CHAPTER 4
SAMPLING PUMPS

Blank Page

Table of Contents **Page**

Blank page

Chapter 4
SAMPLING PUMPS

I. Introduction

Metal and Nonmetal uses constant-flow personal sampling pumps to collect several different types of exposure samples in conjunction with filter cassettes, sorbent tubes (coconut shell charcoal and high purity washed silica gel), or midget impingers. These collection media are used when sampling for respirable and total dust, mineral dusts from silicates, welding fumes and elemental metal dust, asbestos fibers, organic vapors, and ionizing radiation. 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 instrumentation.

II. Definitions

Bubble Generator: a tube assembly that is an integral part of an air sampling pump calibration instrument. When a sampling pump is connected to the bubble generator, the vacuum created draws a soap bubble through the device. The device automatically computes the air flow rate of the sampling pump by calculating the speed of the bubble as it travels through the known volume of the calibration tube.

Burette: a cylindrical glass or plastic tube, usually 1.0 liter in volume, that can be used to calibrate air sampling pumps. With a sampling pump connected to the upper end of the burette, the vacuum created draws a soap bubble through the burette. A stopwatch is used to time the period for the soap bubble to travel a specific distance through the known volume of the burette. The air flow rate of the sampling pump can be calculated from the data collected during the timing of several bubbles. It is considered a primary calibration method.

Calibration: direct measurement of an instrument output using a calibration standard. The levels of calibration standards should bracket the levels for which actual measurements are to be made.

Calibration Standard: a reference used to quantify the relationship between the output of an instrument and the property to be measured. Calibration standards should be traceable to a primary standard.

Dry Calibrator: a calibration instrument which uses a dry piston to measure the output of a sampling pump. The device automatically computes the air flow rate of the sampling pump by calculating the change in volume and movement of the piston over a given time period.

Flow meter: an indicator on an air sampling pump that is used to monitor air flow rate through the pump.

Primary Standard: a measurement device that is directly traceable to the National Institute of Standards and Technology (NIST) or another recognized organization. Examples of a primary standard for volume are soap bubble flow meters and dry-piston type flow meters.

Rotameter: a flow meter 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 air flow rate. The sampling pumps currently used by Metal and Nonmetal are provided with 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.

III. General Characteristics

Metal and Nonmetal primarily uses two different personal sampling pumps. They are the SKC Model 224-44XR (see Figure 4-1) and the Gilian Model HFS 513A-U

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

(see Figure 4-2). As shown in Appendix A to this Chapter, the specifications and operating parameters are very similar. 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 MSHA permissible sampling pumps in gassy mines where required.

Figure 4-2. Gilian Model HFS 513A-U Sampling Pump

A. Pneumatic System - consists of five basic assemblies: pump/valve; pulsation dampener; pressure regulator; flow meter; and inlet filter.

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 air flow. The unit is sealed in a housing to prevent dirt from entering. The DC motor operates from a rechargeable nickel-cadmium (NiCad) battery pack.

2. Pulsation Dampener or Damper Assembly - consists of silicone diaphragms within a housing which stack 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 Meter or Flow Indicator** - a rotameter style flow meter is mounted vertically inside the case and is visible from outside the case through a clear viewing window. It is used to monitor sampling pump flow rates over the operating range of 0.5 to 5.0 liters per minute (Lpm). The rotameters are not precision flow meters (± 20 %) and should be backed up and set by using a more accurate calibration instrument. However, they are repeatable; and once the correct volumes have been established, they are very useful in setting an approximate pump flow on a routine basis.

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.

B. **Electrical or Control System** - consists of battery pack; control panel; and motor control circuitry.

1. **Battery Pack** - five rechargeable NiCad cells arranged in series within a plastic housing or "pack" to provide 6.0 volts at 1.8 to 2.0 Ah (ampere-hours) to the sampler. The battery pack is rechargeable without removal from the sampling pump via the exterior plug-in port.

2. **Control Panel** - consists of 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 turned clockwise increase the flow rate, and counterclockwise turns decrease the flow rate. When sampling a security cover protects the control panel from inadvertent adjustments.

3. **Motor Control Circuitry** - comprises the Constant Flow System which provides for constant air flow 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 over the operating range.

IV. Care and Maintenance

Replacement parts are available from the sampling pump manufacturer. Notify your field office supervisors of the items needed. To maintain the personal sampling pumps in peak operating condition, adhere to the following procedures:

A. Battery Maintenance

"Memory Effect" is a characteristic of all NiCad cells and prevents the batteries from fully recharging even though a full charge is indicated. This can prevent the sampling pump from running a full-shift sampling period in some instances. By using cycling chargers (as furnished by SKC) or battery maintenance stations (as furnished by Gilian), the sampling pump can be discharged and re-charged without turning the pump on or off. This has the same effect as running the sampling pump down and recharging. If cycling chargers or battery maintenance stations are not available, the rechargeable NiCad battery pack should be completely discharged from time to time to minimize the potential for "memory effect". If discharging is necessary, perform the following steps approximately every 10 recharges:

1. Attach a filter cassette to the intake port to prevent the inlet filter from becoming clogged.

2. Turn the sampling pump on using the on/off switch.

3. Set flow rate to 3.0 Lpm.

4. Allow sampling pump to run until the battery discharges completely and the pump stops.

5. Turn the sampling pump off and charge the battery for a full 14 to 16 hours.

Note: Do <u>not</u> check the battery with a volt-ohm-meter to determine voltage since this can result in damage to the battery's resistor.

B. Changing Battery

1. Removal - Remove the two screws which secure the battery to the front case cover and loosen the four case screws above and below the belt clip. Carefully slide the battery pack out to the right from under the belt clip, being careful not to cock it at an angle. Edge rails should guide the pack out.

2. Replacement - Stand the sampling pump up vertically on a flat surface. Slip the front edge of the new battery pack under the belt clip and rotate the battery pack so that the rails engage the slots in the case front. Push the battery to the left until it is properly located, reinstall the battery screws and tighten the case screws.

C. Storage

1. If the sampling pump is stored for long periods, occasionally run the pump down with a filter in line or discharge the battery using a cycling charger/ battery maintenance station (as described in A. above).

2. Recharge battery 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 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. Occasionally 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 and discard the filter membrane and O-ring.

4. Clean the removed filter housing.

5. Insert a new filter membrane and O-ring.

6. Reattach the front filter housing and tighten the four screws.

E. Other

1. Carry sampling pumps in a closed, padded case to avoid damage from impact or dropping.

2. 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 abuse the sampling pump.

3. Clean the sampling pump after each use and visually inspect it for defects and damage.

4. If the sampling pump fails to function properly during a survey, discontinue the survey and void the sample. Report the incident without delay to your supervisor. Do not use the sampling pump again until it is repaired.

V. Calibration Procedures

A. General Instructions

Calibration procedures, equipment, and location should be in accordance with the following procedures:

1. **Equipment** - Metal and Nonmetal uses two types of sampling pump calibrators: manual, using a glass burette, and electronic, using various instruments.

2. **Set-up** - **The calibration instrument used must be assembled with representative media and sampling train in line**. This procedure is necessary to simulate the resistance of the media and sampling train to be used during sampling. Do not use the calibration media for sampling purposes. To include the cyclone (for respirable dust) in-line, it is necessary to enclose the media in an air-tight container (e.g., a Mason jar or flask) as shown in Figures 4-3, 4-4, 4-5, and 4-6.

3. **Location** - Calibrate the sampling pump as near to the sampling site elevation as practical.

4. **Frequency** - Calibrate a fully charged sampling pump before each full-shift usage. Pre-calibration should be conducted within one day of the sampling survey. It is permissible to use a post-calibration check from a

previous sampling survey that has been performed no more than one week prior to the current sampling shift.

5. **Post-Sampling Calibration Acceptability** - Post-sampling calibration checks are acceptable when they agree within ± 5 % of the pre-sampling target flow rate. If the post-sampling check does not agree, the sample is invalid. Post-sampling 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 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.

B. Manual Calibration Using 1.0 Liter Burette and Stopwatch

This method involves the simplest and least expensive equipment. It has the advantage of requiring no calibration, but the equipment is cumbersome to transport in the field and the glass burette is fragile.

1. Pre-inspection Calibration

   a. Assemble using the diagram in Figure 4-3:

      - 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.

   b. Connect the apparatus to the sampling pump with an assembled sampling train in line.

   c. Check the seals on all hose connections. The entire system must be leak-free.

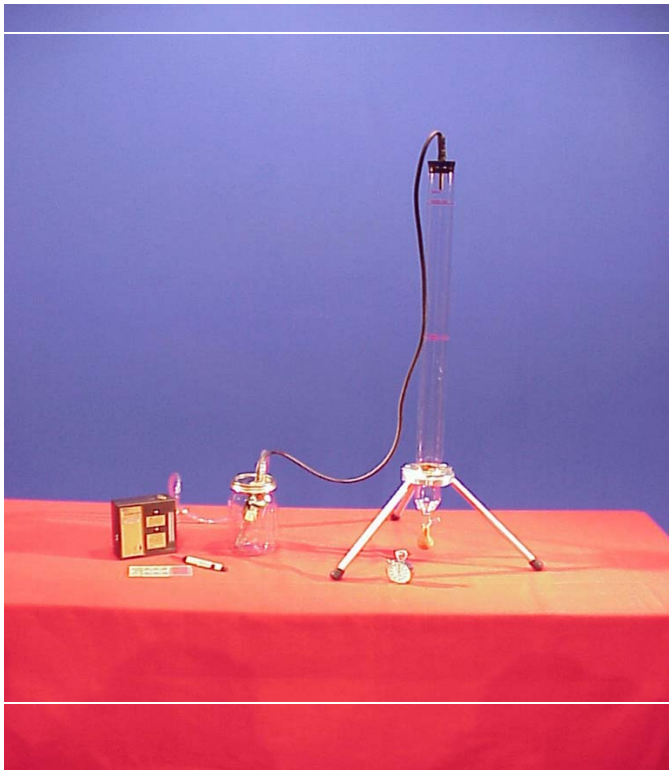

Figure 4-3. Standard 1.0 Liter Burette Set-up for Calibration

d. Turn the sampling pump on; let it run for 5 minutes to dissipate any surface charge and stabilize voltage.

e. 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 after the burette is thoroughly prepared
- Repeat several times until a bubble travels the entire distance up the burette without breaking

f. 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:

Flow Rate	Time
1.4 Lpm	42.8 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:

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

[time in min. X 60 sec./min. = time in sec.]

g. For calculating low-flow rates using a 100 mL burette:

$$\frac{\text{100 mL}}{\text{Desired flow rate (mL/min.)}} = \text{time (min.)}$$

[time in min. X 60 sec./min. = time in sec.]

h. The sampling pump must be within 5 % of the target flow rate. For example, the acceptable range of 1.7 liters per minute (± 5 %) is 1.615 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 by turning the flow adjustment set screw with a screwdriver. When the measured flow rate is within the acceptable ± 5 % range, take two more readings for each sampling pump and average the three.

i. 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.

2. Post-inspection Calibration

- Repeat steps 1.a. through 1.i. above.

- 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.

C. Gilian Gilibrator (Electronic Bubble Generator)

Like 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 calibrator base. While the equipment is more expensive than that used in the previous method, it is more portable than the burette and less time consuming in setup. Each field Gilian Gilibrator requires an annual check against a factory-calibrated instrument. Each field office must submit at least one instrument to the factory on an annual basis to be used as the calibration standard for checking the other office Gilibrator functions against it. The annual check of each field office Gilibrator must fall within a 1% tolerance of the volume measured with the calibration standard.

1. Pre-Inspection Calibration. Refer to Figure 4-4 and follow these steps:

Figure 4-4. Gilian Gilibrator Set-Up for Calibration (Respirable Dust Cassette and Cyclone In-line)

a. It takes 14 hours to fully charge a calibrator; the device can be used while charging.

b. Attach the bubble generator (the plastic cylinder) to the base by placing it upright in the socket on top of the base and turning the bubble generator until it "clicks" into place, with the electrical socket on the side facing toward the rear of the base.

c. Insert the control unit's cable assembly into the sensor block connecting jack located on the back of the sensor block.

d. Add the soap bubble solution through the lower filler boss (or nipple) of the bubble generator to a depth of about 1/8 inch or until the bubble generating ring is immersed in soap solution. Do not overfill!

Figure 4-4a. Total Dust Cassette in-line

Figure 4-4b. MCE Cassette in-line

Figure 4-4c. Asbestos Cassette in-line

Figure 4-4d. Sorbent tube in-line

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

f. Turn on the sampling pump; let it run 5 min. to dissipate any surface charge and stabilize voltage.

g. Prime (wet) the inner walls of the flow tube by depressing the bubble initiator button several times.

h. Turn on the calibrator power switch and wait approximately 10 seconds while the system runs through its check sequence. The calibrator is not ready until the Run LED signal and a series of five (5) dashes displayed on the LCD go off. 'Ready' operation is indicated by a series of four dashes (- - - -).

i. Generate a bubble, and read the flow rate that appears on the LCD display. Actual flow for each bubble will be displayed. The flows will accumulate and be averaged with each successive timing.

Note: 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).

Averaging readings

- Depress and hold the AVG button to display average and number of samples.
- Release the button to display the last flow reading.
- Repress the button to display the number of samples accumulated for that averaging sequence and release again to display the last flow reading.
- Additional pressing and holding will repeat this sequence.

Note: 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.

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.

Reset

- 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.

j. The sampling pump must be within 5 % of the target flow rate. For example, the acceptable range of 1.7 liters per minute (± 5 %) is 1.615 to 1.785 Lpm. Adjust the sampling pump flow rate by turning the flow adjustment set screw with a screwdriver. When the measured flow rate is within the acceptable ± 5 % range, press and hold the reset button on the base until all readings are "0." Then take 3 more readings.

k. 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.

2. Post-Inspection Calibration

- Repeat steps 1.a. through 1.k. above.

- Sampling is valid when the post- and pre-sampling flow rates agree within ± 5 % of the target flow rate for two (2) consecutive timings. Otherwise, the sample is invalid.

- 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.

3. Care and Maintenance

a. Cleaning

- 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 a few days will elapse before doing further calibrations, remove the bubble generator from the base. Rinse the inside of the bubble generator thoroughly with tap 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 tap 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 <u>not</u> disassemble and clean the inside of the bubble generator.**

b. Charging Battery

- "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.

c. Transporting

Do not transport the unit with soap solution or storage tubing in place. When transporting or shipping the electronic calibrator, especially by air freight, it is important to remove one side of the seal 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, possibly resulting in personal injury.

d. Other Maintenance

There is no other 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.

D. Mini-Buck Wet Bubble Calibrator

Like the Gilibrator, this device generates a series of soap bubbles through a tube connected to the air sampling pump. The bubble rise rate is measured automatically and the flow rate is automatically calculated by a computer chip in the calibrator. Each field Mini-Buck Wet Bubble Calibrator requires an annual check against a factory-calibrated instrument in the field office. This requires each field office to submit one instrument to the manufacturer on an annual basis to be used as the calibration standard. The annual check of the Mini-Buck Calibrator against the factory calibrated instrument must fall within a 1% tolerance of the volume measured.

1. Pre-inspection Calibration Procedure. Refer to Figure 4-5.

   a. 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.

   b. 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.

   c. 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.

   d. Turn on the air sampling pump and run it for approximately 5 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.

   e. Firmly press and release the button on the base of the transparent flow cell. A number will flash in the Mini-Buck display.

Figure 4-5. Mini-Buck Wet Bubble Calibrator Set-up for Calibration

Wait until the number stops flashing, 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).

f. The sampling pump must be within 5 % of the target flow rate. For example, the acceptable range of 1.7 Lpm (± 5 %) is 1.615 to 1.785 Lpm. Adjust the sampling pump flow rate as described in the operating instructions for the individual pump by turning a set screw with a screwdriver. When the measured flow rate is within the acceptable ± 5% range, press and hold the "on" button of the Mini-Buck until "0000" is displayed; then take three more readings for that sampling pump (waiting for the flashing to stop between each press of the button).

g. 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.

2. Post-Inspection Calibration

a. Repeat steps 1.a. through 1.g. above.

b. Sampling is valid when the post- and pre-sampling flow rates agree within ± 5 % of the target flow rate for two (2) consecutive timings. Otherwise, the sample is invalid.

c. 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.

d. After 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 a few 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 <u>not</u> attempt to disassemble and clean the inside of the flow cell.

Note: The Mini-Buck automatically shuts-off after <u>seven</u> minutes of non-use.

3. Battery Charging and Replacement

   a. 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.

   b. 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.

4. Maintenance

   There is no 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. Always leave the filler nipples open and disconnected from any tubing when instrument is being mailed or shipped.

CHAPTER 4
APPENDIX
Personal Sampling Pumps

October 2006

Blank page

Chapter 4
Appendix A
Personal Sampling Pumps

Table 4-1. Specifications and Operating Parameters of the Personal Sampling Pumps Used by Metal and Nonmetal

Specification	Sampling Pumps	
	SKC Model 224-44XR	**Gilian Model HFS 513A-U**
Operating Range	0.005 - 5.0 Lpm (5 - 5000 mL/min.)	0.001 - 5.0 Lpm (1 - 5000 mL/min.)
Weight	34 oz. (963 g)	36 oz. (1020 g)
Dimensions	4.9 x 11.9 x 13 cm, 758 cu. cm (1-15/16" x 4-11/16" x 5-1/8", 46.5 cu. in.)	4.8 x 11.7 x 13 cm, 732 cu. cm (1-7/8" x 4-5/8" x 5-1/8", 44.7 cu. in.)
Compensation Range	750 - 2500 mL/min. to 40 in. water back pressure 2500 - 4000 mL/min. to 20 in. water back pressure	750 mL/min. to 35 in. water back pressure 1000 mL/min. to 40 in. water back pressure 2000 mL/min. to 40 in. water back pressure 3000 mL/min. to 35 in. water back pressure 4000 mL/min. to 20 in. water back pressure 5000 mL/min. to 15 in. water back pressure
Flow Control	± 5 % of set point	± 5 % of set point
Run Time	At least 8 hours at 4000 mL/min. and 20 inches of water back pressure on full charge.	At least 8 hours across range of operation on full charge.
Flow Indicator	Built-in flow meter from 0.0 - 5.0 Lpm with 250 mL/min. divisions	Built-in flow meter from 0.0 - 5.0 Lpm with 500 mL/min. divisions.
Battery Assembly	Plug-in rechargeable NiCad battery pack delivers 6.0 volts at 2.0 Ah (ampere-hours)	Plug-in rechargeable NiCad battery pack delivers 6.0 volts at 1.8 Ah (ampere-hours)
Intrinsically Safe	UL approved intrinsically safe for use in hazardous locations: Class I, Groups A, B, C, D; Class II, Groups E, F, G; Class III; and Temperature Code T3C.	UL approved intrinsically safe for use in hazardous locations: Class I, Groups A, B, C, D; Class II, Groups E, F, G; Class III; and Temperature Code T3C.
Operating Temperature	- 20° to 45° C (- 4° to 113° F)	- 20° to 45° C (- 4° to 113° F)
Storage Temperature	- 40° to 45° C (- 40° to 113° F)	- 40° to 45° C (- 40° to 113° F)
Charging	5° to 45° C (41° to 113° F)	5° to 45° C (41° to 113° F)

Table 4-1. Specifications and Operating Parameters of the Personal Sampling Pumps Used by Metal and Nonmetal

Specification	Sampling Pumps	
	SKC Model 224-44XR	**Gilian Model HFS 513A-U**
Temperature		
Operating Humidity	0 to 95 % Relative	0 to 95 % Relative
RFI/EMI Shielding Performance	RFI/EMI Shielded Case with added circuit protection. • Complies with requirements of EN 55022, FCC Part 15 Class B, EN 50082-1 • Frequency range of the radiated susceptibility test was 27 MHZ to 1000 MHZ.	RFI/EMI Shielded Case**.**
Battery Charger(s)	1. Single Unit Charger. Must not charge more than 16 continuous hours. 2. Deluxe Charger. Five unit charger with various battery maintenance functions.	1. Single Unit Charger. Must not charge more than 16 continuous hours. 2. Battery Maintenance Station. Five unit charger with various battery maintenance functions.
Additions	None	1. Battery Charge Indicator - Activated by press-to-test button confirms a sufficient battery capacity to operate a minimum of 8 hours under any conditions within the instrument's range of operation. 2. Flow Fault Indication - LED is activated by either an under voltage, over current, or over pressure condition which occurs when the sampling pump is operated beyond its performance envelope. A suitable time delay (15 – 30 sec) is built into the system to avoid unnecessary shutdowns.