Particle Instruments

Model 3010 Condensation Particle Counter

Instruction Manual

P/N 1933010, Revision F
August 2002

TSI®

Model 3010 Condensation Particle Counter

Instruction Manual

Manual History

The following is a manual history of the Model 3010 Condensation Particle Counter Instruction Manual, P/N 1933010.

Revision	Date
First printing	May 1992
A	July 1993
B	September 1993
C	January 1994
D	May 1996
	January 1999
E	July 2000
F	August 2002

This manual was first published, in final form, May 1992.

In revision A, the following changes were made: a change to Figure 1 labels, incorporates a flow schematic in Chapter 1, a revised packing list in Chapter 2, a CPC dimension drawing in Chapter 4, a typical digital pulse trace illustration in Chapter 6, a revised EPROM replacement procedure in Chapter 7 and an index.

In revision B, the following changes were made: the addition of Model 3010 CPC software in Table 2-1, a correction to Table C-2, the coincidence level change in Table 6-1, and a modification made to the setup instructions in Chapter 4.

In revision C, TSI's customer service number was changed.

In revision D, TSI's "Limitation of Warranty and Liability" on page iii was updated.

In January 1999, TSI's area code was changed from 612 to 651.

In Revision E, TSI's Limitation of Warranty and Liability was updated.

In Revision F, TSI's phone numbers and address were updated and reference to *CPCount Software* was changed to refer to *Aerosol Instrument Manager Software for CPC and EAD*. Appendix D was removed.

Part Number 1933010 / Revision F / August 2002

Address TSI Incorporated / 500 Cardigan Road / St. Paul, MN 55126 / USA

Fax No. (651) 490-3824

E-mail Address particle@tsi.com

Limitation of Warranty and Liability
(effective July 2000)

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

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. 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.

c. 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.

d. 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**.

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 NO EVENT SHALL SELLER BE LIABLE FOR ANY SPECIAL, 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.

Safety

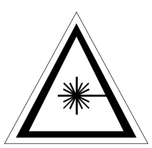
This section gives instructions to promote safe and proper operation of the Model 3010 Condensation Particle Counter (CPC), samples of warnings found in this manual, and labels attached to the instrument.

Laser Safety

The Model 3010 Condensation Particle Counter is a Class 1 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 invisible 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 housing while power is supplied to the instrument



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

Chemical Safety

The Model 3010 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.
- ❑ 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.

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.

WARNING

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.

Labels

Advisory labels and identification labels are attached to the outside of the CPC housing and to the heatsink and optics on the inside of the instrument.

Figure 1 shows the internal and external labels for the Model 3010 CPC.

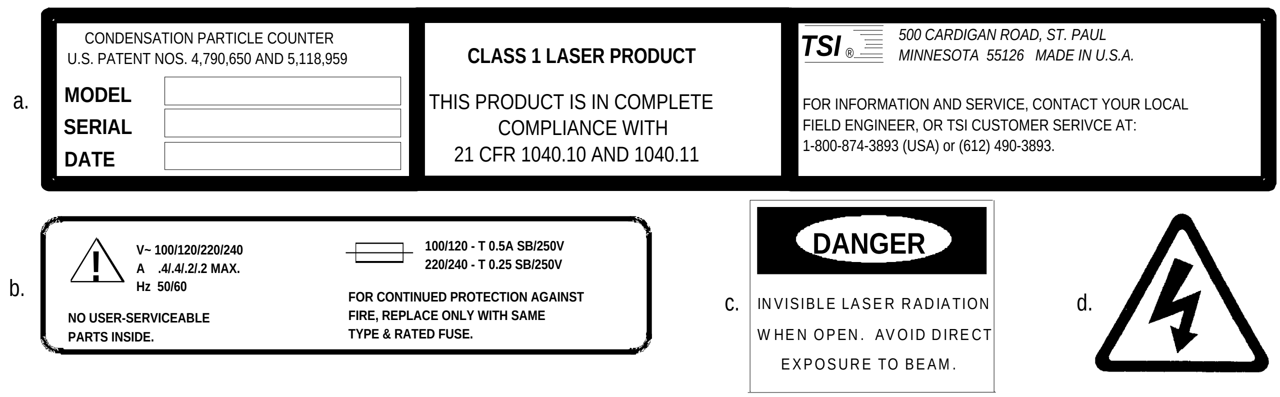


Figure 1
Advisory Labels: (a) identification labels (on heatsink back panel); (b) power requirements label (on heatsink); (c) warning label (on the optics housing); (d) AC receptacle

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About This Manual

Purpose

This is an instruction manual for the installation and operation of the Model 3010 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 CPC, a list of features, and a brief description of how the instrument works.
- **Chapter 2: Unpacking the Condensation Particle Counter**
  This chapter contains a packing list and gives unpacking instructions for the CPC.
- **Chapter 3: Controls, Indicators and Connectors**
  This chapter gives a description of the controls, indicators, and connectors on the CPC.
- **Chapter 4: Setting Up the Condensation Particle Counter**
  This chapter contains procedures for setting up the CPC including checking line voltage configuration, setting DIP switches and connecting the CPC to another system.
- **Chapter 5: Operating the Condensation Particle Counter**
  This chapter contains operating precautions and operating procedures for the CPC.
- **Chapter 6: Application Information**
  This chapter gives general application information for the CPC.
- **Chapter 7: Maintenance and Troubleshooting**
  This chapter contains routine and special maintenance procedures as well as troubleshooting information for the CPC.
- **Chapter 8: Service**
  This chapter gives directions for contacting technical resources at TSI or returning the CPC for service.
- **Appendix A: Specifications**
  This appendix contains operating specifications for the CPC.
- **Appendix B: Theory of Operation**
  This appendix gives a detailed theory of operation for the CPC.

- **Appendix C: Computer Interface and Commands**
  This appendix gives the information you need if you are connecting the CPC to a computer or writing your own software.

Related Product Literature

- ***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 3010 CPC. 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 data collected by a CPC.

Getting Help

To obtain assistance with the Model 3010 Condensation Particle Counter, either refer to Chapter 8, "Service," or contact Customer Service:

TSI Incorporated (Particle Instruments)
500 Cardigan Road
St. Paul, MN 55126 USA
Fax: (651) 490-3824
Telephone: 1-800-874-2811 (USA) or (651) 490-2811

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
St. Paul, MN 55126
Fax: (651) 490-3824

CHAPTER 1
Product Overview

This chapter contains an introduction to the Model 3010 Condensation Particle Counter (CPC) and a brief explanation of how the CPC operates.

Product Description

The Model 3010 CPC, shown in Figure 1-1, is a compact, single-particle counting instrument used in a variety of applications requiring detection of particles 0.01 µm in diameter and larger.

Figure 1-1
TSI Model 3010 Condensation Particle Counter

The CPC, when combined with a suitable vacuum pump, can be used as a stand-alone sensor or can be connected directly to a computer or to a data acquisition system.

Model 3010 CPC features include:

- A sampling flowrate of 1.0 lpm (0.035 cfm)
- An internal microprocessor to allow direct communications with other systems
- An LCD display indicating particle concentration in metric units or in cumulative number of particles counted over a fixed time period
- An automatic working-fluid fill system with a reservoir that allows the instrument to run seven days between refills.

Refer to Appendix A, "Specifications" for Model 3010 CPC operating specifications.

How it Works

The Model 3010 CPC measures the number concentration of individual particles that are 0.01 µm in diameter and larger. The particles are detected by condensing alcohol vapor onto the particles, causing them to grow into droplets. These particles, in droplet form, are easily counted by a simple optical particle detector (Figure 1-2).

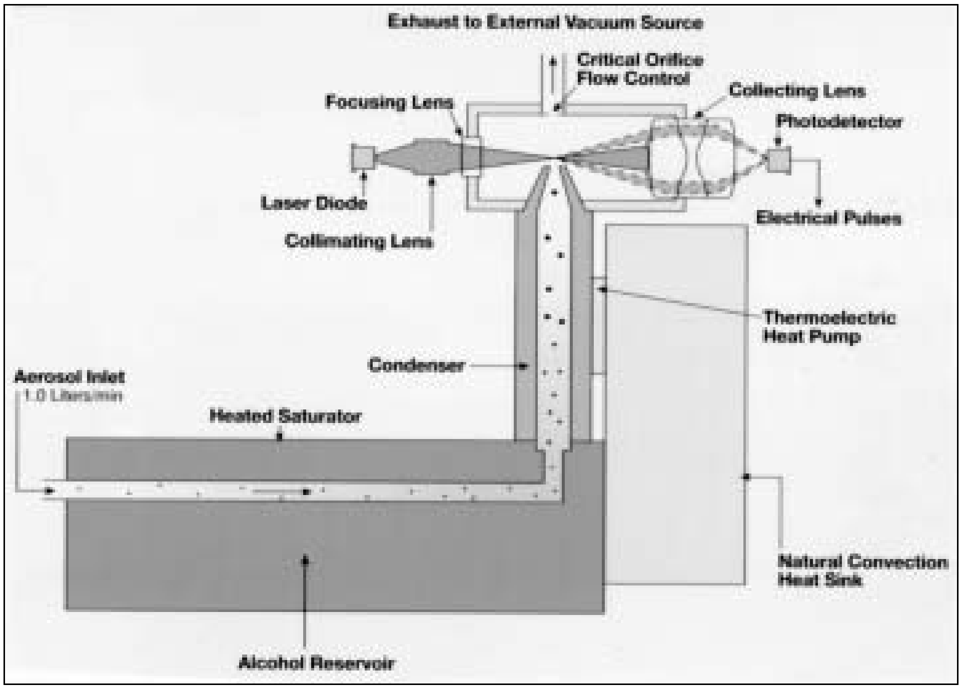


Figure 1-2
Model 3010 CPC Flow Schematic

A heatsink, which makes up the entire back panel of the CPC, dissipates heat by natural convection. A cabinet purge airflow (1.0 lpm) helps to cool the electronics within the cabinet and creates a slight negative pressure within the instrument. Particles that may be generated inside the cabinet are quickly carried out through the vacuum line and do not contaminate the surrounding area.

See Appendix B for a detailed theory of operation for the CPC.

CHAPTER 2

Unpacking

Use the information in this chapter to unpack the Model 3010 Condensation Particle Counter (CPC).

Packing List

Table 2-1 shows the packing list for the CPC.

Table 2-1
CPC Packing List

Qty.	Description		Part No.
1	Model 3010 Condensation Particle Counter		301000
1	12-foot 9-pin (M/F) interface cable		962002
1	Cable adapter 25-pin (F) to 9-pin (M)		962003
1	Power-cable,	110-120 V *or*	1303053
		220-240 V	1303075
1	AQ Filter		1602067
1	Fill bottle assembly (tested)		
	includes: 1 bottle		2002017
	Fill label		2404295
	Silichem tubing, 3 ft.		3001257
	Barb fitting, quick disconnect		1601758
1	Drain bottle assembly (tested)		
	includes: 1 bottle		2002017
	Drain label		2404298
	Silichem tubing, 7 ft.		3001257
	Barb fitting, quick disconnect		1601758
1	Instruction manual		1933010
1	Aerosol Instrument Manager® Software		
	for CPC/EAD		390065
	1 instruction manual		1930062
1	Model 3010 CPC Software		1906097

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.

Unpacking Instructions

The Condensation Particle Counter comes fully assembled with protective coverings on the sampling and vacuum inlets and electrical connections.

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, “Service,” gives instructions for returning the CPC to TSI Incorporated.

CHAPTER 3

Controls, Indicators, and Connectors

Use the information in this chapter to familiarize yourself with the location and function of controls, indicators, and connectors on the Model 3010 Condensation Particle Counter (CPC).

This chapter is organized into two sections: one section describes the front panel display, controls and indicators and one section describes the back panel connectors and switches.

Front Panel

Figure 3-1 shows the front panel of the CPC. The front panel includes an LCD display, control buttons, particle and status indicator lights, a liquid level window, and a sampling inlet**.** Each area is labeled for easy reference.

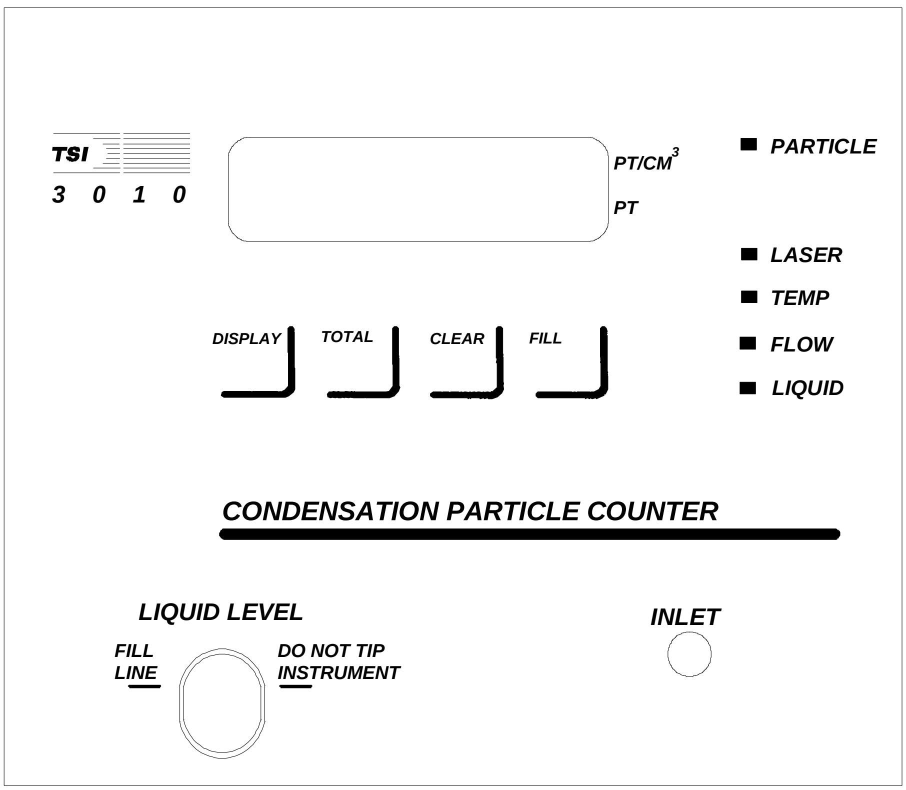


Figure 3-1
CPC Front Panel

LCD Display

The front panel has a 5-digit liquid crystal display (LCD) as shown in Figure 3-2. Using the **Display** and **Total** control buttons, the LCD shows particle concentration readings in particles/cm^3 (PT/CM^3), or total particle count up to 99999 (PT). For more information on LCD display operation, see “Using the CPC Controls” in Chapter 5 and “Operating at Higher Concentrations” in Chapter 6.

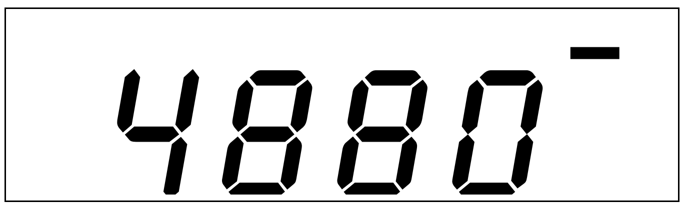


Figure 3-2
LCD Display

Control Buttons

Four control buttons control the LCD display and the fill mode of the CPC. Each button is described below. Operating control buttons with a description of the concentration and totalizer modes is described in Chapter 5.

Display	**Display** controls the output of the display screen. Press **Display** to toggle between two modes: concentration (PT/CM^3) and totalizer (PT).
Total	Press **Total** to enable and disable the totalizer mode. When totalizer mode is enabled, counting is updated internally regardless of whether you are in totalizer or concentration mode.
Clear	Press **Clear** to reset the total count and the preset totalizer time to zero (0). The total count and the totalizer time are reset to zero no matter which display mode (PT/CM^3 or PT) you are in.
Fill	Press **Fill** to manually begin filling the CPC reservoir.

Indicator Lights

Four green status lights on the right-hand side of the CPC front panel monitor these instrument parameters: laser, temperature, flow and liquid. An amber status light monitors the presence of particles.

Note: *Also refer to "Warm-Up Mode" in Chapter 5 and "Identifying Problems" in Chapter 7 for more information on the indicator lights.*

Particle	**Particle** indicates the presence of particles in the viewing volume of the instrument. When the concentration sampled by the instrument is below approximately 200 particles/cm^3 (6000 particles/ft^3), **Particle** blinks once for each particle detected by the instrument. When the concentration is higher, **Particle** constantly lights.
Laser	**Laser** lights when power is supplied to the CPC and the laser is operating within a set power range. **Laser** should always light under normal operation.
Temp	**Temp** indicates the status of the temperature difference between the saturator and condenser sections of the CPC. When power is applied to the CPC, **Temp** flashes until the operating temperature is reached.
Flow	**Flow** indicates there is sufficient vacuum supplied to the critical orifice to produce a correct flow at the inlet. This status light indicates vacuum presence rather than precise flow. As long as there is sufficient vacuum supplied to the instrument, the critical orifice will provide accurate flow control (within 10 percent).
Liquid	**Liquid** indicates there is sufficient fluid in the reservoir to allow the CPC to operate normally.

Liquid Level Window

The liquid level window shows the amount of n-butyl alcohol (butanol) available in the CPC reservoir. Butanol is necessary to operate the CPC and should be in the reservoir at all times, except when moving the instrument.

For directions on filling the CPC reservoir, see “Filling the CPC Reservoir” in Chapter 5.

Sampling Inlet

The sampling inlet is a $^3/_8$-inch outer diameter (9.5 mm) tube. The sampling inlet can be attached to a variety of fittings to allow sampling from many tubing configurations.

Back Panel

Figure 3-3 shows the back panel of the CPC. Back panel features include the COM port (A), BNC output (B), liquid fill connector (C), DIP switches (D), fuse panel (E), power cord inlet (F), vacuum connector (G), and liquid drain connector (H).

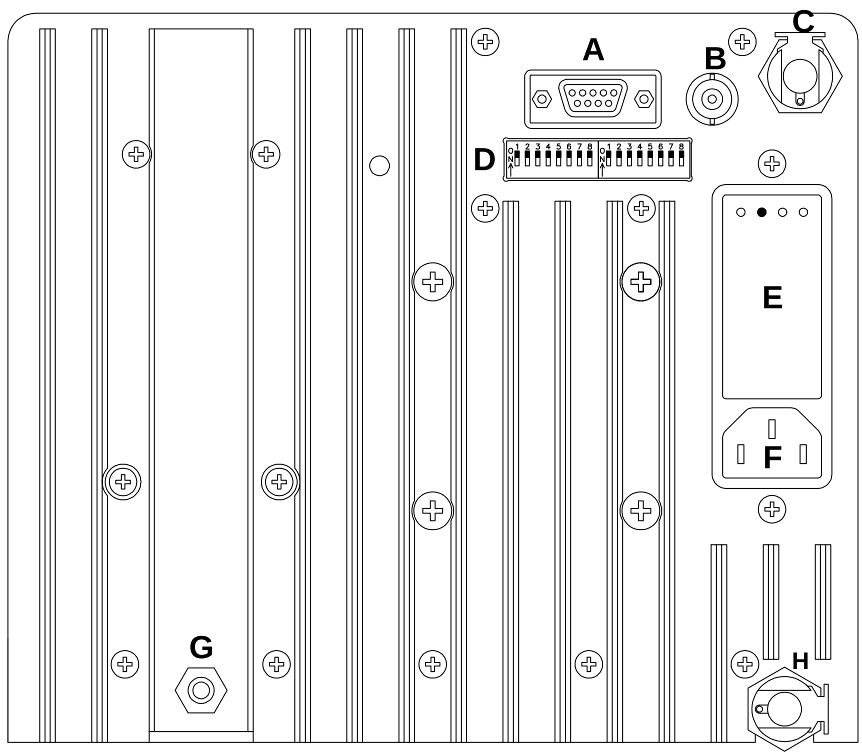


Figure 3-3
CPC Back Panel

Panel features are not labeled directly due to space restrictions but can easily be referenced using the adhesive-back reference card provided with the CPC (see “Setting DIP Switches” in Chapter 4).

Descriptions of the back panel features follow.

COM Port (A)

The COM port is a single 9-pin, D-type, subminiature communications port compatible with RS-232 devices. If you connect the CPC to a computer, use the COM port with a standard 9-pin IBM serial extension cable.

Note: *See Appendix C for a description of the computer interface hardware as well as a software program you can modify for your use.*

BNC Output (B)

You can use the BNC output to accept digital or analog signals from a variety of data acquisition hardware. Depending on the configuration of the BNC output DIP switch, the signal from the CPC corresponds either to a selected analog concentration or to a digital signal where each pulse corresponds to an individual particle counted.

See Chapter 4, "Setting DIP Switches," for information on configuring the BNC output switch.

!

Caution
The BNC output on the Model 3010 CPC is not compatible with TSI's Model 370x multiplexer processors or 71xx series processors. Connecting the BNC output to these instruments will result in damage to the CPC and/or the processors.

Liquid Supply Connector (C)

The liquid supply connector is a quick-disconnect, shut-off connection. Use the liquid supply connector with the liquid fill bottle. Refer to the "Filling the CPC Reservoir " section in Chapter 5 for more information.

DIP Switches (D)

The DIP switch array is made up of two banks of switches, each bank numbered 1 to 8. The first bank allows you to access many CPC functions including: liquid supply mode, totalizer time, analog range, and BNC output. The second bank is reserved for future use.

Refer to Chapter 4, "Setting DIP Switches," for directions on setting the first bank of DIP switches.

Fuse Panel (E)

The fuse panel allows access to the voltage selector card and the fuses. For more information on the card and the fuses, refer to "Checking the Line Voltage Configuration" in Chapter 4.

Power Cord Inlet (F)

The power cord inlet is the receptacle for the AC power cord that is supplied with the CPC.

Vacuum Connector (G)

The vacuum connector, a ¼-inch male Swagelok® connector, connects an external vacuum source to the CPC. Refer to Chapter 4, "Connecting the Vacuum Source," for directions on connecting a vacuum to the CPC.

Liquid Drain Connector (H)

The liquid drain connector is a quick-disconnect, shut-off connection for the liquid drain bottle. Refer to the "Draining the CPC Reservoir" procedure, Chapter 7, for directions on connecting the drain bottle to the liquid drain connector.

®Swagelok is a registered trademark of the Crawford Filling Co., Solon, Ohio.

CHAPTER 4

Setting up the Condensation Particle Counter

Use the information in this chapter to properly set up the Model 3010 Condensation Particle Counter (CPC).

This chapter contains these procedures:

- ❑ Positioning the CPC
- ❑ Checking the line voltage configuration, and if needed, changing the fuses
- ❑ Setting DIP switches
- ❑ Connecting the vacuum source

Positioning the CPC

The Model 3010 CPC should be positioned right-side up as shown in Figure 4-1.

1. Place the CPC on a level surface.
2. Ensure the heatsink on the back panel of the CPC is exposed to cooling, ambient air.
3. Remove the protective caps from the sampling inlet and exit flow ports (front and back panels).

Caution
To avoid damage to the CPC, provide adequate ventilation for the back panel. If you have any questions about the temperature requirements for this instrument, see Appendix A, "Specifications."

Note: *If the CPC has n-butyl alcohol (butanol) in the reservoir, be very careful when moving the CPC. The CPC can be moved on a benchtop if there is no vacuum applied and if you keep the CPC upright. If you decide to move the CPC from one location to another, use the "Draining the CPC Reservoir" procedure in Chapter 7.*

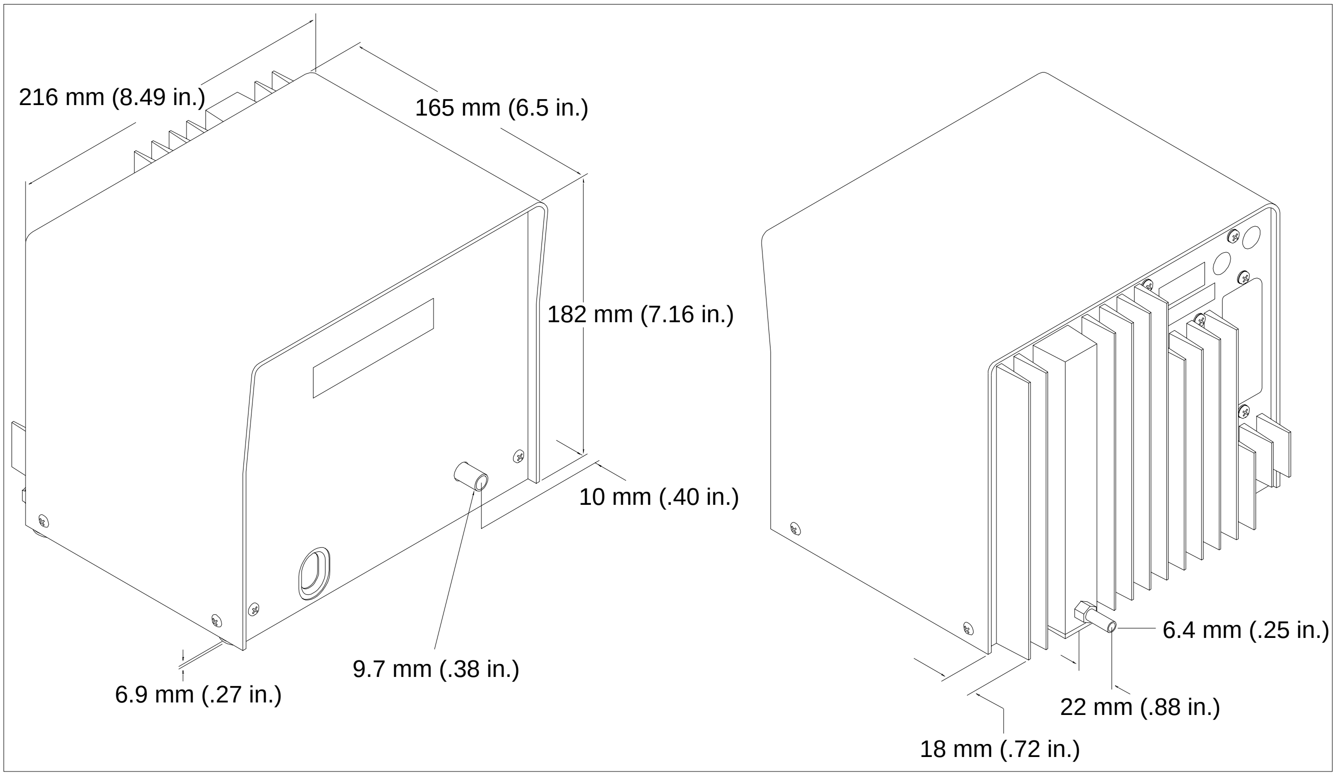


Figure 4-1
Model 3010 CPC, Front and Back Views

Checking the Line Voltage Configuration

To verify that the line voltage configuration matches local line voltages, check the back panel and study Figures 4-2 and 4-3.*

If you need to change the voltage, follow these seven steps:

1. Disconnect the power cord from the power connector.
2. Remove the fuse block/cover assembly (Figure 4-2) from the back panel using a small-blade screwdriver or similar tool. Set aside the cover and fuse-block assembly.

*Drawings reprinted by permission of Corcom Incorporated, Libertyville, Illinois.

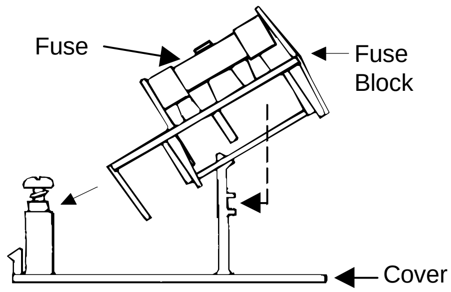


Figure 4-2
Fuse Block/Cover Assembly

3. Use the indicator pin to pull the voltage selector card straight out of the housing.

4. Orient the card so that you can read the desired voltage at the bottom of the card (Figure 4-3).

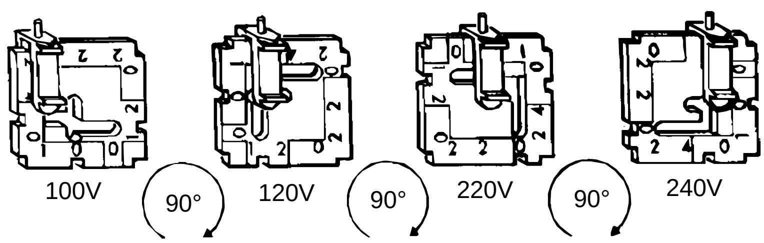


Figure 4-3
Orientation of the Voltage Selector Card

5. Rotate the indicator pin so that it points up when you read the desired voltage at the bottom of the card. If the indicator pin is fixed, you can select higher voltage levels by rotating the card 90° clockwise.

6. Insert the card back into the housing, leading with the edge of the card that bears the desired voltage. Make sure that the *printed* side of the card faces the IEC connector.

7. Replace the fuse block/cover assembly and verify that the indicator pin shows the desired voltage.

Changing the Fuse

To change from North American fusing (Figure 4-5) to European fusing (Figure 4-4), or to simply replace a blown fuse, follow these six steps:

1. Remove the fuse block/cover assembly from the back panel using a small-blade screwdriver or similar tool.
2. Loosen the Phillips-head screw one turn.

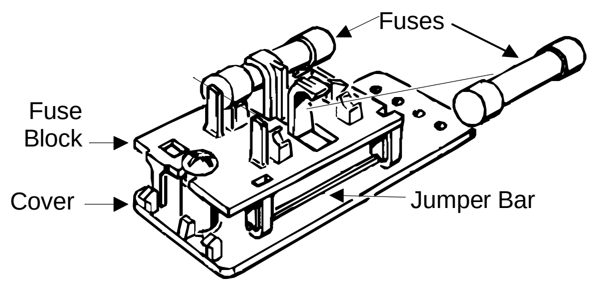


Figure 4-4
European Fusing Arrangement

3. Remove the fuse block by sliding up and away from the Phillips-head screw and then lifting up from the pedestal.
4. Change the fuses, noting that two European fuses are required, although a dummy fuse may be used in the neutral (lower) holder.
5. Invert the fuse block and slide it back onto the Phillips-head screw and pedestal.
6. Tighten the screw and replace the fuse block/cover assembly. Note that the fuse(s) that enters the housing first is the active fuse.

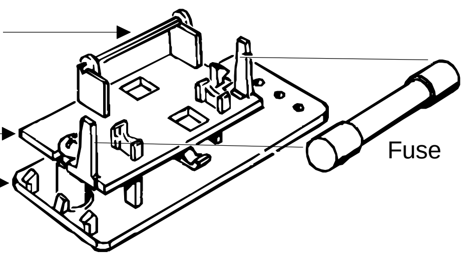


Figure 4-5
North American Fusing Arrangement

Setting DIP Switches

This section shows you how to set DIP switches for the CPC. The first bank of DIP switches, located on the CPC back panel, configures the CPC to match the application with which it is used.

Note: *DIP switches must be set before power is supplied to the CPC. If the switches are not set correctly, remove power from the CPC before resetting the switches.*

Figure 4-6, a reference card on the CPC housing, shows the positions of the DIP switches; Table 4-1 gives a quick reference and functions for the first bank of DIP switches. Detailed descriptions follow.

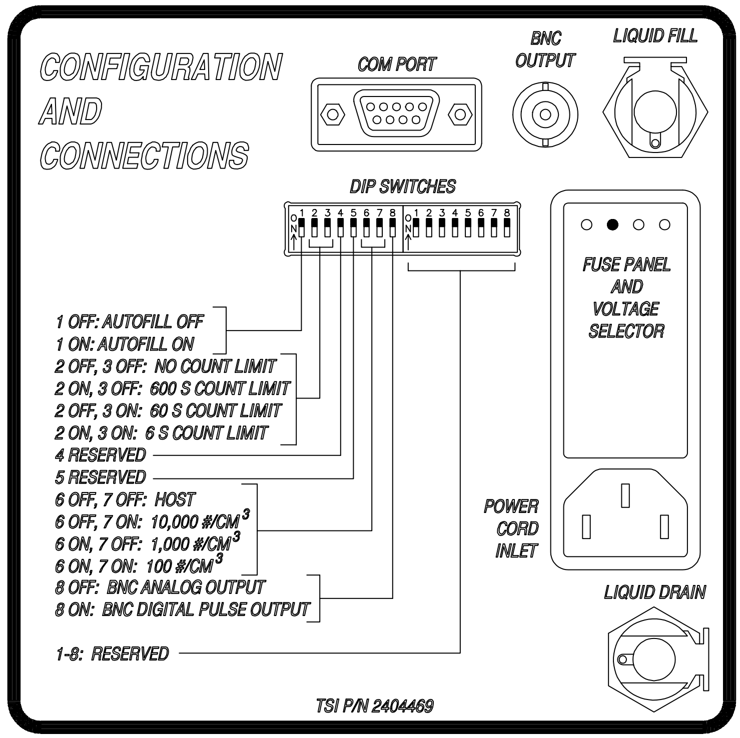


Figure 4-6
CPC Reference Card

Table 4-1
DIP Switch Settings

DIP switch Number	Purpose	Switch Off (disabled)	Switch On (enabled)
1	Fluid Autofill mode	Autofill off	Autofill on
2, 3*	Totalizer time	2 off, 3 off: No limit 2 on, 3 off: 600 secs 2 off, 3 on: 60 secs 2 on, 3 on: 6 secs	
4	Reserved		
5	Reserved		
6,7*	Analog Range (full scale)	6 off, 7 off : Host 6 off, 7 on: 10000 particles/cm^3 6 on, 7 off: 1000 particles/cm^3 6 on, 7 on: 100 particles/cm^3	
8	BNC connector output	Analog	Digital pulse
Second Bank 1-8	Reserved for future use.		

*These switches work in conjuction with each other to produce the indicated settings.

Auto Fill

Enable switch 1 to automatically fill the CPC once a day. The fill sequence is run every 24 hours, at the time of day corresponding to the time the fill sequence was last successfully completed. If switch 1 is enabled and a bottle of butanol is connected to the CPC, the reservoir is automatically filled each day.

If switch 1 is disabled, the CPC reservoir fills when power is supplied to the CPC or when you press the **Fill** button on the front panel.

Totalizer Time

Use switches 2 and 3 to set the amount of time the totalizer counts particles. For example, if switch 2 is off and switch 3 is on, the totalizer counts particles for 60 seconds and then stops.

The 600 seconds time corresponds to a 10 liter sample, 60 seconds corresponds to a 1 liter sample, and 6 seconds corresponds to a 0.1 liter sample. A sample concentration would be:

$$\frac{1250 \text{ particles}}{600 \text{ sec}}\left(\frac{60 \text{ sec}}{1.0 \text{ L}}\right)\left(\frac{1.0 \text{ L}}{1000 \text{ cm}^3}\right) = 0.125 \ \frac{\text{particles}}{\text{cm}^3}$$

Analog Range

Use switches 6 and 7 to set the full scale output for the analog output when the BNC connector output (switch 8) is set for analog output. For example, if switch 6 is off and switch 7 is on, the analog output sends a 0 volt signal for a concentration of 0 particle/cm^3 and 10 volt signal for a concentration of 10,000 particles/cm^3. The output is linear in-between.

Note: *Switches 6 and 7 have no effect if switch 8 is enabled (BNC is set for digital pulse).*

BNC Connector

Use switch 8 to change the BNC output from a selectable analog output corresponding to sampled concentration to a digital output that sends a 5 volt pulse for each particle detected by the instrument. The digital pulse is derived from the raw photodetected pulse and, therefore, the pulse width will vary slightly with the size of the detected pulse.

Connecting the Vacuum Source

The CPC flow, controlled by a critical orifice inside the instrument, requires an external vacuum source. You can use a central building vacuum or a stand-alone vacuum pump.

Connect vacuum tubing between the vacuum source and the vacuum connector on the CPC back panel (see Figure 4-1). Flexible 12-mm (½-inch) OD and 6-mm (¼-inch) ID tubing is recommended.

The CPC requires a minimum vacuum pressure of 460-mm (18 inches) of mercury at a total flowrate of 2 lpm (0.07 cfm).

Note: *Only 1.0 lpm makes up the sample flowstream. The remaining airflow is purge air to remove heat and particles from the cabinet.*

The flow in the CPC is regulated by a critical orifice. Changes in the inlet pressure will affect the flowrate through the instrument.

Although the orifice should not be affected by overpressure, the saturation rate of the fluid may be affected at higher inlet pressures. Therefore, operate the CPC with an inlet pressure of ±0.25 kPa (1 in Hg) compared to ambient pressure.

Connecting the Computer

Connect the serial port of an IBM-compatible computer to the COM port connector on the CPC using a standard IBM 9-pin, serial extension cable . If you are connecting the CPC to a computer system, use the hardware interface information and software protocol in Appendix C.

CHAPTER 5

Operating the Condensation Particle Counter

This chapter contains the following operating information and procedures for the Model 3010 Condensation Particle Counter (CPC):

- ❑ Operating precautions
- ❑ Supplying and removing power
- ❑ Warm-up mode
- ❑ Filling the CPC with butanol
- ❑ Using the CPC controls

Note: *Before supplying power to the CPC, set up the instrument using information in Chapter 4.*

Operating Precautions

Read the following before applying power to the CPC:

- ❑ Review the operating specifications for the CPC in Appendix A.
- ❑ Do **not** operate the CPC outside the range of 10°C 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. The CPC can be moved on a benchtop if there is no vacuum applied and if you keep the CPC upright. If you need to drain the reservoir, use the "Draining the CPC Reservoir" procedure in Chapter 7.

WARNING
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.

Supplying Power and Removing Power

Supply power to the CPC by plugging the AC power cord into the power cord inlet on the back panel and then into an AC source. Remove power from the CPC by unplugging the power cord from the AC source.

Warm-up Mode

When power is supplied to the CPC, the green status lights (**Laser**, **Temp**, **Flow**, and **Liquid**) light or flash.

On power-up, the CPC enters a warm-up mode to bring the condenser and saturator temperatures within the correct operating conditions. This is indicated by a blinking **Temp** indicator light. The warm-up period ends when the difference between the saturator and condenser temperatures and the laser power have reached normal operating levels.

Notes:

- ❑ *The CPC may take up to 30 minutes to warm to normal operating temperatures.*
- ❑ *Particle counts taken by the CPC are not accurate until the **Laser**, **Temp**, and **Flow** green indicator lights are lit and non-blinking.*

Normal Operation

Under most circumstances, you can determine if the CPC is operating normally by observing the LCD display and indicator lights (**Laser**, **Temp**, **Flow** and **Liquid**) on the front panel:

- ❑ On power up, a blinking light indicates the designated parameter is moving towards a normal condition.
- ❑ A lit and non-blinking light indicates the designated parameter is within normal operating range.
- ❑ An unlit **Laser**, **Temp**, or **Flow** light indicates the designated parameter is outside normal operating range. If the **Liquid** light is unlit but other status lights are lit, the CPC should operate provided there is fluid visible in the Liquid Level window.

If you suspect the CPC is not operating normally, see "Troubleshooting" in Chapter 7.

Filling the CPC Reservoir

The CPC reservoir can be filled using four different methods:

- ❑ Automatically, when power is supplied to the CPC
- ❑ Manually, by pressing the **Fill** control button on the CPC front panel
- ❑ Automatically, using the Auto Fill DIP switch
- ❑ Automatically, using a command signal from a computer.

This section includes a procedure for connecting a fill bottle, information on the automatic fill process when power is supplied to the CPC, and a procedure using the **Fill** button to fill the CPC reservoir. See Chapter 4, "Setting DIP Switches" for information on using the Auto Fill DIP switch; see Appendix C for information on sending a command signal from a computer.

The CPC uses reagent-grade n-butyl alcohol (butanol) as a working fluid. Refer to a Material Safety Data Sheet for butanol and the Safety section at the front of this manual for more information on handling butanol.

!

Caution
Butanol is flammable. It 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.

Connecting the Fill Bottle

Use this procedure to connect the fill bottle to the CPC so the CPC reservoir will fill automatically when power is supplied to the instrument.

1. Remove power from, but do not disconnect, the external vacuum pump.
2. Pour the fluid into the fill bottle to at least one-half full. Because of the shut-off fittings, the liquid will not flow into the CPC until the connections are made and the CPC is switched on.
3. Loosen the bottle cap to provide an air vent; then connect the fill bottle fitting to the CPC mating fitting as shown in Figure 5-1.
4. Set or hold the bottle as high above the CPC as you can to allow liquid to flow into the CPC. The fluid drain connector has a check valve that only allows flow out of the instrument. This prevents accidental overfilling of the CPC by attaching the fill bottle to the wrong connector.

Note: *If the CPC optics become flooded during operation, use the "Correcting Flooded Optics" procedure in Chapter 7.*

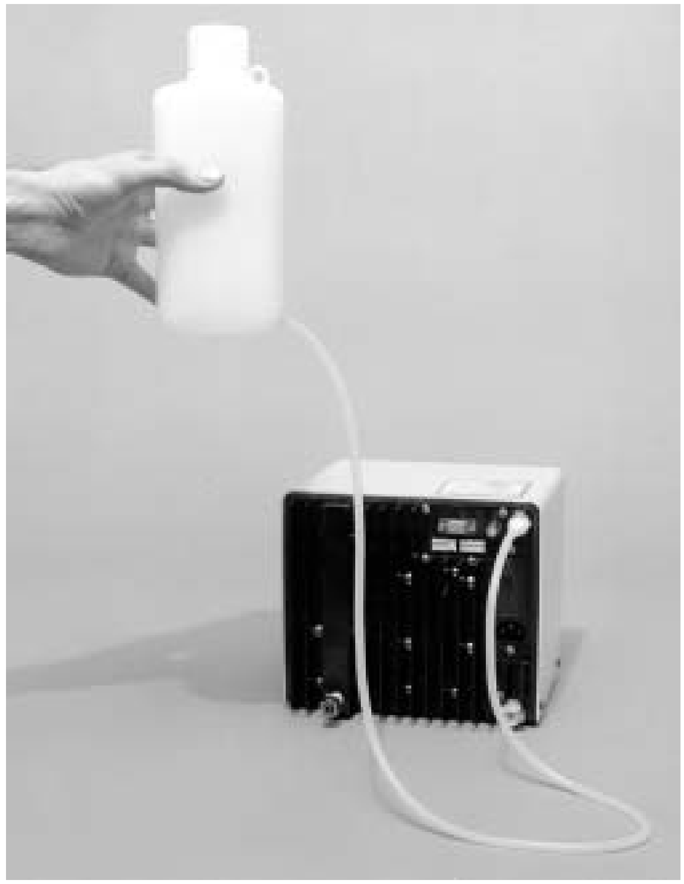


Figure 5-1
Fill Bottle Connection to the CPC

Automatic Fill Process

Fifteen seconds after power is supplied to the CPC, the internal microprocessor checks to see if the fluid reservoir is full (flashing **Liquid** indicator light). If the reservoir is not full, the fill solenoid valve opens allowing fluid to fill the reservoir. Within ten minutes, the reservoir level should rise and stop close to the top of the window. You can check this by observing the Liquid Level window on the front of the CPC. The **Liquid** status light should stay steadily lit.

Note: *The fluid is gravity-fed, so if the bottle is not raised very high above the CPC, you may have to press the* ***Fill*** *button to completely fill the reservoir.*

Pressing the Fill Button

Using the **Fill** button, fill the CPC reservoir after power is supplied:

1. Connect the fill bottle (containing butanol) to the fill fitting on the back of the instrument.

2. Push the **Fill** button. After a 15-second period, the CPC reservoir begins to fill. The **Liquid** status light blinks until the reservoir is full.

   Note: *If you push the* ***Fill*** *button again, the valve closes, the fill process stops, and the* ***Liquid*** *status light goes out.*

3. Check the liquid level window to see the level is rising.
4. If the **Liquid** status light goes out, the reservoir did not completely fill in the given cycle period. Repeat steps 2 and 3 until the **Liquid** status light stays illuminated.
5. Disconnect the bottle.

Maintaining Liquid in the Reservoir

A full reservoir contains enough butanol for the CPC to run continuously for seven days. If you are running the CPC continuously, make sure the working fluid in the reservoir is replenished every seven days.

It is not usually necessary to leave the bottle connected to the instrument unless you are using the DIP switch to automatically fill the reservoir on a daily basis (see “Setting DIP Switches” in Chapter 4).

Fluid helps prevent air from leaking into the sample airstream from the reservoir and generating stray particle counts. It is better to keep some fluid in the CPC reservoir at all times than to allow the reservoir to dry out between refills. However, the filling process itself is likely to generate some particle counts.

Draining the Reservoir

Butanol has a tendency to absorb water over time when it is exposed to humid conditions, so you should drain the CPC reservoir on a weekly or as-needed basis. You should also drain the reservoir if you are moving the CPC from one location to another. Use the “Draining the CPC Reservoir” procedure in Chapter 7.

Using the CPC Controls

This section gives operating information for the four control buttons on the CPC: **Display**, **Total**, **Clear**, and **Fill**.

Display

Display controls the output of the display screen. Press Display to toggle between two modes: concentration (PT/CM^3) and totalizer (PT) .

Concentration Mode

The Model 3010 CPC is suitable for monitoring concentrations up to 10,000 particles/cm^3 with very little coincidence. The displayed concentration value is computed using a 1-second or a 6-second sample period depending on the magnitude of concentration.

Note: *For concentration above 100 particles/cm^3, the concentration is based on 1-second samples. Below 100 particles/cm^3, the CPC uses a 6-second rolling sample. When measuring a rapidly dropping aerosol concentration, the LCD display may pause at 99.9 particles/cm^3 for 2-3 seconds, while the 6-second concentration drops to below 99.9 particles/cm^3.*

In concentration mode, the LCD display is updated each second, as particles are measured. When the LCD display is showing particle concentration, a bar indicator appears on the right-hand-side of the display next to the label PT/CM^3. If a computer is connected, the bar indicator blinks when the CPC receives a command.

Caution
At concentrations above 10,000, the LCD display flashes in the concentration mode (PT/CM^3). If this occurs, the number of particles shown on the display could be substantially lower than the actual concentration.

Totalizer Mode

Totalizer mode is used primarily for displaying low concentrations below 10.0 particles/cm^3. Start and stop the totalizer mode by pressing the Total button.

When the display is in totalizer mode, a bar indicator appears on the right-hand-side of the LCD display next to the label PT. The LCD display updates and the indicator bar flashes while the CPC is counting. The CPC stops counting when the preset totalizer time has elapsed.

Note: *See "Setting DIP Switches," Chapter 4, for the method used to set the totalizer time.*

Total

Press **Total** to stop and start the totalizer mode. When totalizer mode is enabled, the PT indicator bar blinks and LCD display counts up to 99999. If you switch to the concentration mode (PT/CM^3), the CPC continues to count internally until the preset totalizer time has elapsed.

Clear

Press **Clear** to reset the total count and the preset totalizer time to zero (0). The total count and the totalizer time are reset to zero no matter what display mode (PT/CM^3 or PT) you are in.

Fill

Press the **Fill** button to manually begin filling the CPC reservoir; press **Fill** again to stop the process**.** See “Pressing the Fill Button” earlier in this chapter for the procedure to fill the CPC reservoir.

CHAPTER 6

Application Information

This chapter contains special application information for the Model 3010 Condensation Particle Counter (CPC) and consists of these topics:

- ❑ Using the CPC to monitor clean air and gas
- ❑ Operating the CPC at higher concentrations
- ❑ Viewing analog pulses with an oscilloscope.

Clean Air/Gas Monitoring

The CPC is ideal for measuring very low particle concentrations. Since the particle-pulse amplitude is relatively high, there is little chance of falsely triggering on electrical noise when no particles are present. The count accuracy is limited only by the accuracy of the flowrate.

In addition, the CPC is well suited for placement in very clean areas. The CPC has no pump or fan to produce contaminating particles and the hot electrical components are purged with air evacuated from the cabinet to prevent contamination of surrounding areas.

WARNING

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.

Operating at Higher Concentrations

Although the CPC is often used with low concentrations of aerosol, it is capable of detecting particle concentrations of 10,000 particles/cm^3 or greater. This may be advantageous in applications such as filter testing. The limiting factor is coincidence. See below for a discussion of coincidence correction calculations.

The CPC counts single particles, such that each particle scatters a separate pulse of light. At high concentrations, two or more particles are occasionally in the viewing volume at the same time. The pulses they generate overlap and are counted as one particle. The frequency of this event depends on the particle concentration. Within limits, you can determine coincidence.

The coincidence correction is particularly important at high concentrations. For most of the range, especially in clean air, the coincidence effect is insignificant.

For maximum accuracy, compute the actual particle concentration according to the following equation:

$$N_a = N_i \exp\,(N_a\ Q\ t)$$

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 = 0.4 microsecond is the effective time each particle resides in the viewing volume

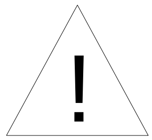
The N_a in the exponent can be approximated by N_i.

Table 6-1 shows the calculated coincidence for several concentrations. Coincidence is $1\text{-}N_a/N_i$.

Table 6-1
Coincidence Levels

Concentration (particles/cm^3)	**Calculated Coincidence (%)**
10	>.01
100	.07
1000	.67
5000	3.5
10000	7.4

As shown in Table 6-1, the CPC is suitable for monitoring concentrations up to 10,000 particles/cm^3 with very little coincidence. For concentrations above those in Table 6-1, contact the Particle Instruments Group at TSI Incorporated for a more suitable particle counter.



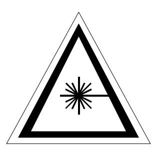
Caution
At concentrations above 10000, the LCD display flashes in the concentration mode (PT/CM^3). If this occurs, the number of particles shown on the display could be substantially lower than the actual concentration.

Viewing Analog Pulses

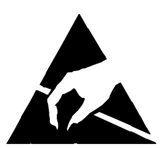
You may want to observe the pulse shape of droplets passing through the CPC optics by looking at the electronic signal produced in the photodetector. This signal is produced when detecting scattered light from the droplets passing through the laser beam. In general, the pulses will be fairly uniform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



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



Caution
To avoid damage to the CPC circuitry, use electrostatic discharge (ESD) precautions when removing the cover of the CPC: ❑ 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 housing.

3. Using Figure 6-1 as a reference, connect the ground lead of an oscilloscope to test point 1 (TP1) on the main PC board (attached to the front panel) and the main lead of the oscilloscope to test point 6 (TP6).

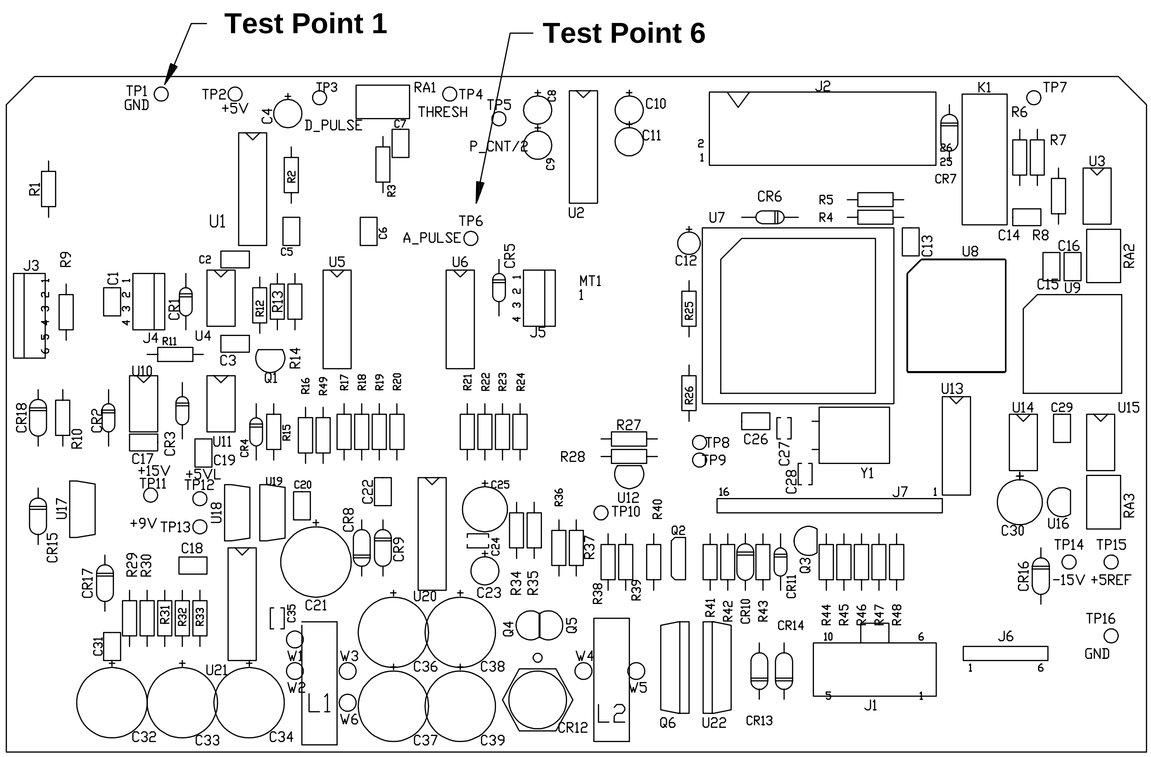


Figure 6-1
Test Points 1 and 6

4. Apply power to the CPC.

The minimum pulse amplitude is about 500 millivolts and the pulse width is about 0.5 microseconds (Figure 6-2). The pulse amplitude may range as high as 1 volt. The electrical noise level is about 10 millivolts, giving an overall signal-to-noise ratio of better than 20:1.

Figure 6-2
Typical Digital Pulse Trace

CHAPTER 7

Maintenance and Troubleshooting

This chapter gives routine and special maintenance procedures, and ways to troubleshoot the Model 3010 Condensation Particle Counter (CPC).

Routine Maintenance

Periodic maintenance on the CPC is necessary to ensure its accuracy. Table 7-1 below lists the procedures and time intervals for recommended maintenance. Most of the procedures follow, in detail.

Table 7-1
Maintenance Schedule

Task	Time Period	Reference
Calibration	not needed	This chapter
Filling the reservoir w/ butanol	7 days/or manually	Chapter 5
Draining the reservoir	weekly/as needed	This chapter
Checking flowrate	6 months/as	This chapter
Changing filters	needed	This chapter
Leak checking	12 months	This chapter
Checking concentration	12 months	Call TSI
accuracy	12 months	Call TSI
Cleaning optics	12 months	

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, since the CPC is a single-particle counter, there is no photometric calibration for concentration.

Draining the CPC Reservoir

Butanol has a tendency to absorb water over time when it is exposed to humid conditions so you should drain the CPC reservoir completely and refill with fresh butanol on a weekly basis or as needed by your application.

If you plan to leave the CPC power off for more than a few days, drain the working fluid from the CPC. Also, you should dry the saturator block if you are shipping the instrument or moving the instrument from one location to another.

Follow these three steps to drain butanol:

1. Connect the drain bottle connector to the liquid drain connector on the back panel of the CPC (Figure 3-3).
2. Loosen the cap on the drain-bottle and hold the bottle below the instrument.
3. Tip the CPC toward the connector to drain the last drops. Even after draining by gravity, keep in mind that a lot of fluid will remain soaked in the porous saturator block.

Note: *To refill the CPC reservoir, use the “Filling the CPC with Butanol” procedure in Chapter 5.*

C a u t i o n
Before shipping the CPC, the saturator block and reservoir must be completely dried. This prevents fluid from passing from the saturator into the optics and damaging the CPC.

Drying the Saturator Block

The saturator block and reservoir should be dried if the CPC is shipped to another location. You can use an simple method, which takes from 12 to 24 hours, or you can use a faster but more complicated method, which takes approximately one hour.

Twelve-Hour Method

You can dry the saturator block by draining the liquid from the CPC reservoir and then running the CPC normally with dry air going through the instrument for 12 to 24 hours.

One-Hour Method

To dry the saturator block, follow these seven steps:

1. Remove the CPC cover by unscrewing the two screws on each side of the instrument.
2. Seal off the vacuum exit tube on the CPC back panel.
3. Using Figure 7-1 as a reference, remove the purge air tube from the CPC. Disconnect the pressure tap, which is connected directly to the optics, at the pressure sensor. Reconnect the end to the fitting that was connected to the purge-air inlet on the heatsink.

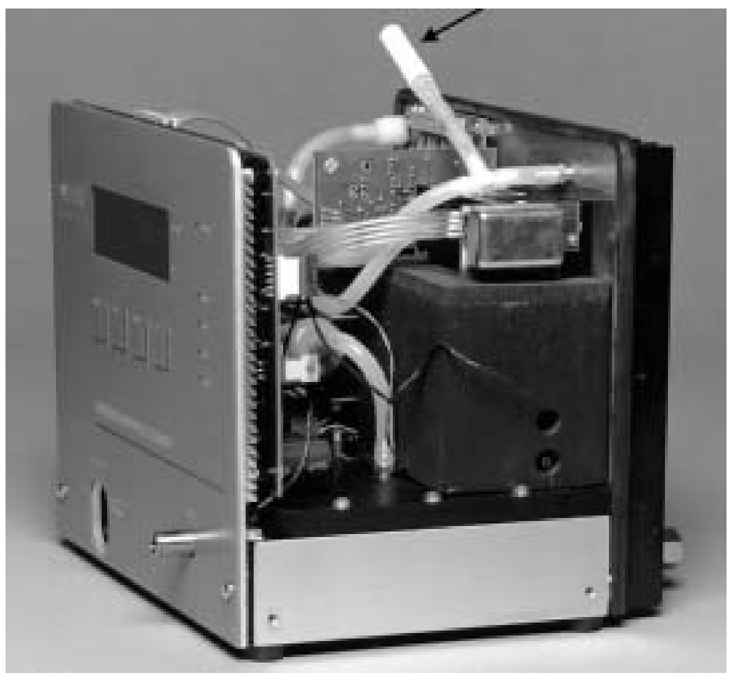


Figure 7-1
Inside View of the CPC-Purge Air Inlet and Filter

4. Attach the connector on the drain bottle to the connector on the CPC and loosen the cap on the bottle so that air can easily escape. *Slightly* tilt the CPC so that the drain connector is lower than the rest of reservoir.
5. Use a clean (filtered), dry compressed air-source to *carefully* introduce a slight pressure (approximately 34 kPa, 5 psig) into the CPC inlet. The pressure forces the liquid out of the saturator block and out through the drain.

6. Vent the air from the drain tube into a hood or other ventilator.

7. Allow the drying air to run for an hour before shipping the CPC.

Note: *Running the air for two or more hours dries the saturator completely.*

Verifying Flowrate

To measure the instrument sample flowrate, connect a low-pressure-drop flowmeter to the CPC inlet. A bubble flowmeter or thermal flowmeter works best. A mass flowmeter should be corrected for atmospheric pressure to give volumetric flow.

The flowrate should be 1.0 lpm (0.035 cfm) ±10 percent. If the flowrate 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. If you suspect a clogged orifice or nozzle, contact TSI for instructions.

Changing Filters

The CPC has three filters that should be replaced periodically: the fluid line filter, the purge air filter, and the reservoir vent filter.

Use the information in Table 7-2 to order replacement filters. Procedures for replacing or cleaning the filters follow.

Table 7-2
Replacement Filters

Filter	TSI Part Number	Other Source
Fluid line filter	P/N 1602088	None
Purge air filter	P/N 1602059	None
Reservoir vent filter	P/N 1602067	Balston Inc., Lexington, MA, U.S.A., 1-800-343-3048, P/N DFU-9922-05-AQ

Caution

To avoid damage to the CPC circuitry, use electrostatic discharge (ESD precautions when removing the cover of the CPC:

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

Fluid Line Filter

The fluid line filter is shown in Figure 7-2. The fluid line filter is located in the fill line of the CPC between the fill connector and the fill solenoid valve. This filter protects the valve from debris that may enter from a dirty fill bottle and prevent the valve from closing properly. The filter is easily replaced by following the six steps below:

1. Unplug the CPC.

2. Remove the cover from the instrument.

3. Locate the in-line filter, between the fill connector and the solenoid valve (the side closest to the AC line connector) and make a note of the direction of the arrow on the side of the filter.

4. Remove the filter by pulling the flexible tubing from either end of the filter.

5. Replace the filter with a new one, making sure the direction of the arrow on the side of the filter matches the direction of the old filter.

6. Replace the cover on the instrument.

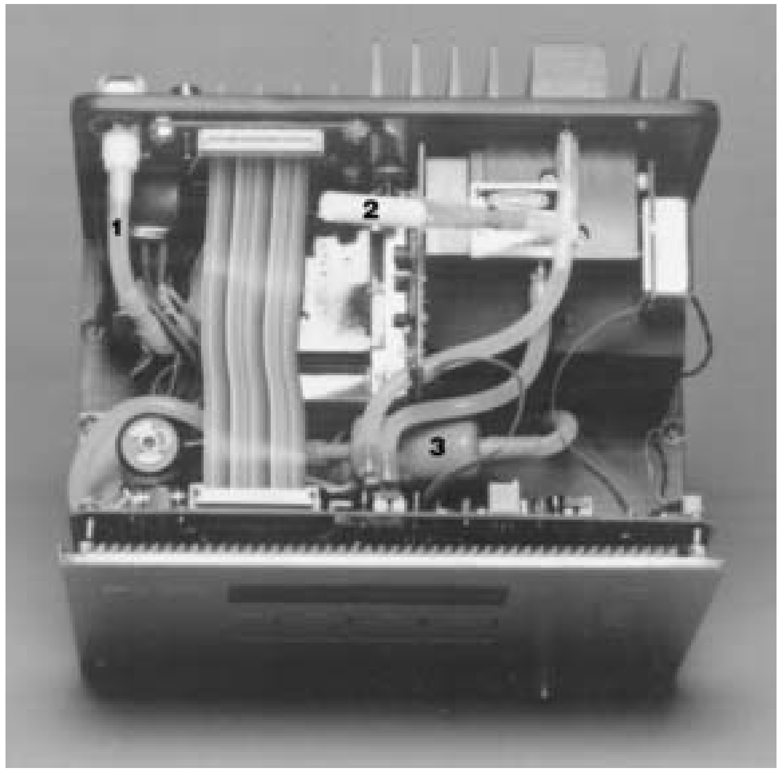


Figure 7-2
Location of Filters: **1** Fluid Line Filter, **2** Purge Air Filter, **3** Reservoir Vent Filter.

Purge Air Filter

The purge air filter is shown in Figures 7-1 and Figure 7-2. This filter protects the critical orifice used to control the flow of purge air from the cabinet. The filter is replaced by following the six steps below:

1. Unplug the CPC.
2. Remove the cover from the instrument.
3. Locate the white, porous, plastic filter attached to tubing near the top of the instrument .
4. Remove the filter by pulling the flexible tubing from the bottom of the filter.
5. Replace the filter.
6. Replace the cover on the instrument.

Reservoir Vent Filter

The reservoir vent filter is shown in Figure 7-2. The reservoir vent filter allows air to enter the reservoir as fluid is displaced in the reservoir.

Replace the reservoir vent filter by performing these steps:

1. Unplug the CPC.
2. Remove the cover from the instrument.
3. Locate the blue capsule filter near the center of the instrument, close to the reservoir and make a note of the direction of the arrow on the side of the filter.
4. Remove the filter by pulling the flexible tubing from either end of the filter.
5. Replace the filter with a new one, making sure the direction of the arrow on the side of the filter matches the direction on the old filter.
6. Reattach all tubing and wiring connectors to the main board. Replace the two screws fastening the front panel to the reservoir.
7. Replace the cover on the instrument.

Checking for Leaks

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, it is likely that the CPC has developed a leak.

To check the CPC for leaks, follow these steps:

1. Unplug the counter and drain any remaining fluid from the reservoir. Dry out the reservoir using the “Draining the CPC Reservoir” procedure in this chapter.
2. Remove the top cover by withdrawing the four screws (two on each side) fastening the cover.
3. Remove the purge air filter shown in Figures 7-1 and 7-2 and plug the tubing so that it is leak tight.
4. Use a cover or plug to seal the vacuum connection on the back of the instrument.

5. Using Figure 7-3 as a reference, connect a vacuum gauge, valve, and vacuum pump to the inlet connector on the CPC. Use the inlet connector, rather than the outlet, to reduce the chance of contaminating the optics.

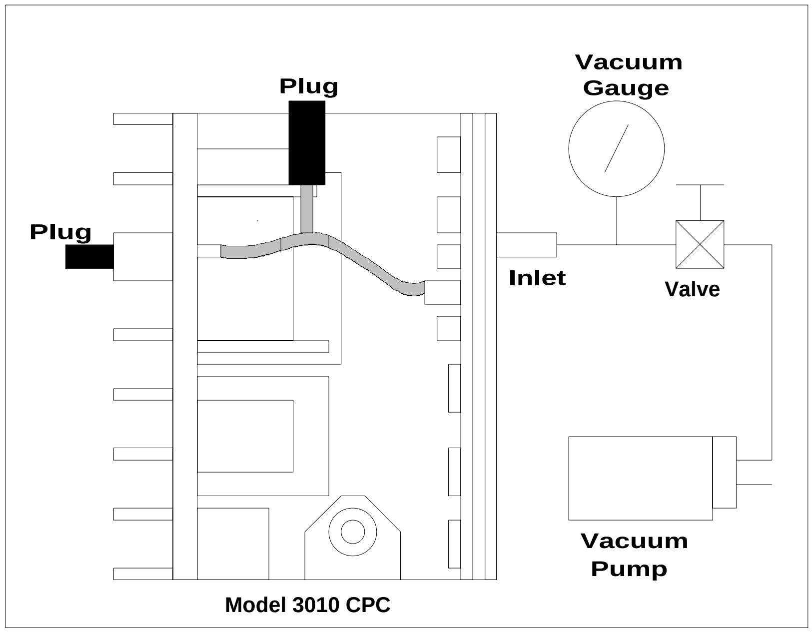


Figure 7-3
Overhead View of the Vacuum Pump Connection

6. Draw at least 560 mmHg (300 in H_2O) of vacuum through the instrument and close the valve. Shut off the vacuum source.

7. Check that the counter loses no more than 5.0 mmHg (3 in H_2O) vacuum in 5 minutes according to the gauge.

8. If you find that the CPC leaks, tighten all fittings and screws and repeat the vacuum test.

9. To locate a small leak, do the following:

   a. Replace the vacuum source with a compressed air source.

   b. Introduce approximately 70 kPa (10 psig) of air into the CPC.

   c. Search for leaks by squirting a soap-and-water solution around fittings, O-ring seals, and other possible leak locations, taking care not to wet the electronics in the process. A leak shows up as numerous small bubbles in the soapy water.

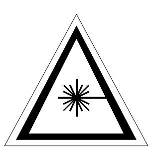
   d. Repair the leak and retest with the vacuum leak test (steps 1-7).

   e. Dry any remaining soap and water from the CPC before plugging it into a power source.

Special Maintenance

Upgrading the EPROM and Correcting Flooded Optics are two special maintenance procedures. These procedures are not considered routine and should only be attempted by someone who is familiar with the operation of the CPC and who is technically qualified.

You are encouraged to call TSI for assistance in performing special maintenance. It may also be helpful to have the technician, tools and the instrument close to the telephone when discussing the problem with a TSI technician. Refer to Chapter 8 for directions on contacting a technical resource at TSI.

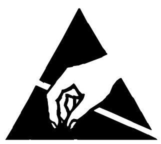


WARNING
The use of controls, adjustments, or procedures other than those specified in this manual may result in exposure to hazardous optical radiation.

Upgrading the EPROM

The EPROM is an electronic chip that contains a firmware program to control all functions of the microprocessor. From time to time, TSI may develop an updated EPROM with new features to enhance the performance of your instrument.

Refer to Figure 7-4 and the following instructions to install a new EPROM.



Caution
To avoid damage to the CPC circuitry, use electrostatic discharge (ESD) precautions when removing the cover of the CPC: ❑ Use only a table top with a grounded conducting surface. ❑ Wear a grounded, static-discharging wrist strap.

Tools Needed

You need a chip extractor (part number 3012038), a Phillips-head screwdriver, a grounded, static-discharging wriststrap, and an antistatic mat.

1. Remove power from the CPC and from any instruments connected to the CPC.
2. Remove the CPC top cover by removing the four screws (two on each side) fastening the cover.
3. Using the chip extractor, remove the old EPROM from its socket (Figure 7-4). Be very careful not to apply too much pressure.

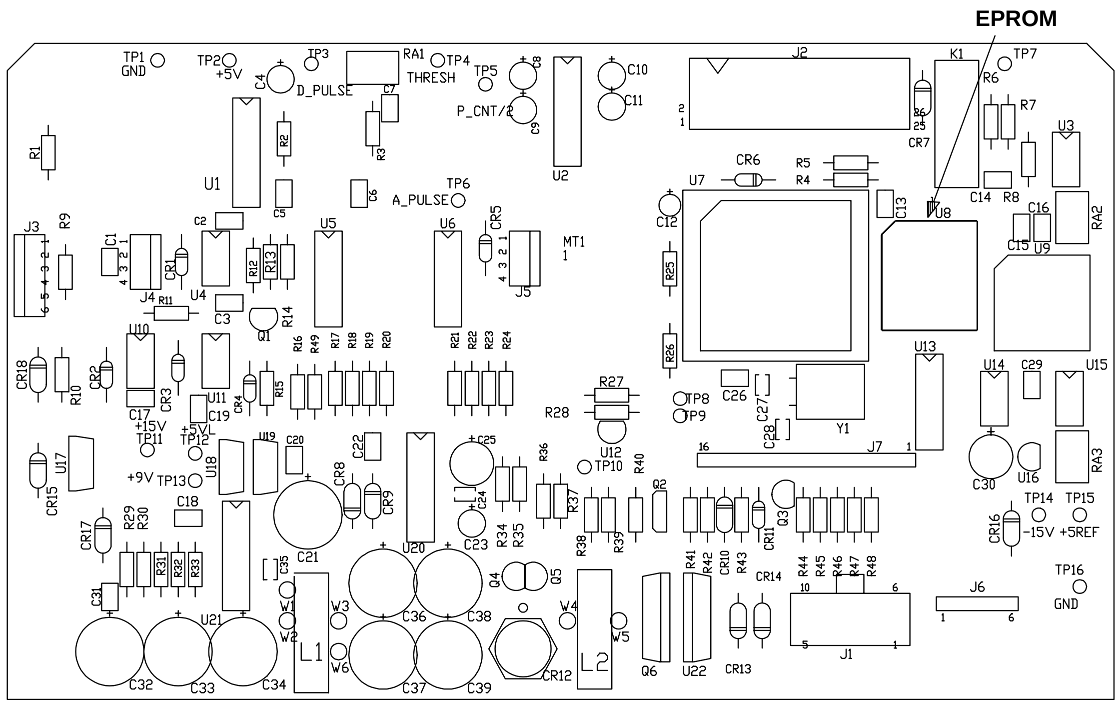


Figure 7-4
EPROM Location on the Main PC Board

4. Remove the updated version of the EPROM from its static protective wrapper.
5. Align the chip in the socket, making sure the clipped corner of the chip matches the clipped corner of the socket as shown in Figure 7-4. Apply pressure to the center of the chip until it snaps down into the socket. Press *firmly* to make sure it is seated properly.
6. Replace the cover on the CPC.
7. Apply power to the 3010 CPC and make sure the LEDs function properly.
8. If the CPC does not function properly, remove power from the CPC and make sure the EPROM is positioned correctly and seated snugly. If the CPC still does not function properly, contact a TSI representative for assistance.

Correcting Flooded Optics

Due to the nature of the reservoir in the CPC, the instrument must not be tilted when it is in operation. If the CPC is bumped or tilted when running, the vacuum flow can draw fluid from the reservoir thorough the entire flow path, including the optics.

Usually the first sign of flooding is the **Flow** light going out or flashing 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. Unplug the CPC and drain any remaining fluid from the reservoir. Dry out the reservoir using the “Draining the CPC Reservoir” in this chapter.
2. Connect a vacuum source to the CPC and tilt the instrument on its back. This will allow any remaining fluid inside the optics chamber to be drawn out. Roll the CPC from side to side until no fluid can be heard or seen in the vacuum line.
3. Remove the cover from the CPC.
4. 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.
5. Disconnect the reservoir vent (blue capsule) filter from the tubing. Blow through this gently with low pressure compressed air. If any fluid comes out of the filter, or there seems to be a blockage in the filter, it is probably wet and should be replaced. See Table 7-2.
6. Connect the good filter in line with the tubing.
7. Run the CPC for 48 hours with vacuum to thoroughly dry out the optics.
8. Refill the CPC with clean working fluid.
9. 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 in Chapter 6.

10. If the pulse height is not within a normal range, the CPC should be returned to TSI to have the optics cleaned. Refer to Chapter 8, “Service,” for directions on returning the CPC to TSI.

Troubleshooting

Use the information in this section to identify problems.

Under most circumstances, you can determine if the CPC is acting normally by observing the LCD display and status LEDs (**Laser**, **Temp**, **Flow** and **Liquid**) on the front panel:

❑ On power up, a blinking status light indicates that the designated parameter is moving towards a normal condition.

❑ A lit but non-blinking status light indicates the designated parameter is within normal operating range.

❑ An unlit **Laser**, **Temp**, or **Flow** status light indicates the designated parameter is outside normal operating range. If the **Liquid** light is unlit but other status lights are lit, the CPC should operate provided there is fluid visible in the Liquid Level window.

Identifying Problems

Use the information in Table 7-3 to identify possible problems with the CPC.

Table 7-3
Problem Symptoms

Symptom	Possible Problem
The **Laser** LED does not light.	Indicates either a lack of power to the CPC or the laser is not working. If other status lights (**Temp**, **Flow**, and **Liquid**) light, the laser is not operating. Using the information in Chapter 8, contact TSI.
The **Temp** LED does not light.	Indicates a circuitry problem, possibly a failed saturator or condenser thermistor. Using the information in Chapter 8, contact TSI.
The **Flow** LED goes out or flashes erratically.	The vacuum supply to the CPC may be too low or off, or fluid from the reservoir may have flooded the CPC optics. Check the vacuum supply and refer to “Connecting the Vacuum Source” in Chapter 4, then see “Correcting Flooded Optics” in this chapter.
The **Liquid** LED flashes for 15 seconds after starting a fill process, but then turns off without filling.	Indicates a circuitry problem, possibly a failed Liquid Level sensor. Using the information in Chapter 8, Contact TSI.
The LCD display flashes.	At concentrations above 10000, the LCD display flashes. See “Operating at Higher Concentrations” in Chapter 6.
The vacuum pump is not functioning correctly or you see fluid in the vacuum lines.	Fluid from the reservoir may have flooded the CPC optics. See “Correcting Flooded Optics” in this chapter.

Solving CPC Processor Problems

The built-in CPC processor is capable of detecting some failures of components within the device but solving processor failures generally requires the advice of a TSI technician. Chapter 8 gives information you need to contact technical personnel at TSI.

CHAPTER 8

Service

This chapter gives directions for contacting people at TSI Incorporated for technical information and directions for returning the Model 3010 Condensation Particle Counter (CPC) for service.

Technical Contacts

- ❑ If you have any difficulty installing the Condensation Particle Counter, or if you have technical or application questions about this instrument, contact an applications engineer at TSI Incorporated, (651) 490-2811.
- ❑ If the Condensation Particle Counter fails, or if you are returning the CPC for service, contact TSI Customer Service at 1-800-874-2811 (USA) or (651) 490-2811.

Returning the CPC for Service

Call TSI Customer Service 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.

Use the original packing material to return the instrument to TSI. If you no longer have the original packing material, seal off the vacuum port and sampling inlet to prevent debris from entering the instrument and ensure that the indicator lights and the connectors on the instrument front and back panels are protected.

APPENDIX A
Specifications

Table A-1 gives the operating specifications for the Model 3010 Condensation Particle Counter.

Table A-1
Model 3010 CPC Operating Specifications

Sample flowrate	1.0 L/min (0.035 cfm) ± 10%
Outlet (total) flowrate	2.0 L/min (0.07 cfm)
Vacuum source	450 mm (18 in.)Hg minimum
Particle size range:	
minimum detectable particle	50% of 0.01 µm particles
maximum detectable particle.	>3 µm
Particle concentration range: ...	0.0001 to 10,000 particles/cm^3 (3 to 2.8 × 10^8 particles/ft^3) with <10% coincidence at 10,000 particles/cm^3
Background count:	<0.0001 particle/cm^3
Working fluid	Reagent-grade n-butyl alcohol
Reservoir capacity	350ml (7 day supply at 22 C)
Light source	50 mW, 780 nm laser diode
Signal-to-noise ratio	20:1 minimum
Digital output:	(note: not compatible with TSI Models 370x or 71xx multiplexer or processors)
square pulse:	5 V, 500 ± 100 ns
16 bit analog output	0-10 volt full scale (0-11 volt under HOST control)
Serial Communications I/O	Pinouts compatible with standard 9-pin IBM-AT style RS-232 cables and interfaces
Power	100/120/220/240 VAC @ 50/60 Hz, 25W maximum
Size (LWH)	19 by 22 by 19 cm (8.5 by 7.5 by 7.5 in)
Weight	5.5 kg (12 lbs)
Ambient temperature range	10 to 35°C
Ambient humidity range	0 to 90% RH

*All specifications are subject to change without notice.

APPENDIX B

Theory of Operation

This appendix gives a detailed theory of operation for the Model 3010 Condensation Particle Counter (CPC) as well as historical notes on the instrument.

Theory

The Condensation Particle Counter operates like an optical particle counter. However, in a CPC, the particles are first enlarged by a condensing vapor to form easily detected droplets. The science behind the counter, therefore, is focused on how to condense the vapor onto the particles.

Note: *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 becomes high enough, condensation can take place even if no particles are present. This is called *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.

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.

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:

$$\text{Saturation Ratio} = \frac{P}{P_s} = \exp\frac{4gM}{rRTd}$$

where g = surface tension of the condensing fluid
M = molecular weight of the condensing fluid
r = 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 CPC this ratio is several hundred percent, whereas in the atmosphere, this ratio is only a few percent for water.

Historical Notes

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.

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, nonpulsating) through the mixing chamber into a single-particle-counting optical detector.

Diffusional Thermal CNC

A continuous-flow, diffusional, thermal-cooling CNC (Bricard et al. [1976], Sinclair and Hoopes [1975], Agarwal and Sem [1980]) first saturates the air sample with vapor as the sample passes over a heated pool of liquid. The vapor-saturated airstream flows into a cold condenser tube where the air is cooled by thermal diffusion. The vapor 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. 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 had a flowrate of 0.3 liters per minute.

Instrument Design

The basic instrument consists of two major subsystems: the sensor and the microprocessor-based signal-processing electronics.

Sensor

The sensor itself is made up of a reservoir, saturator, condenser, and optical detector. The reservoir holds enough liquid to run the sensor continuously for seven days using n-butyl alcohol (butanol). The inlet flow enters the saturator section where it passes through a heated, liquid-soaked porous plastic block. The block continually draws liquid from the reservoir. It is constructed of an electrically conductive material to prevent a build up of charge that could cause particle losses to the walls. The liquid evaporates and saturates the sheath airstream with vapor.

The airstream next enters the condenser where it is cooled using a thermoelectric device outside the condenser. The vapor cools, becomes supersaturated, and begins to condense on the particle nuclei carried in the aerosol stream 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 into the saturator and is absorbed into the saturator block for reuse.

The sensor's focusing optics consist of a laser diode, collimating lens, and cylindrical lens. This combination forms a horizontal ribbon of laser light above the aerosol exit nozzle. The collecting optics incorporate a pair of aspheric lenses that collect forward-scattered light onto a low-noise photodiode. The main beam is blocked by a light-stop in the center of the first aspheric lens. The surface temperature of the optics housing is maintained, by mechanical contact with the heatsink, at or above the saturator temperature to avoid condensation on the lens surfaces.

Microprocessor

The CPC incorporates an Intel 80C552 microprocessor to control all its functions. The processor has 256 bytes of on-board RAM and uses a 256K byte EPROM for program memory. The microprocessor utilizes built-in analog to digital converters to monitor temperatures, voltages, and pressure drop of the CPC. Counters within the microprocessor keep track of the particle pulses detected by the photodetector. The display, pushbutton, and RS-232 communications are also controlled by the microprocessor.

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APPENDIX C

Computer Interface and Commands

This appendix contains hardware information you need if you are connecting the Model 3010 Condensation Particle Counter (CPC) to a computer or to a data acquisition system. This appendix also contains communications protocols and a sample software program you can modify for your application.

Pin Connectors

The Model 3010 CPC has a single 9-pin, D-subminiature connector port on the back panel. The communication port is configured at the factory to work with RS-232 type devices.

Note: *This pin configuration is not compatible with earlier TSI serial cables. The connections have been changed in this instrument to allow compatibility with the standard IBM AT-style serial cables.*

Table C-1 lists the signal connections.

Table C-1
Signal Connections for RS-232 Configurations

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

Baud Rate

The Model 3010 CPC uses a baud rate setting of 9600. The baud-rate setting is the CPC's rate of communication in terms of bits per second (baud). For proper communications, make sure that all software used with the CPC is also set at this rate.

Parity (7-Bits Even)

The Model 3010 CPC uses even parity as the only setting. Parity is the additional bit that accompanies the seven data bits to confirm that they are transmitted correctly. It is set so that the number of "1" bit (high) in a transmitted character is always an even number.

Communications Protocol

The communications protocol used with the Model 3010 CPC is an ASCII-based protocol. This protocol utilizes the RS-232 port of a computer to transmit commands in the form of ASCII strings followed by carriage return.

If the CPC is connected to a computer, the PT/CM^3 indicator bar blinks when the CPC receives a command. In response to any incorrect or undecipherable transmissions, the CPC transmits the word ERROR, followed by a carriage return, back to the computer.

Table C-2 lists the commands and the counter responses used for the ASCII-based protocol. A simple computer program written in BASIC is listed later in this section to demonstrate the possible interfacing that you can do with the CPC. You need to know this information only if you wish to write your own software to interface with the CPC.

Table C-2
ASCII-Based Protocol Commands

ASCII Label	Command Name	ASCII Response	Description
Axx	Address	OK	A dummy address command used to maintain compatibility with older TSI products.
D	Dump	timecounts, 0 0,0 : (15 lines) 0,0	Used to collect particle count information from the CPC. When this command is sent, the CPC returns the sample and counts time since the last "D" or "DC" command (or power-up), the counts since the last "D" or "DC"command, and then 15 additional lines of zeros. The zeros maintain compatibility with older TSI products.
DC	Dump Cumulative Counts	time, counts	Used to collect particle count information from the CPC. When this command is sent, the CPC returns the time since the last "D" or "DC" command (or power-up), and the counts since the last "D" or "DC" command.
R0	Read Liquid Status	FULL/ NOTFULL	Corresponds to the Liquid status light on the front panel of the CPC. For more information on the conditions of this status, refer to "Indicator Lights" in Chapter 3.
R1	Read Condenser Temperature	xx.x	Reads the condenser temperature. The temperature is returned as a number in degrees C with one decimal place.
R2	Read Saturator Temperature	xx.x	Reads the saturator temperature. The temperature is returned as a number in degrees C with one decimal place.
R5	Read Environment	READY/ NOTREADY	If all status parameters (Laser, Temp, Flow, and Liquid) are within their appropriate values, R5 will return READY. If any one of the status parameters is outside its value, R5 will return NOTREADY.

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Table C-2

ASCII-Based Protocol Commands *(continued)*

ASCII Label	Command Name	ASCII Response	Description
RA	Read 6-second buffer	xxxx	Reads the number of counts detected during the last 6-seconds (0.1 liter).
RB	Read 1-second buffer	xxxx	Reads the number of counts detected during the last 1-second (017. liter).
RD	Read display concentra-tion	xxxxx.x	Reads the concentration as it appears on the LCD display.
RT	Read Delta T	xx.x	Returns the temperature difference between the saturator and condenser in degrees C.
RV	Read Vacuum Status	VAC/ LOVAC	Returns the string “VAC” if the vacuum ratio across the main flow critical orifice is above approx 12 in Hg. (This value corresponds approximately to the lower limit of 1000 cm^3/min ±10%.) If the vacuum is below this value, the string “LOVAC” is returned.
Vxxxxx	Set Analog Voltage	OK SWITCH ERROR	Sets analog output to voltage: V0 = 0 volts; V11000 = 11.0 volts Gives SWITCH ERROR if DIP switches 6, 7, and 8 are not all disabled (off).
X5	Execute fill	OK	Executes a fill command as if the Fill button on the CPC front panel was pressed.
X6	Clear Display Buffers	OK	Clears the 1 second and the 6-second display buffers as if the Clear button on the CPC front panel was pressed.

Sample Program

The sample program in Table C-3 is an example of how the CPC communicates with a host computer. The program is written in QuickBASIC® so that it is easy to understand. The program is included with the instrument as a BASIC file and as an executable file.

Note: *Do not confuse this program with Aerosol Instrument Manager® Software for CPC/EAD, which has a separate disk and separate instruction manual.*

To run the program, connect a serial cable between the CPC COM port and your computer COM1 port. Insert the program disk into your computer drive A (or B) and type A:CPC3010 (or B:CPC3010). You need a QuickBASIC or equivalent editor to modify the program for your own purposes.

Note: *TSI does not accept responsibility for modified software.*

Table C-3
CPC3010.BAS Program Listing

```
flag$ = "READ"                                          'declare flag for reading concentration
AVGtime = 5                                             'set concentration averaging time (minimum = 1)
OPEN "COM1:9600,E,7,1,RS,CS,DS,CD" FOR RANDOM AS #1     'open CPC com port
Menu:                                                   'main menu section
CLS                                                     'clear screen
PRINT                                                   'print header
PRINT "********************************************"
PRINT "*   CPC3010.BAS   (c)1991 TSI Incorporated *"
PRINT "*   Version 1.1   R. Caldow  7-17-93       *"
PRINT "*   A Simple program to read a 3010 CPC    *"
PRINT "********************************************"
PRINT
PRINT
PRINT "[1]...Check CPC Connection"                     'print menu
PRINT
PRINT "[2]...Read Liquid Status"
PRINT "[3]...Read Temperature Status"
PRINT "[4]...Read Flow Status"
```

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®QuickBASIC is a registered trademark of Microsoft Incorporated.

Table C-3
CPC3010.BAS Program Listing *(continued)*

```
PRINT "[5]...Read Particle Concentration"
PRINT
PRINT "[Q]...Quit program"
PRINT
PRINT
PRINT "< Select a number 1-4 or Q >"
WHILE 1                                                        'go until quit is selected
choice$ = INKEY$                                               'read the keyboard
 IF UCASE$(choice$) = "Q" THEN                                 'if Q is selected
  GOTO Logout                                                  '  then quit the program
 ELSEIF choice$ = "1" THEN                                     'if 1 is selected
  PRINT #1, "A00": GOSUB CPCread                               '  then send address command to CPC
  IF temp2$ = "OK" THEN                                        '  if we get an 'OK'
   CLS : LOCATE 5, 1: PRINT "The CPC is responding normally"   '    then print normal message
  ELSE                                                         '  otherwise
   CLS : LOCATE 5, 1: PRINT "The CPC is NOT responding"        '    print error message
  END IF
  LOCATE 10, 1: INPUT "Hit <Enter> to continue", ans$          'print return message
  GOTO Menu                                                    'return to menu

 ELSEIF choice$ = "2" THEN                                     'if 2 is selected
  PRINT #1, "R0": GOSUB CPCread                                '  then send the reservoir command to CPC
  IF temp2$ = "FULL" THEN                                      '  if we get an 'FULL'
   CLS : LOCATE 5, 1: PRINT "The reservoir is full"            '    then print normal message
  ELSE                                                         '  otherwise
   CLS : LOCATE 5, 1: PRINT "The reservoir is NOT full"        '    print empty message
  END IF
  LOCATE 10, 1: INPUT "Hit <Enter> to continue", ans$          'print return message
  GOTO Menu                                                    'return to menu

 ELSEIF choice$ = "3" THEN                                     'if 3 is selected
  PRINT #1, "RT": GOSUB CPCread                                '  then send the temperature command to CPC
  deltaT = VAL(temp2$)                                         '  save the temperature in 'deltaT'
  IF deltaT < 16 THEN                                          '  if temperature is below 25 - 1 C then
   CLS : LOCATE 5, 1: PRINT "The temperature is below normal"  '    print below normal message
  ELSEIF deltaT > 18 THEN                                      '  if temperature is above 25 + 1 C then
   CLS : LOCATE 5, 1: PRINT "The temperature is above normal"  '    print above normal message
```

continued on next page

Table C-3
CPC3010.BAS Program Listing *(continued)*

```
    ELSE                                                        '  otherwise
      CLS : LOCATE 5, 1: PRINT "The temperature is normal"      '    print normal message
    END IF
    LOCATE 10, 1: INPUT "Hit <Enter> to continue", ans$         'print return message
    GOTO Menu                                                   'return to menu

  ELSEIF choice$ = "4" THEN                                     'if 4 is selected
    PRINT #1, "RV": GOSUB CPCread                               '  then send the flow command to CPC
    IF temp2$ = "VAC" THEN                                      '  if we get a 'VAC' response
      CLS : LOCATE 5, 1: PRINT "The flow is normal"             '    then print normal message
    ELSE                                                        '  otherwise
      CLS : LOCATE 5, 1: PRINT "The flow is below normal"       '    print below normal message
    END IF
    LOCATE 10, 1: INPUT "Hit <Enter> to continue", ans$         'print return message
    GOTO Menu                                                   'return to menu

  ELSEIF choice$ = "5" THEN                                     'if 5 is selected
    CLS : PRINT USING "Reading Counter at ### second            '  print message on screen
         intervals"; AVGtime
    PRINT #1, "D": FOR i = 1 TO 17: GOSUB CPCread: NEXT i:      '  read once to clear counts
    WHILE INKEY$ = ""                                           '  repeat this loop until a key is hit
      begintime = TIMER                                         '    store the beginning time
      WHILE (TIMER - begintime < AVGtime): WEND                 '    until the avgtime has passed, wait
      PRINT #1, "D"                                             '    read the counts
      GOSUB CPCread: eltime = VAL(temp2$)                       '    store the elapsed time
      GOSUB CPCread: count = VAL(temp2$)                        '    store the counts
      FOR i = 1 TO 15: GOSUB CPCread: NEXT i                    '    read all the zeros
      LOCATE 5, 1                                               '    set the screen location
      PRINT USING "Particle concentration is: ##.##^^^^         'print the concentration
         particles/cc"; count * 60 / (eltime * 1000)
      LOCATE 10, 1: PRINT "Hit <Enter> to stop reading"         'print return message
    WEND
    GOTO Menu                                                   'return to menu
  END IF                                                        'end of menu reading loop
WEND

CPCread:                                                        'subroutine to read CPC
  temp1$ = "": temp2$ = "": i = 0                               'initialize temporary variables
  WHILE i < 1000                                                'read the COM port up to 1000 times
    IF LOC(1) > 0 THEN temp1$ = INPUT$(1, #1): i = 0            'if a character is there, store in temp1
```

continued on next page

Table C-3
CPC3010.BAS Program Listing *(continued)*

```
    IF temp1$ = CHR$(13) THEN RETURN                                  'screen out carriage returns
    IF temp1$ <> CHR$(10) AND temp1$ <> "" THEN temp2$ = temp2$ + temp1$        'store characters in temp2
    temp1$ = ""                                                       'reset temp1
    i = i + 1                                                         'increment loop counter
  WEND                                                                'end of loop
RETURN                                                                'return from subroutine

Logout:
END                                                                   'exit program
```

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Manual Title Model 3010 Condensation Particle Counter ________ **P/N** 1933010 **Rev.** F

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