Particle Instruments

Model 3076
Constant Output Atomizer

Instruction Manual

P/N 1933076, Revision J
June 2005

TSI®

Model 3076 Constant Output Atomizer

Instruction Manual

Manual History

The following is a manual history of the *Model 3076 Constant Output Atomizer Instruction Manual* (Part Number 1933076).

Revision	**Date**
First Version A	March 1989
B	June 1993
C	January 1994
D	September 1994
E	May 1996
F	August 1998
G	July 2000
H	October 2002
I	November 2003
J	June 2005

- Revision C of this manual reformats the manual, modifies the setup instructions, and adds the Safety section.
- In revision D, TSI's customer service number was changed.
- In revision E, revisions were made throughout the manual.
- In revision F, TSI's "Limitation of Warranty and Liability" on page iii was updated.
- In August 1998, TSI's area code was changed from 612 to 651.
- In revision G, TSI's Limitation of Warranty and Liability was updated.
- In revision H, TSI's phone numbers and address were updated.
- In revision I, Liquid consumption rate was added to Table A-1 in Appendix A, "Specifications" and air flow rate 3.0 L/min was revised to read 3.0-3.5 L/min on page 3-1 and in Table A-1.
- In revision J, Model 3075 was removed and figures were updated (manual was previously Model 3075/3076 Constant Output Atomizer Instruction Manual).

Warranty

Part Number

1933076 / Revision J / June 2005

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Address

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

Fax No.

(651) 490-3824

E-mail Address

particle@tsi.com

Limitation of Warranty and Liability
(effective 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.

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

Safety

This section gives instructions to promote safe and proper handling of the Model 3076 Constant Output Atomizer.

The Model 3076 Constant Output Atomizer is designed to release aerosol to a system that is at atmospheric pressure. Therefore, the pressure at the outlet of the Atomizer should be maintained close to atmospheric pressure (below 10 psig).

The atomizer is equipped with a pressure relief valve that actuates whenever the pressure in the bottle exceeds 10 psig. The valve will reseal when pressure in the bottle is reduced below 10 psig. However:

- ❑ Do *not* operate the Atomizer with an outlet pressure exceeding 10 psig in a closed system. Operating the Atomizer above this pressure may result in damage to the plastic-coated glass bottle, which can shatter and cause serious personal injury.
- ❑ Experiments have shown the plastic-coated glass bottle may explode at pressures exceeding 80 psig. Before applying compressed air to the Atomizer, check your system to ensure no blockage of the Atomizer can occur at the Atomizer outlet.
- ❑ The plastic-coated glass bottle may weaken or develop cracks from shock, excessive use, or chemical attack, resulting in fractures at pressures well below 80 psig. Before attaching the bottle to your system, check the bottle to ensure there is no structural weakness. If you suspect your bottle is damaged, contact TSI Incorporated for replacement information.

  Note*: Refer to Chapter 6 of this manual for instructions on contacting technical personnel at TSI.*

WARNING

Do *not* operate the Atomizer with an outlet pressure exceeding 10 psig in a closed system. Operating the Atomizer with an outlet pressure greater than 10 psig may result in damage to the plastic-coated glass bottle, which can shatter and cause serious personal injury. The atomizer is equipped with a pressure relief safety valve that releases pressures above 10 psig from within the bottle. *Never* block the outlet of this valve or remove the valve from the bottle cap.

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About This Manual

Purpose

This is an instruction manual for the operation and maintenance of the Model 3076 Constant Output Atomizer.

Organization

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

- **Chapter 1: Product Overview**
  This chapter introduces the Model 3076 Constant Output Atomizer, gives a list of features, and provides a brief operating description of the instrument.

- **Chapter 2: Unpacking the Atomizer**
  This chapter contains a packing list and gives unpacking instructions for the Atomizer.

- **Chapter 3: Setting Up the Atomizer**
  This chapter contains procedures for setting up the Atomizer in recirculation and nonrecirculation modes.

- **Chapter 4: Operating the Atomizer**
  This chapter contains operating precautions and operating procedures for the Atomizer.

- **Chapter 5: Atomizer Applications**
  This chapter contains information on generating different kinds of particles with the Atomizer.

- **Chapter 6: Atomizer Maintenance and Service**
  This chapter gives some routine maintenance recommendations and directions for contacting technical resources at TSI or instructions on returning the Atomizer for service.

- **Appendix A: Specifications**
  This appendix contains operating specifications for the Atomizer.

- **Appendix B: Technical Paper**
  This appendix contains a technical paper on the Atomizer.

- **Appendix C: Bibliography**
  This appendix contains a list of references used in writing this manual.

Related Product Literature

- ***Model 3074B Filtered Air Supply*** (part number 1933800) TSI Incorporated

  This manual contains setup and operating instructions for a filtered air supply, which can be used with the Model 3076 Constant Output Atomizer.

- ***Model 3012/3012A Aerosol Neutralizers*** (part number 1933012) TSI Incorporated

  This manual contains specifications and installation instructions for the Model 3012 and Model 3012A Neutralizers, which can be used with the Model 3076 Atomizer to neutralize charged particles.

- ***Model 3077/3077A Aerosol Neutralizers*** (part number 1933077) TSI Incorporated

  This manual contains specifications and installation instructions for the Model 3077 and Model 3077A Neutralizers, which can be used with the Model 3076 Atomizer to neutralize charged particles.

Reusing and Recycling

As part of TSI Incorporated's effort to have a minimal negative impact on the communities in which its products are manufactured and used:

- This manual uses recyclable paper.
- This manual has been shipped, along with the instrument, in a reusable carton.

Getting Help

To obtain assistance with the Model 3076 Constant Output Atomizer, either refer to Chapter 6, "Atomizer Maintenance and Service," or contact Customer Service:

TSI Incorporated
500 Cardigan Road
Shoreview, MN 55126 USA
Fax: (651) 490-3824
Telephone: 1-800-861-7919 (USA) or (651) 490-3838
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, mail your comments on another sheet of paper to:

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

For current information
www.tsi.com

CHAPTER 1
Product Overview

This chapter introduces the Model 3076 Constant Output Atomizer, gives a list of features, and provides a brief operating description of the instrument.

Introduction

The Model 3076 Constant Output Atomizer, shown in Figure 1-1, generates submicrometer aerosols that can atomize most solutions or suspensions.

The conventional mode of operation for the Model 3076 Atomizer is the recirculation mode. The atomizer can be modified to work in nonrecirculation mode if necessary.

The number median diameter of the droplets the Atomizer generates is about 0.3 micrometer and the geometric standard deviation is less than 2.0. The mean particle size of the generated aerosol can be varied between 0.02 and 0.3 micrometer by atomizing a solution and evaporating the solvent.

A common problem of conventional recirculation mode is that the solvent gradually evaporates in the Atomizer, causing the solution that remains in the reservoir bottle to become more concentrated and thus yield larger aerosol particles. A significant increase in particle size occurs within several minutes when using volatile solvents such as alcohol. Running the atomizer in nonrecirculation mode eliminates this problem by preventing the recirculation of the solution. Either an extra reservoir bottle or a syringe pump is required to set up the nonrecirculation mode.

Tight tolerances are maintained for all critical dimensions of the Atomizer to ensure the accuracy of its output particle size. The characteristics of typical aerosols are included in this manual for reference.

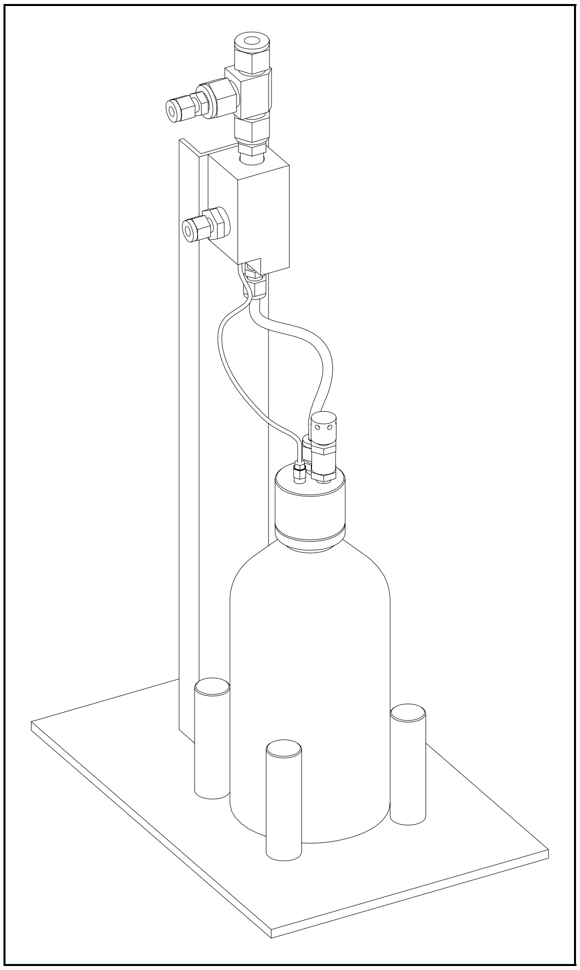

Figure 1-1
Model 3076 Constant Output Atomizer

How the Atomizer Works

This section provides a simple theory of operation for the Model 3076 Constant Output Atomizer. As you read this section, use Figure 1-2 as a reference.

Compressed air expands through an orifice to form a high-velocity jet. Liquid is drawn into the atomizing section through a vertical passage and is then atomized by the jet. Large droplets are removed by impaction on the wall opposite the jet and excess liquid is drained at the bottom of the Atomizer assembly block. Fine spray leaves the Atomizer through a fitting at the top.

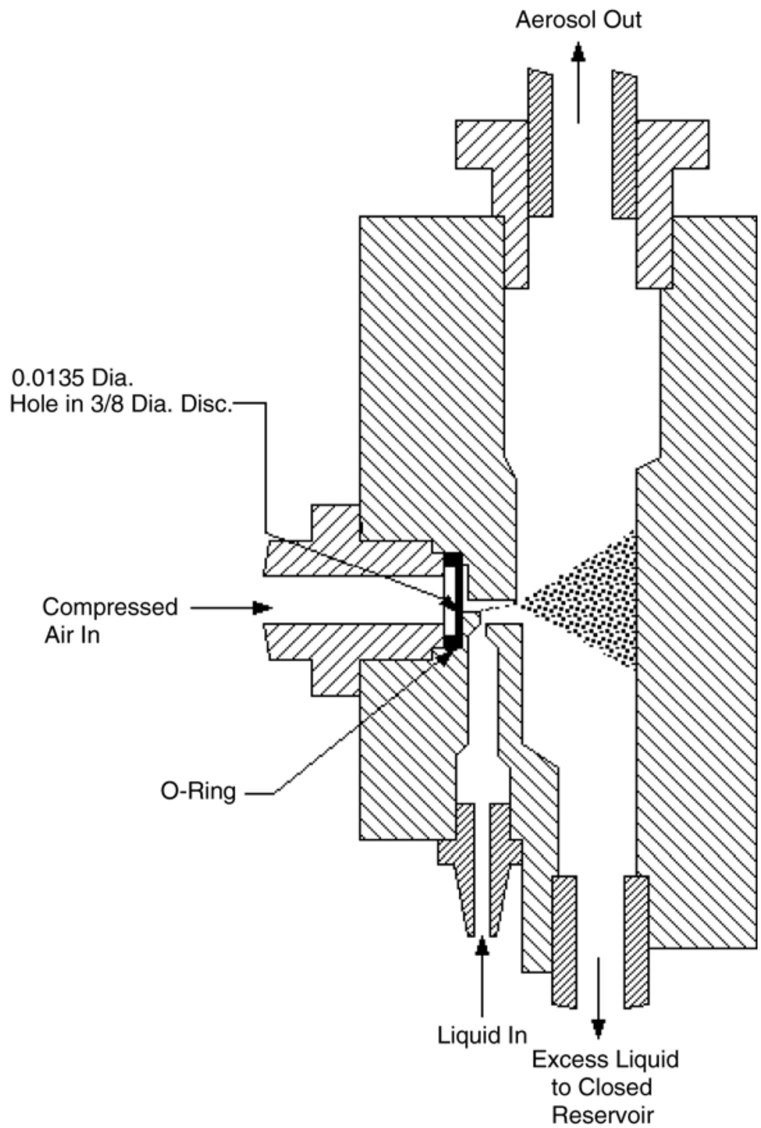

Figure 1-2
Model 3076 Schematic of the Atomizer Assembly Block

The Atomizer may be used in either recirculation mode or nonrecirculation mode. In the recirculation mode, recommended for water-based solutions, the liquid is drawn in from a 1-liter bottle (supplied) and the excess liquid drains into the same bottle. In the nonrecirculation mode, recommended for volatile solvents, either an extra reservoir bottle or a syringe pump should be used. When using an extra bottle, the liquid is drawn from one bottle and the excess liquid drains into a separate reservoir bottle. When using a syringe pump to supply fresh solution to the atomizing jet, one reservoir bottle is needed in the setup to drain the excess liquid. See Chapter 3 for instructions on setting up the Atomizer in recirculation and nonrecirculation modes.

CHAPTER 2

Unpacking the Atomizer

This chapter contains a packing list and gives unpacking instructions for the Model 3076 Constant Output Atomizer.

Packing List

Table 2-1 shows the packing list for the Model 3076 Constant Output Atomizer.

Table 2-1
Model 3076 Atomizer Packing List

Qty	Description		Part No.
1	Model 3076 Constant Output Atomizer		307601
1	Model 3076 Accessory Kit with the following parts		1030833
	1	Instruction manual	1933076
	1	5 ft Teflon® tubing 14 ga	3929552
	2	O-ring 1-010	2501010
	1	Fitting—SS plug, ¼ TU	1601563
	1	Fitting—SS elbow, 1⁄16 NPT	1601642
	1	Fitting—SS conn, ¼ TU— 1⁄16 MPT	1601643
	1	Fitting—SS port conn ½ in.	1602153
	10 ft	Poly-Flo® tubing, ¼ in. O.D.	3929436
	4 ft	Conductive tubing, 0.44 in. I.D.	3001905

®Poly-Flo is a product of Imperial Eastman™
®Teflon is a registered trademark of E.I. du Pont de Nemours and Company
Note*: The extra bottle or syringe pump required for nonrecirculation mode is not included.*

Unpacking Instructions

The Model 3076 Constant Output Atomizer is shipped with protective coverings on the inlets and outlets. If anything is missing or appears to be damaged, contact your TSI representative or contact TSI Customer Service at 1-800-861-7919 (USA) or (651) 490-3838. Chapter 6, "Atomizer Maintenance and Service," gives instructions for returning the Atomizer to TSI.

Refer to Chapter 3, "Setting Up the Atomizer" for instructions on connecting tubing to the Atomizer from the filtered air supply and the Atomizer bottle. Instructions on setting up the atomizer in nonrecirculation mode are also included in Chapter 3.

CHAPTER 3

Setting Up the Atomizer

Use the information in this chapter to properly set up the Model 3076 Constant Output Atomizer. This chapter contains information and procedures on:

- Meeting clean air requirements
- Selecting and preparing the aerosol solution
- Setting up and modifying the Model 3076 Atomizer

Meeting Clean Air Requirements

The Model 3076 Atomizer requires a source of clean, dry air at a flow rate of at least 3.0–3.5 standard liters per minute (standard L/min) at *no more than* 240 kilopascals gauge [35 psig]. If you use ordinary shop air, it must be properly dried, filtered, and regulated. Figures 3-1 and 3-5 show the Atomizer using the recommended TSI Model 3074B Filtered Air Supply.

The Model 3076 Constant Output Atomizer is designed to release aerosol to a system that is at atmospheric pressure. Therefore, the pressure at the outlet of the Atomizer should be maintained close to atmospheric pressure (below 10 psig).

WARNING

Do *not* operate the Atomizer with an outlet pressure exceeding 10 psig in a closed system. Operating the Atomizer with an outlet pressure greater than 10 psig may result in damage to the plastic-coated glass bottle, which can shatter and cause serious personal injury. The atomizer is equipped with a pressure relief safety valve that releases pressures above 10 psig from within the bottle. *Never* block the outlet of this valve or remove the valve from the bottle cap.

For most applications, set the filtered air pressure at or below 35 psig. The performance of a similar Atomizer at various pressure settings has been described by May [2] in Appendix C. Note that the size distribution of the droplets is not significantly affected.

Selecting and Preparing the Solution

Select a solute for generating the aerosol. Common solutes for solid particles are sodium chloride, uranine, and methylene sucrose; for oil particles are dioctyl phthalate (DOP) and olive oil. The recommended solvent for solid particles is fresh distilled water; for oil particles, use clean, reagent-grade alcohol.

Usually 0.0001 gram of solute per cubic centimeter of solvent is convenient for most applications; in the case of a liquid, however, use 0.0001 cubic centimeter of solute per cubic centimeter of solvent. Refer to Chapter 5 for information on the relationship between particle size and solute concentration.

Setting Up and Modifying the Model 3076 Atomizer

This section describes how to set up the Model 3076 for operation in conventional recirculation mode (recommended for water-based solutions) or nonrecirculation mode (recommended for volatile-based solutions).

Before You Begin

The tubing you use to connect the Atomizer to the bottle and to the air supply is provided but must be measured and cut. The ½-inch conductive tubing is also provided for the polydisperse aerosol coming out from the Atomizer block to minimize particle losses to the walls of the tubing due to static charge.

Setting Up in the Recirculation Mode

In the recirculation mode, the 1-liter bottle (with white plastic cap) acts as the reservoir for the solution.

The 1-liter bottle is pre-assembled for use in the recirculation mode. The cap has three fittings: one delivers solution to the atomizer block, one returns excess solution to the bottle from the Atomizer, and the other is the pressure relief valve. The smallest fitting has a hose barb on the outside; on the inside, this fitting is soldered to a stainless steel tube that protrudes into the bottle.

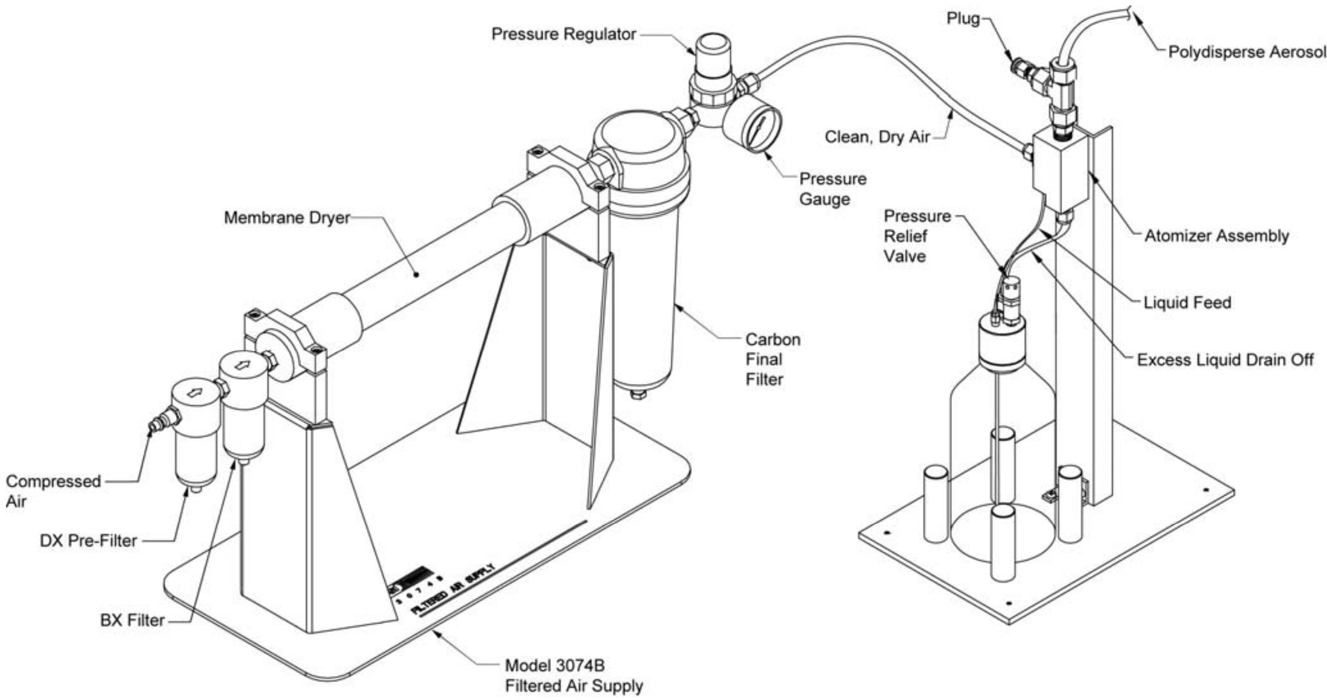

Figure 3-1
Model 3076 Atomizer in the Recirculation Mode

To connect the Atomizer in the recirculation mode, refer to Figure 3-1 and follow these steps.

1. Measure and cut the 14-gauge Teflon tubing for the liquid feed line. Connect the tubing between the feed opening at the bottom of the Atomizer assembly block and the small hose fitting on the white bottle cap.

   Note: *The tubing is easier to slip on if you first stretch out the inside diameter of its two ends with a pencil and use a small square of sandpaper folded over the tube to grip and support it.*

2. Measure and cut ¼-inch Poly-Flo tubing for the excess liquid drain line. Connect one end of the tubing to the excess liquid connector at the bottom of the Atomizer assembly block and the other end to the ¼-inch Swagelok® fitting at the top of the bottle.
3. Measure and cut ¼-inch Poly-Flo tubing from the Atomizer assembly block to either the Model 3074B Filtered Air Supply or to another source of clean, dry, compressed air.

®Swagelok is a registered trademark of Swagelok Co., Solon, OH 44139

4. In the recirculation mode, the side opening at the top of the Atomizer assembly block (side port of the Swagelok tee) is not used. Be sure to seal it with the Swagelok plug (part no. 1601563) provided.

5. Remove the cap and ferrules from the top opening of the Swagelok tee at the top of the Atomizer assembly block and put in the ½-inch Swagelock port connector (part no. 1602153) as shown in Figure 3-2 to connect to the conductive tubing for polydisperse aerosol coming out from the Atomizer.

Figure 3-2
Port Connector for Polydisperse Aerosol Outlet

Refer to Chapter 4, "Operating the Atomizer," for information on connecting compressed air.

Modifying the Model 3076 for use in Nonrecirculation Mode

Figure 3-3 shows how the Model 3076 can be modified for use in the nonrecirculation mode using fittings, tubing, and an extra bottle with cap which is not provided with the instrument*. Fittings are provided to adapt the top of the 1-liter bottle used to collect excess solution draining from the Atomizer. To adapt the bottle cap for the nonrecirculation mode, follow these steps.

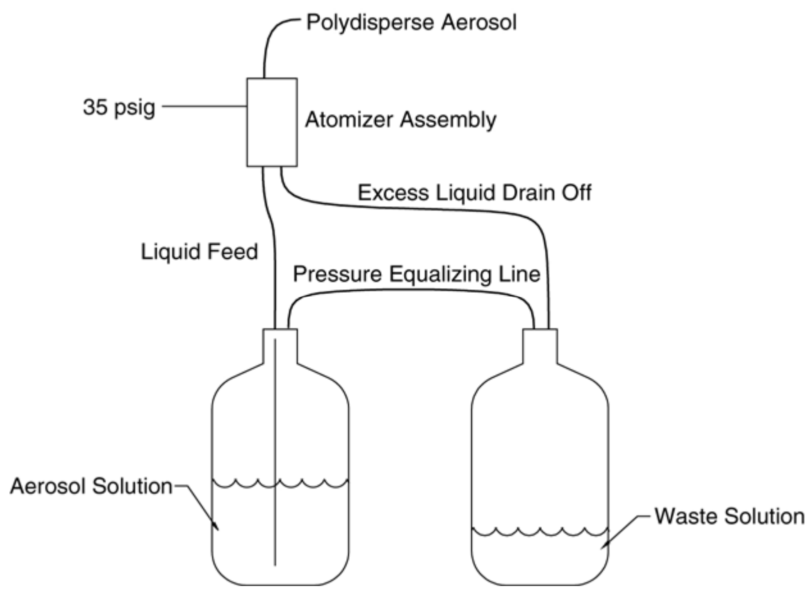

Figure 3-3
Model 3076 Atomizer in the Nonrecirculation Mode with an Extra Bottle

1. The barbed hose fitting on the cap needs to be replaced by an elbow fitting. In order to do that, all three fittings have to be removed first from the cap of the 1-liter bottle. Use wire brush to clean the green loktite® glue off the threads of the fittings.
2. Apply Teflon tape or loktite glue to the threads of the 1⁄16-inch NPT elbow fitting (part no. 1601642) and screw the elbow fitting into the 1⁄16-inch hole on the cap.
3. Apply Teflon tape or loktite glue to the threads of a 1⁄16-inch MPT and a ¼-inch TU Swagelok connector (part no. 1601643) and screw it onto the elbow.
4. Apply Teflon tape or loktite glue to the threads of the pressure relief value and the ¼-inch Swagelok fitting for excess liquid drain line and screw them back onto the cap.

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*The extra reservoir bottle with cap and fittings can be ordered from TSI (part no. 1030411R).

5. Reserve the stainless steel tube assembly for use in the recirculation mode.

The bottle cap adapted for non-recirculation mode is shown in Figure 3-4.

Figure 3-4
Bottle Cap Adapted for Nonrecirculation Mode

When used with alcohol-based solutions, the aerosol solution in the above setup will be used up rapidly. In this case, it is recommended to use a syringe pump to provide solution[†]. The syringe pump feeds the solution at a selected rate, independent of the pressure downstream of the Atomizer. To connect the Atomizer with the syringe pump, refer to Figure 3-5 and follow these steps.

1. Use the 1-liter bottle to collect excess liquid that drains from the Atomizer. Refer to Figure 3-4 and instructions on previous page to adapt the cap of the 1-liter bottle for nonrecirculation mode.

2. Measure and cut the 14-gauge Teflon tubing for the liquid feed line. Connect the tubing between the feed opening at the bottom of the Atomizer assembly block and the syringe.

Note: *The tubing is easier to slip on if you first stretch out the inside diameter of its two ends with a pencil and use a small square of sandpaper folded over the tube to grip and support it.*

3. Measure and cut ¼-inch Poly-Flo tubing for the excess liquid drain line. Connect one end of the tubing to the excess liquid connector at the bottom of the Atomizer assembly block and the other end to the ¼-inch Swagelok fitting at the top of the bottle.

[†]Pump 22 Multiple Syringe Pump, Harvard Apparatus, 84 October Hill Road, Holliston, Massachusetts 01746 or equivalent product from other manufacturers.

4. Measure and cut ¼-inch Poly-Flo tubing to connect the side port of the Atomizer assembly block to the Model 3074B Filtered Air Supply or to the customer's compressed air source.

5. Connect the right-angled Swagelok fitting on the cap to the side fitting at the top of the Atomizer (side port of the Swagelok tee) with ¼-inch Poly-Flo tubing. This line equalizes the pressure between the Atomizer and the bottle and thus allows the excess liquid to drain into the bottle. The Swagelok plug is not needed in this mode.

6. Remove the cap and ferrules from the top opening of the Swagelok tee at the top of the Atomizer assembly block and put in the ½-inch Swagelock port connector (part no. 1602153) as shown in Figure 3-2 to connect to the conductive tubing for polydisperse aerosol coming out from the Atomizer.

Refer to Chapter 4, "Operating the Atomizer," for information on connecting compressed air to the Atomizer.

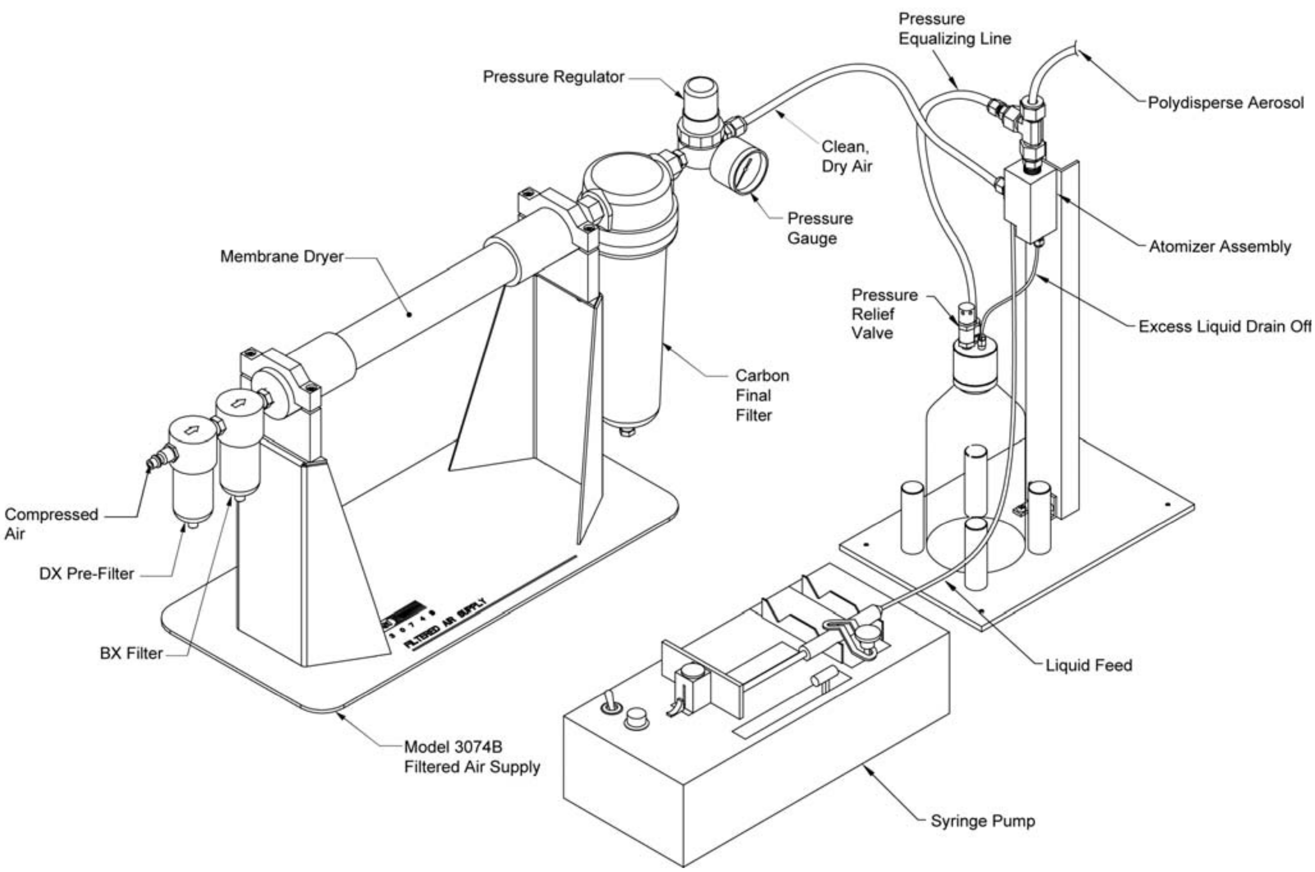

Figure 3-5
Model 3076 Atomizer in the Nonrecirculation Mode with a Syringe Pump

CHAPTER 4

Operating the Atomizer

Use the information in this chapter to operate the Model 3076 Constant Output Atomizer. This chapter contains information on the following:

- ❑ Operating in the Recirculation Mode
- ❑ Operating in the Nonrecirculation Mode
- ❑ Drying the Aerosol using a Model 3062 Diffusion Dryer
- ❑ Neutralizing the aerosol using a Model 3012/3012A or 3077/3077A Aerosol Neutralizer

Operating in the Recirculation Mode

If your solvent is water, the recirculation mode is recommended. Make sure that the reservoir bottle and Atomizer are clean.

1. Fill the bottle about three-fourths full of solution.
2. Connect the bottle to the Atomizer as described in Chapter 3.
3. Set the pressure to the Atomizer at or below 35 psig (240 kPa), and connect the compressed air.

WARNING

Do *not* operate the Atomizer with an outlet pressure exceeding 10 psig in a closed system. Operating the Atomizer with an outlet pressure greater than 10 psig may result in damage to the plastic-coated glass bottle, which can shatter and cause serious personal injury. The atomizer is equipped with a pressure relief safety valve that releases pressures above 10 psig from within the bottle. *Never* block the outlet of this valve or remove the valve from the bottle cap.

The Atomizer begins to operate as the compressed air passes through the system.

Note: *The most important factors for quality atomizing are (1) drying and neutralizing the aerosol; and (2) diluting the aerosol to the desired concentration. See "Drying the Aerosol" and "Neutralizing the Aerosol" sections in this chapter.*

To change the particle size, you must empty the bottle, clean the bottle and Atomizer, fill the bottle with new solution (having a different concentration), and start the Atomizer as before.

Operating in the Nonrecirculation Mode

To feed solution, select the running speed for a given size of syringe that corresponds to the desired liquid feed rate: higher running speeds yield higher flow rates for a given size of syringe.

When using the nonrecirculation mode, follow these five steps:

1. Fill the syringe with the solution you want to atomize (e.g., 50 cubic centimeters of solution); install the syringe on the syringe pump.

2. Connect the air supply to the Atomizer. Adjust the pressure to 35 psig or less.

W A R N I N G

Do *not* operate the Atomizer with an outlet pressure exceeding 10 psig in a closed system. Operating the Atomizer with an outlet pressure greater than 10 psig may result in damage to the plastic-coated glass bottle, which can shatter and cause serious personal injury. The atomizer is equipped with a pressure relief safety valve that releases pressures above 10 psig from within the bottle. *Never* block the outlet of this valve or remove the valve from the bottle cap.

3. Switch on the syringe pump. Wait until the solution fills the liquid feed tubing and enters the Atomizer assembly. A fast running mode may be available to speed up the filling process depending on the syringe pump that you use.

4. The generator is now in operation. Its operation will be stable until the solution in the syringe runs out. The stable operation time depends on the volume and feed rate of the syringe. For example, with a 50 cubic centimeter syringe and a feed rate of 0.59 cubic centimeters per minute, the maximum operating time is about 1 hour. At higher feed rates, the particle concentration is higher and the operation of the Atomizer is more stable; however, the maximum operation time is naturally shorter.

5. To change the aerosol particle size, use a solution of different concentration. Flush the Atomizer with about 25 cubic centimeters of solvent and then refill the syringe with the new solution. (A thorough cleaning—which means disassembling the Atomizer—is usually unnecessary unless you change from a high-solute concentration to a low-solute concentration.) Prepare the Atomizer for operation as done in step **3**.

Drying the Aerosol

When generating aerosols from solid solute, the particles coming out of the Atomizer are still wet and must be dried. Usually, the aerosol is mixed with a large volume of dry, dilution air. Another approach is to pass the aerosol through a diffusion dryer (Figure 4-1). In this device, the aerosol passes through an inner tube, made of wire screen. The silica gel surrounding the inner tube maintains a dry atmosphere at the tube's outer wall and the porous wall absorbs water vapor as aerosol passes through.

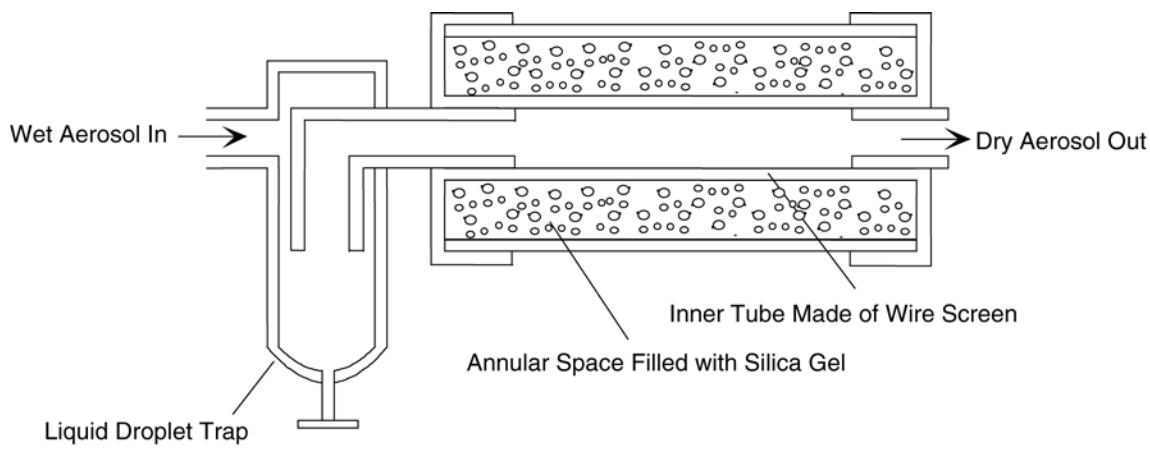

Figure 4-1
Model 3062 Diffusion Dryer

Frequently check the condition of the silica gel around the inner tube of the Atomizer to make sure the silica gel in the region next to the screen tube is in active condition, that is, it looks blue. Install the neutralizer immediately downstream of the diffusion dryer. The dilution air used to dilute aerosol to the desired concentration must be completely dry. Use a Swagelok-brand heat-exchanger tee to mix the aerosol and the dilution air. By using such a tee, the aerosol can be fed into the center of an annular, clean air stream, and thus avoid excessive wall losses.

Neutralizing the Aerosol

The generated aerosol has a high electrostatic charge. Therefore, you may encounter some loss of particles due to static charges in the system unless the particles are neutralized. Charged particles tend to deposit on tube walls and other surfaces. An aerosol charge neutralizer can be used to neutralize the aerosol and to bring the aerosol to the Boltzman charge equilibrium. The neutralizers that can be used with the atomizer include TSI's Model 3012/3012A or Model 3077/3077A with the Model 3012 being the most commonly used one. A neutralizer operates most effectively on dry particles.

The Atomizer may be used to atomize most solutions or suspensions. A few common applications of the Atomizer are described in Chapter 5 of this manual.

CHAPTER 5

Atomizer Applications

This chapter contains applications for the Model 3076 Constant Output Atomizer.

Generating Solid Particles

Materials such as sodium chloride, sugar, uranine, and methylene sucrose are commonly used to generate solid particles.

The concentration of the solute determines the particle size of the aerosol. Figure 5-1 shows the relationship between mean particle diameter and the concentration of sodium chloride; use it as a guide when preparing a solution for a specific size of output aerosol.

Figure 5-2 shows the typical size distribution of sodium chloride aerosols generated by the Atomizer. Figures 5-3, 5-4, and 5-5 show the number, surface area and volume distributions of the sodium chloride aerosol generated from a solution of 0.0001 gram of sodium chloride per cubic centimeter of water. All of the particle size distributions were measured with a Scanning Mobility Particle Sizer™ Spectrometer (TSI Model 3936L85 SMPS™). The geometric standard deviation from these figures is from 1.6 to 2.0.

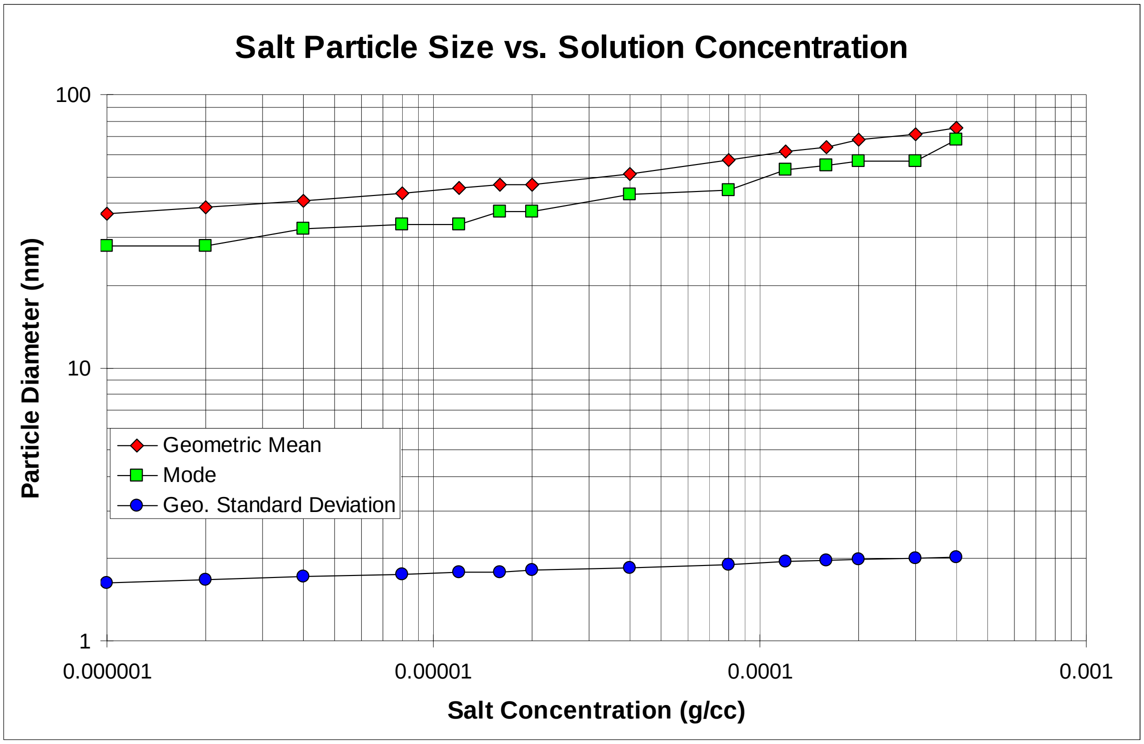

Figure 5-1
Particle Diameter Mean, Mode and Standard Deviation vs. Salt Concentration (grams of NaCl per cm^3 of H_2O)

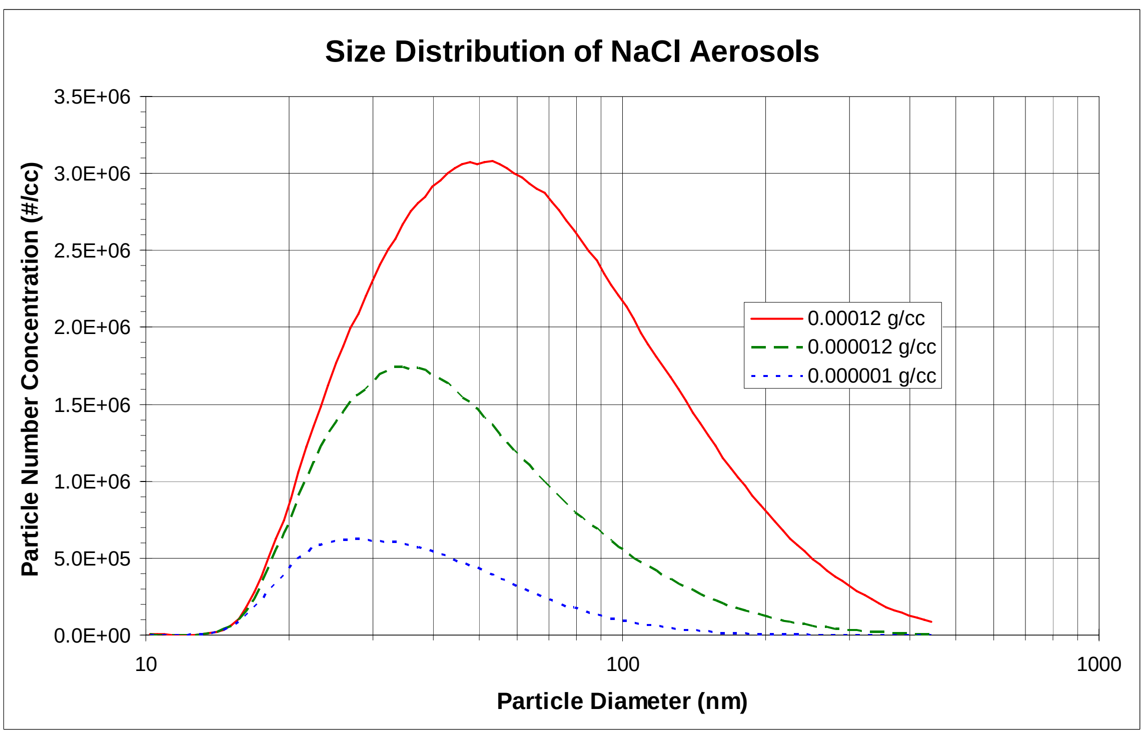

Figure 5-2
Size Distribution of Sodium Chloride Aerosols Generated by the Atomizer

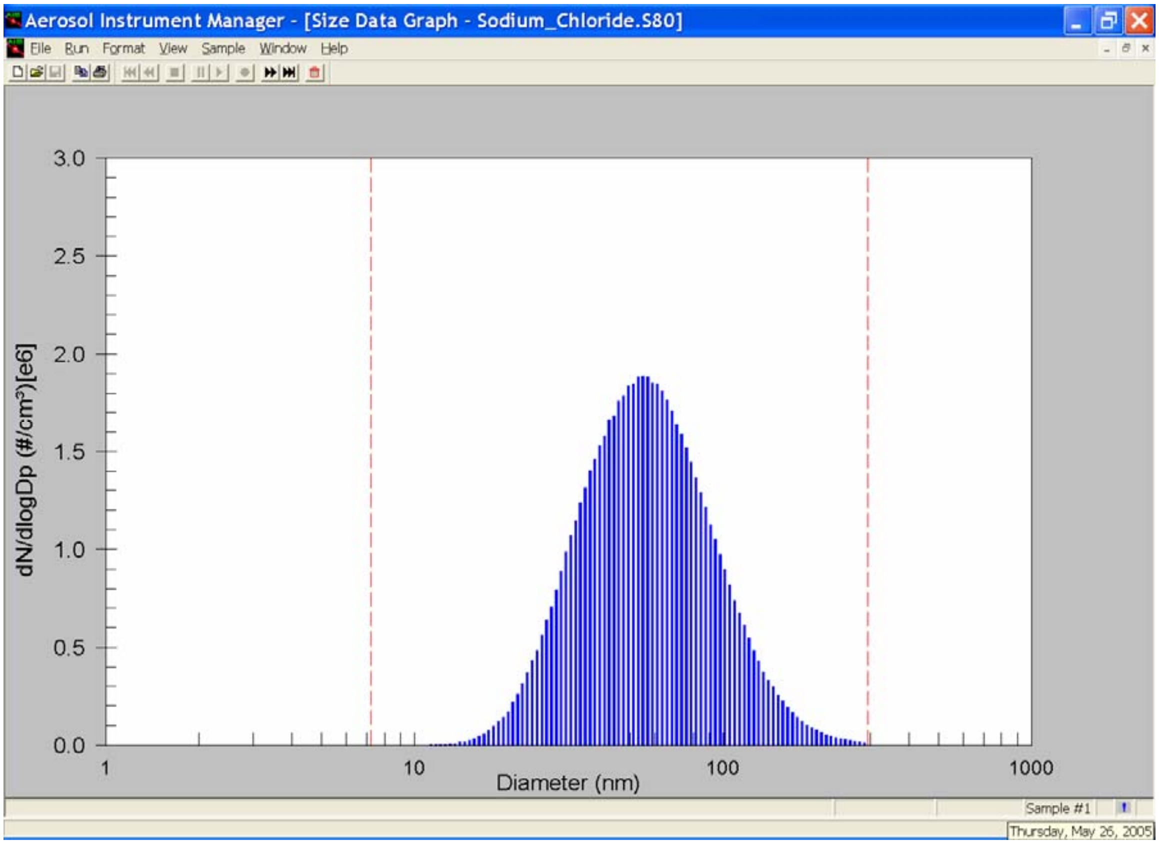

Figure 5-3
Typical Number Distribution of a Sodium Chloride Aerosol Atomized from 0.0001 gram/cm^3 Solution

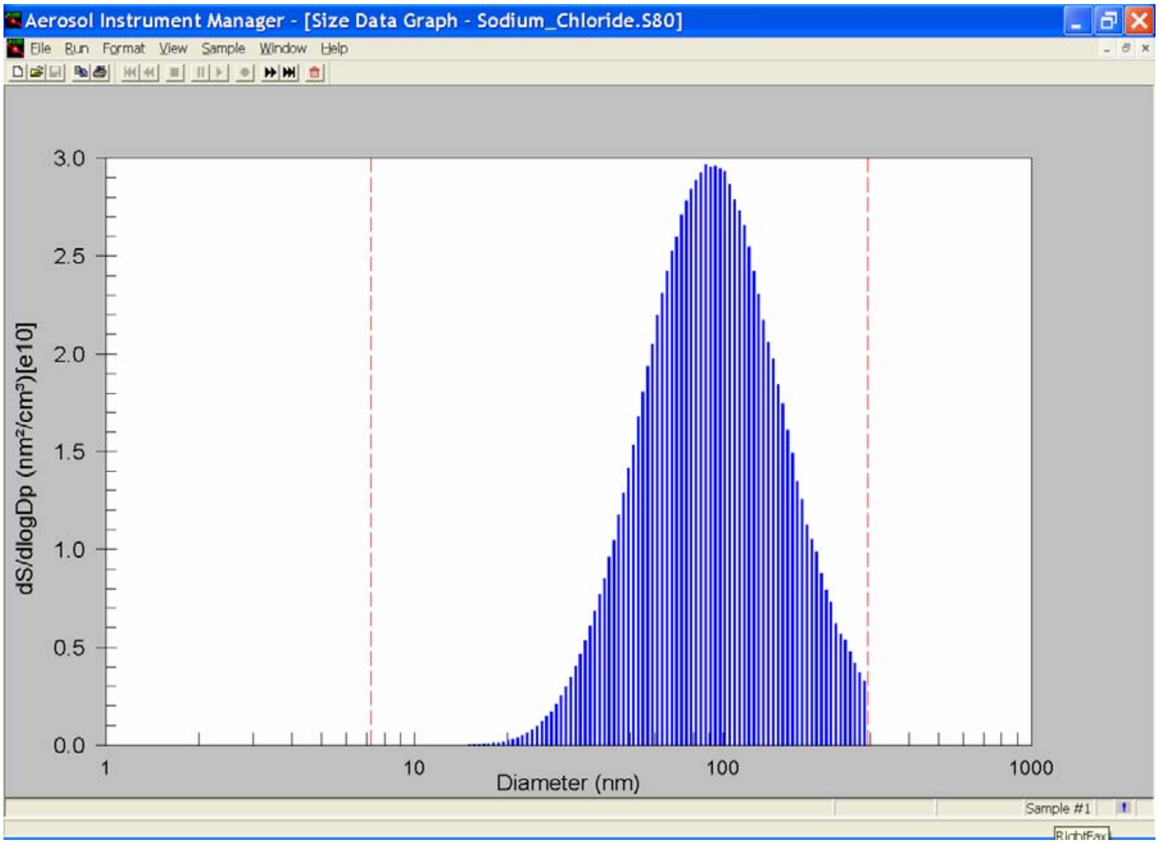

Figure 5-4
Typical Surface Area Distribution of a Sodium Chloride Aerosol Atomized from 0.0001 gram/cm^3 Solution

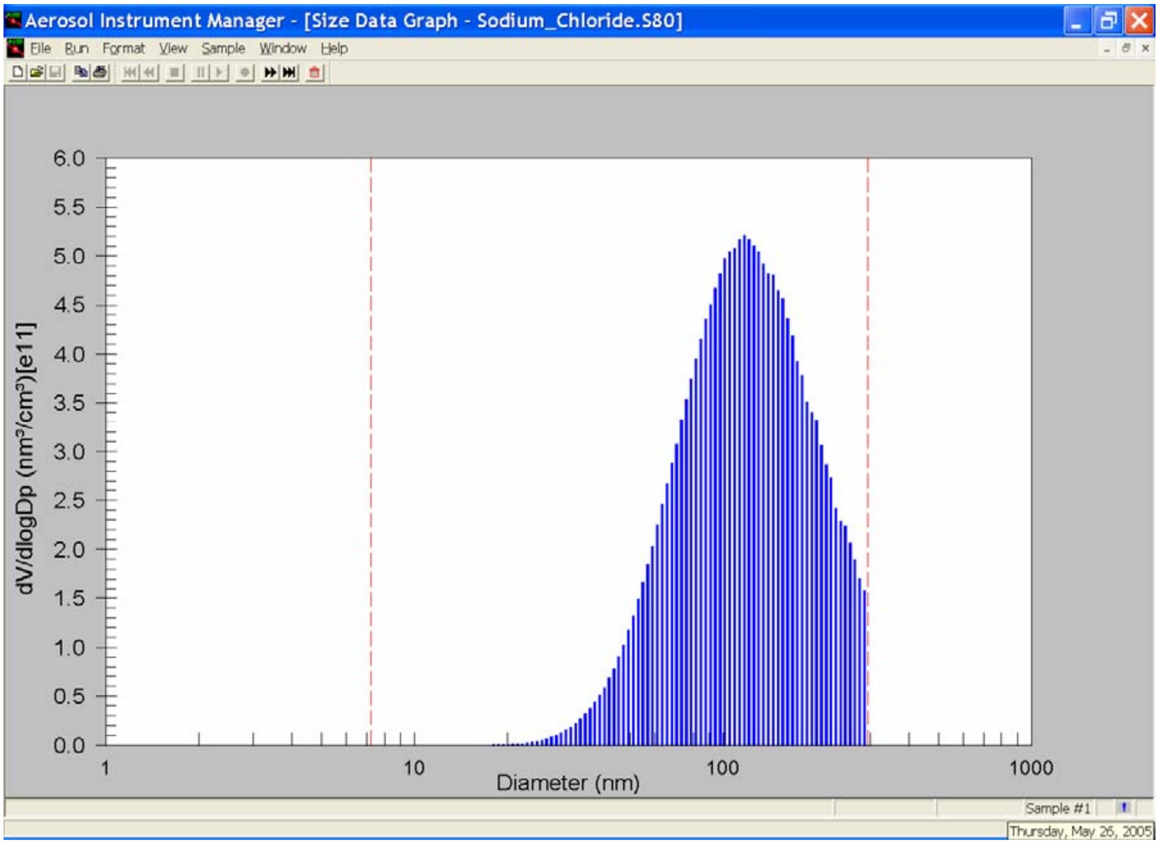

Figure 5-5
Typical Volume Distribution of a Sodium Chloride Aerosol Atomized from 0.0001 gram/cm^3 Solution

It should be emphasized that the aerosol coming out of the Atomizer is wet and has a high electrostatic charge. Until the particles are completely dry, the particle size changes. A diffusion dryer, discussed in Chapter 4, is highly recommended.

Generating Oil Aerosol

Oil aerosol from solutes such as dioctyl phthalate (DOP), olive oil, and oleic acid can be generated either with or without alcohol as the solvent. Use the nonrecirculation mode of operation when using alcohol as the solvent (see Chapter 3). To obtain constant output, provide sufficient damping and mixing in the aerosol stream. You can construct a simple damping chamber with a 1-liter bottle, similar to the reservoir bottle used in the recirculation mode. Feed the aerosol to the bottom of the bottle through one fitting and remove the aerosol through the other.

Dispersing Polystyrene Latex Particles

A common method of generating monodisperse aerosol is to atomize a hydrosol that contains monodisperse solid particles such as polystyrene latex (PSL).

Mix a few drops of PSL with a liter of water and test the aerosol output concentration. If the concentration is too low, add a few more drops of PSL. However, proceed slowly and thoroughly mix the PSL since each droplet of concentrated PSL has a high number of particles.

Dispersing Solid Particles

Nonsoluble submicrometer particles, such as carbon black, have been successfully dispersed using this Atomizer [6]. The complete configuration is shown in Figure 5-6.

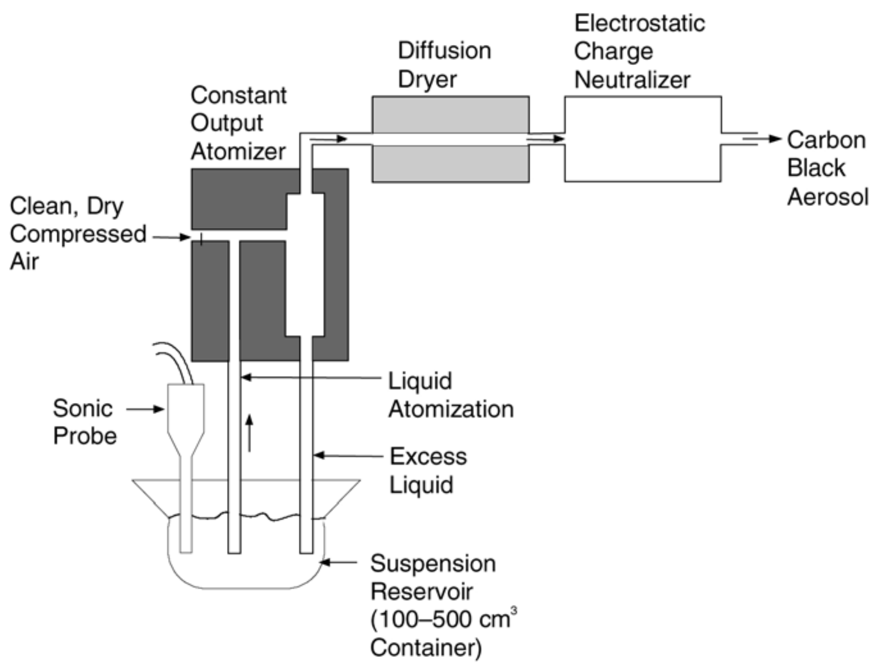

Figure 5-6
Using the Atomizer to Generate Carbon Black Aerosol

The suspension is aspirated through the $\frac{1}{16}$-inch-diameter tube from an open reservoir and excess suspension is returned to the same reservoir. A sonic probe* is used to continuously disperse the particles in the hydrosol reservoir. Results show that the aerosol consists mainly of primary particles—the agglomerates that are fused together by the carbon black manufacturing process—and that the level of agglomerates is very low.

An alternate method, which uses the bottle in the recirculation mode, is to deagglomerate the particles with a sonic probe for several minutes and then stir the suspension with a magnetic stirrer while atomizing. This allows the bottle to be sealed to the Atomizer head. The exact length of time particles remain in suspension (several hours), depends on their size and density.

The performance of the Atomizer was checked according to the method described by Liu and Lee (see Appendix B of this manual).

The most important factors for quality atomizing are (a) drying and neutralizing the aerosol; and (b) diluting the aerosol to the desired concentration. If the silica gel in the dryer is not dry enough, you may notice a gradual increase in the output of the aerosol detector.

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*Sonicator® 3000, Misonix Inc, 1938 New Highway, Farmingdale, NY 11735 or equivalent product from other manufacturers.

CHAPTER 6

Atomizer Maintenance and Service

Use the information in this chapter to maintain the Model 3076 Constant Output Atomizer and to contact TSI Incorporated for service.

Maintaining the Atomizer

The Atomizer needs virtually no maintenance. However, it should be kept clean and free of rust. Even though most of the Atomizer parts are made of stainless steel, solutes such as sodium chloride will eventually corrode them. Therefore, TSI recommends that the Atomizer assembly be disassembled, cleaned, dried, and reassembled after such materials are used. Figure 6-1 shows the various parts of the Atomizer assembly.

Note: *When taking the Atomizer apart, be careful not to damage the delicate platinum nozzle plate.*

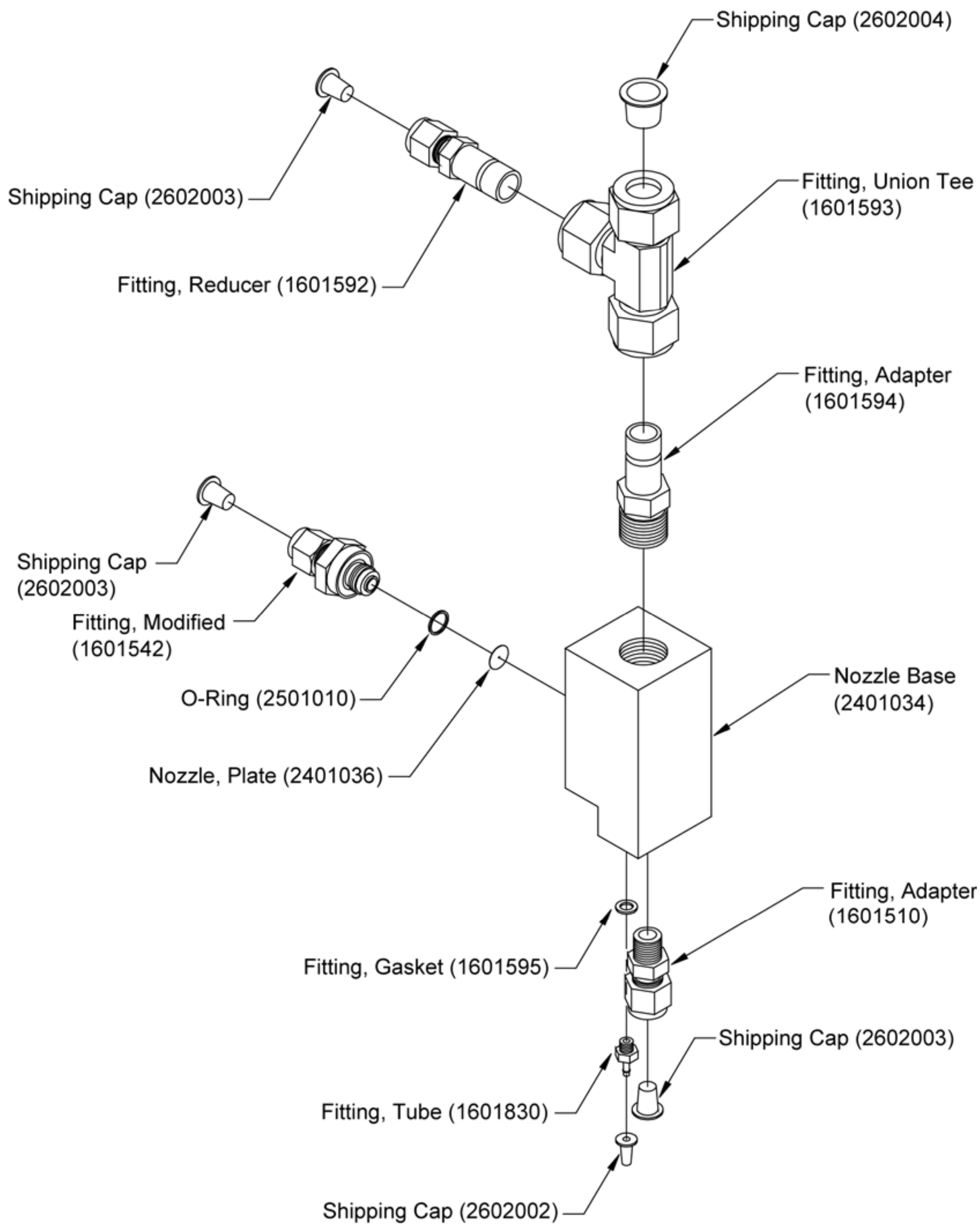

Figure 6-1
Atomizer Assembly

Servicing the Atomizer

Use the information in this section to contact technical personnel at TSI or to return the Atomizer for service.

Technical Contacts

- ❑ If you have any difficulty setting up the Atomizer, if you need to replace the 1-liter bottle, or if you have technical or application questions about this instrument, contact an applications engineer at TSI Incorporated, 1-800-861-7032 or (651) 765-3797.
- ❑ If the Atomizer fails, or if you are returning it for service, contact TSI Customer Service at 1-800-861-7919 (USA) or (651) 490-3838.

Returning the Atomizer for Service

Prior to shipping any components to TSI for service or repair, please utilize our convenient Return Material Authorization (RMA) Form, which is available online at www.tsi.com.

Or, call TSI Customer Service at 1-800-861-7919 (USA) or (651) 490-3838 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 Atomizer to TSI. If you no longer have the original packing material, seal off the inlets and outlets to prevent debris from entering the instrument.

APPENDIX A

Specifications

The following specifications, which are subject to change, describe the most important data of the major components.

Table A-1
Specifications of the Model 3076 Constant Output Atomizer

Number mean droplet diameter .	0.30 µm DOP; 0.35 µm water
Max PSL size	2 µm
Geometric standard deviation	1.6 to 2.0
Particle material	PSL, DOP, oils, and other aqueous or alcohol solutions or suspensions
Generation rate (nominal)..........	2×10^6 particles/cm^3 (10^8 particles/sec)
Air flow rate...............................	3.0–3.5 L/min at 2.5 kg/cm^2 [35 psig]
Liquid flow rate	20 cm^3/min at 35 psig 0.59 cm^3/min nominal with syringe pump”
Liquid consumption rate (water)..	Approximately 0.1 cm^3/min
Dimensions	
Base (L x W)	20×30 cm [7.9×11.8 in.]
Stem (L x W x H)	$6 \times 8 \times 46$ cm [$2.4 \times 3.1 \times 18.1$ in.]
Weight.......................................	4.5 kg [10 lb]

APPENDIX B

Technical Paper

This appendix contains a technical paper by Liu and Lee.

This paper reports on the use of a syringe pump to provide a constant liquid flow to an atomizer to obtain an aerosol generator of high stability. This syringe-pump atomizer has also been used with a vaporizer-condenser to generate monodisperse DOP (di-octyl phthalate) aerosols in the 0.032 to 1μm diameter range.

An aerosol generator of high stability

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Particle Technology Laboratory, Mechanical Engineering
Dept., University of Minnesota, Minneapolis, Minnesota 55455

Introduction

Pneumatic atomizers are frequently used for generating aerosols from substances that are soluble in water or other liquids. By atomizing the solution and evaporating the solvent from the solution droplets an aerosol of the original substance can be obtained. The method has great flexibility in that both solid and liquid particles can be generated and the size of the aerosol can be changed easily by changing the solution concentration.

Various atomizers have been used for generating aerosols. Among the more widely used are the Collison atomizer[1] and the DeVilbis (the DeVilbis Co., Somerset, Penn.) and Lovelace nebulizers (Retec Development Lab., 9730 S.W. Scholls Ferry Rd., Portland, Oregon 97223). While these atomizers are adequate for many applications, they share one disadvantage in common: as the solvent is evaporated from the solution reservoir, the remaining solution in the atomizer becomes more concentrated, thus causing the aerosol particle size to increase. This change in particle size is particularly rapid when a volatile solvent such as alcohol is used. For less volatile liquids such as water, the problem is generally less severe.

Various attempts have been made by different investigators to reduce the change in particle size due to solvent evaporation. These include the pre-saturation of the atomizing air, the compensating addition of liquid solution[2] and a combination approach[3] involving controlled liquid addition and careful pre-saturation by temperature and pressure control. While these attempts have all succeeded partially in improving the atomizer operation, they do not go sufficiently far to solve the problem. In this paper we will describe a new approach that is simple in concept, easy to implement and results in an atomizer of exceptional stability.

B. Y. H. Liu is presently a professor of Mechanical Engineering and the Director of the Particle Technology Laboratory, University of Minnesota. He received his Ph.D. in Mechanical Engineering in 1960.

K. W. Lee is presently a Research Assistant and a candidate for the Ph.D. degree in Mechanical Engineering at the University of Minnesota.

The constant liquid feed atomizer

Figure 1 is a schematic diagram of the atomizer developed for the present study. The atomizer is similar to the conventional atomizer, except in the use of a constant-flow liquid feed system. The actual atomizer nozzle design follows closely that of the Collison atomizer. A 0.343 mm diameter orifice (No. 80 drill hole) is used as the compressed air orifice through which dry filtered compressed air at 35 psi expands to form a high velocity jet. The liquid to be atomized is supplied to the jet through a 1.59

mm (1/16″) diameter hole and becomes atomized by the high velocity jet. Coarse droplets in the spray are removed by impaction on the opposite wall and the excess liquid thus collected is allowed to drain off to a closed

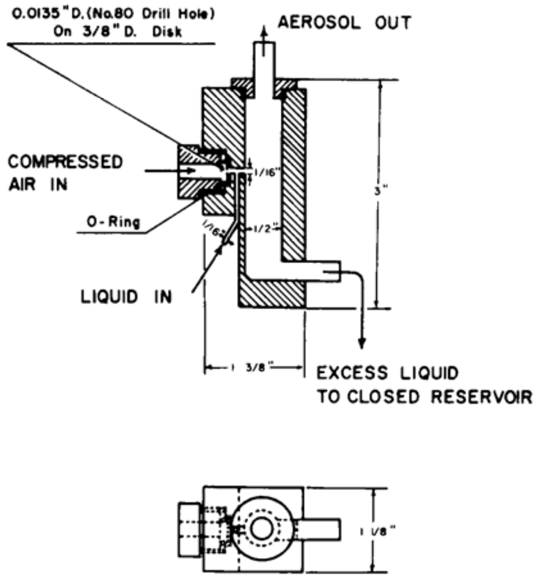

Figure 1 – Design of the atomizer using a constant-flow liquid feed system based on the use of a syringe pump.

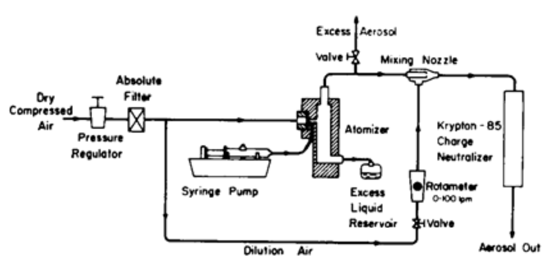

Figure 2 – An atomizer aerosol generator using the syringe pump atomizer.

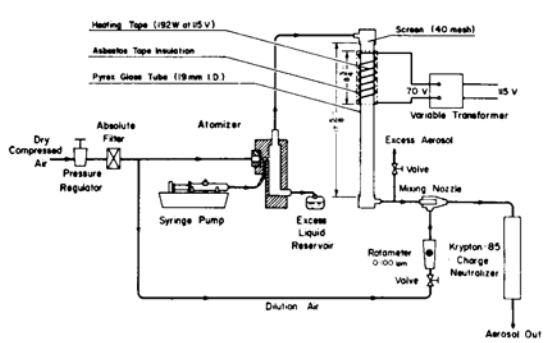

Figure 3 – A condensation aersol generator using the syringe pump atomizer.

reservoir and discarded at the end of the experimental run. The fine spray then leaves the atomizer at the top.

To provide a constant liquid flow to the atomizer, a syringe pump is used. The syringe pump (Model 975, Harvard Apparatus Co., 150 Dover Road, Millis, Mass. 02054) chosen has a synchronous motor drive and is capable of providing stable constant liquid flows. This particular pump can accept standard plastic or glass syringes of 2 to 100 cc capacity. A total of 30 gear positions in the pump allow the liquid flow rates to be varied between 0.00045 and 155 cc/min. Since fresh liquid is supplied continually to the atomizing head by the syringe pump and the excess liquid collected by impaction is not recirculated as in the conventional atomizer, the system is capable of very stable operation, as the data presented below will show.

For generating an aerosol with the atomizer just described the system shown in Figure 2 is used. Here the atomized spray is first mixed with dry-filtered air to evaporate the solvent from the solution droplets. The mixed stream then passes through a Krypton-85 radioactive source to reduce the particle electrostatic charge. A 2 mCi Krypton-85 source is used which is adequate to reduce the particle charge to the minimum level described by the Boltzmann's law.[4] The performance of the Krypton-85 neutralizer has been previously described.[5]

The condensation aerosol generator

The syringe pump atomizer described above has also been used with a vaporizer and con-

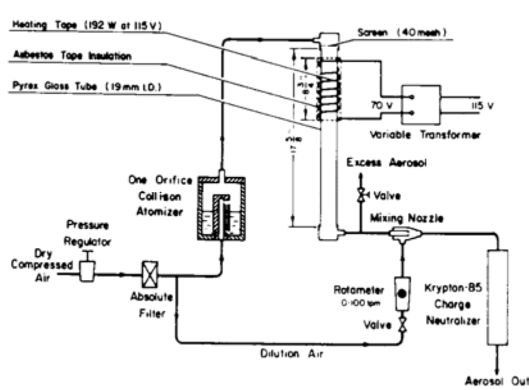

Figure 4 – A condensation aerosol generator using the conventional Collison atomizer.

denser as shown in Figure 3 to produce monodisperse DOP (Di-octyl phthalate) aerosols by vaporization and condensation. In this system the DOP is first dissolved in alcohol and is sprayed by the atomizer. The polydisperse DOP aerosol thus produced is then passed through a vertical glass tube of 1.9 cm diameter. The upper half of the glass tube is heated electrically by a heating tape with a rated capacity of 195 watts at 115 volts and operated at a reduced voltage (70 volts) to reduce the heat generated. The DOP aerosol passing through this heated glass tube is vaporized and the vapor subsequently recondenses to form uniform droplets in the lower half of the glass tube, which is cooled by free convection. The stream then passes through the Krypton-85 neutralizer, as before, to obtain a monodisperse aerosol with a low level of bipolar charge.

Figure 4 is a schematic diagram of a similar condensation generator which uses a conventional Collison atomizer, instead of the syringe pump atomizer described above, to produce the initial polydisperse spray. The Collison atomizer used had a single jet and a liquid reservoir capacity of approximately 100 cc. This particular generator represents a simplified version of an earlier generator[6] developed in our laboratory. It is included here in order to allow the performance of these two types of generators to be compared.

In producing monodisperse DOP aerosols with the condensation generators, a small amount of anthracene was added to the DOP-alcohol solution prior to atomization. Since anthracene has a higher boiling point than DOP, it would remain in the form of small suspended particles in the vaporizing section after the DOP is vaporized. These small suspended particles then provide the necessary nuclei for the condensation of the DOP vapor. Previous experience[6,7] shows that the use of anthracene helped to stabilize the generator operation. In these experiments the DOP-to-anthracene ratio was kept at about 10,000 to 1 by weight.

The performance of the aerosol generator

To monitor the output of the aerosol generator an electrical aerosol detector was used. The detector was comprised of an aerosol charger, which placed a unipolar charge on the aerosol particles, and a charged particle detector, which collected the particles by filtration and measured the total current with an electrometer. The electrical aerosol detector was made from standard components used in the commercial electrical aerosol analyzer (Model 3030, Thermo-

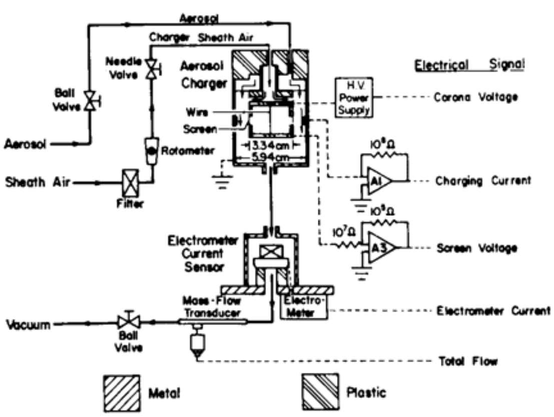

Figure 5–Schematic diagram of the electrical aerosol detector.

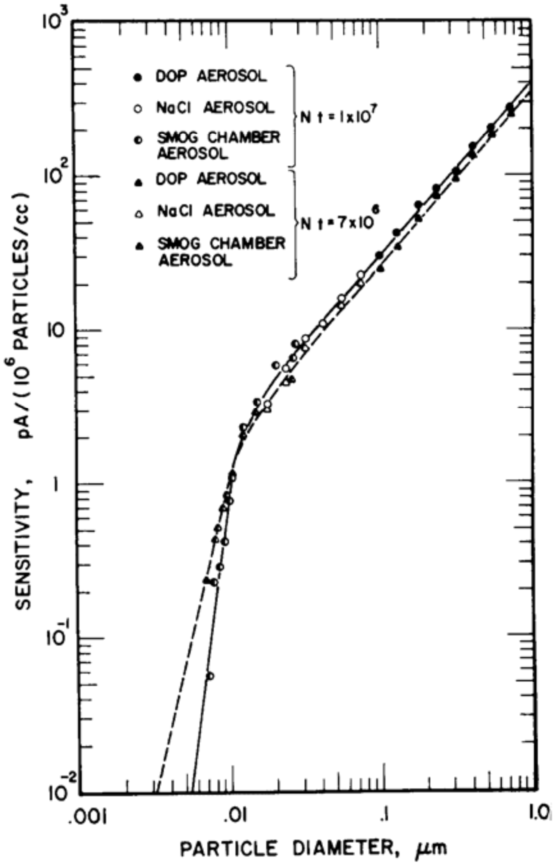

Figure 6–Sensitivity of the electrical aerosol detector as a function of particle size according to Liu and Pui.[8]

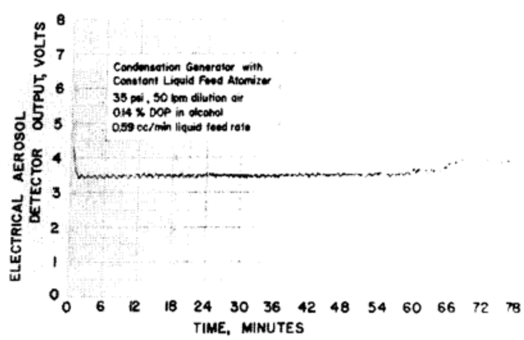

Figure 7–Recorder chart showing the output of the aerosol generator operated with the syringe pump atomizer.

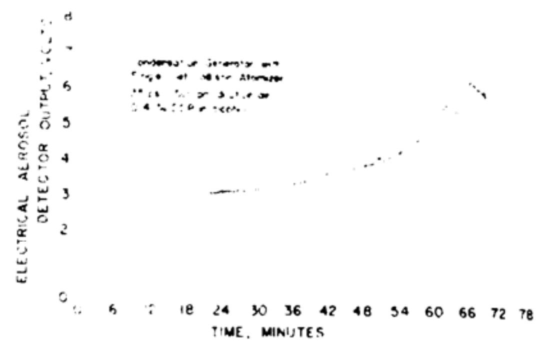

Figure 8 Recorder chart showing the output of the aerosol generator operated with the conventional Collison atomizer.

Systems, Inc., 2500 N. Cleveland Ave., St. Paul, Minn. 55113) which has been described in detail by Liu and Pui.[8] Figure 5 is a schematic diagram of the electrical aerosol detector and Figure 6 shows the sensitivity of the detector as a function of particle size according to calibration data previously reported by Liu and Pui.[8]

Figure 7 is a recorder chart showing the output of the condensation aerosol generator (Figure 3) as monitored by the electrical aerosol detector. The generator operation is seen to become steady about one minute following the start of the syringe pump. The generator ouput then remained steady for about 60 minutes, during which time the aerosol output fluctuated by not more than $\pm 2\frac{1}{2}\%$ from the mean. Finally, when the syringe pump had reached its end position, the generator output fluctuated for about 15 minutes before dropping to zero.

Figure 8 is a similar recorder chart showing the operation of the condensation aerosol generator with the conventional Collison atomizer. The generator output in this case is seen to rise steadily over the 70 minute period when the generator was in operation and the output at the end is nearly 2½ times the initial generator output. The improved performance of the generator with the constant-flow liquid feed system thus becomes obvious.

In obtaining the result shown in Figure 7, the liquid supply system was operated at a flow rate of 0.59 cc/min. and a 50 cc syringe was used with the syringe pump. This combination could provide approximately 80 minutes of steady operation. However, because the syringe used was only partially filled, only 60 minutes of steady operation was obtained. To obtain longer operating time, larger syringes can be used. For instance, by using two 100 cc syringes in parallel which is possible for the particular syringe pump chosen, a total of 200 cc of liquid capacity and approximately 5½ hours of steady operation can be obtained. However, since refilling of the syringe takes only about 1 minute, the single syringe system is capable of essentially indefinite operation if brief interruption in the generator output is permissible.

Several experiments were performed to determine the effect of liquid flow rate on generator operation. The result shows that below a certain minimum flow rate, the generator output became unsteady. Figure 9 is a recorder chart showing this unsteady operation of the generator at a liquid flow rate of 0.21 cc/min. The fluctuation in generator output was apparently caused by the periodic emptying and refilling of the small liquid supply tube just below the jet. This periodic fluctuation ceased when the supply liquid flow exceeded the minimum flow rate of approximately 0.59 cc/min. When the flow rate was higher than this minimum, the excess liquid was simply removed by impaction and drained off from the atomizer chamber into the reservoir. The generator output was not greatly affected. This is seen in Figure 10, which shows the average output of the generator as a function of the supply liquid flow rate. From these experiments, it is concluded that the optimum liquid flow for this particular generator was approximately 0.59 cc/min.

The operation of the atomizer as an aerosol generator without the vaporizer and condenser was similarly monitored in a few cases. The results were very similar to those shown in Figures 7 and 9.

No extensive size distribution measurements were made on the constant liquid-feed

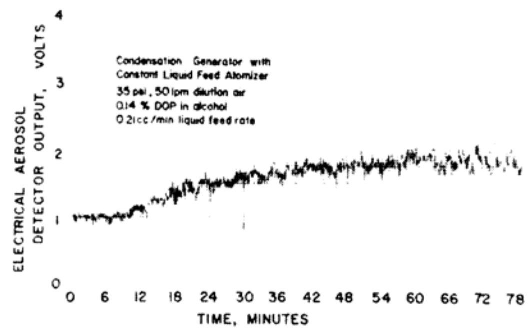

Figure 9 Recorder chart showing the unsteady operation of the syringe pump atomizer at low liquid feed rates.

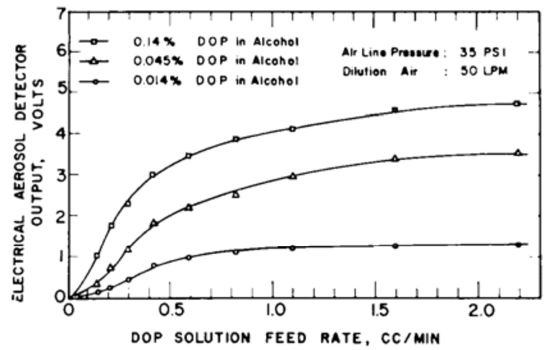

Figure 10 Output of the condensation generator as a function of the liquid feed rate.

atomizer, since the size distribution is not expected to be greatly different from that of the Collison atomizer, on which extensive data already exist. However, the size distribution of the condensation generator was measured with an optical particle counter and the electrical aerosol analyzer in their respective ranges. The results are shown in Figure 11. These data indicate that the median particle size of the aerosol varied from 0.032 μm with a DOP concentration of 0.0048% to 1.3μm for 100% DOP. The measured geometrical standard deviation of the aerosol was found to be between 1.2 for the 100% DOP and about 1.4 for the 0.0048% DOP. These results are in close agreement with those reported previously by Liu et al[6] for the condensation generator using the standard Collison atomizer as the atomizer.

Conclusions

The experimental results reported in this paper show that the use of a constant-flow liquid feed system with a conventional atomizer results in an aerosol generator of exceptional stability. The simplicity of the system, its flexibility and ease of operation should combine to make it a useful device for the generation of laboratory aerosols in experimental aerosol research.

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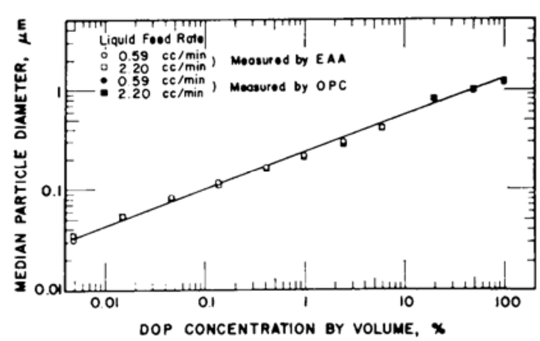

Figure 11 Median particle size of the condensation aerosol generator as a function of the DOP concentration.

APPENDIX C
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