Brechtel Manufacturing Incorporated

Model 9200 Aerosol Generation System Manual
Version 5.0

Date: February 17, 2014

Brechtel Manufacturing Inc.
1789 Addison Way, Hayward, CA 94544
510.732.9723 Fax: 510.732.9153
Web: www.brechtel.com
bmi_info@brechtel.com

Contents

List of Figures

List of Tables

1 Introduction

This manual provides technical information describing the use and maintenance of the BMI aerosol atomizer, in-line desiccant dryer and the optional HTDMA Auto-atomizer electronics chassis shown in figure 1. The manual should be read in its entirety. Pay special attention to items in *italicized* and **boldfaced** items.

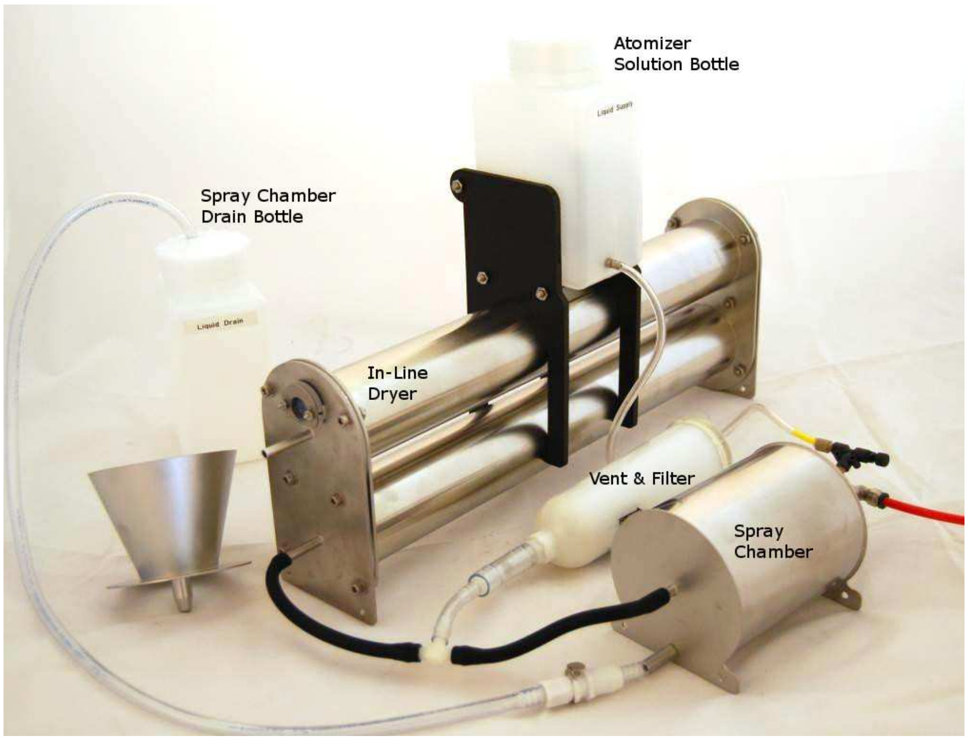

Figure 1: BMI aerosol atomizer system with spray chamber and in-line desiccant dryer.

2 Background of the Atomizer

The major components of the complete aerosol generation system are shown in figure 1 and include:

1. A nalgene bottle, bottle mounting bracket, and liquid metering valve to supply salt solutions, polystyrene latex sphere (PSL) solutions or some other solution to the atomizer sprayer,
2. the aerosol atomizer and spray/dilution chamber,
3. a filtered vent line from the spray/dilution chamber to exhaust excess sprayer sample flow,
4. an in-line desiccant dryer to dry the particles in the output flow of the spray/dilution chamber,

5. a desiccant filling tool to make it easy to replace your desiccant,
6. a liquid drain bottle to allow periodic draining of the spray chamber, and
7. for HTDMA-integrated aerosol generation systems, an optional Auto-atomizer electronics chassis and syringe pump or other liquid control valve to allow software control over an automated 3-way valve and automatic atomizer operation.

The purpose of the atomizer system is to produce particles of known chemical composition and diameter size range, generally for laboratory experiments where specific aerosol chemical properties, size and concentration are desired. Examples of uses include characterizing the size, chemical and concentration response of aerosol instrumentation, smog chamber studies of gas-to-particle conversion processes on pre-existing (atomized) aerosol, and exposure studies to determine the impacts of known doses of aerosols on biological systems.

3 Starting the Atomizer for the First Time

Follow these steps to set up your atomizer system (refer to figure 1) :

1. Find sufficient table top space for the assembly (about 2x2 ft). **The user must supply a filtered pressurized air supply with a pressure range between 25 and 30 psig.** For a 30 psig setting, a 4 lpm flow rate is controlled automatically by the atomizer sprayer orifice diameter and the absolute value of the pressure applied. See table 1 below for the variation of air flow rate with applied pressure. We recommended that the compressed air source be passed through molecular sieve and activated carbon cartridges (supplied by the customer) to remove oils and other undesirable vapors from the air supply if extreme chemical purity is required. If additional cartridges are installed in-line between the compressor and the regulator of the atomizer assembly, then it is recommended that a HEPA-style filter also be installed in-line just upstream of the regulator. The additional cartridges will shed dust that could clog the filter built into the atomizer assembly.
2. Connect the pressurized air supply either directly to the 1/4" diameter tube on the atomizer sprayer (see fig. 2) using the press-on fitting supplied or to the compressed air supply input on the back panel of the HTDMA Auto-atomizer chassis if this option has been purchased.
3. Mix the desired atomizer solution (described in more detail below) and pour it into the top of the nalgene bottle labelled "Liquid Supply Bottle".
4. **Ensure that the 1/8" diameter metal liquid supply tube on the atomizer sprayer (with attached black plastic metering valve) is positioned pointing upward at the "12-o'clock" position when viewed from the input-tubing end (rear) of the assembly. This is critical to proper operation.** Refer to figure 3. This orientation allows the liquid stream to "fall" into the air jet and promotes more constant atomization. The atomizer should have been shipped with the liquid feed tube in the correct orientation. See photos below.

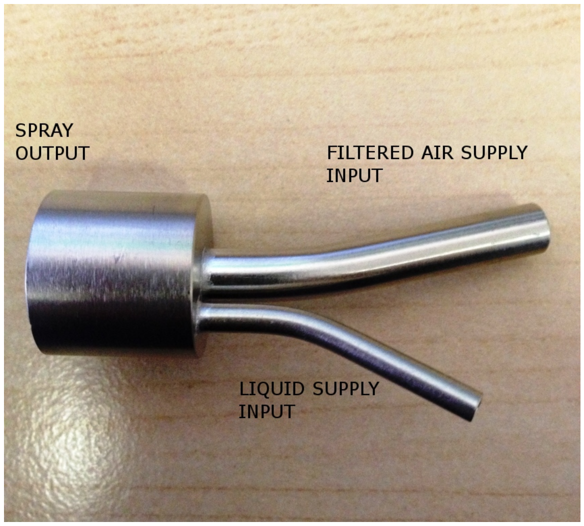

Figure 2: Photo of BMI atomizer showing filtered air supply input line (1/4" outside diameter tube) and liquid supply input line (1/8" outside diameter tube). The liquid stream and filtered air jet mix at the sprayer output on the left side of the photo.

5. If the atomizer will be interfaced to a Auto-atomizer control system (optional, see fig. 4), plug in the AC power chord to the back panel of the Auto-atomizer chassis (see fig. 5) and install the interconnect cable between the atomizer and the front panel of the Humidified Scanning Electrical Mobility Sizer of the Humidified Tandem Differential Mobility Analyzer (fig. 5) . Also connect the syringe pump AC power chord to the front panel power connector on the chassis. See photos below.

6. Complete the Auto-atomizer chassis hookup by connecting the syringe installed in the syringe pump to the liquid metering valve on the atomizer (see fig. 6). See photo below.

7. Connect the atomizer chamber air out flow port to the supplied barbed tee fitting. The perpendicular leg of the tee fitting should be connected to supplied vent exhaust filter. The second in-line leg of the tee fitting attaches to the in-line dryer air in port. See fig. 1.

8. It is important that any excess air from spray/dilution chamber passes through a filter to properly vent any excess air that is not used. The vent allows proper air flow matching between the customer's instrumentation and the total air flow provided by the atomizer. For example, if 4 lpm is flowing out of the atomizer spray/dilution chamber but only 2 lpm of air flow is drawn from the atomizer by the customer's instruments, then 2 lpm will automatically flow out of the tee fitting vent through the HEPA filter.

9. Ensure that any unused tubing connections in the atomizer chamber and dilution chamber are properly capped off and sealed.

10. The Atomizer Chamber liquid drain tube should be connected to the provided drain tube and connector. Open the valve by pressing down

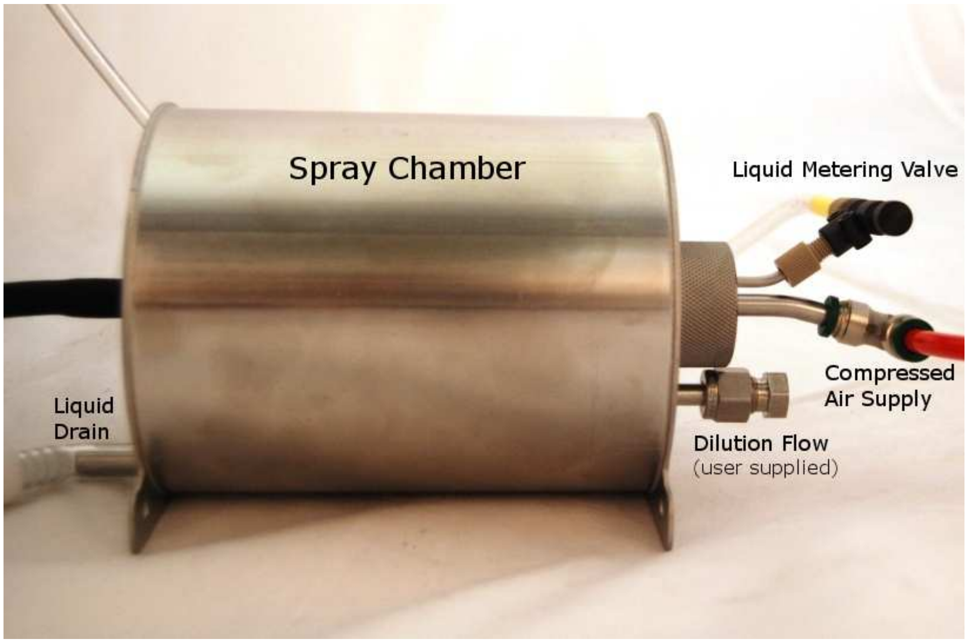

Figure 3: Photo of spray chamber showing filtered air supply input line (1/4" outside diameter tube) and liquid supply input line (1/8" outside diameter tube). Note the position of the liquid metering valve ABOVE the compressed air supply fitting.

the metal tab on the connector and dispense the waste liquid into the drain bottle supplied with the system by inserting the mating fitting on the drain bottle tubing into the drain connector connected to the atomizer assembly. See fig. 1. **The drain bottle must be below the level of the spray chamber for the chamber to be properly emptied.**

11. Connect the "Air Out" port (upper 1/4" diameter tube) of the in-line dryer to your system requiring aerosol. The "Air Out" port is found on the end of the dryer with the view window to observe the state of the desiccant. When the desiccant color is no longer blue it should be changed. See fig. 1.

12. If your application requires polydisperse concentrations below 100,000/cc, reduce the liquid flow rate to the atomizer by turning the small PEEK liquid metering needle valve clockwise. The higher the liquid flow rate, the greater the number of particles. The output concentration is very sensitive to valve position, with concentrations controllable between a few thousand/cc and 150,000/cc by turning the valve through only roughly one-quarter turn from fully closed. Output concentrations can also be lowered by adding dilution flow to the atomizer spray/dilution chamber. Any excess flow will vent from the chamber exhaust port. Minimizing the flow through the in-line dryer maximizes the lifetime of the desiccant.

13. Install the plastic liquid supply bottle holding bracket by slipping it

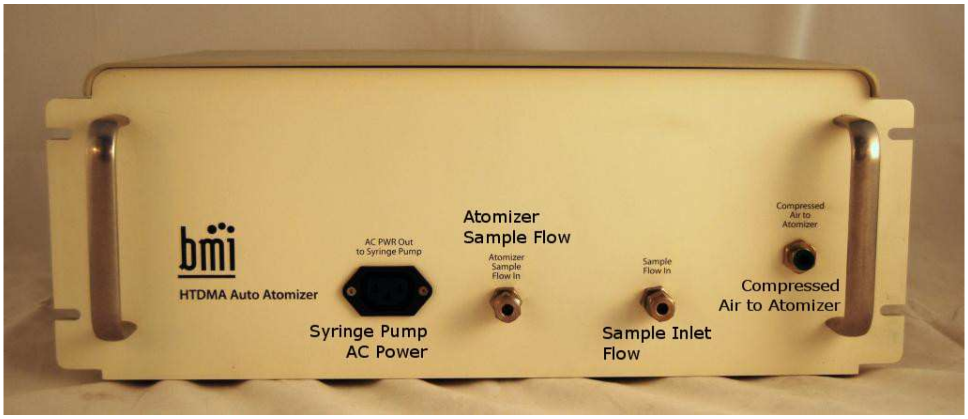

Figure 4: Front of the Auto-atomizer chassis showing the switched syringe pump AC power hookup, atomizer spray chamber hookup, user inlet hookup and switched compressed air output to the atomizer.

over the metal tube body of the in-line dryer and sliding the bottle into place. See fig. 1. The liquid flow is gravity driven to the small black needle valve. Remember to remove the liquid supply bottle from the holding bracket when the atomizer is not in use, otherwise liquid will continue to run out through the valve.

It is recommended that you leak check your atomizer installation by turning off the liquid supply flow to stop the liquid flow and use a particle counter to verify zero counts when only filtered air is supplied to the atomizer. If counts are observed, check the tightness of all fittings, tube connections, and nut and bolt connections.

Avoid delivering atomized droplets or particles directly into the environment from which you are breathing. Always turn off the liquid supply (close the liquid supply valve and empty, rinse and dry the nalgene bottle) or filter the output of vents or other openings in the generation system when particles could be inhaled.

4 Technical Information about the Atomizer System

Technical details describing the individual components are provided in the sections below.

4.1 Atomizer

The atomizer functions by creating a high-speed jet of filtered air into which a liquid stream is dropped like a waterfall. A photo of the atomizer showing the filtered air and liquid supply connections is provided in figure 2. The air jet breaks the liquid stream into small, micron-sized droplets which, when dried, leave residue particles having the chemical composition of the original water-soluble species in the liquid supply bottle solution.

The highest purity (18 Megaohm) water should always be used with the atomizer to minimize artifact particles associated with impurities. Even with high purity water, residue

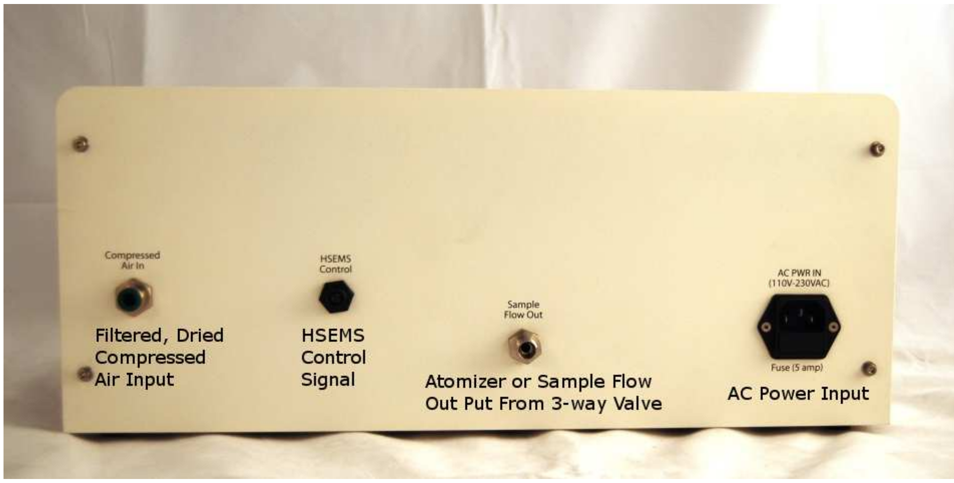

Figure 5: Rear of the Auto-atomizer chassis showing the AC power input, atomizer or user inlet outlet, HSEMS control signal input and the compressed air input to the atomizer.

particles are always found, typically in the 20 to 100 nm diameter size range and at concentrations less than 1000 cm^{-3}. It is recommended that you atomize your pure water and observe the resulting number size distribution of artifact particles. These particles will likely always be present every time the atomizer is operated.

The eventual size of the dry particles created by the atomizer is controlled by the size range of droplets generated by the atomizer and the concentration of the chemical species in the atomized solution. The user has a certain amount of control over each of these parameters. Typically, solution concentrations between 0.01 and 0.5% by mass of ammonium sulfate are used to produce dry ammonium sulfate particle diameters between 30 and 200 nm. The breadth of the generated particle distribution is typically less than a standard deviation of 2.

The higher the operating pressure of the filtered-air source, the smaller the primary droplet size created by the atomizer. The smaller droplet size will correspond to a decreased dry particle diameter for a constant solution concentration. Generally, the operating pressure should be kept below 60 psig. Typical air flow rates for different applied pressures are shown in 1.

Increasing the liquid flow rate to the atomizer increases the number concentration of droplets and therefore also the number concentration of generated dry particles. It is recommended that the liquid flow rate be chosen to provide the minimum acceptable output concentration for your application that can be generated in a stable fashion. Operating at too low of a liquid flow rate will produce fluctuations in the output concentrations that may be unacceptable. The liquid flow rate can be controlled by adjusting the position of the PEEK needle valve attached to the atomizer liquid input tube.

4.2 Atomizer Liquid Supply

The atomizer liquid supply is simply a 1000 ml nalgene bottle with a tube at the bottom to supply liquid to a miniature PEEK metering valve. The valve is set by the user to provide the desired particle concentrations. Under standard experimental conditions, the flow rates are between 0.1 and 20 ml/hour, the precise value will depend on the needs of the user. Adjust the valve and species concentration in the liquid to explore the best operating parameters

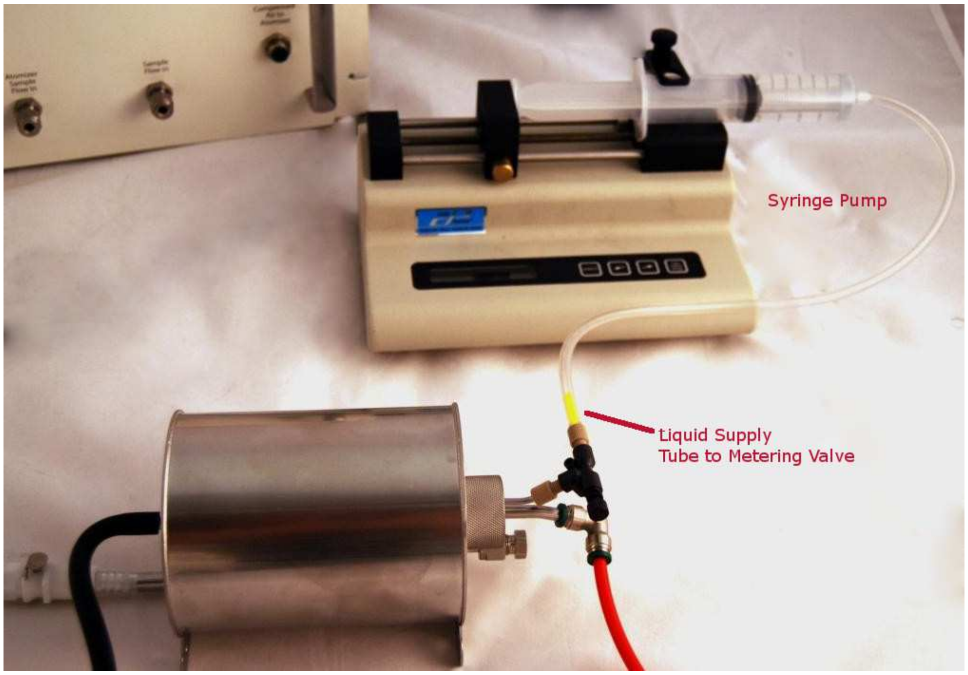

Figure 6: Liquid supply connection between the syringe pump syringe and the liquid metering valve when the Auto-atomizer chassis is used to automate the operation of the aerosol generation system.

for your application. A vent hole in the cap allows liquid flow even when the cap is fully tightened on the bottle.

It is highly recommended that the nalgene bottle be rinsed with methanol and MilliQ water between each use to reduce the concentrations of artifact particles due to cross-contamination between liquid solutions.

The liquid supply bottle must be located at a height of at least 6 inches above the metering valve to drive the liquid flow through the valve using the pressure-head driven by gravity. A mounting bracket for the bottle is provided to allow it to be mounted on top of the in-line dryer. The bottle may also be located on any convenient shelf or other surface as long as it is higher than the metering valve. Take care to keep the bottle from tipping over.

4.3 Atomizer Spray Chamber

The spray chamber is meant to provide a convenient vessel to facilitate droplet drying and can also be used to dilute the output of the atomizer. It is constructed completely from stainless steel and includes the atomizer sprayer assembly Oring compression port, a dilution air inlet port, a diluted sample outlet port with an external tee fitting for excess air to be vented through a filter, and a liquid drain port to allow excess liquid to be drained from the chamber. Details of the various tubing connections are shown in 3. For applications requiring ultrapure particle composition, the dilution air should be passed through a molecular sieve or activated charcoal scrubber and then a HEPA filter. Since the dilution air is often very dry, the droplets from the atomizer may be effectively evaporated within the chamber. Therefore, the chamber also acts as the first drying stage in producing the dry residue particles from the atomizer.

Table 1: Variation of air flow rate inside atomizer spray chamber with applied pressure.

Pressure (psig)	Flow Rate (lpm)
10	2.0
15	2.5
20	3.0
25	3.4
30	3.9
40	4.8
50	5.7
60	6.6

The chamber will filll with atomized solution over time. Between uses, or during use depending the liquid sample flow rate, the chamber should be drained of any accumulated liquid. The liquid may be drained by connecting the drain bottle to the drain connector at the front of the unit. **Do not leave the drain bottle connected during operation unless a filter is installed on the vent hole in the cap or air flow with droplets and particles will be vented through the cap vent hole to surrounding environment.** Tipping the sprayer end of the atomizer sprayer chamber upwards can help drain accumulated liquid from the chamber, which can also simply be operated in an angled orientation to facilitate draining if desired.

It is recommended that the chamber be cleaned periodically (e.g. annually) by flushing with small amounts of methanol and MilliQ water. During periods of heavy use, inspect the dilution chamber weekly to ensure no liquid is accumulating inside the chamber.

4.4 Atomizer In-Line Dryer

The in-line dryer (see fig. 1) is used to perform the final drying of droplets and particles from the atomizer chamber. Any silica gel drying agent may be used in the dryer, as long as the agent is effective at removing water vapor from the flow. For certain applications where organic particles are generated in an organic solvent, activated carbon may also be used inside the in-line dryer. Be sure that the crystal size of any compound used in the dryer is larger than the size of the openings in the mesh tubing. It is worthwhile to minimize the total flow passing through the in-line dryer to maximize the lifetime of the desiccant. Flow rates up to 5 lpm with input relative humidities of 80% should be sufficiently dried to remove particle-bound water.

The in-line dryer is shipped with two types of desiccant installed. Non-indicating desiccant is used for the majority of the annular volume between the stainless steel body and the inner metal mesh tubing. This desiccant does not change color when it is saturated with water and will no longer remove water vapor from the flow. Near the exit of the in-line dryer, a small amount of indicating desiccant is installed to provide an indication of when the desiccant should be removed and either replaced or re-activated. The indicating desiccant shipped by BMI turns from dark blue to a pink color when it becomes saturated. The change in color can be viewed through the clear view port just above the sample air out tube of the dryer. Contact BMI if you require additional desiccant.

To replace the desiccant, follow these steps:

1. disconnect the tubing connections to the dryer
2. loosen the bolts holding the end cover plate (with the view window)

and remove and set aside the end cover plate (see fig. 7 for disassembled dryer photo)

Figure 7: View of open in-line dryer.

3. obtain a large zip loc bag or plastic enclosure to hold the used desiccant

4. in a well ventilated space (or outside), slowly pour the used desiccant out of the dryer and into the storage container. Avoid breathing the dust from the desiccant

5. obtain the desiccant filling tool (metal conical funnel with centering plug attached) provided with your unit and slide the metal centering plug into the mesh tube in the dryer metal tube that will be filled first (see fig. 8 for a photo of funnel)

6. aline the filling cone with one of the mesh tubes and insert the centering piece on the funnel into the mesh tube so that desiccant does not fill the mesh tube when added, see fig. 9.

7. attach the funnel with one screw to keep it from falling off during filling (see fig. 10) and first pour non-indicating desiccant into the lower dryer tube so the lower tube is full, and then move the funnel to the top tube to pour desiccant within a cm of the air flow exit port

8. fill the remaining volume with indicating desiccant so it will be present at the exit end of the top dryer tube and against the viewing window. Either non-indicating or indicating desiccant may be used for the entire annular volume if desired. Shake the assembly to allow the desiccant to settle and then add more to fill the body tubes.

9. visually verify that the mesh tube is approximately centered inside the desiccant as you fill the annular volume

Figure 8: View of filling funnel

10. Apply fresh oring grease to the oring and replace the end cover plate when filling is completed

11. reconnect all tubing connections.

5 Integrated HTDMA Auto-atomizer

To facilitate on-line calibration tests of the BMI Model 3002 HTDMA and other automated atomizer applications, an automated 3-way valve and atomizer liquid supply system has been packaged within a rack-mountable electronics chassis so that the HTDMA software can automatically switch the 3-way valve from the user's sample inlet to the atomizer inlet and start the atomizer operation. The front, rear and inside views of the chassis are shown in figures 4, 5 and 11, respectively. The various hook-ups and key components of the system are shown in the figures. The HTDMA software has a Auto-scheduler feature that allows the switching between the two inlet and automatic atomizer operation to be performed at user specified time intervals.

When the digital control signal from the HTDMA is sent to the rear panel of the chassis, solid-state relays are switched to supply power to the 3-way valve controllers and the front panel AC power connector for the syringe pump. The solenoid valve controlling the supply of compressed air to the atomizer sprayer is also actuated. The configuration of the chassis with the syringe pump is shown in figure 6. The 3-way valve automatically moves to the atomizer inlet position, filtered air flows to the atomizer sprayer and the syringe pump, which has been pre-programmed to power up in the ON state, begins delivering liquid flow. When the signal from the HTDMA is removed, the 3-way valve automatically moves back to the user's inlet position, the syringe pump power is turned off and the compressed air supply is turned off by the solenoid valve.

6 Operating the Atomizer

Once the initial installation steps have been completed as described above, operating the atomizer involves creating new solutions with the various chemical species of interest, filling

Figure 9: View of first steps to attach funnel to in-line dryer.

the nalgene bottle with solution and positioning the bottle in the elevated mounting bracket, setting the liquid flow valve, and turning on the filtered compressed air source.

Depending on the liquid flow rates used, the atomizer spray chamber may start to fill with liquid. Periodically drain the spray chamber so liquid is not allowed to sit in the chamber for longer than a few days. An easy to use drain port and drain bottle has been supplied for this purpose.

If organic particles are generated, especially if oil is used as the liquid, it is important that the atomizer spray assembly and chamber be cleaned when the experiments have been completed. There is a chance that the organic solvent and/or particles could re-volatilize and influence the chemical composition of future particles generated with the system. In general, the 100% stainless steel construction of the atomizer and spray chamber makes it inert to chemical attack. However, tygon and other plastic tubing may not be compatible with some organic solvents used, check chemical compatibility charts.

It is recommended that the atomizer spray assembly and chamber be disassembled a few times every year and thoroughly cleaned with methanol. Under heavy use conditions the cleaning should be performed more frequently.

Detailed technical specifications of the atomizer are provided in the table below.

Figure 10: View of funnel attached to in-line dryer.

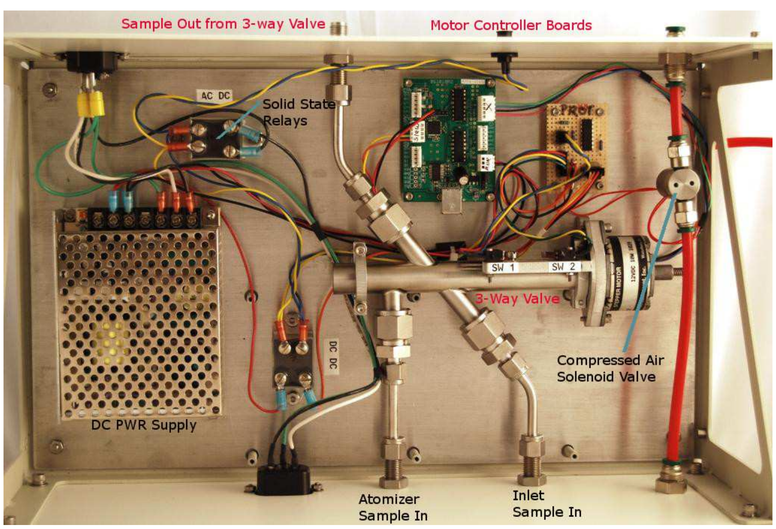

Figure 11: Inside top view of Auto-atomizer chassis showing the various key components.

Table 2: Technical specifications of the BMI Atomizer.

Component	Specification
Air flow rate inside atomizer chamber	2 to 7 lpm
Range of liquid flow rates	0.03 ml/hr to 2 ml/min
Droplet Diameter at 30 psig	1.0 micron
Droplet Diameter at 50 psig	0.8 micron
Mode particle diameter at 30 psig (0.025% NaCl)	50 nm
Mode particle diameter at 50 psig (0.025% NaCl)	45 nm
Typical output concentrations	1,500 to 200,000/cc
Physical Specifications	
Atomizer Chamber Size	4" x 5" (dia x length)
In-line Dryer Size	2.5" x 37" (dia x length)
In-line Dryer Desiccant Capacity	0.75 gallon
Atomizer Bottle Capacity	1000 ml
Dimensions	19"x24"x8" (wxlxh)
Total Atomizer Assy Weight	20 lbs
Electrical Specifications	(Auto-atomizer only)
Supply Voltage	110 or 230 VAC
Power	100 watts
Operating Temperature Range	15-45^{o}C
Operating Pressure Range	0.7 to 1 atm