NANO WATER-BASED CONDENSATION PARTICLE COUNTER
MODEL 3788

OPERATION AND SERVICE MANUAL

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NANO WATER-BASED CONDENSATION PARTICLE COUNTER (N-WCPC)
MODEL 3788

OPERATION AND SERVICE MANUAL

Manual History

The following is a history of the Model 3788 Nano Water-based Condensation Particle Counter (N-WCPC) Operation and Service Manual (Part Number 6003713).

Revision	**Date**
Preliminary	October 2010
A	March 2011
B	August 2011
C	January 2013

Warranty

Part Number 6003713 / Revision C / January 2013

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 June 2011)

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b. Pumps are warranted for hours of operation as set forth in product or operator's manuals;
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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 the TSI Customer Service department at 1-800-874-2811 (USA) or (651) 490-2811.

Trademarks

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Safety

This chapter provides instructions to promote safe handling and correct operation of the Model 3788 Nano Water-based Condensation Particle Counter (N-WCPC).

There are limited user-serviceable parts inside the N-WCPC. All repair and maintenance should be done by qualified, trained technicians. All maintenance and repair information in this manual is included for use by a qualified, trained technician.

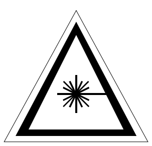
W A R N I N G

It is unsafe to operate this instrument in a manner other than that described in this manual. Failure to follow all of the procedures described in this manual can result in serious injury to you or cause irrevocable damage to the instrument.

Laser Safety

The Model 3788 N-WCPC is a Class I laser-based instrument. During normal operation, you will not be exposed to laser radiation. To avoid exposing yourself at any time to hazardous radiation in the form of intense, focused visible light (exposure to this light can cause blindness), take these precautions:

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



W A R N I N G

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

Description of Safety Labels

This information explains the advisory and identification labels used on the instrument and in this manual to reinforce the safety features built into the instrument.

Caution

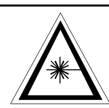
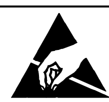
Caution
Caution means ***be careful.*** If you do not follow the procedures described in this manual you may damage the instrument or you may have to begin again. Caution also indicates important information about the operation and maintenance of this instrument.

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.

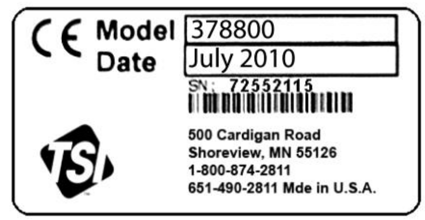
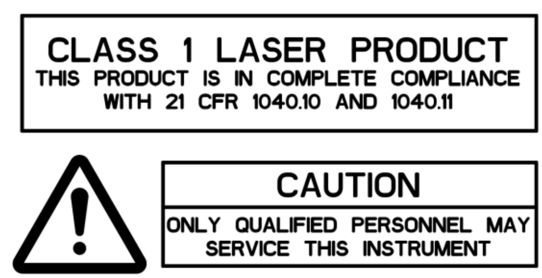
Caution or Warning Symbols

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

	Warns you that un-insulated voltage within the instrument may have sufficient magnitude to cause electric shock. It is dangerous to make any contact with any part inside the instrument.
	Warns you that the instrument contains a laser and that important information about its safe operation and maintenance is included. Read the manual carefully to avoid any exposure to hazardous laser radiation.
	Warns you that the instrument is susceptible to electro-static dissipation (ESD). ESD protection procedures should be followed to avoid damage.
	Indicates the connector is connected to earth ground and cabinet ground.

Labels

Advisory labels and identification labels are attached to the outside of the N-WCPC housing and to the optics on the inside of the instrument. Labels for the Model 3788 N-WCPC are described below:

Serial Number Label—displayed on the back panel.	
Laser safety warning label—displayed inside the N-WCPC near the laser diode assembly.	
High Voltage warning sticker—displayed inside the N-WCPC.	
Class 1 Laser certification and identification label—displayed on the back panel. When operated according to the manufacturer's instruction, 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.	
TSI Service Label—displayed on the back panel.	

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Contents

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Tables

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About This Manual

Purpose

This is an operation and service manual for the Model 3788 Nano Water-based Condensation Particle Counter (N-WCPC).

Organization

The following information is a guide to the organization of this manual.

- **Chapter 1: Product Overview**
  Contains an introduction to the Model 3788 N-WCPC, a list of features, and a brief description of how the instrument works.
- **Chapter 2: Unpacking and Setting Up the Model 3788 N-WCPC**
  Contains a packing list and the step-by-step procedures for installing the Model 3788 N-WCPC.
- **Chapter 3: Moving and Shipping the Model 3788 N-WCPC**
  Describes how to prepare the N-WCPC for moving and shipping.
- **Chapter 4: Instrument Description**
  Describes features and controls that run the N-WCPC, including the components on the front-panel, back-panel, and inside the instrument. It also covers the basic functions of the instrument.
- **Chapter 5: Instrument Operation**
  Describes the operation of the Model 3788 N-WCPC.
- **Chapter 6: Technical Description**
  Describes the principle of operation, theory, and performance of the Model 3788 N-WCPC.
- **Chapter 7: Particle Counting**
  Contains information about the particle counting modes.
- **Chapter 8: Computer Interface, Commands, and Data Collection**
  Describes the computer interface, commands and data collection.
- **Chapter 9: Maintenance, Service, and Troubleshooting**
  Describes the recommended practices for routine maintenance and service, as well as important troubleshooting procedures.
- **Appendix A: Specifications**
  Contains the specifications of the Model 3788 N-WCPC.
- **Appendix B: Firmware Commands**
  Lists all the serial commands for communications between the Model 3788 N-WCPC and the computer.

- **Appendix C: References**
  Contains a list of the references that have been used within the text of the manual as well as a general list of references pertaining to condensation nucleus counters.

Related Product Literature

- ***Model 3007 Condensation Particle Counter Operation and Service Manual*** (part number 1930035) TSI Incorporated
- ***Model 3772/3771 Condensation Particle Counter Operation and Service Manual*** (part number 1980529) TSI Incorporated
- ***Model 3775 Condensation Particle Counter Operation and Service Manual*** (part number 1980527) TSI Incorporated
- ***Model 3781 Water-based Condensation Particle Counter Operation and Service Manual*** (part number 1930111) TSI Incorporated
- ***Model 3783 EPC™ Environmental Particle Counter™ Monitor Operation and Service Manual*** (part number 6003653) TSI Incorporated
- ***Model 3787 General Purpose Water-based Condensation Particle Counter Operation and Service Manual*** (part number 6003712) TSI Incorporated
- ***Aerosol Instrument Manager® Software for CPC and EAD Instruction Manual*** (part number 1930062) TSI Incorporated

  This manual contains operating instructions for Aerosol Instrument Manager® Software for CPC and EAD, a software program that monitors, calculates, and displays particle concentration data collected by a CPC or an EAD.

Getting Help

To obtain assistance with the Model 3788 Nano Water-based Condensation Particle Counter, contact TSI Customer Service:

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

Submitting Comments

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

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

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

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CHAPTER 1
Product Overview

This chapter contains an introduction to the Model 3788 Nano Water-based Condensation Particle Counter (N-WCPC) and provides a brief explanation of how the instrument operates.

Product Description

The Model 3788 N-WCPC is designed primarily for researchers interested in detecting the smallest nanoparticles. It detects particles down to 2.5 nm, and has a high sample flow rate (0.3 L/min) providing for very good counting statistics.

Patented technology enables the Model 3788 N-WCPC to use water as a condensing fluid to enlarge submicrometer particles so that they can be easily detected. The Model 3788 N-WCPC offers fast response, a sheath-air flow design to minimize diffusion losses and produce a sharp, lower cutpoint, and single-particle counting with continuous, live-time coincidence correction. Particle concentration, total counts, or plots of concentration versus time can be displayed on the front panel. The Model 3788 N-WCPC is compatible with SMPS™ systems and TSI's Aerosol Instrument Manager® software. TSI recommends annual maintenance and calibration for the Model 3788 N-WCPC instrument.

Features of the Model 3788 N-WCPC include:

- 6-inch VCA color touch screen with a graphical interface displaying particle concentration, total counts, and a plot of concentration vs. time.
- 2.5-nm detection with a sharp D_{50} efficiency curve.
- Single-particle counting to $4x10^5$ particles/cm^3.
- Continuous, live-time, electronic processing for maximum accuracy.
- Adjustable inlet flow (1.5 or 0.6 L/min).
- Fast response time (<1 sec).
- Flexible data acquisition options including USB flash drive (or memory stick), Ethernet, USB port, and RS-232 port.
- Advanced instrument diagnostics including a novel pulse height analyzer to monitor super-saturation state, wick health, and instrument status.
- Newly designed air flow, wicking, and water handling systems. The use of a sheath air flow reduces diffusion losses.
- Works as part of an SMPS™ system.

Figure 1-1
Model 3788 Nano Water-based Condensation Particle Counter

Acknowledgement

The continuous, laminar-flow, water-based condensation principle on which this product is based is patented technology licensed from Aerosol Dynamics Inc. of Berkeley, CA (U.S. Patent 6712881). 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.

How it Works

The Model 3788 N-WCPC is a water-based condensation particle counter designed to measure the number concentration of sub-micrometer airborne particles. The N-WCPC 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 N-WCPC uses a patented* technology to condense water vapor onto particle, growing them into droplets which are then detected by a conventional optical counting system. The stream of aerosol particles is uninterrupted and follows a laminar flow path from the sample inlet to the optical detector.

The N-WCPC particle counting process is as follows:

1. The aerosol enters the sample inlet at a flow rate of 0.6 L/min or 1.5 L/min (depending upon the setting for the transport flow).

   ***Note**: The transport flow allows fast transportation of the aerosol to the inlet to reduce nanoparticle loss.*

2. The inlet flow is divided. One of the resulting flows is filtered to provide sheath flow. The sheath flow centers the aerosol sample into a region of highest supersaturation. This aerosol focusing provides for detection of very small particle and a shape detection efficiency curve (see Figure 6-1).
3. In the Conditioner, the aerosol sample stream is saturated with water vapor and then temperature and humidity equilibrated.
4. The sample passes to a growth tube where the wetted walls are heated to raise the vapor pressure. The high diffusivity of the 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—creating a supersaturated condition along the radius of the flow stream. These unstable conditions facilitate water condensation on the sample particles.
5. Particles that are larger than the detection limit of the N-WCPC's critical particle size act as condensation nuclei as they pass up the growth tube.
6. The enlarged droplets are detected by the optical detector where a laser illuminates the viewing volume. A light pulse from each particle is converted to an electrical signal that is processed by the N-WCPC electronics.

Figure 1-2 illustrates the flow system of the N-WCPC.

*US Patent No. 6,712,881 Aerosol Dynamic Inc., Drs. Susanne V. Hering and Mark Stolzenburg

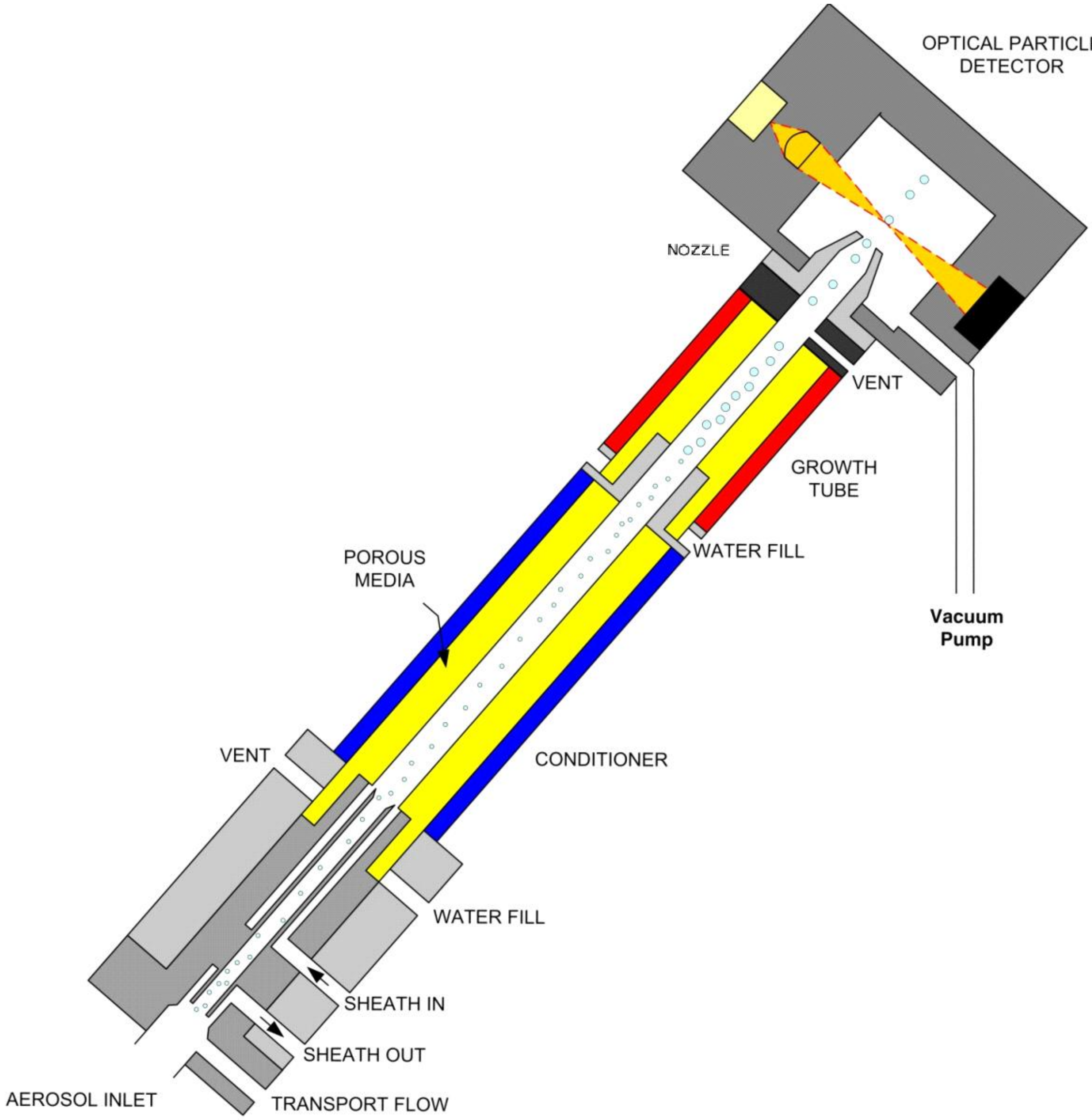

Figure 1-2
Nano Water-based Condensation Particle Counter Diagram

CHAPTER 2

Unpacking and Setting Up the Model 3788 N-WCPC

Use the information in this chapter to unpack and set up the Model 3788 Nano Water-based Condensation Particle Counter (N-WCPC).

Packing List

Table 2-1 shows the components shipped with the Model 3788 Nano Water-based Condensation Particle Counter.

Table 2-1
Model 3788 Nano Water-based Condensation Particle Counter Packing List

Qty.	Part Number/ Model Number	Description
1	3788	Nano Water-based Condensation Particle Counter
1	6003713	Operation and Service Manual
1	6004401	Model 3788 Quick Start Guide
1	N/A	Power cable
1	1180007	Recycle fill bottle
1	N/A	Water supply bottle mounting bracket with 2x screws (6-32 x 3/8 inch)
1	N/A	Calibration Certificate
1	1303740	Computer cable, USB A to B
1	962002	RS-232 Serial cable
1	390065	Aerosol Instrument Manager® Software
1	1188001	Maintenance Kit (for details see Table 2-2 below)

Note: *Some items above and those for future maintenance are available for purchase as kits from TSI. A complete list of replacement part kits is included in the* *Maintenance* *section in Chapter 9.*

Table 2-2
Model 3788 Nano Water-based Condensation Particle Counter Maintenance Kit (Part Number: 1188001)

Qty.	Part Number	Description
1	1180003	3788 Replacement Wicks (pack of 12)
1	1180008	3787/88 Replacement Wick Cartridge
1	1180004	3788 Replacement Critical Flow Control Orifice .011 inch
1	1180005	3788 Replacement Critical Transport Flow Control Orifice .0135 inch
1	1183004	3788 Replacement Filter: Replacement for Critical Flow Control Orifice, Critical Transport Orifice, and Pump Exhaust.
1	1188003	3788 Sheath Filter
1	N/A	Three-foot length of 1/8 inch tubing

Unpacking

Carefully unpack the Model 3788 N-WCPC from the shipping container. Use the Packing List in Table 2-1 to verify that there are no missing components.

Save the original shipping container to be used for future shipping.

If anything is missing, or appears to be damaged, contact your TSI representative or TSI Customer Service using one of the following methods:

Telephone: 1-800-874-2811 (within the US)
001-651-490-2811 (outside the US)
E-mail: technicalservice@tsi.com

See Chapter 9 for instructions on how to return the instrument to TSI.

Caution

The Model 3788 N-WCPC operates using distilled (<6 ppm) or HPLC water as a working fluid. Do **not** tip the instrument more than 10 degrees during normal operation or you may flood the system. Perform the procedures described in Chapter 3 before moving or shipping the instrument.

Do **not**:

- Ship an "undried" instrument.
- Transport an "undried" instrument over long distances.
- Subject 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.

Installation

This section contains instructions for installing the Model 3788 N-WCPC. Follow the instructions in the order given.

The installation procedures, described on the following pages, include the following:

- Removing protective caps.
- Connecting the water supply.
- Connecting the aerosol sample.
- Connecting the USB cable.
- Connecting the power and warming up the Model 3788 N-WCPC.

Equipment

You will need the following to install the N-WCPC:

- Phillips screwdriver.
- Water supply.

Note*: Use either distilled or ultrapure water. Do* ***not*** *use tap water.*

Remove Protective Caps

After unpacking the N-WCPC, remove any protective caps from the **AEROSOL INLET** and remove any covers from the BNC connectors.

Connecting the Water Supply

The Model 3788 N-WCPC uses a gravity-fed water fill system, and a fill bottle designed to recycle water.

Note*: To prevent the water from draining back into the instrument during operation, the bottle must always be placed at a higher level than the instrument.*

To connect the water supply, follow these instructions:

1. Attach the water supply bottle bracket to the back of the N-WCPC using the provided bottle bracket and mounting screws.

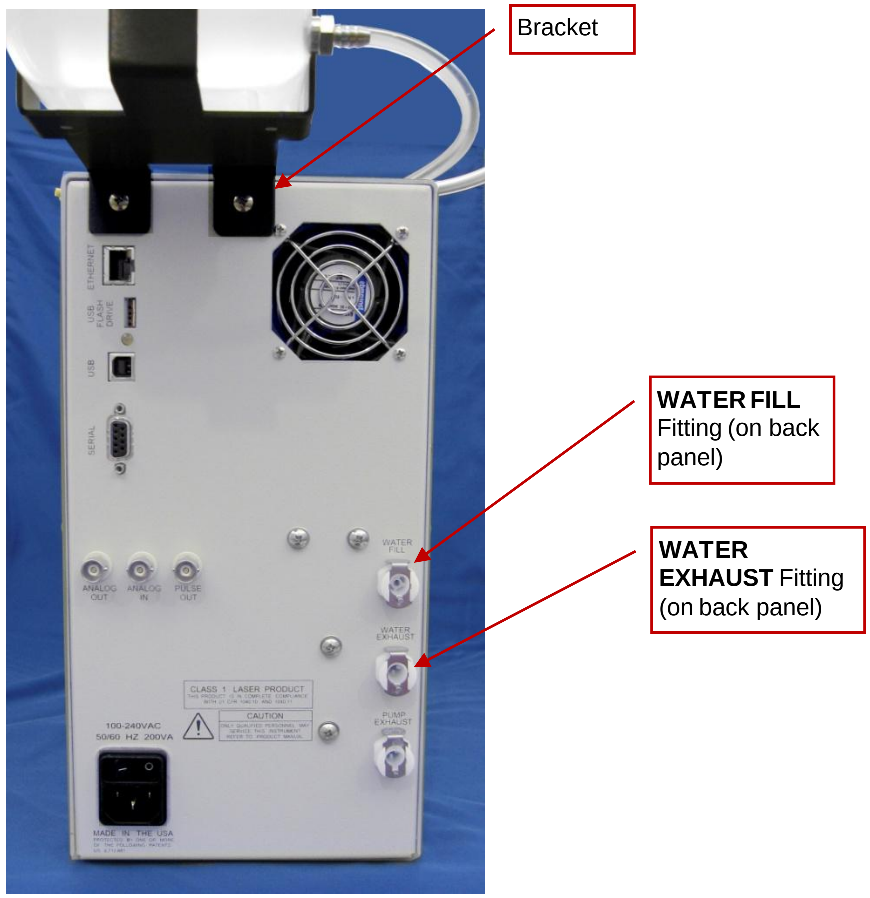

Figure 2-1
Attaching the Water Bottle Bracket

2. Fill the water supply bottle with either distilled (<6 ppm) or HPLC water.
3. Remove any air from the water supply line by pressing the connector (valve) at the end of the supply tube onto a hard surface and allowing the air to bleed from the tubing.
4. Place the bottle in the bracket.
5. Push the connector on the tubing at the **bottom** of the water supply bottle into the **WATER FILL** fitting on the front of the instrument.
6. Push the connector on the tubing at the **top** of the water supply bottle into the **WATER EXHAUST** fitting on the front of the instrument.

Figure 2-2
Attaching the Water Bottle Tubing Connections

Connecting the Aerosol Sample

The Sample inlet for the Model 3788 N-WCPC is located on the front of the instrument. Options for connection to the instrument include

- SMPS™ spectrometer sampling using an electrostatic classifier.
- Using a sampling system connected directly to the aerosol inlet.
- Environmental monitoring using tubing connected directly to the aerosol inlet.

Note: *The Model 3783 EPC™ Environmental Particle Counter™ monitor is the preferred instrument for this application.*

IMPORTANT

The gauge pressure of the sampled aerosol must be within +10/-50 mbar (+4/-20 in H_20) pressure relative to the ambient pressure.

To set up the aerosol supply, connect the aerosol sample line to the aerosol inlet.

Figure 2-3
Connecting the Aerosol Supply

Connecting the USB Cable

Connect the provided USB cable to the USB connector on the back panel of the Model 3788 N-WCPC.

Connecting the Power and Warming Up the N-WCPC

After connecting the power, the first-time warm-up process takes approximately 20 to 60 minutes (depending upon the amount of air in the water supply lines). Subsequent warm-up times are typically less than 20 minutes.

Follow these instructions to connect the power and warm up the Model 3788 N-WCPC:

1. Plug the power cord (provided) with the Model 3788 N-WCPC into the power connector (100 to 240 VAC 50/60 Hz 200 VA) on the back panel.
2. Plug the cord into an earth-grounded AC power source (100 to 240 VAC, 50/60 Hz, 2.0 A).

W A R N I N G
Connection to an improperly grounded electrical source may cause a severe shock hazard—ensure that the ground is secure.

3. Turn on the instrument. The Home screen appears on the display and reads **WARMUP**. During the warm-up process, status messages are displayed at the top left of the home screen. The instrument status can be viewed by pressing the **STATUS** button on the home screen.

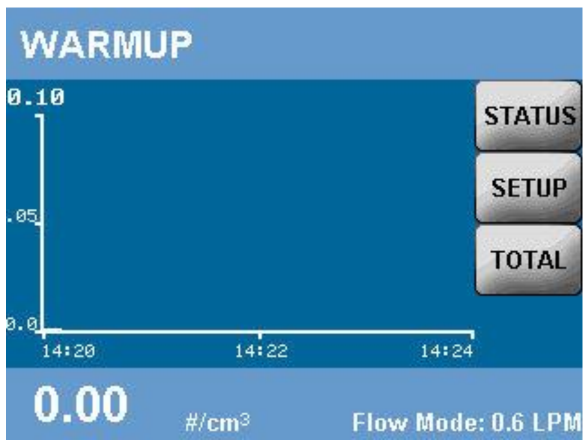

Figure 2-4
Warm-up Screen

4. When the warm-up is complete, if all conditions for operation are in place, the display reads **Ready**. If you do not see the **Ready** message, check the settings with the **SETUP** button and make sure the pump it turned on. On the initial startup of a dry instrument, it may take an additional 10 or 20 minutes after the internal water reservoirs are filled before the internal wicks are wetted and functional.

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CHAPTER 3

Moving and Shipping the Model 3788 N-WCPC

Use the information in this chapter to prepare the Model 3788 Nano Water-based Condensation Particle Counter (N-WCPC) for moving or shipping.

Caution

The Model 3788 N-WCPC operates using distilled (<6 ppm) or HPLC water as a working fluid. Do **not** tip the instrument more than 10 degrees during normal operation or you may flood the system.

Do **not**:

- Ship an “undried” instrument.
- Transport an “undried” instrument over long distances.
- Subject 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.

Moving the Model 3788 N-WCPC Short Distances

The Model 3788 N-WCPC can be successfully transported short distances from one lab to another, or even a short drive in a vehicle without drying it first. However, do ***not*** tip the instrument more than 45° degrees and do ***not*** subject it to prolonged freezing temperatures.

Preparing the Model 3788 N-WCPC for Shipping and Storage

To prepare the N-WCPC for shipping, follow these instructions:

1. Turn on the N-WCPC and allow it to warm up (the display screen reads **Ready** when the warm-up is complete and all the settings are correct).
2. Disconnect the water bottle, empty it, and then reconnect it.
3. Disconnect any connections to the aerosol inlet.
4. Allow the instrument to sample room air. The displayed particle concentration displayed will drop to <10 particles/cm^3 as the growth tube wick dries out. Ten minutes after the concentration drops to this level, the instrument is sufficiently dry for shipment.

***Note**: This drying out period typically takes less than 60 minutes, but extended drying periods will not harm the instrument.*

5. Disconnect the water bottle.
6. Turn off the power.
7. Carefully place the instrument in the original packing materials.

The Model 3788 N-WCPC is now ready for shipping or storage.

CHAPTER 4
Instrument Description

Use the information in this chapter to become familiar with the location and function of controls, indicators, and connectors on the Model 3788 Nano Water-based Condensation Particle Counter (N-WCPC).

Front Panel

The main components of the front panel are shown in the figure below.

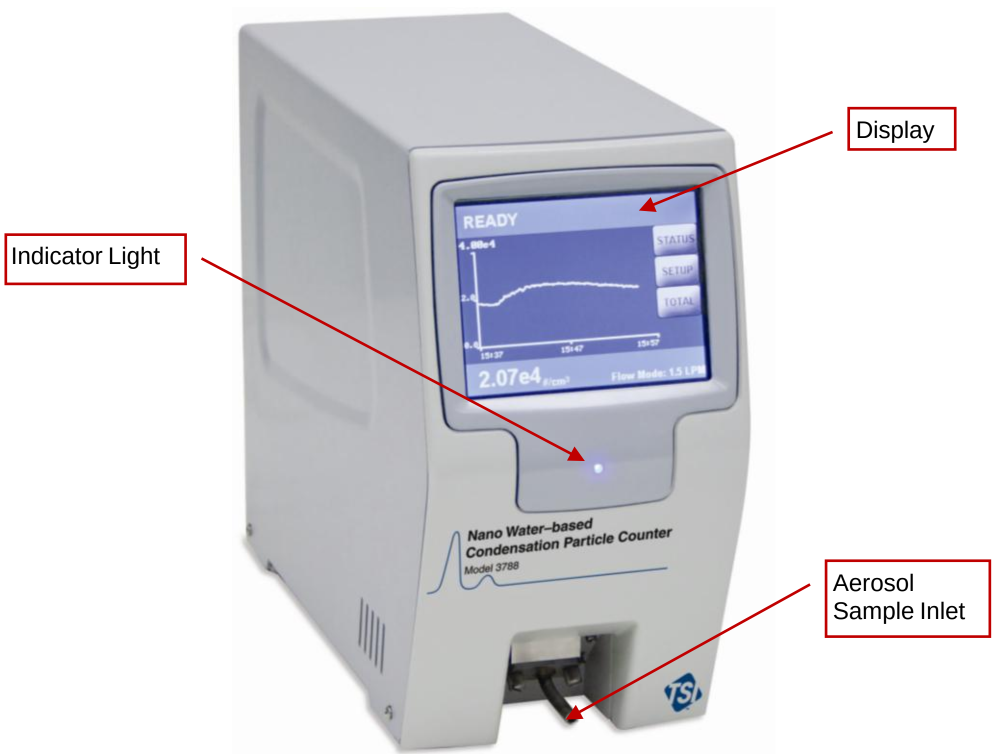

Figure 4-1
Nano Water-based Condensation Particle Counter Front Panel

Display

The quarter VGA color LCD display provides continuous real-time display of sample data as well as user menus and status information. Pressing the display "buttons" allows you to move from one screen to another or to record settings.

Status Indicators

Status indicators are displayed at the top of the home screen. The indicators are as follows:

Status Indicator	Description
Low Water	Water level is low
Warmup	Instrument is warming up
Environment Temp Fault	The environmental temperature is outside the operating range of the instrument
Laser Fault	Laser fault
Inlet Pressure Fault	Inlet pressure is too high/low
Vacuum Fault	Insufficient vacuum
Nozzle Fault	Plugged nozzle or filter
Capillary Flow Fault	Capillary flow out of range
Absolute Pressure Fault	Barometric (Inlet) pressure is out of range
Optics Temp Fault	Optics temperature is out of range
Growth Tube Temp Fault	Growth Tube temperature is out of range
Conditioner Temp Fault	Conditioner temperature is out of range
Separator Temp Fault	Separator temperature is out of range
Pulse Height Fault	Low pulse height
Ready	Warm-up process has finished, the pump is on, and all operating parameters are in range. The instrument is ready for use

***Note**: The fault indicators on the front-panel display are a warning that the instrument is not ready for operation. However, only one indicator can display at a time. Check the Status screen for more specific details about the operating condition of the instrument.*

Indicator Light

The blue indicator light flashes once for each particle detected. At particle concentrations >100 particles/cm^3, the flashing becomes a nearly continuous glow.

Back Panel

The main components of the back panel are show in Figure 4-2. Components include power and data connections, analog input/output connections, and water and sample inlets/outlets.

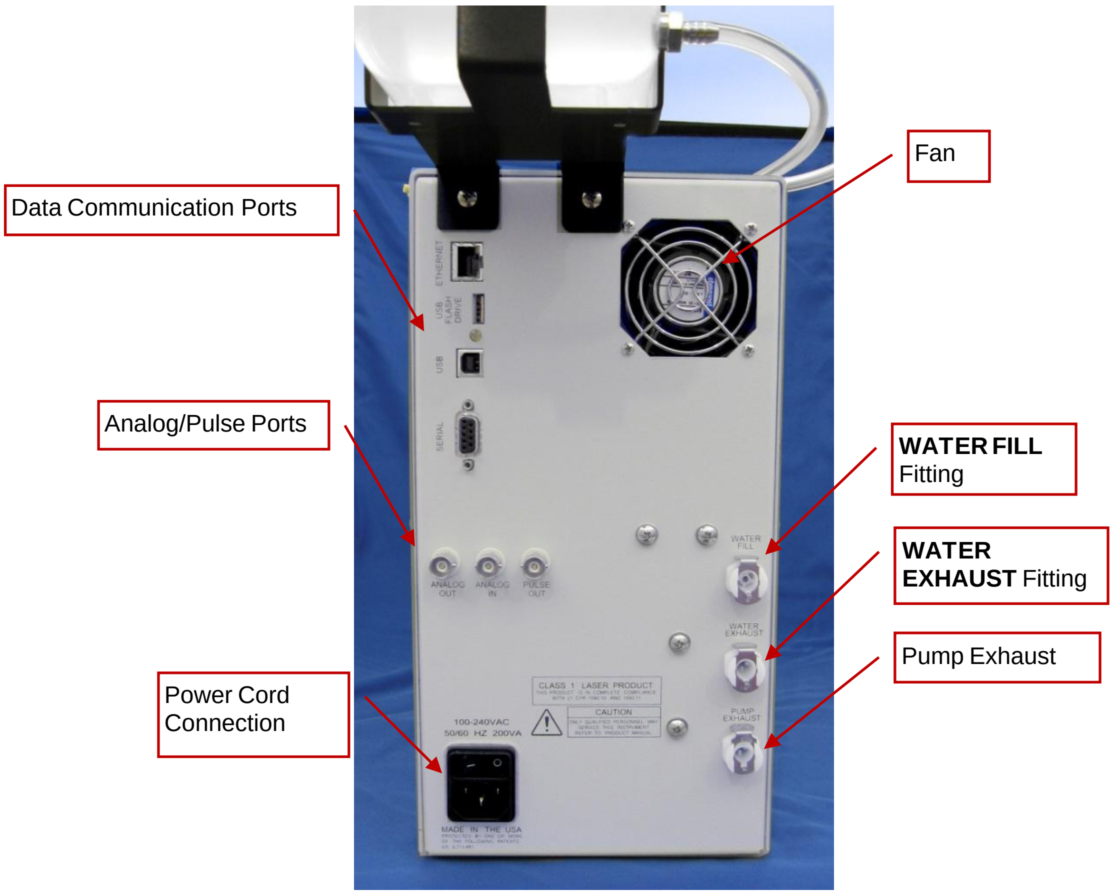

Figure 4-2
Nano Water-based Condensation Particle Counter Back Panel

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CHAPTER 5

Instrument Operation

This chapter describes the basic operation of the Model 3788 Nano Water-based Condensation Particle Counter (N-WCPC) and describes how to use the controls, indicators, and connectors found on the front and back panels.

Operating Precautions

Read the following before applying power to the N-WCPC:

- Review the operating specifications for the N-WCPC described in Appendix A.
- Do **not** operate the N-WCPC at temperatures outside the range of 10 to 35°C. If the N-WCPC is operated outside this range, the displayed concentration may be inaccurate.
- Use the N-WCPC to sample particles in air or nitrogen only.

WARNING

The Model 3788 N-WCPC should not be used with hazardous gases such as hydrogen or oxygen. Using the particle counter with hazardous gases may cause injury to personnel and damage to equipment.

Recommended Operation Procedures

General Operation Procedures

Follow these procedures when operating the N-WCPC:

- Use short sampling lines—particles <10 nm are easily lost in sampling lines.
- Site the N-WCPC as close as possible to the aerosol source to keep particle loss to a minimum.
- Use the 1.5 L/min inlet flow setting when possible to minimize the transit time and to minimize particle loss in sampling lines.
- Inlet pressure must be within the range of the instrument. Inlet pressures above 1 kPa (4 inches/H_2O) will not allow the gravity-fed water system to supply water. The internal vacuum pump with shut down if detected negative pressures drop below the specified operating range.

- Do ***not*** use tap water. Fill the water bottle with 1 liter of distilled (<6 ppm) or HPLC water.
- Check the inlet pressure using one of the following methods:
  - Check the inlet pressure valve on the status screen. Disconnect the aerosol inlet flow and then check the pressure again. The pressure should not drop by more than 250 mbars.
  - Turn the vacuum off and check the pressure.
  - Check the **STATUS** screen to make sure the parameters are still accurate.
- Check the time and date on the Flash Drive every two weeks.

Standard Operation Procedures

Perform these standard procedures every 4 weeks (~700 hours):

- Replace the wick.
- Check the flow using a volumetric flowmeter.
- Fill the water bottle with 1 liter of distilled (<6 ppm) or HPLC water. **Do not use tap water.**
- Check the inlet pressure by either:
  - Checking the inlet pressure value on the status screen, then disconnecting the aerosol inlet flow, and checking the value again. The pressure should not drop by more than 250 mbars.

    or
  - Turn the vacuum off and check the pressure.
- Check the status screen to make sure the parameters are still accurate.
- Check the inlet screen and remove any debris collected there.
- Check the time and date on the Flash Drive.

Perform these standard procedures annually:

- Replace the filters.
- Perform a Zero check by placing a HEPA filter on the N-WCPC monitor inlet and ensuring that particle concentration is <0.01particles/cm^3 measured using 12-hour averaging.

Note: *Detailed information about these procedures can be found in the Maintenance section of* *Chapter 9.*

Sampling Outdoor Aerosols

Follow these procedures when sampling outdoors:

- The N-WCPC should be operated in an environment that meets the temperature and humidity specifications.
- Use short sampling lines and an additional transport flow to keep transport times low and minimize particle loss.

- If the N-WCPC is placed in an environment with temperatures lower than the ambient temperature, consider heating the sample line to reduce condensation, or consider preventing condensation in sampling lines by adding dryers or a sample conditioner.
- Use a particle size pre-cut (<3 µm), such as a cyclone or impactor, when directly sampling an outdoor sample. This protects the instrument from large particles or insects.

Warm-up

When you have successfully made all the connections described in the installation section of Chapter 2, and turned on the power, the Home screen appears on the display and reads **Warmup**. When the warm-up process is complete, and optics and growth tube temperatures are within two degrees of their standard operating temperatures, the display reads **Ready**. Use the menus to do the following:

- Turn flow on and off.
- Set the date and time.
- Set sampling parameters.
- Check flow.
- Collect Data.
- Set the network and data collection options.

Display/User Settings

Read this section for details of the screens, how to make selections, and how to change options.

HOME Screen

The Home screen displays a real-time sample graph of the concentration in particles/cm^3, the **STATUS** of the instrument, and the **SETUP** and **TOTAL** options. Return to the Home screen from any other screen by pressing **HOME**.

The following screens are accessible from the home screen and are described on the following pages:

- STATUS
- SETUP
- TOTAL

STATUS Screens

The two **STATUS** screens display a variety of real-time readings to give you an instant view of the operational status of the instrument. The following status colors are significant:

- Red indicates a parameter that is “out of range.”
- Yellow indicates something “in process.”
- White indicates “normal” conditions.

Press **MORE** on the first Status screen to see the **ADDITIONAL STATUS** settings. The photos below show the **STATUS** and **ADDITIONAL STATUS** screens.

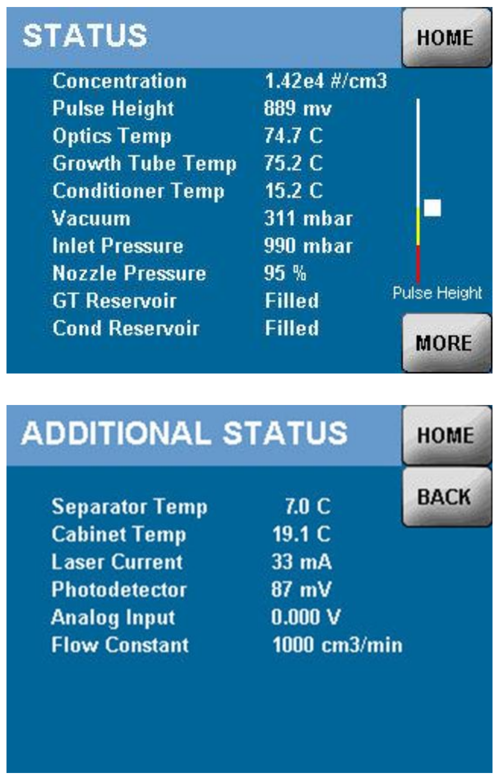


Figure 5-1
Status Screens

The Status screens display the following information:

Status	Description
Concentration	Particle concentration in particles/cm^3
Pulse Height	Particle pulse signal height in mV. The pulse is a measure of the average pulse height, varies with particle concentration, and is useful for indicating wick problems.
Optics Temp	Temperature of the Optics in degrees Centigrade. A normal Optics temperature is 75°C.

Status	Description
Growth Tube Temp	Temperature of the Growth Tube in degrees Centigrade. A normal Growth Tube temperature is 75°C.
Conditioner Temp	Temperature of the Conditioner in degrees Centigrade. A normal Conditioner temperature is 15°C.
Vacuum	The vacuum pressure in mbars (must be less than half of the inlet pressure).
Inlet Pressure	The atmospheric pressure in mbars. This parameter is preset and can be used to indicate a blockage.
Nozzle Pressure	The pressure difference upstream and downstream of the optics assembly. Nominally 100%.
GT Reservoir	Indicates whether the growth tube reservoir is Filled/Not Filled.
Cond Reservoir	Indicates the status of the conditioner reservoir - Filled/Not Filled.
Capillary Flow	The capillary flow rate in cm^3/min.
Separator Temp	Temperature of the Water Separator in degrees Centigrade. A normal Separator temperature is 7°C.
Cabinet Temp	Temperature at the inlet of the Model 3788.
Laser Current	The operating current of the laser in mA.
Photodetector	Indicates photodetector voltage in mV.
Analog Input	Displays the voltage of the analog input.

SETUP Screens

HOME I SETUP

Pressing the **SETUP** button on the home screen takes you to the **SETUP** screen where the following operating parameters can be set:

Parameter	Description
SAMPLE TIME	Select a sample time for updating the display graph. Choices are 1 sec, 2 sec, 3 sec, 4 sec, 5 sec, 6 sec, 10 sec, 12 sec, 15 sec, 20 sec, 30 sec, 60 sec.
PUMP	Select the vacuum pump settings, turning the pump on or off.
INLET FLOW	Set the inlet flow. Choices are 1.5 L/min (total flow), and 0.6 L/min (sample flow).
SET TIME	Set the time for the internal, real-time clock used for data logging purposes.

Parameter	Description
MORE	Takes you to the **NETWORK SETUP** screen.
NETWORK SET UP	Set up network connections including **NETWORK, ADDRESS, MASK**, and **GATEWAY**.
MORE	Takes you to the **ADDITIONAL SETUP** screen.
ADDITIONAL SETUP	Specify the **ANALOG OUTPUT** and **LOGGING** time.
ANALOG OUTPUT	Set an analog voltage range for the output.
LOGGING	Choose intervals for logging data.

The following pages contain descriptions of the **SETUP** options.

SAMPLE TIME

SETUP | SAMPLE TIME

Select a sample time in seconds for the on-screen graph. Press the **SAMPLE TIME** button to scroll through the settings. Sample Time choices are 1, 2, 3, 4, 5, 6, 10, 12, 15, 20, 30, and 60 seconds. If you intend to gather data for long periods of time, use the longer sample times to reduce the number of data files.

PUMP

SETUP | PUMP

Select one of the following vacuum pump settings:

Pump Setting	Description
ON AFTER WARMUP	Turns on the pump. Message displays during the warm-up process.
ON	Turns on the pump valve. Message only displays when warm-up is complete.
OFF	Turns off the pump valve.

***Note**: You can toggle between the ON and OFF settings.*

INLET MODE

SETUP | INLET MODE

Set the inlet flow in liters per minute. Press the **INLET MODE** button to scroll through the settings. Inlet flow choices are:

Inlet Mode Setting	Description
0.6 L/min	When the inlet flow is set to 0.6 L/min, 0.3 L/min is sampled and 0.3 L/min is used for sheath air.
1.5 L/min	When the inlet flow is set to 1.5 L/min, an additional 0.9 L/min of flow is drawn into the inlet. This higher transport flow can reduce the loss of very small particles in tubing external to the N-WCPC.

SET TIME

SETUP | SET TIME

Select the date (year, month, and day) and time (hour, minute, and second) for data collection.

To set the date and time, follow these instructions:

1. Touch the screen option you wish to change. In the screen below, the Year is active (indicated by the line below the number) and ready to be changed.

2. Use the ▲▼ arrows to scroll through the different settings.
3. Touch **BACK** to return to the previous screen when you have made your choices.

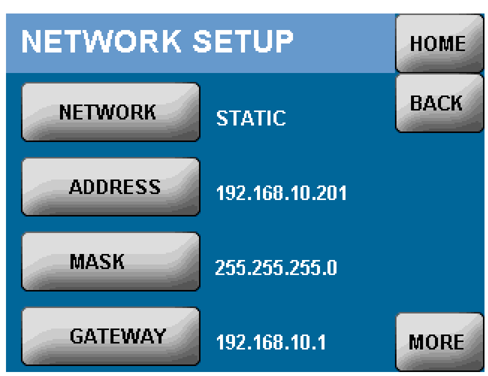
NETWORK

SETUP | NETWORK SETUP | NETWORK

Specify the network settings. The **NETWORK** button toggles between the settings **STATIC** and **DHCP** (shown in the screen below).

Note: *If the network settings have been selected, they are displayed, otherwise, they are blank.*

On this screen, only the network setting has been specified.



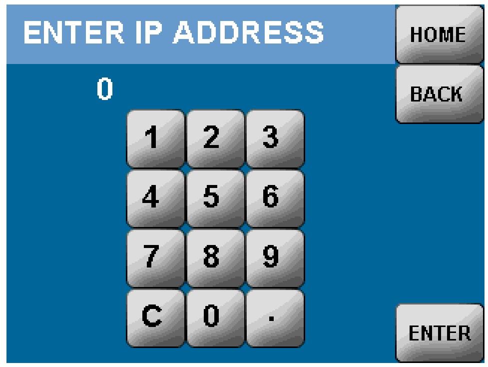
On this screen all network settings have been specified.

ADDRESS

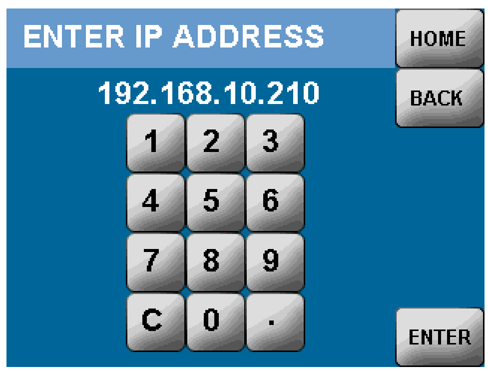
SETUP I NETWORK SETUP I ADDRESS

Specify an IP address for your network. To set the IP Address, follow these instructions:

1. Press the numbers on the on-screen keypad.



2. When all the numbers have been selected, press **ENTER**. The IP Address is now recorded and displayed on the screen.



3. Press **BACK** to return to the Network setup screen where the IP address is now displayed.

MASK

SETUP I NETWORK SETUP I MASK

Specify the network mask.

***Note**: The Mask must match the size of your network. A typical setting is 255,255,255.0 for a small network.*

To set the Mask, follow the instructions for using the onscreen keypad to set the IP Address.

GATEWAY

SETUP I NETWORK SETUP I GATEWAY

Specify the network gateway device. To specify the Gateway, follow the instructions for using the onscreen keypad to set the IP Address.

ANALOG OUTPUT

SETUP | NETWORK SETUP | MORE | ADDITIONAL SETUP | ANALOG OUTPUT

Set the function of the analog output. The analog output port is located on the back of the instrument and provides a 0 to 10V output signal and can be scaled for the user application. Press the button to scroll through the options. Settings are 1.00, 100, 1000, 1.O E^4, 1.O E^5, 1.O E^6, #/cm^3 FS, **LOG OUTPUT** (Logarithmic output), **SMPS MODE**, and **STATUS OUTPUT** (where a normal Status Output is 0. Abnormal output is 5V).

LOGGING

SETUP | NETWORK SETUP | MORE | ADDITIONAL SETUP | LOGGING

Choose intervals for logging data to the Flash Memory Card. Logging options are either one hour, or one day. Press the button to toggle between the options.

TOTAL Screen

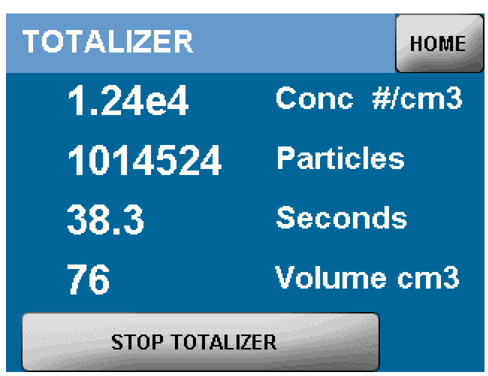
Pressing the **TOTAL** button on the home screen takes you to the **TOTALIZER** screen. The screen displays the following information:

- Current particle concentration in #/cm^3.
- Number of accumulated particles.
- Sample time in seconds.
- Volume based on flow rate and sample time.

This option is useful for manually measuring concentration over a period of time.

There is a toggle button at the bottom of the screen. When you choose **TOTAL** from the Home screen, the toggle button displays **CLEAR TOTALIZER**. When you press **CLEAR TOTALIZER**, the button displays **START TOTALIZER**.

***Note**: If you go to another screen on the display, the **TOTALIZER** continues to run, it can only be stopped by pressing **STOP TOTALIZER**.*



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CHAPTER 6

Technical Description

The Model 3788 Nano Water-based Condensation Particle Counter (N-WCPC) is a continuous-flow condensation particle counter that detects particles down to 2.5 nm with an aerosol sample flow rate of 0.3 L/min. This section describes the function of the N-WCPC, its subsystems and its components. A discussion of operation theory and history is given first.

Theory

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

In *heterogeneous* condensation, the vapor surrounding particles reaches a certain degree of supersaturation and begins to condense onto the particles. In *homogeneous nucleation* or *self-nucleation,* supersaturation is so high that condensation can take place even if no particles are present because molecules of the vapor form clusters (nucleation sites) due to the natural motion of the gas and attractive van der Waals forces. The N-WCPC operates below the supersaturation ratio to avoid homogenous nucleation.

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

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

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

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

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

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

For a curved liquid surface, such as the surface of a droplet, the actual saturation vapor pressure is greater. 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). Liquid particles with diameters smaller than the critical equilibrium diameter will evaporate and larger particles will 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. The lower size sensitivity of the counter is determined by the operating saturation ratio.

History

In 1979, TSI introduced the world's first single-particle-counting condensation particle counter. The Model 3020 was a continuous-flow, diffusional, alcohol-based, thermal-cooling CPC (Bricard et al. [1976], Sinclair and Hoopes [1975], Agarwal and Sem [1980]). In an alcohol-based CPC the air sample is saturated with alcohol vapor when it passes over a heated pool of liquid alcohol. The vapor-saturated air stream flows into a cold condenser tube where the air is cooled by thermal diffusion. The alcohol condenses onto the particles and the droplets grow to approximately 3 to 5 micrometers. The droplets are then counted by a single-particle-counting optical detector.

The Models 3010, 3025, and 3022 were butanol based CPCs introduced in the late 80s and were replaced by Model 3771, 3772, 3775, and 3776 in 2005. A hand-held, battery powered isopropyl alcohol CPC (Model 3007) was introduced in 2004.

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

In 2010, the Model 3783 was developed specifically for measuring high concentrations in single-count mode for environmental monitoring. Also in 2010, the Model 3785 was replaced by the Model 3787, and the 3786 was replaced by the Model 3788. These new instruments have significant improvements to increase reliability and add features.

Models 3772, 3775, 3776, 3785, 3786, 3787, and 3788 can be used as components of a Scanning Mobility Particle Sizer™ (SMPS™) Spectrometer (TSI Model 3936). The SMPS™ provides high-resolution submicron-aerosol size-distribution measurements.

Design of the Model 3788

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

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

Sensor

The sensor contains a conditioner, a growth tube, and an optical detector (shown schematically in Figure 1-2). The sensor grows the sampled aerosol particles into larger droplets that are detected optically.

The sample flow is cooled with a thermoelectric device in the conditioner. The vapor passes into the growth tube where it becomes supersaturated and condenses onto the aerosol particles (acting as condensation nuclei) to form larger droplets. The droplets pass through a nozzle into the optical detector.

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

The Model 3788 operates in single particle count mode up to $4\text{x}10^5$ particles/cm^3. Rather than simply counting individual electrical pulses generated by light scattered from individual droplets, the Model 3788 uses a continuous, live-time correction to improve counting accuracy at high particle concentrations. Live-time correction occurs when the presence of one particle obscures the presence of another particle creating an undercounting error that results in dead time.

Pulse Height

The Model 3788 contains an electronic subsystem for monitoring the amplitude (voltage height) of the particle pulse generated by the optical detector. The actual amplitude of the pulse does not affect the particle counting performance as long as it is large enough to intercept the preset discriminator threshold. Typical pulse amplitudes (1 to 2 volts) are 10 to 40 times higher than the discriminator level which is typically 20 times higher than the RMS noise level of the photo-detector electronics. This large magnitude of “signal-to-noise” margin provides robustness in performance in the optical detection of droplets.

Under normal operating conditions, the pulse amplitude decreases with increasing particle concentration. As particle concentration increases, depletion effects within the growth tube cause the nucleated droplets to grow to smaller sizes than they would at lower particle concentrations.

Note*: The droplet size has been reduced in this instrument compared to those of previous generations—reducing the variation in pulse amplitude with respect to particle concentration to about 2:1 over the concentration range of the instrument.*

Changes in optical alignment, laser power, or optical cleanliness can all reduce pulse amplitude; therefore, the pulse amplitude is a good indicator of the “health” of the N-WCPC. A peak-sense and hold circuit within the Model 3788 measures the pulse amplitude of 50 particles/sec. The average pulse amplitude is displayed both numerically and in a bar graph on the Status screen, and is also included in the data retrieved from the digital interfaces. The limitation of the Pulse Height indication is that it requires the presence of at least 50 particle pulses/sec to provide information. The Pulse Height fault status indication is displayed for particle concentrations over 10 #/cm^3 with a pulse height of <800 mV.

Flow System

Refer to Figure 6-1 while reviewing the instrument flow information.

The Model 3788 N-WCPC has two user-selectable sample air flow modes controlled by critical orifices.

Orifice	Description
0.6 L/min aerosol sample flow mode	Carries the aerosol to be sampled. Used for ambient sampling and systems with short tubes. ***Note****: 0.3 L/min is sampled; the other 0.3 L/min is used for the sheath air flow.*
1.5 L/min transport flow mode	A user-selectable inlet flow rate used to reduce particle losses in external plumbing by reducing the transit time.

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

Critical Flow

To achieve the 0.6 L/min flow through the sensor, an orifice is used and operated at the *critical pressure ratio.* Critical flow is very stable and is a constant volumetric flow, assuring accurate concentration measurements despite varied inlet pressure.

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

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

The following pressure values are displayed on the Status screen and can affect the N-WCPC monitor flow.

Pressure Value	Description
Vacuum	The vacuum pressure
Inlet Pressure	The inlet pressure.
Nozzle Pressure	The differential pressure across the nozzle and filter.

Temperature Control

The temperatures of the conditioner, growth tube, and optics are nominally maintained at 15°C, 75°C, and 75°C, respectively, with specified ambient temperatures in the operating range of 10 to 35°C. Temperatures are controlled through feedback circuits on the main electronics board and are displayed on the Status screen on the front-panel display.

Inlet Pressure Measurement

With the built-in vacuum pump, the instrument is capable of operating at barometric pressures from 75 to 105 kPa. The inlet pressure is measured by an absolute pressure sensor and is equal to the barometric pressure if no inlet restriction is present. When the vacuum pump is turned on, the inlet pressure is recorded. The difference between the recorded pressure and the inlet pressure is the inlet gauge pressure. The inlet gauge pressure is controlled by external connections to the inlet—if this value exceeds the maximum specified value, the pump is switched off. The pump automatically switches on one minute after the gage pressure limit is no longer exceeded.

The Inlet Pressure reading is displayed on the Status screen on the front-panel display.

Water Removal System

The Model 3788 N-WCPC has a water separator and ejection system to remove water from the vapor stream exiting the optics assembly. The water separator condenses the water vapor and then the collected water is ejected through the **WATER EXHAUST** port on the back panel and away from the internal flow control orifices. The water bottle is designed to allow the small amount of expelled water to be recycled by inputting it back into the recycle fill bottle.

Internal Clock

The clock used in the 3788 is a Quartz crystal component embedded in the microprocessor. The accuracy is on the order of about a second per day, but time drift during long periods of data logging is possible. If a higher level of time accuracy is needed, one of the following options should be implemented:

1. Use Aerosol Instrument Manager® software as the data collection tool. The software can be configured to synchronize the 3788 with the computer clock once per day.
2. Send a serial command to the instrument once per day to reset the 3788 clock to synchronize with the data collection tool.
3. If collecting data via the USB stick, reset the clock on the instrument as needed.

Counting Efficiency and Response Time of the Model 3788

The Model 3788 N-WCPC has a sharp lower detection curve with a D_{50} of 2.5 nm. D_{50} is defined as the particle diameter at which 50% of particles are detected. The curve fit shown in Figure 6-1 details the particle detection efficiency

The particle concentration measured by the particle counter is the total number concentration of all particles that the Model 3788 can detect. This measurement provides no size differentiation and it is not corrected using the Model 3788 counting efficiency curve.

The N-WCPC monitor has a fast response time. Figure 6-2 shows the response time curves to a step change in concentration, based on the average of three N-WCPCs. The ~250 millisecond time to a 95% response in concentration in high flow rate mode includes a flow rate based pipe delay. Under normal operation with constant flow, the traditional rise time

(10 to 90%) is <100 milliseconds. The time constant (τ) of the Model 3788 is ~43 milliseconds.

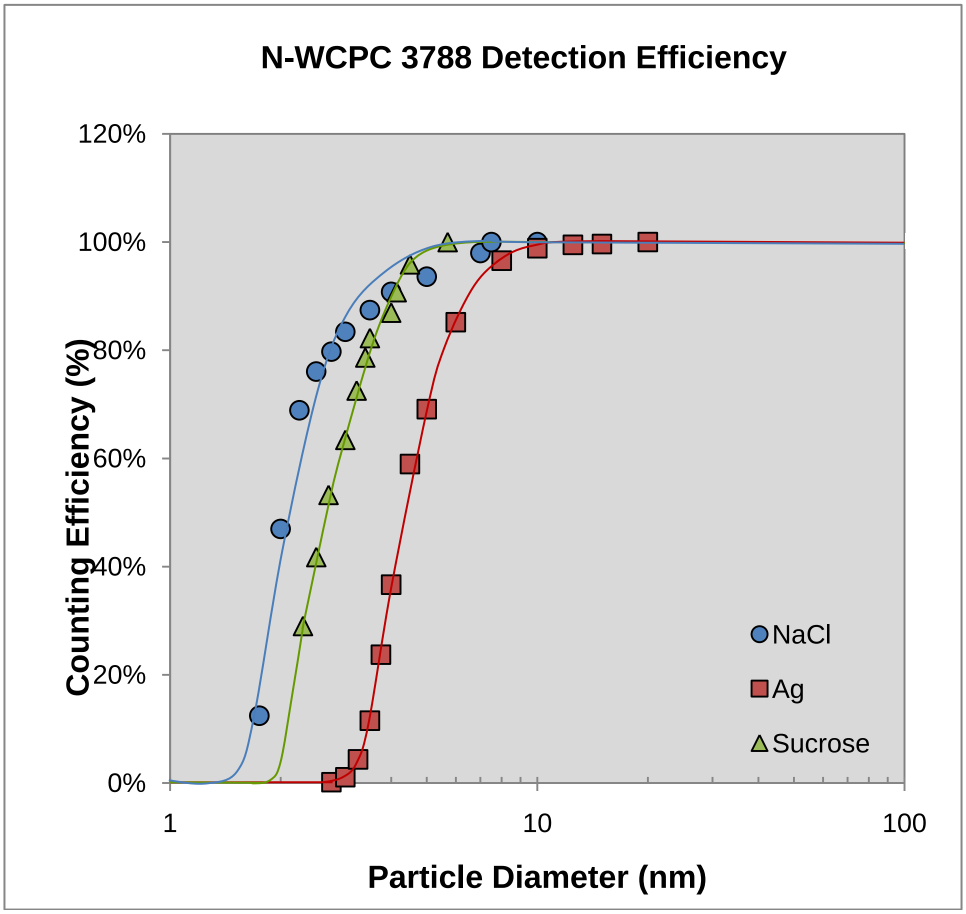

Figure 6-1
Counting Efficiency Curve of Model 3788 Nano Water-based Condensation Particle Counter

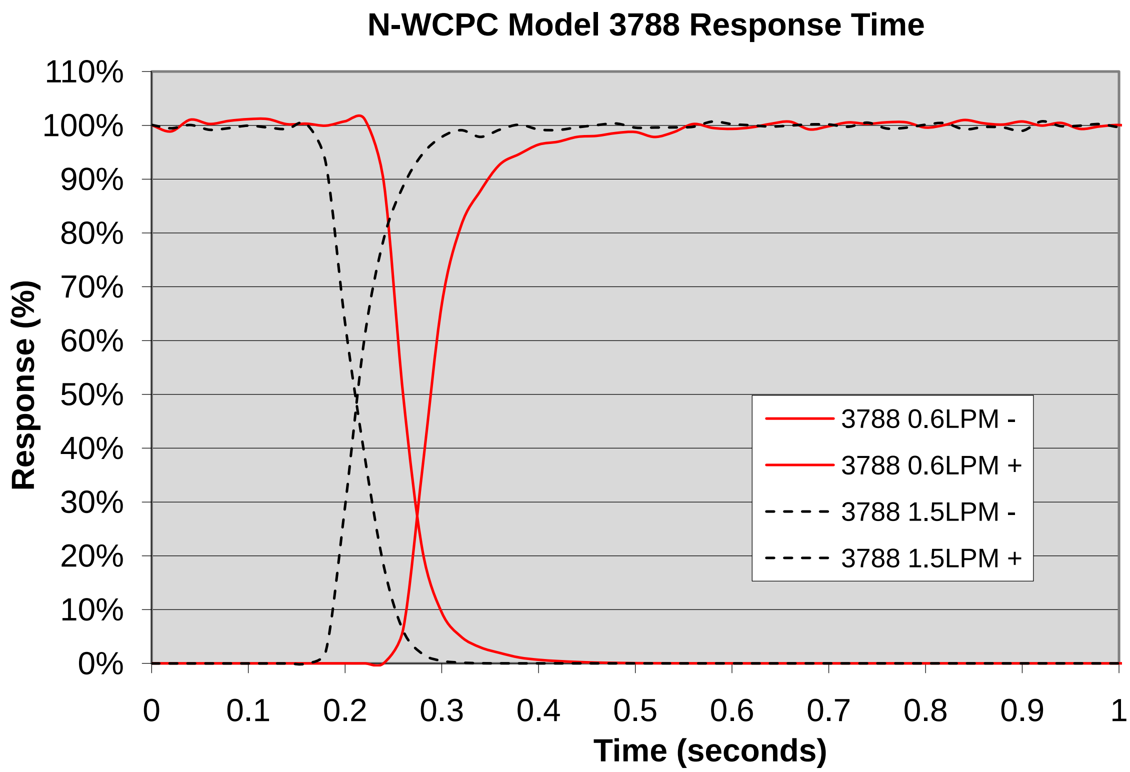

Figure 6-2
Response Time of Model 3788

CHAPTER 7
Particle Counting

This chapter discusses particle counting and particle count measurements performed using the Model 3788 Nano Water-based Condensation Particle Counter (N-WCPC).

Concentration data from the N-WCPC can be viewed on the **HOME** screen and on the **STATUS** screen. The concentration value displayed on the **HOME** and **STATUS** screens is calculated based on one second of particle count, live-time, and flow data based on the following formula:

$$\text{Partical Concentration} = \frac{n}{Q \times t}$$

where
n = The number of particles counted
Q = Sample (capillary) flow rate ratio (nominally 0.30 L/min).
t = sample live-time in seconds.

The displayed value is updated each second, but the actual sample time used in the calculation is always less than one-second because the dead-time for each particle pulse detected reduces this value. At concentrations below 1,000 $\#/cm^3$, the displayed value is based on a ten-second running average of particle counts and sample time.

The concentration graph on the **HOME** screen provides a plot of particle concentration based on the sample time setting in the **SETUP** screen. Each plotted point is based on the sum of particle counts, sample live-time, and an average sample flow over the selected period. Sample periods from 1 to 60 seconds can be selected and the graph time scale will be adjusted accordingly. This value is also used in the data logged to a connected USB Flash drive or from data collected from the serial interfaces based on the Set Mode (SM) command.

Concentration data can also be collected using the Totalizer mode (on the **TOTALIZER** screen). The Totalizer mode is used to measure low particle concentrations. It can also be used to collect concentration data over a specific, manually-controlled, sample period. The Totalizer accumulates the particle counts, sample live-time, and total sample volume. The sample volume is based on the measured sample (capillary) flow of the instrument during the time the Totalizer is operating.

Total Count Accuracy

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

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

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

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

where
Q = Sample (capillary) flow rate ration (nominally 0.30 L/min).
t = sample live-time in sec.

The number of particles in the measured sample is one of the limiting factors of how low a particle concentration can be precisely determined. To calculate low particle concentrations, the Totalizer uses the elapsed time as the sample time in the above calculation.

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% (greater accuracy than that 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.

Live-Time Counting

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

The N-WCPC monitor corrects for coincidence continuously with the instrument electronics performing a “live-time” correction.

Live-time refers to the time between electrical pulses. This is the total measurement time interval minus the time during which the counter is disabled with one or multiple particles in the optical sensing volume (the dead time). The dead time should not be included in the sample time since only the particles already in the viewing column can be counted. The actual particle concentration therefore equals the number of counted particles divided by the live-time (actual sample time) and the aerosol flow rate.

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

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

Note: *At concentrations >4 x 10^5 particles/cm^3, the status reads* ***Over Range****. If this occurs, the Model 3788 is outside of the concentration operating range and the number concentration of particles shown on the display may be inaccurate.*

Concentration Measurement

The N-WCPC monitor can report particle concentration values in the following ways:

- On the front-panel display.
- On the Totalizer display.
- Using the data communications ports.

Particle concentration is presented as particles per cubic centimeter (p/cm^3). The following parameters are important for calculating particle concentration:

- The number of particle pulses counted (measured internally by the Model 3788).
- The sample time (measured internally by the Model 3788).
- The sample flow rate (0.3 L/min as measured by the capillary pressure).

The basic calculation for the number of particles per volume of air is:

$$Concentration = \frac{N}{Q \times t}$$

where:

Concentration is the particle concentration in #/cm^3

N is the number of particle counted

t is the sample time

Q is the sample flow rate in cm^3/second

The number of particles in the measured sample is one of the limiting factors of how low a particle concentration can be precisely determined. To calculate low particle concentrations, the Totalizer uses the elapsed time as the sample time in the above calculation.

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% (greater accuracy than that 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; therefore, the actual sample time needs to be corrected for this blocked or dead time.

To adjust for this particle “coincidence” effect, the Model 3788 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 elapsed 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. Under extreme overload conditions the display will show an “OVER” annotation or a concentration of $9.99e^5$ particles/cm^3.

During operation, the N-WCPC collects single particle counts and dead-time corrected sample time every tenth of a second. The concentration value reported on the front-panel display is updated each second. It uses data collected over the previous second of elapsed time to calculate concentration. If the concentration is <1000.0 particles/cm^3, a 10-second running average of particle count data is used to calculate the displayed value.

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 600 seconds.

Totalizer Mode

The Totalizer mode counts the number of particles in a given time period. This mode is used primarily to improve counting resolution at very low particle concentrations, but it can also be used to take an average over a user-specified time period.

The time, number of counts, accumulated sample volume, and particle concentration are shown on the display. The time is the actual sample time and is shorter than the elapsed time (beginning when the Totalizer is started).

The Totalizer automatically stops when 3600 seconds of sample time have been accumulated.

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CHAPTER 8

Computer Interface, Commands, and Data Collection

This chapter provides information about the computer interface, communications information, and data collection for the Model 3788 Nano Water-based Condensation Particle Counter (N-WCPC). Information about using a Flash Drive is also provided.

Analog Inputs

The Model 3788 N-WCPC can monitor the analog voltage from an external source via the analog input BNC connector on the back panel (labeled Analog In). The input voltage range for these ports is 0 to 15 V. Analog voltages can be displayed together with concentration data on the LCD display and saved to the removable flash drive or a computer. Voltages measured from a device connected to the Analog Input can be correlated to particle concentration in real time.

Amplification of external signals may be needed and supplied by the user to bring low voltage signals to the appropriate 0 to 15 V range for best resolution.

Analog Output

During normal operation of the Model 3788 N-WCPC, the **Analog Out** port provides an analog 0 to 10 V signal proportional (linear or log) to particle concentration. This particle concentration is corrected for coincidence and tracks the displayed concentration.

Pulse Output

Pulse Out provides a 5-volt (50-ohm termination) digital pulse for each particle detected and is a way to get raw count information. This enables you to use external counting electronics hardware to acquire particle count data for special applications. The width of the pulse depends on both the shape of the photo detector pulse and the trigger-level of the pulse threshold. The pulse width for a single particle pulse is typically 0.8. To provide accurate pulse counts, *use a counter that is capable of counting pulses with a width of 500 nanoseconds or less*.

Particle concentrations that are calculated based on the particle counts from the Pulse Output are *not live-time corrected* for particle coincidence. Thus, when particle concentration is high, the concentration will be lower than the displayed concentration. Appropriate coincidence correction should be applied when pulse output is used for high concentration measurements.

Computer Interface

The N-WCPC provides four interfaces to allow for flexible data collection and instrument control. This section of the manual includes information about the following data interfaces:

- Ethernet.
- Flash Drive.
- USB.
- RS-232 (Serial).

The N-WCPC provides a standard 9-pin RS 232 serial connection and a USB 1.1 connect supporting the TSI Aerosol Instrument Manager® software (included with the instrument). The USB port enumerates as a virtual COM port under Windows® operating system, making the USB and serial ports act in a similar manner to the external software. Serial commands are sent to and from the computer to monitor instrument status information, to retrieve and monitor data, and to provide a variety of control functions. When USB or RS-232 serial communications are used with the Aerosol Instrument Manager® software, the computer automatically recognizes the N-WCPC as a TSI instrument. Additional information on communications can also be found in the Aerosol Instrument Manager® software manual.

The USB port is used with an external flash drive.

Instrument status, including particle concentration, of the N-WCPC can be monitored remotely from a local area network or over the internet using the Ethernet communication.

Although four interfaces are provided, only one at a time can be used. The Serial and USB data interfaces share a common communications channel to the N-WCPC microcontroller. Data input to the N-WCPC 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. When the link is established, communications can be received via the USB port but not from the Serial port. When the USB link is terminated, the Serial port can be used.

More details about these interfaces can be found on the following pages.

Ethernet

The Ethernet port on the Nano Water-based Condensation Particle Counter (N-WCPC) can provide system status information or instrument control over a network. In the instructions below, the client is used. Please note that Telnet feature is not included with Windows Vista® or Windows 7 operating systems and it must be enabled to be used.

To enable Telnet in Windows® 7 operating system, follow these instructions:

1. From the **Start** menu, choose **Control Panel** and then choose **Programs and Features**.
2. Choose **Turn Windows features on or off**.
3. Choose **Telnet Client** and then click **OK**. A dialog box appears confirming the installation of new features.

To monitor system status using the Telnet client, follow these instructions:

1. Insert an Ethernet cable into the Ethernet port on the back panel of the N-WCPC and connect the cable to your network or a personal computer.
2. On the N-WCPC home screen, choose **SETUP** then choose **MORE** to view the **NETWORK SETUP** screen.
3. On the **NETWORK SETUP** screen, choose **ADDRESS** and enter a static IP address for this unit that is available on your network. Alternately choose **NETWORK** and select **DHCP**. If your network has a DHCP server, a dynamic address will be selected for you in a few seconds.
4. If you are using a personal computer, from the **Start** menu, choose **Run** then type the command **telnet xx.xx.xx.xx** where **xx.xx.xx.xx** is the IP address determined in step 3.
5. A console screen appears which allows direct entry of firmware of commands.

To test communication between the personal computer (or your network) and the N-WCPC, follow these instructions:

1. From the Start menu, choose **Run**, type **cmd**, and press **Enter**.
2. In the resulting window type **ping xx.xx.xx.xx** where **xx.xx.xx.xx** is the IP address determined in step 3 above.

3. The response shows the response from the instrument if the network connection is valid as shown in the figure below.

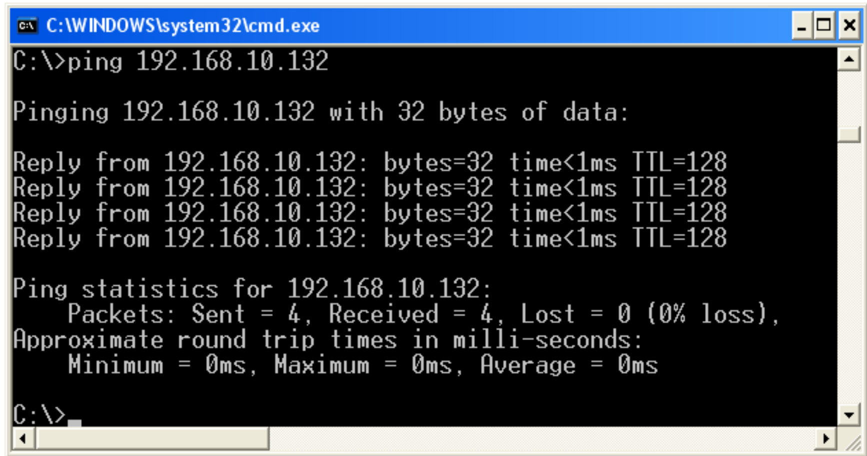

Figure 8-1
Screen Showing Valid Network Connection

Flash Drives

Only one flash drive port can be used at a time. Use the USB and Serial ports to connect to a local computer running data collection and analysis software, such as Aerosol Instrument Manager® software or a terminal emulation program. Use the flash drive port to log data to a USB flash drive (in hourly or daily files) without a host computer. Use the Ethernet port for remote connections via a local (LAN) or extended (Internet) network. The Ethernet connection provides the same data protocols and firmware commands as provided by the USB or Serial connections. RS-232 Serial Communications later in this chapter contains more detailed information about serial communications.

The N-WCPC can store particle concentration data and analog input data to a flash drive inserted into the flash drive port.

Note: *Some Flash drives larger than 16 Gigabytes may not be recognized.*

To insert a flash drive, follow these instructions:

1. Plug the flash drive into the USB flash drive port on the back panel of the N-WCPC monitor.
2. Check the Home screen. You should see a **START** button displayed beneath the other home screen buttons. If you do not see this button, check that your flash drive is inserted correctly. You should also see a status message beneath the button. This message reads **Mem Stick** until you begin data collection.
3. Press **START**. The status message changes to **Logging** and the button displays **STOP**. When you press **START**, a directory named **3788** is created on the flash drive. The data files created within that directory contain either one hour or one day of data (depending upon

the **SAMPLE TIME** you chose on the **SETUP** screen), unless you press **STOP** to discontinue the data logging.

***Note**: The **SAMPLE TIME** cannot be changed while data is being logged. You must stop logging data first.*

4. Press **STOP** to discontinue data logging at any time.

   ***Note**: Do **not** remove the flash drive while logging data.*

Flash Memory Data Files

The data is stored in files with the "dat" extension and a new file is created either every day or every hour (depending upon the Logging selection you have made). If you stop data collection at any time, the current data file is saved even if it contains less than one hour/day of data. These data files can be imported to Aerosol Instrument Manager® software.

Every time you begin a new run, a unique file is created. Each data file has the following format:

Filename	yymmddxx, where yy is the year (no leading zero), mm is the month (1-12), dd is the day of the month, and xx is a sequence number for the day (01-99). Example: 12110601.DAT where 12 is the Year, 11 is the month, 06 is the day, 01 is the file number and .DAT is the extension.
LINE 1	"TSI CPC DATA VERSION 3"
LINE 2	Time stamp for the file: yy/mm/dd,hh:mm:ss where yy is the year, mm is the month, dd is the day of the month, hh is the hours, mm the minutes, and ss the seconds.
LINE 3	Data average period (sample time intervals) in seconds.
LINE 4	Dead-time correction factor, flow calibration constant (mL/min).
LINE 5	Instrument model number, firmware version number, serial number.
LINE 6	Header descriptions.
LINE 7	First data record.
LINE 8	Second data record.

Example of data record:

```
TSI CPC DATA VERSION 3
1268228469,2012/3/10,13:41:09
60
1.05,300
Model 3788 Ver 1.05S/N 123456
"Date","Time","Concentration","Count"," Live-Time","Flow","Abs
Press"," Analog In","Pulse Height"," Pulse STD","Status Flags"
2012/3/10,13:41:57,2.15e4,2522183,58.62,300,970,0.00,567,600,0
2012/3/10,13:41:57,2.32e4,2719488,58.51,300,970,0.00,607,595,0
2012/3/10,13:42:57,2.15e4,2530791,58.62,300,970,0.00,587,609,0
2012/3/10,13:43:57,2.13e4,2505886,58.63,300,970,0.00,581,615,0
```

Data fields include:

- Date
- Time
- Particle Concentration (#/cm^3)
- Raw Particle Counts
- Live-time (seconds)
- Flow (capillary flow in cm^3/min)
- Absoluter Pressure (mbars)
- Analog Input (V)
- Pulse Height average (mV)
- Pulse Height Standard Deviation
- Status flags.

Select the Sample Time (the period over which data is collected and reported) from one of the following choices: 1, 2, 3, 4, 5, 6, 10, 12, 15, 20, 30, or 60 seconds. Data is collected internally 10 times/second and is averaged over the selected sample time. The average is displayed on the graph and can be saved to the flash drive. Data is saved to the flash drive every 10 seconds or at the rate of the data averaging period if it is longer than 10 seconds. The data averaging period is the same as the Sample Time setting. Once the data is being logged to the flash drive, the Sample Time setting cannot be changed.

IMPORTANT

If power is lost at any time, the instrument should continue data logging when the power is returned. The data files created will have the extension **.rdt** so that the previous files are not overwritten.

USB

USB communications are provided with the N-WCPC for use with the supplied Aerosol Instrument Manager® software. USB driver software must be installed on the host computer. For Windows® operating systems the drivers may be downloaded from the USB chip manufacturer's site at: http://www.ftdichip.com/Drivers/VCP.htm

To install the USB driver, follow these instructions:

1. Find the appropriate driver for the host computer's operating system.
2. Download the driver to the host computer.
3. Extract (unzip) the driver to a blank folder.
4. Connect the computer to the N-WCPC USB port.
5. Follow the **Add New Hardware** wizard steps and browse to the folder containing the extracted driver. If the wizard does not start, use the **Add Hardware** function on the Control Panel.

When the USB driver is loaded, the operating system recognizes the N-WCPC as a new serial device. In Microsoft Windows® operating system this is a new port (such as COM2 or COM6). If it is not obvious which COM port is being used, you can check in the computer's Device Manager. To check which COM port is being used, follow these instructions:

1. Open the **Control Panel** and choose **System**.
2. In the **System Properties** dialog box, choose the **Hardware** tab and then click **Device Manager**.
3. In the **Device Manager** dialog box, click the **+** sign next to **Ports (COM & LPT)**. The USB Serial Port indicates in parenthesis which COM port is being used.

Connect the supplied USB cable to the N-WCPC and a computer running the Windows®-based operating system and the Aerosol Instrument Manager® software. In the Aerosol Instrument Manager® software, double-click the correct COM port and the data is displayed in real time (depending upon the sample time you have selected).

Refer to the Aerosol Instrument Manager® software manual for specific system requirements, including operating system version.

RS-232 Serial Communications

The communications ports are configured at the factory to work with RS-232-type devices. RS-232 is a popular communications standard supported by many mainframe computers and most personal computers. The Model 3788 N-WCPC has one 9-pin, D-type subminiature connector on the back panel (labeled Serial).
Table 8-1 lists the signal connections.

Note: *This pin configuration is compatible with the standard IBM® personal computer serial cables.*

Table 8-1
Signal Connections for RS-232 Configurations

Pin Number	RS-232 Signal
2	RXD (Input to N-WCPC)
3	TXD (Output from N-WCPC)
5	GND

An external computer is connected to the Serial 1 or USB ports for basic instrument communications and when Aerosol Instrument Manager® software is used.

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Communications Parameters

All serial communications with the N-WCPC are accomplished using the following communications parameters:

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

All data communications are performed 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.

All input line feeds are ignored.

Terminal Communications

When you have made a Serial or USB connection between the N-WCPC and host computer, you can use Aerosol Instrument Manager® software or a terminal emulation program to communicate with the N-WCPC. You can choose from the following terminal emulation programs:

- Tera Term—a free terminal emulator for Microsoft Windows® operating systems.
- HyperTerminal—included with most Microsoft Windows® operating systems.

You should set up the terminal emulation software so that incoming carriage returns are translated into carriage return line feed sequences and therefore do not overwrite the previous line of data. Also, consider enabling local echoing of characters so that data typed on the keyboard is displayed on the screen.

If you press the **Enter** key when the terminal emulation software is connected and running, you will see an **ERROR** response from the N-WCPC in the terminal emulation software. This is because, although the N-WCPC and computer are communicating, the command is not understood. This error message can be ignored—it is only used for testing the connectivity. When data is being reported to the screen of the terminal emulation software, the data can be cut and paste into a file, or the software's data logging capabilities can be used to capture data. Data in the comma-delimited format can be imported into programs such as Microsoft Excel® spreadsheet software for analysis and graphing.

Appendix B, "Firmware Commands", describes the commands that control the operation and data reporting options for the N-WCPC.

Aerosol Instrument Manager® Software

Aerosol Instrument Manager® software is supplied with the Model 3788 N-WCPC. This program provides many useful data acquisition, display, processing and download functions used in particle measurement. Review the supplied Aerosol Instrument Manager® software manual for complete information on software functions.

Commands

It is important to note the following information about the commands and responses:

- Unless specified as binary-encoded, all commands and responses are sent or received as ASCII characters.
- All messages are terminated with a <CR> (0x0D) character.
- All linefeed (0x0A) characters are ignored and none are transmitted.
- Commands are case insensitive. The backspace character (0x08) deletes previous characters in buffer.
- Values enclosed by "<>" indicate ASCII characters/values sent/received. For example, <,> indicates the comma was sent or received via the communications channel.

The firmware commands are divided into the following categories:

Commands	Description
READ	Used to read parameters from the instrument (such as flow rate, pressure, temperature, etc.). **READ** commands can be identified by a leading "R".
SET	Set an internal parameter to the value(s) supplied with the command (supplied parameters are always delimited by a comma). **SET** commands can be identified by a leading "S". The instrument will reply to all **SET** commands with the string "OK"<CR>.

***Note**: When the instrument does not understand a command, it replies with the string "ERROR".*

To use the firmware commands, a program capable of sending and receiving ASCII text commands can be used. A terminal program such as HyperTerm (supplied with Windows® operating system) is appropriate. To use Hyperterm, follow these instructions:

1. Connect to Serial 1 of the Model 3788.
2. Open the HyperTerminal program by selecting: **Start | Programs | Accessories | Communications | HyperTerminal**.
3. Enter a name for the connection, for example, TSI-WCPC.
4. Enter the communications (COM) port.

5. Enter the following port settings and click **OK:**
Bits per second: 115200
Data bits: 8
Parity: None
Stop bits: 1
Flow control: None

6. Under the settings tab, pick the **ASCII Setup** button and check the following boxes:

   ☐ Send line ends with the feeds

   ☐ Echo typed characters locally

   ☐ Append line feeds to incoming line ends

   ☐ Wrap lines that exceed terminal widths

7. From the **File** menu choose **Save As** and save the file to the desktop for easy access.

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

9. Type in firmware commands to communicate with the N-WCPC. A list of firmware commands can be obtained from Appendix B.

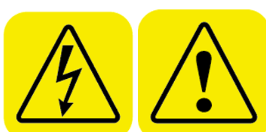
CHAPTER 9

Maintenance, Service, and Troubleshooting

This chapter describes recommended maintenance procedures and is intended to be used by a service technician with skills in both electronics and mechanics. Static preventative measures should be observed when handling any printed circuit board connectors.

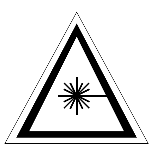
Regular maintenance of the Model 3788 Nano Water-based Condensation Particle Counter (N-WCPC) will help ensure years of useful operation, however the frequency of service depends upon the frequency of use and the cleanliness of the air measured.

If you need to contact TSI for assistance, please have the Model 3788 N-WCPC close to the telephone when discussing the problem with a TSI technician.



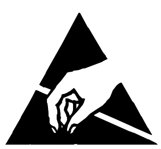
WARNING

Procedures described below may require removal of the instrument cover. The instrument must be unplugged prior to service to prevent possible electrical shock hazard.



WARNING

Unplug the instrument prior to removing the cover to avoid potential of exposure to laser radiation.



Caution

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

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

Removing the Cover

When r the N-WCPC cover to perform service or maintenance, follow the instructions below:

1. Read the warnings and cautions at the beginning of this chapter.
2. Unplug the instrument and remove the instrument cover by loosening the six side panel screws.
3. Lift the cover up.

Replacement Parts Kits

In addition to replacement parts found in your supplied accessory kit, additional replacement items are available from TSI to keep your N-WCPC operating for many years. Parts are available in kits listed below in Table 9-1. Please contact your TSI representative for details and purchase of these items.

Table 9-1
Model 3788 N-WCPC Maintenance and Replacement Kits

TSI Part No.	Name	Description
1188001	3788 Maintenance Kit	See Table 2-2 in Chapter 2 for details.
1180003	Wick Kit 3788	Set of 12 Replacement Wicks (Growth Tube and Conditioner) 3788
1180008	Replacement Wick Cartridge	Replacement Wick Cartridge
1183004	Critical Flow Orifice, Critical Total Orifice, Exhaust Filter	Replacement filter for critical flow control orifice, critical transport flow orifice, and pump
1188003	Sheath Filter	Low-pressure-drop HEPA filter
1180004	Critical Flow Control Orifice 3788	Replacement Critical Flow Control Orifice
1180005	Critical Transport Flow Orifice 3788	Replacement critical transport flow control orifice

Internal Instrument Components

Internal components are described in this section and identified in the photos below.

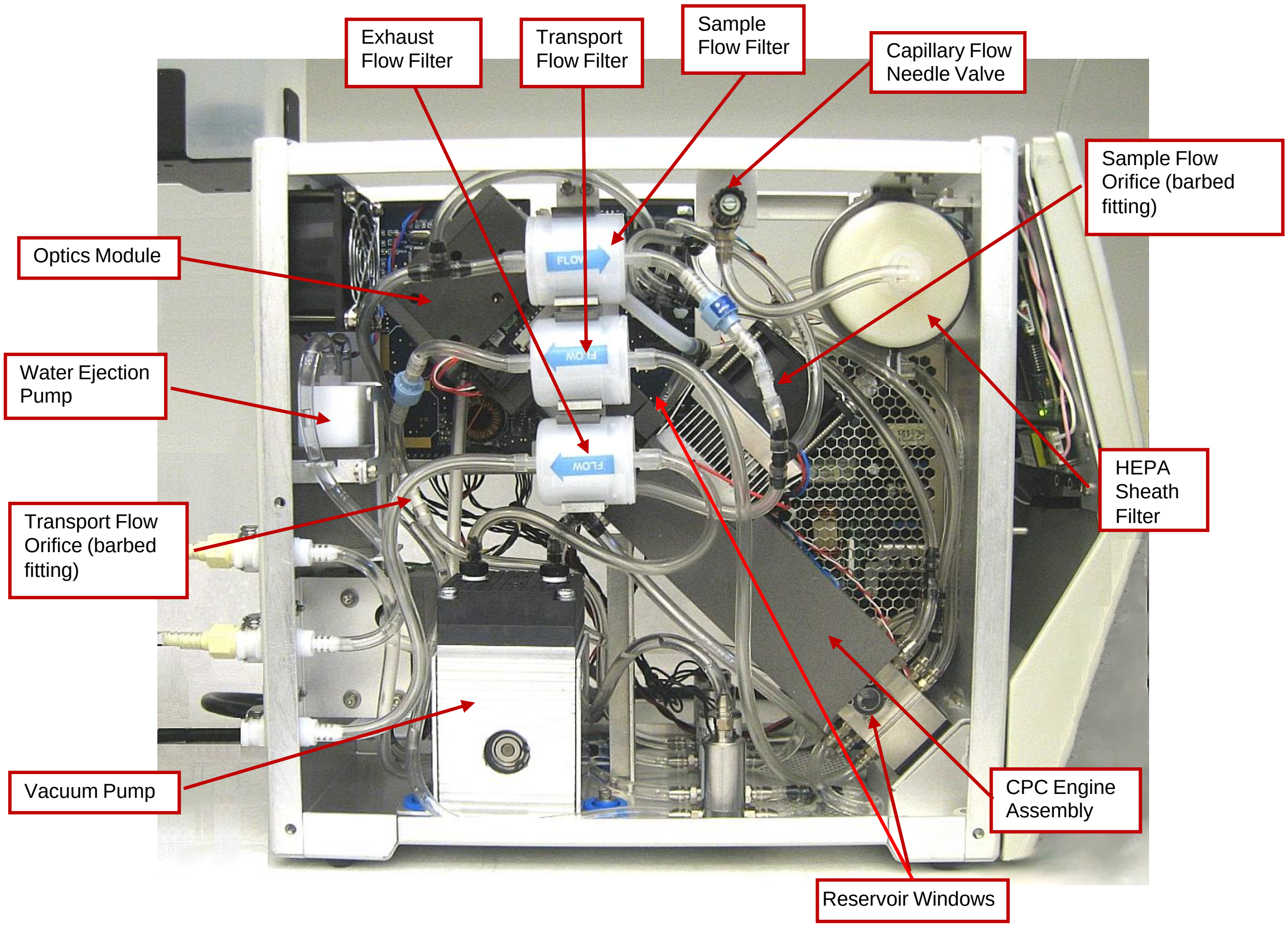


Figure 9-1
Nano Water-based Condensation Particle Counter Internal Components (viewed from left side)

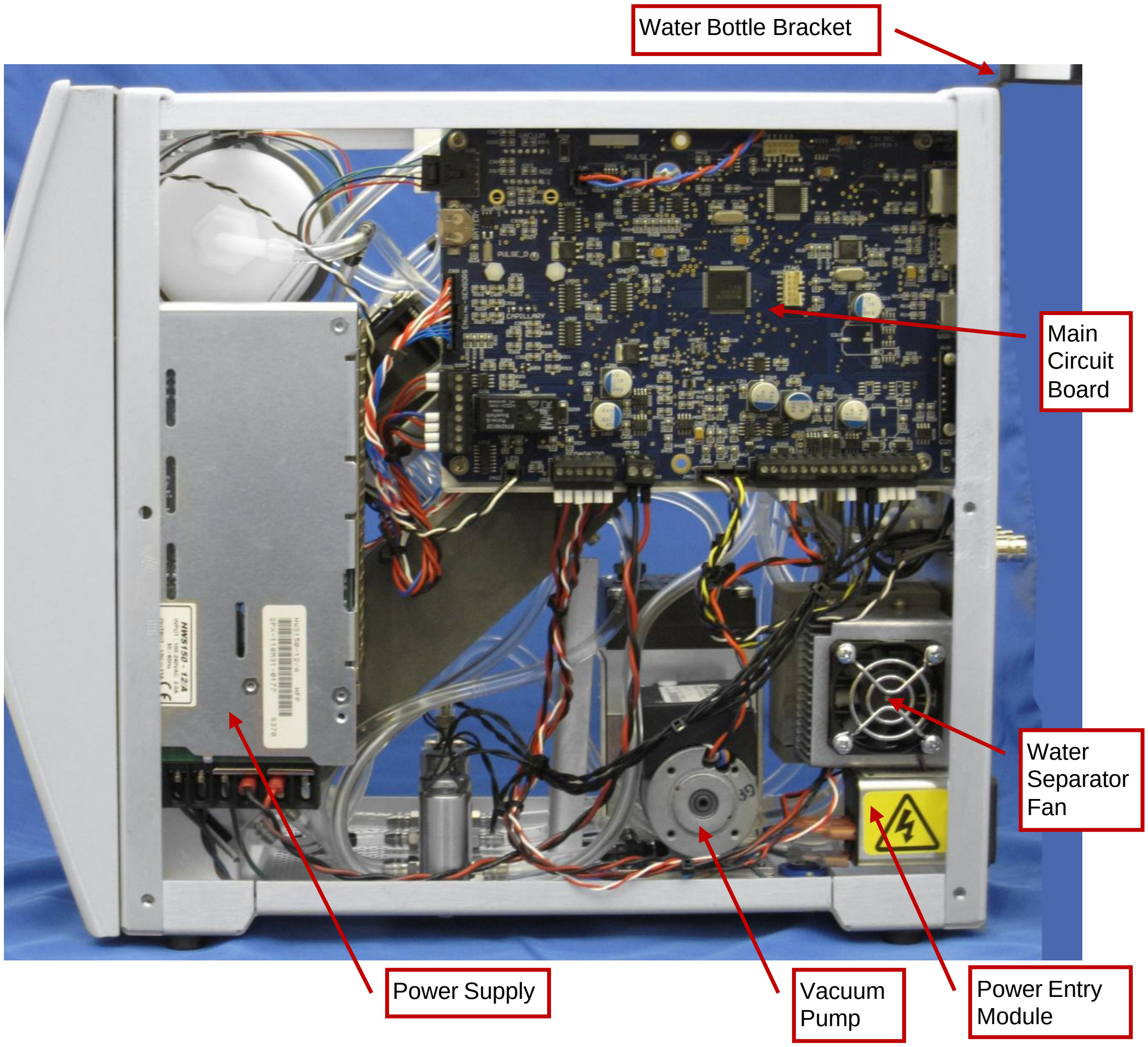


Figure 9-2
Nano Water-based Condensation Particle Counter Internal Components (viewed from right side).

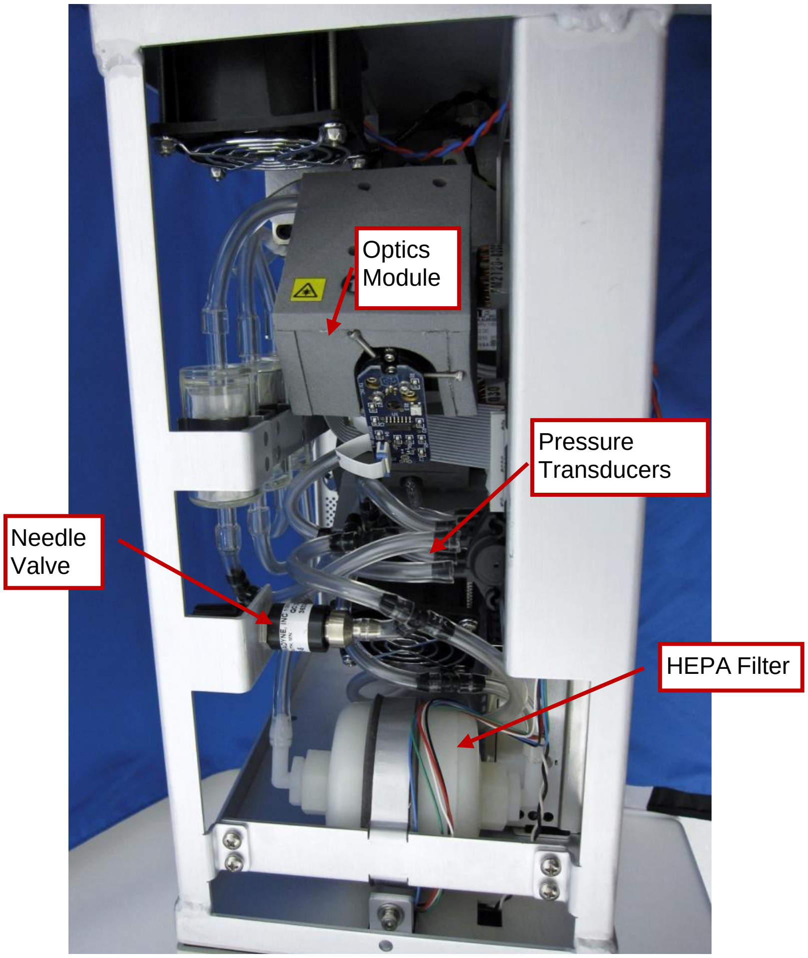


Figure 9-3
Nano Water-based Condensation Particle Counter Internal Components (viewed from above and front)

Optics Module

The optics module detects particle droplets from the growth tube. The optics module contains a laser, photodetector, and the optics, as well as the detector and optics circuit boards.

Vacuum Pump

The Model 3788 N-WCPC contains an internal vacuum pump to draw air through the instrument.

Sheath Flow

The Model 3788 N-WCPC uses a low-pressure-drop HEPA filter with a needle valve for flow adjustment. 0.3 L/min of the total flow is diverted to the HEPA filter. The sample flow is then sheathed with clean air to reduce diffusion losses and provide a path for the sampled particle through the highest super-saturated region of the growth tube.

Water System

The water separator removes water from the vapor stream coming from the optics head. This prevents water from condensing and blocking the flow orifices. Water is pumped from the separator by the water ejector pump.

The conditioner and growth tube have separate wicks, therefore the N-WCPC contains two reservoirs. A sensor in the N-WCPC engine opens a valve to allow intake of an appropriate amount of water from the reservoirs through the wick assembly openings. Figure 9-4 and

Figure 9-5 shows the wick assembly.

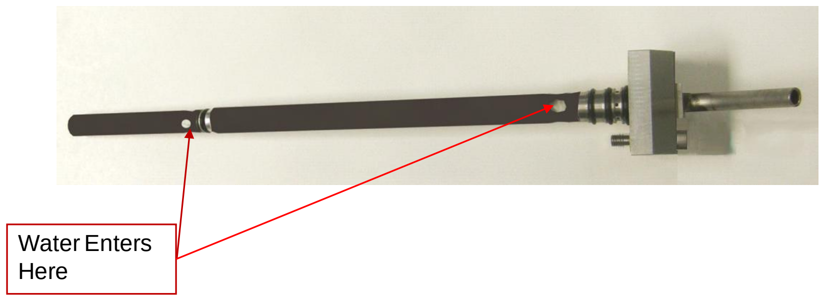


Figure 9-4
Nano Water-based Condensation Particle Counter Wick Assembly

Figure 9-5
Wick Cartridge Growth tube and Conditioner shown separated.

The flow control orifices operate under vacuum from the internal pump. The flow on the upstream side is determined by the orifice diameter. Each orifice has a filter to remove particles from the water stream and protect the orifices.

Fans

Three internal fans cool the instrument; the cabinet fan cools the internal electronics, the conditioner fan dissipates the heat generated during cooling of the conditioner, and the water separator fan cools the heat sink associated with the thermo-electric devices. The conditioner fan is the most powerful of the three fans.

Circuit Boards

The Model 3788 N-WCPC contains the following circuit boards:

- Main board.
- Laser board.
- Detector board.

The main circuit board controls all the primary functions. Feedback circuits on the main electronics board, control the internal temperatures (displayed on the Status screen).

Changing the Filters

The Model 3788 N-WCPC contains three filters. The filters should be replaced as part of the annual service.

To replace a filter, follow these instructions:

1. Turn off the power to the N-WCPC.
2. Remove the instrument cover.
3. Remove the filter you are changing from its filter clip.

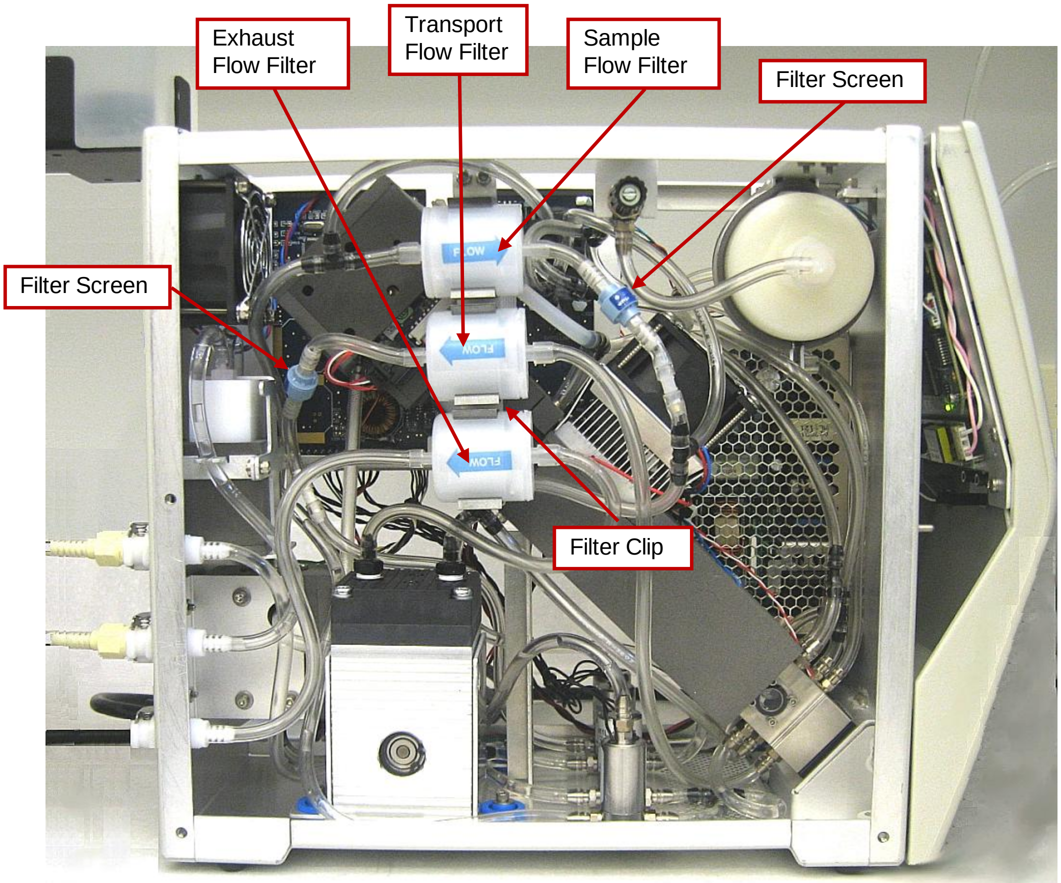


Figure 9-6
Location of Filter Clip

4. Noting the direction of flow, pull the tubing off both ends of the filter.

   Note: *Sometimes it is easier to push rather than pull.*

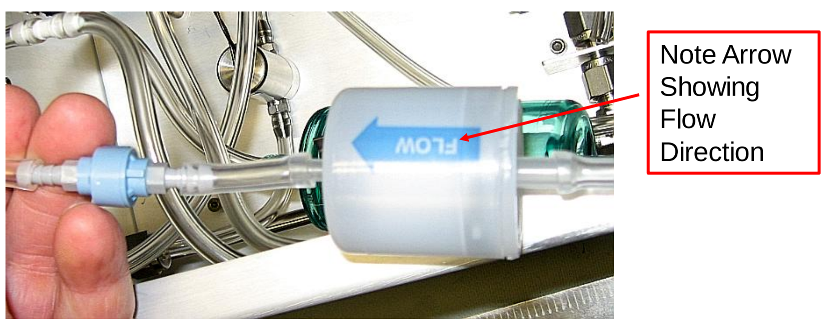


Figure 9-7
Filter noting Direction of Flow

5. Attach the tubing to a new filter making sure the flow direction matches that of the filter you removed.
6. Push the filter into the filter clip.
7. Replace the instrument cover when you have completed your maintenance work.

Replacing the HEPA Filter

The HEPA filter should be replaced as part of the annual service. To replace the filter, follow these instructions:

1. If you have not already done so for a previous maintenance procedure, turn off the power to the N-WCPC and remove the instrument cover.
2. Note the direction of flow and then remove the HEPA filter by loosening the thumb screw holding it in place. Remove the flexible tubing (sometimes it is easier to push the tubing off than to pull it off).
3. Inspect the tubing and replace if needed.

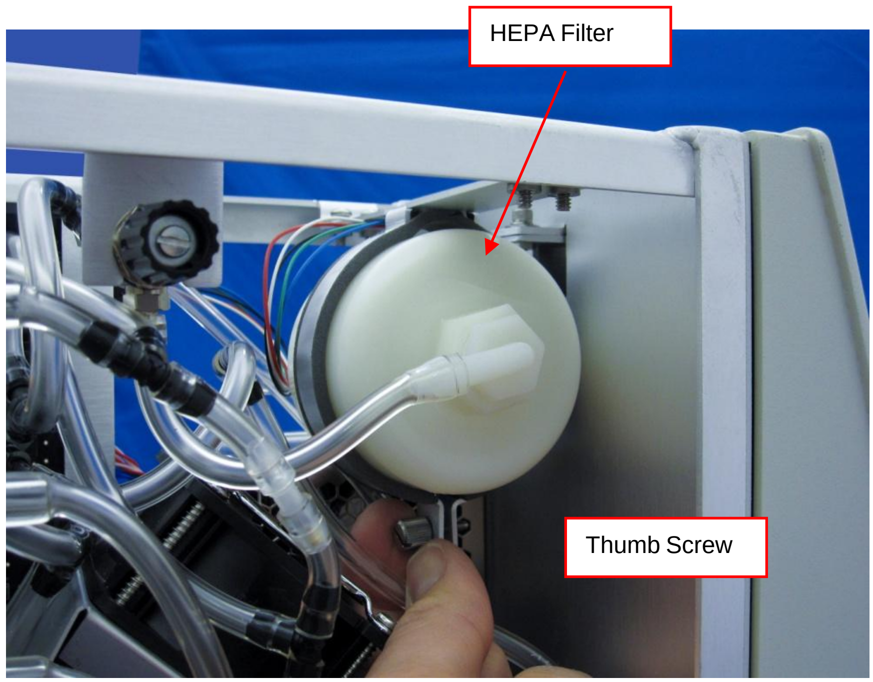


Figure 9-8
Replacing HEPA Filter

4. Insert a new HEPA filter making sure that the direction of flow matches the direction of flow on the filter you removed (see Figure 9-7).

Removing and Installing the Wick

The wick should be replaced after 700 hours of operation or every 3 months (8-hr/day operation). To replace a wick, follow these instructions:

1. With the N-WCPC powered on, disconnect the water supply and operate the instrument with the pump on for two hours to dry the wick to be replaced.
2. Disconnect power from the N-WCPC and move the instrument to the edge of the benchtop. The wick assembly will need clearance below the instrument base during removal.

3. Loosen the aerosol inlet jack-screw using the supplied 1/8" hex wrench. Slowly turn the screw counterclockwise. As you turn the screw, the inlet block and wick cartridge are pushed out of the instrument.

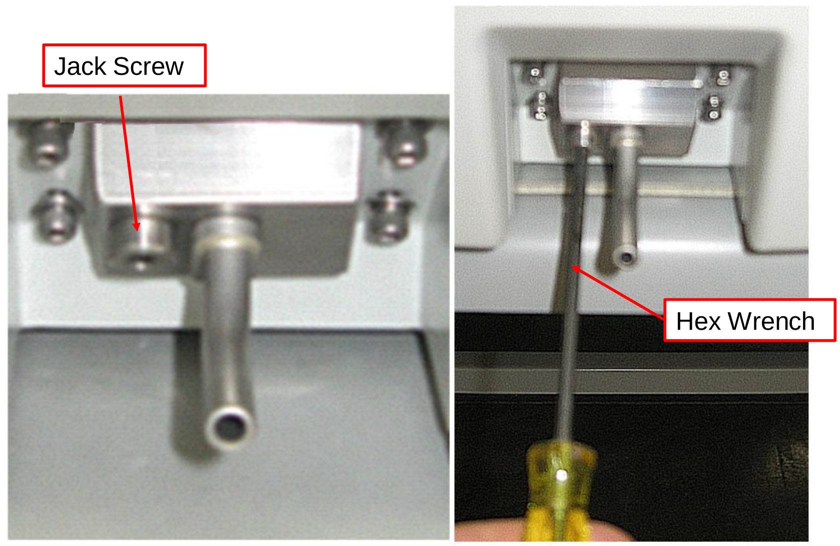


Figure 9-9
Inlet Jack Screw. Removing the wick assembly using a hex wrench to turn the Jack Screw

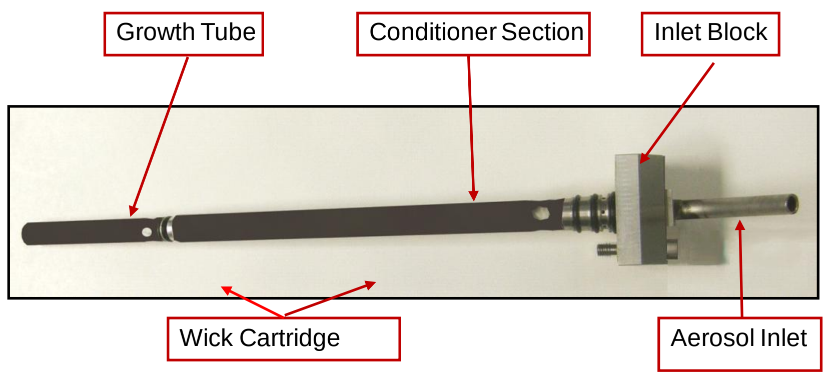


Figure 9-10
N-WCPC Wick Cartridge Inlet Assembly

4. When free, grasp the inlet block with your fingers and carefully pull the wick cartridge from the inlet block assembly. Rotate the inlet block a bit as necessary to reduce O-ring friction.

5. Unscrew the growth tube cartridge (short section) from the Conditioner wick cartridge. If the insulator spacer detaches, reinstall it on the conditioner wick cartridge (longer section)(Refer to Figure 9-11).
6. The conditioner cartridge is in two pieces that can be unscrewed to ease installation of the wick.

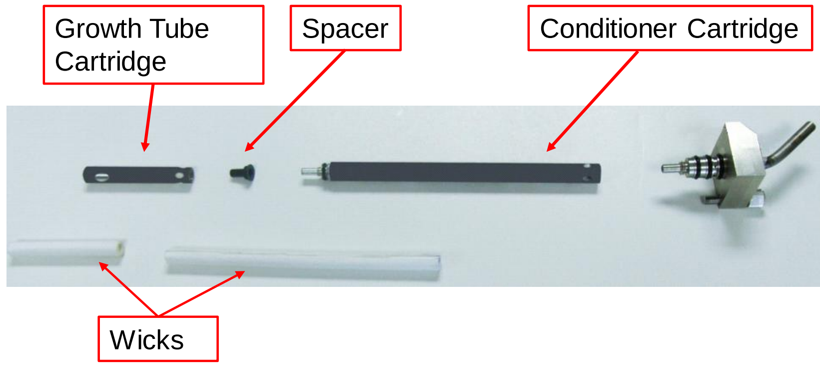


Figure 9-11
Wick Cartridge Disassembled

7. Remove and discard the old wicks from the cartridges. Clean and dry the parts before installing the new wicks. The spare cartridge assembly can be used and prepared ahead of time for a more rapid swap.
8. Place new wicks in the cartridges. Carefully install the wick in each section by gently twisting the wick to ensure the edges are smoothly inserted and the wick does not crimp. Make sure the central flow path is smooth and unobstructed.
9. With the wicks installed in the cartridges, screw the assembly together. Make sure the wicks are seated against the base of each section to ensure the wick material covers the filling holes at the base of each section. Visually inspect the flow path down the assembly before installing the wick cartridge to the mating inlet block.
10. Replace the inlet assembly making sure the assembly is firmly seated against the mating surface.

Flow Checks

The "aerosol flow" through a capillary determines the aerosol concentration. Adjustments to the capillary flow calibration can be made using the firmware command SFS (see Appendix B, "Firmware Commands").

The flow schematic below shows the transport and sample flows through the N-WCPC.

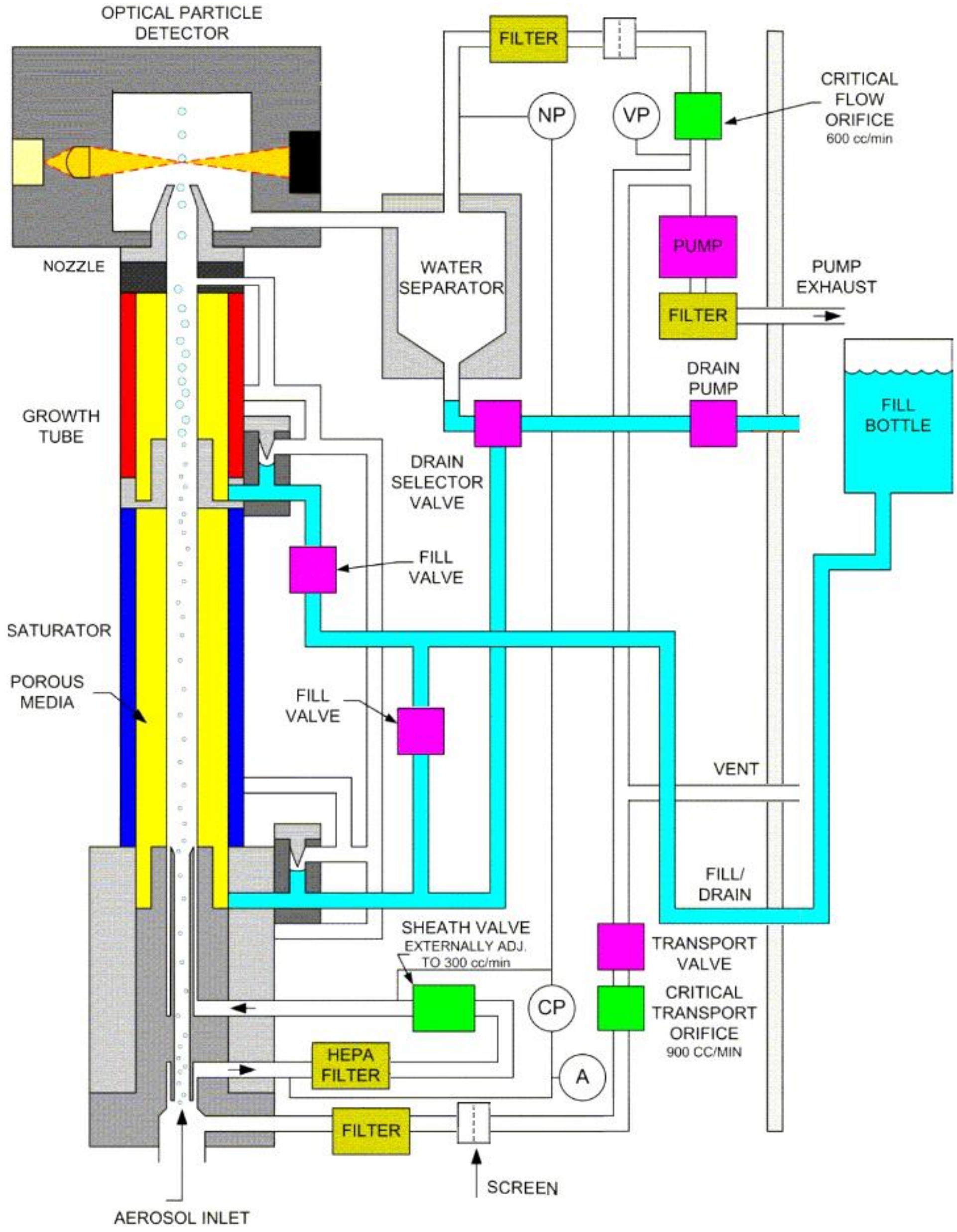


Figure 9-12
Nano Water-based Condensation Particle Counter Flow Schematic

__Note:__ Check each flow after every wick change.

The instructions below describe the procedure for checking the inlet flows.

To check the aerosol flow, follow these instructions:

1. With the instrument powered on, press **SETUP** on the Home screen, then press **INLET MODE**.
2. Check that the inlet flow is 0.6 L/min. If it is not, select 0.6 L/min as the setting.
3. Attach an external flow meter (such as a Gilibrator) to the aerosol inlet.

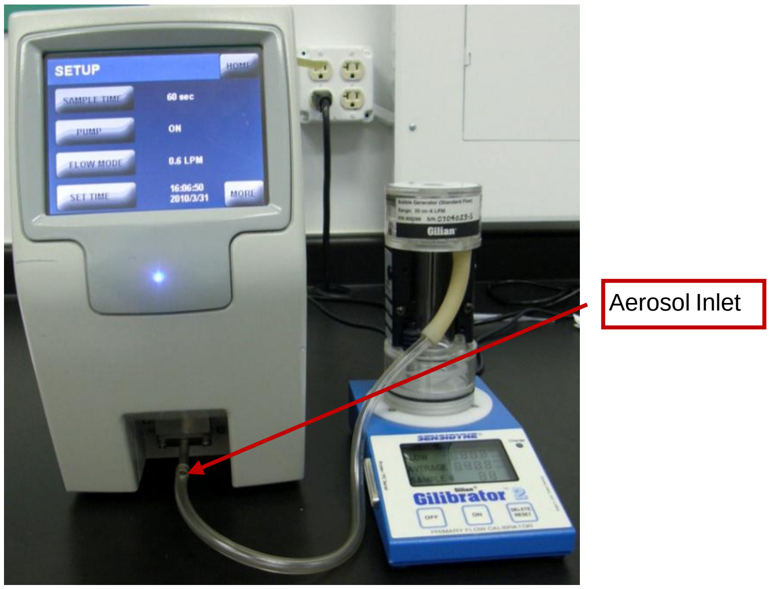


Figure 9-13
Aerosol Inlet

4. Using the external flow meter, measure the flow. Verify that the flow is 0.6 L/min ±10%. Flow readings lower than the specified value may indicate a blocked aerosol flow orifice.
5. The Transport Flow can be checked by changing the inlet flow setting to 1.5 L/min and checking the inlet flow with the external flow meter for a reading of 1.5 L/min ±10%. This flow should be checked after the Aerosol Flow has been verified.

Capillary Flow Adjustment

The capillary (sample) flow as indicated on the status screen may increase over time due to loading of the sheath loop HEPA filter. The particle concentration measured by the N-WCPC corrects for the changes in capillary flow, but the shift in flow over time may cause the flow value to exceed its maximum value 400 cm^3/min. The nominal value 300 cm^3/min may be restored by adjusting the Capillary Flow valve accessible inside the cabinet or with a flat bladed screw driver through an access hole on the upper left side of the instrument. The adjustment should be made while the instrument is operating and the reported capillary flow can be seen on the Status Screen of the instrument. If the nominal value cannot be achieved by opening the valve (CCW) completely, it is likely the sheath flow HEPA filter is loaded with particles and needs to be replaced.

Cleaning the Water Bottle

To prevent bacterial growth and possible contamination, clean the water bottle after every use. To clean the water bottle, follow these instructions:

1. Disconnect the water fill tubing from the **WATER FILL/EXHAUST**.
2. Empty the water bottle.
3. Wash the water bottle with a mild detergent.
4. Thoroughly rinse out the water bottle.

Inspecting and Cleaning the Fans

The fans should not require much maintenance, but it is beneficial to perform a visual inspection at intervals to check for dust build up. If any of the fans or heatsinks are dusty, blow them clean with compressed air.

Clean/Replace the Orifices

The Model 3788 N-WCPC has two orifices:

- Sample (total flow) orifice (0.6 L/min).
- Transport flow orifice (0.9 L/min).

To clean or replace an orifice, follow these instructions:

1. Turn off the power to the N-WCPC.
2. Remove the instrument cover.
3. Note the direction of flow (indicated by an arrow on the label).

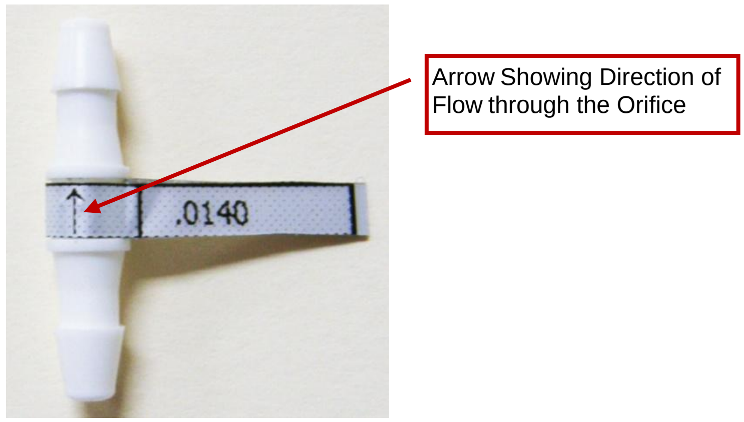


Figure 9-14
Arrow Showing Direction of Flow on Orifice

4. Grasp the tubing on either side of the orifice and pull firmly to detach the tubing from the orifice.
5. Using a microscope, inspect the orifice. If debris is present, soak the orifice in isopropyl alcohol for 20 minutes.

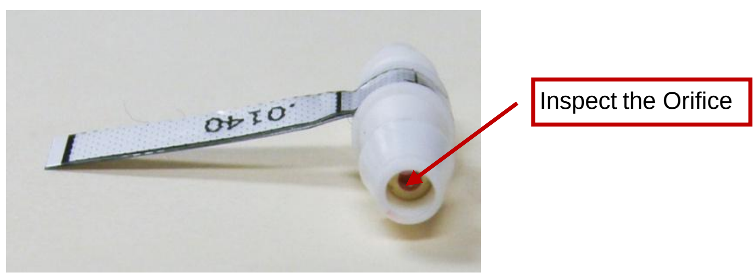


Figure 9-15
Inspect Orifice

6. Using compressed air at <60 psi, blow out the orifice and then re-inspect under the microscope.
7. If the orifice is clean, replace it in the instrument making sure you match the direction of flow with the original direction of flow.
8. If the orifice is not clean, replace it with a new one.
   Note: *Replacement orifices are supplied by TSI Inc.*
9. Replace the instrument cover.

Inspect Tubing

Liquid flow tubing should be inspected to check for cracks, damage, loose fit, or leaks. Inspect the following water filling lines:

- The lines that flow from the fill connectors (located on the front and back panels) to the fill valve.
- The water line from the fill valve to the N-WCPC engine.

Replace any damaged tubing with tubing from the supplied maintenance kit.

Note: *Liquid flow tubing is replaced as part of the TSI factory annual service.*

Status Messages

Status messages display at the top of the Home screen. The messages are as follows.

Table 9-2
Status Messages

Status Message	Explanation
Low Water	Water level is low
Warmup	Instrument is warming up
Laser Fault	Laser malfunction
Inlet Pressure Fault	Inlet pressure is too high/low
Vacuum Fault	Vacuum pressure is too low
Nozzle Fault	Pressure drop across the nozzle is out of range
Capillary Flow Fault	The measured capillary flow is out of range
Absolute Pressure Fault	Barometric pressure is out of range
Optics Temp Fault	Optics temperature is out of range
Growth Tube Temp Fault	Growth Tube temperature is out of range
Conditioner Temp Fault	Conditioner temperature is out of range
Separator Temp Fault	Separator temperature is out of range
Pulse Height Fault	Low pulse height
Prescan	Pre-scan condition – SMPS mode
Up Scan	Scan in the up direction – SMPS mode
Down Scan	Scan in the down direction – SMPS mode
Scan Pause	Pause in the scanning process – SMPS mode
Ready	Warm-up process has finished, the pump is on, and operating parameters are in range. The N-WCPC is ready for use

***Note**: The messages are a warning that there is a problem with the instrument, but only one message can display at a time. Check the Status screen for more details about potential problems.*

Troubleshooting

The **STATUS** screen displays the status of the operating conditions in real-time. The table below provides basic information about some status messages and suggestions for corrective action.

Table 9-3
Troubleshooting

Problem	Cause	Suggestions
Nozzle fault indicated on the Home screen and low Nozzle Pressure (<50%) indicated on the Status screen.	Low sample flow. Likely causes:	Verify 0.6 L/min inlet flow as described in the Flow Checks section of this chapter. If flow is OK, check for the presence of water in the Pressure Transducer sample lines.
	There is an obstruction in the Sample Flow Orifice.	The Sample Orifice is likely clogged or dirty and needs cleaning or replacement.
	The Sample Flow Filter is wet. This may result after a flooding incident, or result from poor performance of the Water Separator.	Replace the Sample filter if it appears wet. A wet filter may indicate flooding or poor performance of the Water Separator. The problem may be seen as presence of water in the tubing immediately upstream of the filter. Replace the Sample Filter. Also mark flow direction with a marker and remove the filter Screen found downstream of the Sample Filter. Use compressed air to blow back through the Screen to remove trapped material. Replace the Screen in its original orientation as indicated by the mark.
	Water present in the pressure transducer sample lines.	Poor performance of the Water Separator may result if the instrument is operated outside its temperature and humidity specification range.
Nozzle fault indicated on the Home screen and high Nozzle Pressure (>300%) indicated on the Status screen.	The pressure over the nozzle is high indicating that the nozzle may be plugged or the path ahead of the nozzle is obstructed. Obstruction may be due to an improperly installed, twisted wick or the presence of excess water.	Verify 0.6 L/min inlet flow as described in the Flow Checks section of this chapter. Disconnect the water bottle and remove the inlet block and wick assembly as described earlier in this chapter. If the Nozzle Pressure % remains high, the nozzle is plugged. The nozzle is not user serviceable, contact TSI. If the Nozzle Pressure % drops to near 100% after wick assembly removal, a restriction in the wick cartridge is indicated. Unscrew the wick cartridge from the inlet block and the growth tube from the conditioner. Look through the wick tube to verify an open path. If there is no clear path, (e.g. the wick is twisted causing a blockage), refer to the manual section on replacing the wick. If there appears to be excessive water dripping from the instrument after inlet removal, flooding may have occurred. Disconnect the water fill bottle at the quick disconnect and allow the instrument to run for a few hours without the wick cartridge installed. This will dry the instrument.

Problem	Cause	Suggestions
Home screen displays Inlet Pressure Fault. Status screen displays a low inlet pressure reading (in red).	There is an obstruction in the aerosol line or N-WCPC inlet.	Check and clear any kinks or obstructions in the tubing upstream of the inlet. Check and ensure that upstream pressure restrictions are within the N-WCPC's operating limits.
Separator/Optics/Growth Tube/Conditioner temperatures out of range. Error messages are displayed on the home screen and the Status screen shows readings in red.	Either the instrument was flooded or environmental temperatures maybe too high. ***Note****: If the instrument was flooded, you will also see water in the tubing and high nozzle pressure readings.*	Disconnect the water bottle from the **WATER INLET**. Run the instrument for 6 to 8 hours to dry it out. When the flow returns to normal, the instrument is dry. Reconnect the water bottle. If concentrations do not return to normal, return the instrument to TSI Inc. for repair.
Status screen indicates Water Reservoir Not Filled.	There is no water in the reservoir. Either the water is not connected, the water bottle is empty, or the water bottle has been placed below the level of the top of the instrument.	Check that the water bottle is filled and connected correctly. Make sure that the bottle is placed at a higher level than the instrument to provide for the gravity flow fill mechanism. If the problem persists, return the instrument to TSI Inc. for repair.
Status screen Pulse Height indicator is too low (in the red area).	The particle pulse height is low. This can be caused by particles with a size near the detection limit of the N-WCPC (2.5 nm), low water or dry wick, optical alignment, or dirty or flooded optics.	This indicator provides an indication of the nominal health of the instrument and the growth of particles. This flag may be present for low concentrations or concentrations of particles near the detection limit of the instrument. If the flag persists while sampling typical room aerosol concentrations, make sure the wicks have been replaced in the normal maintenance cycle (<700 hours). To dry flooded optics: • Disconnect the water bottle from the **WATER INLET**. • Run the instrument for 6 to 8 hours to dry it out. • When the flow returns to normal, the instrument is dry. • Reconnect the water bottle. If pulse heights do not return to normal, return the instrument to TSI Inc. for repair.
The real-time clock does not maintain time when the instrument is turned off.	The clock battery is dead.	Replace the clock battery located on the main electronics board with a BR1225 Panasonic or equivalent.

Technical Contacts

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

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

Returning the Model 3788 for Service

Before returning the Model 3788 N-WCPC to TSI for service, visit our website at http://rma.tsi.com or call TSI at 1-800-874-2811 (USA) or 001 (651) 490-2811 for specific return instructions. When you call, have the following information ready for the Customer Service representative:

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

TSI recommends that you keep the original packaging of the N-WCPC for use whenever the instrument is shipped, including when it is returned to TSI for service. Always seal off the sampling inlet to prevent debris from entering the instrument and dry the N-WCPC before shipping. If you no longer have the original packing material, first protect the N-WCPC by placing it inside a plastic bag. Then package the unit with at least 5" (13 cm) of shock absorbing/packaging material around all six sides of the N-WCPC.

See Moving and Shipping in Chapter 3 for detailed instructions.

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APPENDIX A
Specifications

Table A-1 contains the operating specifications for the Model 3788 Nano Water-based Condensation Particle Counter (N-WCPC). Specifications reflect typical performance and are subject to change without notice.

Table A-1
Model 3788 Nano Water-based Condensation Particle Counter Specifications

Particle Size Range	
Min detectable particle (D_{50})	2.5 nm, verified with DMA-classified sucrose
Max detectable particle	>3 µm
Particle Concentration Range	
Single Particle Counting	0 to 4 x 10^6 particles/cm^3, with continuous live-time coincidence correction
Particle Concentration Accuracy	
Conc Measurement Accuracy	±10% to 400,000 particles/cm^3
Response Time (to step change in concentration)	
High flow mode(3 L/min)	~250 m s to 95% in response to concentration step change <100 ms Rise Time (10 to 90%) ~43 ms Time Constant (τ)
Low flow mode (0.6 L/min)	~400 ms to 95% in response to concentration step change
Flow	
High-flow inlet	1.5 ± 0.15 L/min
Low-flow inlet	0.6 ± 0.06 L/min
Aerosol flow rate	0.3 ±0.03 L/min
False Background Counts	
False background counts	<0.02 particles/cm^3, 12-hour average dew point <30°C (i.e. < 35°C @ 75% RH)
Aerosol Medium	
Aerosol medium	Air only
Environmental Operating Conditions	
Ambient temp range	10 to 35°C (50 to 95°F) Dewpoint <30°C (i.e. <35°C @ 75% RH)
Ambient humidity range	0 to 90% non-condensing
Inlet Pressure Operation	
Inlet pressure operation (absolute)	75 to 110 kPa (0.75 to 1.1 atm)
Inlet pressure gauge	0 to -5 kPa (-20 inch H_20)

Water System	
Condensing liquid	Water [distilled (<6 ppm) or HPLC water; tap water must **not** be used]
Water system	External 1000 ml bottle used in recycle mode for up to 30 days of (continuous) operation
Water consumption	<33 ml/day
Vacuum	
Vacuum	Internal vacuum pump
Communications	
Protocol	ASCII command set
Interfaces	
RS-232	9-pin, D-Sub connector
USB	Type B connector, USB 2.0 compatible at 12 MB
Ethernet	8-wire RJ-45 jack, 10/100 BASE-T, TCP/IP
Data Logging	
Data logging	USB Flash drive
Averaging interval	Data averaging interval of 1 to 3600s 1,2,4,5,6,10,12,15,20,30 or 60s software provides more averaging options.
Outputs	
Digital display	6 inch VCA color touch screen w graphical interface. Graph of conc vs. time, concentration, time and total counts, and status
Analog output	BNC connector, 0 to 10V proportional to concentration or Log10 Conc
Software	
Software	TSI Aerosol Instrument Manager® software included
Calibration	
Calibration	Recommended annually
Power	
Requirements	100 to 240 VAC, 50/60 HZ, 200 W max
Physical Features	
Front panel	Display, sample inlet, LED particle indicator
Back panel	Power connector, USB, Ethernet, RS-232, BNC output, fan, water fill connector, pump exhaust port, fill bottle and bracket
H x W x D	30.5 x 16 x 36 cm (12 x 6.25 x 14.25 in.) not including water supply bracket
Weight	8.2 kg (18 lbs)

APPENDIX B

Firmware Commands

The firmware commands are divided into the following categories:

Commands	Description
READ	Used to read parameters from the instrument (such as flow rate, pressure, temperature, etc.). **READ** commands can be identified by a leading "R".
SET	Set an internal parameter to the value(s) supplied with the command (supplied parameters are always delimited by a comma). **SET** commands can be identified by a leading "S". The instrument will reply to all **SET** commands with the string "OK"<CR>.

***Note**: When the instrument does not understand a command, it replies with the string "ERROR".*

Table B-1 is a quick reference of all the firmware commands. More detailed information about each command can be found on the following pages.

***Note**: The commands are not case sensitive.*

Table B-1
Model 3788 Firmware Commands

Command	Explanation
Read Commands	
RAI	**R**ead **A**nalog **I**nput
RALL	**R**ead Operating Condition
RCT	**R**ead **C**urrent **T**ime
RD	**R**ead **D**isplayed **C**oncentration
RIE	**R**ead **I**nstrument **E**rrors
RIF	**R**ead **I**nlet **F**low Rate
RIS	**R**ead **I**nstrument **S**tatus
RL	**R**ead **L**aser Current
RLL	**R**eads **L**iquid **L**evel
RPA	**R**ead **A**bsolute **P**ressure
RPN	**R**ead **N**ozzle **P**ressure
RPV	**R**ead **V**acuum **P**ressure
RRD	**R**ead **D**ata **R**ecord
RRS	**R**ead **S**tatus **R**ecord
RSF	**R**ead **S**ample **F**low
RTA	**R**ead **C**abinet **T**emperature
RTC	**R**ead **C**onditioner **T**emperature
RTG	**R**ead **G**rowth **T**ube **T**emperature

Command	Explanation
Read Commands	
RTO	**R**ead **O**ptics **T**emperature
RV	**R**ead **V**ersion
Set Commands	
SM	**S**et **M**ode **x**=mode **t**=sample time in tenth of second
SP	**S**et **P**ump On/Off
SR	**S**et **R**eal Time Clock
SSTART	**S**tart a New **S**ample
ST	**S**et **T**ransport Flow On/Off
SMPS™ Spectrometer Scanning Commands	
ZB	**B**egin Scan
ZE	**E**nd Scan
ZT	Set Scan **T**ime
ZU	Scan **U**p
ZV	Set Scan **V**oltage

READ Commands

Read Commands are used to display specific data values. The values, associated parameters, responses returned by the Model 3788, and examples are given on the following pages.

RAI – Read Analog Input Voltage

RAI reads the analog input voltage in V.

RAI		
Command	RAI	
Response	X	X = analog input ZZAs (a floating point number from 0.00 to 10.00)
Example		
Command	RAI	Read Analog Input Voltage
Response	5.22	Voltage = 5.22 V

RALL – Read Operating Condition

RALL reads the Model 3788 N-WCPC's operating condition, calibration parameters, and diagnostic parameters.

RCT – Read Current Time

RCT reads the current time.

RCT		
Command	RCT	
Response	yyyy/mm/dd,hh:mm:ss	yyyy = year mm = month (1 – 12) dd = day (1 – 31) hh:mm:ss = time (hours, minutes, seconds)
Example		
Command	RCT	Read Current Time
Response	2012/12/18,20:22:19	Year = 2012 Month = December Day = 18 Hour = 8 pm Minutes = 22 Seconds = 19

RD – Read Displayed Concentration

RD is a legacy command that reads the displayed concentration in particles/cm^3.

RD		
Command	RD	
Response	x	
Example		
Command	RD	Read Displayed Concentration
Response	$3.16e^4$	

RIE – Read Instrument Errors

RIE reads the instrument errors (displayed as a 16-bit integer in hexadecimal format). The number may be a combination of the values of more than one flag.

RIE		
Command	RIE	
Response	Bit 0 x XXXX	Bit = Hexadecimal character A-F. When the bit is set, the parameter is in error. XXXX = 4-digit number 0x0001 = Conditioner Temperature 0x0002 = Growth Tube Temperature 0x0004 = Optics Temperature 0x0008 = Vacuum Level 0x0020 = Laser Status 0x0040 = Water Level 0x0080 = Concentration Over-range 0x0100 = Pulse Height Fault 0x0200 = Absolute Pressure 0x0400 = Nozzle Pressure 0x0800 = Water Separator Temperature 0x1000 = Warmup 0x2000 = Reserved 0x4000 = Service Reminder 0x8000 = Reserved
Example		
Command	RIE	Read Instrument Errors
Response	C00	Water Separator Temperature and Nozzle Pressure faults (Nozzle Pressure = hexadecimal 4. Water Separator = hexadecimal 8. Added together they make hexadecimal C.)

Note: *Hexadecimal is a numerical system using a base of 16. The symbols 0 to 9 represent the values zero to nine, and the letters A to F represent the values ten to sixteen. It is a useful "shorthand" for computer engineering because each hexadecimal digit represents four binary digits.*

RIF – Read Aerosol Flow Rate

RIF reads the inlet flow rate in liters per minute (L/min).

RIF		
Command	RIF	
Response	X	X = Floating point number either 0.6, or 1.5
Example		
Command	RIF	Read Inlet Flow Rate
Response	1.5	1.5 L/min

RIS – Read Instrument Status

RIS reads the instrument status (displayed as 13 comma-separated fields).

RIS		
Command	RIS	
Response	X	X = 1-13 1 = Concentration (#/cm^3) 2 = Livetime (%) 3 = Flow rate (cc/min) 4 = Inlet Pressure (mBar) 5 = Nozzle Pressure (%) 6 = Inlet Flow Mode (0.6, 1.5 L/min) 7 = Analog Input Voltage (mV) 8 = Pulse Height (mV) 9 = Optics Temp (°C) 10 = Growth Tube Temp (°C) 11 = Conditioner Temp (°C) 12 = Water Separator Temp (°C) 13 = Water Reservoir (Filled/Not Filled, 0/1)
Example		
Command	RIS	Read Instrument Errors
Response	0.00, 100, 300 1002, 100, 1.5, 0.00, 2400, 75.0, 75.0, 15.0, 15.0, 0	Particle Concentration Livetime Capillary Flow Rate Inlet Pressure Nozzle Pressure Inlet Flow Mode Analog Input Voltage Pulse Height Optics Temp Growth Tube Temp Conditioner Temp Water Separator Temp Water Reservoir (Filled)

RL – Read Laser Current

RL reads laser current in mA.

RL		
Command	RL	
Response	X	X = 0 to 50
Example		
Command	RL	Read Inlet Flow Rate
Response	30	30 mA

RLL – Read Liquid Level

RLL reads the liquid level.

RLL		
Command	RLL	
Response	FULL/NOTF ULL X	X = ADC reading from 0 to 4095
Example		
Command	RLL	Read Liquid Level
Response	FULL,2471	FULL – water level ADC - 2471

RPA – Read Absolute Pressure Transducer

RPA reads the absolute pressure transducer in mbars.

RPA		
Command	RPA	
Response	X	X = A floating point number from 150 to 1150
Example		
Command	RPA	Read Absolute Pressure
Response	1001	

RPN – Read Nozzle Pressure Transducer

RPN reads the nozzle pressure transducer in percent.

RPN		
Command	RPN	
Response	X	X = A floating point number from 0 to 2050
Example		
Command	RPN	Read Nozzle Pressure
Response	100	

RPV – Read Nozzle Pressure Transducer

RPV reads the vacuum pressure transducer in mbars.

RPV		
Command	RPV	
Response	X	X = A floating point number from 0 to 1150
Example		
Command	RPV	Read Vacuum Pressure
Response	408	

RRD – Read Data Record

RRD returns the current data values in the “D” record format. Data records are collected according to the time period you have specified for the data collection interval.

RRD		
Command	RRD	
Response	D record (see below)	
	D	Record identifier
	Date	Date in yyyy/mm/dd format
	Time	Time in hh:mm:ss format
	Flags	Status Flags (see information in RIE command description).
	Conc	Aggregated concentration calculated by dividing the accumulated aggregate counts by the live-time of the sample flow rate (2 cm^3/sec). The aggregated counts and live-times are accumulated each 1/10th second interval. The overflow flag is set when the concentration value exceeds the maximum specified concentration.
	AT	Elapsed sample time 0.1 sec resolution (0.1 to 3600).
	LT	Live time 0.001 sec resolution (0.001 to 3600).
	CNT	Accumulated particle counts.
	Photo	Average photo-detector value in mV.
	PH	Average pulse height in mV.
	PSTD	Pulse height standard deviation.

D records contain the following information:

Example D Record:
D,2009/11/2,08:01:21,0,1.04e4,6.0,4.4.769424,140,,0,0

Record Type	Date	Time	Flags	Conc	AT	LT	CNT	Photo	PH	PSTD
D	2012/11/2	08:01:21	0	1.04e4	6.0	4.4	769424	140	0	0

RRS – Read Status Record

RRS returns the current raw analog values in "S" record format for diagnostic use.

RRS		
Command	RRS	
Response	S record (see below)	
	S	Record identifier
	AP	Absolute pressure in mbars
	ST	Saturator Temperature in degrees Celsius
	GT	Growth Tube temperature in degrees Celsius
	OT	Optics temperature in degrees Celsius
	WT	Water Separator temperature in degrees Celsius
	FL	Sample flow rate in cm^3/min

Example S Record:
S,1003,15.0,60.0,60.0,7.0,124.0

Record Type	AP	ST	GT	OT	WT	FL
S	1003	15.0	60.0	60.0	7.0	124.0

RSF – Read Sample Flow Rate

RSF reads the aerosol sample (capillary) flow rate in cm^3/min.

RSF		
Command	RSF	
Response	X	X = A floating point number from 0.0 to 999.9
Example		
Command	RSF	Read Sample Flow
Response	300	300 cm^3/min

RTA – Read Cabinet Temperature

RTA reads the cabinet (ambient) temperature in degrees Celsius.

RTA		
Command	RTA	
Response	X	X = A floating point number from 0.0 to 60.0
Example		
Command	RTA	Read Cabinet Temperature
Response	23.8	23.8°C

RTC – Read Condenser Temperature

RTC reads the conditioner temperature in degrees Celsius.

RTC		
Command	RTC	
Response	X	X = Floating point number from 0.0 to 50.9
Example		
Command	RTC	Read Saturator Temperature
Response	150.0	15.0°C

RTG – Read Growth Tube Temperature

RTG reads the Growth Tube temperature in degrees Celsius.

RTG		
Command	RTG	
Response	X	X = Floating point number from 0.0 to 80.0
Example		
Command	RTG	Read Growth Tube Temperature
Response	75.0	75.0°C

RTO – Read Optics Temperature

RTC reads the optics temperature in degrees Celsius.

RTO		
Command	RTO	
Response	X	X = Floating point number from 0.0 to 80.0
Example		
Command	RTO	Read Saturator Temperature
Response	75.0	75.0°C

RV – Read Firmware Version Number

RV returns the instrument model number, firmware version number, and serial number.

RV		
Command	RV	
Response	Model 3788 Ver v.vv S/N nnnn	v.vv = ranges from 0.01 to 9.99 (3 digits) nnnn ranges from 100 to 99999999)
Example		
Command	RV	Read Version Number
Response	Model 3788 Ver 1.05 S/N 1004	Model 3788 = Model # Ver 1.05 = Version # S/N 1004 = Serial Number

SET Commands

Set commands are used to set instrument parameters and data collection modes. You will use the Set Mode (SM) command to control data collection.

SM – Set Mode

SM is used to set the data collection mode and the sample interval. At the end of each sample interval, the data is reported and, if in a continuous mode, the data is cleared internally and the next sample is started. The four available modes are shown in the list below.

Mode	Description
0	Idle. No data collection.
1	Continuously collects data and reports data ("D" record) at end of every sample interval.
2	Continuously collects data and reports data ("S" record) at end of every sample interval.
3	Continuously collects data and reports data ("D" record) at end of every sample interval. Concatenates "S" record to the "D" record.

SM		
Command	SM,n,tttt	n = mode (0,1,2,3) ttttt – sample interval
Response	OK	Response issued after parameters changed.
Example		
Command	SM,1,60	Continuous data collection (response mode 1) at 6 second sample intervals.
Response	OK	
Command	SM	Parameters not changed.
Response	1,60	Continuous data collection (response mode 1) at 6 second sample intervals.

Note*:* *To stop data collection, enter SM,0 in the Firmware Command field.*

SFS – Set Capillary Flow Rate Calibration Constant

SFS is used to set the flow rate calibration constant for the capillary pressure sensor to return the value of the current setting if no parameter is supplied.

SFS		
Command	SFS,m,b	m = slope, b = offset (1 to 9999)
Response	OK	Response issued after parameters changed.
Example		
Command	SFS,987,1675	Changes the flow rate slope and offsets constants.
Response	OK	
Command	SFS	
Response	987,1675	Parameter not changed. Current setting displayed on record.

SP – Set Pump Vacuum

SP is used to turn the pump vacuum on or off. The default setting at power-up is On.

SP		
Command	SP,x	x = 0 turns vacuum off x = 1 turns vacuum on
Response	OK	Response issued after parameters changed.
Example		
Command	SP,0	Turns the vacuum off.
Response	OK	
Command	SP	
Response		Parameter not changed – current setting displayed on record.

SR – Set Real-time Clock

SR is used to set the real-time clock.

SR		
Command	SR,yy,mm,dd,hh, mm,ss	yy = year (2 or 4 digits) mm = month (1-12) dd = day (1-31) hh = hour (0-23) mm = minutes (0-59) ss = seconds (0-59) Note: mm and ss are 0 if not included.
Response	OK	Response issued after parameters changed.
Example		
Command	SR,12,5,6,15,34	Clock is set to May 6, 2012 3:34 pm
Response	OK	
Command	SR	
Response	10,5,6,15,34	Parameter not changed – current setting displayed on record.

SSTART – Starts a New Sample

SSTART is used to start a new sample routine. U records are displayed when the SSTART,3 command is entered. The records are returned once per second.

SSTART		
Command	SSTART,x	X = 0,1,2,3 0 = Stop 1 = Start data type 1 (not used) 2 = Start data type 2 (not used) 3 = Start s new sample
Response	OK	Response issued after parameters changed.
Example		
Command	SSTART,0	Stops sample.
Response	OK	
Command	SSTART,3	Starts new sample.
Response	OK	
Command	SSTART	
Response	3	Parameter not changed – current setting displayed on record.
	U	Record type.
	X	Elapsed time in seconds (integer).
	C	Concentration in 1/10th second intervals (float).
	R	Raw counts in 1/10th second intervals (integer).
	X	Flow in cm^3/min
	T	Live time in 1/10th seconds (float).
	D	DTC value (float).
	P	Absolute pressure in millibars (integer).
	AN	Analog input.
	HM	Pulse height mean in millivolts (integer).
	HS	Pulse standard deviation in millivolts (integer).
	IS	Instrument Status (use RIE command to see a list of statuses).

Example U record:
UX,C,C,C,C,C,C,C,C,C,C,R,R,R,R,R,R,R,R,R,R,,T,T,T,T,T,T,T,T,T,T,D,P,
AN,HM,HS, IS

ST – Set Transport Flow

ST is used to turn the transport flow on or off. The default setting at power-up is On.

ST		
Command	ST,x	x = 0 turns flow off x = 1 turns flow on
Response	OK	Response issued after parameters changed.
Example		
Command	ST,0	Turns the flow off.
Response	OK	
Command	ST	
Response		Parameter not changed – current setting displayed on record.

SMPS™ Spectrometer Scanning Commands

ZB – Begins SMPS™ Spectrometer Scan

ZB begins the SMPS™ spectrometer scan based on the ZT, ZV, and ZU parameters.

ZB		
Command	ZB	Begins scan
Response	OK	Response issued after parameters changed.

ZE – Ends SMPS™ Spectrometer Scan

ZE ends the SMPS™ spectrometer scan.

ZE		
Command	ZE	Begins scan
Response	OK	Response issued after parameters changed.

ZT – Sets SMPS™ Spectrometer Scan Time

ZT sets the duration of the SMPS™ spectrometer scan in increments of 1/10th second.

***Note**: Do **not** use a comma between the command and the first parameter.*

ZT		
Command	ZTx,y,z	X = delay, 0 to 255 (0 to 25.5 seconds) y = up, 10 to 6000 (1 to 600 seconds) z = down, 10 to 6000 (1 to 600 seconds)
Response	OK	Response issued after parameters changed.
Example		
Command	ZT0,600,100	No delay, scan up time is 60 seconds, scan down time is 10 seconds.
Response	OK	Response issued after parameters changed.
Command	ZT	Returns current setting.

ZU – Sets SMPS™ Spectrometer Scan Direction Up

ZU sets the scan direction up.

ZU		
Command	ZU	Scan direction up.
Response	OK	Response issued after parameters changed.

ZV – Sets SMPS™ Spectrometer Scan Voltages

ZV sets the SMPS™ spectrometer scan voltages in Volts.

***Note**: Do **not** use a comma between the command and the first parameter.*

ZV		
Command	ZVx,y	x = start, 10 to 1000 Volts y = end, 10 to 10000 Volts
Response	OK	Response issued after parameters changed.
Example		
Command	ZV10,1000	Starting voltage 10V, ending voltage 1000V.
Response	OK	Response issued after parameters changed.
Command	ZV	Returns current setting.

DATA Reporting Records

The Model 3788 N-WCPC displays data in real time on the front panel display. You can also collect data records over time. Data records include the following:

D Records	Used for data collection
S Records	Used for data collection
U Records	Used by Aerosol Instrument Manager® software

D Record

D records contain the following information:

D	Record identifier
Date	Date in yyyy/mm/dd format
Time	Time in hh:mm:ss format
Flags	Status Flags (see information in RIE command description).
Conc	Aggregated concentration calculated by dividing the accumulated aggregate counts by the live-time of the sample flow rate (2 cm^3/sec). The aggregated counts and live-times are accumulated each 1/10th second interval. The overflow flag is set when the concentration value exceeds the maximum specified concentration.
AT	Elapsed sample time 0.1 sec resolution (0.1 to 3600).
LT	Live time 0.001 sec resolution (0.001 to 3600).
CNT	Accumulated particle counts.
Photo	Average photo-detector value in mV.
Res	Reserved black space
PH	Average pulse height in mV.
PSTD	Pulse height standard deviation.
CF	Capillary Flow (cm^3/min)

Example D Record:
D,2012/11/2,08:01:21,0,1.04e4,6.0,4.4.769424,140,,0,0,300

Record Type	Date	Time	Flags	Conc	AT	LT	CNT	Photo	Res	PH	PSTD	CF
D	2012/11/2	08:01:21	0	1.04e4	6.0	4.4	769424	140		0	0	300

S Record (Status)

S records are displayed on the Text tab when you enter the command **RRS** in the Firmware Command field. They display status information.

U Record

U records are displayed when the **SSTART,3** command is entered. The records are returned once per second. They contain the following information:

U	Record type.
X	Elapsed time in seconds (integer).
C	Concentration in 1/10th second intervals (float).
R	Raw counts in 1/10th second intervals (integer).
X	Flow in cm^3/min.
T	Live time in 1/10th seconds (float).
D	DTC value (float).
P	Absolute pressure in millibars (integer).
AN	Analog input.
HM	Pulse height mean in millivolts (integer).
HS	Pulse standard deviation in millivolts (integer).
IS	Instrument Status (use **RIE** command to see a list of statuses)

Example U record:
UX,C,C,C,C,C,C,C,C,C,C,R,R,R,R,R,R,R,R,R,R,,T,T,T,T,T,T,T,T,T,T,D,P,
AN,HM,HS, IS

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APPENDIX C
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