter which is out of range. For both CPCs, refer to the table below to help identify the problem.

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 screws before lifting off the cover.

Table 8-2
Troubleshooting

Problem	Description	Problems/Suggestions
Concentration out of range	Concentration is higher than 10^4 particles/cm^3	Concentration entering the CPC is too high. Dilute the aerosol before it enters the CPC.
Saturator temp out of range	Saturator temperature out of range ~±0.5 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 an appropriate environment, allow temperature to stabilize.
Condenser temp out of range	Condenser temperature out of range ~±0.5 degrees 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
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 an appropriate environment, allow temperature to stabilize.
Nozzle or orifice pressure getting near to out of range; aerosol flow rate getting near to out of range – Indicated by a ‘?’ instead of a ‘!’ on the display.	The orifice and/or nozzle flow is getting close to being out of range. This uses tighter criteria than the “Nozzle or orifice pressure out of range” condition described in the next row, so it is a warning and not an error.	Apply sufficient external vacuum. Contact a TSI service technician.

Problem	Description	Problems/Suggestions
Nozzle or orifice pressure out of range; aerosol flow rate is out of range	Orifice pressure is <10 or >90 kPa; Nozzle pressure is <1 or >6 kPa.	Apply sufficient external vacuum. Contact a TSI service technician.
Flooded instrument	Butanol liquid is present in the instrument optics causing a variety of problems including erratic or very low concentration readings and/or changes in transducer pressure measurements.	Although the 3772 and 3771 CPCs have 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 tubing for the presence of liquid. Start by looking at tubing connected to the pressure transducers. Carefully remove and dry out wet tubing then replace. ***Note**: Don't dry the tubing in place to avoid damaging other parts in the CPC.* 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 saturator base without replacing the wick. Turn the instrument on and make sure the external vacuum is on and the fill bottle is disconnected. Allow the instrument to operate for at least 20 hours. Refer to "Correcting Flooded Optics" for detailed instructions.
Status: Laser power low	Detector in the laser indicates low laser power.	Contact a TSI service technician.
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 taking off the cover of the CPC and looking through the reservoir window. If it is difficult to identify the liquid level, using a flash light and tipping the CPC a couple degrees are helpful. 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 4-6). 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 CPC, or if you have technical or application questions about this instrument, contact an applications engineer at TSI Incorporated, (651) 490-2811.
- If the CPC 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 +1 (651) 490-2811
E-mail: technical.service@tsi.com

TSI GmbH
Neuköllner Strasse 4
52068 Aachen
GERMANY

Telephone:	+49 241-52303-0
Fax:	+49 241-52303-49
E-mail:	tsigmbh@tsi.com
Web:	www.tsiinc.de

TSI Instruments Ltd.
Stirling Road
Cressex Business Park
High Wycombe, Bucks
HP12 3ST
UNITED KINGDOM

Telephone:	+44 (0) 149 4 459200
Fax:	+44 (0) 149 4 459700
E-mail:	tsiuk@tsi.com
Web:	www.tsiinc.co.uk

Returning the CPC for Service

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

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

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. See "Moving and Shipping the CPC" in Chapter 4 for detailed instructions.

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).

APPENDIX A
Specifications

Table A-1 contains the specifications for the Model 3772/3771 Condensation Particle Counter (CPC). These specifications are subject to change without notice.

Table A-1
Model 3772/3771 CPC Specifications

Particle size range	
Min. detectable particle (D_{50})	10 nm, verified with DMA-classified sucrose particles
Max. detectable particle	> 3 mm
Particle Concentration Range	0 to 10^4 particles/cm^3, single particle counting with continuous, live-time coincidence correction that can be turned off
Particle Concentration Accuracy ...	±10% at <10^4 particles/cm^3
Response Time...............................	≅3.0 sec to 95% in response to concentration step change
Aerosol Flow Rate	1± 0.05 L/min
Flow source......................................	External vacuum
Flow control......................................	Volumetric flow control of aerosol flow by internal critical orifice; Differential pressure across critical orifice is monitored.
Operating Temperatures	
Saturator	39°C ±0.2°C
Condenser..	22°C ±0.2°C
Optics	40°C ±0.2°C
False Background Counts.............	<0.001 particle/cm^3, based on 12-hr average
Aerosol Medium	Recommended for use with air; safe for use with inert gases such as nitrogen, argon, and helium (performance specifications are for air)
Environmental Operating Conditions	Indoor use Altitude up to 2000 m (6500 ft) Inlet (Ambient) 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 to 90% RH noncondensing Pollution degree II Overvoltage category 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

Table A-1
Model 3772/3771 CPC Specifications

Communications	
Protocol	Command set based on ASCII characters
Interface	USB, type B connector, USB 2.0 compatible at 12 MB
	RS-232, A-pin, "D" subminiature connector, pinouts compatible with standard IBM-style serial cables and interfaces
	Ethernet, 8-wire RJ-45 jack, 10/100 BASE-T, TCP/IP
Data logging and storage (3772)	
Averaging interval	SD/MMC flash memory card (3772 only)
	1, 2, 3, 4, 5, 6, 10, 12, 15, 20, 30, or 60 seconds (set from front panel of 3772), software provides more averaging options
Inputs	
Analog	Two BNC connectors, 0 to 10 volts (data recording for external sensors)
Outputs	
Digital display	Concentration, time and total counts, status (temperatures, pressures, laser power, liquid level, etc.), and user settings
	BNC connector, 0 to 10 volts, user-selectable function output (linear concentration, also DMA voltage control for 3772, DMA voltage control function is not available for Model 3771 CPC)
Analog	BNC connector, TTL level pulse, 50-ohm termination, nominally 350 nanoseconds wide
Software	Aerosol Instrument Manager® software (USB and RS-232 compatible)
Physical Features	
3772 front panel	LCD display, aerosol inlet, LED particle indicator light, LED status indicator light, six-button keypad, flash memory card slot
3771 front panel	Aerosol inlet, LED particle indicator light, LED status indicator light.
Back panel	Power connector, USB, Ethernet, two A-pin D-sub serial connectors, two BNC inputs, two BNC outputs, fan, butanol-fill connector, butanol-drain connector, external vacuum port, fill bottle and bracket
Dimensions (HWD) (nominal)	26 cm × 18 cm × 25 cm (10 in. × 7 in. × 10 in.), not including fill bottle and bracket
Weight	5.5 kg (12 lbs)
Power Requirements	100–240 VAC, 50/60 Hz., 200 W maximum
Fuse	4.0A 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 (MISCLLANEOUS) 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: 1000

RIF Read the inlet flow rate setting in liters per minute

Returns: A floating point number from 0.0 to 9999.9

Example: 1.0

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: 22.0

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 => Calibration Reminder
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: 82.4

RPN Read the nozzle pressure transducer. Units are in kPa

Returns: A floating point number from 0.000 to 10.000

Example: 2.50

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

RALL Read a set of current values

Returns Concentration, instrument errors, saturation temp, cond temp, optics temp, cabinet temp, ambient pressure, orifice press, nozzle press, laser current, liquid level

RLP Reads the laser current in milliamps

Returns: An integer from 0 to 150

Example: 70

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: 3771, 3772, 3775, 3776, 3790 or 100

Example: 3772

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

RD Legacy command to read the concentration in p/cc, 1 sec. avg.

RV Read the version string.

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

RCOUNT1 Reads the 1 second corrected counts buffer

Example: 258

RCOUNT2 Reads the 1 second uncorrected counts buffer

Example: 317

SET Commands

SAV Set analog output full scale voltage

Params
1 => 0 - 1 Volt
2 => 0 - 2 Volt
3 => 0 - 5 Volt
4 => 0 - 10 Volt

Example SAV,4 (A full scale concentration will equal 10V)

SSTART Start a new sample

Params
0 – Stop
1 - Start, data type 1
2 - Start, data type 2

Example SSTART,1 (Starts new sample)

Unit returns once/sec

Data Type 1:

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 => elapsed time(sec), integer

D => tenth sec corrected counts, integer

C => tenth sec concentration, float

AN1 => analog input 1, float

AN2 => analog input 2, float

RIE => See help cmd for RIE

Data Type 2, 3776:

UX,C,C,C,C,C,C,C,C,C,C,R,R,R,R,R,R,R,R,R,R,F,F,F,F,F,F,F,F,F,F,T,T,T,T,T,T,T,T,T,T

UX => elapsed time(sec), integer

C => tenth sec concentration, float

R => tenth sec raw counts, integer

F => flowrate(cc/0.1sec), float

T => tenth sec deadtime(sec), float

Data Type 2, 3771/72/75:

UX,C,C,C,C,C,C,C,C,C,C,R,R,R,R,R,R,R,R,R,R,F,DTC,T,T,T,T,T,T,T,T,T,T

UX => elapsed time(sec), integer

C => tenth sec concentration, float

R => tenth sec raw counts, integer

F => flowrate(cc/sec), float

DTC => deadtime correction, float

T => tenth sec deadtime(sec), float

SCM Set the operating mode. Model 3771 will not go into SMPS 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,22.0 (changes the condenser set point to 22.0 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)

SAO Set analog output voltage proportional to concentration.

The analog output is 0 to 10V.

Params: 0 => Off
1 => 1E1
2 => 1E2
3 => 1E3
4 => 1E4
5 => 1E5 (CPC100 only)

Example: SAO,4 (A concentration reading of 1E4 will equal 10V)

SCOM Setup auxiliary comport

Params: Port => 1,2,3
Baud => 2400,4800,9600,14400,19200,28800,38400,57600,115200
Bits => 5,6,7,8
Parity => E, O, N
Stop => 1, 1.5, 2

Example: SCOM,2,9600,7,E,1 (Set 2nd serial port to 9600, 7 bits, 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)

SFILL Turn on/off auto fill

Params: 0 => Off
1 => On

Example: SFILL,1 (turns on auto fill)

SDRAIN Turn drain on/off for Models 3771, 3772, 3790, CPC100

Params: 0 => Off
1 => On

Example: SDRAIN,1 (turns drain on)

SCC Turn coincidence correction on/off

Params: 0 => Off
1 => On

Example: SCC,1 (turns coincidence correction on)

SCCM Set the concentration correction multiplier

Only concern is multiplied, counts are **not** multiplied

Displayed concern in totalizer mode is **not** multiplied (3775, 3776 only)

Params: Multiplier => 0.5 – 2.0

Example: SCCM,0.953 (multiply concentrations by 0.953)

SCD Set calibration date, reset reminder count and last reminder date

Params: MMDDYY, MM=01–12, DD=01–31, YY=00–99

Example: SCD,110208 (set cal and last reminder date to Nov. 2, 2008, reset count)

Example: SCD (returns cal date, date of last reminder, # of reminders left)

SCCR Clear calibration reminder bit and displayed message

Returns: OK or ERROR if the flag didn't need clearing

Params: none

Example: SCCR (clears 9^{th} bit in RIE command and the display message)

MISC (MISCELLANEOUS) Commands

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)

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). If formatting the flash drive becomes necessary, see the instructions in Chapter 7 "Flash Memory Card Specification".

DIR Read the flash card directory (except 3771).

CD Change the active flash card directory (except 3771).

HELP Commands

Help,Read

Help,Set

Help,Misc

Help,x where x=Command Name

(This page intentionally left blank)

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

Caldow, R.C., M.R. Palmer, and F.R. Quant
"Performance of the TSI Model 3010 Condensation Particle Counter,"
paper presented at the *American Association for Aerosol Research Conference*, San Francisco, California, October 1992. (TSI paper A83)[*]*

[*]Paper refers to TSI Model 3010 CPC, a predecessor of the Model 3772

Fink, M.A., R.C. Caldow, H.S. Han, E.M. Johnson, S.J. Olson, and M.A. Woessner
”Characterization of New Butanol-based Condensation Particle Counters,” poster #8PC1, *American Association for Aerosol Research Conference*, Austin, Texas, October 2005

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
"Characterization of Two New Butanol-based Condensation Particle Counters." Poster #IPC17 at 2005 AAAR, Austin, Texas, October 2005.

Shi Q, H.S. Han, S.W. Kerrigan, and E.M. Johnson
"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

(This page intentionally left blank)

Index

N

O

P–Q

R

S

T

U

V

W–X–Y–Z

Reader's Comments Sheet

Please help us improve our manuals by completing and returning this questionnaire to the address listed in the "About This Manual" section. Feel free to attach a separate sheet of comments.

Manual Title __Model 3772/3771 Condensation Particle Counter__ P/N 1980529

1. Was the manual easy to understand and use?

   ☐ Yes ☐ No

   Please identify any problem area(s) ______________________________

   ____

   ____

2. Was there any incorrect or missing information? (please explain) ______________________________

   ____

   ____

3. Please rate the manual according to the following features:

	Good	Adequate	Poor
Readability	☐	☐	☐
Accuracy	☐	☐	☐
Completeness (is everything there?)	☐	☐	☐
Organization (finding what you need)	☐	☐	☐
Quality and number of illustrations	☐	☐	☐
Quality and number of examples	☐	☐	☐

   Comments: ______________________________

   ____

   ____

4. Which part(s) of this manual did you find most helpful? ______________________________

   ____

   ____

5. Rate your level of experience with the product:

   ☐ Beginning ☐ Intermediate ☐ Expert

6. Please provide us with the following information:

   Name ______________________ Address ______________________

   Title ______________________ ______________________

   Company ______________________ ______________________

UNDERSTANDING, ACCELERATED

TSI Incorporated – Visit our website **www.tsi.com** for more information.

USA	**Tel:** +1 800 874 2811	**India**	**Tel:** +91 80 67877200
UK	**Tel:** +44 149 4 459200	**China**	**Tel:** +86 10 8219 7688
France	**Tel:** +33 1 41 19 21 99	**Singapore**	**Tel:** +65 6595 6388
Germany	**Tel:** +49 241 523030		

P/N 1980529 Rev F Printed in U.S.A.