

Size-Selective Inlets

For Access Sensor Technologies' Ultrasonic Filter Samplers



**ACCESS SENSOR
TECHNOLOGIES**

Sampling made simple.®

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Abbreviations

Abbreviations used throughout this manual are defined below in alphabetical order:

ACGIH	American Conference of Governmental Industrial Hygienists
AST	Access Sensor Technologies
CS	cross section
EPA	Environmental Protection Agency
HHB	Home Health Box
ID	inner diameter
ISO	International Organization for Standardization
PM	particulate matter
PM _{2.5}	refers to a particle size fraction, defined by the U.S. EPA, that generally consists of particles with aerodynamic diameters smaller than 2.5 μm ; often called “fine particulate matter”
PM ₁₀	refers to a particle size fraction, defined by the U.S. EPA, that generally consists of particles with aerodynamic diameters smaller than 10 μm
QR	quick response
PTFE	polytetrafluoroethylene (Teflon™)
UPAS	Ultrasonic Personal Air Sampler
U.S.	United States

1 Introduction

Access Sensor Technologies (AST) sells the following size-selective particulate matter (PM) sampling inlets for use with our Ultrasonic Personal Air Samplers (UPAS) and Home Health Boxes (HHBs):

- PM_{2.5} at 1 L min⁻¹
- PM_{2.5} at 2 L min⁻¹
- Respirable at 2 L min⁻¹
- PM₁₀/Thoracic at 2 L min⁻¹

AST has sold two different generations of size-selective inlets (Figure 1). From 2017–2020, we sold our “Generation 1” (GEN1) PM_{2.5} 1 L min⁻¹ inlet. Since 2020, we have been selling our “Generation 2” (GEN2) PM_{2.5} 1 L min⁻¹, PM_{2.5} 2 L min⁻¹, respirable 2 L min⁻¹, and PM₁₀/Thoracic 2 L min⁻¹ inlets.

All GEN1 and GEN2 inlets can be used on all UPAS models (v2.0, v2.1, v2.1G, and v2.1 PLUS). All GEN2 inlets can be used on all HHBs, but the GEN1 PM_{2.5} 1 L min⁻¹ inlet *cannot* be used on our HHB v2 (manufactured in 2023 and later).

The GEN1 PM_{2.5} 1 L min⁻¹ inlet was black, with a knurled outer circumference, and came with a black 37-mm filter cartridge. The outlet of the PM_{2.5} cyclone is built-in to the top of the GEN1 filter cartridge; therefore, the GEN1 inlet can only be used with the black GEN1 filter cartridge. Do not use the GEN1 inlet with any other filter cartridge. Similarly, only use the black GEN1 filter cartridge with the GEN1 inlet. Do not use the GEN1 filter cartridge with any other inlet.

GEN2 inlets are color coded: the PM_{2.5} 1 L min⁻¹ inlet is black, the PM_{2.5} 2 L min⁻¹ inlet is green, the respirable 2 L min⁻¹ inlet is purple, and the PM₁₀/Thoracic 2 L min⁻¹ inlet is gold (although a few early PM₁₀/Thoracic inlets were silver).

IMPORTANT! GEN1 filter cartridges are NOT cross-compatible with GEN2 inlets. Similarly, GEN2 filter cartridges are NOT cross-compatible with GEN1 inlets.

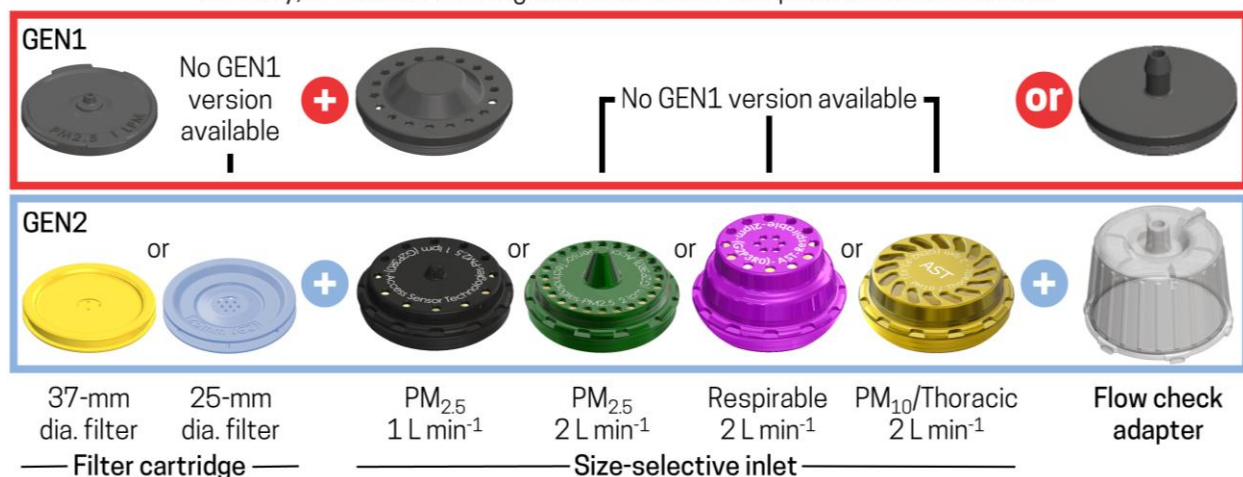


Figure 1. Summary of Generation 1 (GEN1) and Generation 2 (GEN2) size-selective inlet systems.

The top of each GEN2 inlet is labeled with the size cut (PM_{2.5}, respirable, or PM₁₀/Thoracic) and the flow rate at which the inlet is designed to operate.

All GEN2 inlets are designed to be used with our GEN2 filter cartridges (Figure 2). Our samplers are designed to be used primarily with 37-mm-diameter filters; however, we also offer a GEN2 cartridge for a 25-mm-diameter filter.

- If the limit of detection of your primary sample analysis method depends only on the total mass of analyte on the filter (e.g., gravimetric analysis of PM mass), a 37-mm filter is likely preferable. When sampling onto a 37-mm filter, the pressure drop across the filter will be lower, and thus the sampler's battery endurance will be higher, for a given flow rate.
- If the limit of detection of your primary sample analysis method depends on the mass of analyte accumulated per unit area (e.g., infrared transmissometer measurements of black carbon, thermal-optical measurements of elemental carbon, X-ray fluorescence spectroscopy for metals) and you expect your sample mass to be low, you might prefer to use a 25-mm filter. When sampling onto a 25-mm filter, the analyte loading per unit area will be higher, but the pressure drop across the filter will also be higher, and thus the sampler's battery endurance will be reduced, for a given sample mass and flow rate.

Each GEN2 filter cartridge has an 8-mm-diameter inlet hole in the top and is taller than the GEN1 filter cartridge. Early GEN2 37-mm filter cartridges were machined from Ultem™ and had a translucent amber appearance. Currently, GEN2 37-mm filter cartridges are molded from opaque yellow Delrin®. These yellow cartridges have “G2 P3” molded into the inside surfaces of the upper and lower halves. Amber and yellow GEN2 37-mm cartridges are functionally identical and can be used interchangeably. Any of the GEN2 filter cartridges shown in Figure 2 can be used with any of the GEN2 inlets shown in Figure 1.

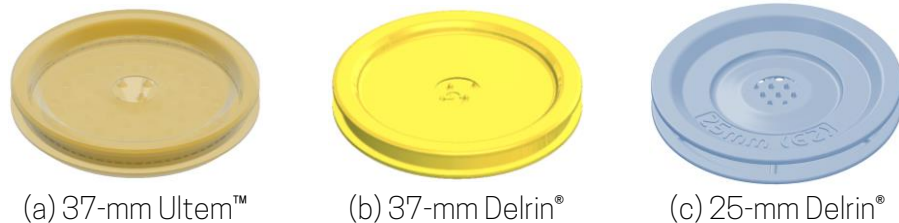


Figure 2. All interchangeable GEN2 filter cartridges: (a) A translucent amber Ultem™ 37-mm filter cartridge. (b) An opaque yellow Delrin® 37-mm filter cartridge. (c) An opaque blue Delrin® 25-mm filter cartridge. The translucent amber and opaque yellow 37-mm filter cartridges are functionally identical.

Accessories for GEN1 and GEN2 size-selective inlets are shown in Figure 3. A “flow check adapter” is used to connect an external flow meter to the inlet of a sampler. The “inlet tool” is used to install/remove GEN2 size selective inlets on/from a UPAS or HHB. The “cartridge opening tool” is used to open GEN2 filter cartridges.



Figure 3. Accessories for size-selective inlets.

One key difference between the GEN1 and GEN2 inlets is the interface used to tighten or loosen the inlet when installing it on or removing it from a sampler. The GEN1 $\text{PM}_{2.5}$ 1 L min^{-1} inlet is designed to be hand tightened or loosened by gripping the knurled outside edge of the threaded aluminum cap. In contrast, GEN2 inlets must be tightened or loosened using an inlet tool (or a flow check adapter) that interfaces with the 12 pockets cut into the top of the threaded aluminum cap.

Another key difference between the GEN1 and GEN2 inlets is the approach used to check the air flow rate through the inlet and/or filter. To check the flow rate through a sampler when using a GEN1 $\text{PM}_{2.5}$ 1 L min^{-1} inlet, the inlet must be removed and the flow check adapter must be screwed down, in place of the inlet, so that the adapter seals to the top of the GEN1 filter cartridge. The user can then connect a piece of tubing between the adapter and a flow meter. When using any of the GEN2 inlets, the size-selective inlet does *not* need to be removed to check the flow rate through the sampler. The GEN2 flow check adapter seals over any of the GEN2 inlets so that the flow rate through the inlet and filter cartridge be checked with the system fully-assembled; this functionality represents a substantial improvement over the GEN1 system.

Finally, the GEN2 PM_{2.5} 1 L min⁻¹ inlet is available with or without the optional “pre-cyclone impactor” shown in Figure 4. In other words, the inlet can be used with or without the pre-cyclone impactor to operate as either:

- A multi-stage inlet in which the size cut is achieved using a multi-stage impactor, which has a 5.4- μm cutpoint at the final stage, followed a cyclone with a 2.5- μm cutpoint at a flow rate of 1 L min⁻¹.
- A single-stage inlet in which the size cut is achieved using just the cyclone.

The pre-cyclone impactor is designed to reduce the likelihood of the GEN2 PM_{2.5} 1 L min⁻¹ inlet becoming overloaded (i.e., the likelihood of particles with aerodynamic diameters > 2.5 μm defeating the cyclone and reaching the sample filter) when sampling in highly-polluted, dusty environments.

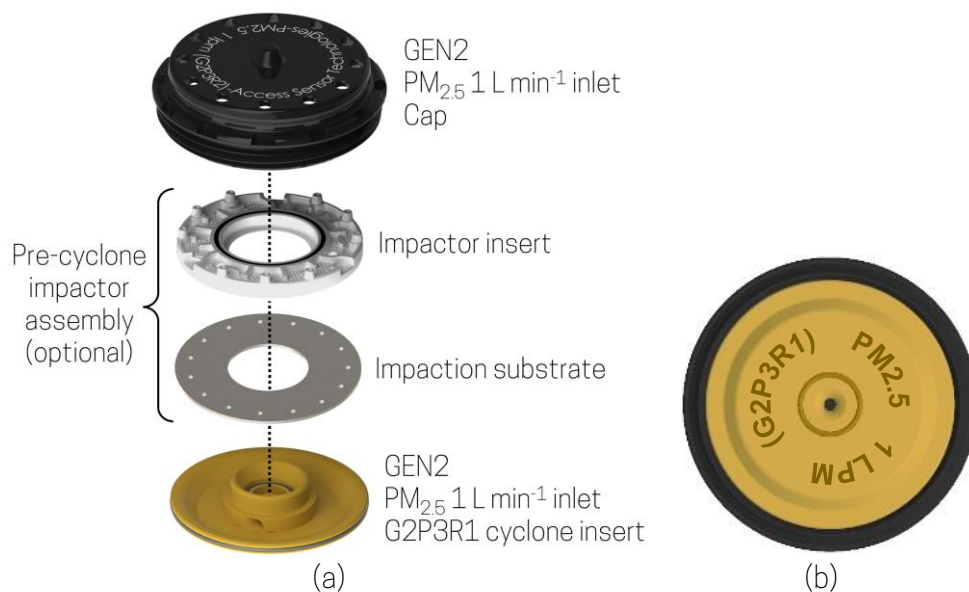


Figure 4. (a) An exploded view illustrating how the GEN2 PM_{2.5} 1 L min⁻¹ inlet is assembled with the optional pre-cyclone impactor. (b) The pre-cyclone impactor can only be installed in a GEN2 PM_{2.5} 1 L min⁻¹ inlet that has “G2P3R1” etched into the translucent amber plastic on the bottom of the cyclone insert as shown here.

The pre-cyclone impactor can only be used with a GEN2 PM_{2.5} 1 L min⁻¹ inlet that has a G2P3R1 cyclone insert (i.e., an inlet with “G2P3R1” etched into the translucent amber plastic insert on the bottom side as shown in Figure 4b; included with all GEN2 PM_{2.5} 1 L min⁻¹ inlets sold since July 2024). The GEN2 PM_{2.5} 1 L min⁻¹ cyclone insert is interchangeable, meaning that an older insert that does *not* have “G2P3R1” etched into the bottom side can be replaced with an R1 insert. If you wish to use the pre-cyclone impactor with a GEN2 PM_{2.5} 1 L min⁻¹ inlet that you already have, but your inlet does not have a G2P3R1 cyclone insert, you can purchase a G2P3R1 cyclone insert to use with the pre-cyclone impactor.

2 Performance

PM_{2.5}

Our PM_{2.5} inlets (Figure 5) are designed to allow particles to pass through and reach the filter in a manner consistent with the U.S. EPA definition of PM_{2.5} (Figure 6). Each inlet includes a cyclone that was designed to have 50% penetration efficiency at an aerodynamic diameter of 2.5 μm when operated at the volumetric flow rate for which the cyclone was designed (either 1 or 2 L min⁻¹). For more information on the development of these cyclone inlets, see:

Volckens, J., Quinn, C., Leith, D., Mehaffy, J., Henry C.S., Miller-Lionberg, D. Development and evaluation of an ultrasonic personal aerosol sampler, *Indoor Air*, 2017, 27(2), 409-416, <https://doi.org/10.1111/ina.12318>.

The final cutpoint of the GEN2 PM_{2.5} 1 L min⁻¹ inlet remains at 2.5 μm whether this inlet is used without or with the pre-cyclone impactor (Figure 7). The pre-cyclone impactor alone has a cutpoint of approximately 5.4 μm .



Figure 5. PM_{2.5} inlets that have been sold by Access Sensor Technologies. PM_{2.5} inlets that are designed to operate at 1 L min⁻¹ have aluminum caps that are anodized black [(a) and (b) above]. PM_{2.5} inlets that are designed to operate at 2 L min⁻¹ have aluminum caps that are anodized green [(c) above].

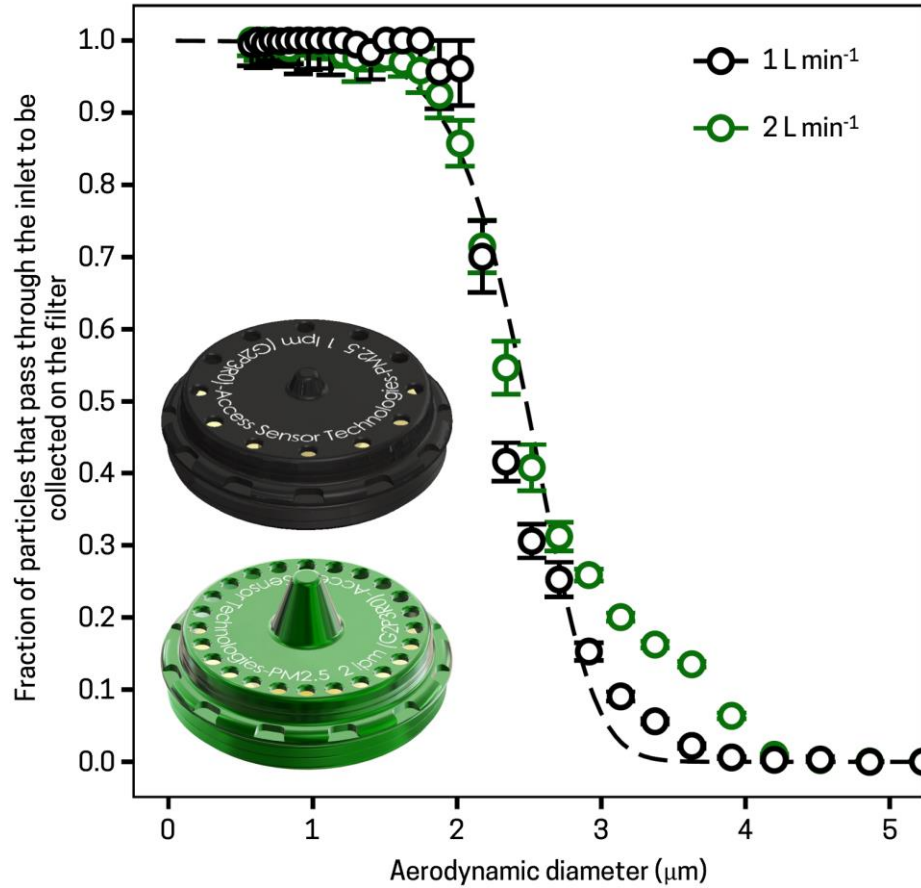


Figure 6. Rates at which 0.5- to 5- μm particles pass through the $\text{PM}_{2.5}$ 1 L min^{-1} inlet (with the G2P3R1 cyclone insert; black points) and the $\text{PM}_{2.5}$ 2 L min^{-1} inlet (green points) compared to the U.S. EPA definition of $\text{PM}_{2.5}$ (dashed line). The experimental data points shown here were measured using oil mist aerosol and a TSI Aerodynamic Particle Sizer® (APS™) 3321. Images of the GEN2 $\text{PM}_{2.5}$ inlets are inset in the graph; the 1 L min^{-1} inlet cap is anodized black and the 2 L min^{-1} inlet cap is anodized green.

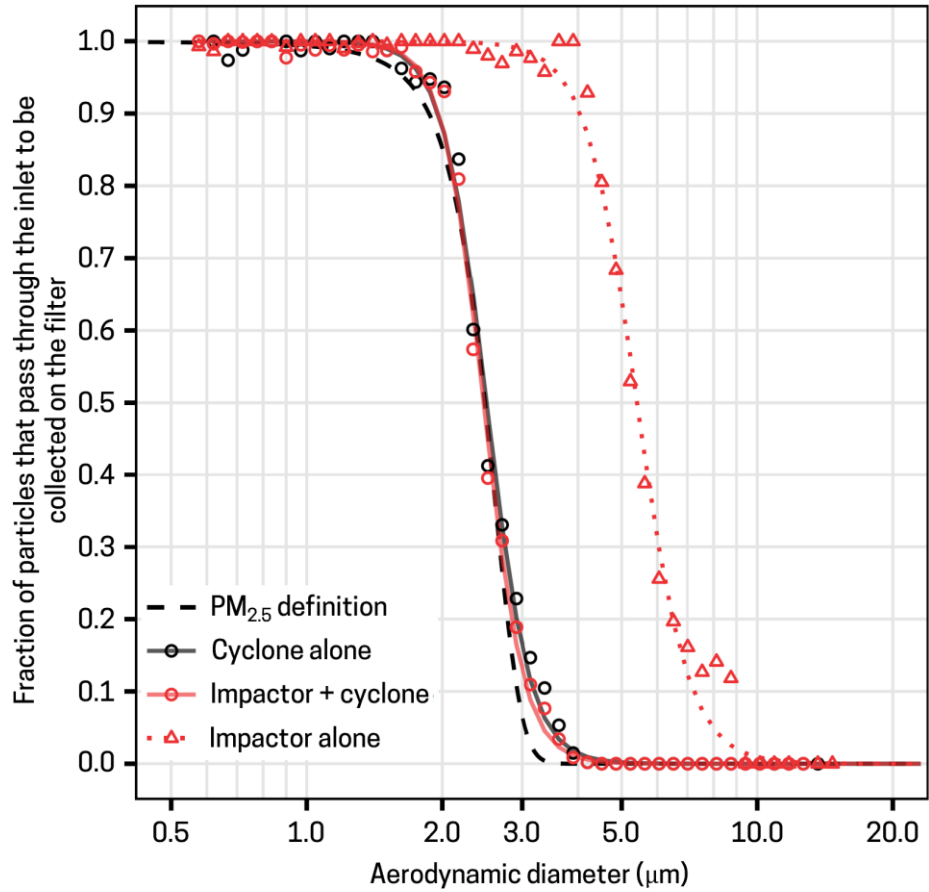


Figure 7. Rates at which 0.5- to 15- μm particles pass through the GEN2 $\text{PM}_{2.5}$ 1 L min^{-1} cyclone alone (with the G2P3R1 insert and *without* the pre-cyclone impactor installed; black circles and solid black line), the GEN2 $\text{PM}_{2.5}$ 1 L min^{-1} inlet with the pre-cyclone impactor installed (red circles and solid red line), and the pre-cyclone impactor alone (red triangles and dotted red line) compared to the U.S. EPA definition of $\text{PM}_{2.5}$ (dashed black line). Circular and triangular markers represent experimental data points measured using a polydisperse oil mist test aerosol and a TSI Aerodynamic Particle Sizer[®] (APS[™]) 3321. The solid and dotted lines represent logistic curves fit to the measurements.

Respirable

Our respirable inlet is designed to allow particles to pass through and reach the filter in a manner consistent with the ACGIH and ISO definition of respirable dust (Figure 8). This inlet is designed to have 50% penetration efficiency at an aerodynamic diameter of 4 μm when operated at 2 L min^{-1} . For information on the design concept behind the respirable inlet, which uses cyclonic separation and impaction in parallel, see:

Leith, D., L'Orange, C., Mehaffy, J., Volckens, J. Design and performance of UPAS inlets for respirable and thoracic mass sampling, *Journal of Occupational and Environmental Hygiene*, 2020, 17(6), 274-282, <https://doi.org/10.1080/15459624.2020.1741595>.

The production version of the respirable inlet, which shown in Figure 8, features a somewhat different implementation of the design concept than is depicted in the publication linked above.

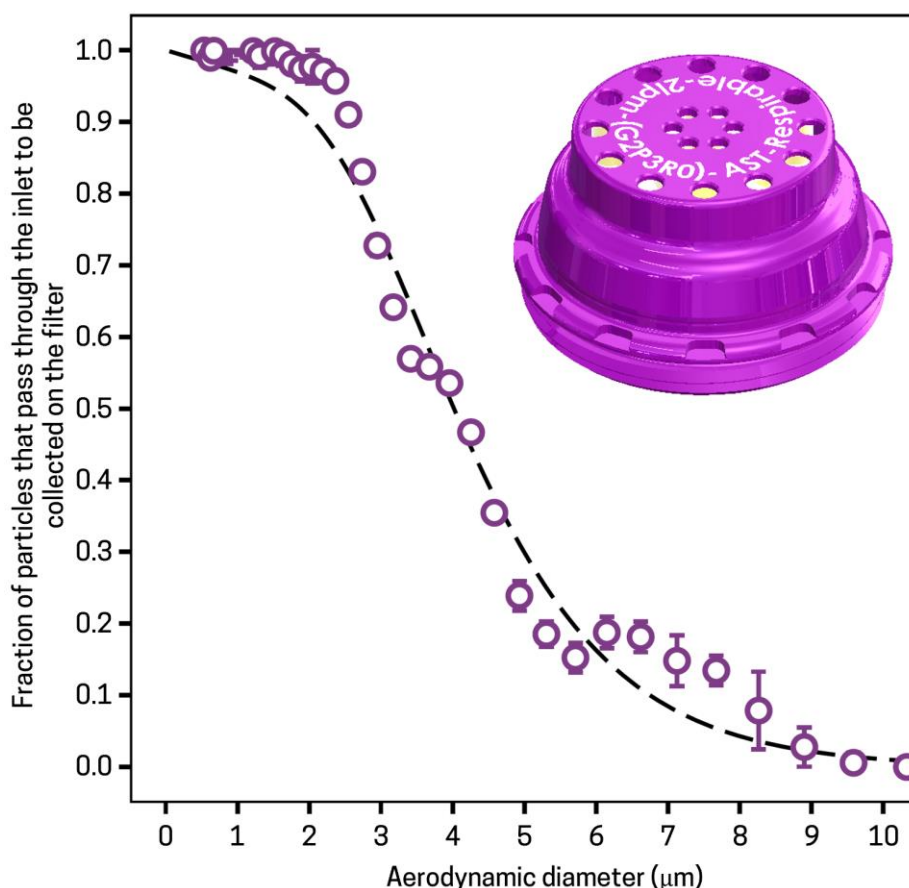


Figure 8. Rates at which 0.5- to 10- μm particles pass through the respirable inlet at 2 L min^{-1} (points) compared to the ACGIH and ISO definition of respirable dust (dashed line). The experimental data points shown here were measured using oil mist aerosol and a TSI Aerodynamic Particle Sizer® (APS™) 3321. An image of the GEN2 respirable inlet is inset in the graph. This inlet has an aluminum cap that is anodized purple.

PM₁₀/Thoracic

Our PM₁₀/Thoracic inlet is designed to allow particles to reach the filter in a manner consistent with the U.S. EPA definition of PM₁₀ and the ACGIH definition of the thoracic fraction (Figure 9). This inlet includes a circular slot impactor that is designed to have 50% penetration efficiency at an aerodynamic diameter of 10 μm when operated at 2 L min⁻¹. For more information on the design of this inlet, see:

Leith, D., L'Orange, C., Mehaffy, J., Volckens, J. Design and performance of UPAS inlets for respirable and thoracic mass sampling, *Journal of Occupational and Environmental Hygiene*, 2020, 17(6), 274-282, <https://doi.org/10.1080/15459624.2020.1741595>.

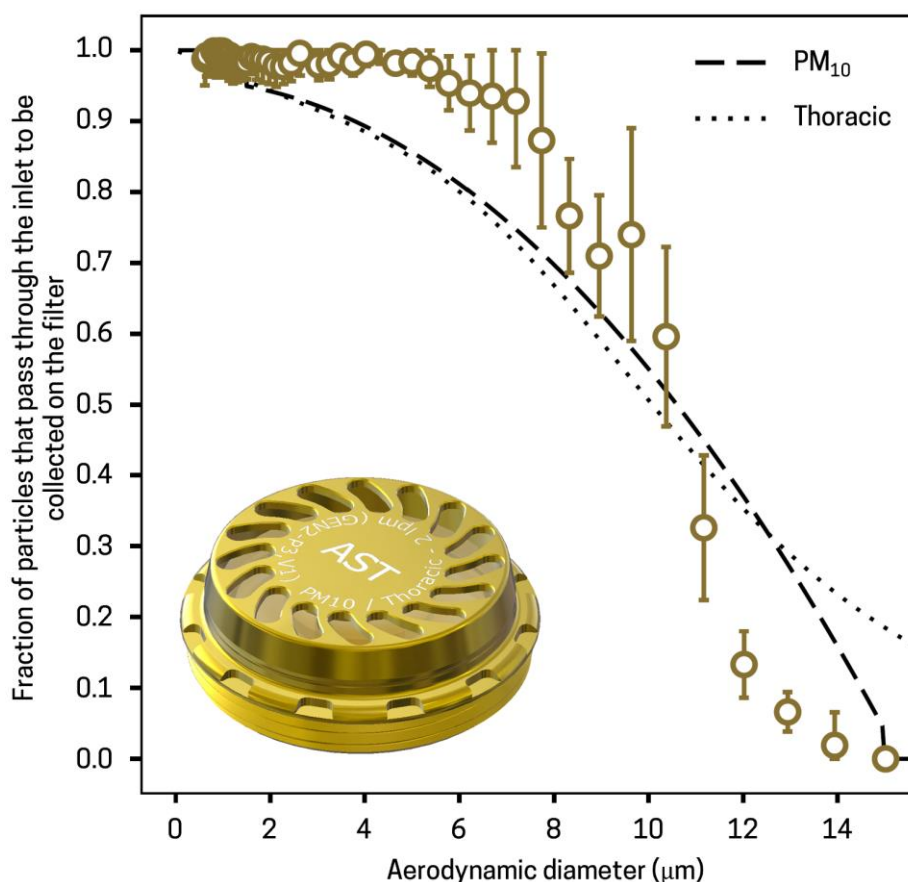


Figure 9 Rates at which 0.5- to 15- μm particles pass through the PM₁₀/Thoracic inlet at 2 L min⁻¹ (points) compared to the US EPA definition of PM₁₀ (dashed line) and the ACGIH definition of the thoracic fraction (dotted line). Experimental data points were measured using oil mist aerosol and a TSI Aerodynamic Particle Sizer® (APS™) 3321.

Some early PM₁₀/Thoracic inlets were produced with aluminum caps that were anodized silver instead of gold. Silver PM₁₀/Thoracic inlets are functionally identical to gold PM₁₀/Thoracic inlets. Silver and gold PM₁₀/Thoracic inlet caps can be used interchangeably.

3 Loading and Unloading the Filter Cartridge

Each filter cartridge consists of an upper half and a lower half (Figure 10). The upper half is equipped with an O-ring that forms an air-tight seal between the upper and lower halves when they are pressed together. Our black GEN1 and yellow GEN2 cartridges are designed to be used with 37-mm-diameter filters. Our blue GEN2 cartridges are designed to be used with 25-mm-diameter filters.

Filter cartridges are typically supplied with a label on the bottom of the lower half that includes a quick-response (QR) code for a unique three-digit alphanumeric identifier. Alternatively, if you or your pre-weighed filter supplier wish to affix your own QR code/alphanumeric identifier labels, the lower half of the filter cartridge can be supplied by AST without a label.

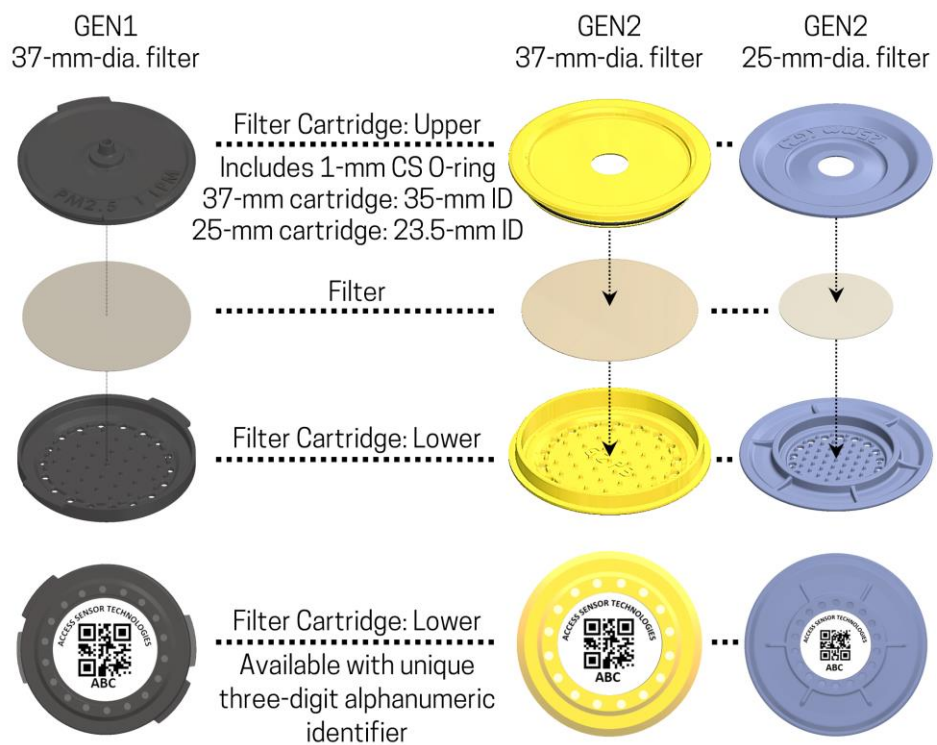


Figure 10. Parts of the GEN1 and GEN2 filter cartridges.

To load a filter into a cartridge, follow the steps illustrated in Figure 11:

- 1 Open the filter cartridge.

GEN1: Pry the offset tabs apart with your fingers to separate the upper and lower cartridge halves.

GEN2: Use any of the following three approaches to separate the upper and lower cartridge halves.

- a) Insert the cartridge opening tool between the upper and lower flanges and then twist the tool as shown in Figure 11.
 - b) Insert the edge of a pair of tweezers into the gap between the top edge of the lip on the lower cartridge half and the bottom edge of the flange on the upper cartridge half. Use the edge of the tweezers to pry the upper and lower cartridge halves apart. Then, grab the flanges on the upper and lower halves and pull them apart to separate the two halves completely.
 - c) Pry the flanges on the top and bottom surfaces of the upper and lower halves apart carefully using your fingers.
- 2 Confirm that the black O-ring is installed in the upper cartridge half, fully-seated in the O-ring groove, and in good condition. If the O-ring is damaged, remove it carefully using tweezers. If the O-ring is damaged or missing, replace it with one that meets the specifications below.
- 37-mm cartridges:** 35.0-mm ID × 1 mm Buna-N (70A durometer)
25-mm cartridges: 23.5-mm ID × 1 mm Buna-N (70A durometer)
- 3 Use a clean pair of tweezers to set the filter in the lower cartridge half. Handle filters with clean tweezers only to prevent contamination.
- Our cartridges are designed to be used *without* backing pads; simply place the filter on top of the support pins in the lower cartridge half.
- 4 Center the upper half of the cartridge over the lower half and press the halves back together. Apply pressure evenly all the way around the upper and lower flanges until the upper half is pressed firmly against the filter.

After completing Step 4, make sure the O-ring on the upper cartridge half is no longer visible above the lip on the lower cartridge half. Under certain conditions, this O-ring can be dragged out of its groove when the cartridge halves are pressed back together. If the O-ring is dragged out of its groove, a portion of the O-ring will remain visible in the gap between the two cartridge halves, even after the halves are pressed all the way back together, and the cartridge will not seal properly. If part of the O-ring remains visible after the cartridge halves have been pressed together, re-open the cartridge, press the O-ring back into its groove, press the cartridge halves back together, and re-inspect the gap between the halves to confirm that the O-ring is no longer visible.

Steps 1–4 above are demonstrated in two videos on our YouTube page:

Short: <https://www.youtube.com/shorts/YI4-7fqJuVk>

Full-length: <https://www.youtube.com/watch?v=4XsJvS1rqxY>

To unload a used sample filter from a cartridge:

- 1 Open the filter cartridge as described previously. Lift the upper half of the cartridge straight out of the lower half. Avoid dragging the bottom surface of the upper half over the filter when separating the halves, as this action can damage the sample and filter.
- 2 Use a clean pair of tweezers to grab the outer edge of the filter and lift it up out of the lower half of the cartridge.

Steps 1–2 above are demonstrated in two videos on our YouTube page:

Short: https://www.youtube.com/shorts/3kBUfd_EioQ

Full-length: https://www.youtube.com/watch?v=5cFNx0nAQ_Q

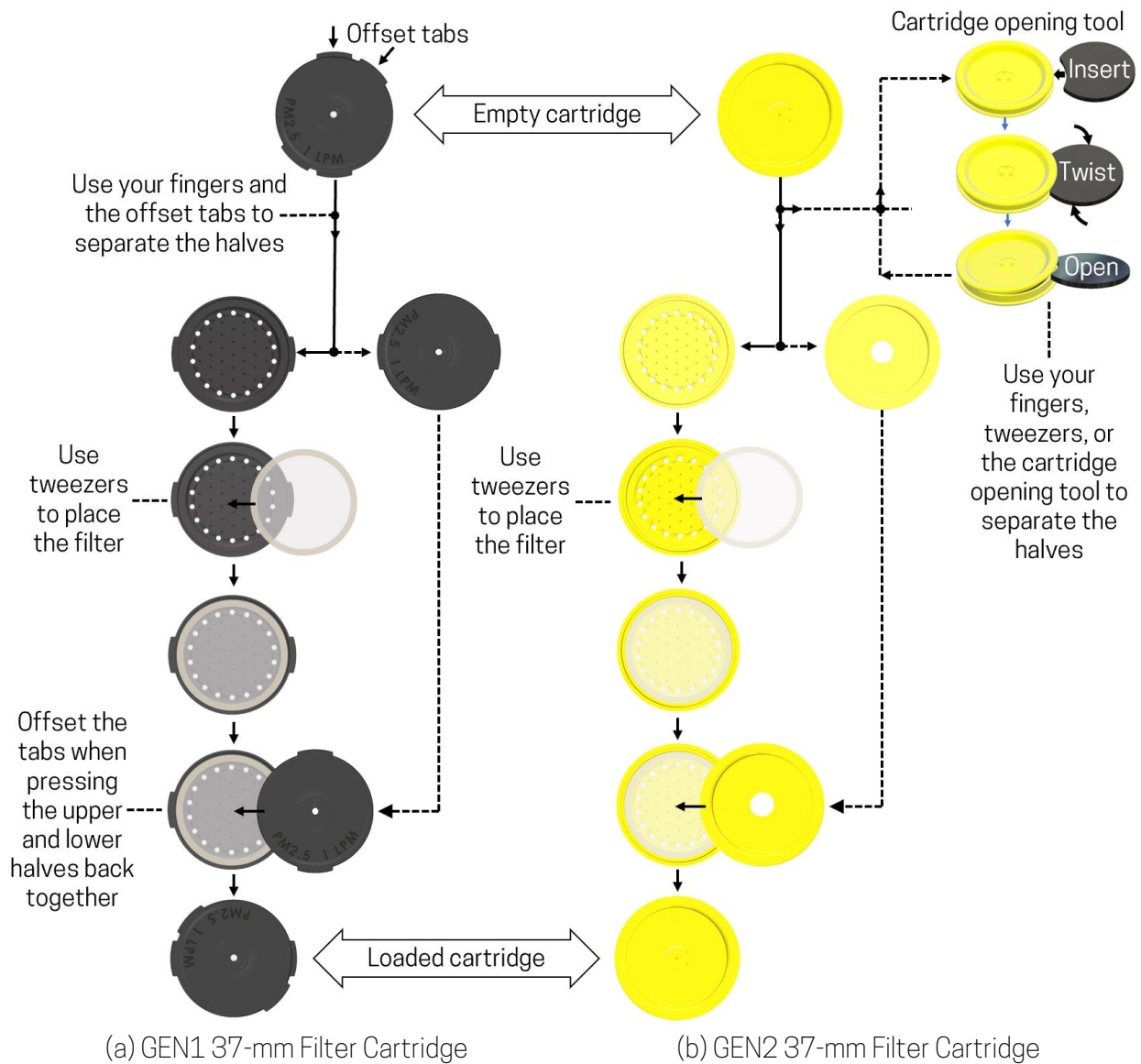


Figure 11. Installing filters in the GEN1 and GEN2 37-mm filter cartridges. For the GEN2 25-mm filter cartridge, follow the instructions for the GEN2 37-mm cartridge.

APPLICATION NOTE: If you are purchasing filters and pre/post sample filter analysis services from an external laboratory, that laboratory might be able to install the filters in the cartridges for you after pre-sample analysis and remove the filters from the cartridges for you before post-sample analysis. This workflow can reduce the risk of sample contamination or damage by reducing the number of times the filter is handled. Contact AST if you need advice on a laboratory that will provide these services.

4 Using the Flow Check Adapter

A “flow check adapter” is used to connect an external flow meter to the inlet of a UPAS or HHB for the purpose of verifying the flow rate through the sampler. We recommend that all users purchase a flow check adapter and verify filter sample flow rates against a reference flow meter regularly.

To get accurate measurements of sample flow rate, it’s important to make sure the flow check adapter O-ring (Figure 12) forms an air-tight seal at the sampler inlet. Before using a flow check adapter, confirm that this O-ring is present, seated properly in the appropriate groove, and in good condition. If the O-ring is damaged (e.g., if the surface is frayed or nicked), remove it carefully with tweezers. Replace damaged or missing O-rings in accordance with the specifications shown in Figure 12 and Table 1. Press down evenly around the circumference of the O-ring to seat a new O-ring or re-seat an existing O-ring.



(a) GEN1 Flow Check Adapter 20-mm ID × 1-mm CS Viton™ (75A) (b) GEN2 Flow Check Adapter 43-mm ID × 1.5-mm CS Buna-N (70A)

Figure 12. Locations and specifications of the flow check adapter O-rings.

To check the flow rate through a sampler when using a GEN1 PM_{2.5} 1 L min⁻¹ inlet, remove the inlet and screw down the GEN1 flow check adapter, in place of the inlet, so that the adapter seals to the top of the GEN1 filter cartridge as shown in Figure 13. The GEN1 filter cartridge must be installed behind the GEN1 flow check adapter.

GEN2 inlets do *not* need to be removed to install the GEN2 flow check adapter and connect the sampler an external flow meter. The GEN2 flow check adapter seals over any GEN2 inlet so that the flow rate through the inlet and filter cartridge can be checked with the sampler fully-assembled. Center the adapter over the inlet and align the tabs on the bottom of the adapter with the 12 pockets in the top of the inlet; then, press the adapter down until the tabs bottom out in the pockets and the O-ring inside the adapter seals to the groove around the circumference of the cap (Figure 14).

Once the flow check adapter is installed, connect the barb on the adapter to a flow meter using flexible tubing (e.g., silicone, Tygon®, Viton™) with a ¼” (6.35 mm) ID and a 1/16” to 3/32” (1.6 to 2.4 mm) wall thickness.

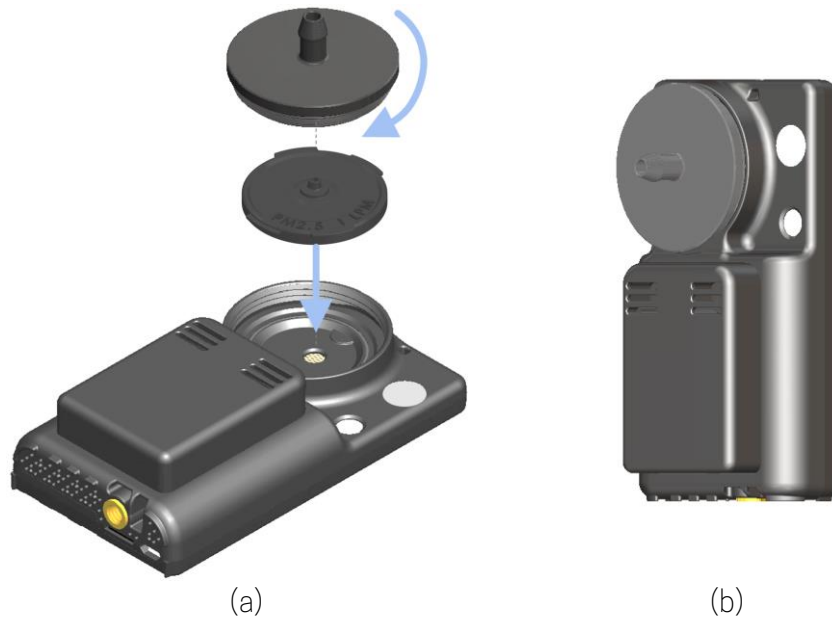


Figure 13. (a) Installing the GEN1 flow check adapter, in place of the GEN1 PM_{2.5} 1 L min⁻¹ inlet, on a UPAS. (b) With the flow check adapter fully installed.

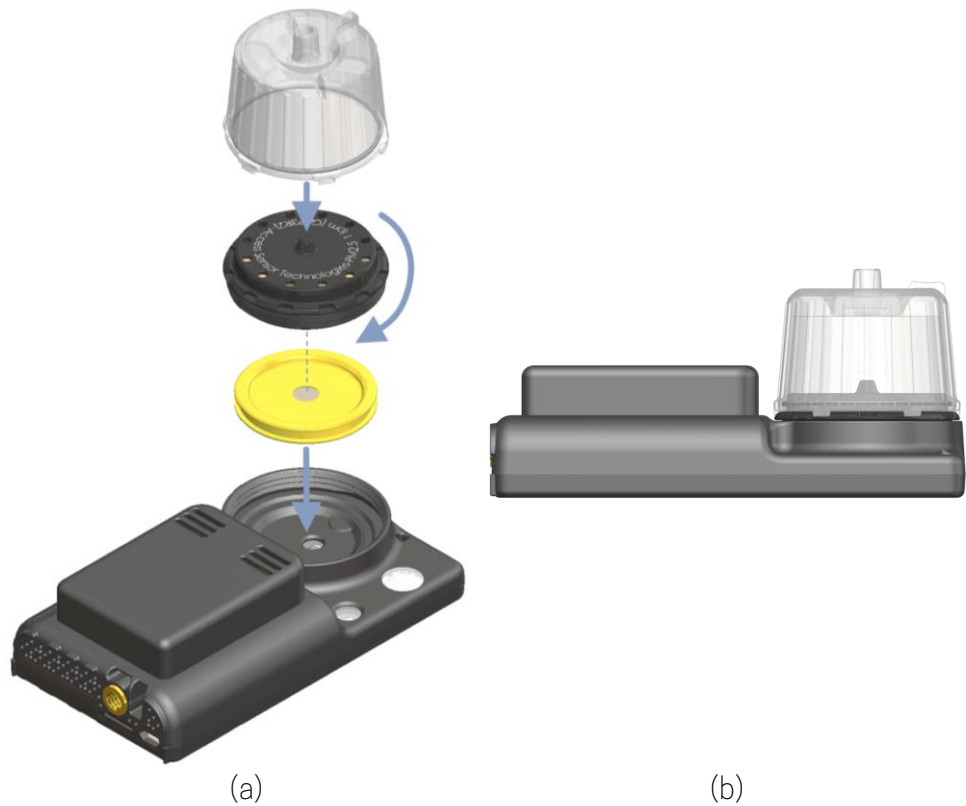


Figure 14. (a) Installing the GEN2 flow check adapter over the GEN2 PM_{2.5} 1 L min⁻¹ inlet on a sampler. (b) With the flow check adapter fully installed.

Checking the flow check adapter O-ring seal

If the flow check adapter O-ring is missing, unseated, damaged, or worn, air can leak around the adapter and, as a result, your flow meter will measure a flow rate that is *lower than* the actual sample flow rate. If air is leaking around your flow check adapter and you adjust your sampler flow rate until your flow meter reports your target flow rate, your actual sample flow rate will be *higher than* your target and you will oversample; therefore, it's important to maintain your flow check adapter so that the O-ring will form an air-tight seal around an inlet.

The following are signs that your flow check adapter might be leaking:

- Your measured sample flow rate is less than 96% of the target value. AST samplers are calibrated at the time of manufacture to control the sample flow rate to $\pm 4\%$ of the target. If you measure a sample flow rate $< 96\%$ of the target, it's possible that: (a) your flow check adapter is leaking, (b) the pressure drop across your sample medium (filter) is too high, or (c) your sampler needs to be repaired or recalibrated by AST.
- Pressing gently on the flow check adapter with your hand causes a substantial change in the measured flow rate.

You can use the following procedure to test whether a GEN2 flow check adapter is forming an air-tight seal around a GEN2 inlet:

- 1 Install the flow check adapter over the inlet as shown in Figure 14 and connect a tube to the barb on the adapter.
- 2 Press the threaded end of the inlet firmly against your palm, so that your palm forms a seal over the bottom of the aluminum inlet cap. It will be easier to seal over the bottom of the cap if your palm is damp.
- 3 On the end of the tube that is not connected to the flow check Adapter, pull a vacuum of up to 50 kPa (15 in. Hg) using a hand-actuated vacuum pump (e.g., Mityvac®; not sold by AST). If you don't have a hand-actuated vacuum pump, you can pull a slight vacuum by sucking air out of the tube with your mouth.
- 4 Check the gauge on the vacuum pump and/or see if you can feel the vacuum pulling against your palm. If the vacuum holds steady or leaks down slowly over >10 s and/or you can feel the vacuum pulling against your palm, the flow check adapter is forming an air-tight seal around the inlet. If the vacuum leaks down quickly over < 10 s and/or you can't feel the vacuum pulling against your palm, the flow check adapter O-ring is not sealing around the inlet.

If the flow-check adapter O-ring is not sealing, re-seat or replace the adapter O-ring and then repeat Steps 1–4 above. If the flow-check adapter O-ring still does not seal after being replaced, contact AST for assistance.

5 Using the Pre-Cyclone Impactor

Size-selective PM sampling inlets are designed to reject particles with aerodynamic diameters larger than the target cutpoint while allowing particles smaller than the cutpoint to pass through. Particles that pass through one of our size-selective inlets will be collected on the sampling filter. It is possible for any size-selective inlet to become so overloaded with rejected particles that the inlet fails to function as intended and allows particles larger than the target cutpoint to pass through. If that happens, the sample will no longer be a valid representation of the intended particle size fraction.

A “pre-cyclone impactor” can be installed in our GEN2 PM_{2.5} 1 L min⁻¹ inlet to reduce the likelihood of that inlet becoming overloaded and failing—especially when sampling in highly-polluted, dusty environments. Use of the pre-cyclone impactor is optional. The overall size-selective performance of the GEN2 PM_{2.5} 1 L min⁻¹ inlet remains the same whether or not the inlet is used with the pre-cyclone impactor (see Figure 7). Use of the pre-cyclone impactor makes the inlet more resistant to overloading but also requires the user to complete additional steps when preparing the inlet for sampling and cleaning the inlet after sampling. If you find that the GEN2 PM_{2.5} 1 L min⁻¹ inlet becomes overloaded often in your sampling application, we recommend using the pre-cyclone impactor. If the GEN2 PM_{2.5} 1 L min⁻¹ inlet never or rarely becomes overloaded in your sampling application, using the inlet without the pre-cyclone impactor will reduce the amount of labor required to collect each sample.

When the pre-cyclone impactor is installed, the GEN2 PM_{2.5} 1 L min⁻¹ inlet becomes a multi-stage inlet consisting of a multi-stage impactor (with a final-stage cutpoint of 5.4 μm) followed by the original cyclone (with a cutpoint of 2.5 μm). The pre-cyclone impactor consists of two components: (1) a white plastic “impactor insert” and (2) a porous sintered stainless-steel “impaction substrate” (Figure 15).

When the pre-cyclone impactor is installed, the GEN2 PM_{2.5} 1 L min⁻¹ inlet removes particles from the airflow in the four steps illustrated in Figure 15:

Step 1: After entering the inlet through the holes in the cap, large particles are removed from the flow via impaction on the top of the impactor insert. This step constitutes the 1st impaction stage.

Step 2: As air passes through the textured flow paths on the top of the impactor insert, large grit and fibers either settle out of the flow or impact on the walls.

Step 3: As air flows through the three holes in the impactor insert, particles with aerodynamic diameters > 5.4 μm are removed from the flow via impaction

on the oiled sintered stainless-steel impaction substrate. This step constitutes the 2nd impaction stage.

Step 4: Air flows through the cyclone, where particles with aerodynamic diameters > 2.5 μm are removed from the flow.

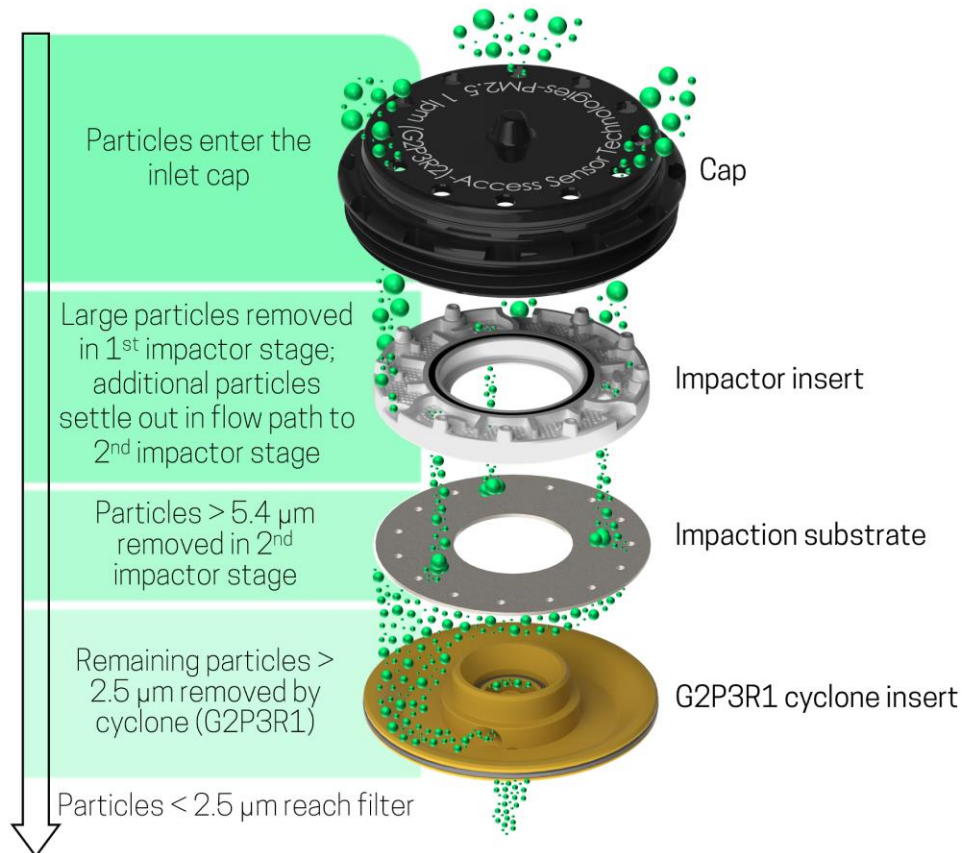


Figure 15. An overview of how the GEN2 PM_{2.5} 1 L min⁻¹ inlet is assembled and functions with the optional pre-cyclone impactor. The pre-cyclone impactor consists of two parts: the impactor insert and the impaction substrate.

The pre-cyclone impactor can only be used with a GEN2 PM_{2.5} 1 L min⁻¹ cyclone insert that has “G2P3R1” etched into the bottom side as shown in Figure 4b, but an older “R0” cyclone insert can be replaced with newer “R1” cyclone insert without replacing the inlet cap. Contact us if you need to purchase a G2P3R1 cyclone insert so that you can install a pre-cyclone impactor in your GEN2 PM_{2.5} 1 L min⁻¹ inlet.

To use the GEN2 PM_{2.5} 1 L min⁻¹ inlet with the pre-cyclone impactor: (a) oil the impaction substrate, (b) optionally oil the 1st-stage impaction and grit settling surfaces on the top of the impactor insert, and then (c) install the impactor insert and impaction substrate in the inlet. Instructions for completing each of these tasks are provided below.

Oiling the impaction substrate

The stainless-steel impaction substrate must be oiled so that particles will stick to it. We oil all impaction substrates before they leave our manufacturing facility; however, we recommend replenishing the oil on the impaction substrate regularly using Super Lube® Silicone Oil with 100 cSt viscosity: <https://www.super-lube.com/silicone-oil>.

To re-oil the impaction substrate, set the part on a lint-free cloth and apply 3 small oil drops around one side at evenly-spaced ($\sim 120^\circ$) intervals as shown in Figure 16. Let the substrate sit for 2 minutes to allow the sintered stainless steel to absorb the oil; then, use a lint-free cloth to wipe away excess oil.



Figure 16. Where to add oil to the stainless-steel impaction substrate.

Oiling the impactor insert (optional step)

If desired, you may apply a tiny amount of the same 100 cSt silicone oil to the 1st-stage impaction and grit settling surfaces on the top of the impactor insert. These surfaces are shaded red and blue, respectively, in Figure 17. Applying oil to these surfaces might help retain large particles and fibers so that they don't break through the PM_{2.5} inlet, but also imposes additional steps in the inlet preparation and cleaning processes.

To oil the impactor insert, place one small drop of oil onto the tip of a foam swab, then use the swab to distribute the oil over the surfaces shaded red and blue in Figure 17. One drop of oil should be sufficient to oil up to three impactor inserts. Only a very thin layer of oil—similar to a fingerprint—should be applied to the surfaces indicated in Figure 17. If oil pools between the bumps on the grit settling surfaces, then too much oil has been applied; dab the impactor insert with a clean, dry swab or lint-free cloth to soak up any excess oil. Do not apply oil to the bottom of the impactor insert or to any other surfaces besides those shaded in red and blue in Figure 17.

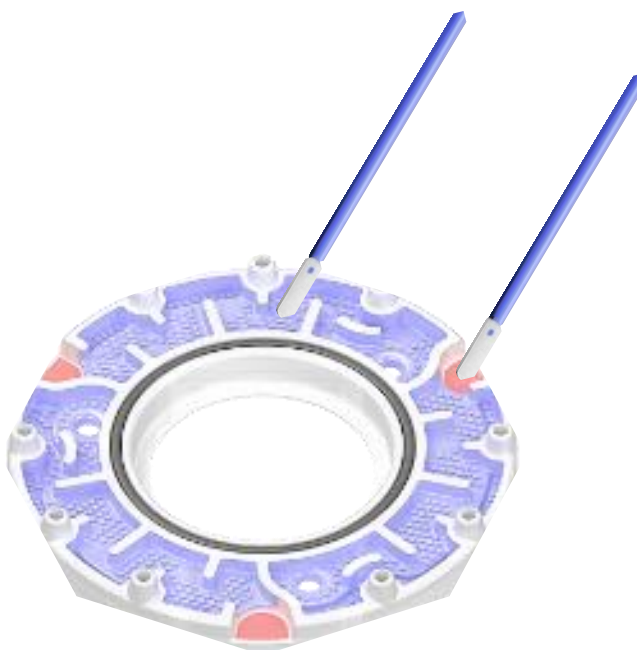


Figure 17. You may optionally apply a thin layer of oil to the 1st-stage impaction surfaces (red) and large grit settling areas (blue) on the top of the impactor insert.

Installing the pre-cyclone impactor in the PM_{2.5} 1 L min⁻¹ inlet

To install the pre-cyclone impactor in a GEN2 PM_{2.5} 1 L min⁻¹ inlet, follow the steps in Figure 18:

- 1 Invert the inlet cap and impactor insert. Align the posts on the top of the impactor insert with the holes in the cap and lower the impactor insert into the cap. You might need to rotate the impactor insert a bit until the posts line up with the holes and drop in.
- 2 Set the impaction substrate down on the impactor insert with the oiled side facing the impactor insert. The impactor substrate can be oriented in any angular position (i.e., it does not have to be indexed or rotated any certain way within the cap).
- 3 Place the cyclone insert into the cap, with the cyclone body facing the impaction substrate and the engraved side facing up; then press the cyclone insert and cap together by pressing firmly all the way around the outer diameter of the insert.

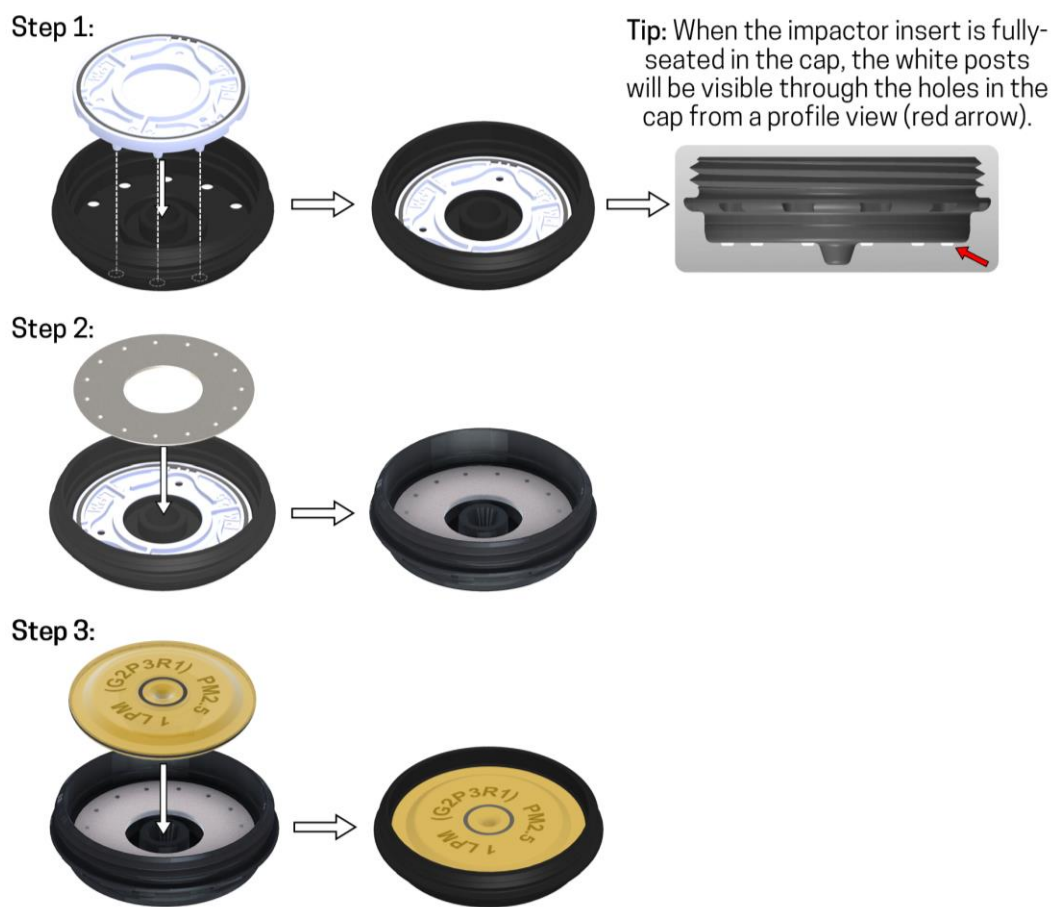


Figure 18. Installing the pre-cyclone impactor in the GEN2 PM_{2.5} 1 L min⁻¹ inlet.

After completing Steps 1-3, verify that the impactor insert, impaction substrate, and cyclone insert are all retained in the cap when the inlet is flipped over. If they are not all retained in the cap, try pressing the insert and cap together firmly all the way around the outer diameter of the insert again.

APPLICATION NOTE: If you have assembled the inlet correctly using Steps 1-3 but cannot get the insert to “stick” in the cap, you can still install the inlet on a sampler by placing the filter cartridge face-down in the inverted inlet (i.e., with the large hole in the top of the cartridge facing the inlet), holding the sampler (e.g., UPAS) with the inlet socket facing “down” (i.e., towards the ground), and threading the inverted cap and cartridge up into the inlet socket.

Cleaning the pre-cyclone impactor between samples

After each sample, remove the pre-cyclone impactor from the inlet, clean the impactor insert, clean the impaction substrate, re-oil these parts (if needed), and then re-install the pre-cyclone impactor in the inlet for the next sample. See Section 6 Disassembly, Cleaning, and Reassembly for detailed instructions.

6 Disassembly, Cleaning, and Reassembly

Disassembling inlets for cleaning

Most of our size-selective inlets consist of an aluminum *cap* and a single-piece plastic *insert*, with two exceptions:

- 1 The GEN2 PM_{2.5} 1 L min⁻¹ inlet might be used with (a) a single-piece plastic cyclone insert alone or (b) the pre-cyclone impactor (impactor insert + impaction substrate) and the cyclone insert (see Figure 4).
- 2 The GEN2 Respirable 2 L min⁻¹ inlet contains a two-piece insert.

Prior to cleaning an inlet, separate the insert (or insert pieces) from the cap.

GEN1: With one hand, hold the knurled outside edge of the inlet cap so that the bottom side of the inlet is facing up (you should be looking at the threaded end of the cap and the O-ring on the bottom face of the insert). Use your other hand to insert a small flathead screwdriver or a pair of tweezers between the cap and the insert. Gently pry the insert up until it separates from the cap.

GEN2: Either of the following approaches can be used to remove the insert (or insert pieces) from the cap.

- a) Place your hand over the top of the inlet and grip the cap around its circumference. Then, firmly tap the bottom edge of the cap against a smooth, firm, flat surface until the insert falls out.
NOTE: It's a good idea to place a thin piece of rubber or paper on the flat surface to avoid marring the surfaces of the cap.
- b) Insert an embossing stylus (narrow neck with 2-mm ball tip) or the end of a pair of blunt-tipped tweezers through the inlet holes in the top of the cap and press down on the insert until it releases from the cap. Press through multiple holes around the top surface of the cap to ease removal of the insert.

Cleaning

Caps

- 1 Once the insert has been removed from the cap, make sure the inlet holes (on the top surface of the cap), the underside of the cap, and the cyclone cone (if present) are all free of dirt, dust, or other debris (see Figure 19). Clean out the cyclone cone carefully using a small foam swab that has been wet with water, isopropyl alcohol, or ethanol.



- 2 After spot-cleaning as described above, it's a good idea to fully-submerge the cap in water, wash it with a mild detergent (e.g., dish soap), and then rinse it with clean water. If clean running water is not readily available, each inlet cap can be wiped down using a lint-free wipe wet with water, isopropyl alcohol, or ethanol.

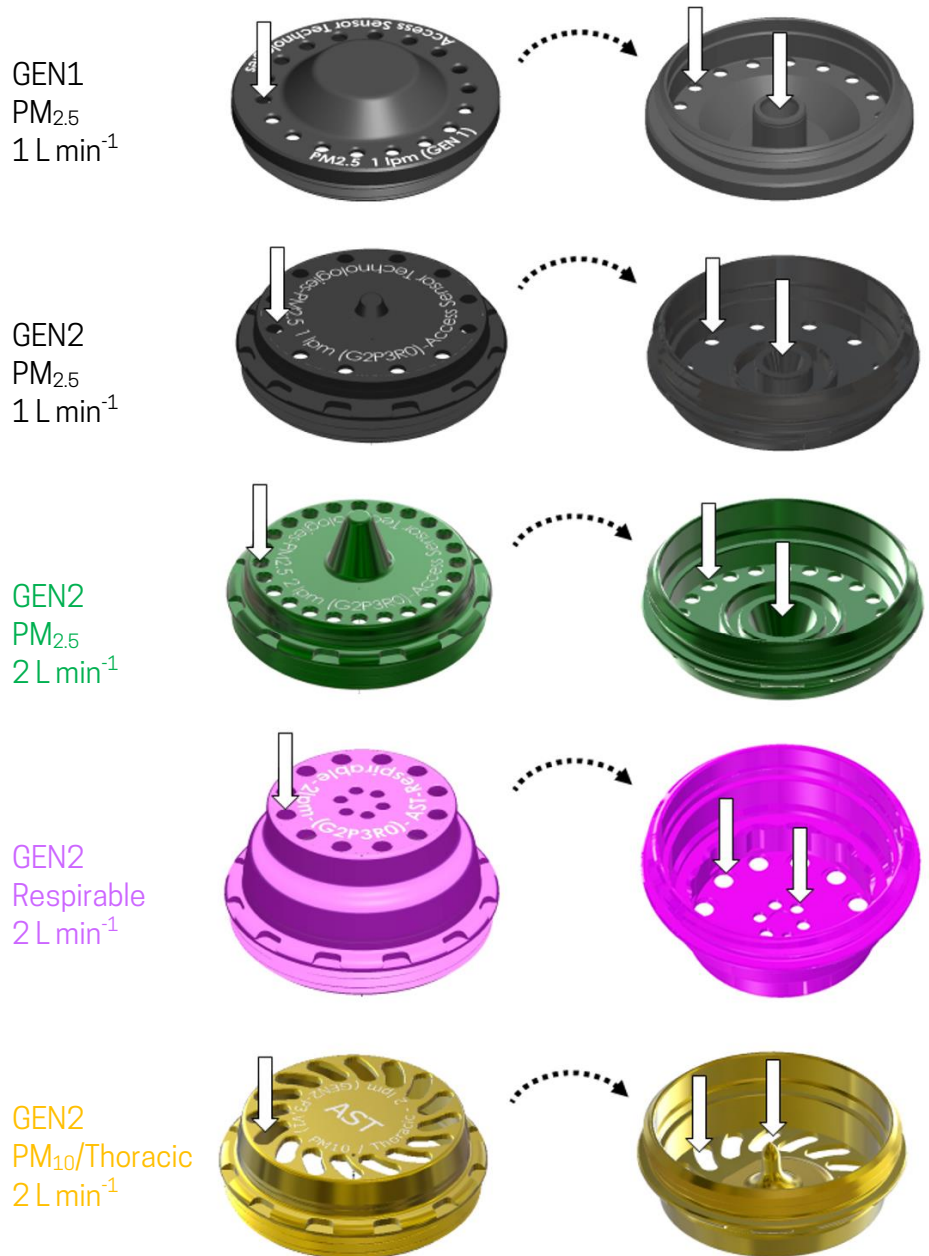


Figure 19. When cleaning the aluminum caps, pay special attention to the inlet holes, the cyclone cone (if present), and any other features indicated with white arrows here.

Inserts

To clean the inserts shown in Figure 20:

- 1 Use a conical foam swab wet with water, isopropyl alcohol, or ethanol to clean out the cyclone body (if present), inlet, and outlet. Insert the swab into the inlet and outlet holes and twist gently to remove dirt, dust, and debris. Then, visually inspect the inlet and outlet holes to confirm that they are clear and clean.

The respirable insert consists of two pieces. Grab the outermost flange on each piece and pull them apart for cleaning. On the upper portion of the respirable insert, gently insert and twist a conical swab into (a) the four holes on the raised columns (red arrows), (b) the six holes in the flange (black arrows), and (c) the two holes in the cyclone cone (yellow arrows). Repeat this step from the top and bottom of the piece. Then, visually inspect all holes to make sure they are clear of debris. On the lower portion of the respirable insert, wipe off the six impaction platforms (black arrows) with a damp swab or lint-free wipe.

Wipe off the top surface of the PM₁₀ insert (indicated by the purple arrow in Figure 20) with a damp swab or lint-free wipe.



- 2 After completing Step 1, it's a good idea to submerge the insert in water, wash it with a mild detergent (e.g., dish soap), and then rinse it with clean water. Alternatively, the insert can be wiped down using a lint-free wipe wet with water, isopropyl alcohol, or ethanol.

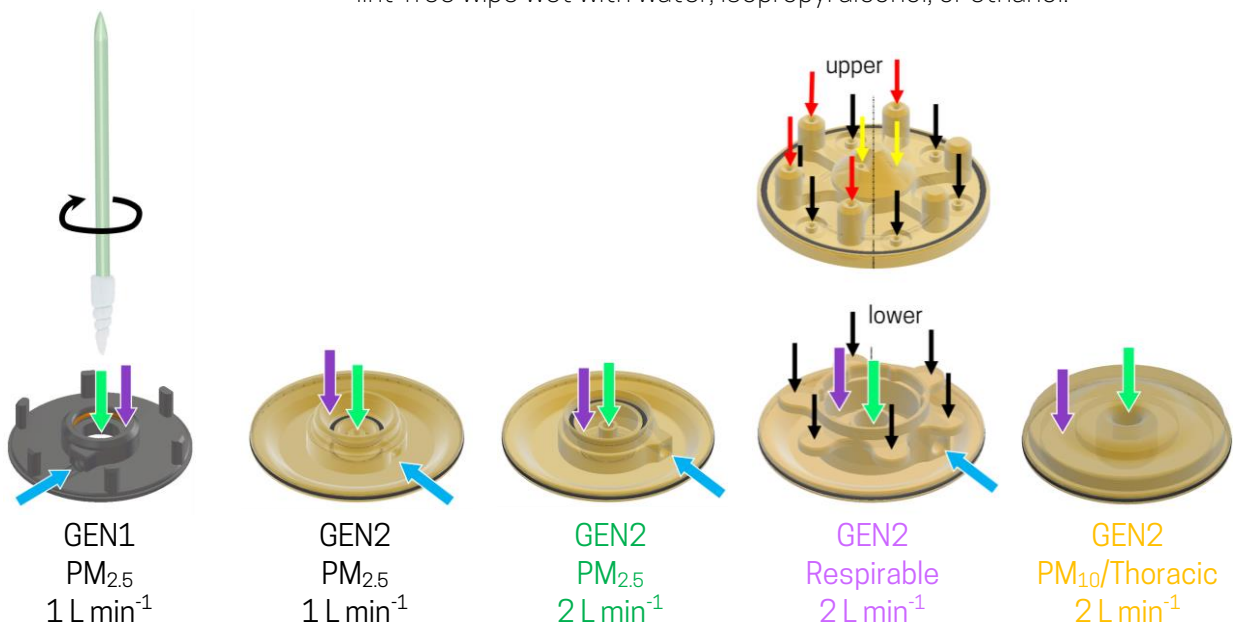


Figure 20. Use a conical foam swab wetted with water, isopropyl alcohol, or ethanol to clean out the cyclone body (purple arrows), inlet (blue arrows), and outlet (green arrows) on each insert. On the upper portion of the respirable insert, clean out the four holes in the top of the raised columns (red arrows), the six holes in the flange (black arrows), and the two holes in the cyclone cone (yellow arrows). On the lower portion of the respirable insert, clean off the six impaction platforms (black arrows). On the PM₁₀ insert, wipe off the top surface (purple arrow).

To clean the GEN2 PM_{2.5} 1 L min⁻¹ inlet impactor insert:



- We recommend submerging the white plastic impactor insert in water; gently scrubbing off all dirt, dust, fibers, and other debris using a soft-bristled brush (e.g., a toothbrush) and mild detergent (e.g., dish soap); and then rinsing the impactor insert with clean water.
- Alternatively, you can rinse dirt, dust, fibers, and other debris off the impactor insert using a squirt bottle filled with water, isopropyl alcohol, or ethanol.
- If neither of the above is practical in your use case, you can wipe dirt, dust, fibers, and other debris off the impactor insert using a foam swab or a lint-free wipe wet with water, isopropyl alcohol, or ethanol.

To clean the GEN2 PM_{2.5} 1 L min⁻¹ inlet pre-cyclone impaction substrate:

- For routine cleaning, we recommend wiping accumulated particles off the impaction substrate, using a lint-free wipe, after each sample.

Wiping the impaction substrate clean, rather than submerging it in water and washing it with detergent, will help retain oil in the sintered stainless steel and will reduce the frequency at which oil must be reapplied to the substrate as well as reduce the amount of oil that must be applied each time the substrate is re-oiled.

- To deep-clean the substrate, submerge it in water, scrub both sides gently with a soft-bristled brush (e.g., a toothbrush) and mild detergent (e.g., dish soap), and then rinse the substrate with clean water.

After deep cleaning the impaction substrate, allow it to dry. Then, apply 6 small oil drops around one side at evenly-spaced (~60°) intervals and let the substrate sit for 2 minutes while the sintered stainless steel absorbs the oil. Finally, wipe any excess oil off the substrate using a lint-free cloth.

Filter cartridges

Filters containing particulate matter samples are typically weighed to the nearest microgram, so it's important to make sure the filter cartridge—especially the inside surfaces—remains free of dirt, dust, lint, and other debris that could be transferred to the filter. If you see any dirt, dust, lint, or other debris on a filter cartridge, make sure to clean it off.

Separate the upper and lower halves of each filter cartridge for cleaning.



- The best way to clean the cartridge halves is to submerge them in water, scrub them gently with a soft-bristled brush and mild detergent (e.g., dish soap), and then rinse them with clean water.
- Alternatively, you can rinse each cartridge half with water, isopropyl alcohol, or ethanol from a squirt bottle to flush off any small debris.

- In a context where neither of the methods listed above is convenient, you can wipe each cartridge half clean using a foam swab and/or a lint-free wipe wet with water, isopropyl alcohol, or ethanol. If you wipe down the lower cartridge half, be careful not to shred the swab or wipe on the filter supports, as this action could leave debris inside the cartridge to contaminate future filter samples.

Reassembling inlets after cleaning

Before reassembling an inlet after cleaning:

- 1 Allow the cap and insert piece(s) to dry completely.
- 2 Confirm that all O-rings are present, seated in their grooves, and in good condition. See Figure 28 for a diagram illustrating where to check for O-rings. Remove damaged O-rings carefully using tweezers. Replace damaged or missing O-rings in accordance with the specifications listed in Table 1 (see Section 7).

Then, reinstall the insert piece(s) in the aluminum cap as shown in Figure 21.

For the GEN1 PM_{2.5} 1 L min⁻¹ inlet, reinstall the insert in the cap using a twist-and-press motion as shown in Figure 22. The insert will snap into place.

When reassembling the GEN2 PM_{2.5} 1 L min⁻¹ inlet *without* the pre-cyclone impactor, the GEN2 PM_{2.5} 2 L min⁻¹ inlet, or the GEN2 PM₁₀ inlet, press the insert straight up into the cap, by pressing up evenly around the bottom surface of the insert flange, until it hits a hard stop.

When reassembling the GEN2 PM_{2.5} 1 L min⁻¹ inlet *with* the pre-cyclone impactor, follow the instructions in Section 5 and Figure 18.

When reassembling the GEN2 Respirable inlet:

- a) Index the notches and grooves on the upper and lower portions of the respirable insert as shown in Figure 23. Once the upper and lower portions are indexed properly, press them back together.
- b) Align the holes in the cap with the raised columns on the upper portion of the insert as shown in Figure 24(a). Once the two-piece insert is indexed properly, press it up into the cap by applying pressure evenly around the bottom surface of the lower insert flange until it hits a hard stop in the cap. When the inlet is assembled correctly, the insert will sit below the bottom edge of the cap as shown in Figure 24(b).

IMPORTANT! When an inlet is assembled correctly, the insert piece(s) will be self-retained inside the cap and a brown O-ring will be visible from the bottom of the inlet (Figure 25). If a brown O-ring is not visible on the bottom of the inlet, the insert is installed upside-down or the O-ring has fallen out. In either case, the inlet will not function correctly; reassemble the inlet correctly or replace the O-ring with one that meets the specifications listed in Table 1.

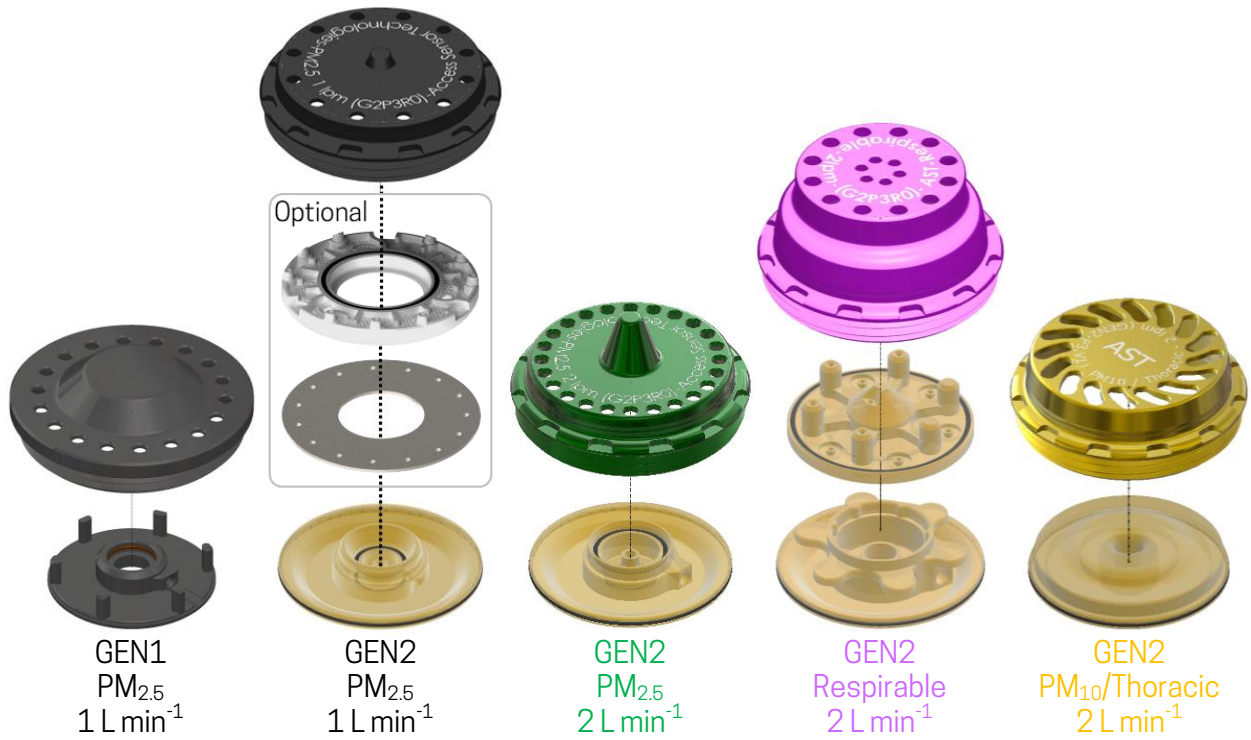


Figure 21. Reassemble each inlet by installing the insert piece(s) into the aluminum cap as shown.

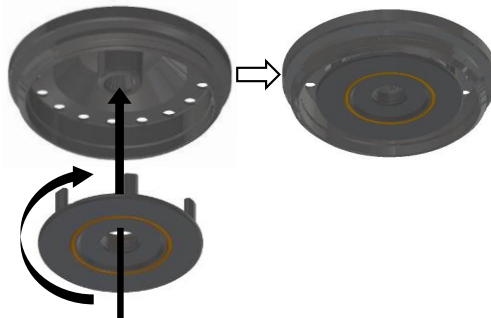


Figure 22. Reassembling the GEN1 PM_{2.5} 1 L min⁻¹ inlet.

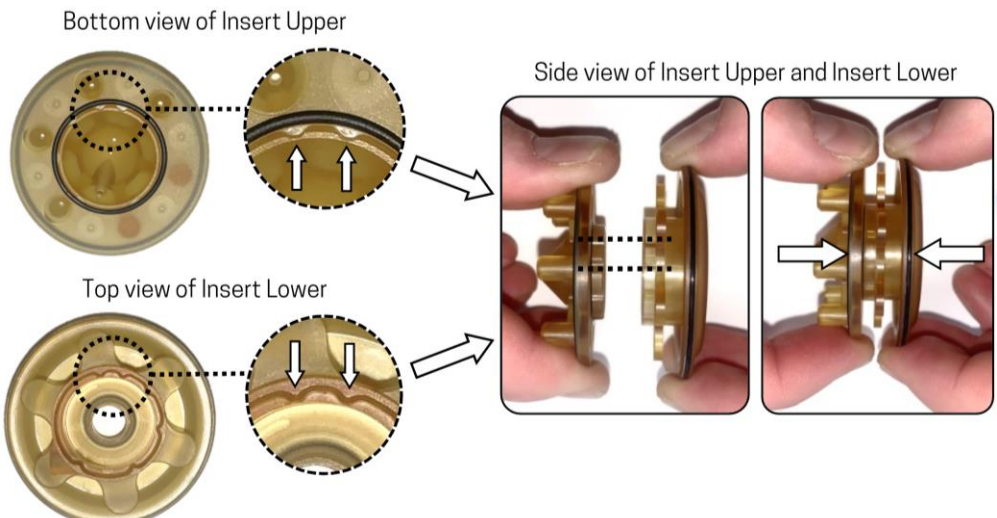


Figure 23. Assembling the lower and upper portions of the GEN2 Respirable 2 L min⁻¹ inlet insert.

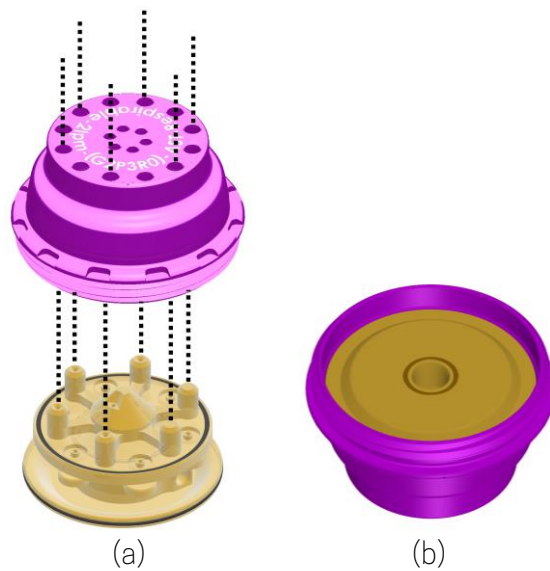


Figure 24. (a) When reinserting the GEN2 Respirable 2 L min^{-1} inlet inserts into the cap, align the raised columns on the upper portion of the insert with the holes in the cap. (b) When the inlet is assembled correctly, the lower insert flange will sit below the bottom edge of the cap as shown.

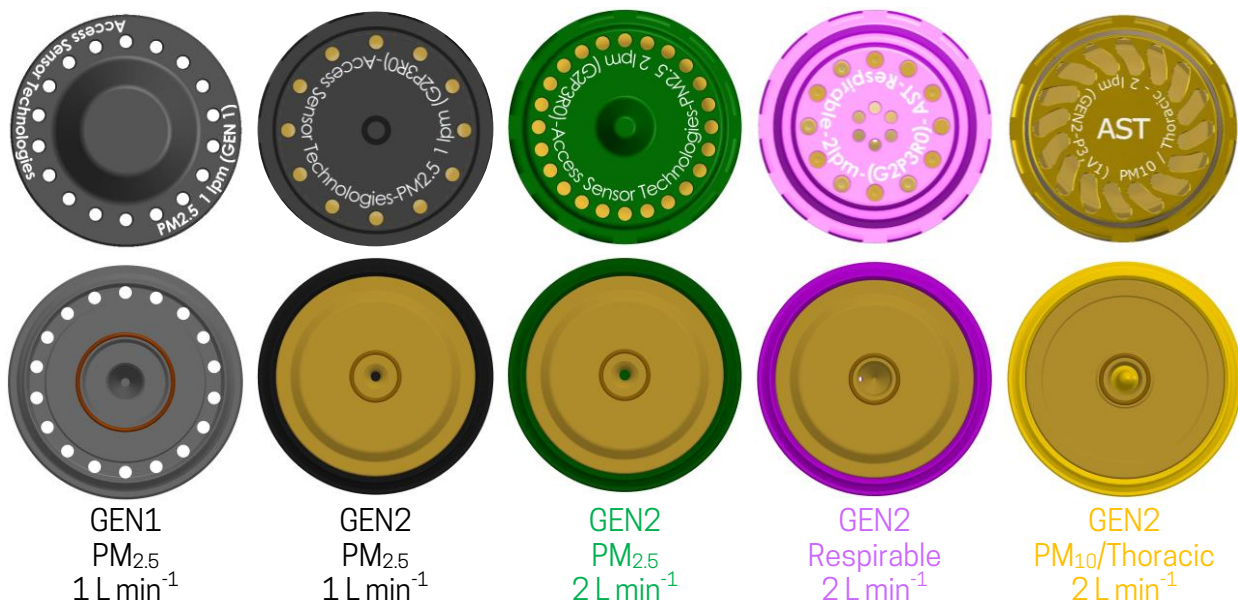


Figure 25. The top and bottom view of each inlet should appear as shown here when the inlet has been assembled correctly.

7 O-ring Replacement

Inspect the O-rings in each filter cartridge (Figure 26), flow adapter (Figure 27), and size-selective inlet (Figure 28) regularly to confirm that all O-rings are present, fully-seated in their grooves, and in good condition. Remove any damaged O-rings carefully using a pair of tweezers. One set of replacement O-rings is included with each filter cartridge, flow adapter, and inlet purchased. Contact AST for additional replacement O-rings. Replace damaged or missing O-rings in accordance with the specifications listed in Table 1.

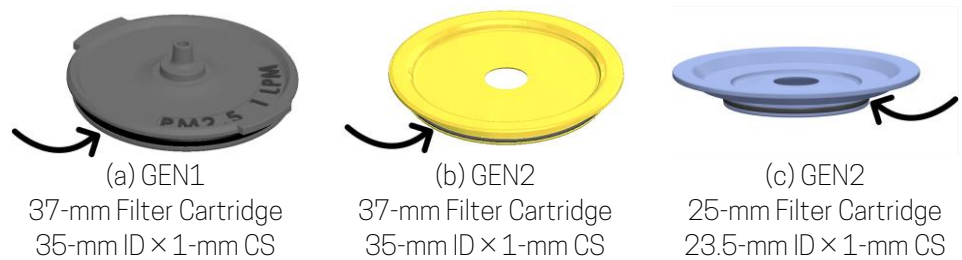


Figure 26. Locations and sizes of the Buna-N (70A durometer) filter cartridge O-rings.

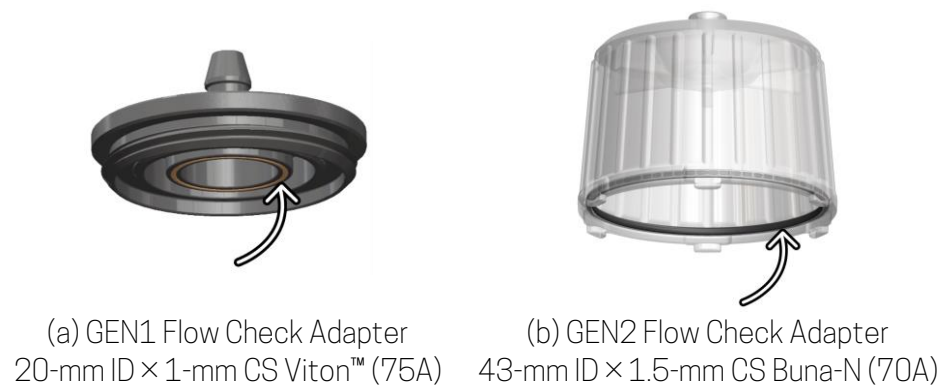


Figure 27. Locations and specifications of the flow check adapter O-rings.



Figure 28. The location of each O-ring in each size-selective inlet.

Table 1. Specifications for replacement O-rings for AST size-selective inlets and accessories. ID = inner diameter; CS = cross section diameter. All O-rings specified here have round cross sections.

Inlet or Accessory	Subcomponent	O-ring location	ID×CS (mm)	Material, color
GEN1 PM _{2.5} 1 L min ⁻¹	Insert	1 Top side	10×1.0	Viton™ (75A), brown
		2 Bottom side	20×1.0	Viton™ (75A), brown
GEN2 PM _{2.5} 1 L min ⁻¹	Impactor insert	1 Top side	22×1.0	Buna-N (70A), black
		2 Bottom side	35×1.0	Buna-N (70A), black
	Cyclone insert	3 Top side	9×1.0	Buna-N (50A), black
		4 Outer edge	39×1.0	Buna-N (70A), black
		5 Bottom side	9×1.0	Viton™ (75A), brown
GEN2 PM _{2.5} 2 L min ⁻¹	Insert	1 Top side	14×1.0	Buna-N (50A), black
		2 Outer edge	39×1.0	Buna-N (70A), black
		3 Bottom side	9×1.0	Viton™ (75A), brown
GEN2 Respirable 2 L min ⁻¹	Insert upper	1 Top side	35×1.0	Buna-N (70A), black
		2 Bottom side	20×1.0	Buna-N (50A), black
	Insert lower	3 Outer edge	39×1.0	Buna-N (70A), black
		4 Bottom side	9×1.0	Viton™ (75A), brown
GEN2 PM ₁₀ /Thoracic 2 L min ⁻¹	Insert	1 Outer edge	39×1.0	Buna-N (70A), black
		2 Bottom side	9×1.0	Viton™ (75A), brown
GEN1 37-mm Filter Cartridge	Upper	Outer edge	35×1.0	Buna-N (70A), black
GEN2 37-mm Filter Cartridge	Upper	Outer edge	35×1.0	Buna-N (70A), black
GEN2 25-mm Filter Cartridge	Upper	Outer edge	23.5×1.0	Buna-N (70A), black
GEN1 Flow Check Adapter		Bottom side	20×1.0	Viton™ (75A), brown
GEN2 Flow Check Adapter		Inside	43×1.5	Buna-N (70A), black

8 Frequently Asked Questions

How often should I clean size-selective PM inlets?

We recommend cleaning size-selective inlets regularly to prevent PM that has accumulated in the inlet from contaminating future samples. The frequency at which an inlet must be cleaned depends on how high the PM concentration is in the environment(s) where the inlet is being used to sample. It's a good idea to clean each inlet after each sample, especially if the inlet was used in a dirty environment and especially if you are using the pre-cyclone impactor with the GEN2 PM_{2.5} 1 L min⁻¹ inlet. We also recognize that cleaning each inlet after each sample might not be feasible in every sampling campaign and might not be necessary in cleaner environments.

We recommend users establish a sample quality assurance protocol that includes a schedule for inlet cleaning, and evaluate the effectiveness of said protocol, before completing a large-scale sampling campaign. The frequency at which cleaning is scheduled should be determined based on: (a) the mass of PM expected to be collected during each sample, (b) field campaign logistics, (c) personnel availability, (d) the requirements of any predefined sampling protocols being used, and (e) the user's own quality assurance goals.

How often should I clean filter cartridges?

We recommend cleaning each filter cartridge after each sample to prevent cross-contamination between samples.

Can I rinse the inlets and filter cartridges with dichloromethane?

No, do not rinse any of the inlet parts or filter cartridges shown in this user guide with dichloromethane.

A note on materials and chemical compatibility: Our inlet caps are machined from aluminum, hard-anodized, and coated with PTFE. The GEN1 PM_{2.5} 1 L min⁻¹ inlet insert, the black GEN1 37-mm filter cartridge, the opaque yellow GEN2 37-mm filter cartridge, and the opaque blue GEN2 25-mm filter cartridge are all molded from Delrin®. The translucent amber GEN2 37-mm filter cartridge and all GEN2 inlet inserts are machined from Ultem™. The GEN1 PM_{2.5} 1 L min⁻¹ pre-cyclone impactor insert is molded from polypropylene; the impaction substrate is cut from sintered stainless steel. These parts can be rinsed with isopropyl alcohol, ethanol, acetone, or hexane.

Should I oil or grease the inlets?

Apply a small amount of Super Lube® 100-cSt Silicone Oil to the GEN2 PM_{2.5} 1 L min⁻¹ pre-cyclone impactor substrate regularly, as described in Sections 5 and 6 above. For routine re-oiling, apply 3 small oil drops, evenly spaced around one side as shown in Figure 16, let the substrate absorb the oil for ~2 minutes, and then wipe any excess oil off the substrate surface using a lint-free cloth.

You may optionally choose to also apply a very thin layer of the same silicone oil to the surfaces of the pre-cyclone impactor insert that are shaded red and blue in Figure 17. Briefly, apply a single drop of silicone oil to a foam-tipped swab and use the swab to coat the indicated surfaces in oil. Dab away any excess oil using a clean, dry swab or lint-free cloth.

When using the GEN2 respirable inlet, you can apply a thin layer of Super Lube® 100-cSt Silicone Oil to the six impaction platforms on the lower portion of the insert (see Figure 20). Clean off and replace this oil each time you clean the inlet. Do *not* apply oil or grease to the inside of the cyclone cone on the respirable inlet. Oil or grease could block the small holes in the cone, which are critical to achieving the correct collection efficiency.



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