Particle Instruments

Model 3786
Ultrafine Water-based Condensation Particle Counter

Operation and Service Manual

P/N 1930072, Revision B
April 2005

TSI®

Model 3786
Ultrafine Water-based Condensation Particle Counter

Operation and Service Manual

Manual History

The following is a history of the Model 3786 Ultrafine Water-based Condensation Particle Counter (UWCPC) Operation and Service Manual, P/N 1930072.

Revision	Date
A	January 2005
B	April 2005

Part Number 1930072 / Revision B / April 2005

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 March 2003)

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 twelve (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.

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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 Customer Service at 1-800-861-7919 (USA) or 651-490-3838. For Technical Support call 1-800-861-7032 (USA) or 651-765-3797.

Safety

This section provides instructions to ensure safe and proper handling of the Model 3786 Ultrafine Water-based Condensation Particle Counter (UWCPC).

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.

Take the following precautions:

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

Description of Caution Symbol

The following symbol and an appropriate caution statement are used throughout the manual and on the UWCPC to draw attention to any steps that require cautionary measures when working with the Model 3786.

Caution

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

Warning

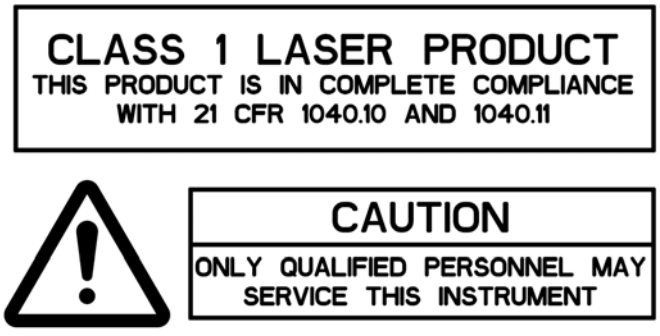
WARNING
Warning means that unsafe use of the instrument could result in serious injury to you or cause irrevocable damage to the instrument. Follow the procedures prescribed in this manual to use the instrument safely.

Caution or Warning Symbols

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

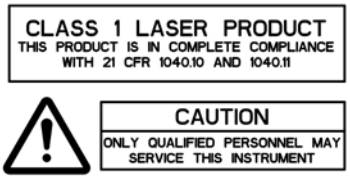
	Warns you that uninsulated voltage within the instrument may have sufficient magnitude to cause electric shock. Therefore, it is dangerous to make contact with any part inside the instrument.
	Warns of hazardous laser radiation if the optical assembly is opened and the instrument is powered. The optical assembly is not user serviceable.
	Indicates the connection is connected to earth ground and cabinet ground.

This device is a Class I laser product as defined by U.S. Department of Health and Human Services standards under the Radiation Control for Health and Safety Act of 1968 when operated according to the manufacturer's instruction. A certification and identification label like the one shown below is presented on the back panel of each instrument.



Labels

The Model 3786 Ultrafine Water-based Condensation Particle Counter has labels on the back of the instrument and on interior components. Labels are described below:

1 Serial Number Label (back panel) TSI Label with Model 3786	
2 Customer Service Label (back panel)	
3 Laser Radiation Symbol Label (located internally on the optical detector assembly)	
4 Class 1 Laser Label (back panel)	

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About This Manual

Purpose

This is a user manual for the Model 3786 Ultrafine Water-based Condensation Particle Counter (UWCPC).

Related Product Literature

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

- ***Model 3007 Condensation Particle Counter Operation and Service Manual*** (part number 1930035) TSI Incorporated
- ***Model 3010 Condensation Particle Counter Instruction Manual*** (part number 1933010) TSI Incorporated
- ***Model 3022A Condensation Particle Counter Instruction Manual*** (part number 1933763) TSI Incorporated
- ***Model 3025A Ultrafine Condensation Particle Counter Instruction Manual*** (part number 1933762) TSI Incorporated
- ***Model 3760A/3762 Condensation Particle Counter Instruction Manual*** (part number 1933772) TSI Incorporated
- ***Model 3782 Water-based Condensation Particle Counter Operation and Service Manual*** (part number 1930073) TSI Incorporated
- ***Model 3785 Water-based Condensation Particle Counter Operation and Service Manual*** (part number 1933001) TSI Incorporated
- ***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.

Submitting Comments

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

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

TSI Incorporated
500 Cardigan Road
Shoreview, MN 55126 USA
Fax: (651) 490-3824
Email: particle@tsi.com

CHAPTER 1

Product Overview

This chapter contains an introduction to the Model 3786 Ultrafine Water-based Condensation Particle Counter (UWCPC) and provides a brief explanation of how the system operates.

Product Description

The Model 3786 UWCPC is a continuous sheathed laminar flow instrument using water as its working fluid. The UWCPC provides rapid measurement of ultrafine particles in air.

Features include:

- Uses water as a working fluid
- Detects particles down to 2.5 nm at a high aerosol flow rate of 0.3 L/min
- Fast response to change in aerosol concentration (T_{95} <2 seconds)
- Sheath-air-flow design minimizes diffusion losses and produces a sharp lower cut-point
- Single particle counting with continuous, live-time coincidence correction for maximum accuracy
- Display provides output of particle concentration, total counts, or plots of concentration vs. time
- Built-in Scanning Mobility Particle Sizer™ (SMPS) Spectrometer compatibility

Figure 1-1
Model 3786 Ultrafine Water-based Condensation Particle Counter (UWCPC)

Acknowledgement

The continuous, laminar flow water-based condensation principle on which this product is based is patented[1] technology licensed from Aerosol Dynamics Inc. of Berkeley, CA. We give our sincere thanks to Susanne V. Hering PhD and Mark R. Stolzenburg PhD for their invention, their clever insights to this unique technology, their numerical models, and the gracious feedback they have provided during the development of this product.

[1] U.S. Patent 6712881

How it Works

The Model 3786 UWCPC is a water-based Condensation Particle Counter designed to measure the concentration of airborne ultrafine particles. In operation the UWCPC draws in an air sample and counts the number of particles in that sample to provide a particle concentration value that is displayed as the number of particles detected per cubic centimeter of sampled air.

The UWCPC uses a laser and optical detector to detect the particles, passing the sampled flow through a viewing volume illuminated by a laser. The instrument relies on a condensation technique to deposit a working fluid on the particle to grow or "amplify" their size to a value that can be detected readily with a conventional optical system. This instrument utilizes a new patented technology (Aerosol Dynamics Inc. Berkeley CA) that allows water to be used as the working fluid without the requirement of mixing or adiabatic expansion techniques. The aerosol sample is uninterrupted and follows a laminar-flow path from the sample inlet to the optical detector. Refer to Figure 1-2 for a diagram of the UWCPC flow system.

The aerosol enters the sample inlet and immediately half of the inlet flow is extracted, filtered and then combined with the remaining sample flow as clean sheath air. This combined flow enters a region surrounded with wetted media. The aerosol stream is saturated with water vapor and is temperature equilibrated. The sample then passes to a growth section where the wetted walls are heated to produce an elevated vapor pressure. The high diffusivity of water vapor allows the vapor to reach the center of the sample stream at a faster rate than the thermal diffusivity of the vapor can equilibrate to the higher temperatures near the walls. This results in a supersaturated condition along the radius of the flow stream. Particles in the flow stream act as nuclei for condensation. Water continues to condense on the particles as it passes up the growth tube and the enlarged particles are then detected by the optical detector. The clean sheath air is used in this system to keep the aerosol sample flow in the center of the growth tube where super-saturation is the highest.

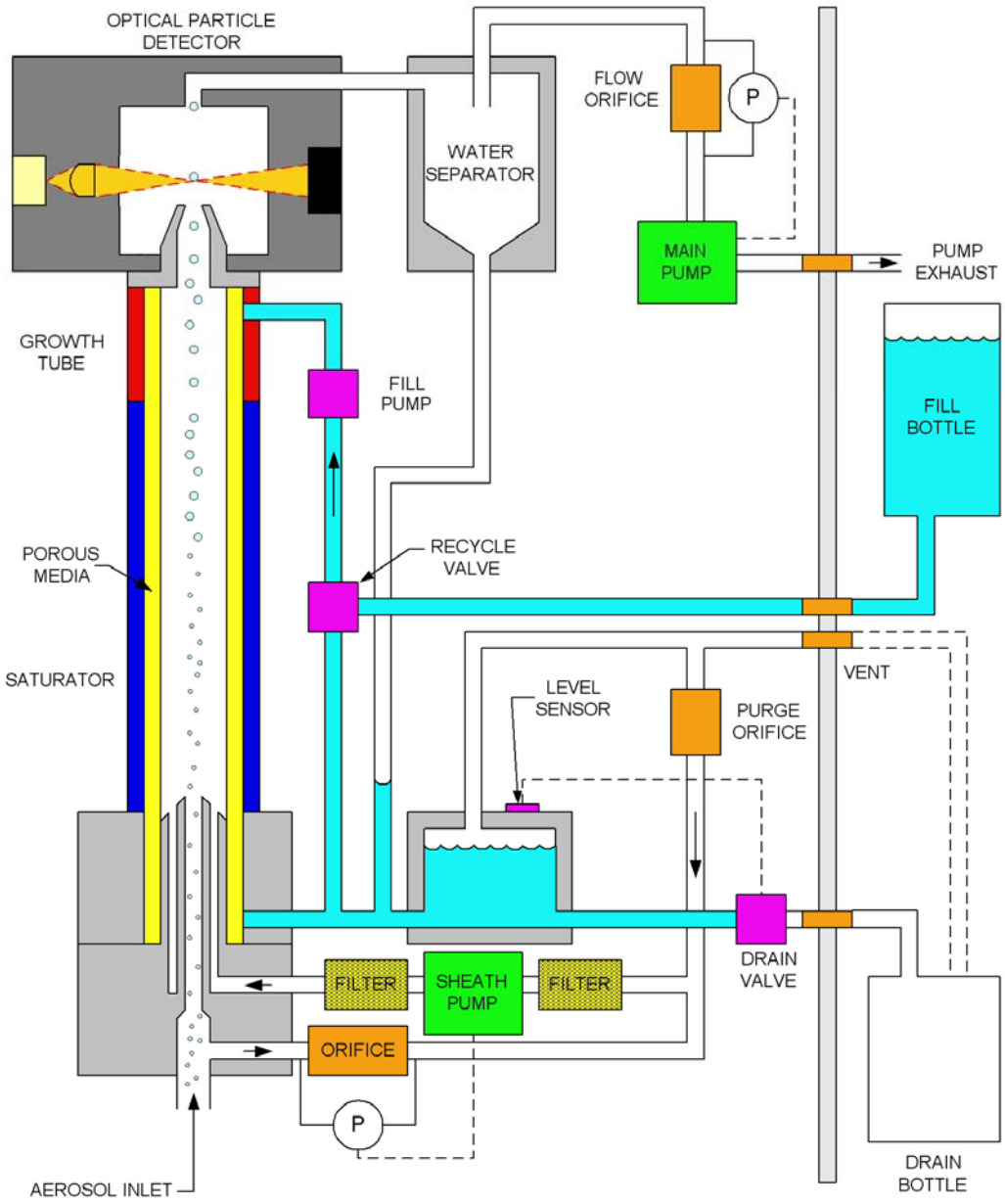


Figure 1-2
UWCPC Flow Diagram

Concentration Calculations

The UWCPC can report particle concentration values in three different ways. These are: the primary concentration display, the totalizer display, and the concentration values reported using the data communications ports.

In operation, the UWCPC internally measures two parameters related to the particle concentration. These are the number of particle pulses counted and the sample time. Another important parameter relating to concentration is the aerosol flow rate which is always assumed to be 0.3 L/min. The flow rate is actually the difference between the total or inlet flow rate which is 0.6 L/min and the sheath flow rate of 0.3 L/min. The basic calculation for the number of particles per volume of air is:

$$C_P = \frac{N_P}{T \times Q}$$

where:

- C_P is the particle concentration in particles/cm^3
- N_P is the number of particles counted
- T is the sample time
- Q is the aerosol flow rate in cm^3/second

The Totalizer uses the elapse time for the sample time in the above calculation to provide a useful way to acquire low particle concentration information on the display. The number of particles in the measured sample is one of the limiting factors of how low a particle concentration can be precisely determined. The formula for this statistical precision is:

$$\sigma_N = \frac{\sqrt{N}}{N} \times 100\%$$

where:

- σ_N is the relative standard deviation in percent
- N is the number of particle counts in the sample

For a sample of 10,000 particles the statistical precision is 1% which is much better than the accuracy of the instrument. At 100 particles the statistical uncertainty increases to 10% and becomes a significant factor in determining the aerosol concentration. The

Totalizer allows for increased statistical precision at low particle concentrations through the use of longer sample times.

When a particle enters the optical viewing volume and is being detected, no other particles can be counted. As the particle concentration increases, the amount of time blocked by the presence of particles becomes significant. If the particle concentration were computed using elapsed time, the value would be under reported. The actual sample time needs to be corrected for this blocked or dead-time. To adjust for this particle coincidence effect, the UWCPC measures the dead-time resulting from the presence of particles in the viewing volume and subtracts it from the sample time. This sample live-time value is used in place of the sample time for the concentration calculations for the primary display when not using the totalizer.

At very high concentrations, the dead-time value grows and the adjustment becomes large. Single particle events may not even be detected since particles are nearly continually in the measurement viewing volume and the accuracy of the live-time measurement begins to diminish. When the measured live-time value drops below 40% of elapse (real time), the display will show an “OVER” annotation indicating that the measured concentration exceeds its specified operating range. When the live-time value drops below 10% of elapse time, the display will show a concentration of 9.99E5 particles/cm^3 indicating an extreme overload condition.

During operation the UWCPC collects: single particle counts and dead-time corrected sample time every tenth of second. The concentration value reported on the primary concentration display is updated each second. It uses data collected over the previous second of elapsed time to calculate concentration. If the concentration is less than 20.0 particles/cm^3, a six-second running average of particle count data is used to calculate the displayed value. A single particle counted during this six-second sample is displayed as 0.03 particles/cm^3 which is the minimum value that can be displayed (other than 0.00) without using the totalizer. Concentration data is also available from the data communications ports and it is “aggregated” or summed from each tenth-second measurement with programmable sample periods from 0.1 second to 3600 seconds.

CHAPTER 2

Unpacking and Setting Up the UWCPC

Use the information in this chapter to unpack your Model 3786 Ultrafine Water-based Condensation Particle Counter (UWCPC) and set it up.

Packing List

Table 2-1 lists the components shipped with the UWCPC.

Table 2-1
Components of the Ultrafine Water-based Condensation Particle Counter

Qty	Description	Part Number
1	Ultrafine Water-based Condensation Particle Counter	3786 or 3786-PC*
1	Model 3786 Accessory Kit with the following parts:	
	1 UWCPC Wick**	1608070
	1 Model 3786 UWCPC Operation and Service Manual	1930072
	1 Serial Cable, RS-232 (9-pin, M/F)	962002
	1 USB Cable, I/O, A/B	1303740
	1 Fill Bottle Assembly	1210365
	1 Drain Bottle Assembly	1210366
	2 Drain/Vent Tubes with Mating Connectors	N/A
	1 Power Cord	N/A

*The 3786-PC is shipped with the PC/104 Single Board Computer installed in the UWCPC cabinet.

**The UWCPC is shipped with a dry wick installed and one spare wick is included with the accessories.

Table 2-2
Replacement Parts for the Ultrafine Water-based Condensation Particle Counter

Qty	Description	Part Number
1	Drain Reservoir O-Rings, Small	2501161
1	Drain Reservoir O-Rings, Large	2501162

Unpacking

Carefully unpack the Model 3786 Ultrafine Water-based Condensation Particle Counter (UWCPC) from the shipping container. Use the packing list (Table 2-1) to make certain that there are no missing components.

Save your original packaging materials for future use should you need to return the instrument to TSI for service.

If anything is missing or appears to be damaged, contact your TSI representative, or contact TSI Customer Service at 1-800-861-7919 (USA) or 001-(651) 490-3838. For Technical Support call 1-800-861-7032 (USA) or 001-(651) 765-3797. Chapter 5 includes instructions on returning the UWCPC to TSI Incorporated.

Important

This instrument operates using water as a working fluid. The instrument can tolerate tipping of up to ten degrees during normal operation. Perform the procedures outlined in the "Transporting" section before moving or shipping the instrument. Examples of improper handling include:

- Shipping an "undried" instrument.
- Transporting an "undrained" instrument.
- Excessive tipping (beyond ten degrees) of an "undrained" instrument.
- Subjecting an "undried" instrument to freezing temperatures.

Any of the above actions can result in the flooding of the optical system, performance degradation, and possible damage to the instrument. Such neglect is not covered under the manufacturer's warranty.

Setting Up

Perform the following steps to set up a new UWCPC or a unit that has been dried for shipment or storage.

1. Remove any protective cap on the Sample Inlet.

2. Install the growth tube wick. The UWCPC is shipped from the factory with the growth tube wick installed. The following wick installation instructions only need to be followed if the wick is not already installed.

   a. Loosen the two thumbscrews located at the Sample Inlet.

   b. Remove Sample Inlet assembly.

   c. Slip growth tube wick over exit end of the Sample Inlet assembly.

   d. Slide growth tube wick into the UWCPC and press to seat the O-ring seal.

   e. Tighten the thumbscrews securing the Sample Inlet assembly.

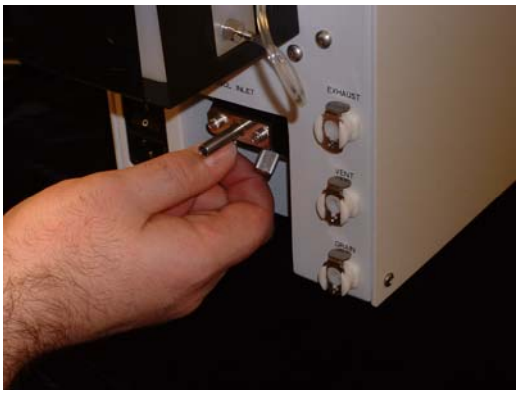


Figure 2-1
Location of UWCPC Wick on Sample Inlet Assembly

Figure 2-2
Installation of UWCPC Wick on Sample Inlet Assembly

3. Attach the water source.

   a. Fill water source bottle with distilled water. Tap water is not recommended.

   b. Place water source bottle into bottle bracket on the back of the UWCPC.

   c. Insert connector from the source bottle into the “Fill” connector on the back of the UWCPC.

Figure 2-3
Fill Bottle Connection

4. Connect the power.
   a. Attach power cord to the AC power inlet on the back of the UWCPC and to an AC power source.
   b. Turn on the AC power switch located just over the power connector.
5. Prime the instrument.
   a. Make sure the pump is off. The pump can be turned off by pressing the Pump button.
   b. Press the Drain/Prime button on the UWCPC front panel.
   c. Press the Drain/Prime button a second time to select the "Prime Growth Tube" function.
   d. Press and hold the Drain/Prime button for at least one second to activate the water priming function which will begin a sequence of twenty water injections.
   e. Each further press of the Drain/Prime button adds to the number of injections that will be performed. Press the Drain/Prime button several more times to increase the number of injections from the initial 20 up to at least 400. **Keep the pump off during this initial priming.**
   f. Repeated or excess priming will not harm the instrument and will only pass excess water to the drain reservoir.
6. Warm-up the instrument.

a. Wait for the UWCPC to warm-up and reach operating temperatures.

b. When the UWCPC is ready, the “status” indicator will be a steady green.

7. Connect the aerosol source.

a. Turn on the pump by pressing the Pump button. The UWCPC remembers the state (on or off) of the sample pump when it is powered off.

b. Connect the Sample Inlet to an aerosol source to be measured to begin measurement of the aerosol sample.

Transporting

This section describes the proper procedure for transporting the UWCPC short distances and how to prepare the instrument for shipping and storage.

Local Transporting

The following procedure may be used to transport the UWCPC over short distances such as across a lab, down the hall on a cart, and even a short drive in a vehicle, as long as the instrument is not subjected to tipping of more than 45 degrees or prolonged freezing temperatures.

1. Disconnect any connections to the Sample Inlet.

2. Turn on the UWCPC.

3. Drain the UWCPC.

a. Connect a Drain bottle to the Drain connector on the back panel of the UWCPC.

b. Press the Drain/Prime button on the front panel of the UWCPC to bring up the drain menu.

c. Press and hold the Drain/Prime button to active the drain cycle. Let the water drain from the reservoir for the one-minute drain cycle. Little or no water may drain if the reservoir is nearly empty.

d. Remove the drain bottle connector.

e. Switch off the instrument and remove the power cord.

4. The UWCPC is ready for local transporting.

Figure 2-4
Drain Bottle Connection

Shipping and Storage

The following procedure must be used in cases where the UWCPC must be shipped, stored, or subjected to freezing temperatures. The instrument must be "dried" using the following procedure.

1. Disconnect any connections to the Sample Inlet.

2. Remove the source water bottle and dry completely.

3. Turn on the UWCPC and let it complete its warm-up cycle.

4. Purge the UWCPC water source tubes.

   a. Press the Drain/Prime button on the UWCPC front panel.

   b. Press the Drain/Prime button a second time to select the "Prime Growth Tube" function.

   c. Press and hold the Drain/Prime button for at least one second to activate the water priming function.

   d. Press the Drain/Prime button several more times to increase the number of injections from the initial 20 up to at least 400. This will purge the water source tubing.

   e. Note that the water injection pump makes more noise when operated dry, this is normal.

5. Drain the UWCPC.

   a. Connect a drain bottle to the Drain connector on the back panel of the UWCPC.

   b. Press the Drain/Prime button on the front panel of the UWCPC to bring up the drain menu.

   c. Press and hold the Drain/Prime button to active the drain cycle. Let the water drain from the reservoir for the one-minute drain cycle. Tipping the UWCPC toward the side will allow for more complete draining of the unit. Tip only to the side and not to the back as shown in Figure 2-5. Little or no water may drain if the reservoir is nearly empty.

   d. Remove the drain bottle connector. Remove the drain bottle and dry completely.

Figure 2-5
Tipping the UWCPC During Drain Cycle for More Complete Drain of the Reservoir

6. Turn the UWCPC off and remove the power cord.
7. Remove the Wick.
   a. Loosen the Sample Inlet thumbscrews and remove the Sample Inlet assembly by pulling downward and out. Do this near the edge of the table so the growth tube wick can be removed by sliding it down over the table edge.
   b. Remove the wick from the Inlet assembly. Allow the wick to air dry and store in a plastic bag with the UWCPC accessories.
   c. Reinstall the Sample Inlet assembly without the wick and tighten the thumbscrews.
8. Drain and dry the reservoir.
   a. Make sure the UWCPC is turned off and the power cord is removed.
   b. Lay the UWCPC on its side over some paper towel. The Fill and Drain connectors must be down toward the work surface.

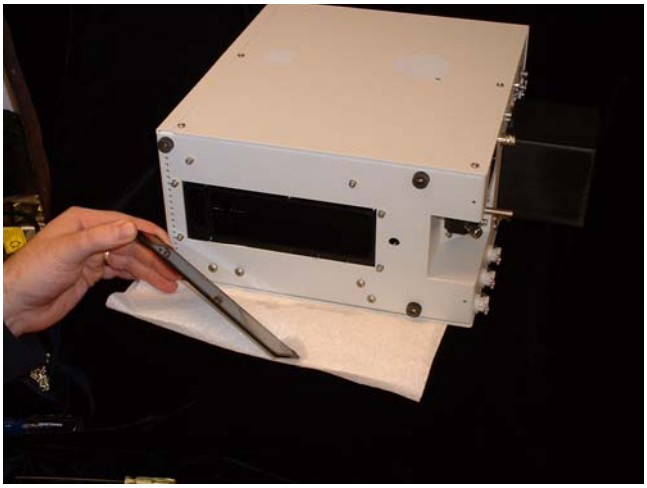


Figure 2-6
Location and Removal of the Reservoir Cover

Caution
Do **not** turn the UWCPC upside down. Flooding of the optical system could result if the unit is inverted with water present in the system.

c. DO **NOT** TURN THE UWCPC UPSIDE DOWN.

d. Remove the reservoir cover from the bottom of the WCPC using the eight screws indicated in Figure 2-6.

e. Tip the UWCPC up on its feet and lay it down on its opposite side to allow the water in the drain lines to purge.

f. Dry the reservoir and the cover completely.

g. Reinstall the reservoir cover being careful to fit the O-ring in place.

h. Set the instrument back in its upright position.

9. Final drying.

a. Connect power cord and turn on UWCPC.

b. Once warm-up cycle is complete, make sure pump is turned on.

c. Let instrument run for at least two hours.

d. Turn off the UWCPC and remove the power cord.

CHAPTER 3

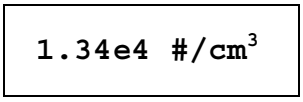
Instrument Operation

This chapter contains operating information for the Model 3786 Ultrafine Water-based Condensation Particle Counter (UWCPC).

The Display

The Display button on the front panel selects what data or status information is shown on the graphics display. During the warm-up period the Display button allows selection between the Warm-up screen and the Status screen. Once warm-up is complete, pressing the Display Button switches the information shown on the graphics display. Up to four different screens of information can be displayed. These screens are the Primary Concentration, Bar Graph, Totalizer, and the Status screen. The content of each of these screens is given below.

Primary Concentration Screen



The Primary Concentration screen is updated each second with an indication of the particle concentration. Displayed values range from 0.00 particles/cm^3 to 9.99e^5 particles/cm^3. For concentrations of 20.0 particles/cm^3 or higher, the display value is calculated on data measured over the previous second. For concentrations less than 20.0 particles/cm^3, six seconds of particle count data is used in the calculation of particle concentration. At this level of concentration, a single particle represents 0.03 particles/cm^3, so there will be significant variation in displayed values from one display update to the next because of the statistical nature of the arrival of particle at the detector. For a more statistically accurate measure of particle concentrations consider using the Totalizer function. The “OVER” is displayed in the upper right-hand corner of the screen when the measured live-time is less than 40% (0.4 seconds) of the real time. This indicates that the particle concentration reported is over the specified range of the instrument.

Bar Graph Screen

The Bar Graph screen displays measured particle concentrations over history. The graph rolls right to left with new data being added on the right for each update. The vertical scale is in units of the log of the particle concentration. The scale is automatically updated to include the highest recorded concentration over the history. Three decades of particle concentrations are displayed. The horizontal time scale is determined by the sample reporting time set by the communications interface. On power-up the sample reporting time is set to six seconds. The Bar Graph display then updates every six seconds with new concentration data. The graph contains a total of 120 time points so twelve minutes of concentration will be displayed.

If the sample reporting time is changed (see the SM command in the Communications section), the time associated with each horizontal bar will changed to match the new setting. If the data collection mode is turned off (SM,0 command), no data will be available to graph and the Bar Graph screen will not be available for viewing. The Bar Graph display also allows a convenient means to monitor data being reported over the communications interface.

Status Screen

The Status screen provides information about the operating condition of the instrument. The top line of the display provides information about liquid handing. The usual display is “Liquid -- Normal” indicating that the instrument has water and the drain reservoir is not full. Other conditions reported on this status line are covered in the section on Water Handling.

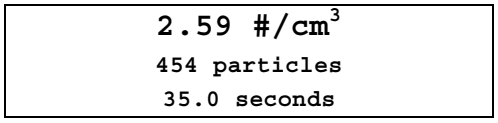
```
    Liquid -- Normal
Optc  75.0   Photo  225
GT    75.0   Abs    983
Sat   12.0   Flow   300
```

The left column under the liquid status line provides the operating temperatures of the Optics (Optc), Growth Tube (GT), and the Saturator (Sat). The temperatures are reported in degrees Centigrade. The value indicated next to the “Photo” label is the

current raw photometric reading which is typically between 150 and 280 for when no particle are detected. This value increases with particle concentration and provides an indication of the amount of light incident on the photo detector. The label “Abs” refers to the absolute inlet pressure and is reported in millibar. The final indicator labeled “Flow” provides the current aerosol flow rate measured by the instrument in units of cm^3/minute.

Totalizer

This screen displays a running total of particle counts, elapse time, and calculated concentration. Operation of the Totalizer is controlled using the Totalizer button. Pressing the Totalizer button will start data collection. Once started, the Totalizer accumulates particle counts and elapsed time. Pressing the button a second time will stop the counter and the timer, holding the current count, time totals, and the calculated concentration. Pressing the button a third time will clear the Totalizer preparing it for a new sample. Subsequent presses of the Totalizer button will repeat the Run, Stop and Reset sequence.



The totalizer function is intended for low concentration measurements and will display “Over” if the concentration exceeds 2000 particles/cm^3. No live-time correction is used in the accumulation of time. The Totalizer will stop automatically when the maximum time of 3600 seconds is reached. Eight digits of particle counts can be displayed. The displayed concentration range is from 0.0000 to 1000 particles/cm^3. The concentration displayed on this screen differs from the value shown on the Primary Concentration display because it is calculated solely on particles counted and elapse time of the totalizer sample.

Status Indicator Lights

Four lights above the display provide a quick indication of the UWCPC's current operating status.

Particle

The particle light is flashed for each particle detected. At particle concentrations in excess of about 5.0 #/cm^3 the flashes turn to a continuous glow.

Status

A steady glow of the status light indicates that the instrument has warmed to its operating temperatures and the laser is running at its normal operating power. A slow blinking of the light (1/second) is displayed when the operating temperatures are not within normal operating values. The indicator blinks fast (3/sec) when the internal laser is either turned off or otherwise not able to operate at its required power output setting.

Flow

The flow indicator displays a steady glow when the current aerosol flow rate is within ten percent of its nominal value of 300 cm^3/minute. The light will rapidly flash when the flow exceeds 110% of its nominal flow and it will flash slowly if the flow rate drops below 90%. The light will be turned off if the pump is switched off.

Liquid

The liquid indicator will be lit during normal operation when the drain reservoir is not full and the growth tube is not dry. The indicator will flash slowly when the drain reservoir is full and will be turned off if the full drain condition persists for more than ten minutes, at which time water injection will cease (see Water Handling). The indicator will flash rapidly if a dry growth tube wick is detected.

Table 3-1
Front Panel Indicator Conditions

Indicator	Particle	Status	Flow	Liquid
Off	No particles	Instrument off	Pump off	Drain reservoir full and water injections stopped
Slow Flashing	Particles detected	Instrument not at operating temperatures	Low flow rate	Drain reservoir full
Fast Flashing	Particles detected	Laser off or not at required power	High flow rate	Growth tube wick is dry
On	Particle concentration is over about 5.0 #/cm^3	Normal operation	Normal flow rate	Normal operation

Air-Flow System

A pair of pumps draw aerosol into the UWCPC and provide the sheath flow. These pumps can be turned on or off by pressing the Pump button on the front panel. The UWCPC saves this on or off condition so when the instrument is turned on, it will resume that state after the warm-up cycle. The Flow indicator light on the front panel provides an indication of the pump and flow status. When operating, a flashing Flow indicator results from the inability of the pumping system to maintain the calibrated flow. This may be the result of excessive pressure variations at the sample inlet.

Inlet flow is feedback controlled to maintain a steady calibrated value of 0.6 L/min volumetric flow rate. The sheath flow is feedback controlled to a value of 0.3 L/min and the difference between these flows is the aerosol flow rate which is nominally 0.3 L/min. The feedback controls includes a measure of the inlet absolute pressure to continuously compensate for pressure changes. There is an internal purge flow (~10% of sheath) that draws air out of the sheath flow loop to minimize any reentrainment of particles into the sample stream during changes in inlet pressure. This maintains the instruments' response time and zero-count performance. The

actual value of purge flow rate does not impact the aerosol flow rate.

Water System

During operation the porous media inside the UWCPC requires a continuous input of water. Excess water exits the media and is collected in a reservoir along with water recovered from the vapor in the sample stream. The UWCPC has several available options on how the water is sourced and how excess water in the reservoir is drained.

All source water initially comes from the connected Fill Bottle located in the bracket on the back of the instrument. After the instrument is primed, the source of water can continue to come completely from the source bottle or can be recycled from recovered water from the reservoir. By using the recycle option, the length of time that the UWCPC can be operated without refilling the Fill Bottle is extended from about a day to over eight days. Also, since the recycled water comes from the reservoir it will only need draining about once a week instead of once a day for the non-recycling mode. During the recycling mode approximately 20% of the water is always taken from the Fill Bottle to ensure that there is always water present in the reservoir.

Regardless of the source mode the reservoir will eventually fill and require draining. When the reservoir fills, a level detector senses the condition which will be indicated with the Liquid status light, and on the Status Screen on the display. If the full condition persists for more than ten minutes, the instrument will stop sourcing water to avoid flooding the instrument sample flow path. The instrument will remain in this shutdown condition until the reservoir is drained. There are three drain modes: Manual, Automatic, and Continuous, which are provided to handle removal of excess water from the reservoir.

The recycle mode along with the drain modes can be selected through the Drain/Prime button on the front panel of the WCPC as described in the Drain Modes section.

Drain Modes

At any time during operation, a drain cycle can be initiated manually by pressing the Drain/Prime button on the front panel and then pressing it a second time and holding it for at least one second. During a drain cycle, the pump will be turned off and a drain valve will be opened allowing the reservoir to be drained. The cycle duration is one minute, but it can be terminated early by pressing the Display button on the front panel. The Drain connector on the back panel is closed if disconnected. This avoids spillage of water, but it will also keep the reservoir from draining if nothing is connected to the Drain connector.

To select the recycle mode and the drain modes, press the Drain/Prime button to access the Drain/Prime menu. Press the button two more times to select the Set Drain Mode option. Press and hold the button for at least a second to access the Set Drain Mode menu. One of four drain modes can be selected through this menu: Recycle/Manual, Recycle/Auto Drain, Auto Drain, and Continuous Drain. These modes can also be selected through firmware commands.

In Manual drain mode, the UWCPC will only perform a drain cycle when initiated through the front panel Drain/Prime menu or by command through a data port.

When operating in Automatic drain mode, the UWCPC will begin a drain cycle when the level sensor detects that the reservoir is full.

During the Continuous drain mode, the drain value is left open and water entering the reservoir immediately drains to the externally connected Drain bottle. The Drain bottle must be tightly sealed and vented to the Vent connector on the back panel.

For all drain modes it is important that the air pressure at the Sample Inlet be equal or higher than the pressure at the drain bottle. If the pressure at the Sample Inlet is lower than the drain bottle, the reservoir will not drain into the bottle, but can potentially flow up and out of the Sample Inlet. The sample pump is turned off during the drain cycle to assist in ensuring that any pressure at the inlet is minimized. In cases where the sample inlet pressure is reduced by external sources, the second port on the

drain bottle must be connected back to the Vent connector on the back panel.

Sample Inlet Connection

The Sample Inlet is located on the back of the UWCPC. Turn off the pump before connecting or disconnecting sample sources. Keep sample lines as short as possible. Use of metallic or conductive sample lines is recommended to reduce particle losses due to electrostatics. Avoid larger pressure restrictions (>25 cm water at 0.6 L/min) or sample sources with pulsating pressure.

CHAPTER 4

Data Collection

This chapter contains information related to the UWCPC's data interfaces and optional embedded PC/104 single board computer for data collection.

Data Interfaces

The UWCPC provides several data interfaces allowing for flexible data collection and instrument control. There are four connectors on the back panel. Two connectors provide direct access to the UWCPC and the remaining two provide access to the optional PC/104 single board computer (SBC). The connectors are:

Serial	Standard RS-232 type serial communications. This interface is provided through the 9-pin D-Sub connector on the back panel of the UWCPC. The connector pin-out is given in Table 4-1.
USB	Universal Serial Bus communications. This interface provides an alternate path for the serial interface mentioned above. To a host computer, this interface acts like an additional serial port to the computer.
PC/104 Serial	Serial communications to the optional internal PC/104 SBC (PC/104 Com1)
PC/104 Ethernet	Ethernet connection to the optional internal PC/104 SBC (PC/104 eth0)

Table 4-1. Serial Connector Signal Connections

Pin Number	Signal	Direction
2	RXD	INPUT TO UWCPC
3	TXD	OUTPUT FROM UWCPC
5	GND	—

When the PC/104 SBC is installed there is an internal connection between the UWCPC and the PC/104 SBC. If the UWCPC is purchased without the optional PC/104 SBC, the associated connectors have no internal connections to the UWCPC.

The Serial and USB data interfaces share a common communications channel to the UWCPC microcontroller. Figure 4-1 provides a diagram of the data communications paths within the UWCPC. Data input to the UWCPC from the Serial interface is exclusive from input via the USB interface. Communications can be received from the Serial interface until a connection is linked to the USB Port. Once this link is established (USB link light is on) communications can be received via the USB Port but not from the Serial port. When the USB link is terminated (disconnected) the Serial port can be again used to provide input to the UWCPC.

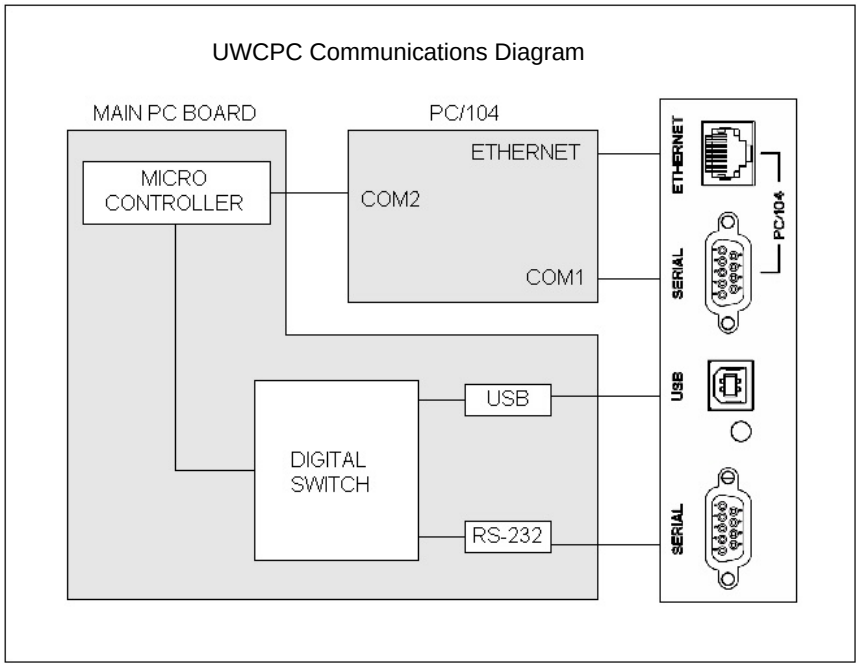


Figure 4-1
UWCPC Data Communications Diagram

The UWCPC can receive serial data commands from the Internal Com and from either the Serial or the USB Port but not both. The UWCPC uses a single receive buffer for communications so care must be taken to ensure that commands are not sent simultaneously causing the data to be jumbled. This is typically not a problem as the Internal Com is not used unless a user initiated program is running on the PC/104 SBC. UWCPC responses to commands received on the Internal Com are returned on the Internal Com and commands received from the Serial or USB interfaces are returned on BOTH of these interfaces.

On power-up, the UWCPC is setup to send a data record to the Serial interface once every six seconds. The USB link light will flash whenever data is transmitted by the UWCPC to the Serial or USB interfaces. When the USB interface is connected to a host device, the link light will turn on and momentarily blink off when data is transmitted.

USB Driver Software

USB drivers software must be installed on the host computer. For Windows® operating systems the drivers may be downloaded from the USB chip manufacturers' site at:

www.ftdichip.com/FTDrivers.htm

or are available from Windows Update.

Perform the following steps to install the Windows USB driver:

1. Download the driver (FT232BM VCP).
2. Extract (unzip) the driver into a blank folder.
3. Connect the computer to the UWCPC USB port.
4. Follow the "Add New Hardware" Wizard steps and browse to the folder containing the extracted driver.
5. If the Wizard does not start, use the "Add Hardware" function from the "Control Panel."

USB device drivers for the Linux Kernel 2.4.0 and greater are built-in the O.S. kernel so no downloads are necessary.

Once the USB driver is loaded, the operating systems recognizes the UWCPC as a new serial device. In MS-Windows this is a new port such as COM2 or COM6. It may not be obvious which Com Port the UWCPC is on and some trial-and-error selecting various ports may be necessary to identify the correct port.

®Windows is a registered trademark of Microsoft Corporation.

Communications Parameters

All serial communications with the UWCPC are accomplished using the following communications parameters:

Baud Rate.....115,200
Bits/Character.....8
Stop bits 1
Parity .....None

All data communication is preformed through ASCII-based character codes.

All multi-field responses are comma separated values (CSV).

All input commands and output responses are terminated with a carriage-return (CR).

All input Line-feeds (LF) codes are ignored.

Terminal Communications

Once the Serial or USB connection is made between the UWCPC and a host computer, a terminal program may be used to communicate with the instrument. Terminal emulation software that can be used includes:

- Tera Term, a free software terminal emulator for MS-Windows available at:
  http://hp.vector.co.jp/authors/VA002416/teraterm.html
- HyperTerminal™ which is included with most MS-Windows operating systems.
- The programs, minicom and xminicom, are included with most Linux distributions.

™HyperTerminal is a trademark of Hilgraeve Inc.

It is recommended that the terminal software be set up to translate incoming carriage returns (CR) to carriage return/line feed (CR/LF) sequences so the data returned from the UWCPC does overwrite the previous written line piling all the data on a single line on the screen. It is also convenient to enable local echoing of characters so data typed on the keyboard is shown on the screen as well.

Once connected and running, pressing the “Enter” key within the terminal software will elicit a response of “ERROR” from the UWCPC. This indicates that the UWCPC and computer are in communication, but it didn’t know what you were asking. Data records beginning with the character “D” will also be displayed every six seconds as the UWCPC reports from its power-up default condition.

Appendix B, “Firmware Commands,” contains a large list of commands that control the operation and data reporting options of the UWCPC. The most immediately useful command is the SM (Set Mode) command which controls what data is reported and its frequency. The power up default mode is SM,2,60 which implies sending a data (D) record continuously at the rate of once every sixty tenths of a second.

Once data is being reported to the screen of the terminal software, it is quite straightforward to cut-and-paste or turn on the software’s logging capability to capture the data. Data in this comma delimited form is easy to import to other programs such as Microsoft Excel for analysis and graphing.

PC/104 Single Board Computer Option

The UWCPC with the -PC option is assembled with an internal PC/104 style single board computer (SBC). The SBC used within the UWCPC at the time this manual was written is a PCM-3347/3348 manufactured by EMAC, Inc. (http://www.emacinc.com). The SBC is loaded with the Linux operating system. It is expected that the user have a working knowledge of Linux and some programming experience in order to use this option.

The SBC is setup to provide the PC/104 Serial port to be a terminal server. A terminal or computer running terminal emulation software can access the SBC through this port. A Null Modem (crossover) cable is needed to connect a computer to this port. The default serial settings for the PC/104 terminal server are:

Baud Rate..... 9600
Bits/Character..... 8
Stop bits 1
Parity ..... None

A login prompt is provided. The user name and password for the default configuration of the SBC are:

User Name: root
Password: emac_inc

The SBC Ethernet port (eth0) is configured to gather an IP address from an external DHCP server. For the SBC to actually acquire an IP address it must be connected to a network with an active DHCP server BEFORE powering up the UWCPC. The connection to the Ethernet port must be made with a shielded twisted pair 10-BaseT network cable. The Ethernet configuration may be changed to provide a static IP address using the start up configuration routine provided.

The terminal emulation program “minicom” has been configured to use one of serial ports (/dev/ttyS1) to communicate with the UWCPC through an internal connection. This program may be used to test operation with the UWCPC and even to capture data. It should be noted that the SBC is setup with a “read-only” file system. This ensures that when the UWCPC is turned off and the SBC is brought down “hard”, the SBC will boot cleanly on the next power up. This also means that for data to be saved to the SBC it must be either written to the “/var” directory which is mounted read-write in RAM, or the file system must be mounted read-write during the moments when data is to be written.

A demonstration program has been included named “WCPCLog” and is located in the directory /home/WCPC. The program written in “C” initiates a SM,2,60 command, captures the data (D) records returned by the UWCPC, timestamps them, stores them, and creates a new data file each day. A link to the /home/WCPC

directory is included in /home/www directory so files created by the program can be accessed via the internal web server.

The UWCPC can receive and send data from two different channels; the Serial/USB source and the Internal Com between the microcontroller and the SBC. Commands received and executed on one channel are responded to on that same channel. Likewise the data records reported as the result of an SM firmware command are returned on whatever channel that instigated it.

CHAPTER 5

Maintenance and Troubleshooting

This chapter provides maintenance and troubleshooting information for the Model 3786 Ultrafine Water-based Condensation Particle Counter (UWCPC).

Replacing Wick

It is recommended that a new wick be installed in the UWCPC a minimum of every six months. Refer to Chapter 2, "Unpacking and Setting Up the UWCPC," for steps involved in removing the old wick. Once the inlet assembly has been removed, simply slip off the old wick from the assembly and slide on the new one. Reinstall the inlet assembly and tighten the thumbscrews. Once the unit is returned to service, prime the new wick with 5 cc water (100 injections).

When replacing the wick it is a good time to also clean any accumulated material from the drain reservoir. See the section on drying the UWCPC in Chapter 2, "Unpacking and Setting Up the UWCPC," for instructions on removing the reservoir cover from the bottom of the instrument. Wipe out any residue from the reservoir with a wet cloth. Reinstall the reservoir cover making sure the O-rings are properly seated.

Flow Calibration

The inlet and sheath flows of the UWCPC are feedback-controlled to set point values stored in non-volatile memory. The inlet flow can be readily checked by connecting a volumetric flow meter to the sample inlet and turning on the pump. The indicated flow value should be 0.6 L/min plus or minus about 5%. The actual aerosol flow rate is the difference between the inlet flow rate and the sheath flow rate. To check this value the instrument cover must be removed and a flow meter connected to the sheath flow tube. The sheath air flows through a tube marked with a green marking tag, refer to Figure 5-1. The tube connected to the UWCPC engine assembly should be separated from the stainless-steel fitting marked with the green tag. Once separated the open end of the stainless-steel fitting can be connected to a flow meter with a short length of flexible tubing. The air flow out of this fitting contains both the sheath flow *and* the

purge flow. To measure the sheath flow without the influence of the purge flow, pinch off the purge flow using a hemostat or thin-nosed pliers on the tube marked with a yellow indicator tag. The value of the flow in the sheath flow line should be 0.3 L/min plus or minus about 5%. Restoring the purge flow should add about 10% to the sheath flow value. The actual value of purge flow is not critical, but the change in flow measured by pinching off the purge line indicates that the line is working and is unobstructed. The flow measurement should be made only when the instrument has been warmed-up and running for at least 15 minutes. Also, the instrument must be fully primed to ensure the internal water trap is filled. Remember to reconnect the sheath flow back to the tube connecting it to the UWCPC engine assembly.

W A R N I N G
High voltage is accessible in several locations within this instrument.

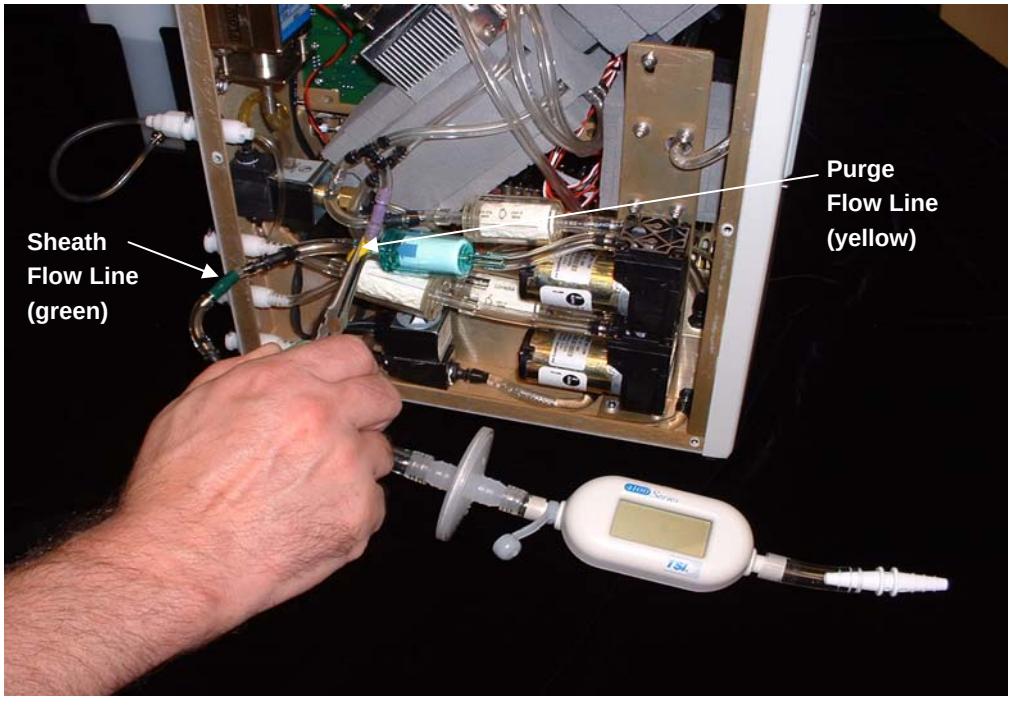


Figure 5-1
Location of Sheath and Purge Flow Lines

To change the flow calibration, the internally stored calibration set point must be changed. A computer running a terminal emulation program as described in Chapter 4 must be connected to the UWCPC. Entering the command SFS (Set Flow Set Point) will echo the current set point value to the terminal screen. The flow set point value can be changed by entering a new value using the same command followed by a comma and the value. Increasing the set point value will increase the flow. Changes to the value of 10 or more may be necessary to see changes in the flow meter reading depending on its sensitivity. The sheath flow calibration set point value can be queried and changed in a like manner using the SHS (Set sHeath Set point) command.

For example:

Command	**Response**	
SFS	1250	UWCPC returns current flow set point value.
SFS,1260	OK	UWCPC accepts new set point and increases flow rate.
SFS	1260	UWCPC returns new flow set point.

The set point value should be adjusted until a flow meter reading of 0.6 L/min is obtained.

Troubleshooting

This section provides information on troubleshooting the following:

- Water in the sample inlet.
- Little or no water flows during drain cycle.
- Water spurts out of pump exhaust.
- High or low photometric readings.
- Rapidly flashing status indicator—laser.

Water in the Sample Inlet

Water flowing out of the sample inlet or gurgling inside the inlet may result from several situations including:

- Tipping of the UWCPC beyond ten degrees.
- A warm humid aerosol sample is condensing within the cooled inlet.
- The drain reservoir is overfilled.

Water in the inlet can be cleared by removing the inlet assembly, slipping off the wick, and drying the sample path with a cotton swab.

The reservoir should be drained.

Some inlet conditioning should be provided to lower the dew-point of the aerosol sample if the cause of water in the inlet is due to condensation.

Little or No Water Flows During Drain Cycle

The lack of water flow from the drain port during a drain cycle is an indication that some reduced pressure exists on the sample inlet or little or no water is in the reservoir. Water in the drain tube connecting the UWCPC to the drain bottle can also impede draining. The Drain bottle must be positioned below the instrument level to allow proper draining. Remove any connection to the sample inlet and reinitiate the drain cycle. Alternatively, connect the Vent connection to the Drain bottle to equalize the pressure. The reservoir will not drain completely during a drain cycle, but draining can be assisted by tipping the UWCPC to the side toward the drain port. Do **not** tip the UWCPC toward the sample inlet as the internal drain port connection to the reservoir is on the side. To prepare the UWCPC for shipment, refer to the Transporting section in Chapter 2, "Unpacking and Setting Up the UWCPC," for details on how to completely dry the UWCPC.

Water Spurts Out of Pump Exhaust

Water emitted from the pump exhaust is typically symptomatic of:

- Insufficient priming during initial startup

When the UWCPC is first started after being dried, the unit must be primed with approximately 400 priming injections before the internal reservoir trap is filled. If the pump is started before trap is filled, the trap will bubble causing water bubble into the pump/flow system and out of the pump exhaust. Other possible causes of water in the pump exhaust are:

- Pressure surges on the sample inlet.
- Excessive tipping of the unit during operation.
- An obstruction of the sample nozzle orifice.
- Failure of the temperature control on the water separator.

All of these situations will cause water to enter the air-flow system downstream of the water separator. Water in these lines needs to be removed before a controlled sample flow can be maintained. Performing the following steps will generally clear the lines and restore normal operation.

1. Turn off the pump and disconnect any connections to the Sample Inlet.
2. Remove the wick and disconnect the Fill Bottle.
3. Connect Drain Bottle and perform a manual Drain cycle.
4. Operate unit with the Pump on for a period of at least eight hours to dry the flow lines.
5. Connect a flow meter to the Sample Inlet and check for proper flow rate. Low flow values may indicate an obstruction in the sample nozzle or other portions of the flow system.
6. Replace the wick and reconnect the Fill Bottle.
7. The unit can now be reprimed with water and returned to service.

Reoccurrence of symptoms may indicate a failure of the water separator or an obstruction in the flow system. Contact TSI for service.

High or Low Photometric Readings

A good check of the instrument's "optical health" is the raw "Photo" value displayed on the status screen. The baseline value should be between about 150 and 280 when the instrument is warmed-up and the pump is off (no flow). Lower values than this should only occur during warm-up when the photo detector has not reached its operating temperature. Values higher than this range may occur before the instrument has reached operating temperature or the optical background light has increased. A typical symptom of water in the optical system (flooded optics) is a very high photometric baseline value. High background light can be confirmed by turning off the laser and observing the resulting baseline value. The laser can be turned off using a computer connected to the UWCPC that is running a terminal emulation program. The command SL,0 will "Set Laser" to off and a SL,1 command will turn the laser on. Powering up the instrument will also turn on the laser. When the laser is turned off, there is no background light so if the baseline photometric value returns to a normal range, it is likely that water or other contaminates are present in the optical system. Apply the following steps as the first approach to drying a flooded optical system:

1. Drain the UWCPC reservoir.
2. Remove the wick.
3. Disconnect the fill bottle.
4. Disconnect any sample source from the sample inlet.
5. Operate unit with pump on in a dry environment for at least 10 hours.

Drying the optics should return the baseline photometric value to its normal range. Flooding of the optical system will likely leave residues on the optical surfaces which may affect the photometric calibration. Reinstall the wick, connect the Fill Bottle, and reprime the unit with water before returning it to operation. For cleaning and recalibration contact TSI and arrange for factory service.

Rapidly Flashing Status Indicator—Laser

A rapidly flashing Status indicator occurs whenever the laser is not operating at its set-point value. This will happen under the following conditions:

- The laser has been turned off using a SL,0 command through one of the serial data interfaces.
- On power-up the UWCPC detected that the laser set-point value exceeded the maximum allowed laser power. This is also accompanied by a message on the display during start-up. The UWCPC leaves the laser off when this condition is detected.
- The laser is no longer able to provide the power necessary for proper operations and needs to be replaced. The laser diode is not a user replaceable part; contact TSI Customer Service for repair.

Technical Contacts

- If you have difficulty setting up or operating the Model 3786 UWCPC, or if you have technical or application questions, contact an applications engineer at 1-800-861-7032 (USA) or 001 (651) 765-3797.
- If the UWCPC does not operate properly, or if you are returning the UWCPC for service, contact TSI at:

  TSI Incorporated
  500 Cardigan Road
  Shoreview, MN 55126 USA
  Phone: 1-800-861-7919 (USA) or 001 (651) 490-3838
  E-mail: technical.service@tsi.com
  Website: http://service.tsi.com

Returning the UWCPC for Service

Before returning the UWCPC to TSI for service, call TSI at 1-800-861-7919 (USA) or 001 (651) 490-3838 for specific return instructions. Or you can fill out our on-line RMA form at www.tsi.com. Customer Service will need the following information when you call or use the on-line form:

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

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

APPENDIX A

Specifications

Model 3786 Ultrafine Water-based Condensation Particle Counter (UWCPC) specifications are as follows (specifications are subject to change):

Particle Size Range	
Minimum detectable particle (D_{50})	2.5 nm (wettable aerosols)
Maximum detectable particle	>3 micrometers
Particle Concentration	
Single particle counting (live-time corrected)	0 to 1×10^5 particles/cm^3
Particle Concentration Accuracy	±12% at $<10^5$ particles/cm^3 (does not include error due to counting statistics)
False Background Counts	<0.001 particle/cm^3 one-hour average
Response Time	<2 seconds for 95% response to concentration step change
Aerosol Medium	Use with air only 10°C to 35°C
Light Source	3 mw 655 nm laser diode
Flow	
Aerosol flow rate	0.3 L/min (nominal)
Sheath flow rate	0.3 ± 0.03 L/min
Inlet flow rate	0.6 ± 0.03 L/min
Flow control	Two internal pumps controlled to calibrated pressure drop across orifice with inlet pressure correction.
Flow source	Two internal diaphragm pumps
Absolute Pressure Operating Range	50 to 110 kPa (0.5 to 1.1 atm)
Inlet Pressure (Gauge)	±2.5 kPa (±10 in. of water)
Condensing Liquid	Water (distilled water recommended)
Filling system	Internal liquid injection valve, with water recycling capability. Source water container located externally.
Optional Auxiliary Single-Board-Computer (SBC)	An internally mounted PC/104 SBC provides externally available Serial and Ethernet ports and internal serial connection to UWCPC. The SBC is provided with Linux OS, Web server, FTP and Telnet services.
Communications	UWCPC control and data can be accessed digitally directly using USB or Serial interfaces. Serial and Ethernet interfaces are available to the internal SBC which has an internal serial interface to the UWCPC.
Analog Output	0-10 volt controlled via communications from PC/104 or serial interface.

Front Panel	
Display	140 × 32 pixel VF Display provides output of particle concentration, bar graph history of particle concentration, particle totalizer, aerosol flow rate, and operating parameters.
LED Indicators	Particle, Status, Flow and Liquid
Buttons	Display, Totalizer, Pump, Drain/Prime
Back Panel Connections	PC/104 - Ethernet Connector, PC/104 – Com1 Connector, USB connector, Com Port connector, Power Connector, Water Source connector, Vent connector (normally closed), Water Drain connector, Pump Exhaust connector, Aerosol Inlet (¼" OD SS tube), Analog Output BNC
Calibration Interval	Recommended Annually
Power requirements	100–230 VAC 50/60 Hz 125 VA
Dimensions (HWD)	31 cm × 16 cm × 28 cm (12 in. × 6 in. × 11 in.), not including fill bottle or bracket
Weight (dry)	5.5 kg (12 lbs.)
Environmental Conditions	Indoor use. Altitude: Up to 3000 m (10,000 ft). Ambient Temperature: 10° to 35°C Ambient Humidity: 0 to 90% RH (non-condensing). Over-voltage Category II. Pollution Degree II.

APPENDIX B

Firmware Commands

This appendix provides a quick reference and description of firmware commands.

Commands—Quick Reference

RD	**R**ead **D**isplay concentration
RL	**R**ead **L**aser
RRA	**R**ead **R**ecord raw **A**nalog
RRC	**R**ead **R**ecord **C**ontrol
RRD	**R**ead **R**ecord **D**ata
RRS	**R**ead **R**ecord **S**tatus
RTO	**R**ead **T**ime **O**n
RV	**R**ead **V**ersion
SAS	**S**et **A**bsolute pressure **S**cale factor
SD	**S**et **D**ryer on/off
SDC	**S**et **D**ead-time **C**orrection value
SDM	**S**et **D**rain **M**ode
SDO	**S**et **D**etector **O**ffset
SDT	**S**et **D**etector **T**hreshold
SFS	**S**et **F**low **S**et point
SFZ	**S**et **F**low **Z**ero value
SG	**S**et **G**rowth heater on/off
SGS	**S**et **G**rowth tube temperature **S**et point
SHS	**S**et s**H**eath flow **S**et point
SIP	**S**et **I**njection **P**rime
SIT	**S**et **I**njection **T**ime interval
SL	**S**et **L**aser on/off
SLM	**S**et **L**ive-time **M**inimum value
SLS	**S**et **L**aser **S**et point
SM,x,t	**S**et **M**ode **x**=mode **t**=sample time
SO	**S**et **O**ptics heater on/off
SOS	**S**et **O**ptics temperature **S**et point
SP	**S**et **P**ump on/off
SS	**S**et **S**aturator temperature controller on/off
SSS	**S**et **S**aturator temperature **S**et point
SV	**S**et analog **V**oltage output
SVS	**S**et analog **V**oltage **S**pan value
SVZ	**S**et analog **V**oltage **Z**ero value
SZ	**S**et auto **Z**ero function

Read Commands

RD **R**ead **D**isplay Concentration

This command returns the primary concentration display value.

Command:	**RD**	
Response:	**c**	c = One-second display concentration value
Example:	**RD**	Read Display Concentration
	6.34E4	Concentration value in paricles/cm^3

RL **R**ead **L**aser

This command returns the current laser power in percent of the laser setting and the laser current in milliamps.

Command:	**RL**	
Response:	**p,c**	p = laser power in percent (0 to 150)
		c = laser current in milliamps (0 to 300)
Example:	**RL**	Read Laser command
	97,45	Laser Power at 97% , laser current at 45 milliamps

RRA **R**ead **R**ecord **A**nalog

This command returns the current raw analog values in the A record format (see below). This command is intended for diagnostic use only.

Command: **RRA**
Response: (A Record - see Data Reporting Records section in this Appendix)

RRC **R**ead **R**ecord **C**ontrol

This command returns the current control values in the C record format (see below). This command is intended for diagnostic use only.

Command: **RRC**
Response: (C Record - see Data Reporting Records section in this Appendix)

RRD **R**ead **R**ecord **D**ata

This command returns the current data values in the D record format (see below).

Command: **RRD**
Response: (D Record - see Data Reporting Records section in this Appendix)

RRS **R**ead **R**ecord **S**tatus

This command returns the current status values in the S record format (see below).

Command: **RRS**
Response: (S Record - see Data Reporting Records section in this Appendix)

RTO **R**ead **T**ime **O**n

This command reports the instruments power-on time.

Command:	**RTO**	Read on-time command
Response:	**hhhh:mm**	hhhh number of on-time hours
		mm number of on-time minutes
Example:	**RTO**	Read power on time
Response:	**456:40**	456 hours and 40 minutes

RV **R**ead **V**ersion

This command returns the instruments Model number, firmware revision and its serial number.

Command:	**RV**	Read Version command
Response:	**Model 3876 Ver v.vv S/N nnnn**	
		v.vv ranges 0.01 to 9.99 (3 digits)
		nnnn ranges 100 to 99999999
Example:	**RV**	Read Version
Response:	**Model 3876 Ver 2.01 S/N 12453348**	

Set Commands

These commands are used to set instrument parameters, data collection modes, and water handling modes. When set commands are issued without a parameter, the return response is the current setting of the parameter or mode. The Set commands will cause interruptions in data reporting, so execution of these commands during the data collection process is not recommended. The primary Set command intended for user control of data collection is SM (Set Mode) command.

Caution
The use of Set commands other than the SM can adversely affect the calibration of the instrument, and possible damage. Use extreme care when executing Set commands.

SAS **S**et **A**bsolute Pressure **S**cale Factor

This command is used to calibrate the absolute pressure sensor. The supplied parameter is stored internally as a gain factor. The nominal value for the parameter is 1000.

Command:	**SAS,x**	Set Absolute pressure sensor scale factor (500 to 1500)
Response:	**OK**	
Example:	**SAS,1020**	Command
	OK	Response
	SAS	Command
	1020	Response - echoing current value of 40 millivolts

SD **S**et **D**ryer

This command allows the dryer to be turned on or off. The dryer is on by default upon power-up.

Command:	**SD,x**	Command to set dryer on or off x = 0 turns dryer off, x = 1 turns dryer on
Response:	**OK**	Response
Example:	**SD,0**	Command turns dryer off
	OK	Response
	SD	Command to read back the current setting
	0	Response indicates dryer is off

SDC **S**et **D**ead-time **C**orrection

This command controls the amount of correction that is applied to the instrument's measured dead-time. The UWCPC measures the dead-time by measuring the time a particle signal exceeds a preset threshold. This value is slightly under reported since the particle signal is of Gaussian shape and the digitized threshold value is less than the time to which the next particle could actually be detected. The actual dead-time value used in the UWCPC is the measured dead-time value multiplied by this factor (in percent).

Command:	**SDC,x**	Command to set dead-time correction x= 0 to 200 in units of percentage
Response:	**OK**	
Example:	**SDC,110**	Command sets dead-time correction to 110%
	OK	Response
	SDC	Command
	110	Response

SDM **S**et **D**rain **M**ode

This command sets the reservoir drain/recycling mode of the instrument. There are 5 drain modes which are described as follows:

Mode	Description
0 or 1	Manual Drain—Setting the drain mode to 1 will initiate a drain cycle. Once the one minute cycle is complete the drain mode will automatically be switched back to the previous setting. Setting the drain mode to 0 will cancel any current drain cycle. In this mode, the reservoir can be drained when initiated by the front panel drain button or setting the drain mode to a non-zero value.
2	Recycle Mode—Setting the drain mode to 2 allows the WCPC to recycle water from the reservoir back into the WCPC. When the reservoir is full, the drain flag will be set along with a front panel indication that the reservoir is full. If the reservoir remains full for one hour, the instrument will halt both water and air-flow pumps waiting for the reservoir to be emptied.
3	Recycle/Auto Drain Mode—Setting the drain mode to 3 allows the WCPC to recycle water from the reservoir back into the WCPC. This mode is similar to mode 2 except that when the reservoir is detected as full, a drain cycle is automatically initiated.
4	Auto Drain Mode—Setting the drain mode to 4 causes the WCPC to automatically initiate a drain cycle once a full condition is sensed in the reservoir.
5	Continuous Drain Mode.

Command:	**SDM,n**	Command to set drain mode
		n = mode ranging 0 to 5
Response:	**OK**	Response
Example:	**SDM,2**	Command to set drain mode to Recycling
	OK	Response

SDO **S**et **D**etector **O**ffset

This command sets the detector offset control. Typically the autozero function (SZ command) is used to automatically set this value. This command can be used to manually set the offset or to read its current value.

Command:	**SDO,xxxx**	Set Detector Offset command
		xxxx ranges 0 to 4095 (2048 is nominal)
Response:	**OK**	
Example:	**SDO,2200**	Command
	OK	Response
	SDO	Command
	2200	Response - echoing current offset control value of 2200

SDT **S**et **D**etector **T**hreshold

This command sets the threshold value in millivolts for particle pulse detection or returns the value of the current setting if no parameter is supplied.

Command:	**SDT,xxx**	Set Detector Threshold command xxx ranges 0 to 120
Response:	**OK**	
Example:	**SDT,50**	Command
	OK	Response
	SDT	Command
	50	Response - echoing current value of 40 millivolts

SFS **S**et **F**low **S**et Point

This command is used to set the inlet flow control set point which represents 0.6 L/min aerosol flow for the flow control system. When issued with a parameter, this command uses that parameter as a control point with which to control pump. The differential orifice pressure is compared to the control point and adjustments are made to the pump drive to maintain a match between the two. The actual control point is compensated by the current value of the Absolute Pressure sensor to compensate for inlet pressure.

Command:	**SFS,xxxx**	Command to set flow control set point x = 0 to 4095
Response:	**OK**	
Example:	**SFS,2312**	Command to set current flow control values
	OK	Response
	SFS	Command to read back the current settings
	2312	Response provides set point

SFZ **S**et **F**low **Z**ero

This command is used to set the flow control zero value. When issued with a parameter, this command uses that parameter as the zero value for the flow system. When issued without a parameter, the command echoes the current flow zero value. The flow zero value is normally set using the SZ command, so this command is seldom needed to actually set the flow zero point value.

Command:	**SFZ,xxx**	Command to set flow zero set point xxx = 1 to 350
Response:	**OK**	
Example:	**SFZ,164**	Command to set current flow zero value
	OK	Response indicates acceptance
	SFZ	Command to read current flow zero value
	164	Response

SG **S**et **G**rowth Heater

The set growth heater command switches the growth tube heater on or off. The heater is always in the "on" condition when the instrument is first powered up.

Command:	**SG,x**	Command to set growth tube heater on or off x = 0 turns heater off, x = 1 turns heater on
Response:	**OK**	
Example:	**SG,0**	Command turns heater off
	OK	Response
	SG	Command to read back the current setting
	0	Response indicates heater is off

SGS **S**et **G**rowth Tube Temperature **S**et point

This command sets the control temperature set point for the growth tube section of the UWCPC. The set point temperature is provided in tenths of a degree Celsius. This parameter is not stored and will revert to the default values on the next power-up cycle. The factory default setting of this value is 750 (75.0 degrees C).

Command:	**SGS,xxx**	Command to set Growth Tube temperature set point xxx = 0 to 800
Response:	**OK**	Response
Example:	**SGS,750**	Command to set Growth Tube temperature to 75.0 deg.
	OK	Response
	SGS	Command to read back the current setting
	750	Response indicates the set point value

SHS **S**et S**H**eath Flow **S**et Point

This command is used to set the sheath flow control set point which represents 0.3 L/min for the sheath flow control system. When issued with a parameter, this command uses that parameter as a control point with which to control pump. The differential orifice pressure is compared to the control point and adjustments are made to the pump drive to maintain a match between the two. The actual control point is compensated by the current value of the Absolute Pressure sensor to compensate for inlet pressure.

Command:	**SHS,xxxx**	Command to set flow control set point x = 0 to 4095
Response:	**OK**	
Example:	**SHS,2990**	Command to set current flow control values
	OK	Response
	SHS	Command to read back the current settings
	2990	Response provides set point

SIP **S**et **I**njection **P**rime

This command initiates a sequence to prime the instrument with injections of water. The supplied parameter indicates the number of injections to perform. Injections are performed at the rate of one every half-second until all the injections are completed. Providing the SIP command with no parameter or with a parameter of 0 will halt the injection sequence. See also the SIT command.

Command:	**SIP,xxx**	Set Injection Prime command xxx ranges 0 to 500
Response:	**OK**	
Example:	**SIP,50**	Command initials 50 water injections
	OK	Response
	SIP	Command cancels the injection sequence
	OK	Response

SIT **S**et **I**njection **T**ime

This command sets the water injection rate in seconds between injections. The factory default setting is 12 seconds.

Command:	**SIT,xxxx**	Set Injection Time command xxxx ranges 0 to 3600 seconds
Response:	**OK**	
Example:	**SIT,12**	Command sets injection interval to 12 seconds
	OK	Response
	SIT	Command to read back the current setting
	12	Response

SL **S**et **L**aser

The set laser command switches the laser on or off. The laser is always in the "on" condition when the instrument is first powered up.

Command:	**SL,x**	Command to set laser on or off x = 0 turns laser off, x = 1 turns laser on
Response:	**OK**	
Example:	**SL,0**	Command turns laser off
	OK	Response
	SL	Command to read back the current setting
	0	Response indicates laser is off

SLM **S**et **L**ive-time **M**inimum

This command sets minimum amount of live-time in proportion to elapse time allowed before the "OVER" annotation is shown on the primary display. The factory default value is 400 which represents 40%.

Command:	**SLM,xxx**	Command to set live-time minimum xxx = 0 to 1001
Response:	**OK**	Response
Example:	**SLM,400**	Command to set live-time minimum to 40%
	OK	Response
	SLM	Command to read back the current setting
	400	Response

SLS **S**et **L**aser **S**et Point

This command is used to set the laser power.

W A R N I N G
Use of this command may damage or destroy the laser diode.

Command:	`SLS,x`	Command to set laser control set point x = 0 to 4095
Response:	`OK`	Response
Example:	`SLS,600`	Command to set laser control value to 600
	`OK`	Response
	`SLS`	Command to read back the current laser drive setting
	`600,600`	Response provides current reading and current set point
	`SLS,2000`	Command to set laser control value to 2000
	`Value exceeds laser set point maximum`	Response indicates value exceeds maximum allowed (maximum set point may not be 2000; it is instrument specific)

SM **S**et **M**ode

This command sets the data collection mode for the instrument along with the sample interval. There are six data collection modes as follows:

Mode	Description
0	Idle—No data collection. The D record holds the last data taken.
1	Collect one sample interval of data and report D record at completion.
2	Continuously collect data and report data at end of every sample interval.
3	Like mode 1, but also includes an S record report at end of sample interval.
4	Like mode 2, but also includes an S record report at end of each sample interval.
5	Collect one sample interval of scanning data and report appropriate number of Z records.
6	Continuously collect scanning data and report Z records as data is collected. (Modes 5 and 6 may not be implemented)
7	Like mode 3, but also includes A & C record reports at the end of each sample interval.
8	Like mode 4, but also includes A & C record reports at the end of each sample interval.

(Modes 7 and 8 are intended for diagnostics only.)

The second parameter provides a sample collection time. At the end of each sample time, the data is reported and if in a continuous mode, the data is cleared internally and the next sample is started.

Command:	**SM,n,ttt**	Command to set data collection mode n = mode ranging 0 - 4, 7,8 ttt = sample interval in tenths of a second (1 to 36000)
Response:	**OK**	Response
Examples:	**SM,2,60**	Command to set data continuous data collection with a six second sample time. D records reported at end of each interval.
	OK	Response (six seconds pass) (D record reported - see D record in Data Reporting Records section in this Appendix)
	SM	Command to read back the current setting
	2,60	Response mode 2 and a 6 second sample time.

For scanning modes (5 and 6) four additional parameters are included. These are a starting voltage (V_{Min}) in microvolts (1000 to 10,000,000), a scanning constant number (τ) in milliseconds (100 to 1,000,000), a front porch time in seconds (0 to 600), and a back porch time in seconds (0 to 600).

The scanning mode provides a ramped analog output voltage in synchronous with particle data collection. During a scanning sample, Z records are reported every second that includes ten particle count values for each tenth second interval during the one second record.

The analog output voltage during scanning mode operation ramps according to:

$$V(t) = V_{Min} e^{\frac{t}{\tau}}$$

where: V_{Min} = Starting voltage in volts

t = time into the scanning ramp in seconds

τ = Scanning constant in seconds

The voltage values during the front and back porch time periods are V(0) and V(t = sample interval), respectively.

Note: *If the combination of sample time, τ and v_{Min} result in a calculated V(t = sample interval) that is greater than 10.000 volts, an error will be returned and the current operating mode will not be changed.*

Command:	**SM,n,ttt,Vmin,tau,tfp,tbp**	
		Scanning command
		N = mode 5,6
		ttt = sample interval in seconds (1 to 600)
		Vmin=starting voltage in microvolts
		tau= scanning constant in milliseconds (100-1000000)
		tfp= front porch dwell time in seconds (0-600)
		tbp= back porch dwell time in seconds (0-600)
Response:	**OK**	
Examples:	**SM,5,60,10000,8686,3,1**	
		Command to begin a scanning sample
	OK	Response
		(Sixty Z records reported - see Z record in Data Reporting Records section in this Appendix)
	SM	Command to read back the current setting
	5,60,10000,8686,3,1	
		Response (sent between Z records)

SO **S**et **O**ptics Heater

The set optics heater command switches the optics heater on or off. The heater is always in the "on" condition when the instrument is first powered up.

Command:	**SO,x**	Command to set optics tube heater on or off
		x = 0 turns heater off, x = 1 turns heater on
Response:	**OK**	
Example:	**SO,0**	Command turns heater off
	OK	Response
	SO	Command to read back the current setting
	0	Response indicates heater is off

SOS **S**et **O**ptics Temperature **S**et point

This command sets the control temperature set point for the optics section of the UWCPC. The set point temperature is provided in tenths of a degree Celsius. This parameter is not stored and will revert to the default values on the next power-up cycle. The factory default setting of this value is 750 (75.0 degrees C).

Command:	**SOS,xxx**	Command to set the optics temperature control set point
		xxx = 0 to 800
Response:	**OK**	Response
Example:	**SOS,750**	Command to set Growth Tube temperature to 75.0 deg.
	OK	Response
	SOS	Command to read back the current setting
	750	Response indicates the set point value

SP **S**et **P**ump

The set pump command enables or disables the pump providing airflow through the instrument. This action is the same as the action provided by the front panel "Pump" button.

Command:	**SP,x**	Command to set pump on or off x = 0 turns pump off, x = 1 turns pump on
Response:	**OK**	
Example:	**SP,0**	Command turns pump off
	OK	Response
	SP	Command to read back the current setting
	0	Response indicates pump is off

SS **S**et **S**aturator Controller

The set saturator controller command switches the saturator temperature controller on or off. The controller is always in the "on" condition when the instrument is first powered up.

Command:	**SS,x**	Command to set saturator controller on or off x = 0 turns controller, x = 1 turns controller on
Response:	**OK**	
Example:	**SS,0**	Command turns controller off
	OK	Response
	SS	Command to read back the current setting
	0	Response indicates controller is off

SSS **S**et **S**aturator Temperature **S**et Point

This command sets the control temperature set point for the saturator section of the UWCPC. The set point temperature is provided in tenths of a degree Celsius. This parameter is not stored and will revert to the default values on the next power-up cycle. The factory default setting of this value is 120 (12.0 degrees C).

Command:	**SSS,xxx**	Command to set saturator temperature control set point xxx = 0 to 800
Response:	**OK**	Response
Example:	**SSS,120**	Response
	SSS	Command to read back the current setting
	120	Response indicates the set point value

SV **S**et Analog Output **V**oltage

This command sets the voltage on the analog output connector on the back panel of the UWCPC. This command will return an ERROR if the UWCPC is operating in scanning mode (SM,5 or SM,6 see SM command).

Command:	**SV,xxx**	Command to set analog output voltage xxx = 0 to 10000 (mv)
Response:	**OK**	Response
Example:	**SV,2000**	Command to set analog output voltage to 2.0 volts
	OK	Response
	SV	Command to read back the current setting
	2000	Response

SVS **S**et Analog **V**oltage **S**pan

This command sets the span value used for the analog output voltage.

Command:	**SVS,xxx**	Command to set analog voltage span value xxx = 1 to 65535
Response:	**OK**	Response
Example:	**SVS,3276**	Command to set analog voltage span to 3276
	OK	Response
	SVS	Command to read back the current setting
	3276	Response

SVZ **S**et Analog **V**oltage **Z**ero

This command sets the analog output zero levels.

Command:	**SVZ,hhh,lll**	Command to set high and low analog output zero level **hhh** = 0 to 4095 **lll** = 0 to 4095
Response:	**OK**	Response
Example:	**SVZ,200,300**	Command to set analog output zero values
	OK	Response
	SVZ	Command to read back the current settings
	200,300	Response

SZ **S**et Auto **Z**ero Function

This command executes an auto zero function that calibrates the photo detector offset, the dead-time measuring circuit, and the flow transducer zero value.

W A R N I N G
This command will affect the instrument's calibration.

Command:	**SZ,1**	Command to set execute an auto zero function
Response:	**c,d,l,h**	Response
		c = change in offset (±bits)
		d = current detector offset (bits)
		l = dead-time zero value (bits)
		h = dead-time span value (bits)
Example:	**SZ,1**	Command to run auto zero function
	100,2900,23,3370	
		Response
	SZ	Command to read back the current values
	0,2900,23,3370	
		Response

Data Reporting Records

D Record (data)

D,Mode,Flags,CN,ST,LT,CNT,PM,RP

D Record Identifier

Mode Current Operating mode

Flags Status Flags

Weighting	Description
1	Live-time was less than minimum set by SLM command for at least a portion of the sample
2	Overflow of data in one of the data record fields
4	The flow was out of range for some portion of the sample
8	Absolute pressure out of range for some portion of the sample
10	Reserved
20	A drain cycle was in process during the sample or the reservoir was detected full
40	Set if dry wick was detected during the sample
80	Set if reservoir full for ten minutes and water injection has stopped
100	Saturator, Growth Tube, or Optics temperatures were out of range during the sample.
200	The laser power was out of range for some portion of the sample.
400	UWCPC in warm-up period
1000	Set during front porch period of a scanning sample
2000	Set during the back porch period of a scanning sample

CN Aggregated Concentration—This concentration value is calculated by dividing the accumulated aggregate counts by the live-time of the sample * 5.0. The aggregated counts and live-times are accumulated each tenth-second interval. If the live-time value for the interval is less than 10%, the aggregated counts are calculated based on the overflow concentration of 9.99e5. Otherwise the aggregated counts accumulated are the total counts detected during the interval and live-time is the live-time value for the interval.

The overflow flag will be set when the concentration value exceeds 9.99e5.

ST Sample time (elapse time) 0.1 second resolution (0.1 to 3600).

LT Live time 0.1 second resolution (0.1 - 3600).

CNT Accumulated particle counts.

PM Place holder, always 0.

RP Raw Photometric value.

Example D Record:

```
D,2,0,2.27e3,6.0,5.875,66784,0,308
```

S Record (status)

S, FL, AP,GT,OT,CT

- S Status Record Identifier
- FL Aerosol flow rate in cm^3/min
- AP Absolute Pressure in millibar
- ST Saturator Temperature in degrees Celsius
- GT Growth tube Temperature in degrees Celsius
- OT Optics Temperature in degrees Celsius

Example S Record:

```
S,300,970,12.0,75.0,75.0
```

Z Record (scanning data)

Z,Mode,Flags,RN,N0,N1… ,N9

- Z Record Identifier
- Mode Current Operating mode (5 or 6)
- Flags See status flags
- RN Record number - (1 to 600)
- Nx Equivalent number of particles counted in tenth second (0 to 99999999) based on live-corrected counts or the photometric value.

Example Z record:

```
Z,5,0,12,0,0,0,12,182,518,641,896,887,871
```

A Record (raw analog -- diagnostic only)

A,a,b,c,d,e,f,g,h,i,j,k,l,m,n,o

- A Record Identifier
- a-o raw analog values (bits)

Example A record:

```
A,2382,3194,1,1108,4095,4095,2735,1284,518,641,896,2278,821,819,1958
```

C Record (flow and temperature control - diagnostic only)

C,a,b,c,d,e,f,g,h,i,j,k,l

- C Record Identifier
- a - l control bit values

Example C record:

```
C,2413,2422,2166,2276,2276,1468,821,820,2894,821,820,1011,2210,2222,2012
```

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