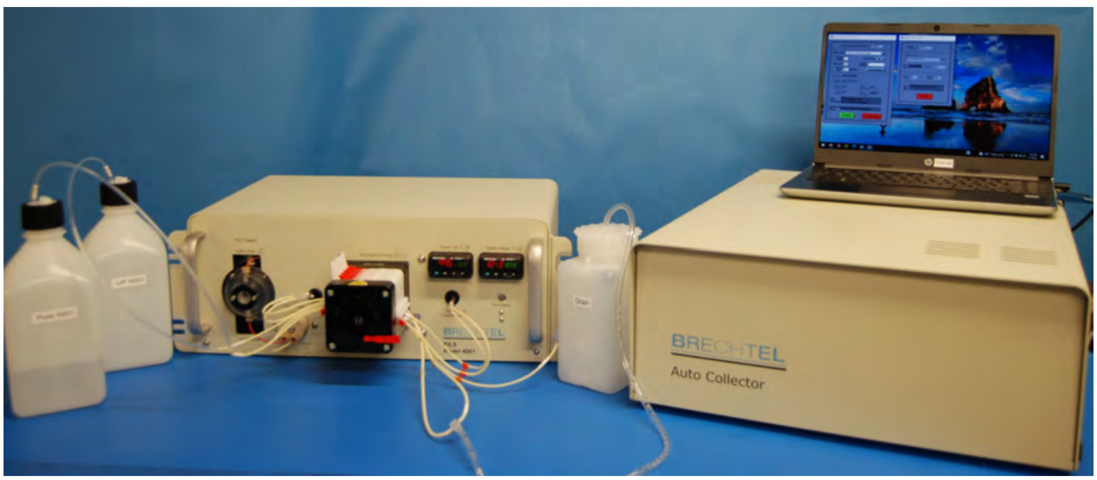
Particle into Liquid Sampler (PILS) Instrument Manual Ver. 3.0

Models 4001-115V and 4001-230V

with PILS-AC80 and PILS-AC38 Auto Collector

For BMI-PILS 4001 v1.0.vi software and BMI-Auto Collector v1.1.vi software



BMI PN: 83-00009-01A

June 6, 2022

Contents

1 Caution

Read this section before operating the device. The operating conditions listed below can be hazardous to you and/or your product.

Symbol	Description
	Indicates a Warning or Hazard requiring further explanation than a label on the device can provide. Consult the user's manual for more information.
	Indicates a hot surface.
	Indicates hazardous voltages.
	Indicates earth (ground) terminal.
	Indicates electrostatic discharge hazard.
	Indicates that you must not discard this electrical/electronic product in domestic household waste.
	Indicates blowing steam hazard.
	Indicates steam energy hazard.

1.1 Indoor use

The model 4001, PILS-AC80, and PILS-AC38 are intended for indoor use only. The operating temperature range of the devices is 0-40C. The operating humidity range of the devices is 10-95%.

1.2 Maximum recommended operating ambient temperature

The maximum recommended operating ambient temperature is 40C.

1.3 Rack-mounting

Only use the hardware and rack-mount ears supplied by the factory to mount the product in a rack.

1.4 Pinch hazard

Do not operate the product with any of the white plastic tubing clamps removed from the peristaltic pump as a pinch hazard may result if a finger, foreign object, or other item becomes lodged between the rollers of the pump.

1.5 Needle puncture hazard

Do not operate the Auto-Collector product with the needle guards removed from the needle housing as a puncture hazard may result if a finger, foreign object, or other item becomes lodged between the needle housing and vial carousel or under the needle as it inserts into a vial.

Do not insert a finger, foreign object, or any other item under the needle housing.

1.6 Burn hazard

 Removing the chassis cover may expose you to items at high temperatures that could burn you. Only trained service personnel should remove the chassis cover. In par-

ticular, if the insulation on the steam delivery tube between the steam heater and the steam injector is removed, the exposed metal surfaces will be hot during operation.

1.7 Electrical shock hazard

Removing the chassis cover may expose you to high AC voltage circuits that can harm you if touched. Only trained service personnel should remove the chassis cover.

1.8 Water leak hazard

Improperly connecting the liquid supply or drain bottle tubes to the peristaltic pump may result in a water leak. Improperly connecting the liquid supply tube from the peristaltic pump to the Auto-collector may result in a water leak. Blockage of the steam tip or steam heater coil tubes may result in back pressure producing a water leak in the steam heater liquid supply line. Take care to locate devices so a water leak near the front of the PILS chassis or the rear panel of the Auto-collector does not create a hazardous condition.

1.9 Replaceable fuses

Only replace AC power fuses with ”H” style fuses having identical size, voltage, and current carrying capacity. The internal 24 VDC fuse may only be replaced by trained service personnel.

1.10 Power cord

Caution: Only use the power cord provided with the Model 4001 PILS. Risk of fire if used with a power cord which has an inadequate rating. Contact Brechtel for a replacement cord if the power cord is damaged or missing.

1.11 Shock during shipping

If the shock watch installed on the shipping case has tripped, contact BRECHTEL. Visually inspect the PILS to check for any components that may have come loose during shipping.

1.12 Freezing during shipping

Components in the PILS may be damaged when exposed to freezing temperatures during shipping. Be sure to dry out the device prior to shipment.

1.13 Accessories

Only accessories approved by BRECHTEL and meeting required factory specifications may be used with the device.

1.14 Lifting and carrying

The PILS and Auto-collector shipping boxes are large and moderately heavy. Take care to lift and carry the boxed devices, as well as the devices themselves, to avoid injury.

1.15 No User serviceable parts

WARNING: There are no user serviceable parts within the device. Removal of the PILS control chassis top cover may expose the user to high voltages, high temperatures, and pressurized steam. Only trained service personnel should remove the chassis cover. Removal of the top cover by anyone other than a trained service personnel will void the product warranty.

1.16 EMI statement (Class A)

US:

NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

CANADA:

This Class A digital apparatus complies with Canadian ICES-003. Cet appareil numérique de la classe A est conforme à la norme NMB- 003 du Canada.

2 Changes

Change Description	Page	Date	Author
v2.0 Update commands	N/A	5/24/2018	FJB
v3.0 Update software discussion; cautions updates; add certifications	Various	6/6/2022	FJB

3 Declaration of Conformity

Name: Particle Into Liquid Sampler

Regulatory Model Number: 4001-115V, 4001-230V

Environmental Conditions: Pollution Degree 2, Installation Category II, Equipment Class 1. This equipment requires the following space for ventilation, maintenance access, and easy access to the Main Power Switch. There must be clear space of at least 30 cm (12”) on all sides of the equipment. The bench in your laboratory must be able to support the entire system and other laboratory equipment.

Conforms to the following safety standards:

Canadian Standards Association (CSA) C22.2 No. 61010-1

Nationally Recognized Test Laboratory (NRTL): ANSI/UL 61010-1

International Electrotechnical Commission (IEC): 61010-1, 61010-2-010, 61010-2-081

EuroNorm (EN): 61010-1

Conforms to the following regulations on Electromagnetic Compatibility (EMC) and Radio Frequency Interference (RFI):

CISPR 11/EN 55011: This is a Class A product. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

IEC/EN 61326-1

AS/NZS CISPR11

US:

NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

CANADA:

This Class A digital apparatus complies with Canadian ICES-003. Cet appareil numérique de la classe A est conforme à la norme NMB- 003 du Canada.

This product complies with the EU RoHS Directive 2011/65/EU, and conforms to EN 50581.

4 Contact BRECHTEL

4.1 Getting Help

Contact BRECHTEL for any questions or assistance with this product.

Include the model *and* serial *numbers when contacting Brechtel.*

Brechtel Manufacturing Incorporated
1789 Addison Way
Hayward, California 94544, USA

Telephone: (510) 732-9723
Fax: (510) 732-9153
Email: sales@brechtel.com

5 Unboxing

Each BRECHTEL PILS is inspected and tested in-house at BRECHTEL to ensure out of the box operation upon delivery. Prior to opening, inspect the packaging container and ShockWatch impact indicators.

Carefully open the package and inspect the instrument and any accessories for broken parts, scratches, dents or other signs of damage incurred during shipping. Notify BMI within 2 days of receiving the package if the shock indicator (Fig 1) has activated or of any other visible damage.

Notify BMI within 2 days of receiving your product if the shock indicator has activated and/or there is any other visible damage.

Retain all shipping packaging, foam inserts and cushions to ensure a safe delivery should the instrument need to be returned.

Verify the contents of the shipment using the information provided in this manual.

Figure 1: The black arrows on the shock-watch indicate the package experienced excessive shock during shipping. Red arrows indicate no shock above the G level indicated.

5.1 Before First Use

⚠ WARNING: The foam shipping blocks under the Auto-collector carousel must be removed before operation. Take care not to damage the optical sensors under the carousel while removing the foam.

6 PILS Overview

6.1 Description

The Particle into Liquid Sampler (PILS) is used to measure the chemical composition of water-soluble components of the ambient aerosol. Brechtel has integrated the PILS droplet impactor and steam generator systems into a complete aerosol sampling system that can be operated autonomously. The PILS has been extensively tested and a summary of the tests and historical field data may be found in the paper by Sorooshian et al., 2006, Aerosol Science & Technology, 40: 396-409 and other references. The PILS can be directly connected to a user-supplied Ion Chromatography (IC) system, Total Organic Carbon (TOC) analyzer, an Optical Waveguide, or other analytical systems to provide on-line composition measurements. Alternatively, the Auto-collector produced by Brechtel may be used with the PILS to allow liquid sample collection into vials.

Figure 2: Photo of the PILS. Shown with Auto-collector and PC.

The major components of the complete PILS system are shown in figure 2 and include:

1. a steam generation system to produce and inject steam into the condensation chamber,
2. the condensation chamber and droplet impactor for growing sampled particles into collectable droplets and collecting them on the quartz impactor plate,
3. a peristaltic pump to supply liquid to the steam generator, provide the impactor washflow and liquid sample flow, and handle waste liquid,
4. a debubbler to remove air from the liquid sample flow,
5. a critical orifice to maintain constant sample air flow,

6. a temperature controller to control the steam heater temperature and a temperature monitor to measure the steam injection tip temperature,

7. instrument software loaded on a user-supplied Windows computer to record the steam heater and steam injector tip temperatures.

6.2 Theory of Operation

The purpose of the PILS is to grow sub-micrometer aerosol into 2 to 3 micrometer diameter water droplets so the grown droplets can be collected for chemical analysis. All particles larger than 0.03 micrometer within the air sample flow entering the PILS are grown into collectable drops, irrespective of their chemical composition. For example, even non-hygroscopic soot aerosol are grown to large droplets that are collected. However, non-water soluble species are not sampled quantitatively as they are deposited and lost to the quartz impactor disk, mesh wick, and other surfaces before arriving at the point of analysis or a vial.

A schematic of the PILS is shown in Fig. 3. The sample air flow is shown with black arrows. The droplet impactor washflow lines are shown with red arrows, while liquid sample out flow lines are shown with open blue arrows. The steam liquid flow to the steam generator is shown with open blue arrows. Waste liquid flows are shown as black filled/blue arrows.

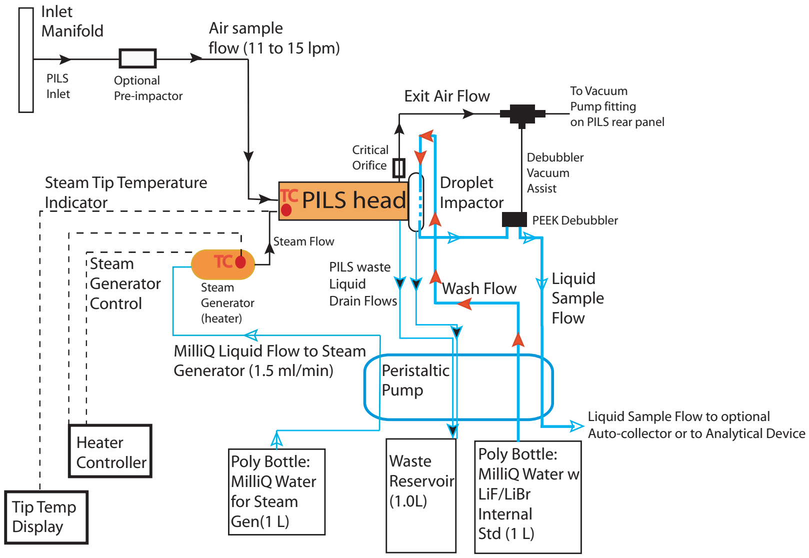


Figure 3: Schematic of the PILS.

In most applications, a pre-impactor with a well-defined cutoff size is installed on the air sample flow inlet to the PILS to exclude particles larger than a desired diameter. Denuders may also be installed on the air sample flow inlet line to remove water-soluble vapors like ammonia, nitric acid, and sulfur dioxide that will be taken up by water in the PILS and appear as measured ammonium, nitrate, and sulfate in the collected liquid sample. The particles in the air sample flow mix with the steam produced by the steam generator inside the PILS head, or condensation chamber, resulting in rapid thermal quenching of the steam and high water supersaturations. Particles rapidly grow to a few microns in diameter during the one second residence time within the condensation chamber. It is important to maintain optimum temperatures in the PILS so particles grow to droplet sizes large enough to be collected but not so large that they are lost through inertial deposition within the PILS. The Heater Controller temperature set point may be adjusted by the user to produce a tip temperature between 98 and 100C. At the end of the condensation chamber, the air flow and droplets are focused through an orifice so that all droplets larger than 1 micrometer inertially impact on a quartz disk in the droplet impactor. The droplets are driven radially outward to the edges of the quartz disk where they are collected by a fine stainless steel mesh wick. A washflow is supplied that continuously flows through the wick, mobilizing the collected droplets so the combined wash/droplet flow can be withdrawn from the bottom of the droplet impactor. A single peristaltic pump is used to deliver the steam generator liquid flow rate (1.4-1.5 ml/min), supply the washflow to the impactor, withdraw the liquid sample flow from the impactor, and to withdraw liquid waste from the condensation chamber. The collected liquid sample flow is passed through a gas debubbler to remove air bubbles and delivered to either on-line analytical instruments for chemical analysis or to vials for storage and off-line analysis.

Chemical Sampling Efficiency of the PILS

Brechtel has tested the chemical sampling efficiency of the PILS by simultaneously sampling laboratory-generated ammonium sulfate particles with the PILS and a scanning electrical mobility sizing system (SEMS). The total volume concentration from the SEMS is multiplied by the density of ammonium sulfate (1.77 $g\ m^{-3}$) to determine the total mass concentration sampled by the PILS. The results from a calibration test are shown in figure 4. In the figure, mass loadings from the SEMS are shown as black lines/pluses and those from the PILS are shown as the red histogram. 'T' denotes a time when the PILS was transitioning from Filter to Sample mode (or vice versa), 'F' denotes a filter sample, and 'S' denotes a time where the three-way valve was set to sample. Arrows denote times when the three-way valve was moved either from sample to filter mode, or from filter to sample mode. The PILS data are adjusted in time to account for the liquid sample residence time in the instrument (roughly 300 sec). The average PILS-observed mass concentration for the first two samples (denoted by 'S' in the figure) is 26.8 $\mu g\ m^{-3}$; the SEMS-observed mass concentration during the same time period is 26.6 $\mu g\ m^{-3}$. The ratio of the PILS- and SEMS-observed mass concentrations is 1.01, demonstrating good agreement between independent techniques for measuring the particle mass concentration. Note in figure 4 that the PILS-observed concentration does not instantaneously decrease to zero when the three-way valve is switched from sample to filter. This is due to the liquid sample residence time on the quartz impactor plate, in PEEK tubing, in the debubbler, and in the peristaltic pump tubing. The total liquid sample residence time varies depending on liquid flow rates, length and inside diameter of tubing. Residence times for each PILS configuration should be determined by the user.

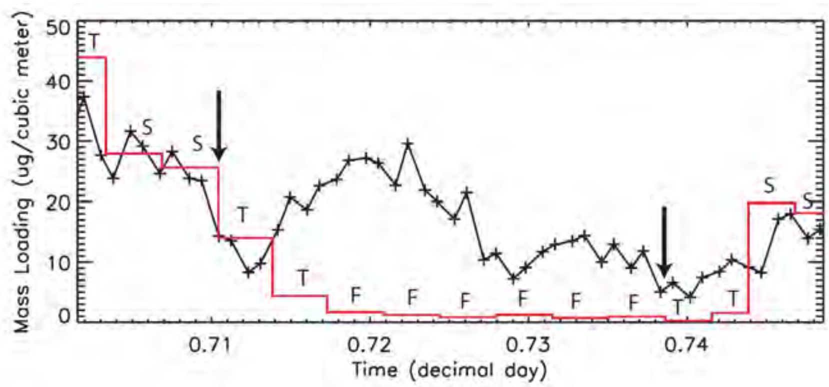


Figure 4: Mass loadings from PILS versus SEMS.

6.3 PILS Chassis

The PILS may be configured for laboratory, bench top usage, or it may be mounted in a standard instrument rack. Normally, the PILS sample air flow is controlled by maintaining critical flow through a critical orifice built into the PILS droplet impactor exit air flow fitting. A detailed view of the front panel of the PILS chassis is shown in figure 5. The photo shows the droplet impactor on the left, the round debubbler between the droplet impactor and peristaltic pump in the middle, and the two temperature controllers on the right side of the front panel. The peristaltic pump speed control potentiometer is directly below the steam heater temperature controller.

Figure 5: Photo of the front panel of the PILS.

Steam Generator System

The steam generator system consists of four basic parts: the peristaltic pump that supplies liquid flow to the heater, the heater itself, the steam injection tip and the temperature controllers mounted in the front of the instrument.

Peristaltic Pump

One important function of the peristaltic pump (see figure 6) is to feed the steam generator a controlled amount of MilliQ water to generate steam. The other channels of the pump are used to supply the PILS droplet impactor washflow, withdraw the liquid sample flow from the PILS, and to draw waste water from the PILS body. The potentiometer setting at the front of the PILS, just below the temperature controllers, controls the rotational speed of the peristaltic pump. Only adjust the potentiometer while measuring the steam generator liquid flow rate with a graduated cylinder and stop watch or with some other liquid flow measuring device.

Note: The peristaltic pump turns clockwise when viewed from the front facing the PILS chassis front panel. Be sure to install the white, tube-holders so the tensioners are on the left side of the pump.

The figure shows the flow input side of the pump on the left and the flow output side on the right. Note the correct orientation of the colored peristaltic pump tubing stop tabs facing downward to prevent twisting of the tubing inside the pump. The grey-grey collared tubes are waste lines, the orange-white collared tubes are washflow and liquid sample out flow lines, the red-red line is the steam generator supply line.

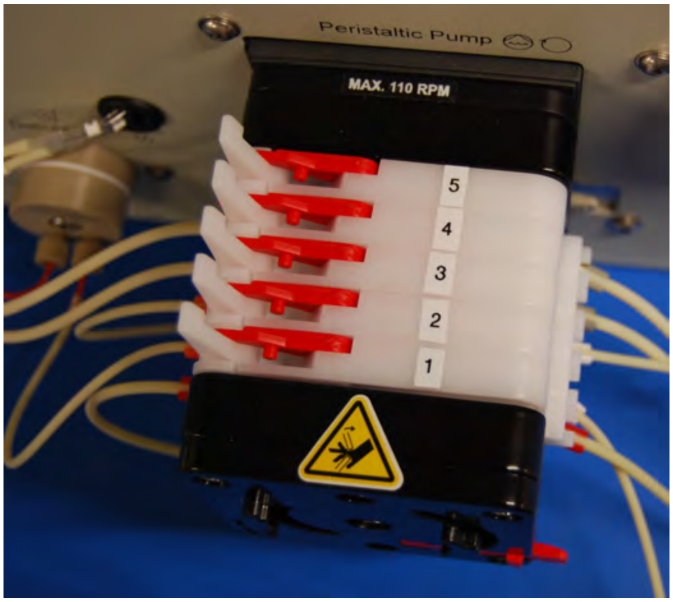


Figure 6: Top view of the peristaltic pump mounted to the PILS chassis front panel.

IMPORTANT: If you adjust the peristaltic pump speed without verifying the proper 1.5 ml/min liquid flow rate, the steam generation system may not function properly.

Figure 7 shows the flow input side of the peristaltic pump. Note the label on the liquid line supplying the steam generator flow as well as the correct orientation of the colored tabs facing downward.

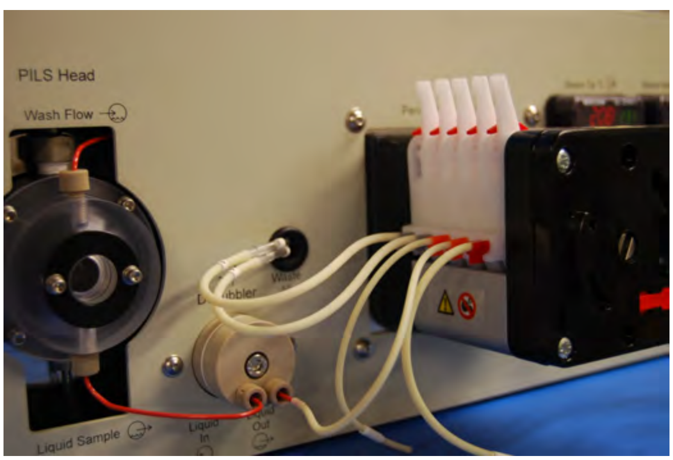


Figure 7: View of flow input side of the peristaltic pump.

WARNING: Do NOT install the peristaltic pump tubing so it is twisted inside the pump where the rollers will destroy the tubing.

To operate the pump, the potentiometer sets a voltage value that controls the pump speed. The nominal steam generator liquid flow rate should be set to 1.5 ml/minute using the potentiometer. The speed is set at the factory and should be checked by the user every few months during regular usage. Although the user can change the steam generator liquid flow rate using the potentiometer, changing the flow rate may adversely influence the tip temperature control if not done properly.

The steam generator liquid flow rate must be kept at 1.5 ml/minute. The flow rate should be checked every few months by disconnecting the liquid feed line from the steam generator and dispensing water into a graduated cylinder for 5 to 10 minutes. Detailed procedures for checking the flow rate are given in the appendices.

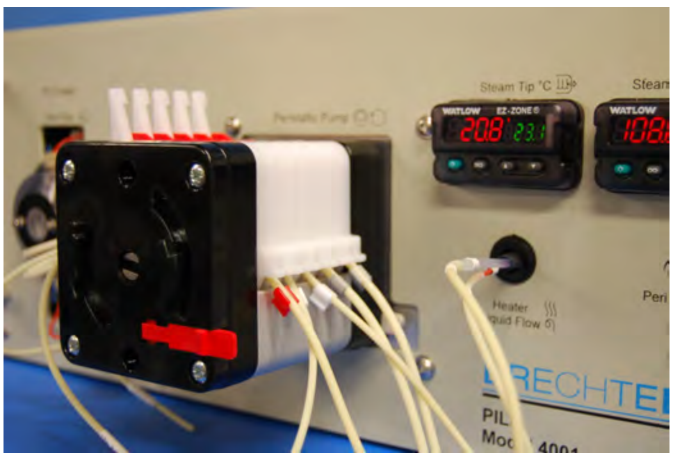


Figure 8: View of flow output side of the peristaltic pump.

As seen in figure 8, each peristaltic pump channel has a white tensioning lever that adjusts the tension on the tubing installed in the channel. The optimum location of the paddle under normal operation is straight up, perpendicular to the top surface of the pump. **Note that changing the tensioning lever position will change the liquid flow rate of that particular channel. Over tensioning the tubing will reduce its lifetime.**

In figure 8, note the correct orientation of the white tensioning levers pointing vertically upward as well as the correct orientation of the colored tubing tabs facing downward.

The one occasion where the liquid flow rate may need to be changed is for high-altitude operation, or operation under other very dry sample air flow conditions. In this instance the user may want to increase the steam generator water flow rate slightly. Note that once the steam heater liquid flow rate it set by the rotational speed of the pump, the washflow and liquid sample outlet flow rates are only determined by the inside diameter of the peristaltic pump tubing installed in the pump.

IMPORTANT: The peristaltic pump speed should not be adjusted to maintain a specific liquid sample outlet or washflow rate - the pump speed should only be set to control the 1.5 ml/min steam generator flow rate. Different tubing inside diameters for the washflow and liquid flow peristaltic pump channels may be used to change these flow rates.

The peristaltic pump automatically removes accumulated waste water from the PILS head chamber and impaction area and delivers it to the PILS 1 l waste bottle. **It is extremely important that the waste bottle is emptied between run cycles and not allowed to overfill.** Run cycles longer than 14 hours may result in overfilling of the reservoir and spilling of liquid water out of the drain bottle. For long run cycles or continuous operation of the PILS, replace the waste bottle with a large capacity carboy or route the waste line directly to a drain.

⚠ **WARNING: There are no interlocks to prevent overfilling of the waste water bottle.**

Periodically inspect the peristaltic pump tubing with the power off by removing the cartridges and visually inspecting the tubing. Rotate the white handles on the peristaltic pump channels downward to loosen the channel and lift it away from the pump. Note the correct orientation of the colored tabs on the tubing according to figure 7. Check for deformed and cracked tubing and replace any tubing that appears damaged. Spare tubing can be purchased from BMI. Details of the peristaltic pump tubing are provided in table 1. The peristaltic pump tubing supplied is double segmented (three tabs), which means it can be installed in the pump in two different positions. Once one section of the tubing has been used, remove the tube and shift its position so the new section of tubing with the tab stops is installed in the pump channel.

IMPORTANT: Avoid installing tubes of different inside diameters in the pump channels controlling the impactor wash flow and the liquid sample outlet flow. Tubing with the same inside diameter, material and age should be installed in the two channels controlling the impactor washflow and liquid sample outlet flow to ensure the flow rates are the same.

Table 1: Selection of peristaltic pump tubing available for the PILS.

Stop Color	ID (mm)	Used On	Max flow ml/min	Flow rate ml/rev
Orange/White	0.63	Impactor	2.6	0.024
Orange/Blue	0.25	Low Flow Kit	0.47	0.004
Orange/Red	0.19	Low Flow Kit	0.30	0.003
Orange/Black	0.13	Low Flow Kit	0.10	0.001
Red/Red	1.14	Steam Heater	8.8	0.08
Grey/Grey	1.29	Waste lines	10.0	0.95

Note that even though flow rates higher than 1.5 to 2 ml/min are shown in table 1, the steam heater flow rate must be 1.5 ml/min under normal operating conditions and the impactor washflow and liquid sample outlet flows must not exceed 2 ml/min under normal operating conditions. Once the peristaltic pump speed is set to deliver 1.5 ml/min to the steam heater, different impactor washflow and liquid sample outlet flow rates are set by installing tubing with different inside diameters - NOT BY CHANGING THE PUMP SPEED.

Temperature Controllers

The heater temperature controller controls the power delivered to the heater and the time that the heater is on. The tip temperature is controlled by the steam heater temperature and is only displayed by the temperature controller labelled 'Steam Tip'. A photo of the controllers mounted in the PILS is shown in figure 2. The 'Steam Tip' temperature controller does not control anything, it is only used to display the tip temperature. The tip temperature should be kept within the range 97.5-100 C. The user must manually adjust the temperature setpoint of the heater temperature controller (labelled

'Steam Heater') using the small up and down arrow buttons on the front of the controller to maintain the tip temperature within the desired range. The PILS is tested extensively prior to shipment and the heater temperature controller setpoint should be set to a value producing acceptable tip temperatures. However, if you find that the tip temperature is lower or higher than the 97.5 to 100 C range, then manually reset the heater controller temperature setpoint using the up or down arrow buttons until the tip temperature reaches an acceptable value. After changing the setpoint, give the system at least 15 minutes to respond.

An example of the variation of tip temperature, heater temperature and instrument pressure is shown in figure 9 below. Excluding periods of extreme pressure change, the tip temperature should typically be maintained within 1.5 C of the 99 C set point value. The heater temperature trace in the figure is red and plotted against the left-hand axis. The tip temperature is blue and plotted against the right-hand axis. Tests at Brechtel show that rapid reductions of instrument pressure (e.g. from 1000 to 680 mb) result in a significant increase in the tip temperature if the heater temperature setpoint is not controlled. The user may need to manually reset the steam heater setpoint temperature under changing sampling conditions to obtain the necessary range of tip temperatures. For example, a pressure reduction could occur during an ascent while aircraft sampling.

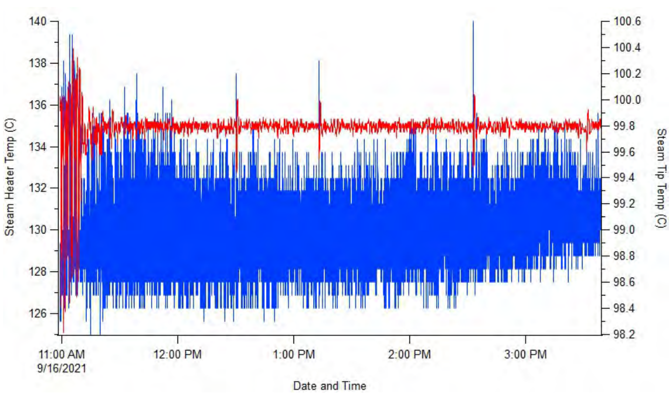


Figure 9: Example steam heater (red) and steam injector tip (blue) temperature timelines.

Condensation Chamber, Droplet Impactor and Debubbler

The PILS condensation chamber and droplet impactor is where the sampled particles are exposed to a water-supersaturated environment and grown to droplets with diameters between 2 and 3 microns. The chamber is mounted at a slight angle to facilitate flow of condensed water on the inside walls to the drain ports so condensate can be removed from the chamber by the peristaltic pump.

IMPORTANT: When installing the PILS be sure to place the instrument on a level surface so that the front of the chassis is perpendicular to the table.

After the particles grow they are collected on a quartz impactor plate. The residence time of droplets inside the chamber is roughly 1 second for a 15 lpm flow rate (13 lpm air flow and 2 lpm steam flow). The PILS may be reliably operated at air flow rates between 11 and 16 lpm. For high-altitude operation, or operation under other very dry sample air flow conditions, the user may want to increase the steam generator water flow rate slightly. During operation of the PILS it is useful to periodically examine the impactor plate and verify that droplets are being impacted and driven by the diverging airflow to the outer diameter of the impaction plate.

The droplet impactor is the heart of the PILS liquid sample collection system. It holds the jet which accelerates droplets so they impact on the quartz impactor disk (see left side of figure 5). The stainless steel wick is also housed within the droplet impactor. The wick facilitates transport of collected droplets from the impactor plate to the PEEK tubing attached to the debubbler. The standard width of the wick is 0.1 inch (2.5 mm). The peristaltic pump delivers a wash flow that moves the collected droplets downward toward the exit PEEK tubing. After continuous operation under heavy aerosol loadings, the quartz impactor plate and wick can become contaminated with non- or sparingly soluble compounds that might influence the performance of the liquid sample collection. The impactor plate should be removed and carefully cleaned when it becomes dirty. The wick should be replaced when dirty.

Extreme care must be taken when re-installing the quartz impactor plate - it is very easy to crush the wick so that liquid sample is no longer collected properly.

Spare wicks are supplied with the PILS and should be cleaned prior to installation. If the impactor plate must be removed for cleaning, it should be reinstalled so that is protrudes 0.185-0.195 inch (4.7-4.9 mm) from the clear droplet impactor housing. Use a vernier caliper to accurately position the quartz impactor plate. While inserting the impactor plate, be sure to push the O-ring fully against its stop before the plate is close to fully inserted and before inserting the metal clamping plate that squeezes the O-ring. If the impactor plate is inserted more deeply into the impactor housing, the wick will be damaged.

The debubbler removes air bubbles from the liquid sample flow drawn from the PILS. Periodic cleaning of the debubbler and replacement of the porous teflon membrane is recommended. Spare membranes can be purchased from BRECHTEL .

6.4 Liquid Supply and Drain Bottles

There are two 1000 ml liquid supply polyethylene bottles used in the PILS (see figure 10). One bottle is used to store the MilliQ water with LiF or LiBr internal standard and supplies the peristaltic pump impactor wash flow channel. The second bottle is used to hold pure MilliQ water for the steam generation system (labelled ”Pure H2O”). A third 1 liter bottle is used to collect waste liquid from the PILS (labelled Drain bottle). The steam generation system operates at a nominal flow rate of 1.5 ml/min. The peristaltic pump draws water from the bottle and pumps it through the steam generation system. The liquid supply bottles supplied with the PILS may be replaced with larger volume containers as long as the required high water purity is maintained. It is the users responsibility to verify background concentrations in the water used to operate the PILS.

The MilliQ water used in the washflow should be spiked with either LiF or LiBr as an internal standard so that evaporative loss or condensational dilution of water vapor during droplet collection inside the PILS can be corrected for during data processing. Typical concentrations of the internal standard are between 50 and 200 ppb, however, the user should adjust the concentration to match the anticipated liquid sample concentration range of the PILS samples. Note that the response of the chemical detection system that will be used to analyze the PILS liquid samples must be characterized for the internal standard species as well as the species analyzed in the actual samples.

Figure 10: Washflow and Steam Liquid Flow (pure H2O) water supply bottles.

The concentration of the internal standard in the supply bottle as well as in the collected liquid samples must be measured during each PILS run cycle in order to apply corrections to measured species concentrations. The concentration of the internal standard in the supply bottle will change over time due to evaporation of water, therefore, acquire one or two aliquots of sample from the bottle before and after each run cycle and analyze the samples with the collected PILS samples.

IMPORTANT: The liquid supply tubes must be inserted so they rest near the bottom of the liquid supply bottles. A labelled collar is installed on the teflon tubes to indicate the full insertion point, however, it is the users responsibility to ensure that the tubes are held properly in place so they remain submerged and so foreign material cannot enter the bottles and contaminate the liquids.

Avoid contacting the tube ends with bare hands, as sodium chloride contamination will result. Over time, ammonia vapor may be taken up by the MilliQ water, resulting in artificially elevated ammonium concentrations. Replacing the MilliQ water daily helps minimize the ammonium artifact. Alternatively, the bottles may be housed within a vented secondary containment with a small volume of citric acid to remove ammonia vapor from the air surrounding the bottles. To facilitate pressure equalization in the bottles, BRECHTEL has installed 20 micron porous frits in each bottle cap.

A 1 liter volume drain bottle is supplied to collect waste condensate from the PILS Head via the peristaltic pump. Note that there is no interlock to prevent over-filling of the drain bottle. Be sure to drain the bottle before each use.

6.5 Sample Air Flow Control System

The sample air flow at the inlet of the PILS is controlled using a critical orifice brazed into the barbed air exhaust fitting attached to the PILS droplet impactor. The user should periodically measure the air flow into the PILS (with steam generation on for a minimum of 30 minutes) to verify that the measured air flow rate agrees with the expected value within +/-3% over the 11.0 to 16.0 lpm range. Be sure to record the measured flow rate for use in the calculation of ambient species concentrations.

The PILS air exhaust flow is saturated with water vapor at about 35 C. Take care to avoid filling vacuum lines with condensed water at cooler temperatures downstream of the PILS.

6.6 Using the PILS with On-line Analysis Systems

The Brechtel PILS may be used with a wide variety of chemical analyzers to perform on-line measurements of aerosol chemical composition. The PILS has been coupled to a variety of IC systems, water-soluble organic carbon analyzers, liquid-capillary waveguides for absorption and species-specific probes and other unique sensing systems.

Ion Chromatography Systems

The majority of PILS applications involve the use of ICs. It is important to use the PILS peristaltic pump to draw liquid sample through the IC sample loop and not to 'push' sample through the loop, as the peristaltic pump could pressurize the IC column during injection. The PEEK tubing from the debubbler that would normally be connected to the peristaltic pump should instead be connected directly to the IC sample loop inlet port fitting of the IC. The sample outlet port of the IC sample loop should be connected to the PILS peristaltic pump liquid sample flow channel. In this way, the peristaltic pump will draw liquid sample through the IC sample loop, allowing the IC to inject small volumes of sample when required without negative interactions between the two instruments. Keep the PEEK tubing runs as short as possible to minimize pressure drops and residence times through the system. A guard column or in-line liquid filter (0.5 micron pore size) should be used to protect the column from insoluble material. Currently, there is no direct communication between the PILS and the IC. The PILS is operated continuously and the IC is configured to perform the desired analysis. The liquid flow from the peristaltic pump liquid sample channel not used by the IC may be routed to another analyzer, the Brechtel Auto-collector to fill vials, or to the PILS waste bottle.

Water Soluble Organic Carbon Monitors

The Brechtel PILS has been successfully interfaced with on-line methods to measure water soluble organic carbon (WSOC). This generally entails determining the minimum liquid sample flow rate requirements of the WSOC device and ensuring this value is less than the maximum deliverable liquid sample flow from the PILS (about 2 ml/min). If the WSOC device requires a higher liquid flow then an additional peristaltic pump may be used to add ultrapure MilliQ water to the PILS liquid sample flow. The next consideration is flow rate matching. In practice, if the WSOC device requires 1 ml/min, the PILS should be configured to deliver 1.25 ml/min, or some other value slightly higher than 1 ml/min, so that a 'tee' liquid fitting can be installed on the line between the PILS and WSOC device inlet to allow the excess liquid flow to go to a waste bottle. This setup ensures that the WSOC device will not 'pull' or 'push' on the PILS liquid sample handling system and that unacceptable pressure gradients do not develop between the two instruments. A final consideration is air bubbles in the liquid sample line. Ensure that the PILS delivers air-free liquid sample to the WSOC device, as many of these units are sensitive to entrapped air.

6.7 Auto-collector

The Auto-collector may be purchased as an option to the PILS and is designed to allow individual sample vials to be filled with liquid sample from the PILS. The basic components of the Auto-collector include the vial carousel turntable, the needle assembly, the vial holding carousel, control electronics and software. The Auto-collector is controlled via RS232 communications and requires one AC power connection. The unit is shipped with an executable program allowing the fill time for each vial to be set by the user as well as the number of vials to fill. It is up to the user to calculate the vial fill volume based on the liquid sample flow rate settings of the PILS. A photo of the front of the Auto-collector is provided in figure 11. The rear of the Auto-collector is shown in figure 12.

Figure 11: Front of the Auto-collector with all covers installed.

The Auto-collector has several different sample vial volume options: 1 ml, 2 ml, and 12 ml. One ml vials come in polyethylene while 2 ml vials come in amber glass; both vials are held in 80 position carousels. Nominal sample collection times for 1 and 2 ml vials are between 30 seconds and 30 minutes. A photo of the Auto-collector with small vials installed is provided in figure 13. The 12 ml vials function with the same basic Auto-collector configuration used for the smaller vials, except that a different vial-holding carousel, with 38 positions, is used in place of the 80 vial carousel. The 12 ml vials are made from polypropylene and come with special snap caps with punched holes that need to be covered with Parafilm during sampling. The 12 ml vials are optimal for ground-sampling applications where multiple-hour sample times for each vial are desired. The caps with holes are replaced with solid caps to store samples. A photo of the Auto-collector with 12 ml vials installed is shown in figure 14.

Figure 12: Photo of the back of the Auto-collector showing the liquid sample supply connection at the rear of the needle assembly (to the left), and the serial communications and power hookups to the right.

In order to remove accumulated liquid sample from the catch basin under the auto-collector needle, a 1 liter drain bottle is connected to the 1/8" tube on the catch basin of the auto-collector. The collection of water into the bottle is assisted by drawing a small air flow through the bottle that draws water out of the catch basin. The air flow is provided by a critical orifice (0.008" dia, 0.4 lpm) assembly that is attached to the PILS vacuum pump line.

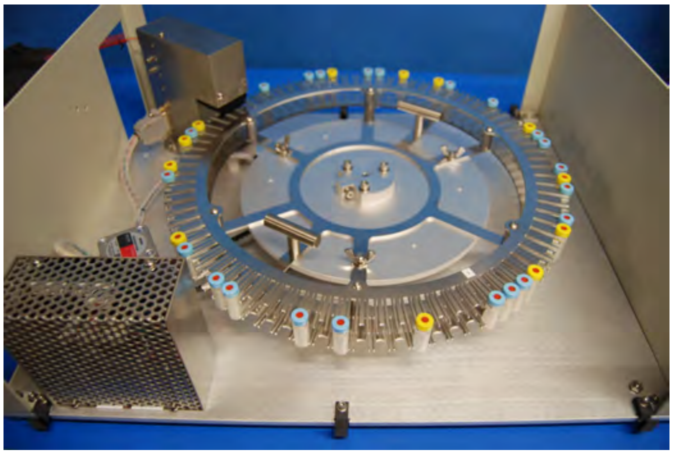


Figure 13: Photo of the Auto-collector with an 80-vial carousel installed.

Nominal sample collection times for 12 ml vials are between 30 seconds and 12 hours. The maximum sample time for an individual vial is set by the minimum droplet impactor wash flow rate that still allows liquid sample to be consistently drawn from the PILS. The minimum wash flow rate is roughly 35 microliters/minute.

IMPORTANT: Use only the modified caps provided by BMI when 12 ml vials are used in the PILS Auto-collector.

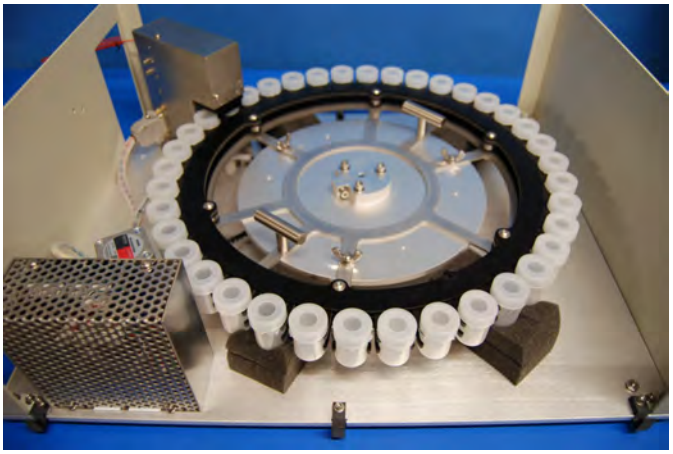


Figure 14: Photo of the Auto-collector with 12 ml vials installed. Note: foam inserts below carousel must be removed before first use.

Auto-collector Software

Brechtel provides software to control the Auto-collector. A screenshot of the Auto-collector software is shown in figure 27. Refer to the operation section of this manual for detailed instructions on operating the Auto-collector.

6.8 Pre-Impactor

If purchased as an option with the PILS, the impactor prevents particles larger than a certain maximum size from entering the instrument sample air flow inlet. If large particles are not prevented from entering the instrument, they may create a potentially interfering chemical artifact by overwhelming measured species concentrations.

IMPORTANT: It is highly recommended that the PILS always be operated with either a 1 or 2.5 micrometer size-cut impactor on the PILS inlet.

Note that, BRECHTEL DOES NOT supply a differential pressure sensor to read the pressure drop across the impactor. Refer to more detailed instructions in the user manual that came with the impactor for more information.

6.9 Vapor Denuders

Inorganic and organic vapor denuders may be purchased as an option to the PILS and are used to remove potentially interfering gasses from the airflow before the sample air enters the PILS condensation chamber. Shown in figure 15, the denuders are off-the-shelf products and require rejuvenation after exposure to air containing sufficient concentrations of vapors that the denuder surfaces become inactive. The PILS is shipped with **uncoated** denuders. Under normal sampling conditions, the inorganic vapor denuders require removal and rejuvenation once every 7 to 14 days of continuous sampling time. Refer to the denuder rejuvenation procedure in the maintenance section of this manual for details.

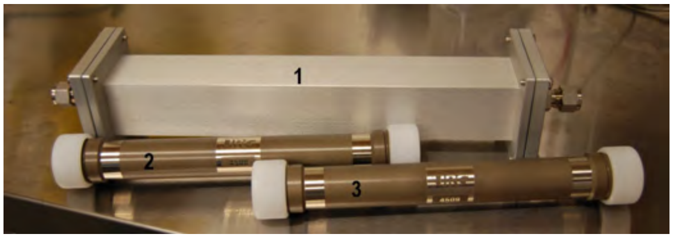


Figure 15: Photo of the organic (1), acid (2), and base (3) gas denuders.

The rejuvenation frequency must be increased under high sulfur dioxide, nitric acid, or ammonia vapor concentration sampling conditions.

6.10 PILS Options

There are several optional accessories external to the device that can be added at any time depending on your changing measurement needs. Refer to the table below and contact Brechtel to purchase your PILS accessories.

Table 2: PILS Accessories

PN	Option
8003	1.0 µm Round Jet Impactor
8005	2.5 µm Round Jet Impactor
CA38	38 vial-holding carousel for PILS Auto-Collector
CA80	80-vial carousel for Model PILS Auto-Collector
CAP12	Modified cap for 12 ml vial
Carbon Strips	Replacement carbon strips for PILS organic denuder - Set of 15
DE	Denuder package for PILS
Debubbler Membrane	Debubbler membrane for PILS
Mesh Wick	Mesh Wick for PILS (Set of 5)
Needle Assy	Needle Assy for PILS Auto-Collector
PEEK Debubbler Assy	PEEK Debubbler for PILS
Peri Tubing	Replacement peristaltic pump tubing for PILS (pack of 5, customer specified tube IDs)
PILS-AC80	Auto-collector with 80 vial holding carousel
PILS-AC38	Auto-collector with 38 vial holding carousel
PILS-Kit	Maintenance Kit for 4001 PILS
PILS-LowFlow	PILS low liquid sample flow rate kit (x6 peristaltic tubes and x6 fittings)
PILS-P115	External vacuum pump for 4001 PILS, 115 VAC
PILS-P230	External vacuum pump for 4001 PILS, 230 VAC
PILS-PC	Computer loaded with 4001 PILS Software
PILS-WickTL	Wick Changing Tool
VM12	Pack of 1,000, 12 ml polypropylene vials and caps (require user-applied parafilm seal)
VS1.2	Pack of 1,000, 1.2 ml polypropylene vials and caps with septa
VS2.0	Pack of 1,000, 2.0 ml polypropylene vials and caps with septa
VS2.0G	Pack of 1,000, 2.0 ml amber glass vials and caps with septa

6.11 PILS Specifications

Table 3: PILS Specifications

Description	Value
Pre-Impactor Cut Size	1.0 or 2.5 micrometer
Pre-Impactor Design Flow Rate	12-16 lpm
Inlet Air Flow NO STEAM (WITH STEAM)	15-16 (12-13) lpm
Minimum activated particle diameter	30 nm
Droplet Impactor cut size	1.0 micrometer
Characteristic droplet size range	2-4 micrometers
Steam Generator liquid flow rate	1.4-1.5 ml/min
Peristaltic Pump LiF+MilliQ Wash flow rate range	0.04-2 ml/min
Peristaltic Pump Liquid Sample flow rate range	0.03-2 ml/min
Waste Condensate collection rate	1.3 ml/min
Residence time of liquid on impactor plate	<15 sec
Temperature Controller DAQ Communication	USB-to-RS485
Tip temperature range	98 to 100C
Heater Temperature range	100-170C
Air flow exhaust Temperature	35C
Heater over-temperature protection switch setpoint	165-175C
Physical Specifications	
Size (width x height x depth)	17x7x12 in/44x18x31 cm
Weight	20 lbs/9.1 kg
Operating Temperature Range	0-40C
Operating Humidity	10-95%
Overvoltage Category	II
Pollution Degree	2

Table 4: PILS Electrical Specifications

Description	Value
Model 4001-115V	
Input Voltage	100-127VAC (90-132VAC)
Input Frequency	50-60Hz
Input Current	2.5 amps
Model 4001-230V	
Input Voltage	200-240VAC (180-264VAC)
Input Frequency	50-60Hz
Input Current	1.25 amps
Models PILS-AC38, PILS-AC80	
Input Voltage	12VDC
Input Current	2.5 amps
AC Adapter: (12VDC, 2.5A)	
Input Voltage	100-240VAC (90-264VAC)
Input Frequency	50-60Hz
Input Current	0.8 amps

6.12 Shipping the PILS

The PILS has several systems that are sensitive to intense shock and vibration; therefore, it should only be shipped in its original packaging and via Air-Ride Truck and/or aircraft.

IMPORTANT: Be sure and save the original packaging in case the unit needs to be returned.

All water must be drained from the bottles and PEEK tubing before packaging the PILS for shipment. A small amount of water in the PILS itself is generally acceptable. Operate the PILS for 30 minutes with no water supply to dry out all tubes. All fittings should be plugged (e.g. cover with parafilm) and the impactor should be removed for shipping. Before closing the box, cover the PILS with a large plastic bag in case the box is exposed to wet conditions. Reset the shock watch installed on the outside of the PILS prior to each shipment to monitor exposure to intense shock and vibration. Note that the PILS shipping box has been carefully designed to reduce exposure to damaging vibrations. The foam platforms have a useful lifetime of several years and should be monitored to verify they are not damaged. If the foam becomes damaged, call Brechtel to order a replacement box. Always ship the PILS using the original packaging.

7 System Setup

7.1 Packing List

The PILS will arrive in a sturdy box holding the PILS chassis, bottles, cables, any ordered accessories, and the ship kit. If accessories were ordered with the PILS they may be packaged in the in additional boxes.

See the Appendix for a complete list of all the parts that come with the PILS. Table 5 shows the parts needed to prepare the PILS for operation.

Note: The PILS is shipped from the factory with all water removed to avoid the possibility of damage to the various components due to freezing during shipment. Before running the instrument control software (*"BMI PILS 4001.exe"*) be sure to fill the water supply bottles.

IMPORTANT: The inorganic vapor denuders (if purchased as an option) are shipped from the factory uncoated. It is the customer's responsibility to properly coat the inside surfaces of the denuder before first use. See the denuder rejuvenation procedures in the maintenance section for more information.

7.2 Assembly

The PILS will arrive with the liquid supply and drain bottles uninstalled. Follow the discussion below together with the figure and table to assemble the various pieces.

Figure 16: View of PILS assembly. Numbers refer to table items.

Table 5: PILS Assembly Parts

#	Description	QTY
1	PILS Chassis	1
2	Washflow Bottle	1
3	Steam Gen Bottle	1
4	Drain Bottle	1
5	Auto-collector	1
6	Auto-col Drain Bot	1
7	Ship Kit	1
8	PILS-PC	1

Before operating the PILS for the first time there are a few important procedures that need to be performed.

Figure 17: Rear panel of the PILS.

Figure 18: Close-up view of the rear panel of the PILS.

7.3 Tubing Connections

The required tubing connections are between the two supply bottles and the peristaltic pump, the liquid sample PEEK tube from the PILS droplet impactor and the peristaltic pump, the peristaltic pump and the drain bottle, the rear panel vacuum fitting and the vacuum pump, and between the user sampling inlet and the air sample flow inlet of the PILS.

Peristaltic Pump

Fill the liquid supply bottles with high-quality, 18 mega-ohm water. The bottle labelled ’Pure H2O+LiF’ feeds the peristaltic pump channel that supplies washflow to the PILS impactor with pure water spiked with internal standard (LiBr or LiF, 50 to 200 ppb). The bottle labelled ’Pure H2O’ should be filled with pure water only for the steam generator. Follow the labels on the peristaltic pump tubing to properly connect the bottles to the pump.

Connect the liquid sample PEEK tubing supplied with the PILS to the liquid sample tubing in the peristaltic pump channel by sliding the PEEK tubing into the pump tubing with a minimum 1/4” engagement. The pump tube should be labelled. Connect the other end of the PEEK tubing to a BRECHTEL Auto-collector to fill vials or to your analytical device so liquid samples may be analyzed. Alternatively, allow the liquid sample out to drip into a beaker and manually fill vials when desired for batch sample collection.

Verify that the peristaltic tubing installed in the pump to supply the impactor liquid washflow and the liquid sample outlet flow will provide an appropriate liquid flow rate for your application. The nominal liquid flow rate of the peristaltic pump tubing installed at the factory (orange/red tubing stops) is between 0.4 and 0.5 ml/min. If a slightly lower flow rate is required, a tee fitting may be installed on the PEEK line and a small by-pass (dump) flow delivered to the PILS Drain Bottle through a metering valve. If a much lower flow rate is required, the "PILS-LowFlowKit" is offered as an accessory so that flow rates as low as 0.03 ml/min can be attained. Contact BRECHTEL if you require a broader selection of tubing.

Vacuum Pump

Connect the vacuum pump to the 3/8" swagelock connector labeled 'VACUUM' on the rear panel of the PILS using the tubing provided in the ship kit. Reference figure 18.

If you supply your own vacuum source be sure it is compatible with the high water vapor content of the PILS exhaust flow.

Sample Flow

Connect your sample air inlet tube (1/2" outside diameter) to the compression fitting connector labeled 'Sample Inlet' on the PILS back panel or to the inlet of the impactor. Ensure the connection is tight and leak free. A short, 1/2" diameter stainless steel tube is provided in the ship kit for use with conductive silicon tubing if desired.

Auto-collector

During normal ground-based operation, the Auto-collector is placed to the side of the PILS on a table top. For rack mount applications, the user may attach the aluminum baseplate to a rack shelf using a minimum of four 10-32 screws (or larger) that pass through the aluminum baseplate of the Auto-collector.

The PEEK liquid sample outlet tubing from the peristaltic pump is attached to the PEEK union in the back of the auto-collector needle assembly so that liquid flows from the PILS to the needle (see figure 19).

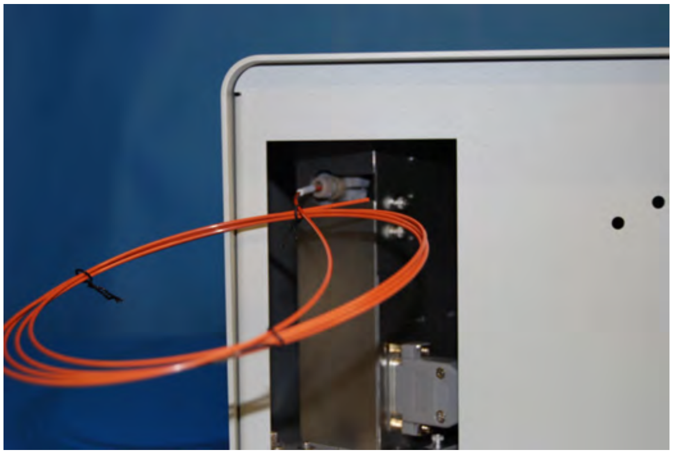


Figure 19: Photo of the back of the Auto-collector needle assembly and location of the union fitting to connect the PEEK tubing from the PILS peristaltic pump.

IMPORTANT: The Auto-collector software does not communicate with the PILS and therefore has no information about liquid flow rate. It is up to the user to configure the vial fill time properly so that the vials are filled with an appropriate volume of water.

As shown in figure 20, the fittings provided with the auto-collector will allow vacuum suction to draw water from the auto-collector needle catch basin so it accumulates in the bottle (item 2 in figure). Connect the tube from the bottle to the needle catch basin tube at location 1 in figure. Be sure the Auto-collector drain bottle tube with the orifice (item 3 in figure) is connected to the tee installed in the vacuum line (item 4 in figure). Make sure the bottle lid is tight. When full, the bottle should be emptied.

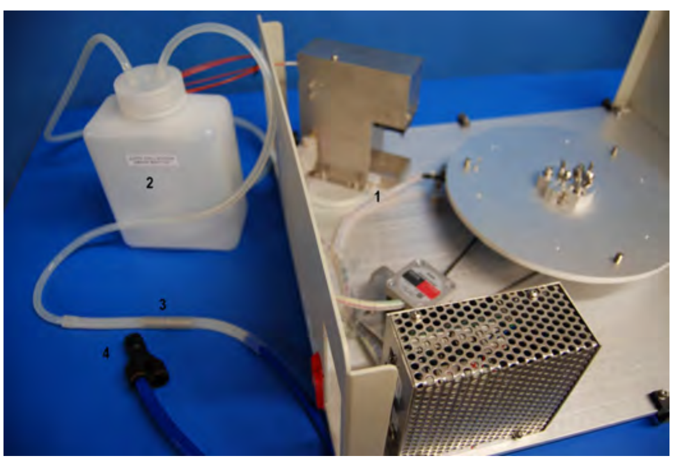


Figure 20: Photo of the Auto-collector drain bottle.

Pre-Impactor

If an impactor was purchased with the PILS, install the impactor in-line on the PILS sample inlet on the back panel of the PILS. Use conductive silicon tubing, compression fittings, or some other electrically conductive connection between the impactor and the sample inlet tubing. If the pressure drop across the impactor will not be monitored, be sure to plug the small hosebarbs to prevent particle leaks into the system. Do not connect the hosebarbs together, this will defeat the purpose of the impactor. The impactor should be shipped with the ports already blocked.

To monitor the potential for impactor jet clogging, the user can connect the small hosebarb pressure ports of the impactor to a differential pressure monitoring device with a full scale measurement range of about 30" of water (1 psi). Alternatively, the two pressure-monitoring ports may be sealed and no differential pressure measurement performed.

IMPORTANT: Do not connect the two impactor differential pressure measurement hosebarb ports together.

To monitor the pressure drop across the impactor, attach tubing to the small hosebarb on the inlet to the impactor to the high pressure port of the pressure sensing device. Attach tubing to the small hosebarb on the exit of the impactor to the low pressure port of the sensing device. The particle pre-impactor should be inspected regularly for build-up of particulate matter and cleaned to prevent clogging. The impactor cleaning procedure is provided in the impactor manual.

IMPORTANT: Familiarize yourself with the typically observed pressure drop measured across the impactor under normal sample air flow operating conditions. If the pressure drop begins to increase, clean the impactor plate.. Refer to the user manual delivered with your impactor for additional details.

Vapor Denuders

If vapor denuders were purchased with the PILS, install them in-line on the PILS sample air flow line downstream of the Pre-Impactor. Install the organic vapor and acidic gasses denuders upstream of the base gasses denuder to remove as much ammonia as possible before the sample flow enters the base gasses denuder.

Use conductive silicon tubing, compression fittings, or some other electrically conductive connection between the denuders and the sample inlet tubing. Refer to the maintenance section for information on rejuvenating the denuders.

7.4 Electrical Connections

There are only two electrical connections required for the PILS: input AC power and serial communication with a computer.

Reference figure 17 for a photo of the back panel of the PILS. The figure shows the 1/2 inch compression fitting for the sample inlet flow, the vacuum connector (3/8" swagelock), the Data connection and the AC power connector and power switch.

WARNING: The PILS requires EITHER 115VAC OR 230VAC input power, depending on the heater installed. Pay special attention to the input power voltage required per the label on the rear panel of your PILS.

Connect the AC power chord found in the ship kit to the back of the PILS. Leave the power switch in the OFF position. Reference figure 17.

7.5 Computer Connections

The RS232 port in figure 17, may be used to establish serial communication with the PILS from a user-supplied computer. An interface cable with a serial connector is provided in the PILS ship kit.

The detailed settings for the serial port: 8 data bits, 1 stop bit, no parity; Baud rates: 38.4k, 57.6k, or 115.2k.

Setup the laptop computer near your PILS and connect the RS-485-to-USB cable from the ship kit to the laptop using a free USB port. Attach the other end of the cable to the Data connector on the back panel of the PILS. Be sure to screw the RS-232 connector on the cable to the mating connector on the rear panel of the PILS to hold it properly in place, otherwise it may become disconnected, resulting in poor communication.

7.6 Software

The software necessary to operate the PILS and Auto-collector (if purchased) are pre-loaded on the instrument laptop (if purchased) and should not need to be reinstalled. If re-installation is necessary, or if the software will be installed on an user-supplied Windows PC, follow the instructions below. It is important to follow the installation procedure to ensure that required hardware drivers are installed first to ensure that the PILS software can properly communicate with the instrument. Follow the procedures below to load the software onto your computer.

1. Obtain the USB stick from the ship kit sent with the PILS. The USB stick includes the installer.
2. Save the contents of USB stick to the Windows computer that will be used to communicate with the PILS.
3. Within the folder copied to the computer, navigate to the PILS/Support Software/Installer Auto Collector and PILS/ directory on the computer.
4. Right click with the mouse on the file AC-PILS-Installer.bat and select "Run as Administrator"
5. Select "Yes" when asked to allow software to modify your computer
6. A pop up window will appear explaining features being installed. The PILS "BMI-PILS 4001 v1.0.exe" and "BMI-Auto-collector v1.1.exe" software will be installed to new directories C:/PILS and C:/Auto Collector, respectively. The Labview 2011 Runtime engine will be installed as well as Adobe Acrobat. The instrument manuals will be copied to the C:/PILS/Manuals/ directory. The Igor data processing script for the PILS data file will be copied to the C:/PILS folder.
7. **NOTE: The computer will shut down 1 minute after completing the install in order to complete the process.**
8. The hardware driver for the USB-to-RS485 converter cable used to communicate with the Watlow temperature controllers will be automatically installed.
9. Plug in the USB-RS485 converter cable to a free USB port on your computer. Verify that Windows automatically loads the driver and reports success, then

the process is complete. If the driver is not automatically found, contact Brechtel.

10. The installer will also create a new directory C:/Auto Collector which will contain the "BMI-Auto Collector v1.1.exe" software.

11. Installation of all software should now be complete. Before running the BMI PILS 4001.exe software, it is important to verify the COM port numbers that have been assigned to the USB-to-serial and USB-to-RS485 converters that were installed, see the next step.

12. In the control panel from the Windows Start Menu, choose Settings and then System.. In the search box type "Device Manager". In Device Manager expand the 'Ports' menu. The USB-RS485 converter should be shown with its assigned COM port number. Make a note of the port number so the correct COM port can be assigned in the BMI PILS 4001.exe software. The converter used for the temperature controllers is often named 'USB Serial Port (COM#). The PILS software will not operate correctly unless the correct COM port value is used. If you enter the wrong COM port in the software, don't worry, just change the value.

13. Perform the same search as described above in Device Manager for the USB-to-Serial converter cable used with the Auto-collector so the correct COM port number can be entered in the Auto-collector software.

7.7 Rack Mounting

The rack mount ears shall be attached to the sides of the chassis using the bolts provided. The ears shall be attached to the rack using a minimum of four 10-32 bolts as shown in the figure below.

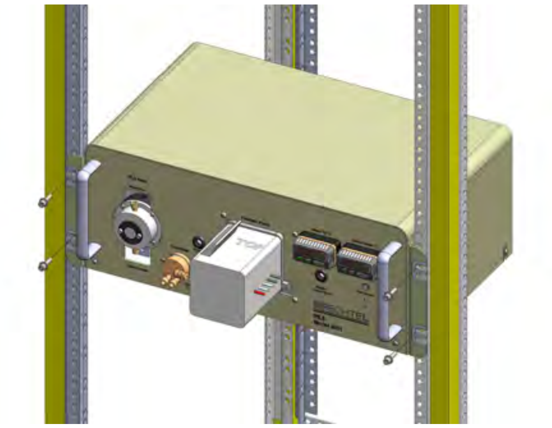


Figure 21: Rack mounting of PILS.

Mount the chassis in the rack so there is at least 2 inches of space around the sides of the chassis to allow for proper ventilation.

The maximum recommended operating temperature of the PILS is 40C.

8 Operating the PILS

8.1 PILS Operating Procedures

We recommend a 15 minute flushing period before each run cycle to allow the instrument to come up to temperature and also to allow the steam generation and liquid flow systems to stabilize. A particle filter may be installed on the PILS inlet during the flushing period and provides a convenient time to obtain zero air background samples from the PILS.

Follow the steps below to operate the PILS:

1. Ensure the MilliQ+LiF (or LiBr) and Pure H2O bottles are full of their respective liquids.
2. *EMPTY THE DRAIN BOTTLE AND RE-ATTACH IT.*
3. Turn on the PILS using the POWER SWITCH on the rear panel.
4. The Steam generator and Peristaltic pump will automatically run when the 'PWR' switch is ON.
5. Turn on the AIR PUMP to initiate the air sample flow.
6. Run the program "BMI PILS 4001 v1.0.exe" (described below) to record temperature data to the PC. Initialize the COM port by selecting 'START', enter a unique Run Cycle descriptor (numeric only) if desired, and select 'START' again to begin saving temperature data to a file.
7. **Visually monitor the steam tip temperature and modify the steam heater controller temperature setpoint upward if the tip temperature drops below 97 C. If the tip temperature is higher than 100 C, reduce the steam heater controller temperature setpoint. Change the steam heater temperature setpoint by 5 C at a time and monitor the change in tip temperature for 10 minutes before changing the heater setpoint further.**
8. The software is not required to operate the PILS - it only creates a convenient record of temperatures during a run cycle.

8.2 BMI PILS 4001 v1.0.exe program

The program *BMI PILS 4001 v1.0.exe* is the standard way to log temperatures from the PILS. It is used for ground-based measurements and aircraft measurements where simple, time-sequential liquid samples are required. A sample front panel display is shown in figure 22. The software executes when opened and the first step is to initialize the Watlow temperature controller COM Port as shown in the figure. The user must select the correct COM port so that proper communications can be established. Once the correct COM Port has been selected using the drop down menu selection, click the 'START' button with the mouse.

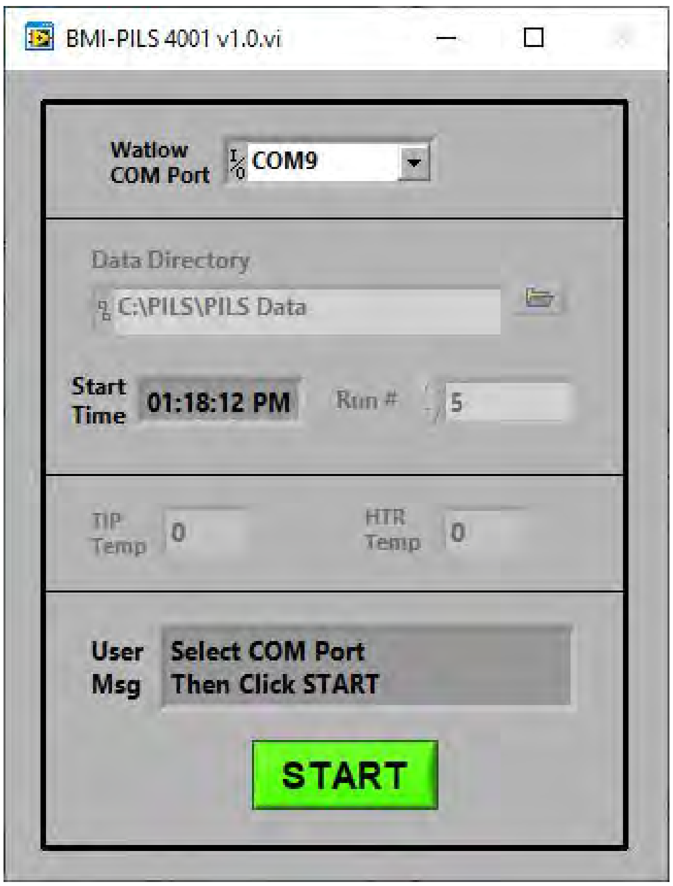


Figure 22: Front panel display of *BMI PILS 4001 v1.0.exe* software.

Once the initialization is complete, as shown in figure 23, the user may enter a run # in the white box to help keep track of different experiments. The run number must be a number and will be recorded to the header of data file with temperatures saved to the PILS computer. The start time for the current run cycle is written to the front panel for reference. If the user wishes to save temperature data to the data output file, select 'START' again. The format of the output data file is described below. To complete a run cycle simply push the shutdown button.

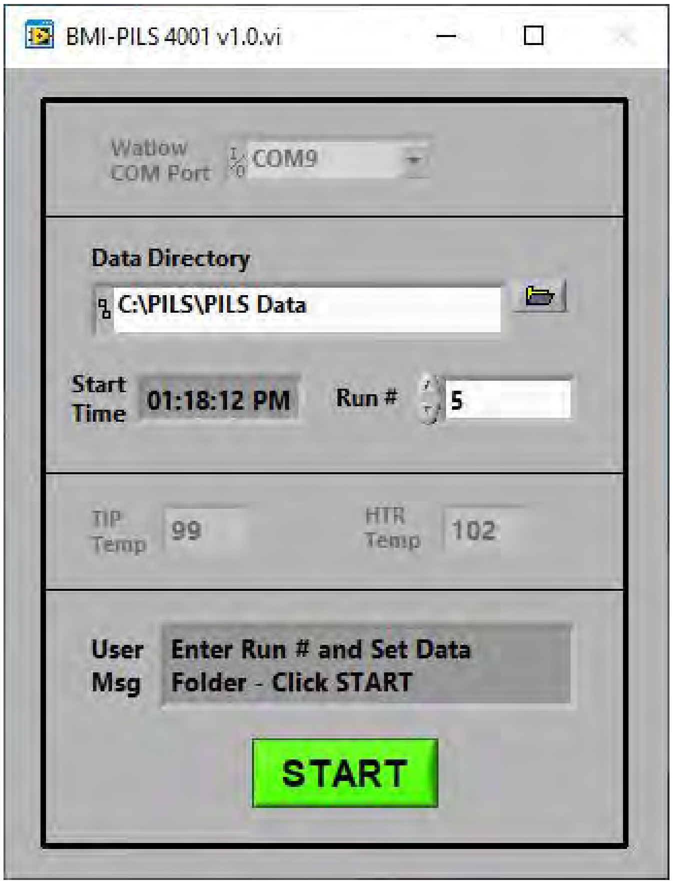


Figure 23: Front panel display of *BMI PILS 4001 v1.0.exe* software showing run number and data directory input.

The tip and heater temperatures are reported (in deg C) on the front panel of the software (figure 24). During normal operation the tip temperature remains between 97 and 100C while the heater temperature varies about the user-entered heater setpoint. Various messages may appear in the user message box. Press 'STOP' to exit the software and stop recording temperature data to file.

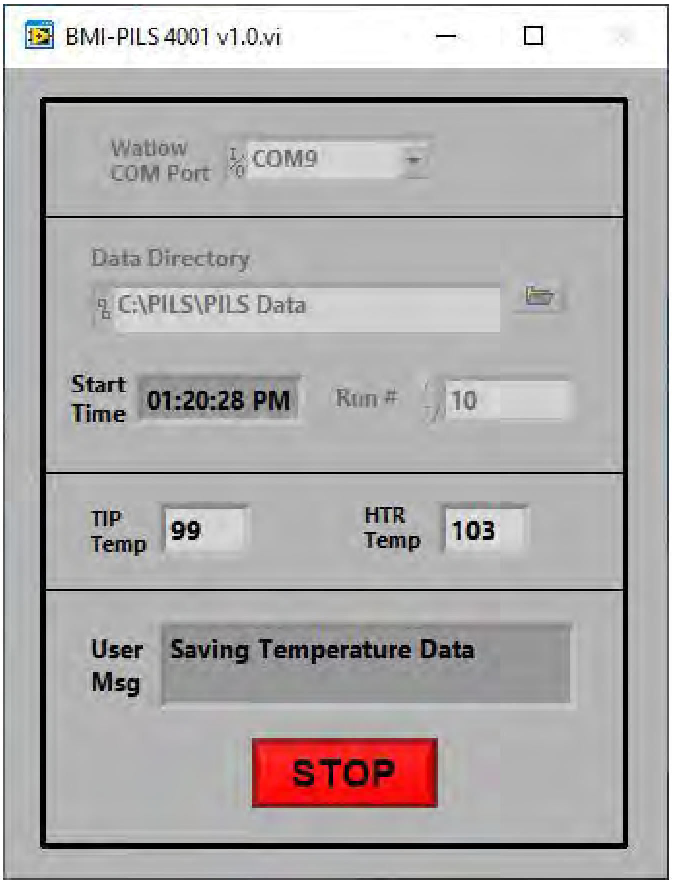


Figure 24: Front panel display of *BMI PILS 4001 v1.0.exe* software showing measured temperatures and normal operation.

8.3 Description of PILS output file

One file is created during each PILS run cycle, this data file contains recorded tip and steam heater temperatures from the temperature controllers. The date, time and number of seconds since the start of the run cycle are included in first, second and third columns, respectively, of the data file. The next two columns represent the tip temperature and steam heater temperature. In the header of the file various run cycle information and descriptors of the data columns are reported. Be sure to account for liquid sample delay times when comparing PILS-derived chemical composition data to other data sets that may have different measurement start times and time resolutions.

8.4 Auto-collector operating procedures

IMPORTANT: The Auto-collector software does not communicate with the PILS and therefore has no information about liquid flow rate. It is up to the user to configure the vial fill time properly so that the vials are filled with an appropriate volume of water.

WARNING: When installing the vial-holding carousel to the carousel turn table, be sure to properly align the locating pin on the turn table with the small hole in the vial-holding carousel. Improper installation of the carousel will cause the needle to strike the carousel resulting in damage and failure of the Auto-collector. See figure 25 for proper orientation.

Ensure that the small locating pin on the carousel turn table is inserted properly inside the mating hole on the carousel. Note that an arrow cutout on the carousel turn table points to the locating pin for easy reference. Once the carousel is resting flat on the turn table, install and tighten the three wing nuts to ensure the carousel is held tightly during sampling.

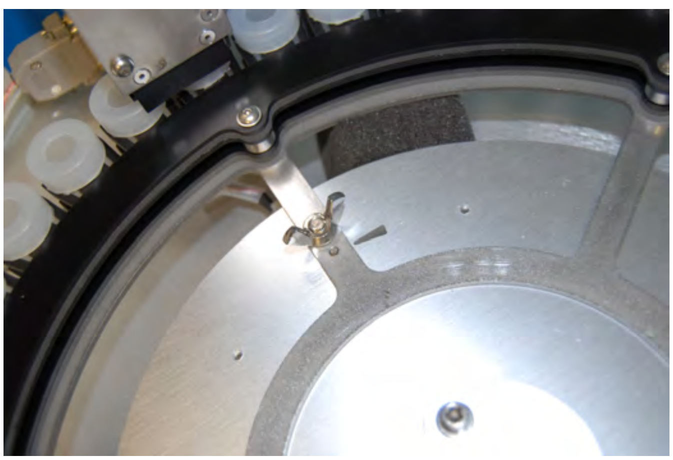


Figure 25: Photo of a properly installed vial-holding carousel.

Be sure to drain the Auto-collector drain bottle when it is full.

Auto-collector Software

Brechtel provides software to control the Auto-collector. A screenshot of the Auto-collector software immediately after first running the software is shown in figure 26, this step requires the COM port to be properly set.

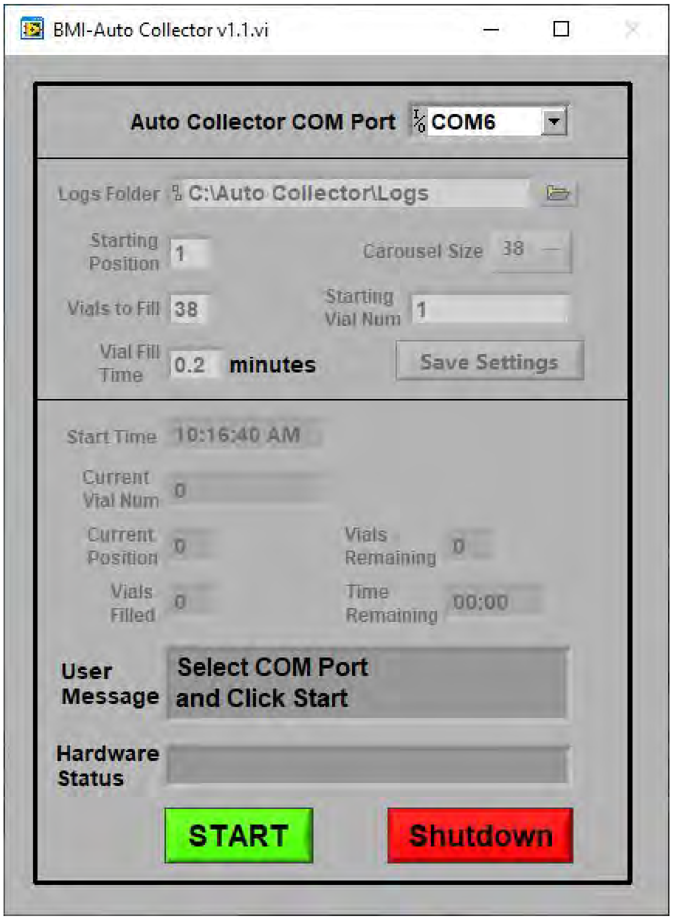


Figure 26: Front panel of the Auto-collector control software showing COM port selection.

After the COM port is set and the 'START' button pushed, the run configuration screen of the software (shown in figure 27) will appear.

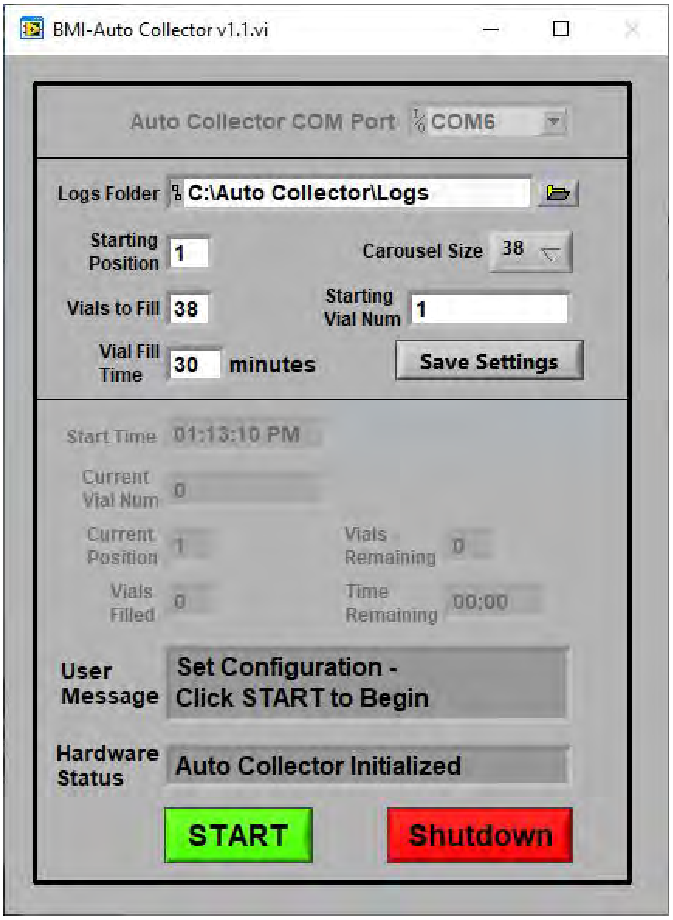


Figure 27: Front panel of the Auto-collector control software showing run configuration entries.

In summary, to operate the Auto-collector and software follow these procedures:

1. connect the USB connector of the USB-to-Serial converter cable to a USB port of a Windows computer and determine the COM port number assigned to the converter
2. connect the serial connector of the converter cable to the serial connector of the Auto-collector
3. connect the AC-to-DC power converter to your AC wall socket and the small DC power connector to the back of the Auto-collector electronics box through the access hole cut in the back panel of the Auto-collector

4. ensure your PILS is fully warmed up and delivering liquid sample to the Auto-collector needle
5. run the *BMI-Auto Collector v1.1.vi* software, select the correct COM port at the top and select 'START' to initialize the port and to home the needle and carousel
6. ensure the correct carousel size (80 or 38 vials) is selected in the software
7. change the starting position (usually 1), vials to fill, vial fill time, carousel size and starting vial number to values that meet your needs
8. click 'Save Settings' if you want the above values to be your default values the next time the software runs
9. once the above settings are made, select 'START' again to begin operating the Auto-collector

After the run configuration details are set and the 'START' button pushed, the operating screen of the software (shown in figure 28) will appear.

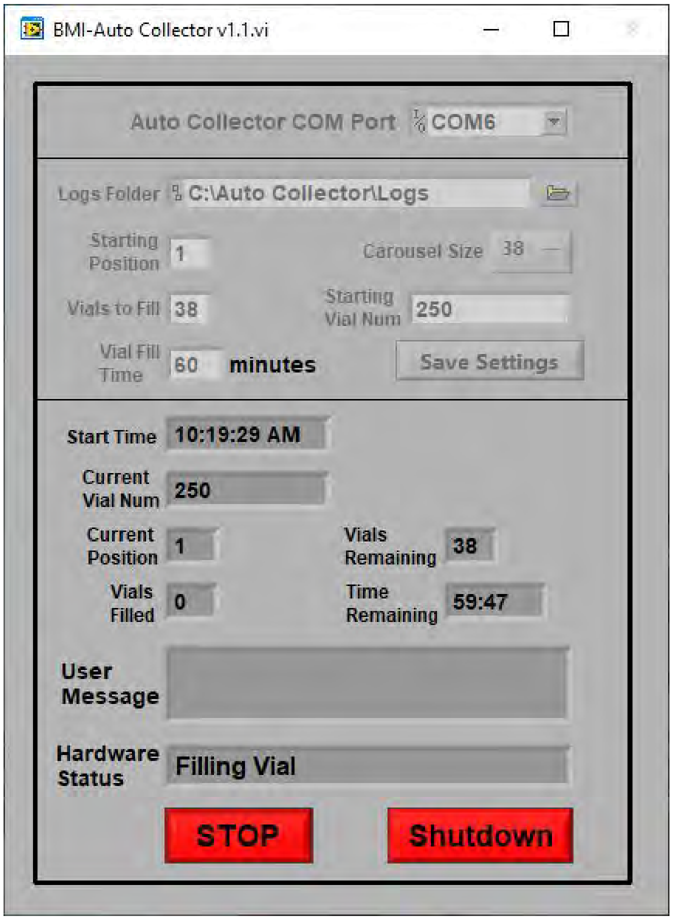


Figure 28: Front panel of the Auto-collector control software showing run configuration entries.

If you select the 'STOP' button during normal Auto-collector operation, the unit will enter 'Pause' mode (shown in figure 29)and will wait until either 'START' is selected to continue the run or 'SHUTDOWN' is selected to stop the run. Note that liquid sample will continue to be delivered to the needle. If a vial is installed underneath the needle water may not be captured by the catch basin.

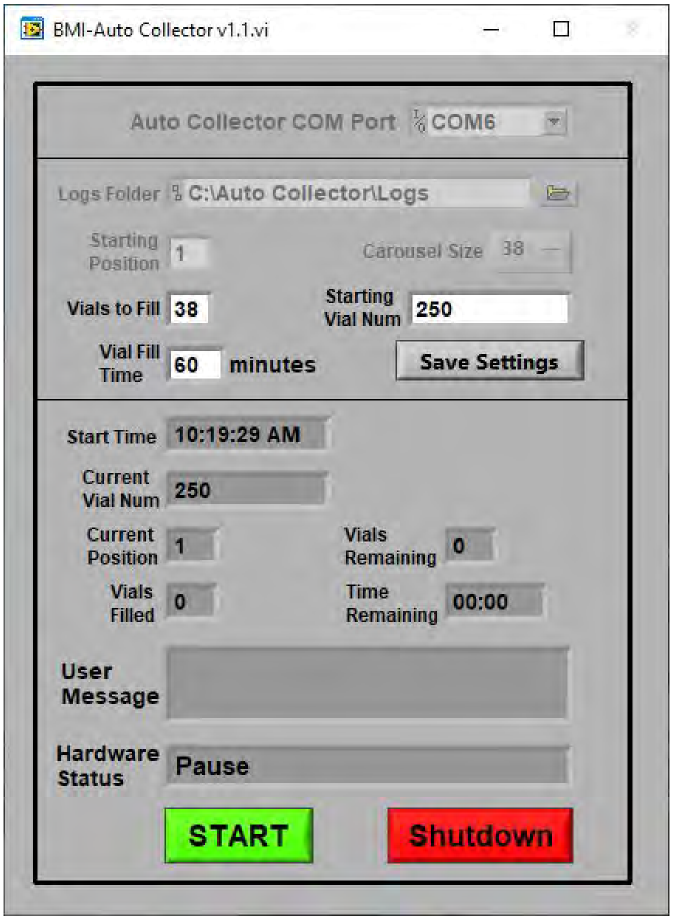


Figure 29: Front panel of the Auto-collector control software showing PAUSE mode.

During operation, the software will report the current vial number being filled (based on the user-entered starting vial number), the current carousel position and how many vials have been filled. The number of vials remaining to be filled as well as the time remaining for the current vial fill to complete are also reported on the front panel. Any error messages are reported to the User Message field and the current status of the hardware (filling, pause, raising needle, rotating carousel, etc.) is shown in the Hardware Status field. Each time the Auto-collector software is run, a log file is created in the user-designated directory so that a record is maintained of each vial fill time. The basic configuration of the Auto-collector is also written to the top of the log file.

WARNING: Be sure to configure the carousel size to the correct setting (38 or 80 vial carousel) in the software. Incorrectly setting the carousel size will cause the needle to be damaged and failure of the Auto-collector.

To pause sampling, click the 'STOP' button. Reclicking the 'START' button will resume sampling. To immediately stop the Auto-collector, click the 'Shutdown' button.

Description of Auto-collector output file

Each Auto-collector run cycle creates a unique log file with the date and start time in the filename. The files are stored in directories (folders) named with the date of the run. The header of the log file contains the log file directory path, carousel size, start position, starting vial number, number of vials, vial fill time and Auto-collector COM port.

The main body of the log file contains five columns: date, time, seconds since start of the run, carousel position and sample vial number. These data are important in that they allow the user to time synchronize liquid samples collected into vials with data from other instruments. Other user messages like "Begin Fill Vials", "Begin Shutdown" and "Shutdown Complete" are also written to the log file to track the tasks performed by the device.

Errors are also recorded in the log file. For example, if the needle is unable to properly insert into the vial a "Needle Insert Fail" error will be written to the file. Other errors include: "Needle Retract Fail", "Carousel Homing Error" and "Carousel Rotate Error".

8.5 Pre-Impactor

The particle pre-impactor should be inspected regularly for build-up of particulate matter and cleaned to prevent clogging. The impactor cleaning procedure is provided in the impactor manual.

IMPORTANT: Familiarize yourself with the typically observed pressure drop measured across the impactor under normal sample air flow operating conditions. If the pressure drop begins to increase, clean the impactor plate!. Refer to the user manual delivered with your impactor for additional details.

8.6 Vapor Denuders

The vapor denuders should be inspected regularly for particle build-up and the surfaces must be rejuvenated when they become saturated. Rejuvenation of the surfaces may be indicated by higher background chemical species concentrations in the PILS liquid sample, especially during filtered air sampling.

The inorganic vapors denuder rejuvenation scheme is described in the maintenance section. The organic vapor denuder contains 15 carbon impregnated paper strips that should be removed and replaced with new strips about once per year. Apply new vacuum grease to the Oring in the organic vapor denuder when replacing the carbon strips.

9 Maintenance

This section provides guidance to maintain your PILS to keep your system healthy and producing high quality data.

9.1 Mesh Wick

The mesh wick mounted around the edge of the quartz impactor disk is a critical component of the liquid sample collection process. Over time, insoluble material can build up on the wick causing it to no longer collect sample droplets. In this case, the liquid sample flow rate can become unstable or decrease to zero. Water accumulation over the face of the quartz impactor disk is an indication of a liquid collection problem. Discoloration (greying) of the quartz impactor disk is also an indication that significant insoluble material may have accumulated on the wick. Replace the wick under the aforementioned conditions. A video is available describing how to replace the wick.

9.2 Peristaltic Pump Tubing

Under continuous use, the peristaltic pump tubing should be replaced or moved to the unused stop position every few months, when an inspection of the tubing reveals stretched, deformed sections that have been permanently flattened by the rollers. It is advised to replace ALL of the tubes at the same time. Note that the tubes have two installation positions (double stop tubing), so used tubing can removed from the white plastic pump clamps and re-installed so a fresh section of tubing is inside the clamp.

WARNING: Do NOT insert your finger or other foreign object into the peristaltic pump rollers or a pinch hazard may result.

Be sure to replace the white tubing clamps so the movable plastic clamp paddles are on the LEFT side of the pump (closer to the PILS Head) when viewed from the front towards the chassis front panel.

After replacing the white tubing clamp in the pump, be sure to raise the white plastic clamp paddle so it points straight up to properly clamp the tube in place.

Always measure the steam liquid flow rate and reset the peristaltic pump speed so the flow rate is correct after replacing the tubing. Run the pump for one hour before setting the pump speed to stretch the tubing.

9.3 Peristaltic Pump Flow Rate Measurement

The tubing in the peristaltic pump will stretch over time with use. Changes in the tubing may impact the liquid flow rate delivered by the pump for a given speed. Follow these procedures to verify the peristaltic pump liquid flow rate:

1. Disconnect the peri pump steam heater liquid flow tube from the barb connecting it to the teflon tube leading into the chassis to the steam heater.
2. Tape the graduated cylinder to the bench top next to the peri pump so it won't fall over.
3. Set the loose end of the peri tube into the top of the graduated cylinder.
4. Ensure that liquid is available in the steam generator liquid supply bottle.
5. Verify that the tube supplying water to the peri pump from the bottle is submerged inside the bottle.
6. Procure a stopwatch to time the liquid volume dispense time.
7. Turn on power to the PILS and start your stop watch. The peri pump will automatically begin pumping liquid. Operating the steam heater without water flow will not damage the unit. Start the timer when you see water drops first dispensing into the graduated cylinder.
8. For a 5 minute dispense, 7.5 ml should accumulate for a 1.5 ml/min flow rate. Stop the peri pump by turning off power and stop the stopwatch at the same time power is removed and measure the volume dispensed in the graduated cylinder.
9. If the measured flow rate is different than 1.5 ml/min by more than 5%, adjust the potentiometer and repeat the measurement until the measured flow rate is 1.5 ml/min.

9.4 O-rings

O-rings inside the PILS head assembly where the droplets are collected will become dry with use. There are six O-rings in total. Apply fresh grease to the O-rings roughly once per year. Visually inspect the o-rings for damage and replace any that appear cracked or deformed. Contact the factory if you require new O-rings.

9.5 Cleaning the PILS

Under persistent high aerosol loading conditions, the pre-impactor, denuders, condensation chamber, droplet impactor, quartz impactor plate, mesh wick, debubbler, and liquid sampling tubing may become contaminated with insoluble material like soot or sparingly soluble organic species. Copmponents like the pre-impactor, denuders, quartz impactor plate and mesh wick will require regular attention and cleaning, likely on a monthly or few-week basis depending on sampled mass concentrations. Other items typically require cleaning annually.

Monitor background concentrations of key species and visually inspect items for deposits to determine when a full system cleaning is required. Disassemble the various items and clean with pure water and alcohol, using a lint free cloth to clean surfaces. Be sure not to leave behind any lint or cleaning material. Replace used liquid handling tubing once soiled. Replace the debubbler membrane and clean the inside of the PEEK debubbler. Replace the mesh wick when obviously dirty or when the liquid sample flow rate is no longer stable. Refer to the manual that came with your pre-impactor for procedures on cleaning and using it.

The low background concentrations attainable with the PILS assume the unit is clean and free of semi-soluble deposits that may leach ions over time, degrading your baseline.

9.6 Bottles

After long-term use the plastic material of the bottles may become brittle and prone to shatter. Contact the factory if you require new bottles.

9.7 Peristaltic Pump

After long-term use, the motor, gearbox and rollers of the pump may become worn and not work properly. Contact the factory if you require a new pump.

9.8 Fuses

The in-line fuse installed on the 24 VDC power circuit of the peristaltic pump and temperature controllers is only to be replaced by trained service personnel.

Replace the AC power fuse in the power entry module only with 5AH, 250V, 5x20mm type fuses.

9.9 Inorganic Denuder Rejuvenation

The two annular glass denuders (URG-2000-30-242-3CSS) are coated with one of two solutions for the removal of potentially interfering acidic and basic gases.

For the removal of the acids (nitric, nitrite, sulfur dioxide, acetate, HCl, formic and oxalic acid), a coating solution is used containing 2% sodium carbonate in a solution of 500 ml deionized water, 20 ml of glycerol, and 750 ml of methanol.

For the removal of bases (ammonia), phosphoric acid is substituted for the sodium carbonate in the solution mixture described above. At a flow rate of 15 lpm, the denuders are typically changed-out after 1 week of continuous operation. Monitoring concentrations of ammonium and nitrate in PILS zero-air samples will provide an indication of the need to rejuvenate the denuders.

To rejuvenate the denuders follow the following procedure:

1. remove the denuders from the sample inlet
2. remove the aluminum denuder bodies from the teflon end caps with fittings
3. wash four solid denuder end caps
4. install one solid end cap on each denuder
5. fill each denuder with MilliQ water, install the other cap and rotate the denuder (30 times over 1 minute) to allow the water to wash the inside surfaces
6. undo the caps and empty the water from the denuders
7. repeat the last two steps 3 times with MilliQ water and then 3 times with clean Methanol

8. allow the denuder to dry either by sitting overnight in a laminar flow hood or by passing dry, filtered, chemically-scrubbed air through it
9. visually verify that no water droplets remain inside the denuders
10. dry the solid end caps
11. replace one end cap on each denuder
12. add 50 ml of the acidic-gasses coating solution to the denuder labeled for use with acidic-gasses and install the second solid end cap
13. rotate for 1 minute and remove the liquid (dispose of properly)
14. allow the denuder to dry under a clean hood or pass dry, filtered, chemically-scrubbed air through it.
15. repeat the last three steps on the second denuder with the basic-gasses coating solution

9.10 Organic Denuder Rejuvenation

The square cross-section aluminum organic vapor denuder contains fifteen carbon-impregnated paper strips that should be replaced on an annual basis. New strips may be purchased from BMI. Be sure to remove fibers from the new strips using clean, compressed air to blow them off prior to installation.

To replace the carbon paper strips follow these steps:

1. remove the organic vapor denuder from the sample inlet
2. remove the four screws holding the end plate on the inlet side with the fitting, do not remove the other end plate
3. carefully slide the cartridge of strips out of the aluminum body
4. blow out the aluminum body with clean compressed air, visually checking that no contamination remains
5. remove the old paper strips from the cartridge assembly
6. blow dry or wipe with methanol the cartridge assembly with strips removed

7. before handling the new paper strips, put on latex gloves
8. carefully blow off any loose fibers from the new strips using clean compressed air
9. install the new paper strips into the cartridge, carefully inserting the metal rod spacers between each strip
10. slide the cartridge assembly back into place
11. remove gloves
12. apply a very small amount of Oring grease to the Oring in the aluminum end plate
13. apply a small drop of fresh loctite to the four denuder end plate screws
14. re-attach the aluminum end plate with the four screws, making sure they are tight
15. reinstall the denuder into the sample inlet

9.11 Droplet Impactor Wick Replacement and Quartz Cleaning

During normal operation of the PILS, the stainless steel wick surrounding the circumference of the quartz impactor plate will become loaded with undissolved particulate matter. The quartz impactor plate can also begin to appear grey in color due to the impaction and sticking of soot and other particles. Periodically inspect the wick and quartz for cleanliness and verify that the liquid sample collection system is operating properly (no air in liquid sample outlet flow from peristaltic pump and expected liquid sample flow rate).

To replace the wick and clean the quartz plate, the acrylic piece holding the quartz impactor disk does not need to be removed. A video is also available showing how to replace the wick. Follow these procedures to remove the quartz plate and replace the wick:

1. Loosen and remove the two 6-32 stainless steel allen head cap screws holding the black anodized aluminum ring around the quartz plate. These screws are screwed into the acrylic piece holding the quartz. Gently remove the aluminum ring. Store in a safe place.

2. Grasping the outside of the quartz plate, carefully rotate counterclockwise and pull towards you. The quartz plate has an O-ring around it that should come out with the plate. If the O-ring comes loose from the quartz, be sure to catch it. Try to pull straight out and avoid cocking the quartz at an angle.
3. You should now be able to see the wick resting in a counterbore cut into the acrylic droplet impactor body. Use a pair of very sharp tweezers to grasp the wick at the overlap point of the ends and remove the wick from the acrylic piece.
4. Rinse the new wick in isopropyl alcohol for 15 minutes and then triple-rinse with 18 mega-ohm water.
5. Obtain the wick rolling tool and follow the instructions that came with the tool (or view the installation on You Tube). The basic steps are also outlined below:
6. Wipe the inside of the acrylic body with a clean wipe and rinse with water.
7. Roll the wick around the wick changing tool so the ends overlap at the small notch cut into the outside edge of the tool. Use tweezers to grab the wick at the overlap and gently pull the wick straight off the tool.
8. Insert the new wick into the acrylic body being careful not to bend the wick. Position the wick so that the overlap region is located away from the wash-flow entrance and sample-flow exit holes.
9. Verify that the wick is seated properly around the circumference of the bore in the acrylic body. It must rest directly against the acrylic with no air pockets underneath the wick.
10. Rinse the various surfaces of the quartz impactor disk with isopropyl alcohol and triple-rinse with pure water.
11. Apply a very small amount of O-ring grease the O-ring that seals on the quartz impactor disk. Wipe off all excess grease.
12. Reinstall the O-ring around the quartz by resting the O-ring on a flat, clean surface and pushing the quartz into the O-ring.

13. Using a very small screw driver, re-install the quartz plate, using the screw driver the push the O-ring into the gap between the outside diameter of the quartz and the inside diameter of the acrylic.
14. Very carefully insert the quartz plate until it seats against the wick. It is extremely important that the quartz plate be in full contact with the wick. While holding the quartz with your index finger and thumb, use the screwdriver to push the O-ring up against its sealing surface. Do not over-insert the quartz, or push on the quartz with too great a force, or the wick will be crushed. If you bend the wick during installation of the quartz you must repeat the procedure with a new wick. Be sure the O-ring around the quartz is fully seated before re-attaching the aluminum ring.
15. Once the quartz is fully installed. Slide the aluminum ring over the quartz. Once the flange on the aluminum piece is flush up against the O-ring surrounding the quartz plate, rotate the aluminum so the clearance holes match up with the threaded holes in the acrylic.
16. Do NOT use loctite on the allan head cap screws holding the aluminum ring to the acrylic, loctite will disintegrate the acrylic.
17. Re-install the two 6-32 screws, with both flat and lock washers, holding the aluminum ring to the acrylic. Do not over tighten as the acrylic will crack.
18. Run the PILS for at least one-hour after changing the wick. Then re-check your background concentration levels to verify leak-free operation. We also recommend repeating the ammonium sulfate calibration study just to be sure the droplet collection system is operating properly. Verify the peristaltic pump liquid sample outlet flow rate agrees with expected values.

9.12 Droplet Impactor Replacement Procedures

Removal of the acrylic piece holding the quartz impactor disk may be necessary to inspect proper mating between the fine-mesh wick and the quartz plate or to clean the quartz impactor disk and wick. Follow these procedures to remove the acrylic piece (with quartz installed):

1. Unscrew the two PEEK nuts and carefully pull them from the acrylic - note how the PEEK tubing extends beyond the dark blue ferrule. This is done purposefully to minimize the liquid residence time and minimize contact of the liquid water with the acrylic. If the nuts are too difficult to break loose by hand, use a pair of pliers.
2. When pulling the lower PEEK nut and tubing from the acrylic piece, do not worry about letting it 'snap back' as the design prevents the PEEK tube from contacting the wick.
3. Wrap both nuts and PEEK tubing ends in parafilm to keep them from getting dirty.
4. Loosen and remove the four 4-40 stainless steel allen head cap screws holding the acrylic piece to the black anodized aluminum droplet jet body. Store in a safe place.
5. Grasping the outside body of the acrylic carefully rotate counterclockwise and pull towards you. The acrylic has a step and O-ring indexing the inside diameter of the black aluminum and this joint is tight. Try to pull straight out and avoid cocking the acrylic at an angle.
6. With your index finger, make one circumferential wipe of the inside surface of the black aluminum that contacts the O-ring of the acrylic piece.
7. If the O-ring on the replacement acrylic piece does not have vacuum grease on it, remove it (with a plastic tool to avoid scratching the O-ring groove), clean it with IPA, and wipe vacuum grease on the O-ring. Only a very small amount of grease is needed. Wipe off all excess grease.
8. Procure a small plastic screwdriver or O-ring handling tool to help you during the installation of the new acrylic piece.
9. Holding the new acrylic piece flush up to the mating black aluminum piece, push and slowly rotate about 30 degrees to insert the acrylic into the aluminum. Watch the O-ring to ensure it isn't bulging out and getting pinched between the two pieces. If this occurs, use a plastic tool to push the O-ring into the O-ring groove of the acrylic.

10. Once the flange on the acrylic piece is flush up against the black aluminum, rotate the acrylic so the clearance holes match up with the threaded holes in the aluminum.

11. Do not use loctite on the allen head cap screws holding the acrylic to the aluminum, loctite will disintegrate the acrylic.

12. Re-install the screws, with both flat and lock washers, holding the acrylic to the aluminum. Do not over tighten as the acrylic will crack.

13. Re-attach the PEEK nuts and tubing. Note that the PEEK tubing must slide inside the hole machined into the acrylic. You cannot push the tubing too far, so you cannot damage the wick. The PEEK tubing should be positioned within 1 or 2 mm of the wick.

9.13 Steam Generator Removal Procedures

WARNING: This procedure requires access to inside the PILS chassis and may only be performed by trained service personnel.

Follow the instructions below if the heater used to generate steam within the steam generator assembly is no longer working.

1. Shut down the instrument and remove the power cord.

2. Remove the top cover and disconnect the teflon water supply tube from the 1/8" swagelock elbow, disconnect the heater power connector and the thermocouple connector. Cut any tie wraps holding these connectors if necessary.

3. Using a pair of small wire cutters, remove the small diameter stainless steel tie wire wraps holding the reddish-orange silicone insulation around the steam injector tubing going from the outlet of the steam heater assembly into the PILS head. Make sure no stray pieces of metal tie wire fall into the chassis. Take a picture of the assembly before cutting.

4. Unwrap and store the pieces of silicone insulation as you remove them so you can use them again, take a picture of how the pieces were installed so you know

how to put them back on. Be very careful of the small diameter thermocouple wire coming out of the PILS head, if you stress it too much, it can break.

5. Using a backing wrench on the swagelock fitting joining the heater exit tube to the steam injector tube to the PILS head, loosen the nut on the fitting. Be very careful not to overly stress the 1/16" OD stainless tubing going into the PILS head assembly, if you bend this tubing you may alter the position of the tip inside the PILS head where the steam is injected. Either way, once you have the new steam heater installed, you will take apart the PILS condensation chamber and watch the steam being injected so you know that the jet is colinear with the aerosol sample flow.
6. Loosen the two bracket screws holding the steam generator assembly to the metal bracket bolted to the bottom of the chassis. This will loosen the whole assembly, so cradle the assy in your left hand as you remove the screws so it doesn't fall out.
7. Slide the loosened heater assembly straight back from the PILS head to clear the 1/16" OD tip tubing from the fitting.

The above procedures should leave you with the steam assy in your hand. Pack it up in a small box and ship it to Brechtel after contacting us to obtain a Return Materials Authorization (RMA) number.

Table 6: Estimated annual costs to maintain the BMI PILS. Replacement frequency of 0.5 means once every 2 years.

PILS Maintenance Costs			
Item	Cost per Item	Replacement Frequency (/yr)	Cost per Year
Organic Denuder Carbon Paper Strips	$258.00	1	$258.00
HEPA filter	$100.00	0.5	$50.00
PEEK Tubing	$60.00	0.3	$20.00
Fuse	$3.00	1	$3.00
Steam injector Assembly	$1,250.00	0.5	$625.00
Wick (pack of 5)	$60.00	2	$120.00
Peristaltic pump tubing	$273.00	1	$273.00
Quartz impactor disk Oring	$1.00	1	$1.00

10 PILS Errors

One common error in the PILS is a steam tip temperature that drifts below 98C. The tip temperature should be kept between 98 and 100C. Do not operate above 100C or you will begin to volatilize your sample. Adjust the steam heater controller temperature setpoint by 5C when the tip temperature drops below 98. Wait 10 minutes after each steam heater temperature setpoint adjustment. Continue adjusting the steam heater setpoint until the desired tip temperature is reached.

Another common error is a tip temperature reading near room temperature when the steam heater is operating at its setpoint. This usually indicates that there is no liquid flow to the steam heater and that either the supply bottle is empty or there is a problem with the peristaltic pump line supplying the steam heater with liquid.

11 Troubleshooting

Table 7: Common PILS Troubleshooting Solutions

Problem	Likely Cause	Solution
Will not power on	No AC pwr	Plug in AC power
	PWR switch open	Close PWR switch
	Fuse blown	Replace fuse
No liquid sample flow	Dirty wick	Replace wick
	Dirty debubbler	Replace debubbler membrane
	Leaking peri tube	Replace peri tube
	No washflow	Fix washflow
	Poorly seated wick	Make wick flush to bore
	Failed peri pump	Replace pump
	Blown 24VDC fuse	Call factory
Air sample flow too low	Pump failure	Replace pump
	Orifice clogged	Ensure orifice is clean
	Pre-impactor clogged	Clean pre-impactor
	Steam flow too high	Adjust steam flow
Tip temperature too low	Steam heater too cold	Increase heater setpoint
	Steam flow too low	Adjust steam liquid flow
	Liquid drop on tip	Remove liquid drop
	Air flow too high	Fix air flow rate
Background concentrations too high	Dirty wick	Replace wick
	Dirty debubbler	Clean debubbler
	Old peri tubing	Replace peri tubing
	Dirty PEEK tubing	Replace PEEK tubing
	Washflow dirty	Replace washflow

Table 8: Common Auto-collector Troubleshooting Solutions

Problem	Likely Cause	Solution
Will not power on	No AC/DC pwr	Plug in AC/DC power
	Motor board failure	Call factory
Needle insert or retract error	Wrong carousel size	Set correct size
	Carousel rotate error	Fix carousel position
	Motor sticking	Call factory
	Bent needle	Replace needle
	Foreign item in needle housing	Remove item
	Limit switch failure	Call factory
	Motor failure	Call factory
	Board failure	Call factory
Carousel rotate error	Belt loose	Tighten belt
	Vial sticking out from carousel	Install vial properly
	Foreign item stopping carousel	Remove item
	Limit switch failure	Call factory
	Motor failure	Call factory