GUIDANCE DOCUMENT

H-PEM

(Harvard School of Public Health Personal Exposure Monitor)

Built by BGI under exclusive license from the Harvard Licensing office

BGI Incorporated
58 Guinan Street
Waltham, MA. 02154
Tel: 781.891.9380
Fax: 781.891.8151
e-mail: info@bgiusa.com
http://www.bgiusa.com

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1.0 Introduction

The BGI H-PEM (Harvard-Personal Exposure Monitor) is a development of the Environmental Science and Engineering Group at the Harvard School of Public Health. Its development in 2000, is described in a peer reviewed publication.[1] The H-PEM is a single stage impactor intended to be worn by an individual during the course of a study to determine their personal exposure to particles with diameters of PM_{10} (Inhablable) or $PM_{2.5.}$ (Fine). These impactors may also be used for ambient air and micro-environmental measurements. There are two sample flow rates and two size-selective cutpoints, so there are four partially interchangeable variations as detailed in Table 1 and Figure 1.

Catalog Number	Color	D_{50} Cut µm	Flow Rate lpm	Pressure Drop[A,B] Cm of H_2O
HP1040	Blue	10	4	3.32
HP2540	Red	2.5	4	4.89
HP1018	Blue	10	1.8	1.23
HP2518	Red	2.5	1.8	2.39
HP2560	Red	2.5	6	8.14
HP4090	Green	4	9	10.8

[A]Pressure drop is measured with Pall Teflo R2PJ 037 filter installed
[B]Precise laboratory measurement of single specimens

Table 1. H-PEM Configurations

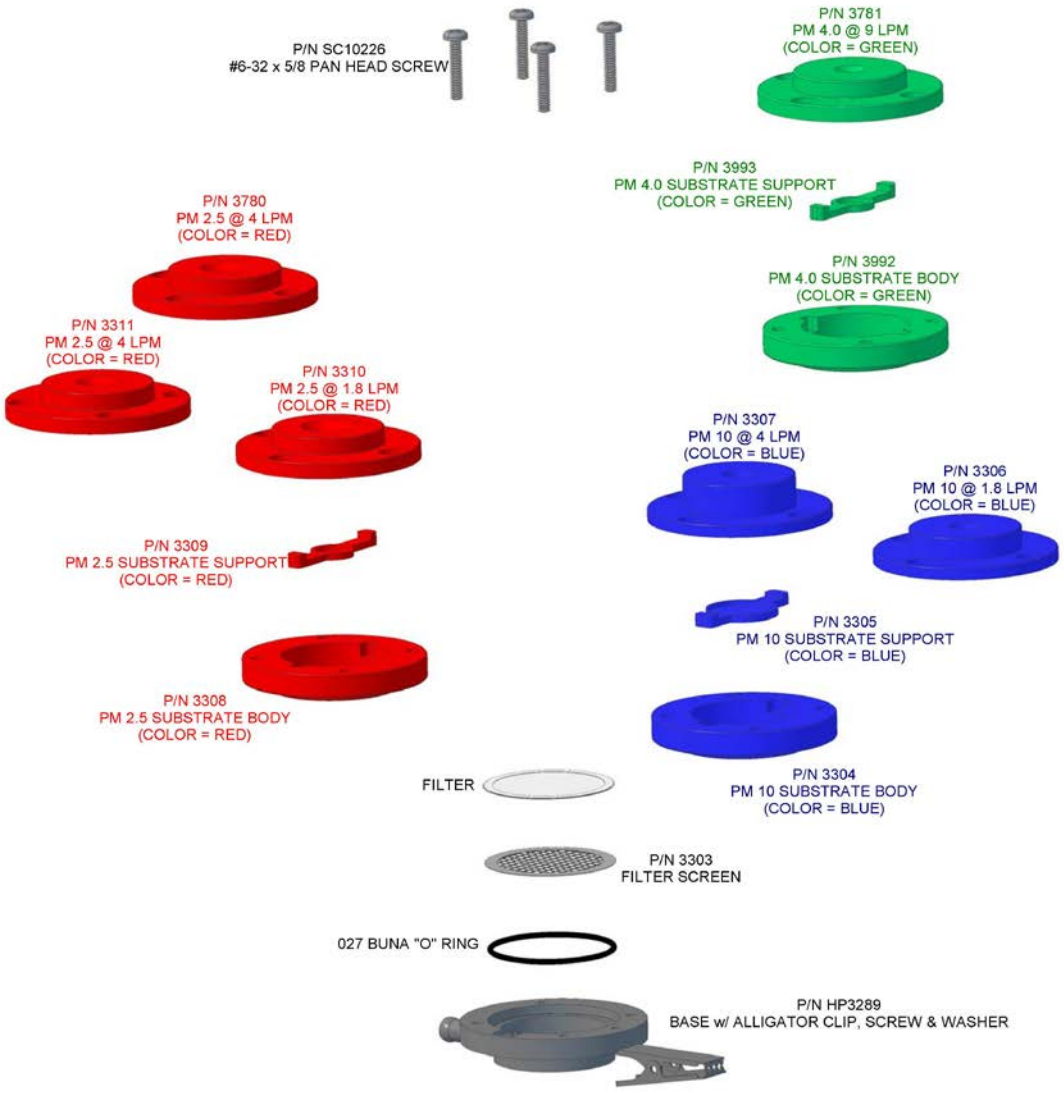

Figure 1. Combinations of the H-PEM Illustrated

As can be appreciated in Figure 1, after selecting the initial size selective cutpoint and instrument to be utilized in a study, further variations may be achieved with the purchase of additional components. Color coding and fully engraved flow rate and cut point further ensure freedom from error. Many hundreds of these Harvard PEM units are presently in use.[2.]

2.0 Specifications

Diameter: 2.10 in. (5.34 cm.)
Thickness: 0.97 in. (2.46 cm.)
Weight: 2.72 oz. (77 grams)
Body material: Anodized Aluminum.
Screws: Stainless steel. 4 x #6-32 pan head screws, Phillips x 5/8 in. long.
Support screen: Electro etched stainless steel. 37 mm x .25 mm thick. PTFE coated on one side.
Latex Rubber vacuum tubing: 36 in long. 1/4 in. I.D. x 3/32 in. wall

3.0 Principle of Operation

If an aerosol distribution is accelerated in a nozzle and the jet is pointed at a solid surface a proportion of the distribution will be captured by that surface. This is true for liquid particles and also true for solid particles if the impaction surface has “capture” properties, i.e. grease/oil/foam. The critical considerations in impactor design have been carefully worked our by Marple et.al. and applied to the Harvard PEM design [3]
The principal dimensions are shown in Figure 2, which are taken form the work of Marple and Rubow. [4]
Impactor grease is used as the collection surface, which minimizes the effects of dry particle bounce or overloading. The full development and testing of these H-PEM’s may be appreciated in the original design and testing publication in Reference 1 .

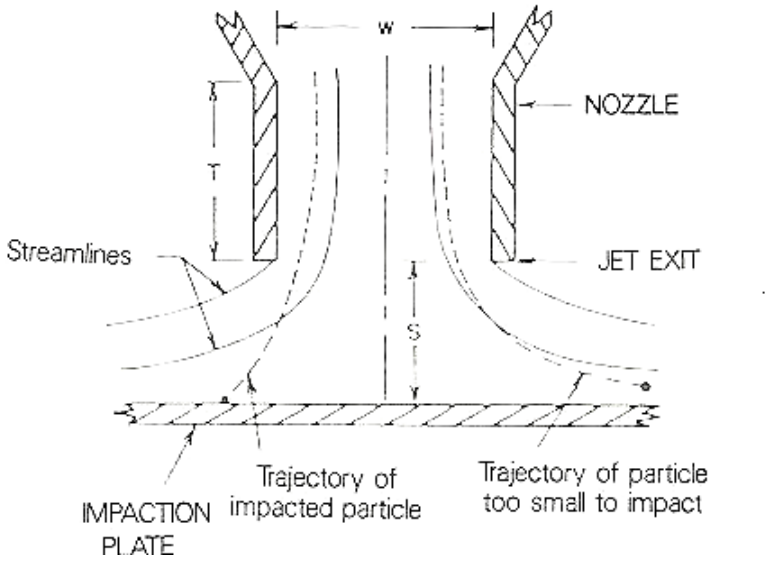

Figure 2. Schematic Diagram of a Typical Impaction stage Showing Streamlines and Particle Trajectories (after Marple et. al.) [4]

4.0 Instrument Setup

The parts of an H-PEM comprise a range of 4 possible inlets, 2 substrate support rings and 2 substrate supports. There is one type of support screen, “O” ring and base. These parts are clearly illustrated together with their part numbers in Figure 1.

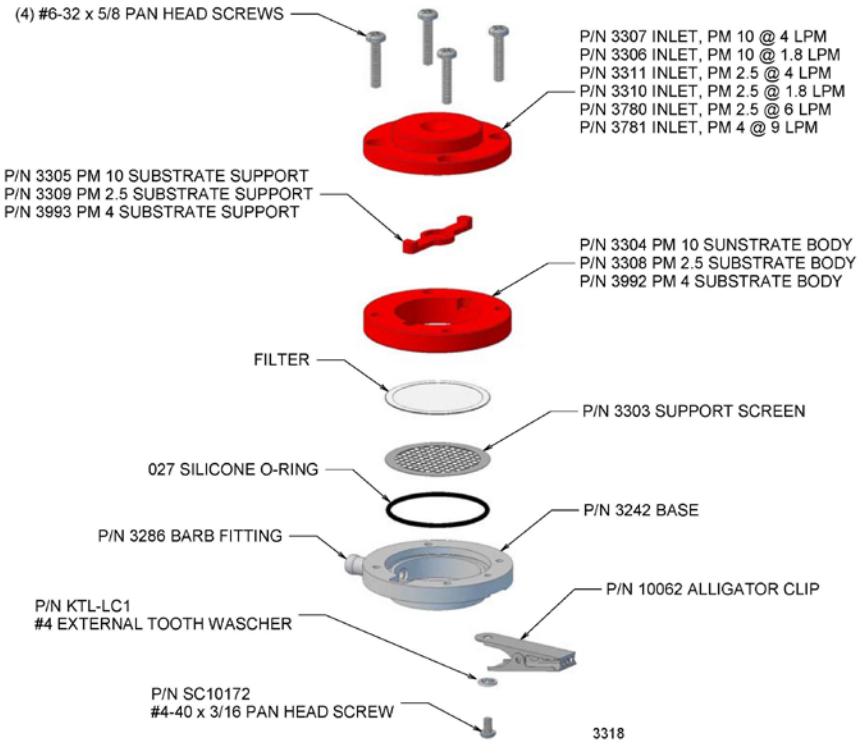

Figure 3. Exploded View of H-PEM

An active graphic of the disassembly/reassembly procedure is available on the BGI web page, http://www.bgiusa.com/iaq/3318 BGI-PEM ASSEMBLY.pdf
(Adobe Acrobat Reader v. 8.0 or later required)

A new H-PEM is received fully assembled from the factory. It is clean and free from contaminants, as received but should nonetheless be subjected to analytical grade cleanliness as detailed in Appendix 1.

- Remove the four screws holding the assembly together, using a Phillips blade screwdriver. (An instrument grade swivel head screw driver will prove to be an advantage).
- The Inlet may now be removed and set aside.
- The Substrate body, together with the substrate support may be removed.
- The substrate support lifts, easily out of the substrate body. This feature simplifies cleaning and the refilling of the support with the substrate (Silicone grease).
- If a filter was present it may be removed and preserved. Tweezers must be used and a lifting recess is provided.
- Remove the support screen, noting that one side is PTFE coated and should be facing “up” so that the filter rests on the PTFE coating.

Disassembly is now complete and the equipment is ready to be prepared in the manner described in Appendix A, by the Deep Cleaning method (weekly) or the Daily method.

Mechanically, reassembly is merely a reversal of the disassembly procedure. However, cleanliness is essential and an excellent procedure is presented in appendix A.

5.0 Calibration

It is fully accepted practice to calibrate the pumps used in a study at the start of a study and at intervals thereafter mandated by: Regulatory Guidelines, internal audit rules, client requirements and/or experience. Modern, microprocessor controlled equipment is highly reliable but some, older, uncompensated instruments require verification, before and after each sampling event. The most convenient and accurate flow rate calibration instrument for this requirement is the BGI Challenger (http://www.bgiusa.com/cal/the_challenger.htm) Other devices such as Rotameters and bubble meters are also suitable depending upon the accuracy requirements of the study.

In order to calibrate the pump used with any of the H-PEMS, a Calibration Adaptor is necessary
(P/N HP3312). It is installed by pressing the “O” ring lined cavity over the boss on the inlet side of the H-PEM. The procedure is made clear in Figure 4.
The calibration procedure is to:

a.) Assemble the H-PEM with a representative sample of the filter media being used.
b.) Connect the H-PEM to the pump being used via the tubing provided with the H-PEM.
c.) Press the Calibration Adaptor over the H-PEM inlet.
d.) Switch on the Challenger and attach it to the Calibration Adaptor with user supplied tubing. Wait 15 seconds before starting the vacuum pump.
e.) Switch on the pump and adjust the flow to either 1.8 or 4.0 lpm depending upon the H-PEM configuration being utilized.
f.) Switch off the pump and remove the Calibration Chamber. The specific H-PEM pump combination is now calibrated.

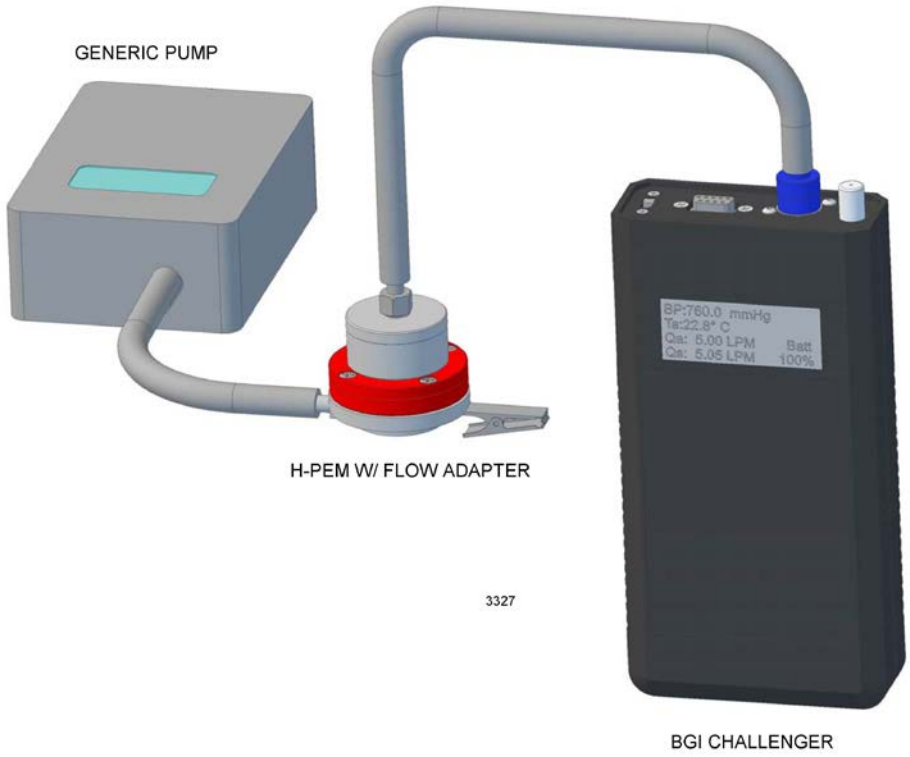

Figure 4. Schematic Diagram of Typical Calibration Arrangement.

6.0 Sampling

The H-PEM was originally designed for personal monitoring. That means it is intended to be worn on the person, however it can be used as an area monitor if steps are taken to ensure a reasonable sample event. It is desirable that it be worn as close to the breathing zone as is convenient. This usually means clipped to a shirt collar or lapel. There are certainly other means of deployment such as clipped to a backpack. The actual design of the study and wearing of the equipment is beyond the scope of this document and up to the individual investigator. The exact procedures may be mandated by a national or local agency, or a certified industrial hygienest. The H-PEM may also be used, with suitable location criteria, for ambient air or microenvironmental measurements.

The selection of the personal sampling pump is also up to the individual user. It is only necessary that the pump selected be capable of providing the requisite flow rate at the stipulated resistance (Table 1) for the length of time required by the study design. If pumps are just being purchased, check with the manufacturer. Pumps on hand should be charged and tested in the laboratory for confirmation. For investigations which are closely supervised, unsophisticated pumps may be utilized whose functionality involves only Off/On and displayed elapsed time. Larger studies involving untrained volunteer personal will require samplers which are capable of being programmed. The range of available sampleing pumps is further narrowed if ultra quiet pumps are required. Pumps sold or distributed by BGI, suitable for this application are detailed in Table 2 and specified on the BGI web catalog at http://www.bgiusa.com/

Pump	Range- lpm	Flow Comp.	Microprocessor	Direct Cal	Silent
BGI 400	3-6	Yes	No	No	Yes
BGI Omni	2-12	Yes	Yes	Yes	Yes
Casella Apex	0.8-4	Yes	Yes	No	No
Casella Tuff	0.8-4	Yes	Yes	No	No

Table 2. BGI Manufactured/Distributed Pumps Suitable for the H-PEM

Each pump manufacturer provides detailed instructions for the set up, maintenance, calibration and operation of their pumps. Table 2, provides direct links to all of the instruction manuals, for the pumps available. It is worth noting that Personal sampling pumps have been on the market for almost 50 years. Flow controlled pumps have now been available for 30 years. Therefore, there is little remaining rationale for the utilization of obsolete or third rate equipment, which is not equipped with some kind of flowrate compensation system, even if newly made and cheaply available.

7.0 Analysis

The most common form of analysis is gravimetric, wherein the filter media is weighed before and after the sampling event. Depending upon the nature of the study and the composition of the particles being sampled, the filters will be weighed under controlled conditions of temperature or in some cases, desiccated. The exact procedures and calculations should be a part of the specific experimental design.
It must be understood that the H-PEMS were designed to work with only one specific type of filter. This is: Pall Corporation Teflo™ PTFE Membrane with plastic Ring, BGI P/N R2PJ037 2 µm, 37 mm. The Polypropylene ring is an important part of the sealing mechanism.
They may be obtained from Pall distributors such as VWR:

For other distributors contact:
Pall Corporation
600 South Wagner Road
Ann Arbor, Michigan 48103

Other analysis for specific chemicals, known as speciation analysis may be found in general sources, and the U.S. EPA.

8.0 Safety

There are no particular safety concerns with an instrument having no moving parts. Because of the necessity to minimize contamination, assembly/disassembly will be conducted in the laboratory by trained personnel.
Trained/untrained persons wearing an instrument in the field, must be aware that they are abnormally encumbered with a belt, pump, hose and H-PEM on their person. It is all to easy to “snag” on something and cause injury. Vigilance is necessary.

9.0 Warranty Information

BGI Incorporated warrants equipment of its manufacture and bearing its nameplate to be free from defects in workmanship and material. We make no warranty, express or implied, except as set forth herein. BGI's liability under this warranty extends for a period of one (1) year from the date of BGI's shipment. It is expressly limited to repairing or replacing at the factory during this period and at BGI's option, any device or part which shall within one year of delivery to the original purchaser, be returned to the factory, transportation prepaid and which on examination shall in fact be proved defective.

BGI assumes no liability for consequential damages of any kind. The purchaser, by acceptance of this equipment, shall assume all liability for consequences of its misuse by the purchaser, his employees or others. This warranty will be void if the equipment is not handled, installed, or operated in accordance with our instructions. If damage occurs during transportation to the purchaser, BGI must be notified immediately upon arrival of the equipment. The equipment will be returned via collect shipment.

A defective part in the meaning of this warranty shall not, when such part is capable of being repaired or replaced, constitute a reason for considering the complete equipment defective. Acknowledgment and approval must be received from BGI prior to returning parts or equipment for credit. BGI Incorporated makes engineering changes and improvements from time to time on instruments of its manufacture. We are under no obligation to retrofit these improvements and/or changes into instruments which have already been purchased.

No representative of ours has the authority to change or modify this warranty in any respect.

Appendix A – SOP

A1. Procedural

A1.1. PEMs Deep Cleaning (at beginning of study and then weekly, or at longer intervals, depending on frequency of use and amount of particles collected on grease substrates)

Materials

5 large beakers	Powder-free latex gloves
Distilled water	Ethanol
Non-serrated forceps	Mild dish detergent
Large Kimwipes	H-PEM O-rings
H-PEM tops	H-PEM bases
H-PEM impaction plates	Metal screens
4 to 5 plastic trays	Paper tape
Permanent marker	

a) Remove any remaining grease from impactor plates using a small spatula or cotton Q-Tip.

b) Label two beakers with paper tape using permanent marker to denote contents as "soap and water."

c) Fill both beakers with distilled water and add several drops of a mild dish detergent.

d) Wash bases and tops in one of the beakers, using a brush to ensure that the H-PEM inlets are clear.

e) Wash the impactor plates in the second beaker, using a brush to ensure that as much grease is removed from the impactor plates as possible.

f) Rinse contents of beaker twice (or until water is free of soap) in clean distilled water.

g) To dry H-PEM tops, bases, and impactor plates rapidly, shake excess water from them, then rinse in ethyl alcohol. Place the tops and bases onto trays covered in Kimwipes; cover with an additional layer of Kimwipes. Mark tray as "Clean PEM Parts."

A1.2 Screens and O-rings:

a) Place metal screens and O-rings in a third beaker filled with ethanol. Allow to soak for several minutes. Remove screens from the ethanol and lay flat on a tray. Using a brush and more ethanol, scrub both sides of the screens. Place the scrubbed screens in a fourth beaker filled with distilled water and several drops of mild dish detergent. Carefully agitate contents of beaker using a brush, being careful to avoid bending the screens.

b) To clean O-rings, place in a fifth beaker with distilled water and a few drops of mild dish detergent. Carefully agitate contents of beaker using a brush.

c) Rinse contents of beakers twice (or until water is free of soap) in clean distilled water.

d) Remove metal screens and O-rings from the drained beakers using non-serrated forceps and place on trays covered with Kimwipes. Arrange screens PTFE side up. Allow O-rings to dry naturally; do not place into alcohol. Screens can be rinsed a final time in ethanol prior to drying on Kimwipes. Cover with additional Kimwipes while drying. Mark tray as "Clean PEM Parts."

A2.1. Standard Cleaning (done daily during study)

a.) Wipe off bases and tops with a dampened Kimwipe and allow to dry on a tray between Kimwipes

b.) Screens and O-rings are cleaned following the same procedures as for deep cleaning, above.

Impaction Plates:

a.) Using a small spatula or Q-Tip, remove the top layer of grease from the middle of the impaction surface, along with the collected particles. Remaining grease does not need to be removed. This prepares the impaction surface for re-greasing

A3.1. PEM Assembly

Materials:

Plastic or PTFE-coated forceps	Milli-Q water
Trace metals-grade methanol	Clean tops
Clean and oiled impaction plates	Clean bases
Clean metal screens	Clean O-rings
37-mm PTFE filters	3 plastic trays
Razor blades	Phillips screwdriver
Harvard PEM screws (4 per PEM)	Large foam swab

a.) The impaction surface should be re-greased with Dow Corning – High Vacuum Grease, using a small spatula. The grease should be smoothed with a razor blade so that it is evenly flat with the impactor surface (for the PM2.5 impactor plates, a razor blade cut in half works best and for the PM10 impactor plates, 3/4 of a razor blade

works best). Make sure grease is very smooth. Use large foam swab to clean excess grease from around impactor surface. Greased impaction plates should be taped in stacks with the greased sides facing together and stored in a sealed container until ready for use.

b.) Pair up the H-PEM bases and tops. See Figure 3 for details of the components.

c.) Using non-serrated forceps, place the O-ring into the lip on the base of the Harvard PEM. Place a metal support screen for the filter into the base. The screen should be inserted without the PTFE coating on the side facing the PEM base. Care should be taken to avoid using bent or warped screens.

d.) For PM2.5: Wash plastic or PTFE-coated forceps with Milli-Q water then rinse with trace-metals grade methanol to dry.

e.) For PM10**:** Metal forceps can be used; these can be cleaned using a Milli-Q-dampened Kimwipe and dried using ethanol.

f.) For PM2.5: Using the clean plastic or PTFE-coated forceps, to remove a 37-mm PTFE filter from the Petri dish by the plastic outer-ring. Pass both sides of the filter over the ^{210}Po source to remove static. Place the filter on top of the PTFE coated screen in the PEM base with the shiny outer-ring side facing up.

g.) For PM10: Using the metal forceps, to remove a mm 37-mm PTFE filter from the Petri dish by the plastic outer-ring. Pass both sides of the filter over the ^{210}Po source to remove static. Place the filter on top of the PTFE coated screen in the PEM base with the shiny outer-ring side facing up.

h.) Inspect the impaction plate to make sure grease is smooth. Then place the impaction ring on top of the PTFE filter with the greased side facing up.

i.) Place a PM10 or PM2.5 inlet on top of the impaction plate, and secure the top and base together using four screws and a Phillips screwdriver. Ensure that all four are tightened evenly

Appendix B. QA/QC

B2.1. Leak Test Procedures

a.) Non flow controlled pumps should be avoided whenever possible and are not often encountered. If one is in use it can only be calibrated/ leak tested with a bubble type flow meter.
After running for 30 minutes, the initial flow is measured using a NIST-traceable, non pulsating calibrator. The pump should be adjusted to set the flow rate to which the H-PEM will be operated. This flow is measured twice and recorded.

b.) Attach a calibration cap to the PEM with the other end attached to the calibrator. Then attach the PEM directly to the pump. Check the flow rate for each of the PEMs after assembly. If there are no leaks, the flow should be within 5% of the initial pump flow. If not, check the tightness of the PEM screws; if they are too loose, leakage will occur. If this does not work, then open the PEM and check the O-ring placement, as this may have moved.

B2.2. After Deployment in the Field

a.) In the field, the initial flows should be within 5% of target limits. If the flow rate is not within the required range, then the pump must be adjusted.

b.) H-PEMs are transported to and from the field, in resealable bags.

c.) Each sample filter is placed in a Petri dish that is taped closed.

d.) Petri dishes containing PTFE filters are stored in the refrigerator; Petri dishes containing quartz filters are wrapped in aluminum foil and stored

e.) Shipping of samples is done in coolers with blue ice by priority overnight mail.

References

1. P. Demokritou, I.G. Kavouras, S.T. Ferguson , P. Koutrakis, Development and Laboratory Performance Evaluation of a Personal Multipollutant Sampler for Simultaneous Measurements of Particulate and Gaseous Pollutants., J. of Aerosol Sci. and Tech.,35:741-752 (2001)

2. Numerous application references are available on line:

3. Marple, V.A., Rubow, K.L., Olson, B.A. (1993). Inertial, gravitational, centrifugal and thermal collection techniques, in *Aerosol Measurement,* Willeke K. and Baron P.A., Eds., Van Nostrand Reinhold, New York, pp: 106-232

4. Marple, V.A. and Rubow, K.L, (1986). Theory and Design Guidelines, in *Cascade Impactor,* Lodge, J.P. and Chan, T.L. Eds., J. AIHA Publication, Akron, pp:79-101

Revision History

Version 1.0.0	First Public Release of BGI Version	May, 2009
Version 1.0.1	Added HP2560 and HP4090 PEMS	Aug, 2013