

CHAPTER 4
SAMPLING PUMPS
&
AIRFLOW CALIBRATORS

Chapter 4

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CHAPTER 4 SAMPLING PUMPS & AIRFLOW CALIBRATORS

I. Introduction

Metal and Nonmetal uses constant-flow personal sampling pumps to collect several different types of occupational exposure samples in conjunction with sampling media, such as; filter cassettes, or sorbent tubes (e.g., coconut shell charcoal and high purity washed silica gel). These collection media are used when sampling for respirable and total dust, mineral dusts, welding fumes and elemental metal dust, asbestos fibers, radon, and organic vapors. To preserve the integrity of each sample, the sampling pump must be operating properly. That is, the sampling pump must be sufficiently charged, properly maintained, and calibrated with appropriate airflow calibrator instrumentation.

II. Definitions

Airflow Calibrator: a flow metering device or electronic metering instrument used to calibrate or measure the airflow rate created by a sampling pump.

Bubble Generator: a tube assembly that may be used as an integral part of an air sampling pump calibration procedure. When a sampling pump is connected to the bubble generator, the vacuum created draws a soap bubble through the device. An electronic sensor automatically computes the airflow rate of the sampling pump by calculating the speed of the bubble as it travels through the known volume of the calibration tube. It is considered a wet calibration method.

Burette: a cylindrical glass or plastic tube, typically 1.0 - 2.0 liter in volume, which can be used to calibrate air sampling pumps and verify airflow meter calibration. With a sampling pump connected to the upper end of the burette, the vacuum created draws a soap bubble through the burette. A timer is used to measure the period for the soap bubble to travel a specific distance through the known volume of the burette. The airflow rate can be calculated from the data collected during the timing of several bubbles. It is considered a primary standard of the highest quality if the burette is manufactured to class A volumetric glassware standards and is National Institute of Standards and Technology (NIST) traceable.

Calibration: a set of operations, which establish, under specified conditions, the relationship between values indicated by a measuring system; i.e., instrument, and the corresponding known value of a standard. There are two types of calibration; operational and periodic. Operational calibration is carried out routinely as part of instrument usage. The operational calibration program involves initial calibration and verification, and continuing calibration checks. Periodic calibration is a distinct process with frequency set by manufacturers' recommendations or by enforcement policy requirements.

Calibration Standard: a reference used to quantify the relationship between the output of an instrument and the property to be measured. The parameters of calibration standards should bracket the levels for which the actual measurements are to be made. Secondary standards, also known as transfer standards, are used for calibration and traceable to a primary standard.

Dry Calibrator: a type of airflow calibrator which uses air to set and/or verify flow rate of a sampling pump. The electronic instrument automatically computes the airflow rate of the sampling pump by calculating the change in volume and movement of the instrument's piston over a given time period.

Rotameter: a flow metering device consisting of a transparent tube with a small float inside. The air flowing through the device causes the float to rise inside the tube to indicate the approximate airflow rate. Several sampling pumps currently used by Metal and Nonmetal are provided with built in rotameter type flow meters.

Sampling Pump: a mechanical, battery-operated device that is used to draw air through specific collection media (filter or sorbent tube) in order to collect a representative sample of airborne contaminant(s) in the mine environment.

Wet Calibrator: a type of airflow calibrator which uses a soap bubble to set and/or verify flow rate of a sampling pump. The electronic instrument automatically computes the airflow rate of the sampling pump by calculating the change in volume by measuring the bubble distance traveled over time.

III. General Characteristics

Metal and Nonmetal uses a variety of personal sampling pumps. Some examples in use are the SKC Model 224-44XR (see Figure 4-1) and the Sensidyne Gilian (see Figures 4-2, 4-3).



Figure 4-1. SKC® Model 224-44XR Sampling Pump.

The internal components of each sampling pump work on the same basic principles. Sections A and B below outline these components and their respective functions.

Note: Use intrinsically safe MSHA-approved permissible sampling pumps where required in gassy mines (e.g., SKC 224-PCXRM, Gilian GilAir).



Figure 4-2. Gilian® Model 5000 Sampling Pump.



Figure 4-3. Gilian GilAir® Plus Sampling Pump (in docking station).

- A. Pneumatic System** - consists of six basic assemblies: pump/valve, pulsation dampener, pressure regulator, flow indicator, inlet filter, and barometric pressure compensation.
- 1. Pump/Valve Assembly** - the pump consists of dual silicone diaphragm pistons driven by a high-efficiency DC motor. The diaphragm pump is combined with low pressure, positive acting valves to direct airflow. The unit is sealed in a housing to prevent dirt from entering. The DC motor operates from a rechargeable Nickel-Cadmium (NiCad), or Nickel-Metal Hydride (NiMH), or Lithium ion, battery pack depending upon the model.
 - 2. Pulsation Dampener or Damper Assembly** - consists of silicone diaphragms within the pump stack housing directly above the pump motor to provide pulsation-free flow. During the intake stroke, the diaphragms are stretched inward by vacuum. During the exhaust stroke, the diaphragm elasticity forces the diaphragms apart, maintaining a continuous vacuum on the intake to the pump.

3. **Pressure Regulator Assembly** - used for low flow sampling from 1 to 750 milliliters per minute (mL/min). The purpose of the regulator is to maintain suction or discharge at a nominal pressure drop (20.0 to 25.0 inches of water) across the control restrictor. The regulator is not used at flows above 750 mL/min. A manual valve is provided on the sampling pump to connect the regulator in and out of the system for low and high flow applications, respectively.
 4. **Flow Indicator** - this may be either a digital LCD display on the side of the pump or a rotameter style flow meter mounted vertically inside the case and visible from outside the case through a clear viewing window. Both are useful to confirm continuing operation of the pump. Rotameters are not precision flow meters ($\pm 20\%$). Flow readings must be verified with a more accurate calibration instrument.
 5. **Inlet Filter Assembly** - consists of a transparent plastic housing and filter membrane held in place with an O-ring. All air drawn into the sampling pump passes through the pump inlet filter. As dust collects on the sampling pump inlet filter over time, the transparent housing permits the operator to view the filter to determine when changing is necessary.
 6. **Barometric pressure compensation** - newer pumps have built in capability to correct for changes in altitude between calibration site and sampling site.
- B. Electrical and Control System** - consists of battery pack, control panel, and motor control circuitry.
1. **Battery Pack** - the number of cells contained in a battery pack is dependent upon the pump size and permissibility. The battery pack may contain from four to five rechargeable NiCad, NiMH, or Lithium ion cells arranged in series within a plastic housing or “pack” to provide the necessary voltage to the sampler. The battery pack is rechargeable without removal from the sampling pump via an exterior plug-in port.
 2. **Control Panel** - consists of either key pads or an on/off switch and recessed flow adjustment control. The flow adjustment control is used to adjust flow rates from 0.75 Lpm to 5.0 Lpm (750 mL/min. to 5000 mL/min). Adjustments may be made by either using the up/down arrows on the keypad or turning a small recessed screw clockwise to increase the flow rate, or counterclockwise to decrease the flow rate. A security cover or code protects the control panel from inadvertent adjustment changes when sampling.
 3. **Motor Control Circuitry** - comprises a *Constant Flow System* which provides for constant airflow even though the back pressure of the collecting device may have increased. For example, pressure increase caused by dust accumulation on a filter. As the back pressure increases, the motor voltage is automatically corrected to maintain constant flow.

IV. Sampling Pump Care and Maintenance

Replacement parts are available from the sampling pump manufacturer. Notify the District Industrial Hygienist or Health Specialist through your field office supervisor of the items needed. To maintain the personal sampling pumps in peak operating condition, adhere to the specific procedures for your respective pump model:

Appendix 4A-1. Sampling Pump Care and Maintenance, SKC 224-44XR, and 224-PCXR4M

Appendix 4A-2. Sampling Pump Care and Maintenance, Gilian 5000 & GilAir Plus

Appendix 4A-3. Sampling Pump Care and Maintenance, SKC AirChek 2000

Appendix 4A-4. Sampling Pump Care and Maintenance, SKC Pocket Pump (low flow)

In general:

- Carry sampling pumps in a closed, padded case to avoid damage from impact or dropping.
- When sampling, position the sampling pump in the safest location available on the person being sampled. Instruct the person not to adjust, turn off, bump, drop, or otherwise tamper with the sampling pump.
- Clean the sampling pump and visually inspect it for defects and damage after each use or when submitting it for maintenance or calibration.
- If the sampling pump fails to function properly during a survey, discontinue the survey and void the sample. Report the incident to your supervisor. Do not use the sampling pump again until it is repaired.

V. Sampling Pump Calibration Procedures

A. Background and General Instructions

Whenever constant flow personal air sampling pumps are used to collect a miner's exposure using filter cassettes, sorbent tubes, etc, the integrity of each sample must be preserved and the sampling pump must be operating properly and able to draw a constant known flow. To ensure this, the sampling pump must be sufficiently charged, properly maintained, and calibrated with appropriate airflow meter instrumentation and technique. Calibration procedures, equipment, and location should be in accordance with the following:

1. **Equipment** - Metal and Nonmetal uses two types of sampling pump airflow calibrators: 1.) manual, using a glass burette, and 2.) electronic airflow meters, using various manufacturers' instruments. The manual glass burette method is not usually used in the field setting. Refer to Appendix 4B Sampling Pump

Calibration, and Flowmeter Calibration, Manual, 1.0 Liter Burette and Stopwatch, for using this method.

2. **Set up** - The airflow calibration instrument used must be assembled with similar representative media and sampling train included. This procedure is necessary to simulate the resistance of the media and sampling train to be used during the sampling. Do not use the calibration media for sampling purposes. When using a combination cyclone in a calibration jar as shown in Figure 4C-1-1a, the jar must be air tight. The calibration jar and tubing should be periodically inspected for leaks, deformed tubing, cracked rubber grommets, etc. If leaks are found, either replace the defective part(s) or the calibration jar.
3. **Location** – To replicate atmospheric conditions, calibrate the sampling pump as near to the sampling site elevation as practical.
4. **Frequency** - Calibrate a fully charged and stabilized sampling pump before each full-shift usage.
5. **Post-Sampling Calibration Acceptability** - Post-sampling calibration checks are acceptable when the average of consecutive timings agree within $\pm 5\%$ of the pre-sampling target flow rate. If the post-sampling check does not agree, the sample is invalid. Post-sampling checks should be conducted as soon as possible after the sampling shift, preferably within one day of the sampling survey. Do not charge the pump before conducting post-sampling calibration.
6. **Record of Calibration** - A written record of sampling pump calibrations and post-sampling calibration checks must be kept with, or made part of, the inspection Health Field Notes Form 4000-31A or B.

B. Electronic Calibration Equipment for Air Sampling Pumps

Sampling pump calibration may be accomplished using the glass burette method or an electronic airflow calibrator instrument. The most convenient and most common calibrating procedure utilizes electronic flowmeters to adjust (set) the sampling pump airflow. Metal and Nonmetal uses a variety of electronic airflow meter measurement devices to calibrate air sampling pumps. To conduct pre- and post- sampling calibration for your sampling pumps, follow the calibration procedures for the specific **Airflow Calibrator** you are using, i.e.:

Appendix 4C-1. Sampling Pump Calibration, Electronic, (wet) Sensidyne[®] Gilian Gilibrator[™] Airflow Calibrator.

Appendix 4C-2. Sampling Pump Calibration, Electronic, (wet), A.P. Buck[®], Inc. mini-BUCK Calibrator and SKC UltraFlo[®] Airflow Calibrator.

Appendix 4C-3. Sampling Pump Calibration, Electronic, (dry), Bios[®] DryCal-Lite and Defender[™] Airflow Calibrator.

Appendix 4C-4. Sampling Pump Calibration, Electronic, (dry), TSI® 4146 Airflow Calibrator.

VI. Electronic Airflow Calibration Quality Assurance Procedures

The electronic airflow calibrators must be periodically checked against a known accurate instrument to ensure they are functioning properly. All electronic airflow calibrators used for calibrating sampling pumps must be included in a quality assurance (QA) program, whereby, each field airflow calibrator requires an annual check against a laboratory or manufacturer's factory calibrated reference instrument. Our primary way to quality assure electronic airflow calibrator performance is to conduct an annual operational check of field office airflow calibrators. The airflow calibrator unit must fall within tolerance of the reference volume measured by a master calibration standard. Each unit must fall within $\pm 1\%$ of the reference volume measured with the certified (NIST traceable) laboratory/factory calibrated master unit. For example; for a designated master airflow calibrator certified by a manufacturer's laboratory at 1.700 Lpm, all other similar type airflow calibrators compared against it must read between 1.717 to 1.683 Lpm. The laboratory data sheet or factory's certification record for the master unit and a record of each airflow calibrator's QA check must be maintained by ID number, results, and date, for the life of the instrument or a minimum five year history. An example of a calibration verification record form can be found in Appendix 4E. Electronic airflow calibrators not meeting the accuracy requirements are sent back to the manufacturer or laboratory/factory for adjustment/repair and a new calibration certification.

Appendices 4D-1, & 4D-2 provide guidance on calibration verification procedures that can be used for checking the performance of the field airflow calibrators. For specific QA procedures, go to:

- Wet method (i.e., Gilian) airflow calibrators QA procedures. See Appendix 4D-1.
- Dry method (i.e., Bios, TSI) airflow calibrators QA procedures. See Appendix 4D-2.

Appendix 4A-1

Sampling Pump Care and Maintenance, SKC Models 224-44XR, and 224-PCXR4M

A. Battery Maintenance

1. The SKC models may have NiCad batteries that will develop reduced capacity over time due to age, long periods of nonuse, or if they are not fully discharged/recharged after sampling which can result in “memory effect”. This can prevent the sampling pump from running a long full-shift sampling period in some instances.
2. SKC NiCad (5 cell) batteries are no longer being produced and are being replaced by the new Nickel-Metal-Hydride (NiMH) battery that does not develop “memory effect”. Battery maintenance procedures however are still applicable.
3. Use the “PowerFlex” battery charger to automatically perform this function.
4. If you have the “Master Charger” model charger, ensure the discharge button is always pushed when charging the sampling pump. This will reduce the cause of “memory effect”.
5. NiMH batteries stored for extended time periods should be recharged every 1-2 months to avoid complete discharge. The NiMH battery pack has an estimated life of 300–500 charge/discharge cycles, depending on use. The NiCAD battery pack has an estimated life of 400–600 charge/discharge cycles, depending on use.

B. Changing Battery

1. Removal - Follow the pump manufacturer’s recommendation for removing the battery pack. In general, remove the screws which secure the battery to the pump. Slide or remove the battery from the pump. Carefully slide the battery pack out to the right from under the belt clip, being careful not to cock it at an angle. The edge rails should guide the pack out.
2. Replacement - Install the new battery making sure the contacts are properly positioned. Push the battery to the left until it is properly located, reinstall the battery screws and tighten the case screws. All pump manufacturers recommend the battery pack be fully charged before installing into the pump. Likewise, the battery pack should be fully charged before use to ensure maximum longevity and performance.

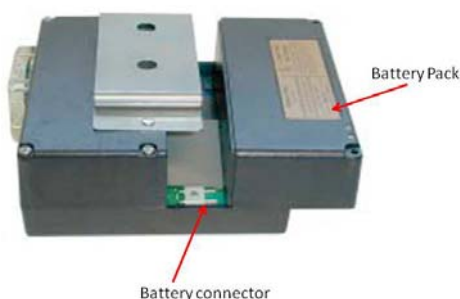


Figure 4A-1-1. SKC 224-44XR Sampling Pump.

C. Storage

If the sampling pump is stored for long periods (1-6 months), use a cycling charger/ battery maintenance station (as described in **A. Battery Maintenance** above) and return sampling pump to storage.

D. Sampling Pump Inlet Filter

The sampling pump inlet filter, located inside the clear plastic intake port housing, prevents liquids and/or particulates from being drawn into the pump mechanism. As the filter becomes dirty or clogged, it can create an excessive load on the sampling pump, decreasing pump performance. Periodically inspect the sampling pump inlet filter and replace as necessary. Replace the inlet sampling pump filter and O-ring as follows:

1. Wipe or blow all dust and debris from around the filter housing.
2. Remove the four screws and the front filter housing.
3. Remove the filter membrane and O-ring. Check the O-ring for visible damage and replace as necessary.
4. Clean the removed filter housing.
5. Insert a new filter membrane (and new O-ring if necessary). Ensure the small center O-ring is properly seated inside the pump.
6. Reattach the front filter housing and tighten the four screws.

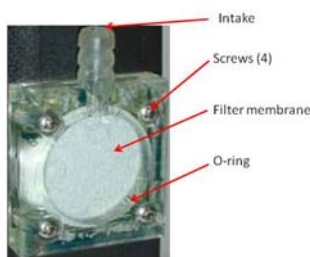


Figure 4A-1-2. SKC 224-44XR Pump Inlet Filter Housing.

For specific and detailed sampling pump instructions refer to the SKC Operation Manuals, available at www.skcinc.com.

Appendix 4A-2
Sampling Pump Care and Maintenance, Gilian 5000, & GilAir Plus

For specific detailed instruction refer to the Gilian 5000, and GilAir Plus air sampling pump Operation Manuals, available at www.sensidyne.com

A. Battery Maintenance

1. These pumps use rechargeable Nickel-Metal-Hydride (NiMH) batteries that must be fully charged before using the pump and properly maintained for maximum run time. The battery pack requires less than a 4 hour charge from complete discharge.
2. All NiMH batteries lose charge even when not in use. If the battery pack has not been charged for 3-4 days, recharge battery before use. Use the Fast Charger battery charger or Five-Unit Power Station to automatically perform this function. This ensures that batteries are fully charged just prior to sampling. Do not operate the pump during charging. Charging cycle will begin immediately and will complete as indicated by the charger LED status.
3. NiMH batteries stored for extended time periods should be recharged every 1-2 months to avoid complete discharge. The battery pack has an estimated life of 300–500 charge/discharge cycles, depending on use and storage conditions.

B. Changing Battery

1. Removal - Follow the pump manufacturer's recommendation for removing the battery pack. Remove the screws which secure the battery to the pump. Then remove the battery from the pump.
2. Replacement - Install the new battery making sure the contacts and pins are properly positioned. Pay attention to wire routing so as not to pinch the wires/harness. Replace the screws and carefully tighten (do not overtighten). Fully charge the battery pack before use.

C. Storage

Battery life can be extended by storing in cool conditions. High temperatures accelerate aging. When the sampling pump is stored for long periods (1-6 months), use a cycling charger/power station, as described in **A. Battery Maintenance** above, for long term storage.

D. Sampling Pump Inlet Filter

The sampling pump inlet filter, located inside the clear plastic intake port housing, prevents particulates and/or liquids from being drawn into the pump mechanism. As the filter becomes dirty or clogged, it can create an excessive flow resistance and increased back pressure, thus decreasing pump performance. Periodically inspect the sampling pump inlet filter and replace as necessary.

To replace the sampling pump inlet filter:

- Gilian 5000: go to the Maintenance section of the Operation Manual for detailed instruction. Note that the replacement filter for the Gilian 5000 goes rough side down.
- GilAir Plus: go to the User Maintenance section of the Operation Manual for detailed instruction. Note the importance of clear and proper gasket and O-ring positioning when replacing the filter and reassembling the filter housing.

Operation Manuals are available on the internet, at: <http://www.sensidyne.com>

Appendix 4A-3
Sampling Pump Care and Maintenance, SKC AirChek® 2000

A. Battery Maintenance

1. This pump uses either rechargeable NiCad or NiMH batteries that must be fully charged before use as all batteries lose charge when not in use. If the battery pack has not been charged for 3-4 days, recharge battery before use. The battery pack has a charge time of 6 to 8.5 hours based upon battery capacity and level of discharge.
2. Use the “PowerFlex” battery charger to automatically perform this function. The “PowerFlex” battery charger will automatically perform a discharge/recharge cycle on the NiCad batteries to minimize the “memory effect”. This ensures that batteries are fully charged just prior to sampling. The pump should not be used during charging.
3. The manual states that “After charging the battery pack, it is good practice to run the pump for approximately 5 minutes before calibrating. This ensures the battery is in more steady-state conditions and improves the agreement in pre- and post-sampling calibrations.” To ensure stability, run the pump at least 5 minutes before calibrating.
4. NiMH batteries stored for extended time periods should be recharged every 1-2 months to avoid complete discharge. The NiMH battery pack has an estimated life of 300–500 charge/discharge cycles, depending on use. The NiCad battery pack has an estimated life of 400–600 charge/discharge cycles, depending on use.

B. Changing Battery

1. Removal - Follow the pump manufacturer’s recommendation for removing the battery pack. Release the battery pack by removing the two security screws located on the bottom of the battery pack. See Figure 4A-3-1. Pull the battery pack away from the pump body. See Figure 4A-3-2.

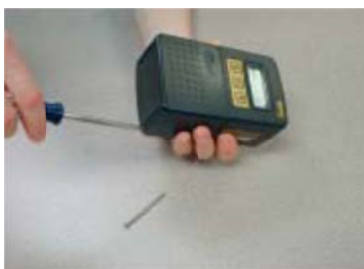


Figure 4A-3-1. SKC AirChek 2000 Battery Pack Removal Step 1.



Figure 4A-3-2. SKC AirChek 2000 Battery Pack Removal Step 2.

2. Replacement - Carefully align the battery jack on the replacement battery pack with the battery terminal on the bottom of the pump base plate and push the battery pack into place. See Figure 4A-3-3.



Figure 4A-3-3. SKC AirChek 2000 Battery Pack Replacement

3. Replace and tighten the two security screws removed in Step 1. Fully charge the battery pack before use.

C. Storage

If the sampling pump is stored for long periods (1-6 months), use a cycling charger/ battery maintenance station (as described in **Battery Maintenance** above) and return to storage.

D. Sampling Pump Inlet Filter

The sampling pump inlet filter, located inside the clear plastic intake port housing on top of the pump, prevents particulates and/or liquids from being drawn into the pump mechanism. As the filter becomes dirty or clogged, it can create an excessive load on the sampling pump, decreasing pump performance. Periodically inspect the sampling pump inlet filter and O-ring and replace as necessary. Replace the inlet sampling pump filter and O-ring as follows:

1. Remove the three screws that secure the inlet port housing to the top of the pump.
2. Remove the inlet port housing and gasket. Carefully remove the O-ring.
3. Remove and discard the filter. Insert the new filter.
4. Insert O-ring.
5. Replace the gasket.
6. Align the inlet port housing with the three screw holes and the LED.

Appendix 4A-4

Sampling Pump Care and Maintenance, SKC Pocket Pump® (low flow)

Note: These pumps are used for specialized purposes and unique processes.

A. Battery Maintenance

1. This pump uses either rechargeable NiCad or NiMH batteries that must be fully charged before use as all batteries lose charge when not in use. Newer pumps use the NiMH battery, however while the NiCad batteries are found in the older models, NiMH batteries can be retrofitted in them.
2. **Important note for this pump.** New battery packs **MUST** be completely charged **BEFORE** installing them into the pump. This initial slow (16-hour) charge will provide optimum battery performance. After completely charging, then install the new battery pack into the pump.
3. Once the new battery has been charged and installed in the pump, plug the charger into a standard wall outlet and the charging plug into the battery port on the bottom of the pump. The fast charging function of the battery pack will completely recharge the battery in approximately 6 hours or less. The pump should not be running during charging.
4. NiMH batteries stored for extended time periods should be recharged every 1-2 months to avoid complete discharge. The NiMH battery pack has an estimated life of 300–500 charge/discharge cycles, depending on use. The NiCad battery pack has an estimated life of 400–600 charge/discharge cycles, depending on use.

B. Changing Battery

1. Removal - Follow the pump manufacturer's recommendation for removing the battery pack. Begin by pressing down on the sliding keypad cover near the SKC logo. Push the keypad cover down and away from the display until it is free from the pump case.
2. Lay the pump on a flat surface with the LCD facing upward. Remove the two screws on the front panel of the pump.
3. Turn the pump over so that the LCD faces down. Remove the belt clip by unscrewing the single locking screw, and remove the battery compartment cover.
4. Remove the old battery pack by carefully lifting it upward and from the pump.
5. Align the jack on the new fully charged replacement battery pack with the pins on the pump. Press into place. Replace the battery compartment cover and belt clip removed in Step 3.
6. Turn the pump over so that the LCD faces upward. Replace the two screws on the front panel of the pump (do not overtighten the screws). Replace the keypad cover by aligning it with the ridges on each side of the keypad, pressing it down, and pushing it upward.

C. Storage

When the sampling pump is stored for long periods (1-6 months), use a cycling charger/power station, as described in **Battery Maintenance** above, for long term storage.

D. Sampling Pump Inlet Filter

The sampling pump inlet filter, located inside the plastic intake port housing on top of the pump, prevents particulates and liquids from being drawn into the pump mechanism. As the filter becomes dirty or clogged, it can create an excessive load on the sampling pump, decreasing pump performance. Periodically inspect the sampling pump inlet filter and replace as necessary.

Appendix 4B
Sampling Pump Calibration and Airflow Calibrator Calibration, Manual,
1.0 Liter Burette and Stopwatch

This method is the simplest and least expensive to calibrate sampling pumps, and quality assure airflow calibrator performance. However, the procedure is labor intensive, the equipment is cumbersome to transport in the field, and the glass burette is fragile.

A. Pre-inspection Calibration

1. Assemble using the diagram in Figure 4B-1:
 - Assemble the tripod stand by screwing the legs into the sockets in the tripod base. Attach the support rod and clamp to the base. Place the tripod/support rod assembly upright on a level surface.
 - Wet the entire inside surface of a 1.0 liter glass burette by pouring water through it or holding under a faucet. Insert the burette into the tripod base right side up, until it is several inches above the level surface.
2. Connect the apparatus to the sampling pump with an assembled sampling train in line.
3. Check the seals on all hose connections. The entire system must be leak-free.

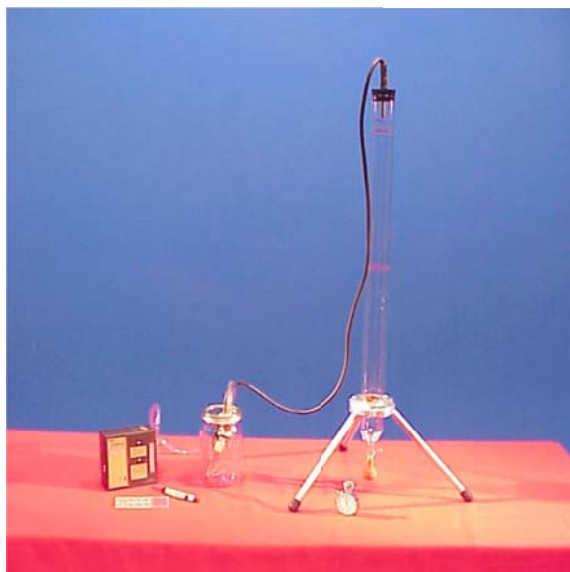


Figure 4B-1. Burette Set up for Sampling Pump Calibration.

4. Turn the sampling pump on; let it run for 10 minutes to stabilize flow.
5. Raise the beaker containing the soap solution and momentarily submerge the opening of the burette.

- Raise the beaker to form one bubble at a time.
 - Repeat several times until a bubble travels the entire distance up the burette without breaking.
6. Using a stopwatch, time the travel of the bubble from the 'zero' line (0.0 liter) to the 1.0 liter mark.

- Travel times for common flow rates are:

<u>Flow Rate</u>	<u>Time</u>
1.4 Lpm	42.9 sec.
1.7 Lpm	35.3 sec.
2.0 Lpm	30.0 sec.

- For other flow rates, use the formula below to calculate the time required for the bubble to travel the length of the burette:

$$\frac{1.0 \text{ liter}}{\text{Desired flow rate (Lpm)}} = \text{time (min.)}$$

$$[\text{time in min.} \times 60 \text{ sec./min.} = \text{time in sec.}]$$

7. The sampling pump must be within 5 % of the target flow rate. For example, the acceptable range of 1.7 liters per minute (Lpm) ($\pm 5\%$) is 1.615 Lpm to 1.785 Lpm. This is the same as the bubble passing the 1.0 liter length of the burette between 33.7 and 37.0 seconds. Adjust the sampling pump flow rate as described in the operating instructions for the individual pump. When the measured flow rate is within the acceptable $\pm 5\%$ range, take three more readings for each sampling pump and average.
8. Record the following in the Health Field Notes:
- Sampling pump ID number;
 - Calibrated flow rate (average of three readings);
 - Date and location of calibration; and
 - Name of person performing calibration.

B. Post-inspection Calibration

1. Repeat Steps A. 1. through A. 8. above (see **V. A. 5.**).
2. If more than a few days will elapse before doing further calibrations, remove the burette from the tripod stand and rinse the inner surface of the burette thoroughly with tap water to avoid buildup of soap residue.

Appendix 4C-1**Sampling Pump Calibration, Electronic, (wet), Sensidyne® Gilian Gilibrator™ Airflow Calibrator**

Similar in principal to the burette, this method generates a series of soap bubbles through a tube connected to the air sampling pump. However, the time for the bubble to rise the length of the tube is measured automatically and the flow rate is subsequently calculated by a computer chip in the airflow calibrator's base. While the equipment is more expensive than that used in the burette method, it is much more portable than the cumbersome burette and less time consuming in setup. [For detailed instructions please refer to the Gilibrator manual, available at: www.sensidyne.com].

- A. Pre-Inspection Calibration.** Refer to Figure 4C-1-1a., b. and follow these steps:



Figure 4C-1-1a. Sensidyne Gilian Gilibrator Set up for Calibration (respirable dust cassette/filter and cyclone in-line inside cal jar)



Figure 4C-1-1b. Sensidyne Gilian Gilibrator Set up for Calibration (welding fume MCE cassette/filter in-line)

1. It takes at least 14 hours to fully charge a calibrator; the device can be used while charging.
2. Grasp the lower portion of the flow cell and attach it to the base by placing it upright on the control unit mounting plate. While grasping only the flow cell base, gently rotate it until it “clicks” into place and the electrical socket on the side is facing toward the rear of the base.
3. Insert the control unit’s cable assembly into the sensor block connecting jack located on the back of the sensor block.
4. Remove the storage tubing from the air outlet boss of the flow cell. Using the rubber storage tubing as a funnel, slowly add soap solution from the dispenser. The amount of soap needed is determined by depressing the bubble initiate button and holding it down in the lower position. Continue to add enough soap solution until the angled edge at the bottom of the bubble generator ring is immersed in the solution (see Figure 4C-1-2.).

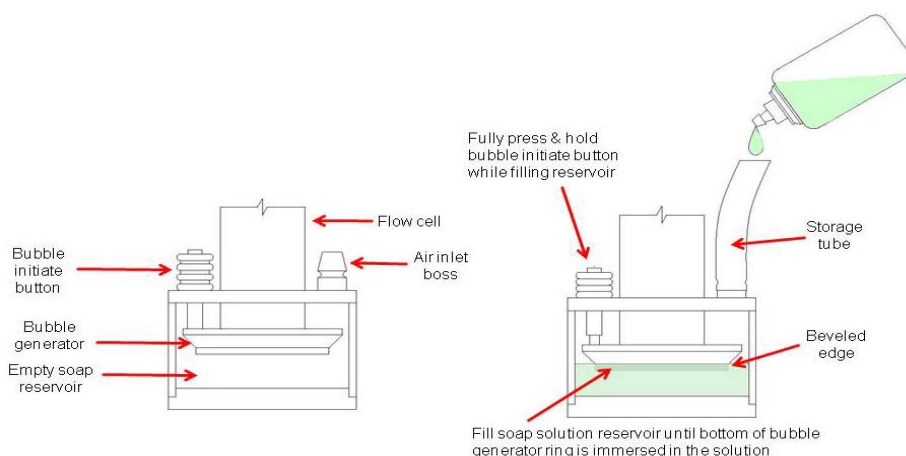


Figure 4C-1-2. Adding Liquid Soap Solution to the Gilibrator Airflow Calibrator.

5. Connect the sampling pump (with the sampling train in line) to the upper outlet boss.



Figure 4C-1-3. Total Dust Cassette In-line.



Figure 4C-1-4. MCE Cassette In-line.



Figure 4C-1-5. Asbestos Cassette In-line.



Figure 4C-1-6. Sorbent Tube In-line.

6. Turn on the sampling pump; let it run 10 minutes to stabilize.
7. Prime (wet) the inner walls of the flow tube by depressing the bubble initiator button several times.
8. Turn on the calibrator power switch and wait while the system runs through its self-check sequence. The calibrator is not ready until the Flow, Average, and Sample # are shown in the LCD panel of the Gilibrator.
9. Generate a bubble, and read the flow rate that appears on the LCD display. The actual flow for each bubble will be displayed. The flows will accumulate and be averaged with each successive pressing of the bubble generator.

Note: Each time the button is pushed, the display will show the flow rate in cubic centimeters per minute (ccm), which is the same as milliliters per minute (mL/min). Convert these values to liters per minute (Lpm) by dividing the number by 1000 (or moving the decimal point three places to the left).

If a bubble breaks before the time sequence is completed, timing will continue until another bubble is generated. The subsequent bubble will cause an erroneous reading. To subtract the erroneous reading from the average, push the DEL (delete) button.

- a. Deleting readings:

To delete obvious false readings, push the DEL button. This will automatically delete the false information from the average and reset the average and sample number back to the previous reading.

- b. Resetting:
- To reinitiate the sequence for additional sampling pump calibrations, push the RESET button. This zeroes out all samples and average registers within the unit and starts a new sequence.
 - The RESET button is also used if a malformed bubble is generated and has not been subtracted from the average by use of the DEL button.
10. The sampling pump must be within $\pm 5\%$ of the target flow rate. For example, the acceptable range of 1.7 liters per minute ($\pm 5\%$) is 1.615 Lpm to 1.785 Lpm. Adjust the sampling pump flow rate by turning the flow adjustment set screw with a screwdriver or using the up/down arrow buttons, depending upon pump model. When the measured flow rate is within the acceptable $\pm 5\%$ range, press and hold the reset button on the base until all readings are "0." Then take 3 more readings.
11. Record the following in the Health Field Notes:
- Sampling pump ID number;
 - Calibrated flow rate (average of three readings);
 - Date and location of calibration; and
 - Name of person performing calibration.

B. Post-Inspection Calibration

1. Repeat Steps A.1. through A.11. above.
2. Sampling is valid when the post- and pre-sampling flow rates agree within $\pm 5\%$ of the target flow rate for three (3) consecutive timings. Otherwise, the sample is invalid.
3. This post-sampling calibration check may be used as the pre-sampling calibration flow-rate for the next full-shift sample if the sampling pump is used within a week.

C. Maintenance and Calibration

1. Between uses and if the calibrator is not to be used for a period of time, reinstall the rubber storage tubing between the inlet and outlet bosses. This will prevent evaporation which may alter the soap solution's concentration. If more than several days will elapse before doing further calibrations, remove the bubble generator from the base. Rinse the inside of the bubble generator thoroughly with water to avoid buildup of soap residue. The easiest way to rinse the bubble generator is to fasten a short piece of rubber hose to the bottom nipple of the bubble generator, place the open end of the hose under the tap, and let the water run freely through the hose, into the generator, and out the top nipple. Remove excess water by turning the bubble generator alternately upside down and right side up and gently shaking it. Allow the cylinder to dry thoroughly before using or placing it in the storage case. Do not disassemble and clean the inside of the bubble generator.

2. “Low Battery” will appear on the display if the battery voltage is too low to operate the unit properly on battery power alone. The battery charges automatically when the charger unit is plugged into an electrical outlet and the charger unit cord is plugged into the Gilibrator base. The charger also serves as an AC adapter. An indicator light, glows red when charging is taking place.
3. Do not transport the unit with soap solution or storage tubing in place. When transporting or shipping the electronic calibrator by air, it is important to remove one side of the storage tube that connects the inlet and outlet bosses. This allows for equalizing internal pressure within the generator.

Caution: Do not pressurize the flow cell. Excessive pressure may cause the cell to rupture.

4. Each Sensidyne Gilian Gilibrator used in the field requires at least an annual check against a laboratory or factory calibrated instrument. The annual check of each field office Gilibrator must fall within a $\pm 1\%$ tolerance of the volume measured with the laboratory/factory certified master Gilibrator airflow calibrator (see also Appendix 4D-1). Or, the matched set is sent as a unit to the laboratory/factory for testing and certification. There is no other regular maintenance required by the user. If the unit requires repair (including replacement of the rechargeable NiCad battery) coordinate repairs through the District Health Specialist or Industrial Hygienist.

Appendix 4C-2
Sampling Pump Calibration, Electronic, (wet), A.P. Buck[®], Inc. mini-BUCK[™] Calibrator and SKC UltraFlo[®] AirFlow Calibrators

Like the Gilibrator, these devices connect to an air sampling pump and generate a series of soap bubbles through a tube (i.e., wet method). The bubble rise rate is measured electronically and the flow rate is automatically calculated by an internal computer chip.

A. Pre-inspection Calibration. Refer to Figure 4C-2-1.

1. Using the squeeze bottle included, pour enough soap solution through the bottom nipple (at the rear of the transparent tube assembly) to cover the bottom of the flow cell (bubble generator). The level of the solution should not be higher than the etched line.
2. Fasten a piece of rubber or Tygon[®] hose (several inches in length) to the upper (not the filler) nipple. Fasten a filter cassette (of the same type to be used in sampling) onto the loose end of the rubber or Tygon hose. The inlet side should face toward the nipple.
3. Fasten a second piece of hose between the air sampling pump and the filter. Do not connect the filter to the mini-BUCK's filler nipple.
4. Turn on the fully charged air sampling pump and run it for approximately 10 minutes to ensure the voltage (and flow rate) has stabilized. Wet the inside of the flow cell by rapidly pressing and releasing the spring-loaded button (front of the transparent tube assembly) until complete bubbles rise all the way to the top of the tube. At the same time, push the mini-BUCK "on" switch. The Calibrator will display "0000." If the Calibrator does not turn on, it may be operated on AC current by plugging it into its charger unit and plugging the charger unit into an electrical outlet.



Figure 4C-2-1. mini-BUCK (wet bubble) Sampling Train Calibration Set up.

5. Firmly press and release the button on the base of the transparent flow cell. A number will flash in the mini-BUCK display. Wait until the number stops flashing, and then repeat twice until one or more bubbles rise all the way to the top of the bubble generator and the reading is stable. Each time the button is pushed, the display will show the flow rate in milliliters per minute (mL/min.). Convert these values to liters per minute (Lpm) by dividing the number by 1000 (or moving the decimal point three places to the left).
6. The sampling pump must be within $\pm 5\%$ of the target flow rate. For example, the acceptable range of 1.7 Lpm ($\pm 5\%$) is 1.615 to 1.785 Lpm. Adjust the sampling pump flow rate as described in the operating instructions for the pump. When the measured flow rate, is within the acceptable $\pm 5\%$ range, press and hold the “on” button of the mini-BUCK until “0000” is displayed; then take three more readings (waiting for the flashing to stop between each press of the button).
7. Record the following in the Health Field Notes:
 - Sampling pump ID number;
 - Calibrated flow rate (average of three readings);
 - Date and location of calibration; and
 - Name of person performing calibration.

B. Post-Inspection Calibration

1. Repeat steps A. 1. through A. 7. above.
2. Sampling is valid when the post- and pre-sampling flow rates agree within $\pm 5\%$ of the target flow rate for three (3) consecutive timings. Otherwise, the sample is invalid.
3. This post-sampling calibration check may be used as the pre-sampling calibration flow-rate for the next full-shift sample if the sampling pump is charged and used within a week.
4. After post-calibrating all sampling pumps, press the “off” button, disconnect the rubber hoses and plug both nipples (usually with a short piece of rubber tubing that connects the two nipples) to keep the flow cell from drying out. If more than several days will elapse before doing further calibrations, remove the flow cell from the base by unscrewing the three screws on the underside of the base. Rinse the inside of the flow cell thoroughly with tap water to avoid buildup of soap residue. Fasten a short piece of rubber hose to the bottom nipple, place the open end of the hose under the tap, and let the tap water run gently but freely through the hose, into the flow cell, and out the top nipple. Remove excess water by turning the flow cell alternately upside down and right side up and gently shaking it. Dry the outside of the flow cell with a soft paper or cloth towel and reinstall in the mini-BUCK base by replacing the three screws. Allow the inside to air dry; do not attempt to disassemble and clean the inside of the flow cell.

Note: The mini-BUCK automatically shuts-off after seven minutes of non-use.

C. Battery Charging and Replacement

1. The battery charges automatically when the charger unit is plugged into an electrical outlet and the charger unit cord is plugged into the mini-BUCK base. The charger also serves as an AC adapter. Do not leave the AC adapter plugged in when not in use, as this could damage the battery supply.
2. The fully charged battery will operate the unit for up to 8 hours. Low Battery light will appear on the faceplate of the mini-BUCK if the battery voltage is too low to operate the unit properly. The mini-BUCK requires 16 hours to charge the battery fully.

D. Maintenance and Calibration

Each field mini-BUCK Calibrator requires an annual check against a laboratory/factory calibrated instrument. The annual check of the mini-BUCK calibrator against the laboratory/factory master calibrated instrument must fall within a 1% tolerance of the referenced volume. Or, the unit itself can be sent to the laboratory/factory for testing and certification. No maintenance is performed by the user. If the unit requires repair (including replacement of the rechargeable NiCad battery) coordinate repairs through the District Health Specialist or Industrial Hygienist. Always clean the unit and leave the filler nipples open and disconnected from any tubing when instrument is being shipped.

Appendix 4C-3 Sampling Pump Calibration, Electronic, (dry), Bios® DryCal DC-Lite and Defender™ Airflow Calibrators

Both the Bios DryCal DC-Lite and Defender do not use liquids or generate bubbles and are another type of field-portable flow calibrators for industrial hygiene airflow measurement applications (i.e., dry method). **Both of these Bios airflow meters** (and the only airflow calibrators) **do not use the jar** for calibrating sampling trains. The units use a near-frictionless dry piston technology that can be conveniently used in the field.

A. Bios DryCal DC-Lite

1. Press the On button to turn the DryCal DC-Lite on. An initializing screen will display the microprocessor revision number and then the standard screen will be displayed. Note: The DryCal DC-Lite has an energy saving auto shut-off feature. After 5-minutes of non-use the unit will automatically shut itself off.



Figure 4C-3-1. Bios DryCal DC-Lite (front).



Figure 4C-3-2. Bios DryCal DC-Lite (side).

2. The DryCal DC-Lite's inlet and outlet ports are located on the right side of the unit. Connect the tubing from the sample pump including the in-line calibration media (e.g., asbestos, sorbent tube, total dust, welding fume cassette) to the Outlet (bottom) port. See Figure 4-C-3-6.
NOTE: For respirable dust sampling pump calibration, the dust/cassette including the cyclone and holder are **not** in-line. Connect the sampling pump tubing to the Outlet (bottom) port and the respirable dust sampling assembly on a short 2.5 inch tubing to the Inlet (top) port. See Figure 4-C-3-7. Do not re-use calibration media assemblies for sampling.
3. Press and release the Read button on top of the unit to take a single reading. Pressing the Read button again will cause the unit to take another reading. After the first single reading, all subsequent readings will be used to calculate the average flow. After 10 readings, the average will be cleared to begin a new averaging sequence. You will know a reading has begun when the valve "clicks" shut, the flow cell's green LED lights are on, and the piston rises within the flow cell.

4. The flow measurement will appear on the LCD display in milliliters or liters, as applicable.
5. To take continuous readings press and hold the Read button to initiate a reading, then release. A continuous read session will begin. To end the continuous read session, press the Stop button once. The display will indicate the current flow reading (Flow), the average flow value (Average), and the number of readings in the average (Number in Average) up to 10.
6. The number of readings in an averaging sequence can be reset to (00) at any time by pressing and holding the Stop button for 2 full seconds.

B. Bios “Defender”.

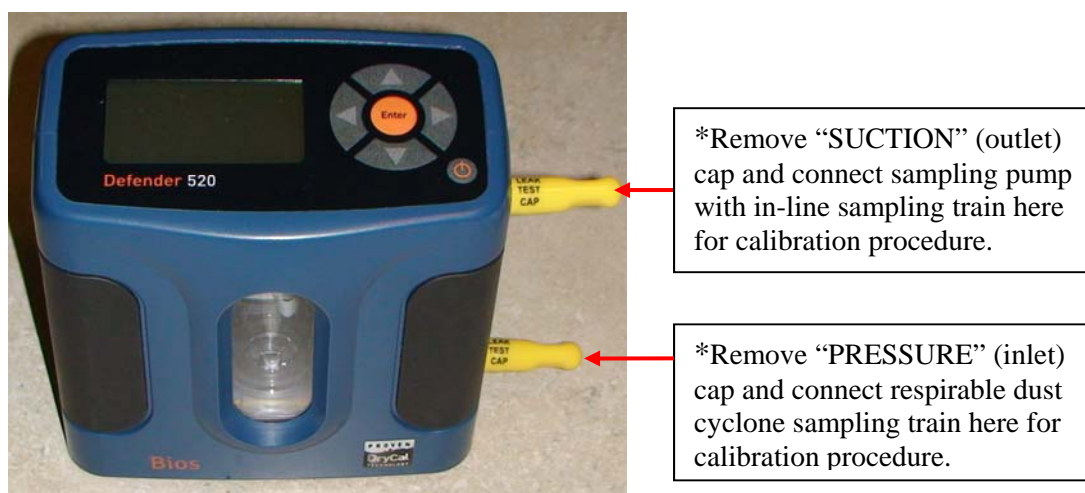


Figure 4C-3-3. Bios Defender 520.

1. Press the On/Off button for 1 second to turn the Defender on. To turn off, press and hold the On/Off button for 3 seconds.
2. An initializing screen will display the product name, model number, flow range and then the standard screen will be displayed.
3. Connect the sampling calibration train to the appropriate Defender port using ¼ inch diameter tubing*. The pump is connected to the SUCTION port and the sampling train is connected to the PRESSURE port. See Figures 4C-3-3 and 4C-3-4. For in-line calibration of asbestos, sorbent tube, total dust, or welding fume samples connect one end of 2.5 inch tubing to the inlet side of the cassette /sorbent tube assembly. Connect the other end of the 3 foot tubing to the outlet side of the cassette /sorbent tube assembly. The 2.5 inch tubing is connected to the SUCTION Defender port and the 3 ft tubing is connected directly to the sampling pump.
4. Choose the measurement type, Single, Burst, or Continuous, then press enter. The Burst and Continuous measurements can be either set to factory default or changed to different settings. Refer to the operating manual if changes need to be made.



Figure 4C-3-4 Bios Defender 510/SKC Pump with Sorbent Tube Sampling Train Calibration (in-line) Set up.

5. Take readings. The sampling pump must be within $\pm 5\%$ of the target flow rate. For example, the acceptable range of 1.7 Lpm ($\pm 5\%$) is 1.615 to 1.785 Lpm. Adjust the sampling pump flow rate as described in the operating instructions for the individual pump (typically with a screwdriver turning a set screw). When the measured flow rate is within the acceptable $\pm 5\%$ range, then take three or more readings for that sampling pump and record the average.



Figure 4C-3-5. Bios Defender 510/ SKC Pump with Respirable Dust Sampling Train Calibration Set up (Note: NO jar, not in-line).

C. Bios DryCal-Lite / Defender Jar-less Respirable Dust Cyclone Calibration.

Background.

There has been an ongoing issue with the Bios DryCal primary calibrators and the use of the calibration jars. The issue has been the differences in flow rates observed when compared to other types of airflow measurement devices. To minimize the effect on the Bios DryCal, Bios Inc. recommends **no calibration jar**. Do not use a cal jar for respirable dust or DPM sampling calibration. To accurately calibrate sample pumps with cyclones, Bios recommends: “Connect the pump directly to the Defender’s outlet (suction) via a typical section of tubing. Then, connect the cyclone filter to the Defender’s inlet (pressure) with only the minimal length of

tubing necessary. Next, set the Defender to take at least 20 flow measurements in the average in order to average out the flow variations caused by direct connection of the pump to the calibrator.” Note: The “Defender” is Bios’s newest dry calibrator but the method for calibration using a cyclone mentioned above also pertains to the Bios DryCal DC-Lite with regard to the outlet and inlet directions.

1. Bios Jar-less Calibration Method. To perform the pre- and post-calibration measurements for respirable dust, follow the steps below:
 - a. You will need to have and keep two pieces of tubing. The lengths needed are one length of 2.5 inches and the second length of 3 feet. The 3 foot tubing is to simulate the length that is used for personal respirable dust sampling.
 - b. Connect one end of the 2.5 inch tubing to the stainless steel outlet tube of the respirable dust cassette cyclone holder assembly. Connect the other end of the tubing to the Inlet of the DryCal DC-Lite (PRESSURE for Defender). See Figure 4C-3-2, Figure 4C-3-4, and Figure 4C-3-7.
 - c. Connect one end of the 3 foot tubing to the sample pump to be calibrated. Connect the other end of the 3 ft tubing to the Outlet of the Bios DryCal DC-Lite (SUCTION for Defender). See Figure 4C-3-2, Figure 4C-3-4, and Figure 4C-3-7.



Figure 4C-3-6. Total Dust Cassette In-line Calibration Set up for Bios DryCal DC-Lite.



Figure 4C-3-7. Respirable Dust Calibration Set up for Bios DryCal DC-Lite. (Note: NO jar, Not in-line).

- d. Turn on the Bios. Turn on the sampling pumps and let them run for 10 minutes to stabilize. Afterwards, begin taking calibration measurements.
- e. Adjust the pump flow rate as necessary to obtain a flow rate as close to 1.7 Lpm as possible. Take 3 sets of 10 measurements and average the 3 sets to obtain your flow rate. Record these in your Health Field Notes. Note: The DryCal DC-Lite automatically takes and averages 10 flow measurements in a cycle.

D. Maintenance and Calibration

Each Bios airflow calibrator used in the field requires at least an annual field check against a laboratory/factory calibrated instrument or, it is sent to the laboratory/factory for calibration and certification. The annual check of each field office Bios must fall within a $\pm 1\%$ tolerance of the volume measured with the laboratory/factory certified master Bios airflow calibrator. See Appendix 4D-2, A. These units require regular leak checks to ensure proper function. See Appendix 4D-2, B. Those units failing the leak check should be sent into the manufacturer or contract laboratory for maintenance. [For detailed instructions please refer to the appropriate manual, which is available at: www.biosint.com].

Appendix 4C-4 Sampling Pump Calibration, Electronic, (dry), TSI® 4146 Airflow Calibrator

The TSI Model 4146 Calibrator measures volumetric flow rate inside the flow tube. Volumetric flow rate is displayed continuously so adjustments to pump flow can be made in real-time. No liquids or bubbles are involved (i.e., dry method). It has a thermal sensor inside that is exposed to the airflow and must be protected from foreign matter and particles. The TSI Model 4146 airflow calibrator has a filter that is connected to the inlet of the calibrator; however, any filter will work as long as it has a minimum efficiency of 99.9%. It is best to use the supplied filter.

A. Pump Calibration.

1. Note the flow direction marked on the TSI Model 4146 Calibrator. Flow direction is identified by the large arrow on the bottom side of the calibrator and the bottom of the battery pack.

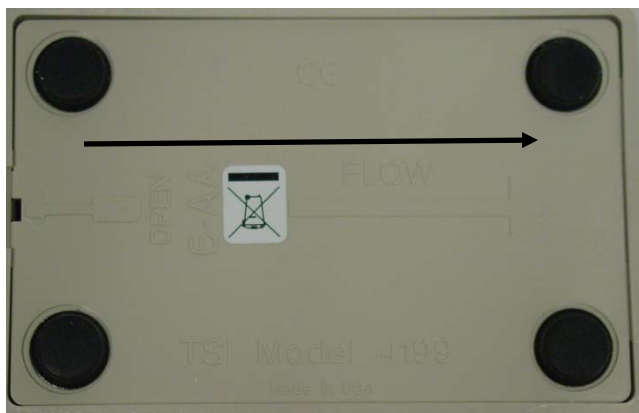


Figure 4C-4-1. TSI 4146 Base Underside Showing Airflow Direction Arrow (stamped into case).



Figure 4C-4-2. TSI 4146 with Filter and Hose Connector.

2. Attach the filter to the inlet of the calibrator using supplied tubing and/or adapters. Connect the tube adapter to the outlet side of the calibrator. To minimize leakage, make sure the other end of this tubing is fully seated over all of the barbed flanges of the TSI fitting. This tubing should be no more than 12 inches in length; trim it if it is longer than this. This will help to ensure stable readings and assure that all tubing is snug on barbed fittings.

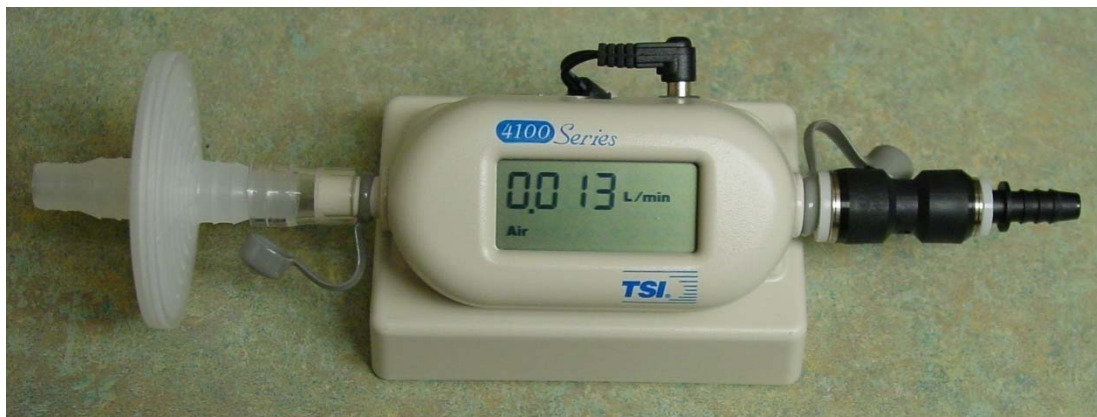


Figure 4C-4-3. TSI Model 4146 Prepared for Sampling Pump Calibration.

Note: Always use a filter on the inlet of the calibrator. Failure to filter the airflow may change the calibration and/or permanently damage the sensor.

3. Slide the switch to the ON position. The LCD displays volumetric flow in units of liters per minute (L/min). Let it and the pumps warm up for 10 minutes prior to setting any flow rates or conducting any calibrations.
4. Prepare the calibration sampling train with the desired sampling media. Use a calibration jar if calibrating for respirable dust or DPM sampling.
5. Connect the outlet of the TSI Model 4146 Calibrator to the inlet of the sample media and connect the other end of the tubing to the sample pump.



Figure 4C-4-4. TSI Model 4146 Set up for Asbestos Sampling Calibration.

6. Take 3 readings. The sampling pump must be within $\pm 5\%$ of the target flow rate. For example, the acceptable range of 1.7 Lpm ($\pm 5\%$) is 1.615 Lpm to 1.785 Lpm. Adjust the sampling pump flow rate as described in the operating instructions for the individual pump (typically with a screwdriver turning a set screw). When the measured flow rate is within the acceptable $\pm 5\%$ range, record the readings. The volumetric flow in units of liters per minute (L/min) will be continuously displayed on the LCD of the calibrator.

B. Maintenance.

1. Flow Sensor. Periodically inspect the flow sensor by looking into the outlet of the calibrator. Remove dust, particles, and fibers from the sensor with clean, dry compressed air. The flow sensor may break if touched. ***Never run liquids through the calibrator and never touch the sensor with a brush.*** Dust or other deposits on the flow sensor will degrade the flow accuracy.

NOTE: The calibrator must be switched off for cleaning. Only use clean, dry, compressed air when attempting to remove contamination from the sensor.

2. Storage. When storing the calibrator, always cover the ends of flow tubes with the caps provided to prevent dust or other foreign matter from entering the tube.
3. Annual requirement. Just as with other pump calibrators, TSI airflow calibrators must be checked each year against a laboratory/factory calibrated master unit. Or, it is sent to the laboratory/factory for certification. (See Appendix 4D-2.) Maintain all records of the unit's certification or annual verification checks. Any field unit that fails to perform within $\pm 1\%$ of the master unit's referenced flow rate must be removed from service and returned to the manufacturer laboratory/factory for repair and certification. Coordinate with the District Industrial Hygienist or Health Specialist.
[For detailed instructions please refer to the manual that is available at:
www.tsi.com]

Appendix 4D-1**Calibration Verification Procedures for Wet Method Electronic Airflow Calibrators
(e.g., Sensidyne Gilian)**

Note: A laboratory/factory certified instrument designated as the master to be used for field unit checks should not be used in the field but kept as a matched cell and base unit for calibration verification check procedures only. All other similar calibration instruments can be checked annually against it.

A. Procedure.

You will need the following:

- Current Sensidyne Gilian Gilibrator factory calibration certificate or the laboratory data sheet certificate for the calibrator. See Figure 4D-1-1 for a manufacturer's certificate.
 - One fully charged air sampling pump capable of fine airflow adjustments.
 - Pieces of tubing approximately 2 feet in length to attach the wet airflow calibrator to the sampling pump (note: the shorter the length the less internal airflow resistance).
1. On a Calibration Verification Record, See Appendix 4E. Record the following information:
 - a. The ID/serial number of the flow cell that was laboratory/factory calibrated/certified and the serial number of the matched electronic microprocessor base piece.
 - b. The referenced calibration flow rate from the Sensidyne calibration certificate (See Figure 4D-1-1.) This is the MEAN (average) flow for the field unit; circled as shown in Figure 4D-1-1, (i.e., 2020.3 cc/min).
 - c. The calculated +1% and the -1% flow rate differences. The calculated $\pm 1\%$ tolerance flow rate for this Sensidyne example is:
 - (i) +1% of 2020.3 cc/min = 2040.5 cc/min or 2.0405 Lpm
 - (ii) -1% of 2020.3 cc/min = 2000.1 cc/min or 2.0001 Lpm
 - d. The pressure, temperature and relative humidity, at the location and time the calibration check is performed (optional).
 2. Start the sampling pump and allow it to run for 10 minutes to warm up and stabilize.
 3. Attach the tubing to the laboratory/factory certified calibrator, then attach to the sampling pump and let the pump stabilize. From the laboratory/factory calibration certificate use the referenced mean flow rate value to adjust the flow rate of the sample pump to match. (Allow the pump to stabilize for 1-2 minutes between adjustments.) For example, from Figure 4D-1-1, the factory mean calibration flow result is 2020 cc/min or 2.02 Liters/min. Adjust the sampling pump flow rate to 2020 cc/min (or 2.02 Lpm). Do this by taking 3

sets of 5 readings, record each reading, and average each set. Then average the 3 average results and record this value to demonstrate the pump flow rate matches the referenced flow rate.

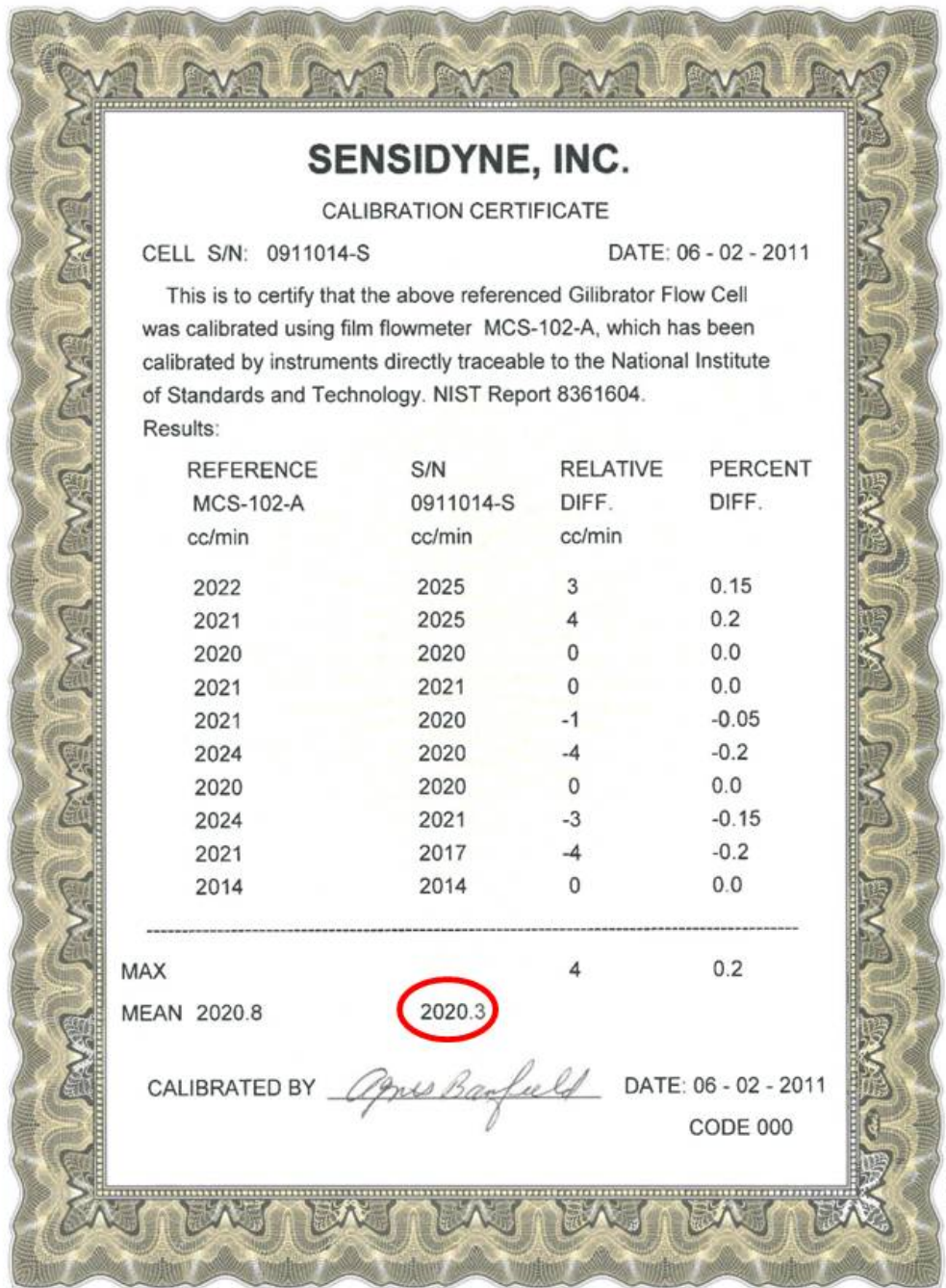


Figure 4D-1-1. Sensidyne Factory Calibration Certificate for Gilibrator Flow Cell.

4. **DO NOT TURN OFF THE SAMPLING PUMP.** Carefully remove the tubing from the laboratory/factory calibrated calibrator and attach the pump to the Gilibrator to be compared. Let the pump stabilize for 10 minutes. **DO NOT RE-ADJUST THE PUMP FLOW RATE.**
5. Take 3 sets of 5 readings each, record each reading on the Calibration Verification Record Form, and average each set. Then average the 3 average results. The final overall average of the checked calibrator must be within 1% tolerance of the listed laboratory/factory calibration referenced flow. From this example the final average result must be between 2.00 Lpm and 2.04 Lpm.
6. Calibration verification check test results.
 - a. Meets the $\pm 1\%$ tolerance. The Calibration Verification Record Form is signed by the person performing the check and also reviewed and signed by the Field Office Supervisor.
 - b. Does NOT meet the $\pm 1\%$ tolerance. Repeat the test again. If the unit checked fails the 1% tolerance test the second time, the unit must be removed from service. The Calibration Verification Record Form is signed by the person performing the check. Contact the District Industrial Hygienist or Health Specialist for maintenance assistance.
 - c. Retain record on file for the life of the instrument or minimum of five years. Provide a copy of the completed record to the District Industrial Hygienist/Health Specialist.
6. Once the Gilibrator calibration has been verified, the flow cell and the microprocessor base piece must remain together as a unit. They must not be interchanged with other like parts unless a new calibration comparison check or laboratory/factory calibration is conducted and verified/certified as a unit.

Appendix 4D-2
Calibration Verification Procedures for Dry Method Electronic Airflow Calibrators
(e.g., TSI, Bios)

Note: A laboratory/factory certified instrument designated as the “master unit” for field unit checks should not be used in the field but kept in the office for calibration verification check procedures only. All other similar calibration instruments can be checked annually against it.

A. Procedures

You will need the following:

- Current factory calibration certificate or the laboratory data sheet certificate for the airflow calibrator. See Figure 4D-2-1 and Figure 4D-2-2 for examples of manufacturers’ certificates.
- One fully charged air sampling pump capable of fine airflow adjustments.
- Pieces of tubing approximately 2 feet in length to attach the airflow calibrator to the sampling pump (note: the shorter the length the less internal airflow resistance).

1. On the Calibration Verification Record, see Appendix 4E-1, record the following information:
 - a. The ID/serial number of the laboratory/factory calibrated/certified unit.
 - b. The referenced calibration flow rate chosen from the TSI calibration certificate (See TSI Mass Flowmeter Calibration Certificate, Figure 4D-2-1.). Which for this example is 1.981 “Measured (SLPM)” because it is mid-range and closest to 1.7 Lpm.

[Note: For Bios use the 1,006.4 ccm Instrument Reading value recorded for the unit in Calibration Data, (from Figure 4D-2-2 Example).]

- c. The calculated + 1% and the – 1% flow rate differences. The calculated $\pm 1\%$ tolerance flow rate in this TSI example is:
 - (i) +1% = 2.000 Lpm
 - (ii) -1% = 1.961 Lpm
 - d. The pressure, temperature and relative humidity, at the location and time the calibration check is performed.
 2. Start the sampling pump and allow it to run for 10 minutes to warm up and stabilize.
 3. Attach the tubing to the master laboratory/factory certified calibrator. Then attach to the sampling pump. Let the pump stabilize for 10 minutes. From the laboratory/factory calibration certificate use the referenced mean flow rate value to adjust the flow rate of

- the sample pump. (Allow the pump to stabilize for 1-2 minutes between adjustments.) For example, from Figure 4D-1-2, the factory calibration flow result was listed as 1.981 Liters/min (or 1981 cc/min). Adjust the sampling pump flow rate to 1.981 Lpm. Do this by taking 3 sets of 5 readings, record each reading, and average each set. Then average the 3 average results and record this value to demonstrate that the pump flow rate matches the referenced flow rate.
4. **DO NOT TURN OFF THE SAMPLING PUMP.** Carefully remove the tubing from the laboratory/factory calibrated calibrator and attach the pump to the calibrator to be checked. Let the pump stabilize for 10 minutes. **DO NOT RE-ADJUST THE PUMP FLOW RATE.**
 5. Take 3 sets of 5 readings each, record each reading on the Calibration Verification Record, and average each set. Then average the 3 average results. The final overall average of the checked calibrator must be within 1% tolerance of the listed laboratory/factory calibration referenced flow. From this example the final average result must be between 1.961 Lpm and 2.000 Lpm.
 6. Calibration verification check test results.
 - a. Meets the $\pm 1\%$ tolerance. The Calibration Verification Record Form is signed by the person performing the check and also reviewed and signed by the Field Office Supervisor.
 - b. Does NOT meet the $\pm 1\%$ tolerance. Repeat the test again. If the unit fails the 1% test the second time that unit must be removed from use. The Calibration Verification Record Form is signed by the person performing the check. Contact the District Industrial Hygienist or Health Specialist for maintenance assistance. [If the unit is to be sent to the District, the completed Calibration Verification form must accompany the unit].
 7. Retain record on file for the life of the instrument or minimum of five years. A copy of the completed record is provided to the District Industrial Hygienist/Health Specialist.



Mass Flowmeter Calibration Certificate

Model 4146 Revision D
 Serial Number 41460732003

Flowmeter Calibration Verification

Calibration Date Wed 11-Aug-2010 17:29
 Verification Date Wed 11-Aug-2010 17:37
 Temperature 20.8 °C
 Pressure 14.16 psia

Air - As Left

Tolerance: 1.75% reading or 0.005 SLPM

Actual (SLPM)	Measured (SLPM)	Difference (%)	Tolerance (%)
0.064	0.063	-1.9	-24
0.162	0.159	-2.0	-66
0.316	0.316	0.0	0
0.454	0.452	-0.4	-22
1.009	1.012	0.3	18
1.977	1.981	0.2	10
3.745	3.796	1.4	79
7.511	7.592	1.1	62
15.05	15.03	-0.1	-7

Temperature - As Left
 Tolerance: ±1.000 °C

Actual (°C)	Measured (°C)	Difference (%)	Tolerance (%)
20.80	20.71	-0.44	-9

Pressure - As Left
 Tolerance: ±0.110 psia

Actual (psia)	Measured (psia)	Difference (%)	Tolerance (%)
14.17	14.16	-0.01	-1
21.51	21.52	0.02	3

This flowmeter has been calibrated on the TSI Flowmeter Calibration Facility (TSI 9120254) using the procedures outlined in TSI 9010581. The calibration of the Flowmeter Calibration Facility maintains NIST traceability in accordance with TSI 9120254.

TSI Standard Conditions: 70 °F (21.11 °C) and 14.7 psia

Verified By:

Calibration Standard:	FLOWCAL1
Std. Last Verified:	29-Jun-2010
Std. Next Verify Due:	27-Sep-2010

Shipping Address: TSI Inc., 500 Cardigan Rd, Shoreview, MN 55126 USA

Printed: Wednesday 11-Aug-2010 18:56

Figure 4D-2-1. TSI Airflow Calibrator Calibration Certificate.



Bios
Driving a Higher Standard
in Flow MeasurementSM

Calibration Certificate

Certificate No. 510689
Product Defender 520 Medium Flow
Serial No. 123002
Cal. Date 7/12/2011
Sales Date 8/9/2011 *Calibration interval commences on sale date.*

All calibrations are performed in accordance with ISO 17025 at Bios International Corporation, 10 Park Place, Butler, NJ, 07405, 800-663-4977, an ISO 17025:2005 – accredited laboratory through NVLAP. This report shall not be reproduced except in full without the written approval of the laboratory. Results only relate to the items calibrated. This report must not be used to claim product certification, approval, or endorsement by NVLAP, NIST, or any agency of the Federal Government.

All units tested in accordance with Bios International Corporation test number PR17-13 using high-purity bottled nitrogen or dry filtered laboratory air.

Calibration Data

Technician Zenaida Ortiz
Lab. Pressure 745 mmHg
Lab. Temperature 22.5 °C

Instrument Reading	Lab Standard Reading	Deviation	Allowable Deviation	As Shipped
100.98 ccm	100.66 ccm	0.32 %	1.00%	In Tolerance
1,006.4 ccm	1006 ccm	0.04 %	1.00%	In Tolerance
5,012.7 ccm	5004.7 ccm	0.16 %	1.00%	In Tolerance
22.5 °C	22.5 °C	-	±0.8°C	In Tolerance
745 mmHg	745 mmHg	-	±3.5 mHg	In Tolerance

Bios International Standards Used

Description	Standard Serial Number	Calibration Date	Calibration Due Date
ML 500-24	113774	3/29/2011	3/28/2012
Precision Thermometer	300907	4/20/2011	4/19/2012
Precision Barometer	2981392	5/27/2011	5/26/2012

Calibration Notes

Bios is an ISO 17025-accredited metrology laboratory. Each Bios primary gas flow standard is dynamically verified by comparing it to one of our laboratory standards, which is a Proven DryCal® Technology volumetric piston prover of much higher accuracy but of similar operating principles. For this purpose, a flow generator of ±0.03% stability is used. Our laboratory standards are qualified by direct measurement of their dimensions (diameter, length and time) using NIST-traceable precision gauges and instruments, such as depth micrometers and laser micrometers. NIST numbers for these gauges and instruments are available upon request. Rigorous analyses of our laboratory standards' uncertainties have been performed, in accordance with The Guide to the Expression of Uncertainty in Measurement (the GUM), assuring their traceable accuracy.

Harvey Padden, President and Chief Metrologist

Bios International • 10 Park Place Butler, NJ 07405 • 800.663.4977 • www.biosint.com

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Figure 4D-2-2. Bios Airflow Calibrator Calibration Certificate Example.

B. Supplemental Bios Information.

A leak test should be performed every 6 months. If at any time the unit fails the leak test, the display will read “Maintenance Reqd Push Read.” Try the test again, and if necessary, call the District Industrial Hygienist/Health Specialist and inform them of the problem. The unit may require shipment to Bios Inc. for maintenance/repair.

1. Bios DryCal Inlet Port Leak Test.
 - a. Locate the leak test tubing that came with the Bios DryCal (DC-Lite). This tubing is a short piece of latex with a red plug at one end. Place the leak-test accessory over the inlet port (top port), See Figure 4-D-2-4 below.
 - b. If the DryCal is turned off, press and hold the **Stop** button, then press the **On** button. If the DryCal is already turned on, then press and hold the **Stop** button while also pressing the white recessed **Hard Reset** button on the back of the Bios DryCal.
 - c. The display will read “Leak Test, Invert & Push Read.” If the unit does not display this message, follow the previous instructions again, or call the District Industrial Hygienist/Health Specialist.
 - d. Invert the DryCal so that the piston moves to the top of the cell, which is now facing downwards. Press the **Read** button to close the internal valve.
 - e. Return the unit to an upright position, make sure that the piston is beginning at the top of the cell, and place the DryCal on a flat, vibration-free surface.
 - f. As the piston falls from the top of the cell, its descent is timed. This may take as long as 15–20 minutes. Note that the piston may not fall to the bottom of the cell, and may not move far at all.
 - g. If completed successfully, the display will read “Test OK Press Read.”
 - h. Press the **Read** button and the internal valve will open, allowing the piston to fall any remaining distance to the very bottom of the cell.
 - i. Record the test results on a Leak Check Record Form, Bios DryCal/Defender, see Appendix 4-F.

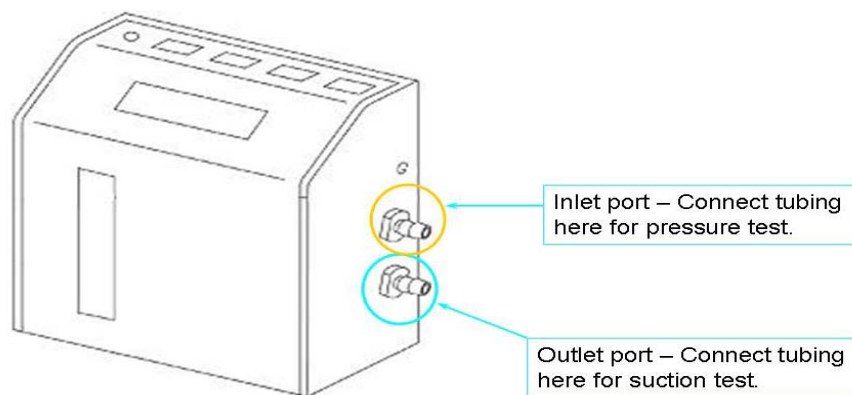


Figure 4D-2-4. Bios DryCal DC-Lite Tubing Port Connections.

2. Bios DryCal Outlet Port Leak Test.
 - a. Place the leak-test accessory tubing over the outlet port (lower port). See Figure 4-D-2-4 above.
 - b. If the DryCal is turned off, press and hold the **Stop** button, then press the **On** button. If the DryCal is already turned on, then press and hold the **Stop** button while also pressing the white recessed **Hard Reset** button on the back of the Dry Cal.
 - c. The display will read “Leak Test, Invert & Push Read.” If it does not say this, follow the previous instructions again, or call the District Industrial Hygienist/Health Specialist.
 - d. Invert the DryCal so that the piston moves to the top of the cell, which is now facing downwards. Press the **Read** button to close the internal valve.
 - e. Return the unit to an upright position, make sure that the piston is beginning at the top of the cell, and place the DryCal on a flat, vibration-free surface.
 - f. As the piston falls from the top of the cell, its descent is timed. This may take as long as 15–20 minutes. Note that the piston may not fall to the bottom of the cell, and may not move far at all.
 - g. If completed successfully, the display will read “Test OK Press Read.”
 - h. Press the **Read** button and the internal valve will open, allowing the piston to fall any remaining distance to the very bottom of the cell.
 - i. Record the test results on a Leak Check Record, Bios DryCal/Defender, see Appendix 4F. The Bios Dry Cal biannual leak check verification form is signed by the person performing the biannual verification check and also reviewed and signed by the Supervisor. It is maintained on file and a copy of the completed form goes to the District Industrial Hygienist/Health Specialist.

3. Bios Defender Leak Test.

The Defender Leak Test is designed only to verify the internal integrity of the instrument and alert you to an internal leak. Perform the Leak Test only as an intermediate quality control check or whenever the integrity of the instrument is questioned due to possible damage. The leak test does not assure operational accuracy and is not a substitute for the comprehensive overall performance examination and calibration that occurs when it is submitted for periodic laboratory/factory service.

- a. Invert the Defender and allow the piston to travel to the top.
- b. Cap the port under test using the Bios supplied leak test cap, see Figure 4C-3-3. Leave the other port uncapped.
- c. Press Enter on the control panel while the unit is still inverted.
- d. Return the unit upright. The leak test will progress
- e. If the Defender leak test is unsuccessful, first check to make sure that the leak test cap is on correctly and it is not leaking through the leak test cap itself. If the leak test cap is correct perform a leak test both at the pressure and suction side. If it fails, contact your District Industrial Hygienist/Health Specialist.
- f. When the test is complete, select exit to return to the main menu.
- i. Record the test results on a Leak Check Record, Bios DryCal/Defender, see Appendix 4F. The Bios DryCal/Defender biannual leak check verification form is signed by the person performing the biannual verification check. If the test is performed in the field, the form is reviewed and signed by the Field Office Supervisor. Please send a copy of the completed form to the District Industrial Hygienist/Health Specialist. [For detailed instructions please refer to the appropriate manual, which is available at: www.biosint.com].

**Appendix 4E
Calibration Verification Record**

1. Laboratory/Factory calibrated master unit information:

Model:	ID/SN:	ID/SN:
Date calibrated:	Referenced flow rate:	+1% upper limit:
		-1% lower limit:

2. Adjust air sampling pump flow rate to match the measured reference flow rate reading of the laboratory/factory for the master unit's certification.

a. Take 3 sets of 5 readings each, record in table below each reading, and average each set.

b. Average the 3 Average results. Record this Overall Avg₁ in the table below. Overall Avg₁ = Referenced flow rate. **Do not turn off the sampling pump.**

	Reading 1	Reading 2	Reading 3	Reading 4	Reading 5	Average
1.						
2.						
3.						
						Overall Avg ₁

Field instrument for calibration verification check information:

Note: Instrument must be same brand as the laboratory/factory calibrated unit.

Model:	ID/SN _{base} :	ID/SN _{cell} :

3. Carefully remove the tubing from the laboratory/factory calibrated unit calibrator and attach the pump to the calibrator to be checked. Take 3 sets of 5 readings, record in table below each reading 1-5, and average each set 1-3. Then average the three Average results. The final overall average must be within 1% tolerance of the listed laboratory/factory calibration Referenced flow rate. **The Overall Avg₂ result must be between the ±1% upper and lower limits recorded above.**

	Reading 1	Reading 2	Reading 3	Reading 4	Reading 5	Average
1.						
2.						
3.						
						Overall Avg ₂

[Note: Units that fail two verification tests shall be removed from service and returned to the laboratory or factory for maintenance and certification.]

4. Calibration verification was conducted at the _____ District or _____ field office, in accordance with the current MSHA Health Handbook, and the electronic calibration quality assurance program procedures, using a constant flow air sampling pump, at _____ °F, _____ %R.H., _____ Atm. Pressure.

5 This field use flowmeter calibrator was found to: **Meet** or **Not Meet** the ±1% tolerance test.

Note: Retain record on file for five years. Copy to District Industrial Hygienist/Health Specialist.

Calibration checked by: _____ Date _____

Reviewed by: _____ Date _____

**Appendix 4F
Leak Check Record, Bios DryCal/Defender**

1. DryCal/Defender Information:

Model Name:	ID/Serial Number:	Date Leak Checked:

NOTE: Perform leak test procedure every 6 months.

The unit must pass both leak tests.

2. Inlet Port Leak Test:

a. Passed:

b. Failed: Display message: _____.

3. Outlet Port Leak Test.

a. Passed:

b. Failed: Display message: _____.

NOTE: If at any time the unit fails the leak test, call the District Industrial Hygienist/Health Specialist and inform them of the problem. The unit may require shipment to Bios for maintenance/repair.

4. This calibrator was found to: (check one of the following) **Meet** or **Not Meet** the leak test requirements per manufacturer's instructions.

NOTE: Retain record on file for one year.

Leak Checked by: _____ Date _____

Reviewed by: _____ Date _____

Copy to the District Industrial Hygienist/Health Specialist.