

Model 3025A
Ultrafine Condensation
Particle Counter

Instruction Manual

*P/N 1933762, Revision I
July 2002*





Model 3025A Ultrafine Condensation Particle Counter

Instruction Manual

Introduction	1
Unpacking and Setting Up	2
Operation and Display	3
Configuring the UCPC	4
Technical Description	5
Particle Counting	6
Computer Interface and Commands	7
Maintenance and Service	8
Applications	9
Appendixes	

Manual History

The following is a manual history of the Model 3025A Ultrafine Condensation Particle Counter Instruction Manual (Part Number 1933762).

Revision	Date	Revision	Date
Final	October 1992	F	September 1997
A	January 1993		September 1998
B	November 1993	G	July 2000
C	June 1994	H	July 18, 2000
D	May 1996	I	August 2002
E	November 1996		

The Model 3025A Ultrafine Condensation Particle Counter instruction manual (P/N 1933762) was originally published as the Model 3025/3027 Ultrafine Condensation Particle Counter instruction manual (P/N 1933025) in June 1989. Changes have been made throughout the manual to reflect the model number and engineering changes.

Revision B revises the voltage or the DET parameter, corrects the concentration specification, and updates drawing 9060266 in Appendix D to Revision F.

Revision C revises Figure 8-4, updates drawing 9060265 in Appendix D to Revision F, revises TSI's customer service number, and revises the aerosol concentration.

Revision D updates TSI's "Limitation of Warranty and Liability" on page iii.

Revision E adds European Community "CE Mark" standards, revisions to Chapter 2, "Changing the Line Voltage Configuration" and "Changing Fuses," updates drawing 9060266 in Appendix D to Revision I, and minor changes were made to rest of manual.

Revision F revises equations on pages 6-2 and 6-3.

In September 1998, TSI's area code was changed from 612 to 651.

In Revision G, the fuse rating in Table B-1 was corrected to read 100/120V ~ 2.0A/250V.

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

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

Part Number

1933762 / Revision I / August 2002

Copyright

©TSI Incorporated / October 1992-2002 / All rights reserved.

Address

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

Fax No.

651-490-2811

E-mail Address

particle@tsi.com

**Limitation of Warranty
and Liability**

(effective July 2000)

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

- a. Hot-wire or hot-film sensors used with research anemometers, and certain other components when indicated in specifications, are warranted for 90 days from the date of shipment.
- b. Parts repaired or replaced as a result of repair services are warranted to be free from defects in workmanship and material, under normal use, for 90 days from the date of shipment.
- c. Seller does not provide any warranty on finished goods manufactured by others or on any fuses, batteries or other consumable materials. Only the original manufacturer's warranty applies.
- d. Unless specifically authorized in a separate writing by Seller, Seller makes no warranty with respect to, and shall have no liability in connection with, goods which are incorporated into other products or equipment, or which are modified by any person other than Seller.

The foregoing is IN LIEU OF all other warranties and is subject to the LIMITATIONS stated herein. **NO OTHER EXPRESS OR IMPLIED WARRANTY OF FITNESS FOR PARTICULAR PURPOSE OR MERCHANTABILITY IS MADE.**

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

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

Service Policy

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

Safety

This section gives instructions to promote safe and proper operation of the Model 3025A Ultrafine Condensation Particle Counter (UCPC), samples of warnings found in this manual, and labels attached to the instrument.

Laser Safety

The Model 3025A Ultrafine Condensation Particle Counter is a Class I laser-based instrument. During normal operation, you will not be exposed to laser radiation. However, you must take certain precautions or you may expose yourself to hazardous radiation in the form of intense, focused invisible light. Exposure to this light can cause blindness.

Take these precautions:

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



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

Chemical Safety

The Model 3025A UCPC uses n-butyl alcohol (butanol) as a working fluid. Butanol is flammable. Butanol is also toxic if inhaled. Refer to a Material Safety Data Sheet for butanol and take these precautions:

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



C a u t i o n

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



W A R N I N G

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

Description of Safety Labels

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

Caution



C a u t i o n

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

Warning

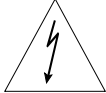





W A R N I N G

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

Caution or Warning Symbols

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

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

Labels

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

Figure 1 shows the internal and external labels for the Model 3025A UCPC.

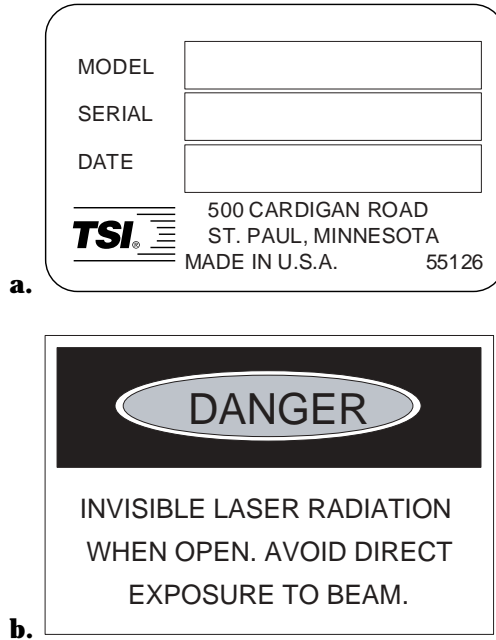


Figure 1

Advisory Labels: (a) identification label (on the back panel); (b) warning label (on the optics housing)

Contents

Manual History	ii
Safety	v
Laser Safety	v
Chemical Safety	v
Description of Safety Labels	vi
Caution	vi
Warning	vi
Caution or Warning Symbols.....	vii
Labels	vii
About This Manual	xv
Purpose.....	xv
Organization	xv
Related Product Literature	xvii
Getting Help.....	xvii
Submitting Comments	xviii

Chapters

1 Introduction	1-1
Product Description	1-1
Features.....	1-2
Applications	1-2
2 Unpacking and Setting Up	2-1
Packing List	2-1
Unpacking Instructions.....	2-1
Initial Setup	2-2
Protective Caps.....	2-2
Checking the Line Voltage Configuration	2-2
Changing the Fuse	2-4
Changing Between European and American-Style Fuses.....	2-4
Mounting the Bottle Bracket.....	2-6
Filling the Bottle with Fluid.....	2-7
Applying Power to the UCPC.....	2-7
3 Operation and Display	3-1
Front Panel Functions.....	3-1
Warmup Mode.....	3-2

Primary Functions.....	3-2
Pump	3-3
Display.....	3-3
Total.....	3-3
Clear	3-4
Range.....	3-4
Secondary Functions.....	3-4
Shift	3-4
Status	3-5
Flow Hi/Lo	3-6
Filling.....	3-6
Indicator Lights	3-6
Particle.....	3-7
Flow	3-7
Auto	3-7
Optics, Condenser, Saturator	3-7
Laser	3-7
Liquid Level.....	3-7
Back Panel Functions	3-8
COM Port	3-8
Analog Output.....	3-8
Mux Output	3-9
Pulse Output.....	3-9
Liquid Supply.....	3-9
Makeup Air	3-9
Pump Exhaust	3-10
Operating Specifications and Precautions.....	3-10
Ambient Temperature.....	3-10
Inlet Pressure.....	3-10
High Flow Mode.....	3-10
Low Flow Mode.....	3-11
Moving the Counter.....	3-11
Drying the Counter	3-12
First Method.....	3-12
Second Method.....	3-12
4 Configuring the UCPC.....	4-1
Enabling the Configuration Mode	4-1
Running the Configuration Function	4-2
Flow Calibration.....	4-6
Condenser Flow Calibration	4-7
Aerosol Flow Calibration.....	4-8
High Flow Calibration.....	4-10
Photometric Calibration	4-10

5	Technical Description	5-1
	Theory.....	5-1
	Historical Notes.....	5-2
	Adiabatic Expansion CNC.....	5-3
	Two-Flow Mixing CNC	5-3
	Diffusional Thermal CNC.....	5-3
	Design of the UCPC.....	5-5
	Sensor.....	5-5
	Microprocessor.....	5-6
	Flow System.....	5-7
	High Flow.....	5-8
	Low Flow	5-8
	Filters and Restrictors	5-8
	Flowmeters.....	5-9
	Pump	5-10
6	Particle Counting	6-1
	Optical Detection	6-1
	Single-Particle, Realtime Counting	6-1
	Total Count Accuracy.....	6-3
	Single-Particle, Live-Time Counting.....	6-4
	Autoranging	6-4
7	Computer Interface and Commands	7-1
	Computer Interface	7-1
	Pin Connectors.....	7-1
	Baud Rate	7-2
	Parity	7-2
	Commands.....	7-3
	BASIC Program: TSIUCPC	7-6
8	Maintenance and Service	8-1
	Changing the Filters.....	8-1
	HEPA Filter	8-1
	Tube Filter	8-2
	In-Line Filters.....	8-4
	Installing an EPROM.....	8-4
	Checking the Counter for Leaks	8-8
	Failures.....	8-10
	Technical Contacts.....	8-11
	Returning the UCPC for Service.....	8-12

9 Applications	9-1
Clean Air	9-1
Using the Counter With a Multiplexer/Processor	9-2
Using the Counter With a Diffusion Battery	9-2
Differential Mobility Particle Sizer.....	9-3

Appendixes

A References	A-1
B Specifications	B-1
C Technical Paper	C-1
D Data Sheet	D-1
E Software Disk	E-1

Figures

1 Advisory Labels: (a) identification label (on the back panel); (b) warning label (on the optics housing)	viii
1-1 Model 3025A Ultrafine Condensation Particle Counter.....	1-1
2-1 Power Entry, Fuse, and Voltage Module.....	2-3
2-2 Orientation of the Voltage Selector Card	2-3
2-3 North American–Fusing Arrangement	2-5
2-4 European–Fusing Arrangement	2-5
2-5 Fuse Block/Cover Assembly	2-5
2-6 Mounting the Bottle Bracket.....	2-6
3-1 UCPC Front Panel.....	3-1
3-2 UCPC Back Panel	3-8
3-3 Saturator: (a) Front of Counter; (b) End Plate With Four Screws.....	3-13
3-4 Saturator: (a) Front of Counter; (b) Wick; (c) Fill Sensor Connector; (d) End-Plate (Removed); (e) Sheath Air Line; (f) Fluid Line	3-14
4-1 Locations of PC Boards and Potentiometers	4-1

4-2	Setting the Configuration Switch to Enable the Configuration Mode	4-2
4-3	Location of Sheath Air Valve (a) and Bypass Variable Orifice (b).....	4-8
4-4	External Flowmeter in the Sheath-Air Line	4-9
5-1	Flow Schematic of the UCPC.....	5-7
6-1	Typical Digital Pulse Trace From the Photodetector.....	6-2
7-1	Connector Pin Designations.....	7-1
8-1	Locating the Filter Plug Inside the UCPC (a) Front Panel; (b) Filter Plug	8-2
8-2	Replacing the Filter Tube: (a) Filter	8-3
8-3	Model 3025A Screw Locations.....	8-6
8-4	EPROM Location on the Model 3025A UCPC Display Board	8-7
8-5	Checking for Leaks with a Vacuum.....	8-9
8-6	Checking for Leaks with Compressed Air	8-10
9-1	Counter, Diffusion, Battery and Switching Valve System for Measuring the Size Distribution of Aerosols Below 0.2 Micrometer in Diameter	9-3
9-2	Schematic of the DMPS/UCPC in the Underpressure Mode	9-4

Tables

2-1	Model 3025A UCPC Packing List.....	2-1
6-1	Coincidence Correction for Concentrations up to 10,000 Particles/cm ³	6-3
7-1	Signal Connections for RS-232 Configurations	7-2
7-2	Computer Commands.....	7-3
8-1	Replacement Filters	8-4
8-2	Troubleshooting UCPC Problems	8-11
B-1	Model 3025A Specifications.....	B-1

About This Manual

Purpose

The Model 3025A Ultrafine Condensation Particle Counter (UCPC) instruction manual is written for both the installer and the operator, whether a technician or the head of a research laboratory.

Organization

The following chapters of this manual describe the UCPC and explain how to setup, operate, and maintain it.

- ❑ **Chapter 1: Introduction**
This chapter serves as an introduction to the Model 3025A Ultrafine Condensation Particle Counter.
- ❑ **Chapter 2: Unpacking and Setting Up**
This chapter describes the step-by-step procedure for getting the UCPC ready to operate.
- ❑ **Chapter 3: Operation and Display**
This chapter describes all of the features and controls that run the UCPC, including the front-panel functions and controls, the back-panel components, and some operating specifications and precautions.
- ❑ **Chapter 4: Configuring the UCPC**
This chapter describes a feature that allows the you to set up and select certain functions and outputs that are controlled by the internal microprocessor. You must read this chapter to learn how to enter the configuration mode.
- ❑ **Chapter 5: Technical Description**
This chapter details the principle of operation and theory of the condensation nucleus counter.
- ❑ **Chapter 6: Particle Counting**
This chapter describes how the UCPC counts and averages data, and displays the particle concentration.

- ❑ **Chapter 7: Computer Interface and Commands**
This chapter describes the computer interface hardware and associated software commands. Included is a simple program written in BASIC that demonstrates how to communicate with the UCPC.
- ❑ **Chapter 8: Maintenance and Service**
This chapter describes the recommended practices and schedule for routine cleaning, checking and calibration.
- ❑ **Chapter 9: Applications**
This chapter describes some typical applications of the UCPC including the Differential Mobility Particle Sizer (DMPS) and Diffusion Battery.
- ❑ **Appendix A: References**
This chapter lists all of the references that have been used within the text of the manual. In addition, a general list of references pertaining to condensation nucleus counters is included.
- ❑ **Appendix B: Specifications**
This appendix lists the specifications of the Model 3025A Ultrafine Condensation Particle Counter.
- ❑ **Appendix C: Technical Paper**
This appendix includes a technical paper.
- ❑ **Appendix D: Data Sheet**
This appendix contains a data sheet specifically for your Model 3025A UCPC.
- ❑ **Appendix E: Software Disk**
This appendix contains the software disk for the BASIC program provided with the Model 3025A UCPC.

Related Product Literature

- ❑ **Model 376060 Particle Size Selector Instruction Manual**
(part number 1930013) TSI Incorporated

This manual contains operating instructions for the Model 376060 Particle Size Selector, an accessory for the Model 3025A UCPC. The Model 376060 is a separating device that removes small particles from an aerosol while passing larger particles.

- ❑ **Aerosol Instrument Manager® Software for CPC and EAD Instruction Manual** (part number 1930062) TSI Incorporated

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

Getting Help

To obtain assistance with the Model 3035A Condensation Particle Counter, either refer to Chapter 8, “Maintenance and Service,” or contact Customer Service:

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

Submitting Comments

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

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

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

CHAPTER 1

Introduction

The Model 3025A Ultrafine Condensation Particle Counter (UCPC), shown in Figure 1-1, is a refined version of the Model 3022A Condensation Particle Counter (CPC). The Model 3025A uses a vapor sheath technique to improve the instrument's lower particle size sensitivity. This means that the counter is capable of measuring the number concentration of submicrometer airborne particles that are larger than 3 nanometers in diameter.



Figure 1-1
Model 3025A Ultrafine Condensation Particle Counter

Product Description

The particles are detected and counted by a simple optical detector after a supersaturated vapor condenses onto the particles, causing them to grow into larger droplets. The range of particle concentration detection extends from less than 0.01 particle/cm³ to 9.99×10^4 particles/cm³.

The UCPC uses a laser-diode light source; a condensing fluid; an internal microprocessor control; volumetric flow control; and a front-panel display of both particle concentration and instrument status; the instrument also offers the capability of full computer interfacing.

Features

The 3025A UCPC is an improved version of TSI's earlier Model 3025/3027 UCPCs with these features:

- New color and graphics
- New membrane switches on the front panel
- New mounting for the display PC board to make it easy to replace an EPROM
- New transformer and internal electrical changes to meet IEC 1010 specifications
- New standard RS-232 connector for IBM-style compatibility.

Applications

The Model 3025A UCPC is a research instrument that can be used in a variety of applications where particles in the nanometer size range are of interest. Typical applications include clean air measurement, particle research, and atmospheric studies. The UCPC can also be used as a particle detector in the Differential Mobility Particle Sizer (DMPS) or the Scanning Mobility Particle Sizer (SMPS) system, and with a diffusion battery.

Note: See Chapter 9 for more information on applications.

CHAPTER 2

Unpacking and Setting Up

This chapter gives unpacking and setup information for the Model 3025A Ultrafine Condensation Particle Counter (UCPC).

Packing List

Table 2-1 shows the packing list for the Model 3025A UCPC.

Table 2-1
Model 3025A UCPC Packing List

Qty.	Description	Part No.
1	UCPC	3025A
1	Power cable, 110–120V	1303053
	220–240V	1303075
1	12 foot 9-pin (M/F) interface cable	962002
1	Cable adapter 25-pin (F) to 9-pin (M)	962003
1	Bottle bracket	1503475
1	Fill bottle assembly (tested)	1035590
1	BQ filter	1602060
2	MicroFibre Filter tubes	1602061
2	AQ filters	1602067
1	DQ filter	1602080
1	Nylon plug	1601834
1	Filter media for fan	1602071
2	Screws, 8-32 × 3/8, Phillips, pan-head	5094090
2	Washers, no. 8 internal tooth	5329031
1	Instruction manual	1933762
1	Software disk, 3.5-inch format	1905118

Unpacking Instructions

The UCPC comes fully assembled with protective coverings on the Inlet and Liquid Fill ports and electrical connections.

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

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

Initial Setup

This section contains instructions for initial setup of the Model 3025A UCPC. Follow the instructions in the order given.

Protective Caps

Remove all protective caps from the inlet and exit flow ports, as well as from the BNC connectors.

Checking the Line Voltage Configuration

The Model 3025A requires 100/120 volts AC at 1.2 amps or 230/240 volts AC at 0.6 amp with 50 to 60 hertz at any of the voltages. Use the information in this section to verify the line voltage configuration and fusing arrangement matches your local line voltages.

Check the back panel of the instrument for the voltage and fusing requirements. The label is located just above the power entry module.

To change the voltage setting, follow these steps:

1. Disconnect the power from the Model 3025A and remove the line cord. Locate the power-entry module on the back panel of the Model 3025A (Figure 2-1).*
2. Lift off the cover of the fuse and voltage module cover on the back panel of the Model 3025A using a small-blade screwdriver or similar tool (Figure 2-1). Set aside the cover/fuse block assembly.

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

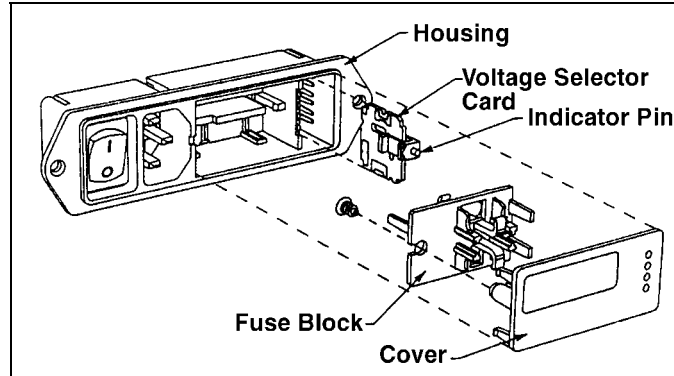


Figure 2-1
Power Entry, Fuse, and Voltage Module

3. Grasp the indicator pin and pull the voltage-selector card straight out of the housing (Figure 2-1).
4. Orient the selector card so that the desired voltage is readable at the bottom.
5. Orient the indicator pin so that it points up when the desired voltage is readable at the bottom. When the pin is fixed and in place, rotate the card 90° clockwise (Figure 2-2).

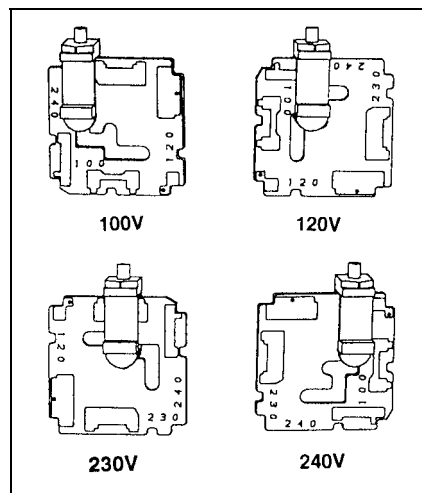


Figure 2-2
Orientation of the Voltage Selector Card

6. Insert the voltage-selector card into the housing, making sure the edge containing the desired voltage is inserted first and the printed side of the card faces the IEC (power cord) connector.
7. Replace the cover, making sure that the indicator pin shows the desired voltage.

Changing the Fuse

1. Disconnect the power from the Model 3025A and remove the line cord.
2. Lift off the power-entry module on the back panel of the Model 3025A using a small-blade screwdriver or similar tool (Figure 2-1).
3. Replace the fuses. Make sure the Fuse(s) are the proper size and rating for the line voltage you are using. The Fusing label is located just above the power entry module on the back panel of the Model 3025A.

Note: *Two European-style 5 × 20 mm fuses are required in the European-Fusing arrangement (Figure 2-4).*

4. Replace the power-entry module cover.

Changing Between European and American-Style Fuses

Before installing the Model 3025A, make sure the fuse is compatible with your site. The Model 3025A works with both North American and European-style fuses. The 100/120-volt model comes with the North American-style fuse and the 230/240-volt model is equipped with the European-style fuse. If you need to change the fuse from North American (Figure 2-3) to the European style (Figure 2-4), or vice versa, follow these steps:

1. Disconnect the power from the Model 3025A and remove the line cord.
2. Lift off the power-entry module on the back panel of the Model 3025A cover using a small-blade screwdriver or similar tool.

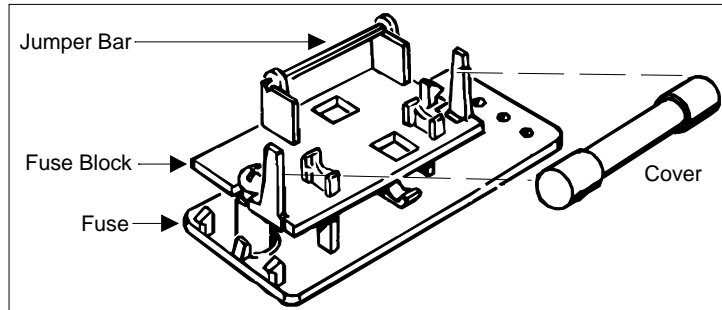


Figure 2-3
North American–Fusing Arrangement

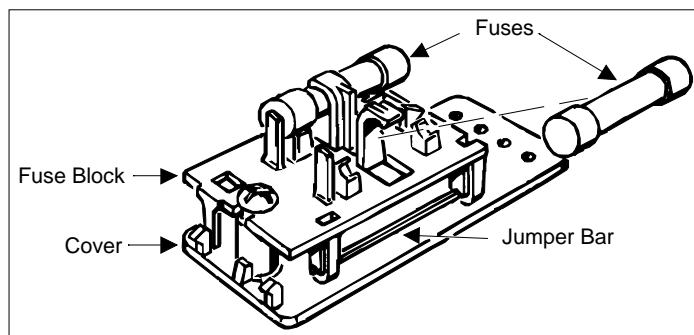


Figure 2-4
European–Fusing Arrangement

3. Loosen the screw on the fuse block two turns.
4. Remove the fuse block (Figure 2-5) by sliding it up and away from the screw. Lift the block from the pedestal.

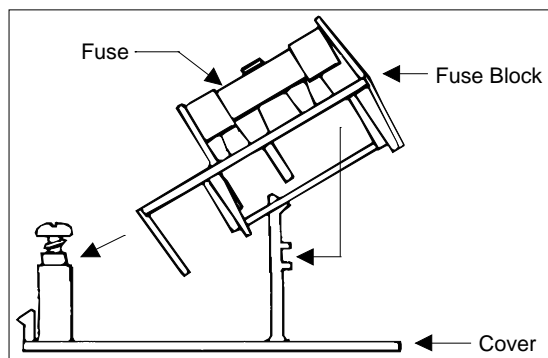


Figure 2-5
Fuse Block/Cover Assembly

5. Change the fuses:

Note: Two European 5 × 20 mm fuses are required in the European-Fusing Arrangement.

Invert the fuse block and slide it back onto the screw and the pedestal.

6. Tighten the screw and replace the power-entry module cover. The fuse(s) that enters the housing first is the active one.

Mounting the Bottle Bracket

Mount the black anodized aluminum bracket (found in the accessory kit) to the back panel using two 8-32 × 3/8-inch screws and two no. 8 lockwashers as shown in Figure 2-6.

Place the fill bottle in the bracket (also found in the accessory kit with tubing and a quick-disconnect fitting). Connect the fitting to the Liquid Supply connector on the back panel. Both mated fittings are leak-tight when disconnected.



Figure 2-6

Mounting the Bottle Bracket: (a) Bottle Bracket; (b) Screw, 8-32 × 3/8 Phillips Pan-head Lockwasher, #8 Internal Tooth; (c) UCPC Back Panel

Filling the Bottle with Fluid

The UCPC is calibrated for use with n-butyl alcohol (butanol). Pour the fluid into the fill bottle to at least one-third full. Because of the shut-off fittings, the liquid will not flow into the UCPC until the connections are made and the instrument is switched on.

Note: *Butanol is not supplied with the UCPC. Butanol may be purchased from scientific chemical-supply houses.*



C a u t i o n

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

Applying Power to the UCPC

Plug the power cord into the connector on the back panel and then plug it into the AC power source.

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

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

The front panel displays the phrase “TSI” and begins a warm-up sequence. After warm-up, the fluid begins to fill the internal reservoir in the saturator.

CHAPTER 3

Operation and Display

This chapter describes the basic functions of the Model 3025A Ultrafine Condensation Particle Counter (UCPC) controls, indicators, and connectors on the front and back panels, as well as giving operating specifications and precautions.

Note: *Specific applications are covered in Chapter 9.*

Front Panel Functions

The front panel, shown in Figure 3-1, provides information on particle concentration, particle counts, and the status of various operations. Through push buttons, it provides access to three types of functions: primary, secondary, and configuration. (The configuration functions are a special case described in Chapter 4.)

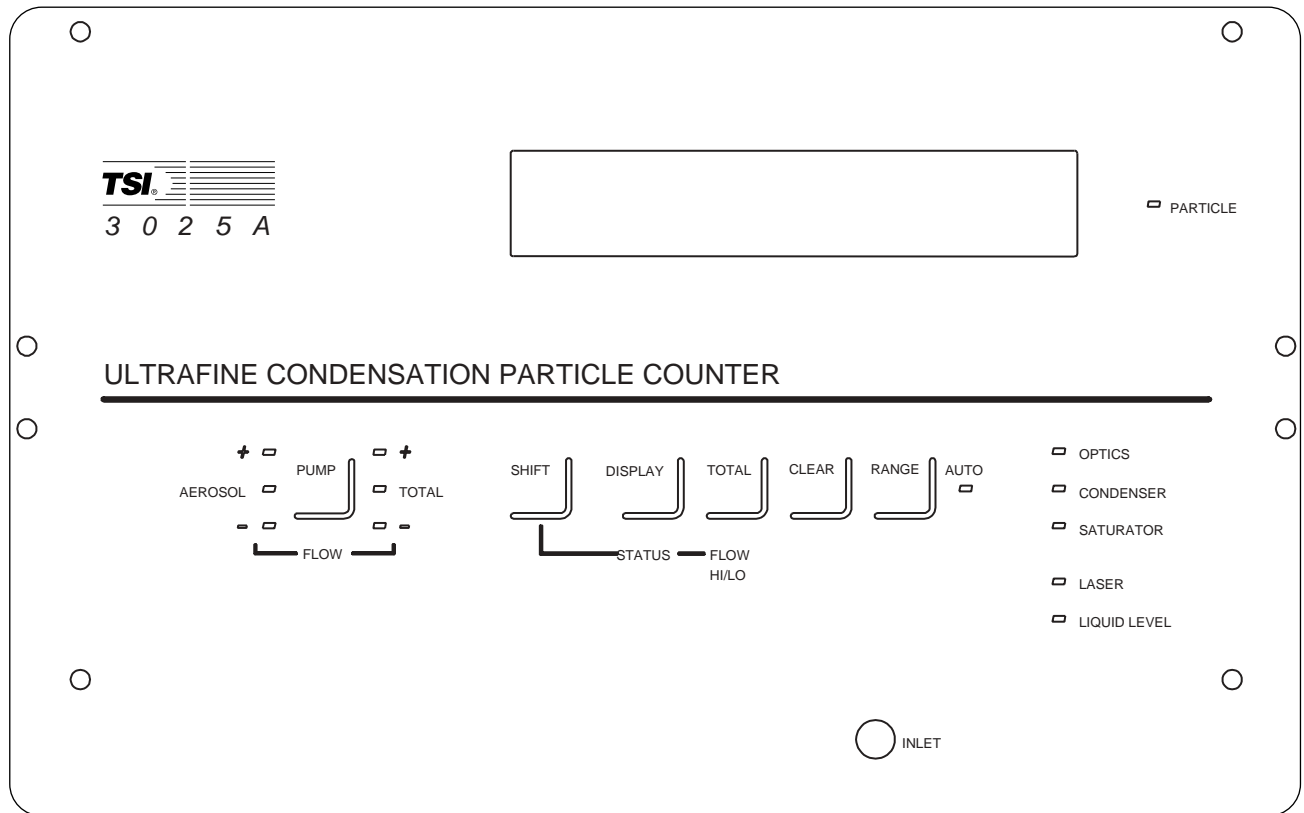


Figure 3-1
UCPC Front Panel

Warmup Mode

On power-up, after the initialization sequence, the UCPC displays WARM-UP XXX (where XXX is the warm-up period in seconds) and counts down to zero. During the warm-up period, the UCPC does not display concentration values or total counts, but all other functions are accessible.

Since the warm-up period ends when all temperatures and the laser power have reached normal operating levels, the warm-up may end before 600 seconds have elapsed. If normal operating conditions are not reached within the 600-second countdown, the UCPC simply remains in the warm-up mode, without further countdown, until all operating parameters are within normal ranges.

Note: *The UCPC should never take more than 20 minutes to warm up to normal ambient temperatures.*

After warm-up, the UCPC displays a value for concentration or total counts and the pump comes on or stays off depending on how the instrument was configured when it was last switched off.



C a u t i o n

Do *not* run the UCPC for more than a few hours while sampling ordinary room air. Large fibers may clog the delicate aerosol capillary tube, which would then require service. Protect the UCPC with a filter on the inlet or switch off the pump when the instrument is not in use.

Primary Functions

Primary functions are accessed directly through the front panel's five push buttons (*without* first pushing the Shift button, which is needed to access the secondary functions). They are identified by the labels above the buttons: Pump, Display, Total, Clear, and Range.

Pump

Press the Pump button to switch the pump on or off. Since the UCPC uses a sheath air system, there are two flows to control for proper operation. Amber lights indicate that the flows are too high (+) or too low (-). The green Flow lights indicate that the flow through the aerosol path is $0.5 \pm 0.05 \text{ cm}^3/\text{s}$ and that the flow through the condenser path is $5 \pm 0.5 \text{ cm}^3/\text{s}$, provided the flowmeters were calibrated accurately. This is done by ensuring that the pressure drop is correct through the sheath air and condenser flow capillaries.

To display the flow values, use the Status button (described below under "Secondary Functions"). Both flows and the voltage supplied to the pump can be monitored through the analog output on the back panel (see Chapter 4).

Display

Use the Display button to display two types of information: concentration (CONC) and total counts (COUNTS). Pushing the button toggles between the two types.

The concentration value is averaged over a varying period of time depending on the magnitude of the concentration. The data is displayed in units of particles/cm³. Detailed information about concentration averaging is given in Chapter 6.

The total count represents a cumulative number of particles up to a total count of 99,999,999. For the count to be valid, the concentration must be less than 10^5 particles/cm³. If the aerosol concentration exceeds 10^5 particles/cm³ for more than 5 seconds at any time during counting, the display will flash but continue to count.

Total

Press the Total button to start and stop the count totalizer. The sample automatically stops when the time is equal to the pre-programmed time setting that you enter during setup (see Chapter 4). The maximum particle count is 99,999,999. If the count is exceeded, the totalizer stops counting and displays 99,999,999.

When counting is in progress, a star flashes on the left side of the display. If the star is not present, then counting has stopped. The Total function is operational even if the display shows averaged concentration and not the count total.

If the aerosol concentration exceeds 10^5 particles/cm³ for more than 5 seconds at any time during counting, the display will flash but continue to count.

Clear

Press the Clear button to clear the buffers for storing Total values and concentration averaging values.

Range

Press the Range button to select a fixed exponential range or an Autorange for the concentration display. The green light is *on* when the UCPC display is in the Autorange mode; it goes off when the display is in any of the fixed ranges. The fixed ranges are e1, e2, e3, e4, and “no exponent.” If you are using a fixed range and the concentration exceeds it, the display flashes the highest number for that range. Most applications can use Autorange.

Secondary Functions

The two secondary functions are accessed by first pressing the Shift button and then pressing one of the buttons that are used for the primary functions. These functions are identified by the labels below the buttons: Status and Flow Hi/Lo.

Shift

Pressing the Shift button serves two purposes: it accesses the secondary functions, or, if already in the secondary functions mode, it returns to the primary display (concentration values). In the first function, the display reads Shift until a second button is pressed. If Shift is pressed again, the display returns the concentration values.

You can access the secondary functions only when the display reads “Shift.”

Status

Pressing the status button displays a set of parameters that allows you to check the operation of the UCPC. Pressing the Status button repeatedly steps through the following six parameters:

Aero Flow	The aerosol flow is measured in units of 0.5 cm ³ /s. A peaked hat (^) in front of the number indicates the UCPC is in the high-flow mode; an underline () in front of the number indicates the low-flow mode (see Chapter 5).
Cond Flow	The condenser flow is measured in units of 5.0 cm ³ /s. A peaked hat (^) in front of the number indicates that the UCPC is in the high-flow mode; an underline () in front of the number indicates the low-flow mode (see Chapter 5).
T _o	The optics temperature should be 39°C for n-butanol.
T _c	The condenser temperature should be at 10°C for n-butanol.
T _s	The saturator temperature should be at 37°C for n-butanol.
DET	The [DET]ector voltage is a measure of the light scattered from particles as detected by the photodetector. The DET should be 0.000 ±0.100 volts when no particles are passing through the sensor. (Either the air is clean or the pump is off.)

Note: For more information on status parameters, see Chapter 4, “Configuring the UCPC.”

Flow Hi/Lo

Flow Hi/Lo switches the inlet flow between the low flowrate (5 cm³/s) and the high flowrate (25 cm³/s). According to the flow mode, the display reads High Flow or Low Flow and then redispays the concentration value.

Note: *The condenser flow is always 5 cm³/s regardless of the inlet flow. In the high-flow mode, the extra volume of 20 cm³/s becomes an internal bypass flow. If you attach transport tubing to the inlet of the UCPC, the high-flow mode allows the sample to be brought to the sensor faster with lower losses caused by particle diffusion.*

In the low-flow mode, extra air is brought through the makeup-air port from the back panel. This keeps the pump running at a high RPM to stabilize and smooth the flow through the sensor.

Filling

To fill the UCPC, connect a liquid-filled bottle to the Liquid Supply connector on the back panel and place the bottle in the mounting bracket. The UCPC automatically opens and closes the fill valve to keep the internal reservoir full.

You can configure the UCPC so that the liquid reservoir must be full to get a readout of the concentration (see “Enabling the Configuration Function” in Chapter 4). This measure ensures that the UCPC is fully operational before any data can be taken. In this mode the display reads “Filling” whenever the fill valve is open for more than 5 seconds.

If the UCPC is not configured this way, a concentration value is displayed even if the reservoir is not full. Obviously, if there is no liquid or too little liquid, the concentration value would be wrong. In this mode the display does not read “Filling” when the fill valve is open.

Indicator Lights

The front panel of the UCPC uses these indicator lights: Particle, Flow, Auto, Optics Condenser, Saturator, Laser, Liquid Level, described in this subsection.

Particle

The amber light next to Particle flashes briefly each time a particle is detected.

Flow

A green light comes on next to Flow when the flowrate is $5 \pm 0.5 \text{ cm}^3/\text{s}$. A yellow light comes on above Flow when the flowrate is too high; a yellow light comes on below Flow when the flowrate is too low.

Auto

A green light comes on below Auto (and next to Range) when you set the display range to the auto-range mode.

Optics, Condenser, Saturator

A green light comes on across from Optics when the optics temperature is $\pm 2^\circ\text{C}$ of the correct temperature. A green light comes on across from Condenser and Saturator when the temperature of each is within 0.5°C of their correct values. The microprocessor normally controls the temperatures to within $\pm 0.3^\circ\text{C}$ of the correct temperature for the condenser and saturator.

Laser

A green light comes on across from Laser when the laser is *on* and operating at the correct power level.

Liquid Level

A green light comes on across from Liquid Level when the liquid level sensor indicates that the reservoir is full.

Back Panel Functions

Refer to Figure 3-2 as you read the following descriptions of the back panel functions.

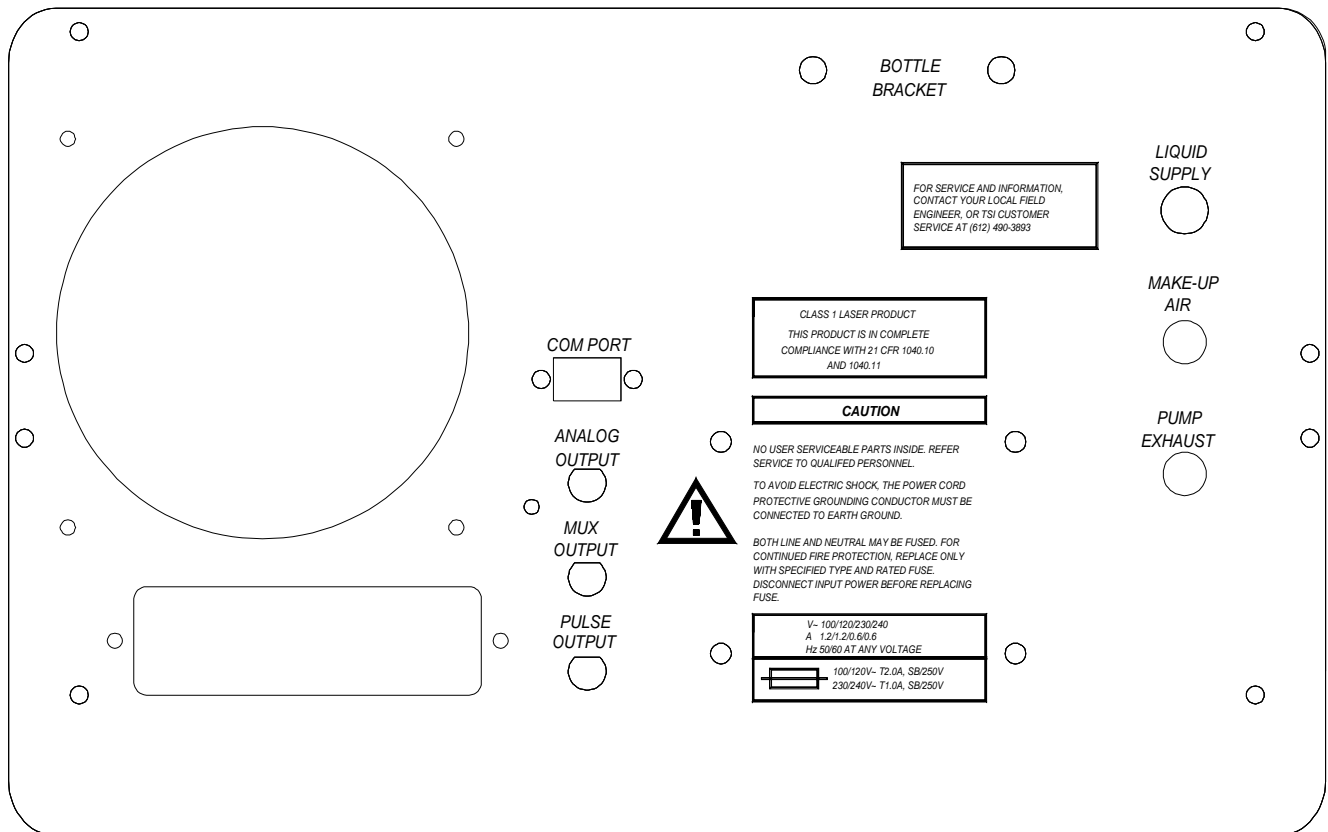


Figure 3-2
UCPC Back Panel

COM Port

The 9-pin, D-type, subminiature connector labeled COM PORT, is the communications port compatible with RS-232 devices. A detailed description of this computer interface and its commands is given in Chapter 7.

Analog Output

Analog Output is a BNC connector that transmits a signal of 0 to 10 volts. The analog output is useful when the UCPC is connected

to an Electrostatic Classifier (Model 3071A) as part of a Differential Mobility Particle Sizer (DMPS) system or a Scanning Mobility Particle Sizer (SMPS) system.

Use the configuration function to select the voltage you want to output (see Chapter 4). An external computer can override and control the output up to 11 volts. For a description of the computer interface and commands, see Chapter 7.

Mux Output

Mux Output is a BNC connector compatible with TSI's Model 31XX and 71XX series processors. The signal transmitted through the output—one for each detected particle—is a 13-volt, 6.4-microsecond square pulse. The output is valid only for concentrations less than 350 particles per cm^3 [10 million/ ft^3].

Pulse Output

Pulse Output is a BNC connector that transmits a 12-volt square pulse, one for each detected particle. The width of the pulse depends on the shape of the photodetector pulse and on the trigger-level of the pulse threshold. A typical width is 3.3 microseconds.

Liquid Supply

Liquid Supply is a quick-disconnect, shut-off connection. Use it with the liquid supply bottle to supply a continuous flow of working fluid to the instrument.

Makeup Air

The Makeup Air outlet uses a ¼-inch nylon Swagelok connector. Makeup air is used in the low-flow mode to increase the pump speed and stabilize the flow through the sensor. The air is filtered in the UCPC before it joins the pump flow. If the inlet is sampling from a slight vacuum, the makeup air may need to be restricted to force more air to enter through the inlet (see “Inlet Pressure” below).

Pump Exhaust

Pump Exhaust uses a ¼-inch nylon Swagelok connector to vent the pump exhaust. If you are sampling from a slightly pressurized system or from a vacuum system, equalize the pressure across the UCPC by connecting the pump exhaust to the system downstream of the sampling port (see “Inlet Pressure” below).

Operating Specifications and Precautions

This section contains operating specifications and precautions. Also refer to the Safety section at the front of this manual and Appendix B, “Specifications.”

Ambient Temperature

Do *not* operate the UCPC in ambient temperatures outside the range of 10° to 37° C. If you operate the UCPC outside of this range, the data collected may be invalid.

Inlet Pressure

The built-in pump and flow sensor cannot control the flow when the pressure at the aerosol inlet, the makeup air inlet, or the pump exhaust is too high or too low. The remedy depends on the mode you are in: high-flow or low-flow.

First, view the flow display by activating the secondary function “Status;” then follow the directions given for either the high-flow or low-flow mode. As a further aid, monitor the pump-control voltage of the microprocessor using the Analog Output jack on the back panel (see Chapter 5 and “Analog Output” earlier in this chapter).

High Flow Mode

In the High Flow mode, connect the Pump Exhaust outlet to the same pressure conditions that apply to the inlet so that the pressure drop across the UCPC is close to normal conditions.

If you are sampling from a closed system, add a pressure-equalizing line from the pump exhaust to the system downstream of the sample port. Ensure your sample port does not sample air from the pump exhaust.

If you cannot vent the pump exhaust back into the system, you must add a flow restrictor (excess pressure at the inlet) or add an additional vacuum pump (insufficient pressure at the inlet) to the pump exhaust port. For example, do this if the system cannot tolerate the vapors of the working fluid or the potential particle contamination from the pump exhaust.

Low Flow Mode

The Low Flow mode is slightly more complicated than the high-flow mode because it also involves the makeup air inlet. Try to equalize the pressure at all the ports so that the microprocessor pump-control voltage is at mid-range. The exact flowrate through the makeup air is unimportant.

If the aerosol inlet pressure is too low, try adding a flow restrictor to the makeup air port. (Use an orifice, filter, valve, or other device.) If the inlet pressure is low enough, you may need to completely close off the makeup air and/or equalize the pressure from the pump exhaust port as described above under “High Flow.” If the inlet pressure is too high, add a restrictor to the pump exhaust.

Moving the Counter

When the liquid reservoir is full, avoid tipping or moving the UCPC so that liquid does not spill, get sucked up into the optics or bypass air line, or out the inlet.



C a u t i o n

While the pump is on, do not tip the counter more than 12° to either side or 45° from front or back. In general, it is better to dry the UCPC (see below) before you move it. If the UCPC is tilted for more than a few seconds, disconnect the bottle of working fluid to prevent flooding the sensor.

Drying the Counter

The UCPC must be completely drained of fluid and dry before shipping (air freight, truck, ship, etc.)

There are two methods of drying the UCPC:

First Method

- 1.** Disconnect the working fluid supply bottle.
- 2.** Switch on the pump and run dry air through the UCPC for 24 to 48 hours.

Second Method

The UCPC may develop leaks due to the disassembly process or the sensor may become damaged using this faster process.

- 1.** Disconnect the working fluid supply bottle.
- 2.** Remove the wick from the reservoir. To do so, follow refer to Figures 3-3 and 3-4 and follow these steps:
 - a.** First remove the top and bottom covers.
 - b.** Disconnect the Swagelok tee-fitting and inlet tubes.
 - c.** Remove the four screws from the saturator's end-plate. When removing the end plate, be careful not to bump the fragile glass-coated level sensor screwed into the end-plate.
 - d.** Pull the wick from within the saturator.
 - e.** Either ship the instrument without the wick, dry the wick and reinstall it, or install a new wick.
 - f.** Replace the wick with the cut-away facing downward to clear the liquid level sensor.
 - g.** Reassemble the end-plate and inlet tubes.

3. Switch on the pump and run dry air through the UCPC for 2 to 3 hours.

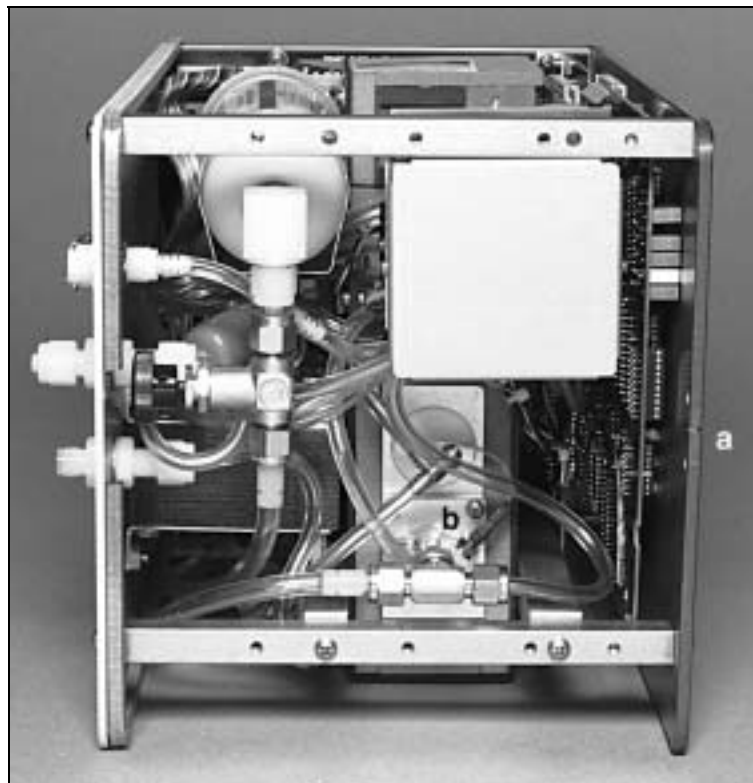


Figure 3-3
Saturator: (a) Front of Counter; (b) End Plate With Four Screws

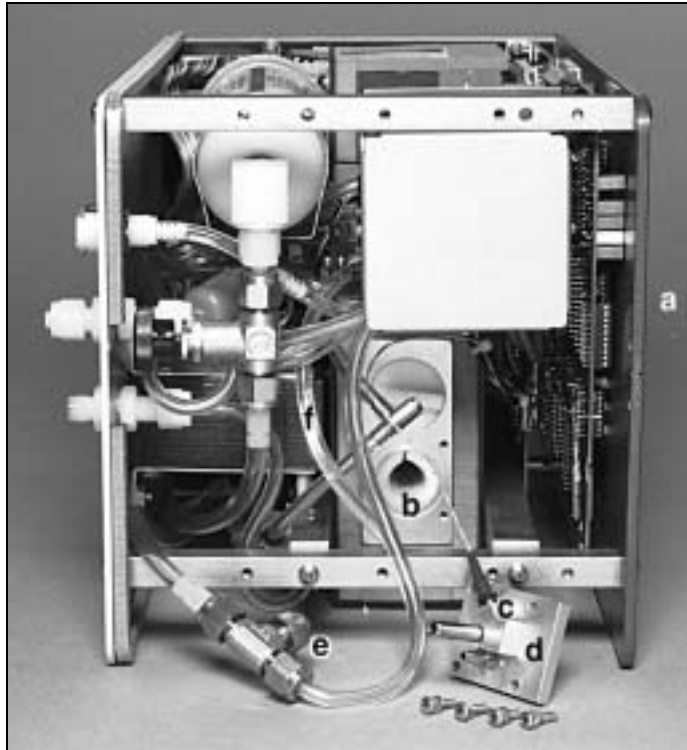


Figure 3-4
Saturator: (a) Front of Counter; (b) Wick; (c) Fill Sensor Connector; (d) End-Plate (Removed); (e) Sheath Air Line; (f) Fluid Line

Configuring the UCPC

This chapter describes how to enable the Configuration mode and select the various microprocessor outputs and controls for the Model 3025A UCPC. This chapter also explains how to calibrate the Digital/Analog (D/A) and Analog/Digital (A/D) converters and the flow meter.

Enabling the Configuration Mode

To enable the Configuration mode, first set the red paddle switch on the Display printed circuit (PC) board to “enable.” The board is shipped in the “disable” position so that you do not accidentally alter the calibration and setup configuration.

1. Remove power from the UCPC and from any instruments connected to the UCPC.
2. Remove the top cover from the UCPC (see the “Installing an EPROM” procedure in Chapter 8 for directions on removing the cover).

The Display board is next to the front panel as shown in Figure 4-1.

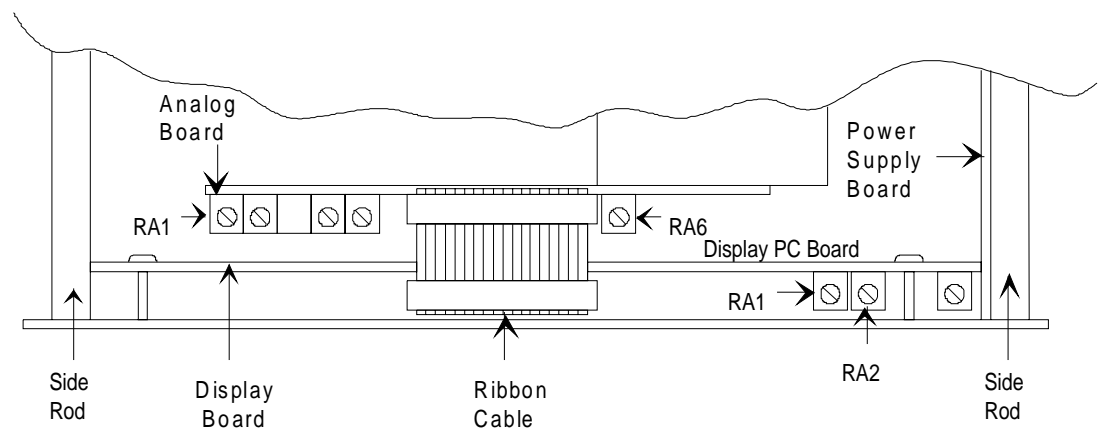


Figure 4-1
Locations of PC Boards and Potentiometers

3. Move the red paddle switch to the far right position (Figure 4-2).

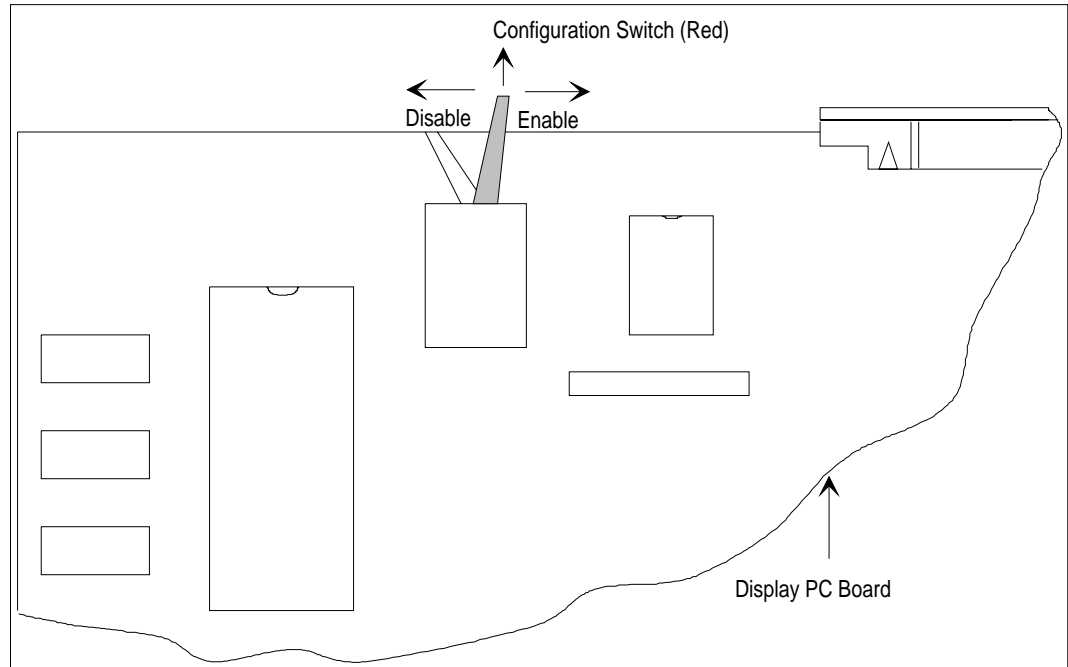


Figure 4-2
Setting the Configuration Switch to Enable the Configuration Mode

- 4.** Run the configuration sequence (see “Running the Configuration Function” in this chapter). Be sure the UCPC is fully warmed-up before resetting any calibration points.
- 5.** After configuring the UCPC, it is a good idea to set the switch back to the disable position to prevent tampering.
- 6.** Replace the top cover.

Running the Configuration Function

The configuration process is programmed in the UCPC and altered by pressing function buttons in response to questions posed on the display.

- 1.** To enter the configuration mode, press the Shift and then press Pump. “Set Up Mode” appears momentarily on the front panel display.

2. To view the possible responses, press the Total button until the desired response appears. Select the response and move on to the next question by pressing the Display button.

Note: *If you answer yes to the question “Calibrate?,” you must make some adjustments to the electronics inside the UCPC cabinet. The directions for making these adjustments are given in the right-hand column of the table that follows.*



C a u t i o n

Do not answer yes to the calibration question until you have completely read this section.

3. When you have completed the steps in the configuration process, press Clear.

Question	Answer	Explanation
Must fill?	Y	Yes: A yes requires that the liquid reservoir be full for concentration display.
	N	No (Default)
Total?	20s	Total seconds; when the time has elapsed, the counting stops.
	60s	
	200s	
	600s	
	2000s	
	6000s	
	9999s	
	No Lmt	No limit
Output?		Concentration range for analog output; see “Analog Output” in Chapter 3.
	E1	0 to 10 particles/cm ³
	E2	0 to 100 particles/cm ³
	E3	0 to 1000 particles/cm ³
	E4	0 to 10,000 particles/cm ³
	E5	0 to 100,000 particles/cm ³

continued

Question	Answer	Explanation
	LOG	Logarithmic concentration output; (0 to 10 volts) log: 10 volts = 100,000 particles/cm ³ 0 to 100,000 particles/cm ³ 8 = 100,000 7 = 10,000 6 = 1,000 5 = 100 4 = 10 3 = 1 2 = 0.1 1 = 0.01 0 = <0.01
	COND	Calibrated condenser flow in units of cm ³ /s as measured by the volumetric flowmeter; 1 volt = 1 cm ³ /s.
	AERO	Calibrated aerosol flow in units of cm ³ /s as measured by the volumetric flowmeter; 1 volt = 0.1 cm ³ /s.
	PUMP	Percent of microprocessor pump control; 0-10 volts, microprocessor control range (0-100%) to the pump. 0 volts represents 1.55 volts to the pump; 10 volts represents 12 volts to the pump. Pump voltage = P (12) + (1-P) (1.55) where P=pump. See "Back Panel Functions: and "Analog Output" in Chapter 3.
	HOST	0-11 volt signal that can be set by a [HOST] computer via the RS-232 port. This mode is useful when controlling an instrument such as the Electrostatic Classifier with the 3025A UCPC as part of a DMPS or SMPS system.
	DET	The [DET]ector voltage is a measure of the light scattered from particles as detected by the photodetector. The DET should be 0.000 ± 0.100 volts when no particles are passing through the sensor (either the air is clean or the pump is off).

continued

Question	Answer	Explanation
Baud?	110 300 600 1200 2400 4800 9600 19200	Baud rate for RS-232 communication Default
Parity?	Even None	Default
Calibrate?	N Y	No: to exit from Setup Yes. To enter calibration of D/A, A/D and flow.
D/A Zero		To calibrate the D/A zero, measure the voltage with a digital voltmeter from the Analog Output jack on the back panel. Note: This step is independent of your selection for the analog output above. Remove the top cover of the UCPC. Adjust potentiometer RA2 (Figure 4-1) to 0 ±1 mV. Press the Display button.
D/A 10v		Measure the voltage from the Analog Output jack. Adjust potentiometer RA1 on the Display PC Board (Figure 4-1) to 10 V ±1 mV. Press the Display button.
Cal A/D?	N Y	No Yes: Answering yes uses the D/A 10-volt output that you just set as a reference in order to set the A/D 10-volt output.
Det	0.000v	This is the “photodetector zero.” Adjust potentiometer RA6 (Figure 4-1) so the display reads 0.000 ±0.100. Press the Display button.
Ref	2.000– 5.000v	The reference photodetector. Potentiometer RA1 on the Analog Board (Figure 4-1) has been set to maximum so the display reads 2 to 5 volts. Press the Display button.
Cond Cal?	N Y	No: calibrate condenser flow Yes: Answering yes requires an external means of measuring the flow to calibrate the internal volumetric flowmeter; see “Flow Calibration” below.
5.00 cm ³ /s 128		Follow instructions under “Condenser Flow Calibration.”

continued

Question	Answer	Explanation
Zero flow		The pump switches off. Wait 30 seconds until the flow is absolutely zero. Press Display.
Aero Cal?	N Y	Calibrate aerosol flow: No Yes: Answering yes requires an external means of measuring the flow to calibrate the internal volumetric flowmeter.
0.5 cm ³ /s		Follow instructions under "Aerosol Flow Calibration" below.
Zero flow		The pump switches off. Wait 30 seconds until the flow is absolutely zero. Press Display. After a brief delay, the front panel momentarily displays "Set Up Done." Exit the configuration mode.

Flow Calibration

Since a single pump in the counter controls two flows, calibrating the flows is rather involved.

Both calibrated flows are measured by the pressure drop across a capillary tube. The pressure drops of the flows are measured with a sensitive transducer that has an output of 0 to 5 volts, corresponding to ± 2.5 inches of water.

When the condenser flowrate is calibrated, the microprocessor in the instrument is programmed to maintain a specific pressure-transducer voltage. The pump voltage is adjusted to maintain a steady pressure drop, which in turn maintains a constant volumetric flow through the sensor.

After the condenser flow has been calibrated, the aerosol flow is set using a valve. This may have to be readjusted if the pressure drop in the sheath flow is changed after calibration.

The calibration is done at two points only: zero flow and operating flow. Other flowrates that may be displayed on the front panel are calculated on the basis of physical principles and normalized to the calibrated points. While these other flows may not be accurate they are used to show that the flow is either too high or too low by an approximate amount.

When calibrating the flow, chose an external flowmeter that will have a low pressure drop and measure the actual volumetric flow. If you use a mass flowmeter (one calibrated to standard conditions), convert the standard flow to actual flow with the following equation:

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

where $T = ^\circ \text{Kelvin}$
 $P = \text{kPa}$.

Condenser Flow Calibration

To calibrate the condenser flow follow these four steps:

1. When the display on the counter reads “Cond Cal? N,” press the Total button until the “N” changes to “Y.” Press the Display button to continue the calibration. If you answered yes to the calibration, the display changes to “5.00 cm³/s 128.” This indicates the target flow into the counter inlet (5.00 cm³/s) and the power to the pump (0-255), initially set at 128.
2. Connect a flowmeter to the inlet of the UCPC and measure the flow. If the flow is *higher* than 5.00 cm³/s, press the Total button repeatedly (the 128 number will decrease) until the external flowmeter reads 5.00 cm³/s. If the flow is *lower* than 5.00 cm³/s, press the Range button repeatedly (the 128 number will increase) until the external flowmeter reads 5.00 cm³/s.

Note: *The condenser flowmeter voltage is available at the Analog Output for reference.*

3. When the flow is correct (as measured by the external flowmeter), press the Display button to record the operating voltage of the internal flowmeter.
4. The display now reads “Zero Flow.” Allow the pump to come to a complete stop (30 seconds) and then press the Display button to record the zero-flow voltage of the internal flowmeter. The display now asks whether the aerosol flow should be calibrated. Answering yes requires that the aerosol flow be calibrated as outlined below. Answering no allows you to exit the calibration procedure and return at a later time.

Note: *Both flows should be calibrated before using the UCPC.*

Aerosol Flow Calibration

The aerosol flow calibration should be performed only after the condenser flow has been calibrated as outlined above. Follow these nine steps:

1. Make sure that the instrument is in the Configuration setup and displaying “AeroCal? N.”
2. Remove the top and bottom covers from the instrument so that the sheath-air valve is accessible (see Figure 4-3).



Figure 4-3
Location of Sheath Air Valve (a) and Bypass Variable Orifice (b)

3. Connect an external flowmeter, with a low pressure drop, in the sheath-air line downstream of the valve and filter as shown in Figure 4-4.



Figure 4-4
External Flowmeter in the Sheath-Air Line

4. Use the Total button to answer yes to the Calibrate question on the display and then press the Display button to continue. The display now shows “0.5 cm³/s.” By setting the sheath air to 4.50 cm³/s, the aerosol flow is set to 0.50 cm³/s since the condenser flow is 5.00 cm³/s.

Note: *The aerosol flowmeter voltage is available at the Analog Output for reference.*

5. Adjust the sheath air valve until the flow through the external flowmeter is 4.50 cm³/s. This may take several repetitions of adjusting and flow-checking.
6. When the flow is correct, press the Display button to continue.
7. The display now shows “Zero Flow.” Reconnect the sheath air connections. Allow the pump to come to a complete stop (30 seconds) and then press the Display button to record the zero-flow voltage of the internal flowmeter. The UCPC exits the configuration mode.

- 8.** Press the Shift button and then the Status button. The number displayed should be the aerosol flow of approximately $0.50 \text{ cm}^3/\text{s}$. Adjust the sheath air as in step 5, until the display reads " $0.50 \text{ cm}^3/\text{s}$."
- 9.** Place the top and bottom covers on the instrument and secure them with the side screws.

High Flow Calibration

The high flow calibration should be performed only after the condenser and aerosol flows have been calibrated as outlined above. Follow these four steps:

- 1.** Press the Shift button on the front panel followed by the Totalizer button. The display should show "Hi Flow." If the display shows "Lo Flow," repeat the two button strokes until "Hi Flow" is displayed.
- 2.** If not already done, remove the top and bottom covers from the instrument.
- 3.** Using a small, standard screwdriver, adjust the bypass variable orifice (see Figure 4-3) until the flow through the inlet to the instrument is $1500 \text{ cm}^3/\text{min}$ ($\pm 10\%$) measured by a low-pressure-drop flowmeter.
- 4.** Replace the top and bottom covers on the instrument and secure them with the side screws. The flows on the instrument are now fully calibrated.

Photometric Calibration

The UCPC uses a single photometric calibration point to check the overrange status of the counter in single-count mode. This calibration point, 0.5 volt, normally should not be changed over the life of the instrument.

Technical Description

The Model 3025A UCPC is a continuous-flow, condensation particle counter that can detect particles as small as 3 nanometers in diameter. This section describes the function of the UCPC, its subsystems, and components. A discussion of its theory and history is given first.

Theory

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

When the vapor surrounding particles reaches a certain degree of supersaturation, the vapor begins to condense onto the particles. This is called *heterogeneous* condensation. If supersaturation becomes high enough, condensation can take place even if no particles are present. This is called *homogeneous nucleation* or *self-nucleation*, whereby molecules of the vapor form clusters due to the natural motion of the gas and attractive van der Waals forces to form nucleation sites.

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

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

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

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

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

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

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

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

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

Historical Notes

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

Adiabatic Expansion CNC

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

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

Two-Flow Mixing CNC

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

Diffusional Thermal CNC

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

For high-concentration measurements, a classical photometric light-scattering technique is used. The first commercial version of this type of CNC (TSI Model 3020) used n-butyl alcohol as the condensing fluid and has a flowrate of 0.3 liter per minute. Other versions include a cleanroom CNC (TSI Model 7610, U.S. patent no. 4,790,650), a respirator-fit test CNC (TSI Model 8010) and the versatile Model 3010 CPC. TSI's Model 3020 CNC was replaced in 1988 by the Model 3022A CPC. This CPC is a general-purpose instrument suitable for a wide variety of applications. It uses the photometric mode of operation (unlike the UCPC) to monitor high particle concentrations up to 10^7 particles/cm³. The UCPC is a high-sensitivity version of the CPC.

When growing the particles in the condenser chamber, the highest saturation ratio occurs on the centerline of the flowstream at some distance down the condensing tube (Stolzenburg [1988]). Although the saturation ratio is not uniform across the flow profile due to thermal gradients, the lower size-sensitivity can still be predicted and measured. Using sheath air, the UCPC confines the aerosol to the centerline of the condenser tube where supersaturation is the highest. The result is very high detection efficiency for small particles down to 3 nanometers and fast response time. This is a distinct advantage over the Model 3022A CPC but with an increase in the complexity of the instrument and a reduction in sample flow-rate.

The high sensitivity of the Model 3025A counter makes it the only instrument of its kind that can detect particulates below 0.01 micrometer. This makes it useful for atmospheric studies, cleanroom monitoring, and basic aerosol research as well as for new applications that are possible only with the UCPC. Both the UCPC and CPC are also commonly used with submicron size-distribution measurement systems such as the Diffusion Battery (Sem et al. [1980]) and the Differential Electrical Mobility Classifier (Keady et al. [1983]).

Design of the UCPC

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

Sensor

Using Figure 5-1 as a reference, the sensor part of the UCPC itself is made up of a saturator, condenser, and optical detector. The aerosol entering the instrument is split twice to form aerosol sample flows, a sheath flow, and a bypass transport flow. (See “High Flow” below for information on the bypass flow.) The sheath flow is filtered before entering the saturator section where it passes over a heated, liquid-soaked wick. The wick continually draws liquid from the reservoir bottle. The liquid evaporates and saturates the sheath airstream with vapor.

The aerosol stream, in the meantime, passes through a capillary tube and is injected into the centerline of a vertical condenser tube. At this point the aerosol stream is rejoined with the vapor-saturated sheath air as a laminar flow. These streams are then cooled using a thermoelectric device in the condenser. The vapor cools, becomes supersaturated, and begins to condense on the particle nuclei carried in the aerosol stream to form larger droplets. The droplets pass from the condenser tube through a nozzle into the optical detector. Liquid that condenses on the walls of the condenser tube runs back down into the saturator and is absorbed into the wick for reuse.

The sensor’s focusing optics consist of a laser diode, collimating lens, and cylindrical lens. This combination forms a horizontal ribbon of laser light above the aerosol exit nozzle measuring 10 micrometers by 2 millimeters. The collecting optics incorporate a pair of aspheric lenses that collect the light scattered by the droplets at 90° side-scatter angle and focus the light onto a low-noise photodiode. The main beam is blocked by a light-stop in the rear of the sensing chamber. A reference photodiode is mounted at the back of the light-stop to monitor the intensity of the incident beam. The surface temperature of the optics housing is maintained at or above the saturator temperature to avoid condensation on the lens surfaces.

The counter uses two modes of particle counting: single-particle realtime counting and single-particle “live-time” counting.

At concentrations below 10,000 particles/cm³, the individual electrical pulses generated by light scattered from individual droplets are *all* counted over the actual time, that is, in “real” time. At concentrations between 10,000 and 100,000 particles/cm³, the individual electrical pulses are counted, but only when the signal-processing electronics is available for counting, that is, in “live-time.” The length of time during which a particle is actually being detected is called the “dead-time” and is not included in the live-time. This arrangement automatically corrects for particle coincidence.

Microprocessor

The UCPC incorporates an Intel 80188 microprocessor to control all its functions. The microprocessor uses a 512KB EPROM* chip for program memory and an 8KB RAM** chip for making calculations and running count buffers. An additional 8KB of EEPROM*** stores nonvolatile information such as the photometric calibration.

An analog-to-digital (A/D) converter is connected to the microprocessor and measures photodetector voltages, temperatures, and flowrates. (The temperatures and flowrate controls are based on the raw data received by the A/D converter). Counters within the microprocessor keep track of the particle pulses detected by the photodetector. The display, push buttons, and RS-232 communications are also controlled by the microprocessor.

* Electronically Programmable Read Only Memory

** Random Access Memory

*** Electronically Erasable Programmable Read Only Memory

Flow System

Using Figure 5-1 as a reference, the UCPC has two inlet flow options: high flow (1500 cm³/min) and low flow (300 cm³/min). The flowrate through the sensor is always 300 cm³/min, independent of the inlet flow. For information on how to enter these modes, see “The Front Panel” in Chapter 3.

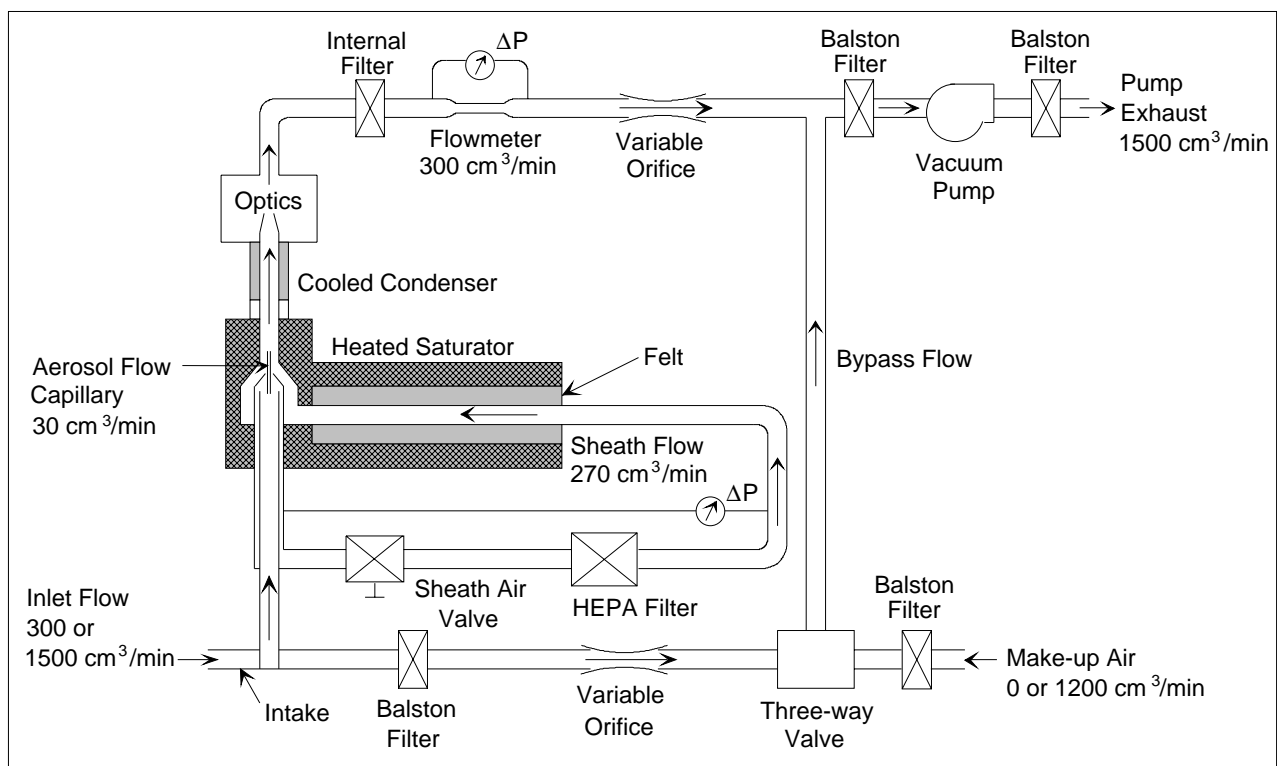


Figure 5-1
Flow Schematic of the UCPC

High Flow

The high-flow option allows the sample to be brought to the UCPC faster to minimize response time and diffusional particle losses. In the high-flow mode, the three-way valve is opened to the bypass flow and the flow of makeup air is shut off. A total of 1500 cm³/min ($\pm 10\%$) is drawn into the UCPC's inlet. The flow splits so that 300 cm³/min flows through the sensor and 1200 cm³/min flows through the bypass. Together, the flowmeter and microprocessor control the vacuum pump to maintain the flowrate through the condenser ("Total" indicator on the front panel). The accuracy of the sensor flow is based on a two-point calibration at 0 and at 300 cm³/min.

Low Flow

The low-flow option allows the minimum flowrate when a high flow is undesirable, for example, when using the counter with the Differential Mobility Particle Sizer (DMPS). In the low-flow mode, the three-way valve is open to the flow of makeup air, the bypass flow is shut off, and the two-way valve is open. Only 300 cm³/min is drawn into the inlet and carried directly into the sensor.

The flowmeter and microprocessor control the vacuum pump to maintain the flowrate through the sensor, just as is done in the high-flow mode. The makeup flow is uncontrolled and the magnitude of the flowrate is unimportant. It is important, however, that the pump operate below its maximum 12 volts so that there is some range in the feedback control. If the inlet pressure is lower than the pressure of the makeup air, you may need to add a restrictor to the makeup air to force more air to come through the inlet and produce a lower pump voltage. For more details, see "Inlet Pressure" under "Operating Specifications and Precautions" in Chapter 3.

Filters and Restrictors

Referring to Figure 5-1, four filters are used to clean the airstream, two filters are used as dampers or restrictors, and two orifices and a valve are used to control internal flows. A valve is used to control the sheath flow. A low-pressure-drop, HEPA filter is used in the sheath flow to filter the sheath air. A filter is used between the inlet and the bypass flow to protect the variable orifice. The orifice is

used to control the bypass flow. Also on the bypass flow, a filter is used upstream of the three-way valve to act as a restrictor to allow flow through the inlet. An internal filter is used to collect all counted particles in the condenser flow. Downstream of this filter, an orifice controls the balance between the bypass and condenser flows for a given pump speed. Flow upstream of the pump is protected by a damping filter. A final filter protects the environment from pump-exhaust contamination.

Flowmeters

The volumetric flowmeters use sensitive pressure transmitters to measure the pressure drop across capillary tubes. The condenser capillary tube (Total button on the front panel) has an inside diameter of 0.1092 centimeter and length of 3.777 centimeters. The aerosol capillary tube has an inside diameter of 0.0495 centimeter and length of 1.422 centimeters. The pressure drop through the capillaries is linearly related to volumetric flowrate plus an additional contribution that is equal to $0.58 \rho u^2$ (Schlichting [1955]). The pressure drop can be calculated from the following relationship:

$$\Delta P = aQ^2 + bQ$$

where ΔP = pressure drop in dynes/cm²

$a = 8(1.16)\rho / (\pi^2 d^4)$, where ρ = gas density in g/cm³

$b = 128\mu l / (\pi d^4)$, where μ = gas absolute viscosity in g/cm/s and l = capillary length in cm

d = capillary diameter in cm

Q = flowrate in cm³/s

The pressure drops of the condenser capillary and aerosol capillary are approximately 1.2 centimeters of water at 5.0 cm³/s and 0.95 centimeter of water at 0.5 cm³/s, respectively. The pressure drops for each instrument vary according to the actual diameter of the capillary tube, its length, and surface roughness. The temperature of the tubes are held constant because they are next to the heat-controlled saturator block. This keeps the dimensions of the tubes stable.

Pump

The compact pump is an oil-free rotary pump with eight carbon vanes. It uses a DC motor and is nearly pulsation-free. The components that come in contact with the air are corrosion-resistant materials.

CHAPTER 6

Particle Counting

The Model 3025A Ultrafine Condensation Particle Counter (UCPC) uses two methods of particle counting for concentration calculations: single-particle realtime counting and single-particle live-time counting. This chapter focuses on counting the individual particles up to a concentration of 100,000/cm³.

Optical Detection

Submicrometer particles are drawn into the counter and enlarged by condensation of a supersaturated vapor into droplets that measure several micrometers in diameter. The droplets pass through a lighted viewing volume where they scatter light. The scattered-light pulses are collected by a photodetector and converted into electrical pulses. The electrical pulses are then counted and their rate (calculated) is a measure of particle concentration. The optical detector used in this process is described in Chapter 5.

Single-Particle, Realtime Counting

At particle concentrations below 10,000/cm³, the concentration is calculated by counting the individual pulses from the photodetector and by counting the real time. The particle pulses are typically 1.4-volts high, 5-microseconds wide at the base, and 3.3-microseconds wide at the trigger-threshold point* (see Figure 6-1). The counting trigger-threshold voltage is about 750 millivolts. The threshold has a hysteresis of about 100 millivolts so that another particle cannot be detected until the voltage first drops below 650 millivolts. This prevents false counting of noise pulses riding on top of the particle pulse.

While the pulse exists, the counter is disabled, that is, it cannot count another pulse until the present pulse is completed. A second particle entering the viewing volume while the first remains can extend the pulse width and thus, the time the counter is disabled. In this situation the counter can be described as “paralyzable,”

* Actual pulse heights for your UCPC are listed on the data sheet in Appendix D.

because at sufficiently high particle rates the pulse width extends indefinitely, thus paralyzing the counter.

The statistics for a paralyzable counter give the relationship of the measured particle concentration to the true concentration as:

$$C_a = C_i \exp\left(\frac{QtC_a}{10}\right)$$

where C_a = actual or true concentration in particles/cm³

C_i = indicated or measured concentration in particles/cm³

Q = flowrate at 5.0 cm³/s

t = time the counter is disabled for a single particle (approximately 4 μs in the UCPC)

$\frac{QtC_a}{10}$ = the average number of particles that occur during the disabled period t .

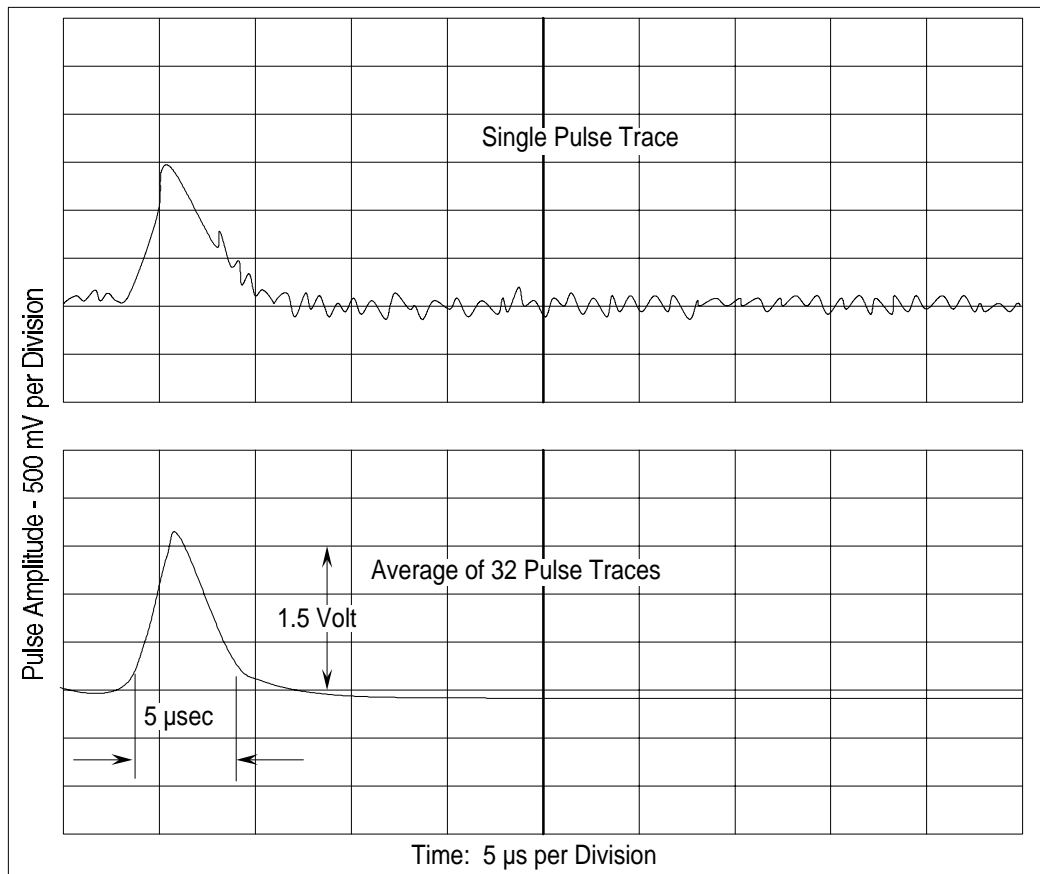


Figure 6-1
Typical Digital Pulse Trace From the Photodetector

Since C_a cannot be solved directly and is a double-valued function of C_i , the equation can be closely approximated by using C_i in place of C_a in the exponent.

For low concentrations—where the average time between the arrival of particles is much larger than the disable time $\left(\frac{QtC_a}{10} < 0.01\right)$ —coincidence is low and no correction of the measured concentration is necessary. At higher concentrations, correction of coincidence is required and the internal microprocessor does *not* automatically correct for coincidence.

The effect of coincidence in the UCPC up to 10,000 particles/cm³ is small, as can be seen in Table 6-1.

Table 6-1
Coincidence Correction for Concentrations up to 10,000 Particles/cm³

Indicated Concentration (particles/cm ³)	Correction Factor $\exp(QtC_i)$	Correct Concentration (particles/cm ³)
9.99e3	1.020	1.02e3
9.00e3	1.018	9.16e2
5.00e3	1.010	5.05e2
1.00e3	1.002	1.00e2

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 (total mode) in each interval is very small, the uncertainty in the count is large. The statistical error of the count σ_r is related to the total count n by

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

The accuracy of the concentration is increased by sampling for a longer period. The concentration is calculated by:

$$\text{concentration} = \frac{\text{total counts}}{\text{volume of air sampled}}$$

$$\begin{aligned} \text{where volume} &= Q \times \text{time} \\ &= 5 \text{ (cm}^3/\text{s)} \times \text{time (s)}. \end{aligned}$$

Single-Particle, Live-Time Counting

In the concentration range of 10,000 to 100,000 particles/cm³, the counter uses a different method of counting single particles that is independent of t . The coincidence correction is applied directly by measuring particle counts over the live-time of the counter.

Since the time t during which the particle passes through the viewing volume effectively disables the counter, the value should not be included in the sample time. The actual particle rate equals the number of counted particles divided by the time no pulses were present during the measurement time. A high-speed clock and accumulator measure the live-time or the time in the spaces between particle pulses. At the start of the measurement, the accumulator is cleared and the clock started. The accumulator adds up the live-time and the counter adds up pulse counts until the accumulator reaches a value that triggers the counter and clock to stop. The particle concentration is then calculated by

$$C_a = \frac{\text{number of counted particles}}{\text{accumulated live - time}} \times \frac{1}{\text{flowrate}} \times 10$$

Autorangeing

Three running-average buffers and two live-time buffer are used to average particle counts. The live-time buffers are updated every 1/10th of a second which is somewhat longer than real time, depending on the concentration. The UCPC display is updated one time per second.

There is one buffer for each of five averages: 1/10, 1, 2, 20, and 200 seconds. The 1/10 second live-time counter is used with exponent display, e4; the 1-second live-time counter is used with exponent display, e3; the 2-second buffer with exponent display, e2; the 20-second buffer with exponent display, e1; and the 200-second buffer is used with exponent display e0, showing three digits after the decimal.

The autoranging algorithm chooses among these buffers. A downward hysteresis of 10 percent is used when going from one exponent range to another in order to avoid rapid and unreadable display changes. If the display is on a fixed exponent range, then the correct buffer is used for the concentration magnitude, but the display has a fixed exponent range.

All buffers are cleared when you press the Clear button.

CHAPTER 7

Computer Interface and Commands

This chapter gives computer interface and communications information for the Model 3025A Ultrafine Condensation Particle Counter (UCPC) as well as a transcript of the BASIC program provided with the UCPC.

Computer Interface

This section gives the hardware connection information for the Model 3025A UCPC.

Pin Connectors

The Model 3025A UCPC has one 9-pin, D-type subminiature connector on the back panel labeled COM PORT. An external computer, if used, should be connected to COM PORT (shown in Figure 7-1). If more than one UCPC is used, each UCPC must be connected to a separate COM port on the computer.

The communications port is 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. Figure 7-1 shows the connector pins on the COM PORT; Table 7-1 lists the signal connections.

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

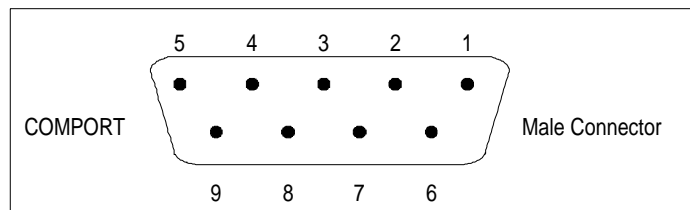


Figure 7-1
Connector Pin Designations

Table 7-1
Signal Connections for RS-232 Configurations

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

Baud Rate

The baud-rate setting is the UCPC's rate of communication in terms of bits per second (baud). The standard setting is 9600 baud, or about 960 characters per second. At higher baud rates, the distance between the computer and the UCPC may need to be shortened to reduce transmission errors. The recommended maximum distance is 100 meters.

The baud rate, which must match that of the host device connected to the COM PORT. The possible baud rates are 110, 300, 600, 1200, 2400, 4800, 9600, and 19200. Select the baud rate in the configuration function (see Chapter 4).

Parity

Parity is the additional bit that accompanies data to confirm that it is transmitted correctly. It is set in the Configuration mode (Chapter 4) so that the number of "1" bits (HIGH) in a transmitted character is always an even number—hence, *even* parity. In the configuration mode you can select either even parity or no parity. The UCPC uses even parity as the default setting.

Commands

The commands that are transmitted to the UCPC are ASCII strings; they are followed by a carriage return and a line feed. In response to any incorrect or undecipherable transmissions, the UCPC transmits the word ERROR followed by a carriage return and line feed. Table 7-2 lists the commands and the counter responses. A simple computer program written in BASIC is listed in the next section to demonstrate the possible interfacing that you can do with the UCPC.

Table 7-2
Computer Commands

Command	Typical UCPC Response	Description
Cx,y	OK	The Calibration command saves a photometric particle concentration value for a given voltage. To enter the calibration data, the configuration paddle switch must first be in the enable position (see Figure 4-2). There are 121 calibration points in the counter: "x" is any voltage in units of one-tenth of a volt. For example, 1 = 0.1 volt and 120 = 12.0 volts. "y" is particle concentration in particles/cm ³ , where 9,990,000 is the largest number allowed. Example: C0,0 C107,9990000 C120,9990000
C	C0,0 C1,0 C2,0 C3,0 C4,0 C5,0 C6,9990000 C120,9990000	The C command by itself lists the one point calibration data.

continued

Table 7-2
Computer Commands (*continued*)

Command	Typical UCPC Response	Description
D	Time Counts,0 0,0 . .(16) . . 0,0	The Dump command initiates a dump of the time and count data in the same manner as a Model 3701 Multiplexer. The currently saved accumulator data is transferred to the serial port. "Time" is the number of seconds since the last D command (99,999,999 maximum). The Channel A (total) and Channel B counts are sent (99,999,999 counts maximum) for each of the 16 channels. Since the UCPC has only one channel of data, Channel B and the last 15 pairs of data are all zero.
ESC	No Response	The Escape command (ASCII 27) causes the counter to clear its address command to the power-on condition (null address) and then pass an ESC to Port B. This command does not require a carriage return or line feed.
I	Label	Identify calibration label
Label	OK	The Label command inputs the calibration label (80 characters maximum). To enter the label, the configuration paddle switch must first be in the enable position (see Figure 4-1). A typical label might include the date of calibration.
R0	FULL NOTFULL	Read liquid level status
R1	10.0	Read condenser temperature, °C
R2	37.0	Read saturator temperature, °C
R3	39.0	Read optics temperature, °C
R4	5.01	Read flow, cm ³ /s

continued

Table 7-2
Computer Commands (*continued*)

Command	Typical UCPC Response	Description
R5	READY NOTREADY	Read environment. READY implies that the temperatures, flow and alcohol level are all within the operating range.
R6	2.000	Read reference detector, volts (set for maximum of 2-4 volts)
R7	0.023	Read detector voltage, volts
R8	558604	Read 200-second buffer, counts
R9	57851	Read 20-second buffer, counts
RA	5618	Read 2-second buffer, counts
RB	2875	Read 1-second buffer, counts
RD	5.84E3	Read the concentration as displayed on the front panel. The concentration may have been derived from the single-particle counting or live-time counting.
RE	128	Read microprocessor pump-control value (a number from 0 to 255, corresponding to a pump voltage of approximately 1.55 to 12 volts).
S	3 0 . .(16) . 0	The Sensor command sends data on the current saved sensor types (identical to the Model 3701). Sensor type 3 is for the Model 3025A UCPC or Model 3022A CPC. There are 16 lines total, the last 15 of which are zeros.
Vx	x	The Voltage Set command is used for the analog output where the response "x" is a number from 0 to 11000 that equals the desired voltage in millivolts.

continued

Table 7-2
Computer Commands (*continued*)

Command	Typical UCPC Response	Description
Wdisplay	OK	Write a message to be displayed on the front panel display. For example: "WHello" displays "Hello" on the front panel. "W@" returns the display to normal. The front panel has a maximum of 12 characters.
X0	OK	Execute laser <i>off</i>
X1	OK	Execute laser <i>on</i>
X2	OK	Execute pump motor <i>off</i>
X3	OK	Execute pump motor <i>on</i>
X4	OK	Does not apply.
X5	OK	Execute filling (open fill valve until full). The fill valve does not open if the liquid level sensor indicates that the reservoir is full.
X6	OK	Execute Clear of concentration buffers
X7	OK	Execute low-flow mode
X8	OK	Execute high-flow mode

BASIC Program: TSIUCPC

The following basic program, which runs only on IBM personal computers or IBM-compatibles, demonstrates how the computer interfaces with the counter using the commands described above. The program can be used to read concentration and total counts over regular preset time intervals. The data can be stored on disk or printed on a printer. A computer is not necessary for normal operation of the counter.

The program is loaded on one 3.5-inch disk. To run the program, first boot the computer and load BASICA or a compatible BASIC interpreter. To load the program, type <LOAD"TSIUCPC.BAS"> and then type <RUN>.

The program has self-explanatory, easy-to-use menus. The various tasks performed by the program are explained in earlier sections of this manual.

This program is intended as a reference guide to those who wish to write their own software. It may be modified as desired. However, TSI cannot support any user-written software except as illustrated in this manual.

Note: *The display nested under (3) Read Menu, (D) Read time, counts and concentration, and (1) Start the measurement gives two concentration measurements. The first is the concentration that can be read from the front panel of the UCPC. The second is the averaged concentration over the time interval. It is calculated by dividing the counts by the time and the flowrate:*

$$\text{Concentration} \left(\frac{\text{Particles}}{\text{cm}^3} \right) = \frac{\text{Counts}}{\text{Time} \times \text{Flowrate}}$$

```

110 REM
12 REM *****
14 REM
15 REM PROGRAM: TSIUCPC.BAS VERSION 1.0 8-AUG-1989
16 REM THIS PROGRAM IS A TEST PROGRAM FOR THE COUNTER 3025A. IT
18 REM PROVIDES THE COMMANDS FOR THE UNIT TO INTERFACE WITH THE
20 REM COMPUTER.
22 REM
24 REM *****
26 REM
28 CLEAR : KEY OFF : WIDTH 80
30 REM
34 OPTION BASE 1 : J =1 : PSIG$ = "OFF" : PFLAG = 2
36 REM
38 CLS : LOCATE 4,25 : PRINT " TSI INCORPORATED"
40 LOCATE 9, 18 : PRINT "*****"
41 LOCATE 10,18 : PRINT "*"
42 LOCATE 11,18 : PRINT "*" TEST PROGRAM FOR counter 3025A "*"
43 LOCATE 12,18 : PRINT "*"
44 LOCATE 13,18 : PRINT "*****"
48 LOCATE 15,18 : PRINT "PRESS ENTER TO CONTINUE"
50 LOCATE 16,18 : PRINT "PRESS 'ESC' TO END"
52 REM
54 I$ = INKEY$ : IF I$ = CHR$(27) THEN CLS : END
56 IF I$ = "" THEN 54 ELSE 58
58 IF I$ = CHR$(13) THEN 130 ELSE 54
126 REM
127 REM -----
128 REM
130 A = INP (1021) : OPEN "COM1:1200,E,7,1,RS,CS,DS,CD" AS #3
132 PRINT # 3, "A00" : GOSUB 9000
140 CLS : LOCATE 4,25 : PRINT "MAIN MENU"
142 LOCATE 7,15 : PRINT "( 1 ) REINITIALIZE THE ADDRESS OF THE UNIT"
144 REM LOCATE 8,15 : PRINT "( 2 ) PURGE THE UNIT" (3022A OPTION ONLY)
146 LOCATE 9,15 : PRINT "( 3 ) READ MENU"
148 LOCATE 10,15 : PRINT "( 4 ) SET ANALOG OUTPUT VOLTAGE"
150 LOCATE 11,15 : PRINT "( 5 ) WRITE MESSAGE TO DISPLAY"
151 LOCATE 12,15 : PRINT "( 6 ) DELETE MESSAGE ON DISPLAY"
152 LOCATE 13,15 : PRINT "( 7 ) TASK MENU"

```

```

154         LOCATE 14,15 : PRINT "(ESC) TERMINATE THE PROGRAM"
156 I$ = INKEY$ : IF I$ = "1" THEN GOSUB 180 : GOTO 140
158 REM       IF I$ = "2" THEN GOSUB 190 : GOTO 140
160           IF I$ = "3" THEN GOSUB 200 : GOTO 140
162           IF I$ = "4" THEN GOSUB 210 : GOTO 140
164           IF I$ = "5" THEN GOSUB 220 : GOTO 140
165           IF I$ = "6" THEN GOSUB 230 : GOTO 140
166           IF I$ = "7" THEN GOSUB 240 : GOTO 140
168           IF I$ = CHR$(27) THEN CLOSE # 3 : CLS : END
170           GOTO 156
171 END
172 REM
175 REM -----
176 REM
178 REM   REINITIALIZE THE UNIT TO A POWER ON CONDITION
179 REM
180 CLS : PRINT # 3, CHR$(27);
181 LOCATE 8,15 : PRINT "ENTER A NEW ADDRESS TO THE UNIT "
182 LOCATE 9,15 : PRINT "(the address can be 00 thru 99)"
183 LOCATE 12,18 : INPUT ADRES : AD$ = STR$(ADRES) : ADD$ = A$ + AD$
184 PRINT # 3, ADD$ : GOSUB 9000
185 RETURN
187 REM
188 REM : PURGE THE UNIT FOR THE GIVEN NUMBER OF SECONDS
189 REM   (3022A OPTION ONLY)
190 REM CLS : LOCATE 8,15 : PRINT "ENTER THE NUMBER OF SECONDS FOR PURGING"
191 REM       LOCATE 9,15 : PRINT "(maximum is 999 seconds)"
192 REM       LOCATE 10,15 : INPUT PTIME : PP$ = STR$(PTIME) : PL = LEN(PP$)
193 REM       P% = "P" + RIGHT$(PP$,PL-1) : GOSUB 2000
194 REM       RETURN
197 REM
198 REM   GO TO THE READ MENU FOR VARIOUS READINGS
199 REM
200 CLS : GOSUB 270 : RETURN
207 REM
208 REM   SET THE ANALOG OUTPUT VOLTAGE
209 REM
210 CLS : LOCATE 8,15 : PRINT "ENTER THE ANALOG OUTPUT VOLTAGE IN millivolt"
211       LOCATE 9,15 : PRINT "(maximum is 11000 millivolts)"
212       LOCATE 10,15 : INPUT AVOLT : AV$ = STR$(AVOLT) : AL = LEN(AV$)
213       AV$ = "V" + RIGHT$(AV$,AL-1)
214       PRINT # 3, AV$ : GOSUB 9000
215 RETURN
217 REM
218 REM   WRITE MESSAGE TO DISPLAY ON THE FRONT PANEL
219 REM
220 CLS : LOCATE 8,15 : PRINT "ENTER THE MESSAGE TO BE DISPLAY ON THE PANEL"
221       LOCATE 9,15 : PRINT "(maximum # of characters is 12)"
222       LOCATE 10,15 : INPUT D$ : D$ = D$ + " " : WW$ = "W" + D$
223       PRINT # 3, WW$ : GOSUB 9000
225 RETURN
227 REM
228 REM   CLEAR THE MESSAGE ON THE FRONT PANEL DISPLAY
229 REM
230 CLS : PRINT # 3, "W " : GOSUB 9000 : PRINT # 3, "W@" : GOSUB 9000
231 RETURN
237 REM
238 REM   PERFORM VARIOUS TASKS -- TASK MENU
239 REM
240 CLS : LOCATE 4,25 : PRINT "TASK MENU"
241       LOCATE 7,15 : PRINT "( 1 ) EXECUTE LASER OFF"
242       LOCATE 8,15 : PRINT "( 2 ) EXECUTE LASER ON"
243       LOCATE 9,15 : PRINT "( 3 ) EXECUTE PUMP MOTOR OFF"
244       LOCATE 10,15 : PRINT "( 4 ) EXECUTE PUMP MOTOR ON"
245 REM     LOCATE 11,15 : PRINT "( 5 ) EXECUTE DRAINING" (3022A OPTION ONLY)
246       LOCATE 12,15 : PRINT "( 6 ) EXECUTE FILLING"
247       LOCATE 13,15 : PRINT "( 7 ) EXECUTE RESET OF CONCENTRATION BUFFER"
248       LOCATE 14,15 : PRINT "( 8 ) LOW FLOW SETTING"

```

```

249         LOCATE 15,15 : PRINT "( 9 ) HIGH FLOW SETTING"
250         LOCATE 16,15 : PRINT "(ESC) RETURN TO THE MAIN MENU"
251 I$ = INKEY$ : IF I$ = "1" THEN GOSUB 500 : GOTO 240
252         IF I$ = "2" THEN GOSUB 510 : GOTO 240
253         IF I$ = "3" THEN GOSUB 520 : GOTO 240
254         IF I$ = "4" THEN GOSUB 530 : GOTO 240
255 REM     IF I$ = "5" THEN GOSUB 540 : GOTO 240
256         IF I$ = "6" THEN GOSUB 550 : GOTO 240
257         IF I$ = "7" THEN GOSUB 560 : GOTO 240
258         IF I$ = "8" THEN GOSUB 570 : GOTO 240
259         IF I$ = "9" THEN GOSUB 580 : GOTO 240
260         IF I$ = CHR$(27) THEN RETURN
261         GOTO 251
262 RETURN
267 REM
268 REM -----
269 REM
270 CLS : LOCATE 4,25 : PRINT "READ MENU" : FILE$ = ""
275 LOCATE 8,15 : PRINT "( 1 ) READ liquid level"
280 LOCATE 9,15 : PRINT "( 2 ) READ CONDENSOR TEMPERATURE"
290 LOCATE 10,15 : PRINT "( 3 ) READ saturator TEMPERATURE"
300 LOCATE 11,15 : PRINT "( 4 ) READ optics TEMPERATURE"
310 LOCATE 12,15 : PRINT "( 5 ) READ condenser FLOW
320 LOCATE 13,15 : PRINT "( 6 ) READ environment"
330 LOCATE 14,15 : PRINT "( 7 ) READ reference detector"
340 LOCATE 15,15 : PRINT "( 8 ) READ detector voltage"
350 LOCATE 16,15 : PRINT "( 9 ) READ 200 SECOND BUFFER"
360 LOCATE 17,15 : PRINT "( A ) READ 20 SECOND BUFFER"
370 LOCATE 18,15 : PRINT "( B ) READ 2 SECOND BUFFER"
380 LOCATE 19,15 : PRINT "( C ) READ 1 SECOND BUFFER"
390 LOCATE 20,15 : PRINT "( D ) READ TIME, COUNTS AND CONCENTRATION"
391 LOCATE 21,15 : PRINT "( E ) READ THE MICROPROCESSOR PUMP CONTROL OUTPUT"
392 LOCATE 22,15 : PRINT "(ESC) RETURN TO THE MAIN MENU"
393 J$ = INKEY$ : IF J$ = "1" THEN GOSUB 2050 : GOTO 270
394         IF J$ = "2" THEN GOSUB 3000 : GOTO 270
395         IF J$ = "3" THEN GOSUB 3050 : GOTO 270
396         IF J$ = "4" THEN GOSUB 4000 : GOTO 270
397         IF J$ = "5" THEN GOSUB 4050 : GOTO 270
398         IF J$ = "6" THEN GOSUB 5000 : GOTO 270
399         IF J$ = "7" THEN GOSUB 5050 : GOTO 270
400         IF J$ = "8" THEN GOSUB 6000 : GOTO 270
401         IF J$ = "9" THEN GOSUB 6050 : GOTO 270
402         IF J$ = "A" THEN GOSUB 7000 : GOTO 270
403         IF J$ = "B" THEN GOSUB 7050 : GOTO 270
404         IF J$ = "C" THEN GOSUB 8000 : GOTO 270
405         IF J$ = "D" THEN GOSUB 8050 : GOTO 270
406         IF J$ = "E" THEN GOSUB 8950 : GOTO 270
407         IF J$ = CHR$(27) THEN RETURN
408         GOTO 393
409 RETURN
495 REM
496 REM -----
497 REM
498 REM   COMMANDS CORRESPOND TO THE TASK MENU
499 REM
500     PRINT # 3, "X0" : RETURN
510     PRINT # 3, "X1" : RETURN
520     PRINT # 3, "X2" : RETURN
530     PRINT # 3, "X3" : RETURN
540 REM   PRINT # 3, "X4" : RETURN (3022A OPTION ONLY)
550     PRINT # 3, "X5" : RETURN
560     PRINT # 3, "X6" : RETURN
570     PRINT # 3, "X7" : RETURN
580     PRINT # 3, "X8" : RETURN
590 REM
1996 REM -----
1997 REM
1998 REM   SUBROUTINE FOR PURGING

```

```

1999 REM (3022A OPTION ONLY)
2000 REM PRINT # 3, P$
2001 REM CLS : LOCATE 5,15 : PRINT "PURGING IS IN PROGRESS"
2002 REM TT = TIMER + PTIME
2003 REM LOCATE 10,15 : PRINT "PURGING TIME IS IN " : LOCATE 10,42 : PRINT "SEC
ONDS:
2004 REM WHILE TIMER < (TT - .5)
2006 REM     LOCATE 10,35 : PRINT INT(TT - TIMER)
2008 REM WEND
2009 REM GOSUB 9000
2010 RETURN
2012 REM
2046 REM-----
2047 REM
2048 REM SUBROUTINE FOR READING THE LIQUID LEVEL
2049 REM
2050 PRINT # 3, "R0"
2052 GOSUB 9000 : IF ZZ$ = "" THEN 2052 ELSE 2054
2054 LIQLEVEL$ = ZZ$
2056 CLS : LOCATE 5,15 : PRINT "THE LIQUID LEVEL IS "; LIQLEVEL$
2058 LOCATE 22,15 : PRINT "HIT 'M' TO RETURN TO THE MAIN MENU"
2060 I$ = INKEY$ : IF I$ = "M" OR I$ = "m" THEN RETURN ELSE 2060
2062 REM
2996 REM-----
2997 REM
2998 REM SUBROUTINE FOR READING THE CONDENSOR TEMPERATURE
2999 REM
3000 PRINT # 3, "R1"
3002 GOSUB 9000 : IF ZZ$ = "" THEN 3002 ELSE 3004
3004 CONDTEMP = VAL(ZZ$)
3006 CLS : LOCATE 5,15 : PRINT "THE CONDENSOR TEMPERATURE IS "; CONDTEMP ;
"oC"
3008 LOCATE 22,15 : PRINT "HIT 'M' TO RETURN TO THE MAIN MENU"
3010 I$ = INKEY$ : IF I$ = "M" OR I$ = "m" THEN RETURN ELSE 3010
3012 REM
3046 REM-----
3047 REM
3048 REM SUBROUTINE FOR READING THE SATURATOR TEMPERATURE
3049 REM
3050 PRINT # 3, "R2"
3052 GOSUB 9000 : IF ZZ$ = "" THEN 3052 ELSE 3054
3054 SATTEMP = VAL(ZZ$)
3056 CLS : LOCATE 5,15 : PRINT "THE SATURATOR TEMPERATURE IS ";SATTEMP ; "o
C"
3058 LOCATE 22,15 : PRINT "HIT 'M' TO RETURN TO THE MAIN MENU"
3060 I$ = INKEY$ : IF I$ = "M" OR I$ = "m" THEN RETURN ELSE 3060
3062 REM
3996 REM-----
3997 REM
3998 REM SUBROUTINE FOR READING THE OPTICS TEMPERATURE
3999 REM
4000 PRINT # 3, "R3"
4002 GOSUB 9000 : IF ZZ$ = "" THEN 4002 ELSE 4004
4004 OPTTEMP = VAL(ZZ$)
4006 CLS : LOCATE 5,15 : PRINT "THE OPTICS TEMPERATURE IS "; OPTTEMP ; "oC"
4008 LOCATE 22,15 : PRINT "HIT 'M' TO RETURN TO THE MAIN MENU"
4010 I$ = INKEY$ : IF I$ = "M" OR I$ = "m" THEN RETURN ELSE 4010
4012 REM
4046 REM-----
4047 REM
4048 REM SUBROUTINE FOR READING THE CONDENSER FLOW
4049 REM
4050 PRINT # 3, "R4"
4052 GOSUB 9000 : IF ZZ$ = "" THEN 4052 ELSE 4054
4054 FFLOW = VAL(ZZ$)
4056 CLS : LOCATE 5,15 : PRINT "THE FLOW IS " FFLOW ; "cc/second"
4058 LOCATE 22,15 : PRINT "HIT 'M' TO RETURN TO THE MAIN MENU"

```



```

4060     I$ = INKEY$ : IF I$ = "M" OR I$ = "m" THEN RETURN ELSE 4060
4062 REM
4996 REM-----
4997 REM
4998 REM  SUBROUTINE FOR READING THE ENVIRONMENT
4999 REM
5000     PRINT # 3, "R5"
5002     GOSUB 9000 : IF ZZ$ = "" THEN 5002 ELSE 5004
5004     ENV$ = ZZ$
5006     CLS : LOCATE 5,15 : PRINT " THE ENVIRONMENT IS "; ENV$
5008     LOCATE 22,15 : PRINT "HIT 'M' TO RETURN TO THE MAIN MENU"
5010     I$ = INKEY$ : IF I$ = "M" OR I$ = "m" THEN RETURN ELSE 5010
5012 REM
5046 REM-----
5047 REM
5048 REM  SUBROUTINE FOR READING THE REFERENCE DETECTOR
5049 REM
5050     PRINT # 3, "R6"
5052     GOSUB 9000 : IF ZZ$ = "" THEN 5052 ELSE 5054
5054     REFDET = VAL(ZZ%)
5056     CLS : LOCATE 5,15 : PRINT "THE REFERENCE DETECTOR IS "; REFDET; "volt"

5058     LOCATE 22,15 : PRINT "HIT 'M' TO RETURN TO THE MAIN MENU"
5060     I$ = INKEY$ : IF I$ = "M" OR I$ = "m" THEN RETURN ELSE 5060
5062 REM
5996 REM-----
5997 REM
5998 REM  SUBROUTINE FOR READING THE DETECTOR VOLTAGE
5999 REM
6000     PRINT # 3, "R7"
6002     GOSUB 9000 : IF ZZ$ = "" THEN 6002 ELSE 6004
6004     DETVOLT = VAL(ZZ$)
6006     CLS : LOCATE 5,15 : PRINT "THE DETECTOR VOLTAGE IS "; DETVOLT; "volt"
6008     LOCATE 22,15 : PRINT "HIT 'M' TO RETURN TO THE MAIN MENU"
6010     I$ = INKEY$ : IF I$ = "M" OR I$ = "m" THEN RETURN ELSE 6010
6012 REM
6046 REM-----
6047 REM
6048 REM  SUBROUTINE FOR READING THE 200 SECOND BUFFER
6049 REM
6050     PRINT # 3, "R8"
6052     GOSUB 9000 : IF ZZ$ = "" THEN 6052 ELSE 6054
6054     BUF200 = VAL(ZZ$)
6056     CLS : LOCATE 5,15 : PRINT "THE 200 SECOND BUFFER IS "; BUF200
6057     LOCATE 22,15 : PRINT "HIT 'M' TO RETURN TO THE MAIN MENU"
6058     I$ = INKEY$ : IF I$ = "M" OR I$ = "m" THEN RETURN ELSE 6058
6060 REM
6996 REM-----
6997 REM
6998 REM  SUBROUTINE FOR READING THE 20 SECOND BUFFER
6999 REM
7000     PRINT # 3, "R9"
7002     GOSUB 9000 : IF ZZ$ = "" THEN 7002 ELSE 7004
7004     BUF20 = VAL(ZZ$)
7006     CLS : LOCATE 5,15 : PRINT "THE 20 SECOND BUFFER IS "; BUF20
7008     LOCATE 22,15 : PRINT "HIT 'M' TO RETURN TO THE MAIN MENU"
7010     I$ = INKEY$ : IF I$ = "M" OR I$ = "m" THEN RETURN ELSE 7010
7012 REM
7046 REM-----
7047 REM
7048 REM  SUBROUTINE FOR READING THE 2 SECOND BUFFER
7049 REM
7050     PRINT # 3, "RA"
7052     GOSUB 9000 : IF ZZ$ = "" THEN 7052 ELSE 7054
7054     BUF2 = VAL(ZZ$)
7056     CLS : LOCATE 5,15 : PRINT "THE 2 SECOND BUFFER IS "; BUF2
7058     LOCATE 22,15 : PRINT "HIT 'M' TO RETURN TO THE MAIN MENU"
7060     I$ = INKEY$ : IF I$ = "M" OR I$ = "m" THEN RETURN ELSE 7060

```

```

7062 REM-----
7996 REM-----
7997 REM
7998 REM SUBROUTINE FOR READING THE 1 SECOND BUFFER
7999 REM
8000 PRINT # 3, "RB"
8002 GOSUB 9000 : IF ZZ$ = "" THEN 8002 ELSE 8004
8004 BUF1 = VAL(ZZ$)
8006 CLS : LOCATE 5,15 : PRINT "THE 1 SECOND BUFFER IS "; BUF1
8008 LOCATE 22,15 : PRINT "HIT 'M' TO RETURN TO THE MAIN MENU"
8010 I$ = INKEY$ : IF I$ = "M" OR I$ = "m" THEN RETURN ELSE 8010
8012 REM
8046 REM-----
8047 REM
8048 REM MENU FOR THE CONCENTRATION, COUNTS AND TIME MEASUREMENTS
8049 REM
8050 CLS : LOCATE 4,25 : PRINT "CONCENTRATION MENU"
8052 LOCATE 7,15 : PRINT "( 1 ) START THE MEASUREMENT"
8054 LOCATE 8,15 : PRINT "( 2 ) SET THE TIME INTERVAL"
8056 LOCATE 9,15 : PRINT "( 3 ) STORE DATA IN DATA FILE"
8058 LOCATE 10,15 : PRINT "( 4 ) HAVE PRINTOUT DURING MEASUREMENT"
8059 LOCATE 11,15 : PRINT "( 5 ) NO PRINTOUT DURING MEASUREMENT"
8060 LOCATE 12,15 : PRINT "(ESC) RETURN TO THE READ MENU"
8061 LOCATE 22,5 : PRINT "PRINTER IS ' " ; PSIG$ ; "' : "
8062 LOCATE 22,30 : PRINT "FILENAME IS ' " ; FILE$ ; "' "
8063 LOCATE 23,5 : PRINT "TIME INTERVAL IS " ; DT ; "seconds"
8064 I$ = INKEY$ : IF I$ = "1" THEN GOSUB 8500 : GOTO 8050
8065 IF I$ = "2" THEN GOSUB 8800 : GOTO 8050
8066 IF I$ = "3" THEN GOSUB 8900 : GOTO 8050
8068 IF I$ = "4" THEN PFLAG = 1 : PSIG$ = "ON" : GOTO 8050
8070 IF I$ = "5" THEN PFLAG = 2 : PSIG$ = "OFF" : GOTO 8050
8072 IF I$ = CHR$(27) THEN CLOSE # 1 : RETURN
8074 GOTO 8064
8076 RETURN
8078 REM
8496 REM-----
8497 REM
8498 REM SUBROUTINE FOR THE CONCENTRATION, COUNTS AND TIME MEASUREMENTS
8499 REM
8500 CLS : LOCATE 4,10 : PRINT "THE TIME INTERVAL IN seconds"
8503 LOCATE 16,10 : PRINT "THE AVERAGE CONCENTRATION OVER THE TIME INTERVAL IN p
articles/cc"
8504 LOCATE 8,10 : PRINT "THE counter CONCENTRATION IN particles/cc"
8506 LOCATE 12,10 : PRINT "THE COUNTS SINCE THE LAST MEASUREMENT "
8508 LOCATE 22,10 : PRINT "HIT 'S' TO STOP:"
8509 IF PFLAG = 1 THEN LPRINT " TIME CONCENTRATION COUNTS"
8510 REM
8512 GOSUB 8568 : IF I$ = "S" OR I$ = "s" THEN RETURN ELSE GOSUB 8532 : GOSUB 860
0
8514 REM
8516 IF FFLAG = 1F THEN PRINT # 1, REALT$, CON, TCOUNT, AVECON
8517 IF PFLAG = 1 THEN LPRINT REALT$, CON, TCOUNT, AVECON
8518 REM
8520 I$ = INKEY$ : IF I$ = "S" OR I$ = "s" THEN RETURN ELSE 8522
8522 IF I$ = "" THEN 8512 ELSE 8520
8526 REM
8528 REM READ CONCENTRATION
8530 REM
8532 PRINT # 3, "RD"
8533 GOSUB 9000 : IF ZZ$ = "" THEN 8533 ELSE 8534
8534 CONL = VAL(ZZ$) : IF CONL > 10000 THEN 8542 ELSE 8550
8536 REM
8538 REM READ PHOTOMETRIC CONCENTRATION
8540 REM
8542 PRINT # 3, "RC"
8544 GOSUB 9000 : IF ZZ$ = "" THEN 8544 ELSE 8546
8546 CONH = VAL(ZZ$)
8548 CON = CONH : GOTO 8558

```

```

8550 CON = CONL
8552 REM
8554 REM PRINTOUT THE CONCENTRATION
8556 REM
8558 LOCATE 10,18 : PRINT "          " : LOCATE 10,18 : PRINT CON
8559 RETURN
8560 REM
8561 REM-----
8562 REM
8564 REM SUBROUTINE FOR COUNTING THE TIME INTERVAL IN SECONDS
8566 REM
8568 T = TIMER + DT
8570 WHILE TIMER < (T - .5)
8571     IF T > 86399! AND TIMER < .5 THEN T = T - 86400!
8575     LOCATE 6,20 : PRINT INT(T - TIMER)
8576     I$ = INKEY$:IF I% = "s" OR I$ = "S" THEN RETURN
8578 WEND
8579 REM RETRIEVE THE REAL TIME FROM THE COMPUTER
8580 REM
8582 REALT$ = TIME$ ' the real time has the form "hh:mm:ss"
8584 RETURN
8586 REM
8596 REM-----
8597 REM
8598 REM SUBROUTINE FOR TAKING THE TOTAL COUNTS
8599 REM
8600 PRINT # 3, "D"
8602 GOSUB 9000 : TOTIME = VAL(ZZ$)
8604 GOSUB 9000 : N = LEN (ZZ$) : N1 = N - 2 : ZZZ$ = LEFT$(ZZ$,N1) : TCOUNT = VA
8605 AVECON = TCOUNT/(TOTIME*5)
L(ZZZ$)
8606 FOR I = 1 TO 15
8608     GOSUB 9000
8610 NEXT I
8612 LOCATE 14,18 : PRINT "          " : LOCATE 14,18 : PRINT TCOUNT

8613 LOCATE 18,18 : PRINT "          " : LOCATE 18,18 :
PRINT AVECON
8614 RETURN
8616 REM
8796 REM-----
8797 REM
8798 REM GET THE TIME INTERVAL
8799 REM
8800 CLS : LOCATE 10,5 : PRINT "ENTER THE TIME INTERVAL IN SECONDS"
8802 LOCATE 12,8 : INPUT DT
8804 RETURN
8806 REM
8896 REM-----
8897 REM
8898 REM INPUT THE DATA FILE NAME
8899 REM
8900 CLS : LOCATE 10,5 : PRINT "INPUT THE FILENAME OF THE DATA FILE"
8902 LOCATE 12,8 : INPUT FILE$
8904 OPEN FILE$ FOR OUTPUT AS # 1
8906 FFLAG = 1 'set FFLAG = 1 for storing the data
8908 RETURN
8910 REM
8912 REM-----
8940 REM
8942 REM SUBROUTINE FOR READING THE MICROPROCESSOR PUMP CONTROL OUTPUT
8944 REM
8950 PRINT # 3, "RE"
8952 GOSUB 9000 : IF ZZ$ = "" THEN 8952 ELSE 8954
8954 DUTYC = VAL(ZZ$) : DUTYV = 10.45/255! * DUTYC+1.55
8956 CLS : LOCATE 5,15 : PRINT "OUTPUT OF THE MICROPROCESSOR CONTROL : "
8958 LOCATE 6,20 : PRINT "(output of 0 is equivalent to 1.55 volt;"
8960 LOCATE 7,20 : PRINT " output of 255 is equivalent to 12 volt. )"

```

```

8962     LOCATE 8,22 : PRINT "OUTPUT = "; DUTYC; " ("; DUTYV; "volt)"
8964     LOCATE 22,15 : PRINT "HIT 'M' TO RETURN TO THE MAIN MENU"
8966     I$ = INKEY$ : IF I$ = "M" OR I$ = "m" THEN RETURN ELSE 8966
8968 REM
8970 REM-----
8996 REM-----
8997 REM
8998 REM  SUBROUTINE TO TAKE DATA FROM counter
8999 REM
9000 Z$ = "" : ZZ$ = "" : K = 0
9002 WHILE K < 1000
9004     IF LOC(3) > 0 THEN Z$ = INPUT$(1,#3) : K = 0
9006     IF Z$ = CHR$(13) THEN RETURN
9008     IF Z$ <> CHR$(10) AND Z$ <> "" THEN ZZ$ = ZZ$ + Z$ : Z$ = ""
9010     K = K + 1
9012 WEND
9014 RETURN
9016 REM
9020 REM*****

```

CHAPTER 8

Maintenance and Service

Regular maintenance of the Model 3025A Ultrafine Condensation Particle Counter (UCPC) will help ensure years of useful operation. The frequency of service depends on the frequency of use and the cleanliness of the air measured. This section describes how to check and service some components of the UCPC.

Changing the Filters

There are four types of filters inside the UCPC. Change them at regular intervals (depending on use) or whenever they become dirty, clogged, or wet.

Note: *Several replacement filters are included in the accessory kit.*

HEPA Filter

The large HEPA filter collects particles from the combination of sample flow before the flow enters the pump. The filter has a very large surface area for collecting the particles and requires infrequent changing.

To change the filter, remove the top cabinet cover and pull the filter out of its holding clips. Remove the two end fittings and replace them on a new filter. Make sure that the connections are leak-tight.

To order replacement HEPA filters, use part number 1602051; or, you can order HEPA capsule filters (no. 12144) directly from the manufacturer:

Gelman Sciences, Inc.
600 S. Wagner Road
Ann Arbor, MI 48106 / USA
Telephone: (313) 665-0651
Telex: 810-223-6037

Tube Filter

The tube filter is in the sensor housing, surrounded by pink insulation. It filters out particles from the sample air after the air passes by the optical detector and before the air reaches the capillary flowmeter. Replace it at least once a year. Follow these six steps.

1. To replace the tube filter, disconnect the fill bottle.
2. Remove the covers at the top and bottom of the cabinet.
3. Find the filter plug on the lower left-hand side of the counter (Figure 8-1) above the inlet to the saturator.
4. Unscrew and remove the filter plug.



Figure 8-1
Locating the Filter Plug Inside the UCPC (a) Front Panel; (b) Filter Plug

5. Pull out the filter tube and replace it with a new filter (Figure 8-2). Make sure the tube is centered and fits snugly inside the mounting hole.
6. Replace the filter plug and tighten it so that the end of the plug is flush with the sensor housing.



Figure 8-2
Replacing the Filter Tube: (a) Filter

To order the tube filters, order part number 1602061; or, order a Microfibre filter tube (no. 050-11-BX) directly from the manufacturer:

Balston, Inc.
703 Massachusetts Avenue
P.O. Box C
Lexington, MA 02173
U.S.A.
Telephone: (800) 343-3048
Telex: 92-3481

In-Line Filters

Several types of in-line filters are used in the counter to filter the aerosol and to provide flow control (see Chapter 5). These become dirty or clogged over time and may require replacement.

Replacement filters may be ordered from TSI or directly from the manufacturer listed below. The appropriate part numbers are:

Table 8-1
Replacement Filters

Mfg. Part No.*	TSI Part No.
DFU-9922-05-AQ	1602067
DFU-9922-05-BQ	1602060
DFU-9922-05-DQ	1602080

*Balton, Inc.; 703 Massachusetts Avenue; P.O. Box C; Lexington, MA 02173; U.S.A.; Telephone (800) 343-3048; Telex 92-3481.

Installing an EPROM

Upgrading the EPROM is a special maintenance procedure. This procedure is not considered routine and should only be attempted by someone who is familiar with the operation of the UCPC and who is technically qualified.

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



C a u t i o n

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

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

Refer to Figures 8-3 and 8-4 and the following instructions to install an EPROM in a Model 3025A UCPC.

Tools Needed

You need a small, flat screwdriver or 28-pin chip extractor, a Phillips-head screwdriver, a grounded, static-discharging wriststrap, and an antistatic mat.

- 1.** Remove power from the UCPC and from any other instruments connected to the UCPC.
- 2.** Place the UCPC on an antistatic mat. If the liquid reservoir is full, avoid tipping or moving the UCPC so that liquid does not spill.
- 3.** Using Figure 8-3 as a reference, remove the following screws on the UCPC. Separate the screws as you remove them so you can reassemble the UCPC correctly.
 - a.** Remove three screws from each side of the UCPC top cover and remove the top cover.
 - b.** Remove the four corner screws from the UCPC front panel.
 - c.** Remove the four screws and washers from the UCPC front panel connecting the panel to the side bars.

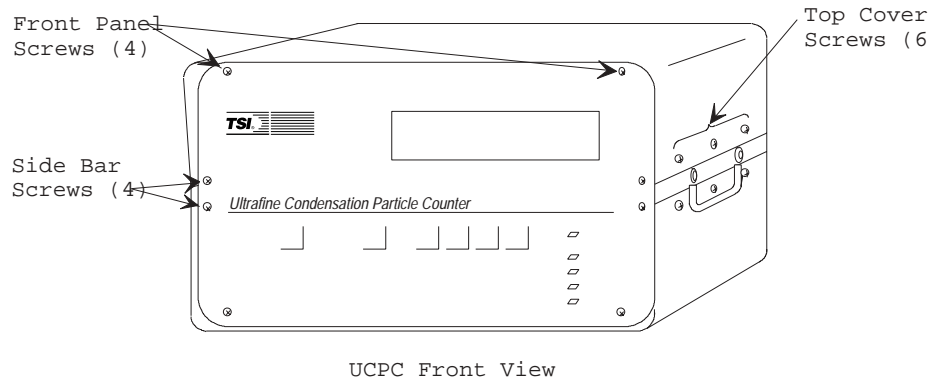


Figure 8-3
Model 3025A Screw Locations

4. Remove the front panel.

Note: Optional

The UCPC front panel is connected to the display board with a ribbon cable. (The display board is the large circuit board parallel to the front panel.) As you remove the front panel, you can disconnect the ribbon cable on the display board, or you can leave it attached.

5. Find the EPROM on the display board, the large circuit board parallel to the UCPC front panel (Figure 8-4). To remove the old EPROM from the display board, use a 28-pin chip extractor or insert the tip of a medium-size flat screwdriver under the short sides of the chip and *gently* twist.

6. Remove the updated version of the EPROM from its static protective wrapper.

7. Align the new EPROM in the socket, making sure the EPROM's notch matches the notch on the circuit board (Figure 8-4). Apply pressure to the center of the chip until it snaps down into the socket. Press *firmly* to make sure it is seated properly and ensure there are no bent or unseated pins.

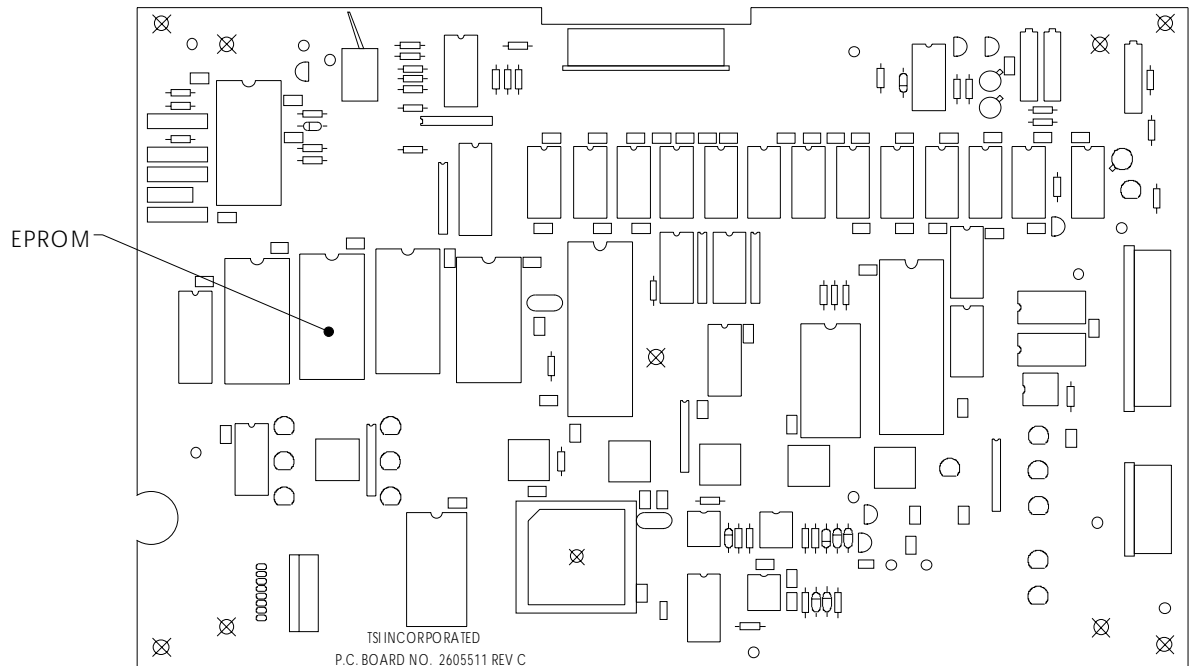


Figure 8-4
EPROM Location on the Model 3025A UCPC Display Board

8. Using Figure 8-3 as a reference, reassemble the UCPC:

- a.** If disconnected, reconnect the ribbon cable connector to the display board.
- b.** Replace the front panel, threading the inlet nozzle through the hole on the panel and positioning the top of the panel so it is level with the UCPC chassis.
- c.** Replace four screws with washers on the UCPC front panel, attaching the panel to the side bars.
- d.** Replace four corner screws on the UCPC front panel, attaching the panel to the chassis.
- e.** Replace the top cover on the UCPC. Make sure the vented side of the cover is opposite the UCPC fan. Attach the cover with six screws.

9. Apply power to the UCPC and make sure the LEDs function.

10. If the UCPC is not functioning properly, remove power and make sure the EPROM is positioned correctly and seated, and there are no bent pins. If the UCPC still does not function properly, contact a TSI representative for assistance.

Checking the Counter for Leaks

A leak anywhere in the counter sensor upstream of the flowmeter changes the flowrate of the sample air. Symptoms of a leak include incorrect flows, incorrect particle concentrations, as well as larger and/or wider photodetector pulse heights than are indicated by the calibration data sheet.

Note: *If you cannot locate and/or repair a leak yourself, contact TSI for assistance.*

To check the UCPC for leaks, perform the following eight steps.

1. Drain the unit of liquid and switch off the power.
2. Remove the top cabinet cover.
3. Disconnect the pump for the leak-check by disconnecting the fitting to the inlet side of the pump at the plastic tee in front of and below the HEPA filter.
4. Disconnect the pressure transducer air tubes and plug the ends. The pressure transducers must *not* be subjected to high vacuum or high pressure.
5. Plug the plastic tee side connected to the pump. Connect a vacuum source to the counter inlet. Connect a pressure gauge or manometer to the vacuum as shown in Figure 8-5. Install a shut-off valve between the vacuum pump and the pressure gauge.
6. Draw at least 560 mm Hg [300 inches of water] vacuum through the instrument and close the valve. Switch off the vacuum pump.
7. Check that the counter loses no more than 5.6 mm Hg [3 inches of water] vacuum in a 10-minute period.

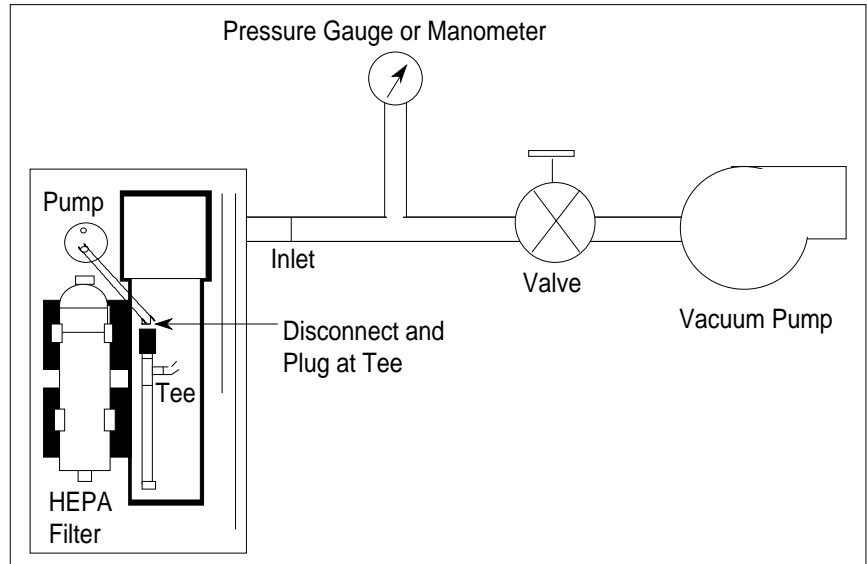


Figure 8-5
Checking for Leaks with a Vacuum

- 8.** If you find that the counter leaks, first tighten all fittings and screws and repeat the vacuum test. To locate a small leak, replace the vacuum source with a compressed air source as shown in Figure 8-6. Introduce approximately 69 kPa [10 psig] into the counter. Search for leaks by squirting a soap-and-water solution around fittings, O-ring seals and any other possible leak locations. A leak shows up as numerous small bubbles in the soapy water. Repair the leak and retest with the vacuum leak test.



C a u t i o n

When using a soap-and-water solution to check for leaks, make sure that the solution does not come in contact with electrical components. If this happens, dry the component thoroughly before turning on the power to the instrument.

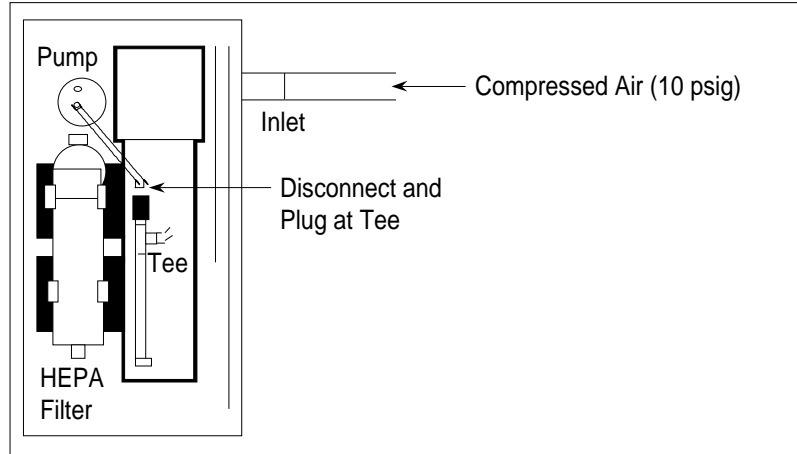


Figure 8-6
Checking for Leaks with Compressed Air

Failures

The microprocessor in the UCPC checks many of the internal parameters for functional failures. If your counter should encounter any of these failures, the front panel reads "FAILURE #X" where "X" is the code number of the failure. The following table lists the failures and possible ways to correct them. If you cannot fix the problem yourself, call TSI for assistance.

Table 8-2
Troubleshooting UCPC Problems

No.	Problem	Suggested Solution
1	Optics temperature is out of normal operating range.	Change optics thermistor.*
2	Condenser temperature is out of normal operating range.	Change condenser thermistor.*
3	Saturator temperature is out of normal operating range.	Change saturator thermistor.*
4	Calibration data is nonmonotonic because the calibration data is missing or incorrect.	Reload the 1-point overrange calibration.*
5	A/D measuring the 10-volt reference is out of range (8000–15,000 equivalent counts per 10 volts).	Recalibrate the A/D in the configuration (Chapter 4). Check that the D/A is producing 10 volts. Change the EPROM.*
6	Total maximum number is invalid.	Rerun the configuration (Chapter 4).
7	Analog output voltage is invalid.	Rerun the configuration (Chapter 4).
8	Baud rate is invalid.	Rerun the configuration (Chapter 4).

Technical Contacts

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

Returning the UCPC for Service

Call TSI Customer Service at 1-800-874-2811 (USA) or (651) 490-2811 for specific return instructions. Customer Service will need this information when you call:

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

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

CHAPTER 9

Applications

The following discussion covers just a few of the many applications for the Model 3025A Ultrafine Condensation Particle Counter (UCPC).

Clean Air

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

The UCPC may not be suitable for placement in very clean areas since its pump, fan and hot electrical components may produce some contaminating particles. If you wish to use the UCPC in a cleanroom or clean zone, place the instrument downstream and out of the way of any critical clean areas.

The Model 3010 CPC, the Model 7610 (formerly Model 3760) CPC, and the Model 7620 (formerly Model 3761) CPC are more suitable for monitoring clean areas because these instruments are designed not to produce particles. Please contact TSI for more information about these CPCs.



C a u t i o n

Although the UCPC is well-suited for monitoring process gases (since it has very low noise counts), it should *not* be used with volatile gases such as oxygen.

Using the Counter With a Multiplexer/Processor

TSI Multiplexer/Processors (M/P) are central, data collection and data processing instruments for up to 16 cleanroom-monitoring particle sensors or environmental sensors. They require a digital, 13-volt input pulse, 6.4-microseconds wide. The maximum concentration that can be collected is 350 particles/cm³ [10 million/ft³]. The Mux Output on the back panel of the UCPC provides the correct digital pulse output for the M/P.

Using the Counter With a Diffusion Battery

The counter measures the number concentration of an aerosol, but gives no information about its size distribution; the droplet size is independent of the size of the initial particle. A diffusion battery separates particles according to their size for particle diameters below about 0.2 micrometer. For a more complete measurement of the concentration and size distribution of an aerosol, operate the counter in series with a diffusion battery.

TSI's Model 3040/3042 Diffusion Battery and Switching Valve consists of a diffusion battery with a pump, flowmeter, and automatic switcher for sampling successive ports in the battery. The system in Figure 9-1 automatically steps through the ports to make repeated measurements of the concentration and size distribution of any test aerosol smaller than 0.2 micrometer. Use the UCPC's Low-flow mode when sampling from the diffusion battery or switching valve.

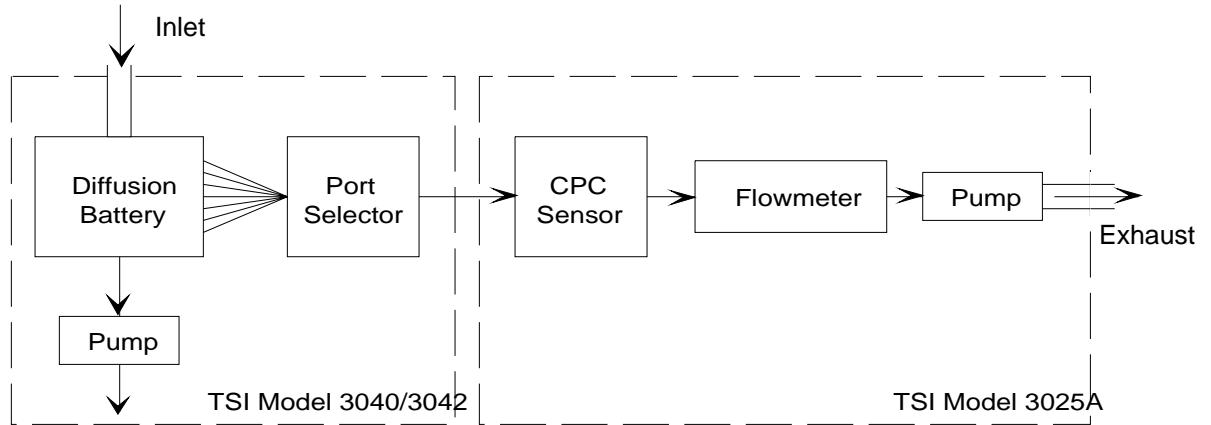


Figure 9-1
Counter, Diffusion, Battery and Switching Valve System for Measuring the Size Distribution of Aerosols Below 0.2 Micrometer in Diameter

Differential Mobility Particle Sizer

A higher resolution system that measures size distribution consists of a counter with an electrostatic classifier (EC) along with interconnecting hardware and software. Figure 9-2 shows the DMPS system in the underpressure mode.

The UCPC has some advantages over the earlier Model 3020 CNC because it can control the EC's center-rod voltage directly from the counter. There is no need for an additional interface box.

To electrically connect the counter to the EC, connect a cable from the analog BNC port on the back panel of the counter to the external program input of the EC on the back panel. Connect the computer's interface cable between the serial port of the computer and the COM PORT on the back panel of the counter. Set the analog output to HOST (see "Configuration" in Chapter 4). To run the DMPS system, follow the instructions given in the menus of the DMPS computer program.

The tubing connections depend on the flowrate you select for the electrostatic classifier. For monodisperse aerosol flows greater than 1.5 liters per minute, run the counter in the high-flow mode. For monodisperse aerosol flows less than 1.5 liters per minute, you

must run the counter in the low-flow mode. In the Low-flow mode, you will likely need to restrict the makeup air flow to force more air to be drawn from the reduced-pressure inlet (see “Inlet Pressure” in Chapter 4). You may have to plug off the makeup air completely.

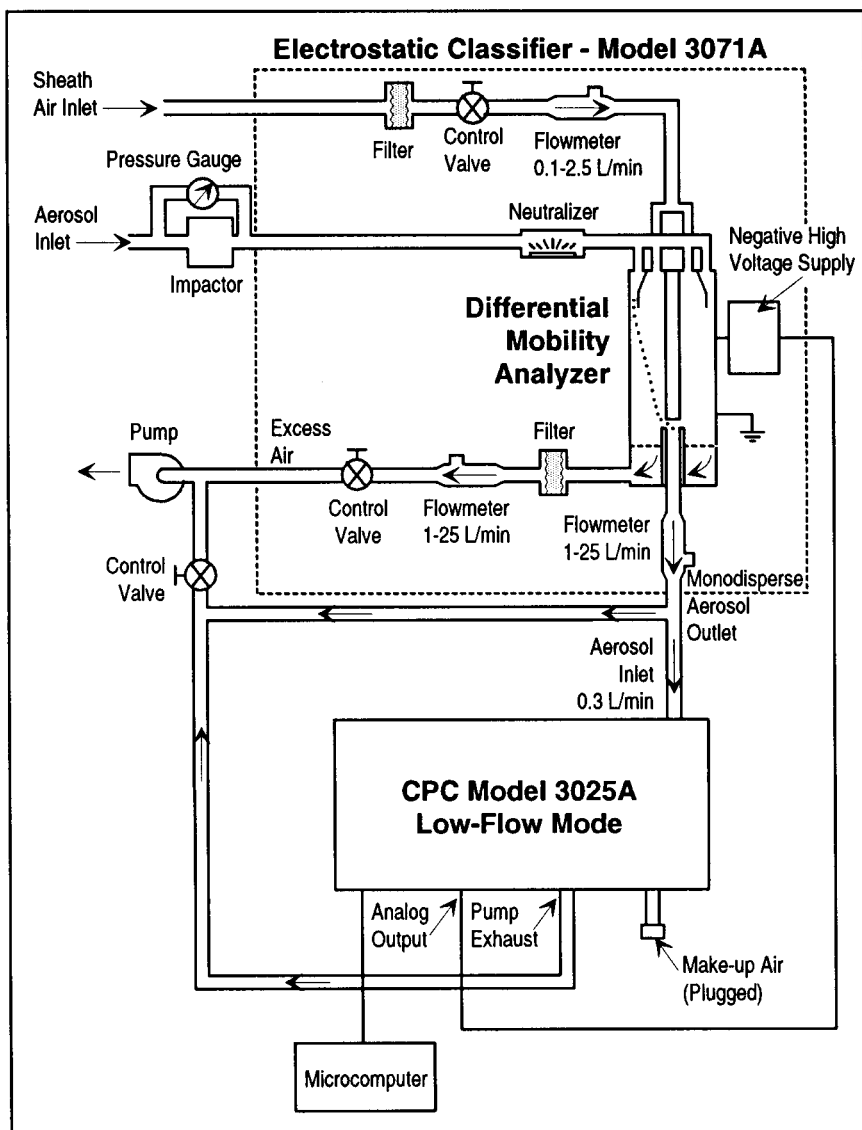


Figure 9-2
Schematic of the DMPs/UCPC in the Underpressure Mode

APPENDIX A

References

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

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

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

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

Bradbury, N.E. and H.J. Meuron [1938]
“The Diurnal Variation of Atmospheric Condensation Nuclei”
Terr. Magn., 43, pp. 231-240

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

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

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

Keady, P.B., F.R. Quant and G.J. Sem [1983]
“Differential Mobility Particle Sizer: A New Instrument for High Resolution Aerosol Size Distribution Measurement Below 1 μm ”
TSI Quarterly, Vol. 9, No. 2, pp. 3-11

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

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

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

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

Kousaka, Y. T. Nida, K. Okuyama and H., Tanaka [1982]
“Development of a Mixing-Type Condensation Nucleus Counter”
J. Aerosol Sci., Vol. 13, No. 3, pp. 231-240

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

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

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

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

- Pollak, L.W. and A.L. Metnieks [1959]
 “New Calibration of Photoelectric Nucleus Counters”
Geofis. Pura Appl., Vol. 43, pp. 285–301
- Quant, F. R., R. Caldow, G.J. Sem, T.J. Addison [1992]
 “Performance of Condensation Particle Counters with Three
 Continuous-Flow Designs”, presented as a poster paper at the
 European Aerosol Conference, Oxford England, Sept. 7-11, 1992.
- Rich, T.A. [1955]
 “A Photoelectric Nucleus Counter with Size Discrimination”
Geofis. Pura Appl., Vol. 31, pp. 60–65
- Scheibel, H.G., and J. Porstendorfer [1983]
 “Generation of Monodisperse Ag- and BaCl- Aerosols with Particle
 Diameters Between 2 and 300 nm. *Journal of Aerosol Science*, 14,
 113-126
- Schlichting [1955]
Boundary Layer Theory, 6th ed., McGraw-Hill, New York
- Sem, G.J., J.K. Agarwal and C.E. McManus [1980]
 “New Automated Diffusion Battery/Condensation Nucleus Counter
 Submicron Sizing System: Description And Comparison with an
 Electrical Aerosol Analyzer”
 Proc. 2nd Symp. Advances in Particulate Sampling and
 Measurement, U.S. Environ. Protection Agency, Research Triangle
 Park, North Carolina
- Sinclair, D. and G.S. Hoopes [1975]
 “A Continuous Flow Nucleus Counter”
J. Aerosol Sci., Vol. 6, pp. 1–7
- Stolzenburg, M.R., and P. H. McMurry [1991]
 “An Ultrafine Aerosol Condensation Nucleus Counter.” *Aerosol
 Science and Technology*, 14, 48-65
- Stolzenburg, M.R. [1988]
 “An Ultrafine Aerosol Size Distribution Measuring System”
 Ph.D. Thesis, University of Minnesota, Minneapolis, Minnesota,
 July

APPENDIX B

Specifications

Table B-1 contains the operating specifications for the Model 3025A Ultrafine Condensation Particle Counter (UCPC). These specifications are subject to change without notice.

Table B-1
Model 3025A Specifications

Minimum particle size	50% detection at 3 nm 90% detection at 5 nm
Flowrate	
Aerosol	30 ± 3 cm ³ /min
Condenser	300 ± 30 cm ³ /min
Inlet, high-flow	1500 ± 150 cm ³ /min
Inlet, low-flow	300 ± 30 cm ³ /min
Working fluid	
n-butyl alcohol	
saturator temperature	37°C ±0.3°C
condenser temperature	10°C ±0.3°C
optics temperature	39°C ±2.0°C
Concentration	0 to 9.99 × 10 ⁴ particles/cm ³
Accuracy	±10% up to 9.99 × 10 ⁴ /cm ³
Particle-pulse height of the photodetector	≅1.4 V typical
Laser power	≅3–5 mW
Detector	See calibration data, Appendix D
Environmental conditions	Indoor use Altitude up to 2000 m (6500 ft) Ambient temperature range n-butyl alcohol 10–37°C Ambient humidity 0–90% RH noncondensing Overvoltage category II Pollution degree II
False background counts	<0.01 particle/cm ³
Response time.....	<1 second for 95% response to concentration step changes when sampling in high-flow mode; <5 seconds when sampling in low-flow mode
Dimensions L × H × W (nominal)	24 cm × 25 cm × 38 cm (9.5 in. × 10 in. × 15 in.)
Weight	11 kg (25 lb)
Power	100/120 V at 50/60 Hz, 180 W, 1.2 A (maximum) 230/240 V at 50/60 Hz, 180 W, 0.6 A (maximum)
Fuse	100/120V ~ T 2.0A/250V 230/240V ~ T 1.0A/250V

APPENDIX C

Technical Paper

This appendix contains this technical paper:

Agarwal, J.K. and G. J. Sem [1978]

“Generating Submicron Monodisperse Aerosols for Instrument
Calibration”

TSI Quarterly, Vol. 4, No. 2, May–June, pp. 3–8

GENERATING SUBMICRON MONODISPERSE AEROSOLS FOR INSTRUMENT CALIBRATION

Jugal K. Agarwal, Ph.D. and Gilmore J. Sem
 TSI Incorporated, St. Paul, Minnesota

The electrostatic classification method is the only known technique for generating monodisperse submicron aerosol of known size. Conventionally, an aerosol electrometer measures the particle concentration of such aerosol. A newly developed condensation nucleus counter, capable of counting single particles, provides another primary method for submicron particle concentration measurements. We found the experimental agreement between these two primary methods to be within 5%.

I. Introduction

A monodisperse aerosol of known size and concentration is useful for instrument calibrations, for basic research on the behavior of aerosols, and for studies of other physical phenomena. The electrostatic classification method of Liu and Pui¹ is the only known technique for generating submicron monodisperse aerosols of known size and concentration. The purpose of this paper is to describe the electrostatic classification method and its application in calibrating a newly developed condensation nucleus counter.

II. Description

The basic electrostatic classification method consists of first generating a polydisperse aerosol with an atomizer and then extracting particles within a narrow size range from this aerosol with a differential electrical mobility classifier. An aerosol electrometer measures particle concentration.

Figure 1 schematically shows the complete system needed to generate monodisperse aerosol for instrument calibration. The first element is an air supply system (TSI Model 3074) used to supply clean, dry air to the

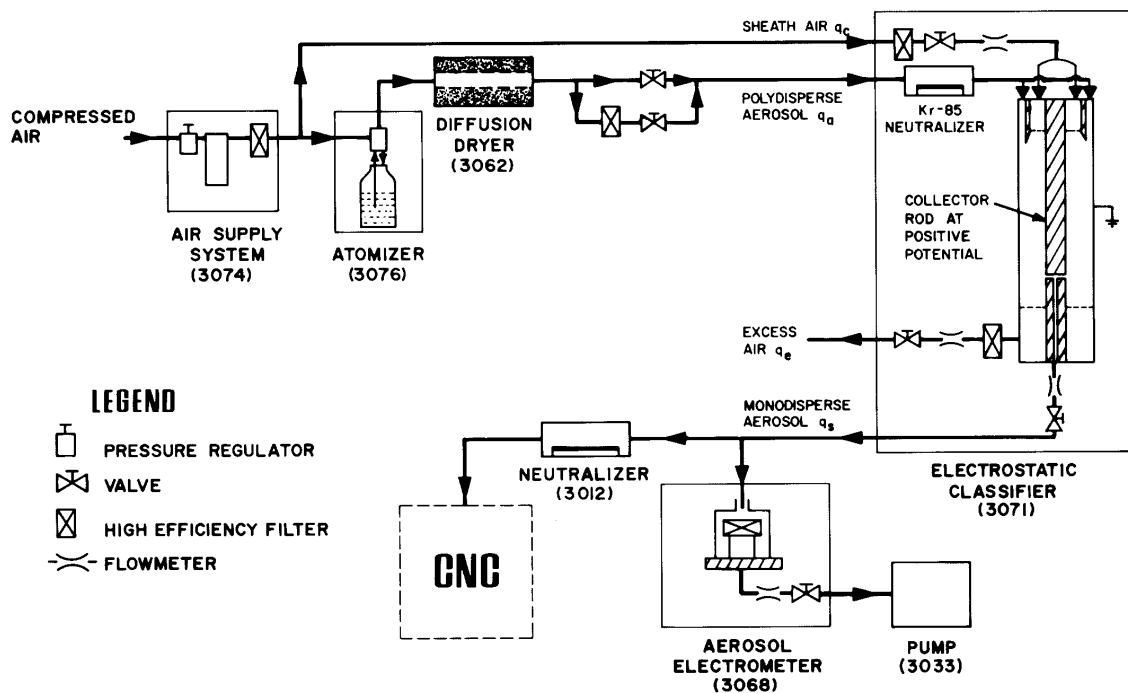


Figure 1. Schematic representation of the electrostatic classification method for generating submicron monodisperse aerosol. TSI model numbers shown in parentheses.

atomizer and to the classifier. The air supply contains a pressure regulator, desiccant air drier, and high efficiency filter. The desiccant air drier removes water and oil vapors from a laboratory compressed air supply. The second element of the system is an atomizer (TSI Model 3076) used to generate polydisperse aerosol. The atomizer, using a recirculating solution, can generate polydisperse aerosol from nearly any water soluble material. The polydisperse aerosol then enters a diffusion drier where the aerosol dries without being diluted. The diffusion drier consists of an inner cylinder made of wire screen and an acrylic outer cylinder. The annular space between the two tubes contains silica gel which absorbs moisture from aerosol passing through the inner tube. The dried polydisperse aerosol then enters the electrostatic classifier (EC, TSI Model 3071).

Classifier

In the EC, a Kr-85 radioactive source brings the polydisperse aerosol to a stable, Boltzmann equilibrium charge level. This process is called aerosol neutralization. At this equilibrium state, the distribution of charges on the particles is given by Boltzmann's Law:

$$\frac{N_{n_p}}{N_0} = \exp\left(-\frac{n_p^2 e^2}{D_p k T}\right) \quad (1)$$

where N_{n_p} and N_0 are the relative number of particles carrying n_p and 0 units of charge, D_p is particle diameter, k is Boltzmann's Constant, T is absolute temperature, and e ($= 1.6 \times 10^{-19}$ coulombs) is the elementary unit of charge. Table I shows the predicted charge distribution according to Boltzmann's Law for particles of various sizes. For $D_p < 0.1 \mu\text{m}$, Table I shows that the majority of particles are either neutral or singly charged.

The neutralized aerosol then enters a differential mobility analyzer (DMA) which classifies the particles according to their electrical mobility. The electrical mobility of a particle is a measure of its ability to move in an electrical field, expressed as the field-induced velocity component per unit electric field intensity. For spheres, the electrical mobility Z_p is related to particle diameter D_p by Equation 2:

$D_p, \mu\text{m}$	Percent of particles carrying n_p elementary charge units									
	$n_p = -4$	-3	-2	-1	0	+1	+2	+3	+4	
0.01				0.34	99.32	0.34				
0.02				5.23	89.53	5.23				
0.04			0.23	16.22	67.10	16.22	0.23			
0.06		0.01	1.25	21.30	54.88	21.30	1.25	0.01		
0.08		0.08	2.78	23.37	47.53	23.37	2.78	0.08		
0.10		0.26	4.39	24.09	42.52	24.09	4.39	0.26		
0.20	0.32	2.33	9.66	22.63	30.06	22.63	9.66	2.33	0.32	
0.40	2.19	5.92	12.05	18.44	21.26	18.44	12.05	5.92	2.19	
0.60	3.82	7.41	11.89	15.79	17.36	15.79	11.89	7.41	3.82	
0.80	4.83	7.94	11.32	14.00	15.03	14.00	11.32	7.94	4.83	
1.00	5.42	8.06	10.71	12.70	13.45	12.70	10.71	8.06	5.42	

Table I. Distribution of charges on aerosol particles according to Boltzmann's Law²

$$Z_p = \frac{neC}{3\pi\mu D_p} \quad (2)$$

where n is the number of elementary charges on the particle, μ is the gas viscosity, and C is the Cunningham slip correction. Figure 2 shows the relationship between electrical mobility and particle diameter for singly-charged particles.

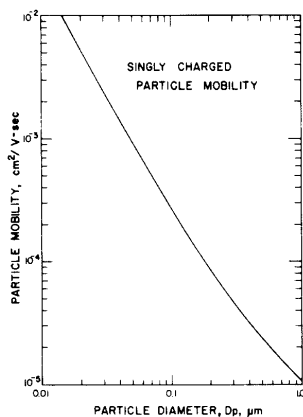


Figure 2. Electrical mobility as a function of particle diameter for singly-charged particles.

Figure 3 schematically shows that the DMA consists of two concentric metal cylinders. Polydisperse aerosol (q_a) and clean sheath air (q_c) enter the analyzer at the top and flow laminarly down the annular space between the cylinders. The aerosol surrounds the central clean air core. A negative volt-

age, applied to the inner metal cylinder (collector rod), causes the particles of positive polarity to be attracted to the collector rod. Particles with higher mobility are precipitated on the upper portion of the rod and those with lower mobility are carried along with the excess air. Only a few particles within a narrow range of electrical mobilities exit through the slit at the bottom of the collector rod.

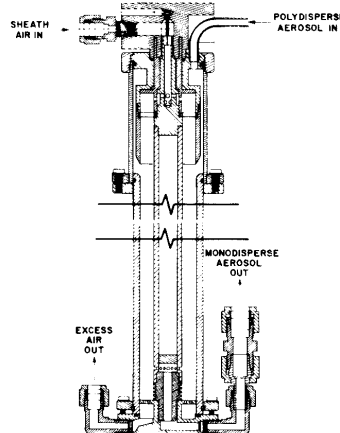


Figure 3. Cross-sectional view of the differential mobility analyzer.

The mean electrical mobility Z_p of the particles extracted through the slit is given by:

$$Z_p = \frac{\left[q_t - \frac{1}{2}(q_s + q_a) \right] \ln \frac{r_2}{r_1}}{2\pi VL} \quad (3)$$

where q_t is total air flow, q_a is polydisperse aerosol flow and q_s is monodisperse aerosol flow, r_1 and r_2 are the inner and outer radii of the annular space, V is the applied voltage on the collector rod, and L is the length of the collector rod between the center of the aerosol entrance and the center of the exit slit.

Particles carrying no charge have zero electrical mobility and are not extracted through the slit of the collector rod. Table I shows that, for particles smaller than $0.1 \mu\text{m}$, the singly-charged particles outnumber the particles with more charges. Thus, if we set the collector rod voltage to extract particles smaller than $0.1 \mu\text{m}$, particles exiting from the differential mobility analyzer will be essentially singly-charged. The diameter of particles exiting through the slit for any voltage setting, can then be calculated from Equations 2 and 3. Figure 4 shows the relationship between the diameter of singly-charged particles and the collector rod voltage for normal operating conditions of the commercial DMA.

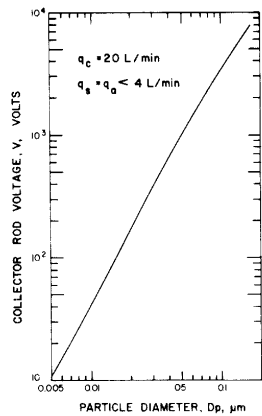


Figure 4. Collector rod voltage as a function of particle diameter for normal operating conditions of the DMA.

Aerosol Electrometer

An aerosol electrometer (AE, TSI Model 3068) measures the particle concentration of aerosol exiting from the classifier. Aerosol is drawn into the AE by an external pump. A built-in flowmeter measures aerosol sample rate. An electrically isolated high efficiency filter collects the charged particles. A highly sensitive electrometer measures the electrical current draining from

the filter. Since the particles exiting from the classifier are primarily singly-charged, the electrometer current is directly proportional to particle concentration. The particle concentration N of the sampled aerosol is:

$$N = I/eQ \quad (4)$$

where I is electrometer current, e is the elementary unit of charge, and Q is volumetric aerosol flow rate.

III. Interference Effect of Multiply-Charged Particles

The output aerosol contains not only the singly-charged particles of the desired size, but also some multiply-charged particles of larger sizes. A first approximation for correcting the effect of doubly-charged particles was described by Pui and Liu². Figure 5 shows the size distribution of polydisperse aerosol generated by an atomizer. Let us suppose that we set the DMA to extract $0.2 \mu\text{m}$ singly-charged particles. According to Table I, 22.6% of $0.2 \mu\text{m}$ particles carry one positive unit of charge. This is represented by the cross-hatched area under the curve at $0.2 \mu\text{m}$. The doubly-charged particles of $0.32 \mu\text{m}$ diameter have the same electrical mobility as the singly-charged particles of $0.2 \mu\text{m}$.

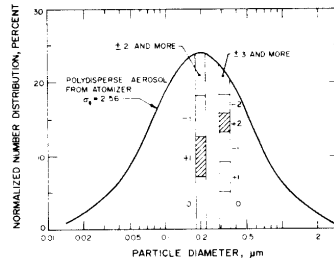


Figure 5. Typical size distribution of the polydisperse aerosol generated by an atomizer. Singly-charged particles and doubly-charged particles of same mobility are extracted by the DMA².

These particles are also extracted through the slit of the DMA. The AE counts each $0.32 \mu\text{m}$ particle as two $0.2 \mu\text{m}$ particles. To account for doubly-charged particles, Equation 4 is rewritten:

$$N = \frac{I}{eQ} K_2 \quad (5)$$

where K_2 is the correction factor accounting for the interference effect of doubly-

charged particles, ignoring any particles with more than 2 charges. Let us suppose that the concentration of singly-charged and doubly-charged particles in the aerosol extracted from the DMA are N_1 and N_2 respectively. Then the electrometer current I is:

$$I = Q(N_1 e + N_2 2 e) = QN' e \quad (6)$$

Where N' is the apparent particle concentration. The true particle concentration N is:

$$N = N_1 + N_2 \quad (7)$$

Combining Equations 6 and 7:

$$K_2 = \frac{N}{N'} = \frac{N_1 + N_2}{N_1 + 2N_2} = \frac{1 + N_2/N_1}{1 + 2N_2/N_1} \quad (8)$$

The ratio N_2/N_1 , and hence K_2 , is calculated from the particle size distribution of incoming polydisperse aerosol and Boltzmann's Law.

The median size of a polydisperse aerosol generated by a standard atomizer is controlled by atomizing a solution of specific concentration. Figure 6 shows the relationship between median particle diameter of the polydisperse aerosol and solute concentration in the recirculating atomizer. The concentration of the solute must be selected so that the median diameter of the polydisperse aerosol matches the monodisperse aerosol exiting from the EC. For this condition, the particle concentration of monodisperse aerosol exiting from the EC is maximized. The EC should not be used to extract monodisperse particles smaller than the median size of incoming polydisperse aerosol because of the interference effect of multiply-charged particles increases significantly.

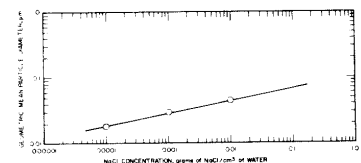


Figure 6. Relationship between NaCl concentration and mean particle diameter for TSI Model 3076 Atomizer.

The electrostatic classification method described above provides a convenient source of monodisperse aerosol for instrument

calibration. The diameter of the aerosol particles is calculated using Equations 2 and 3. The AE measures particle concentration. Equation 5 describes the number concentration of the monodisperse aerosol in terms of AE measurements. The result is a monodisperse submicron aerosol with known particle diameter and concentration. The next section describes the application of this system to the calibration of a condensation nucleus counter (CNC).

IV. Calibration of CNC

A CNC is an instrument which measures the number concentration of submicron aerosol particles. Figure 7 schematically shows a new CNC³ (TSI Model 3020). Aerosol first enters an inclined tube covered with a Dacron felt lining which saturates the aerosol with n-butyl alcohol vapor at 35°C. The saturated aerosol then enters a vertical condensation tube maintained at 10°C. In the condenser, alcohol vapor condenses on the aerosol particles, making the particles grow into larger droplets. The droplets then exit through a 1.0 mm diameter nozzle into a viewing volume illuminated by a narrow beam of light. The light beam is generated by an optical system consisting of a light bulb, a focusing lens, a narrow slit aperture, and an imaging lens. The beam is

stopped before the receiving lens. The receiving lens collects light scattered by the droplets and focuses the scattered light onto a photodetector.

The CNC has two modes of operation: (1) count mode and (2) photometric mode. In the count mode, the CNC counts electrical pulses generated by the light scattered from individual droplets as they pass through the viewing volume. The instrument calculates particle concentration from the number of pulses per second and the aerosol sample rate. The CNC automatically switches to the photometric mode if particle concentration is higher than 10^3 particles/cm³. In the photometric mode, the CNC detects the mean dc level of total light scattered by all particles in the viewing volume. In this mode, the CNC must be calibrated with an aerosol of known concentration.

We generated 0.05 μm diameter NaCl aerosol using the system shown in Figure 1. We used a 0.001 gm/cm³ NaCl-water solution in the atomizer. We adjusted the pressure regulator of the air supply system to 35 psig (240 kPa). We connected the output of the atomizer to the polydisperse aerosol inlet of the EC through a dilution system (see Figure 1). We varied the particle concentration of monodisperse aerosol

exiting from the classifier by changing the concentration of polydisperse aerosol entering the classifier. Sheath air, monodisperse aerosol, and excess air flow rates of the classifier were 20, 3, and 20 L/min, respectively. The collector rod voltage was 1 kV.

The monodisperse aerosol exiting from the classifier was simultaneously sampled by the AE and the CNC. A Kr-85 radioactive source neutralized the aerosol entering the CNC. The AE sample rate was 2 L/min. We obtained a maximum particle concentration of 2×10^5 particles/cm³ using this arrangement. By setting the pressure regulator of the air supply system at 55 psig (380 kPa) we obtained a maximum particle concentration of 7×10^5 particles/cm³. Figure 8 shows the CNC photodetector output as a function of aerosol particle concentration. All data points shown in Figure 8 were obtained in a few hours. The scatter between calibration points is small.

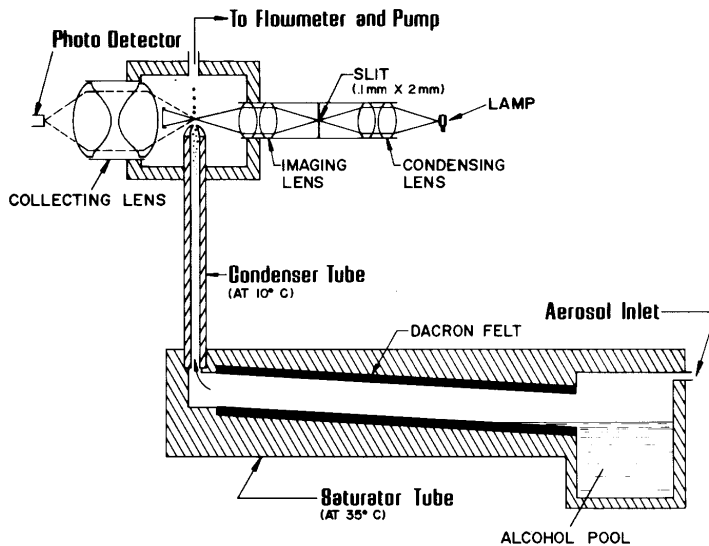


Figure 7. Schematic diagram of the condensation nucleus counter.

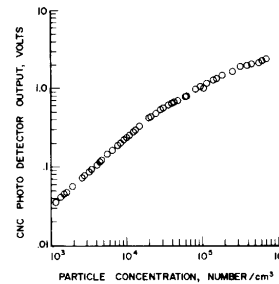


Figure 8. Calibration of CNC in the photometric mode.

The electrostatic classification method described above provides a fast, convenient, primary method for calibrating submicron instruments. Other methods, such as collecting the particle samples on a substrate and then counting them under an electron microscope are expensive and time consuming. We have extensively used this method during the development of the CNC to optimize various operating parameters of the CNC. We could change a parameter and recalibrate the CNC (5 - 10 data points) in less than one hour, saving considerable time over any other known method.

V. Comparison Between the AE and the CNC Count Mode

The CNC operating in the count mode provides another primary method for measuring the particle concentration of submicron

aerosol. In this mode, the particle concentration is computed from the number of pulses counted per second and the aerosol sample rate. However, the occasional presence of multiple particles in the sensing volume at a given time limits this method to particle concentrations below 1000 particles/cm³. We compared the CNC operating in the count mode with AE measurements. For this comparison, we mixed the excess air and the monodisperse aerosol exiting from the EC and fed this diluted aerosol to the AE and the CNC. The AE sampled aerosol at a rate of 10 L/min. Figure 9 shows the comparison between the two techniques. The CNC readings were corrected for coincidence losses³. The two primary methods agree within 5% of each other, well within the limits of experimental accuracy. Such close agreement between two independent, primary methods not only proves the validity of both methods but also testifies to the precision of both methods.

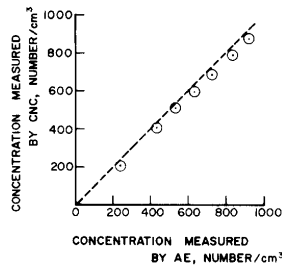


Figure 9. Comparison between the aerosol electrometer and the CNC count mode.

VI. Particle Size Distribution Measurement

To experimentally measure the particle size distribution of the generated monodisperse aerosol, a particle sizer of high resolution is necessary. Knutson and Whitby^{4,5} and Hoppe⁶ have used a DMA similar to the one described in Section II for particle size distribution measurements. We have used a DMA and CNC combination to measure the particle size distribution of the generated monodisperse aerosol.

Figure 10 schematically shows the experimental set up. Section II described the monodisperse aerosol generation system shown on the left. We generated 0.05 μm NaCl particles by selecting the operating parameters described in Section IV. The collector rod voltage of the first EC was

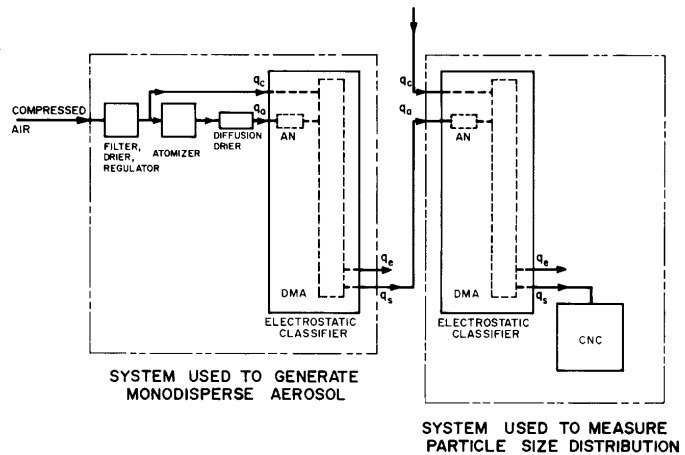


Figure 10. Schematic diagram of the system used to measure the size distribution of the aerosol. AN – aerosol neutralizer, DMA – differential mobility analyzer.

set at 1 kV. At this voltage, the mobility of particles exiting through the slit of the collector rod is $9.26 \times 10^{-4} \text{ cm}^2/\text{V}\cdot\text{sec}$.

Singly-charged 0.05 μm , doubly-charged 0.074 μm and triply-charged 0.091 μm particles, all had the mobility of $9.26 \times 10^{-4} \text{ cm}^2/\text{V}\cdot\text{sec}$ and exited through the slit of the collector rod. The aerosol then passed through a neutralizer which again applied the Boltzmann charge level to the particles. Table II shows the distribution of charges on the 0.05 μm , 0.074 μm , and 0.091 μm particles according to Boltzmann's Law. The 0.05 μm particles were all singly-charged before entering the neutralizer. After passing through the neutralizer, 62.2% of them carry no charge and 18.24% carry one positive unit charge. Similarly, the 0.074 μm particles were all doubly-charged before neutralization, but after neutralization, 49.56% have no charge, 22.9% have one positive unit charge, and 0.62% have two

positive unit charges. We then measured the particle size distribution of this neutralized 'monodisperse' aerosol with a second DMA followed by a CNC as shown on the right side of Figure 10. The aerosol entered into the second DMA through the polydisperse aerosol entrance. The clean sheath air to the second DMA came from an external clean air source. The CNC measured the particle concentration of the aerosol exiting through the slit of the collector rod of the second DMA. For a given collector rod voltage setting, particles of a specific electrical mobility exit through the slit. Equation 3 shows the relationship between the collector rod voltage and the particle mobility. We varied the collector rod voltage over the entire range for which the CNC could detect any particles. Figure 11 shows the relationship between the collector rod voltage and the CNC count. We observe four (4) distinct peaks. Table III shows the particle mobility corresponding to the collector rod voltage at which

$D_p, \mu\text{m}$	Percent of particles carrying n_p elementary charge units						
	-3	-2	-1	0	+1	+2	+3
0.050		0.62	19.24	60.20	19.24	0.62	
0.074	0.05	2.27	22.90	49.56	22.90	2.27	0.05
0.091	0.16	3.64	23.87	44.68	23.87	3.64	0.16

Table II. Theoretical distribution of charges on the aerosol particles used for CNC calibration according to Boltzmann's Law

Analyzer Voltage Corresponding to Peak, V (Volts)	Corresponding Mobility, Z_p ($\text{cm}^2/\text{V}\cdot\text{sec}$)	Particle Size, d_p (μm)	Concentration Measured by CNC (No/cm^3)	Concentration After Correcting for CNC Coincidence (No/cm^3)	Calculated No. Conc. in the Test Aerosol* (No/cm^3)
950	9.26×10^{-4}	0.05	630	692	3597
1950	4.51×10^{-4}	0.074	200	206	900
2800	3.14×10^{-4}	0.091	72	73	301

*Calculated by dividing the coincidence corrected CNC measurement by the fraction carrying a single positive charge from Table II.

Table III. Measured relative number concentration of the aerosol particles used for CNC calibration

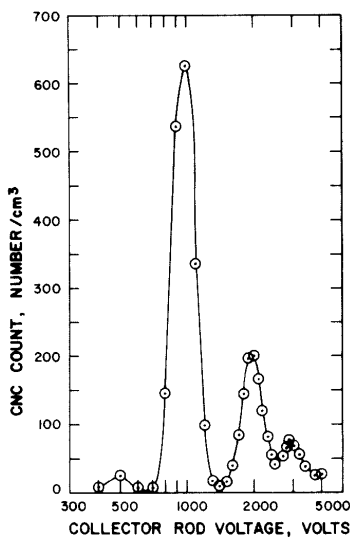


Figure 11. Particle concentration measured by the CNC vs. collector rod voltage of the second DMA.

these peaks occurred. From the relationship of particle size to electrical mobility (see Figure 2), it is evident that the peaks at 950V, 1950V, and 2800V correspond to

the singly-charged particles with diameters of 0.05 μm , 0.074 μm , and 0.091 μm , respectively. The peak at 500V represents the doubly-charged 0.05 μm diameter particles.

Figure 11 shows the relative particle concentration of the singly-charged fraction of 0.05 μm , 0.074 μm , and 0.091 μm particles that exited from the second DMA. Table II shows that 19.24% of the 0.05 μm particles entering the second DMA were singly-charged. The true particle concentration of the 0.05 μm entering the second DMA can be obtained by dividing the measured peak concentration by 0.1924. The calculated true particle concentrations of 0.05 μm , 0.074 μm and 0.091 μm particles are shown in the last column of Table III. Table III shows that the generated aerosol consisted primarily of 0.05 μm particles. The percentage of 0.074 μm and 0.091 μm particles are small. The interference effect of these larger particles can be accounted for by a procedure similar to the one described in Section III.

The DMA/CNC combination used here to measure the size distribution of the monodisperse aerosol is a powerful particle sizing tool. Its high sensitivity and high resolution

is demonstrated by detecting and resolving the four peaks in the aerosol. Hoppel⁶ has recently shown that this technique can be applied to polydisperse submicron aerosols of unknown size distribution.

VII. Conclusion

The electrostatic classification method of generating submicron monodisperse aerosol is a very useful technique for instrument calibration. We have used this technique not only for the final calibration of our new CNC, but also for optimization of various operating parameters during the development of the CNC.

The new CNC operating in the single particle counting mode and the electrostatic classification technique are both primary methods of measuring certain aerosol concentrations. When compared, the two primary methods agree within 5%, well within the limits of experimental accuracy.

The EC combined with a highly sensitive CNC becomes a submicron particle sizing technique with high resolution and sensitivity. This technique will be a very useful tool for future aerosol measurements.

References:

- Liu, B. Y. H., and D. Y. H., Pui: "A Submicron Aerosol Standard and the Primary, Absolute Calibration of the Condensation Nuclei Counter," *Journal of Colloid and Interface Science*, 47:155 (1974).
- Pui, D. Y. H., and B. Y. H. Liu: "Electrical Aerosol Analyzer: Calibration and Performance," Presented at Aerosol Measurement Workshop, University of Florida, Gainesville, Florida, March 24 - 26, 1976. To be published in *Aerosol Measurement*, D. A. Lundgren, ed., University of Florida Press, Gainesville (1978).
- Agarwal, J. K., G. J. Sem, and M. Pourprix: "A Continuous Flow CNC Capable of Counting Single Particles." Proceedings of the Ninth International Conference on Atmospheric Aerosols, Condensation and Ice Nuclei, Galway, Ireland, September, 1977. To be published by Pergamon Press (1978).
- Knutson, E. O., and K. T. Whitby: "Aerosol Classification by Electric Mobility: Apparatus, Theory, and Applications." *Aerosol Science*, 6:443 (1975).
- Knutson, E. O., and K. T. Whitby: "Accurate Measurement of Aerosol Electric Mobility Moments." *Aerosol Science*, 6:453 (1975).
- Hoppel, W. A.: "Determination of the Aerosol Size Distribution from the Mobility Distribution of the Charged Fraction of Aerosols." *Aerosol Science*, 9:41 (1978).

APPENDIX D

Data Sheet

This appendix includes the following data sheet:

- Calibration Data Sheet

APPENDIX E

Software Disk

This appendix includes a 3½-inch software disk for the TSIUCPC.BAS program.

Refer to Chapter 7 for information on using the software.

Reader's Comments

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

Manual Title Model 3025A Ultrafine Condensation Particle Counter **P/N** 1933762 **Rev.** I

1. Was the manual easy to understand and use?

Yes No

Please identify any problem area(s) _____

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

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

	Good	Adequate	Poor
Readability	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Accuracy	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Completeness (is everything there?)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Organization (finding what you need)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Quality and number of illustrations	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Quality and number of examples	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: _____

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

5. Rate your level of experience with the product:

Beginning Intermediate Expert

6. Please provide us with the following information:

Name _____ Address _____

Title _____

Company _____



TSI Incorporated
500 Cardigan Road, Shoreview, MN 55126 U.S.A.
Web: www.tsi.com