SCIENCE. SERVING PEOPLE.

PPI®

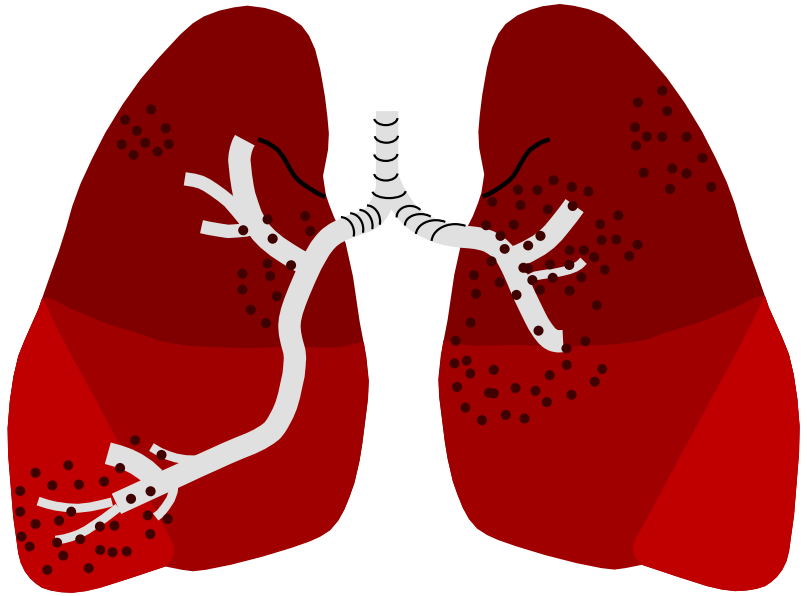
Parallel Particle Impactor

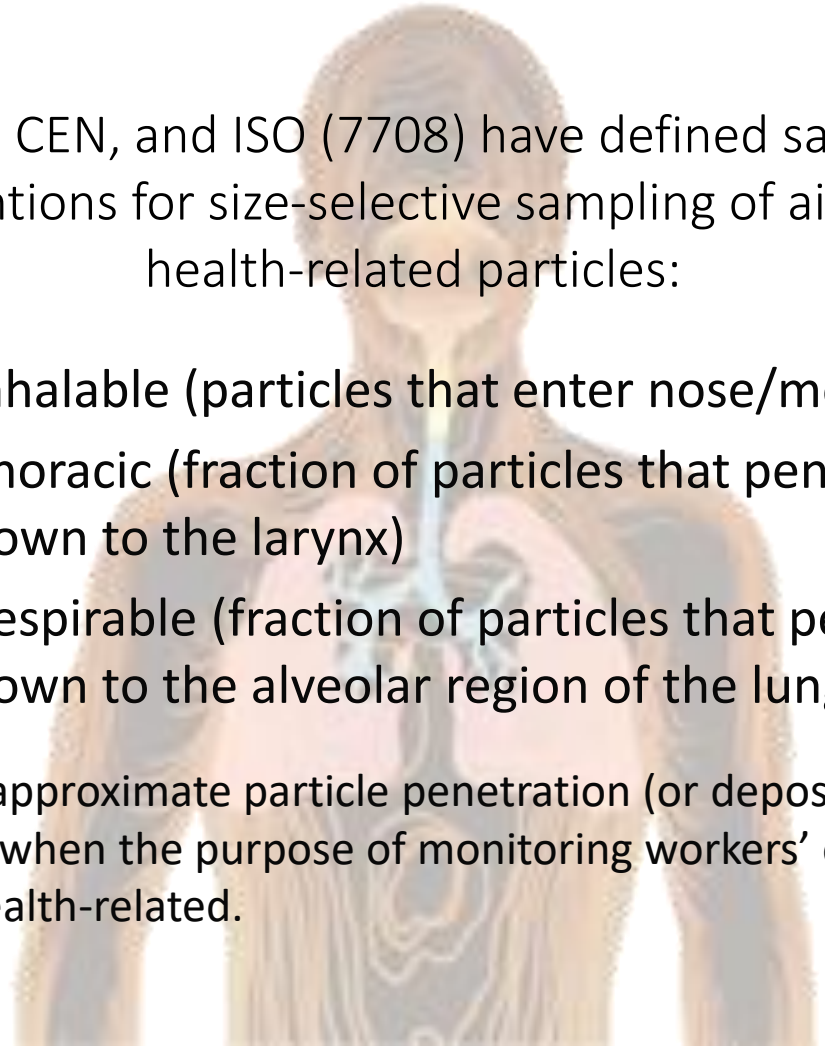
The New Era of Respirable and Thoracic Particulate Sampling

SKC

SIZE CHARACTERISTICS OF AIRBORNE PARTICULATES

Determine the deposition site in the respiratory tract. Smaller particles will tend to deposit deep into the gas exchange region of the lungs.



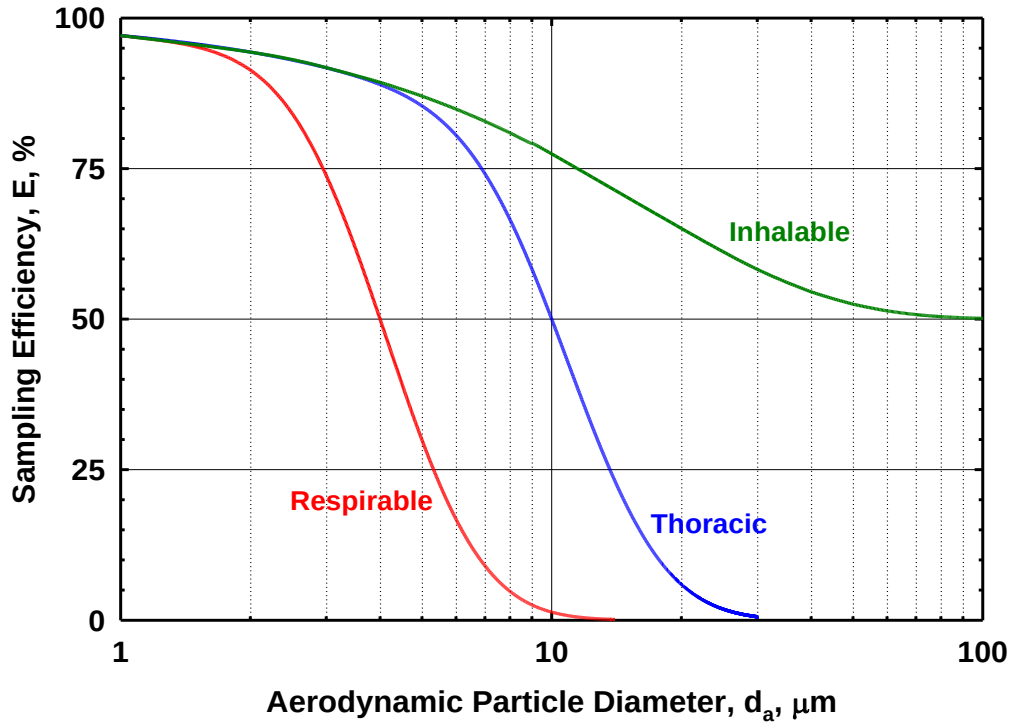


ACGIH, CEN, and ISO (7708) have defined sampling conventions for size-selective sampling of airborne health-related particles:

- Inhalable (particles that enter nose/mouth)
- Thoracic (fraction of particles that penetrates down to the larynx)
- Respirable (fraction of particles that penetrates down to the alveolar region of the lungs)

Sampler should approximate particle penetration (or deposition) through human respiratory tract when the purpose of monitoring workers' exposure to airborne particulates is health-related.

Size-selective Sampling Conventions for Health-related Airborne Particulates



PM FRACTIONS

Inhalable- the fraction that enters the nose and/or mouth during breathing (D_{50} of sampler= 100 µm)

Thoracic- the sub-fraction of inhalable that penetrates the respiratory tract below the larynx (D_{50} of sampler= 10 µm)

Respirable- the sub-fraction of inhalable that penetrates to the alveolar region of the lung. (D_{50} of sampler= 4 µm)

(AIHA Aerosol Committee Publication)

Traditional Respirable Dust Samplers:

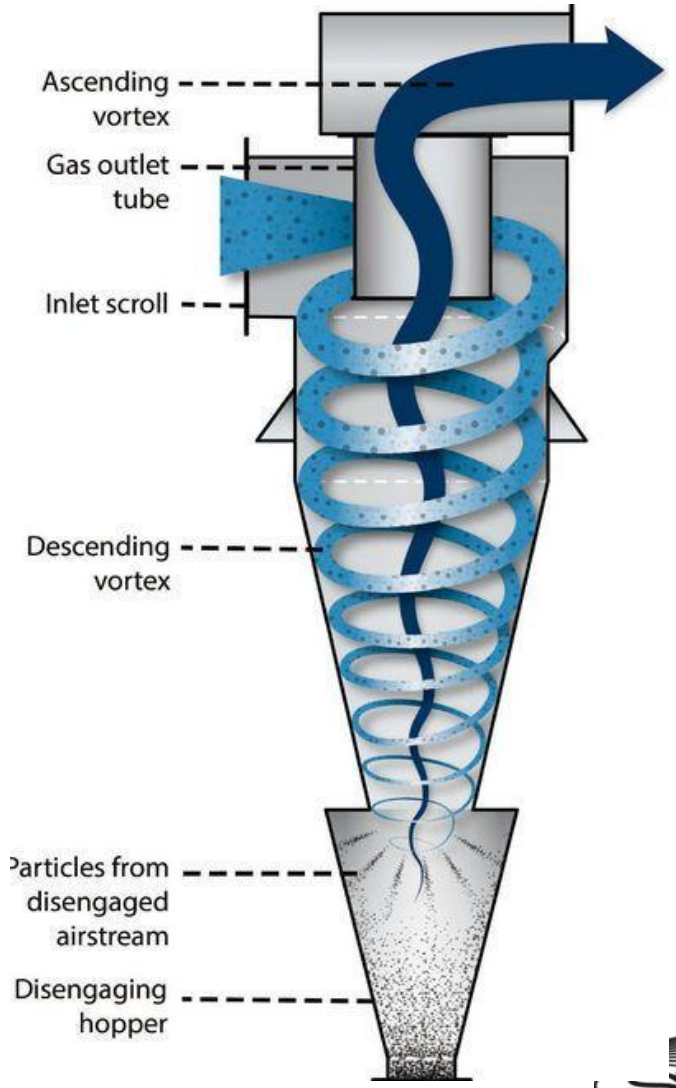
To meet OSHA and MSHA criteria

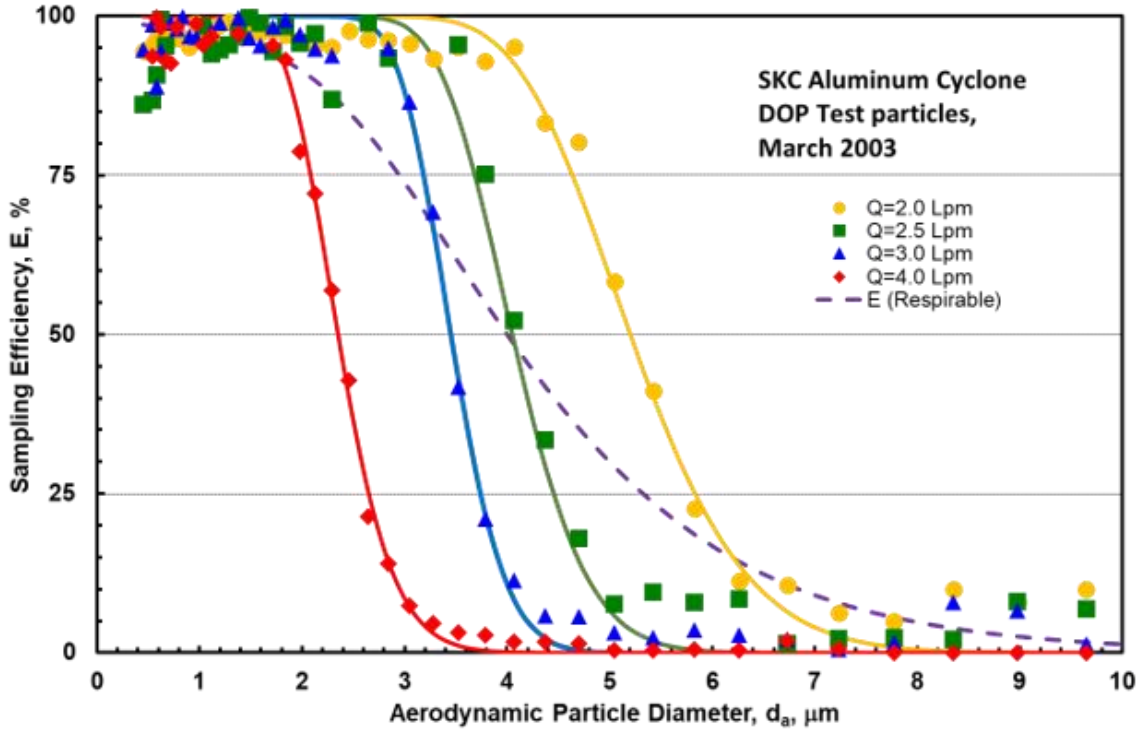
CYCLONES

- All cyclones are not created equal!
- Each cyclone has different operating specifications to meet the required performance criteria.
- Be sure you know the flow rate specified before using any cyclone.

Basic Principles of Cyclone Operation

- **Inlet Flow:** Contaminated air enters the cyclone separator at high speed through a tangential inlet.
- **Vortex Formation:** The air spirals downward in a circular motion inside the cyclone, creating a strong centrifugal force.
- **Particle Separation:** The centrifugal force causes heavier particles to move outward toward the cyclone walls. These particles lose momentum, slide down the walls, and are collected in a hopper or “grit pot” at the bottom.
- **Clean Air Exit:** The cleaned air, now free of heavier particulates, moves inward to the center of the cyclone and exits through an outlet pipe called a vortex finder at the top.





Small Particles

Large Particles

CYCLONE OPERATION

- Cyclones are inserted into filter cassettes containing PVC filters and are attached to sample pumps.
- Air enters through a slit on the side of the cyclone, which creates cyclonic action.
- Through centrifugal force, large particles fall into the cap at the bottom (called a grit pot) and are discarded. Small particles are thrown onto the filter for analysis.

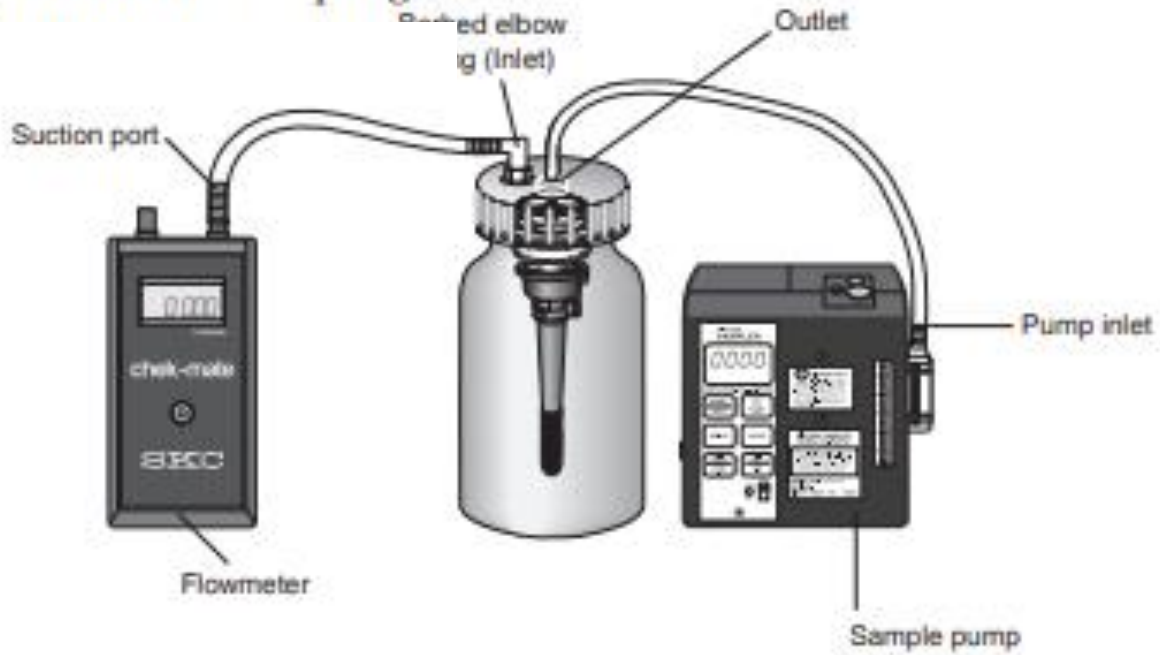
Cap must be in place during sampling!

MORE ON CYCLONE OPERATION

- After sampling, the cyclone is removed, and the filter is capped and sent to the lab.
- DON'T TURN THE CYCLONE UPSIDE DOWN UNTIL YOU HAVE REMOVED THE FILTER!!
  - If the large particles in the cap at the bottom get dumped onto your filter, your sample is invalid (and the results will look very high).
- Clean the cyclone with soap and water between every use or the dust stuck to the interior walls of the cyclone will affect your results.

SKC ALUMINUM CYCLONE

and/or media for sampling.



AVOID COMMON MISTAKES IN CYCLONE SAMPLING

1. Make sure that you use the correct flow rate designated for your brand of cyclone. All cyclones are not created equal and don't use the same flow rate.
2. Make sure that you keep the "grit pot" (cap on the bottom) in place during sampling.
3. Load SKC cyclones into the MIDDLE RING of a cassette.
4. Don't tip over the cyclone when it's attached to the filter.
5. Have a consistent cleaning process after sampling

New Option for Respirable Dust Sampling

To meet ISO 7708 & OSHA and MSHA criteria

PPI® - Parallel Particle Impactor

Types of PPI®

Disposable

Reusable

Thoracic

IMPORTANT NOTE
IN THE OSHA FINAL RULE

Page 16439

- The new silica rule states on page 16439 that employers can use ANY sampling device that conforms to the ISO/CEN convention.
- "There are also personal impactors available for use at flow rates from 2 to 8 L/min that have been shown to conform closely with the ISO/CEN convention".
- This data was the PPI samplers was supplied by SKC to the OSHA docket.

Federal Register Excerpt (OSHA)

For most workplace conditions, the change in the criteria for respirable dust in the final rule would theoretically increase the mass of respirable dust collected over that measured under the previous criteria by an amount that depends on the size distribution of airborne particles in the workplace. Soderholm (1991, Document ID 1661) examined these differences based on 31 aerosol size distributions measured in various industrial workplaces (e.g., coal mine, lead smelter, brass foundry, bakery, shielded metal arc [SMA] welding, spray painting, pistol range) and determined the percentage increase in the mass of respirable dust that would be collected under the ISO/CEN convention over that which would be collected under the 1968 ACGIH criteria. Soderholm concluded that, for all but three of the 31 size distributions that were evaluated, the increased respirable dust mass that would be collected using the ISO/CEN convention for respirable dust instead of the 1968 ACGIH criteria would be less than 30 percent, with most size distributions (25 out of the 31 examined, or 80 percent) resulting in a difference of between 0 and 20 percent (Document ID 1661, pp. 248–249, Figure 1). In the PEA, OSHA stated its belief that the magnitude of this effect does not outweigh the advantages of adopting the ISO/CEN convention. In particular, most respirable dust samplers on the market today are designed and calibrated to perform in a manner that closely conforms to the international ISO/CEN convention.

Incorporating the ISO/CEN convention in the definition of cyclone samplers on the market, such as the Dorr-Oliver, Higgins-Dewell (HD), GK2.69, SIMPEDS, and SKC aluminum. In the PEA, OSHA reviewed several studies demonstrating that these samplers collect respirable particles with efficiencies that closely match the ISO/CEN convention (Document ID 1720, pp. IV–21—IV–24). In addition to cyclone samplers, there are also personal impactors available for use at flow rates from 2 to 8 L/min that have been shown to conform closely with the ISO/CEN convention (Document ID 1834, Attachment 1). Cyclones and impactors both separate particles by size based on inertia. When an airstream containing particles changes direction, smaller particles remain suspended in the airstream and larger ones impact a surface and are removed from the airstream. Cyclones employ a vortex to separate particles centrifugally, while impactors use a laminar airflow around a flat surface such that particles in the desired size range impact onto the surface.

The current OSHA sampling method for crystalline silica, ID–142, is the method used by OSHA to enforce the silica PELs and is used by some employers as well. It specifies that a respirable sample be collected by drawing air at 1.7 ± 0.2 liters/minute (L/min) through a Dorr-Oliver 10 millimeter (mm) nylon cyclone attached to a cassette containing a 5-µm pore-size, 37-mm diameter polyvinyl chloride (PVC) filter (Document ID 0946). NIOSH sampling and analysis methods for crystalline silica (Method 7500, Method 7602, Method 7603) have also adopted the ISO/CEN convention Method 7500 also allows for the use of an aluminum cyclone at 2.5 L/min. NIOSH is revising its respirable dust method to include any sampler designed to meet the ISO/CEN criteria (Document ID 3579, Tr. 218).

The devices discussed above, when used at the appropriate flow rates, are capable of collecting a quantity of respirable crystalline silica that exceeds the quantitative detection limit for quartz (the principle form of crystalline silica) of 10 µg for OSHA's XRD method (Document ID 0946). For several scenarios based on using various devices and sampling times (8-hour, 4-hour, and 1-hour samples), OSHA calculated the amount of respirable quartz that would be collected at quartz concentrations equal to the existing general industry PEL, the proposed (and now final) rule's PEL, and the proposed (and now final) rule's action level. As seen in Table IV.3–A, computations show that the 10-mm nylon Dorr-Oliver operated at an optimized flow rate of 1.7 L/min, the aluminum cyclone operated at 2.5 L/min, the HD cyclone operated at 2.2 L/min, and the GK2.69 operated at 4.2 L/min will all collect enough quartz during an 8-hour or 4-hour sampling period to meet or exceed the 10 µg quartz limit of quantification for OSHA Method ID–142. Therefore, each of the commercially available cyclones is capable of collecting a sufficient quantity of quartz to exceed the limit of quantification when airborne concentrations are at or below the action level, provided that at least 4-hour air samples are taken. Table VII–7 also shows that the samplers can collect enough silica to meet the limit of

IMPORTANT NOTE
IN THE MSHA FINAL RULE

§ 60.12 (e)(4) - The mine operator shall use respirable-particle-size-selective samplers that conform to ISO 7708:1995

Pg 28331

- Under the final rule, MSHA requires mine operators to use respirable-particle-size-selective samplers that conform to the ISO 7708:1995 standard to determine compliance with the PEL. Mine operators are allowed to use any type of sampling device for respirable crystalline silica sampling**, as long as the device is designed to meet the characteristics for respirable-particle-size-selective samplers that conform to the ISO 7708:1995 standard**

- Cyclone samplers include, but are not limited to, the Dorr-Oliver 10-mm nylon cyclone, as well as the Higgins-Dewell, GK2.69, SIMPEDS, and **SKC aluminum cyclone**.

- Under the final rule, the **PPI sampler** would be acceptable.

Federal Register Excerpt (MSHA)

thoracic, and respirable fractions. The ISO standard also provides formulas for determining the fractions based on the aerodynamic diameter of the particles present. MSHA is incorporating by reference ISO 7708:1995 in § 60.12(e)(4) to ensure consistent sampling collection by mine operators through the utilization of samplers conforming to ISO 7708:1995.

Under the final rule, MSHA requires mine operators to use respirable-particle-size-selective samplers that conform to the ISO 7708:1995 standard to determine compliance with the PEL. Mine operators are allowed to use any type of sampling device for respirable crystalline silica sampling, as long as the device is designed to meet the characteristics for respirable-particle-size-selective samplers that conform to the ISO 7708:1995 standard and, where appropriate, meet MSHA permissibility requirements.

Sampling devices, such as cyclones [74] and elutriators,[75] can separate the respirable fraction of airborne dust from the non-respirable fraction in a manner that simulates the size-selective characteristics of the human respiratory tract and that meets the ISO standard. These devices enable collection of dust samples that contain only particles

creates and regulates the flow rate of incoming air. As the flow rate of air increases, a greater percentage of larger and higher-mass particles are removed from the airstream, and smaller particles are collected with greater efficiency. Adjustment of the flow rate changes the particle collection characteristics of the sampler and allows calibration to a specified respirable particle size sampling definition, such as the ISO criterion.

A cyclone sampler calibrated to operate at the manufacturer's specified air flow rate that conforms to the ISO standard can be used to collect respirable crystalline silica samples under this final rule. MSHA reviewed OSHA's feasibility analysis for its 2016 silica final rule and agrees that there are commercially available cyclone samplers that conform to the ISO standard and allow for the accurate and precise measurement of respirable crystalline silica at concentrations below both the action level and PEL (OSHA, 2016a). Cyclone samplers include, but are not limited to, the Dorr-Oliver 10-mm nylon cyclone, as well as the Higgins-Dewell, GK2.69, SIMPEDS, and SKC aluminum cyclone. Each of these cyclones has different operating specifications, including flow rates, and

the ISO 7708:1995 standard (Document ID 1375). This commenter stated that there is a disconnect between the cyclone samplers mentioned in the proposed rule and the use of PPI samplers as an acceptable sampling device, implying that PPI samplers are not acceptable because they were not included in the list of example samplers that meet the ISO 7708:1995 standard in the Sampling Methods section of the proposed rule. This commenter also suggested that the PPI sampling device be considered acceptable under this final rule. Similarly, the NMA, AEMA and SKC stated that MSHA's proposal implies that only cyclone and elutriator type samplers meet the specifications for acceptable sampling devices.

MSHA clarifies that cyclone and elutriator type samplers are not the only acceptable sampling devices that can be used to conduct sampling for respirable crystalline silica under this rule. In the Sampling Methods section of the proposed rule, MSHA included a list of example samplers that conform to the ISO 7708:1995 standard. This list was not meant to be all-inclusive, but rather provide several examples of samplers currently available in the marketplace that conform to the ISO 7708:1995 standard (88 FR 44921). As stated above,

Federal Register Excerpt (MSHA)

These devices enable collection of dust samples that contain only particles small enough to penetrate deep into the lungs. Size-selective cyclone sampling devices are typically used in the U.S. mining industry. These samplers generally consist of a pump, a cyclone, and a membrane filter. The cyclone uses a rapid vortical flow of air inside a cylindrical or conical chamber to separate airborne particles according to their aerodynamic diameter (*i.e.,* particle size). As air enters the cyclone, the larger particles are centrifugally separated and fall into a grit pot, while smaller particles pass into a sampling cassette where they are captured by a filter membrane that is later analyzed in a laboratory to determine the mass of the respirable dust collected. The pump

[74] A cyclone is a centrifugal device used for extracting particulates from carrier gases (*e.g.,* air). It consists of a conically shaped vessel. The particulate-containing gas is drawn tangentially into the base of the cone, takes a helical route toward the apex, where the gas turns sharply back along the axis, and is withdrawn axially through the base. The device is a classifier in which only dust with terminal velocity less than a given value can pass through the formed vortex and out with the gas. The particle cut-off diameter is calculable for given conditions.

[75] An elutriator is a device that separates particles based on their size, shape, and density, using a stream of gas or liquid flowing in a direction usually opposite to the direction of sedimentation. The smaller or lighter particles rise to the top (overflow) because their terminal sedimentation velocities are lower than the velocity of the rising fluid.

these cyclones has different operating specifications, including flow rates, and performance criteria, but all are compliant with the ISO criteria for respirable dust with an acceptable level of measurement bias. MSHA's determination is that cyclone samplers, when used at the appropriate flow rates, can collect a sufficient mass of respirable crystalline silica to quantify atmospheric concentrations lower than the action level and meet MSHA's crystalline silica sample analysis specifications for samples collected at MNM and coal mines.

MNM mine operators who currently use a Dorr-Oliver 10 mm nylon cyclone can continue to use it at a flow rate of 1.7 L/min, which conforms to the ISO standard, to comply with the requirements. For coal mine operators, the gravimetric samplers previously used to sample RCMD (*i.e.,* coal mine dust personal sampling units (CMDPSUs)) were operated at a 2.0 L/min flow rate. Those CMDPSUs can be adjusted to operate at a flow rate of 1.7 L/min to conform to the ISO standard.

The NMA, AEMA, and SKC Inc., noted that samplers other than cyclones and elutriators should be considered acceptable under the final rule (Document ID 1428; 1424; 1366). A miner health advocate stated that when conducting sampling under OSHA requirements, they currently use a type of sampler called a "parallel particle impactor," or PPI sampler, that meets

that conform to the ISO 7708:1995 standard (88 FR 44921). As stated above, mine operators can use any type of sampling device, as long as it is designed to meet the characteristics for respirable-particle-size-selective samplers that conform to the ISO 7708:1995 standard and, where appropriate, meet MSHA permissibility requirements. MSHA clarifies that under this final rule, any sampling device that meets the ISO 7708:1995 particle size selective criteria for respirable dust samplers are acceptable for respirable crystalline silica sampling, even if the sampler is not specifically mentioned in the list of examples. Under the final rule, the PPI sampler would be acceptable.

Several commenters, including labor organizations and a federal elected official, noted the need for sampling devices with real-time or near real-time sample analysis capabilities for respirable crystalline silica (Document ID 1449; 1447; 1398; 1412; 1399; 1439). The AFL–CIO stated that one of the most significant items not included in the proposal (that was included in the 2014 Coal Dust Rule) was personal dust monitoring devices with real-time analysis (Document ID 1449). The commenter recommended the adoption of new technology used by the domestic or international mining community to better protect miners. An individual stated that MSHA should consider and incorporate continuous and rapid quartz

DISPOSABLE PPI SAMPLERS

Same filter and same analysis as with cyclones

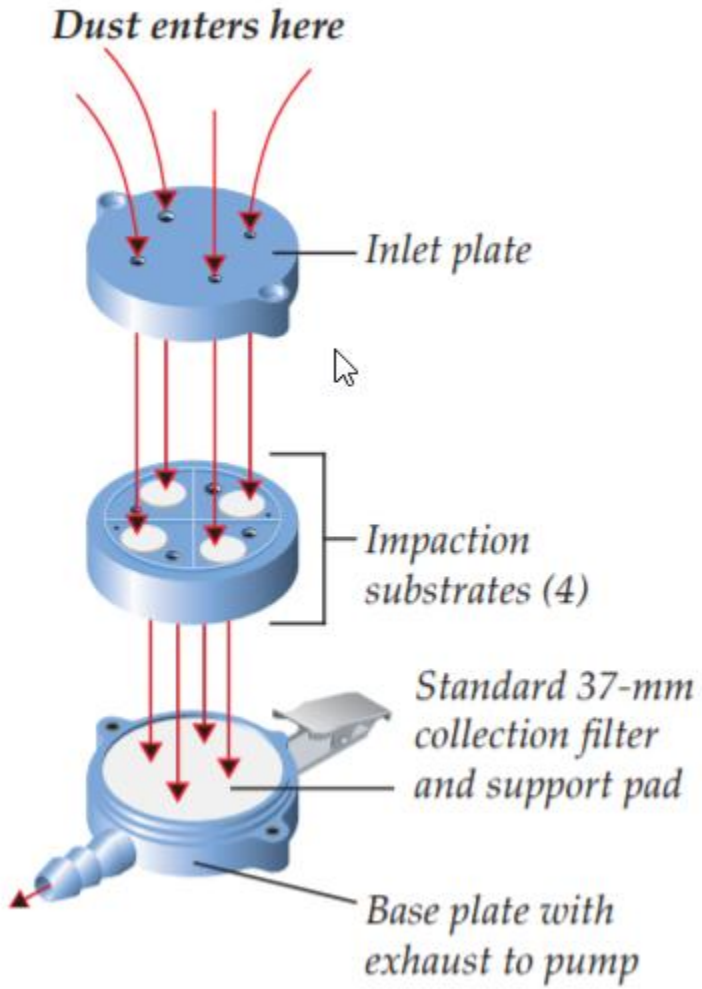
Instead of a cyclone effect, the PPI impactors have 4 internal, pre-oiled plates (oiled substrates) that scrub out larger particles. The impactor plates are sonically welded into place by SKC and require no assembly.

PPI Principle of Operation

The pump draws the air into the PPI. Larger particles are scrubbed out onto the plates and the smaller respirable dust is collected onto the PVC filter for analysis as usual.

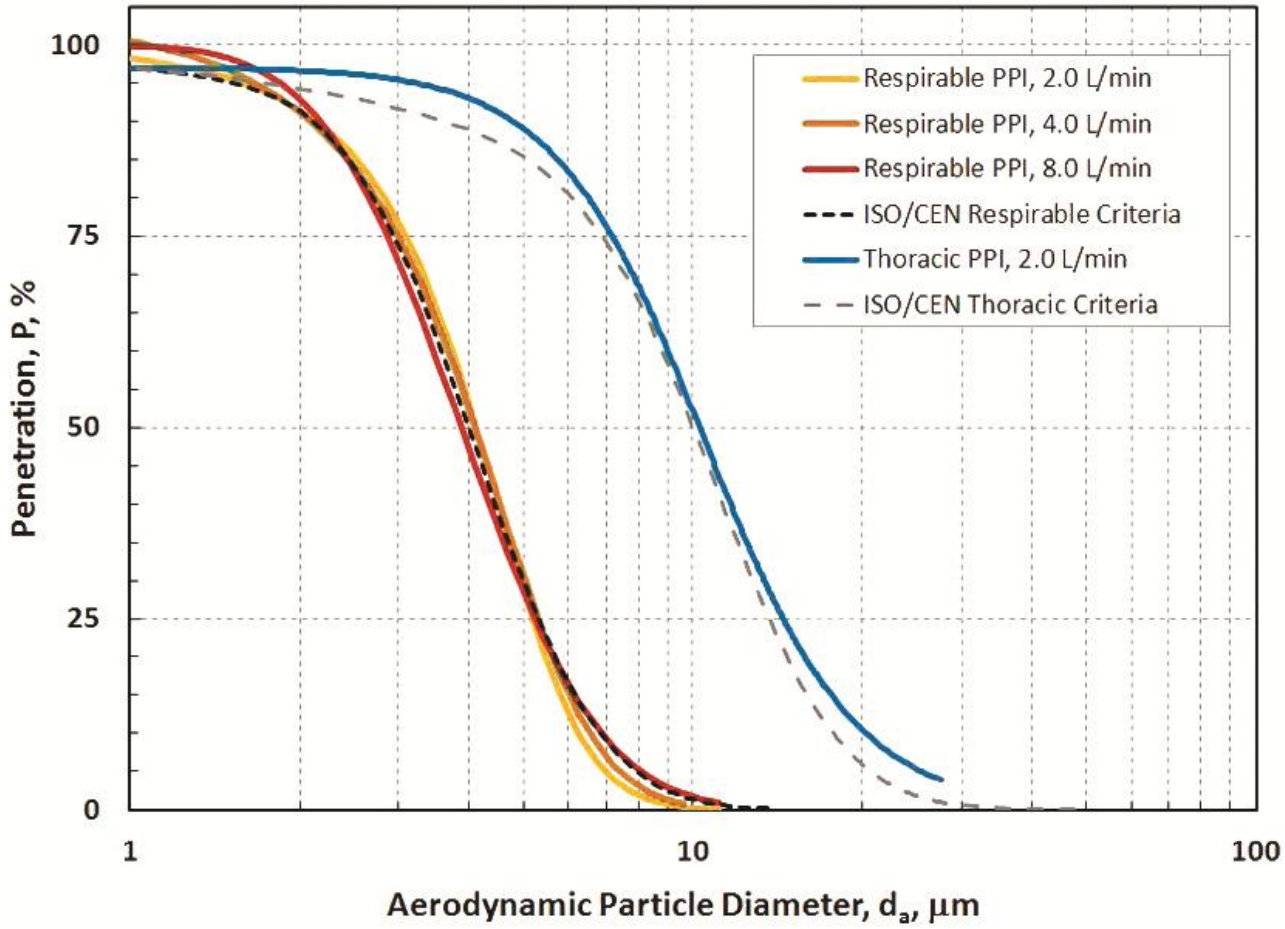
Principle of Operation

- Parallel Particle Impactor (PPI)
  - Size selection
  - Four small impactors
  - 50% cut-point
  - 2, 4, and 8 L/min options

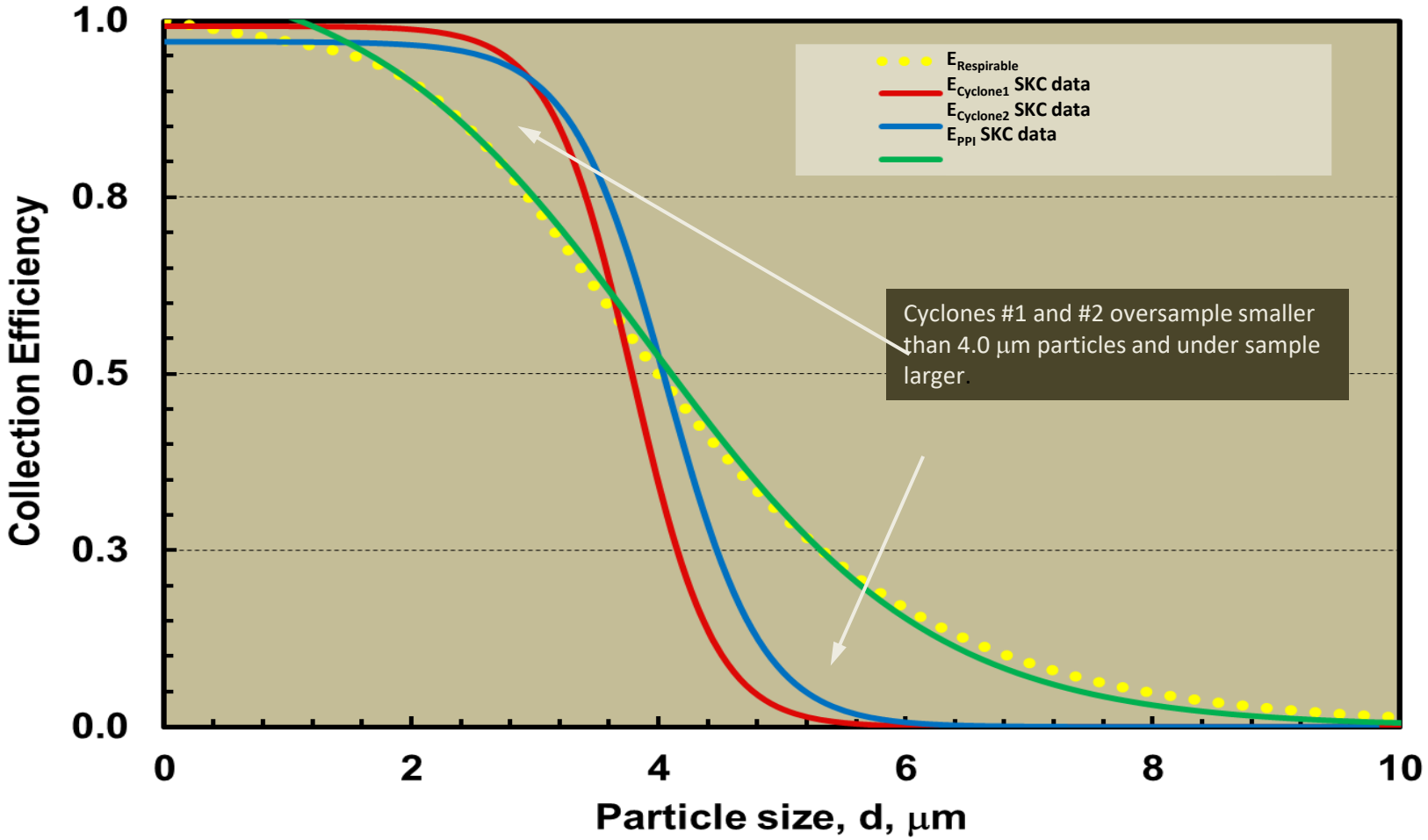


PPI SAMPLER PERFORMANCE

COMPARED TO ISO/OSHA CRITERIA

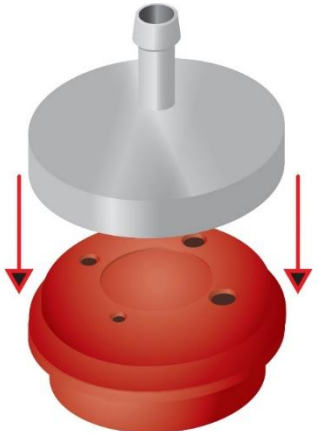


Cyclone vs PPI®



MORE PPI ADVANTAGES

- A handy calibration adapter is available to attach the disposable PPI to the calibrator (flowmeter).
- No tipping hazard. You can invert the sampler without causing large particles to land on the filter invalidating the sample.
- No cleaning necessary for the disposable PPI after the sampling
- Readily available through SKC, SKC West, and our Lab Partners



Disposable PPI

Flow Rate Options

8 L/min

- Red
- Respirable
- Pre-weighed filters
- PVC or MCE filters

4 L/min

- Orange
- Respirable
- Pre-loaded or empty
- Preweighed filters
- PVC or MCE filters

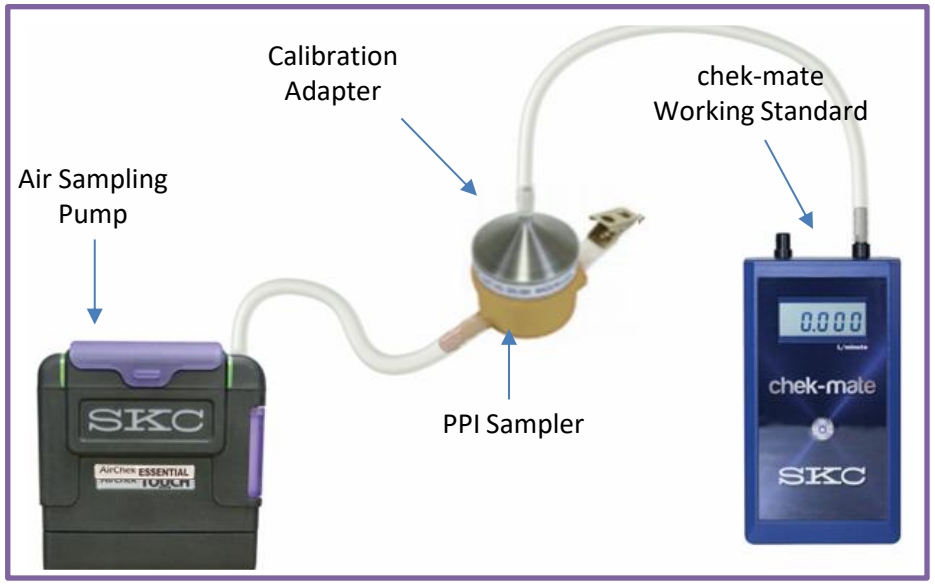
2 L/min

- Gold
- Respirable
- Pre-loaded or empty
- Preweighed filters
- PVC or MCE filters

2 L/min

- Blue
- Thoracic
- MCE filter only

Calibration and Operation



Andy Bragg
Director of Sales
770-845-4014
abragg@skcinc.com