



The Science of Separation: Impactors vs. Cyclones

Understanding the Dynamics of Size-Selective Samplers and Why Impactors Makes Sense

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The Leader in Sampling Solutions and Expertise for OEHS Professionals

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Learning Objectives

- Understand how size-selective samplers work and why they matter for silica sampling
- Learn how impactor and traditional cyclone performance compare
- Explore common mistakes in silica sampling—and how to avoid them
- Break down the true cost of sampling, including the risk of “bad data”
- Gain practical tips for successful field use and how samples are analyzed



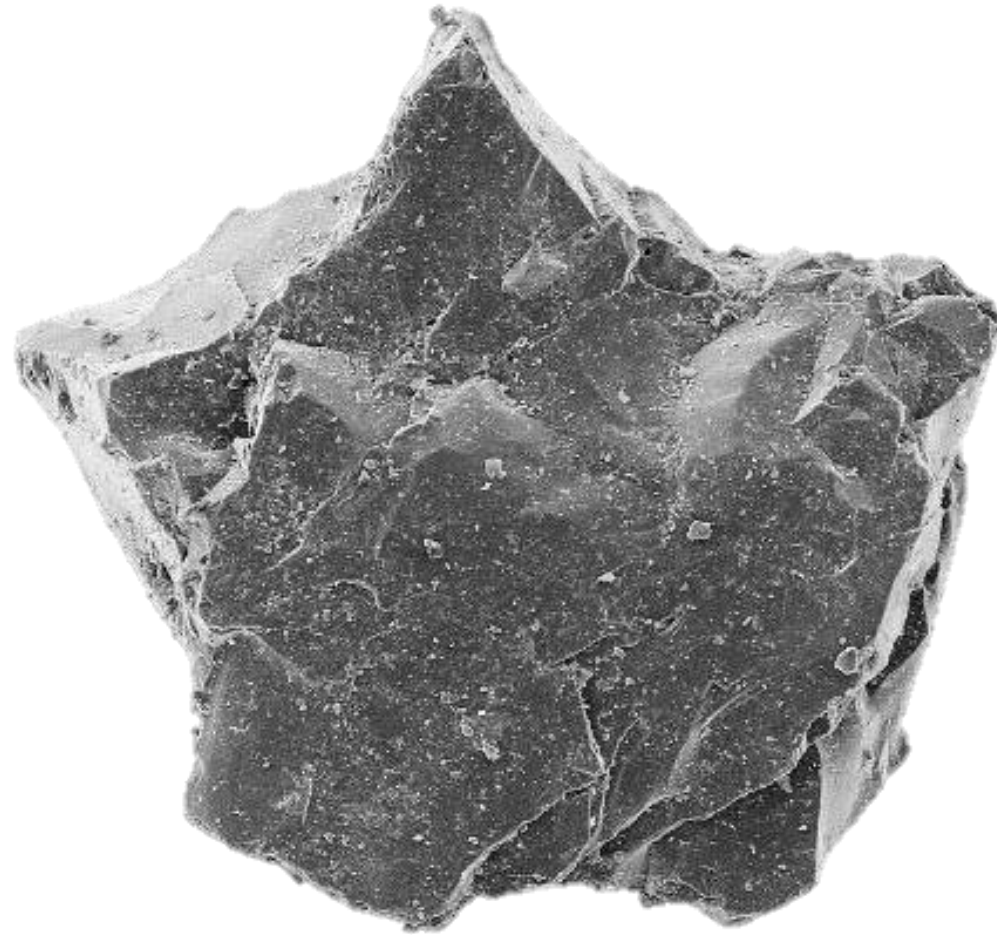
Outline

- Why Silica Accuracy Matters
- Understanding Size-selective Sampling
- Impactors: What Makes them Different?
- Don'ts of Silica Sampling
- Affects of Using the Wrong Flow Rate
- The True Cost of Sampling



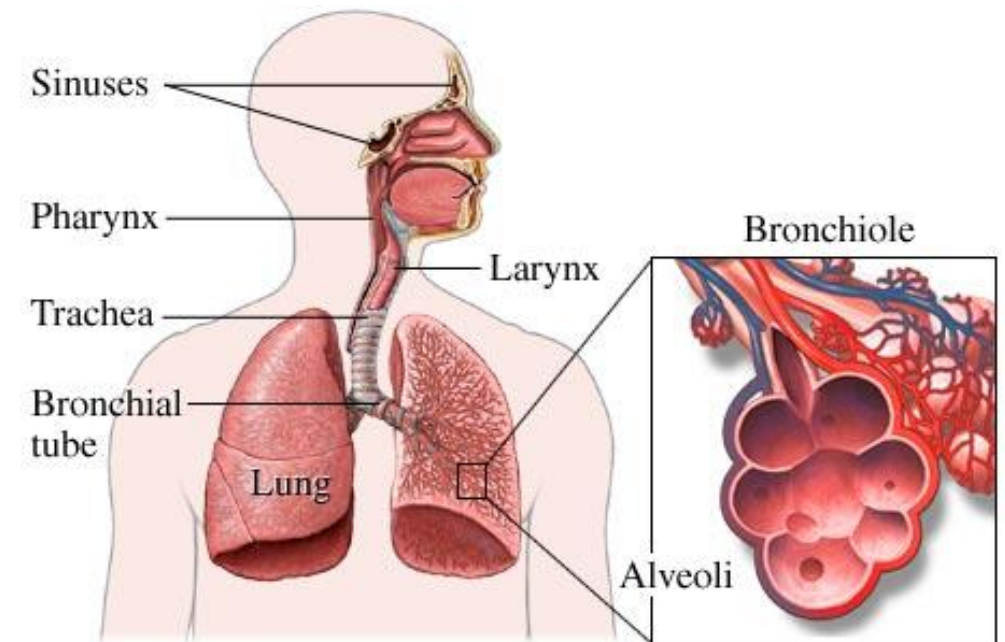
The Invisible Danger

Let's zoom in...



Delayed Harm from Silica

- Respirable crystalline silica is microscopic in size and has a sharp, crystalline structure.
- These small particles travel deep into the lungs, causing inflammation and scarring of lung tissue.
- Prolonged exposure can result in debilitating lung diseases such as silicosis and chronic obstructive pulmonary disease (COPD). **This can take years or decades of exposure.**



What is Size-selective Sampling?

- Size-selective sampling is the process of collecting airborne particles in a way that **selectively captures** only those within a specific aerodynamic size range, **based on the health effect of concern.**



THE RELATIVE SIZE OF PARTICLES

From the COVID-19 pandemic to the U.S. West Coast wildfires, some of the biggest threats now are also the most microscopic.

A particle needs to be 10 microns (μm) or less before it can be inhaled into your respiratory tract. But just how small are these specks?

Here's a look at the relative sizes of some familiar particles \blacktriangleright

HUMAN HAIR 50-180 μm \blacktriangleright
FOR SCALE

FINE BEACH SAND 90 μm \blacktriangleright

GRAIN OF SALT 60 μm \blacktriangleright

WHITE BLOOD CELL 25 μm \blacktriangleright

GRAIN OF POLLEN 15 μm \blacktriangleright

DUST PARTICLE (P₁₀) <10 μm \blacktriangleright

RED BLOOD CELL 7-8 μm \blacktriangleright

RESPIRABLE CRYSTALLINE SILICA 10 μm \blacktriangleright

DUST PARTICLE (P_{M2.5}) 2.5 μm \blacktriangleright

BACTERIUM 1-3 μm \blacktriangleright

WILDFIRE SMOKE 0.4-0.7 μm \blacktriangleright

CORONAVIRUS 0.1-0.5 μm \blacktriangleright

T4 BACTERIOPHAGE 0.225 μm \blacktriangleright

ZIKA VIRUS 0.045 μm \blacktriangleright



Pollen can trigger allergic reactions and hay fever—which 1 in 5 Americans experience every year.

Source: Harvard Health

The visibility limits for what the naked eye can see hovers around 10-40 μm .

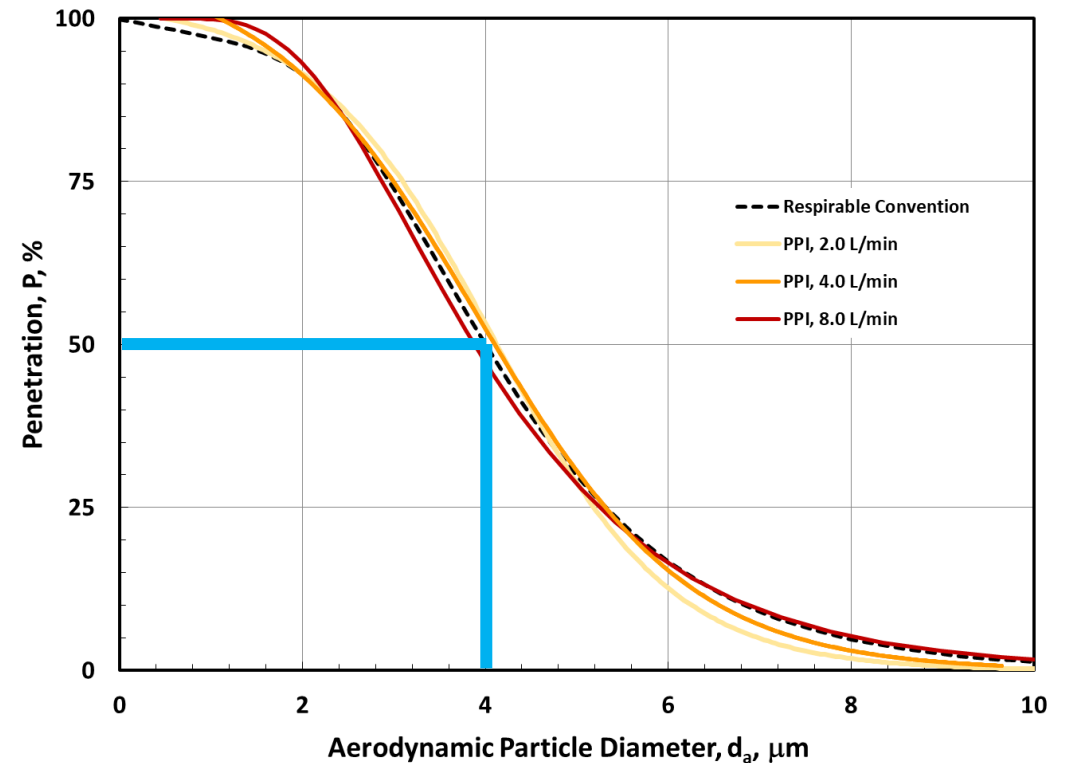
Will travel deep into the lungs



Wildfire smoke can persist in the air for several days, and even months.

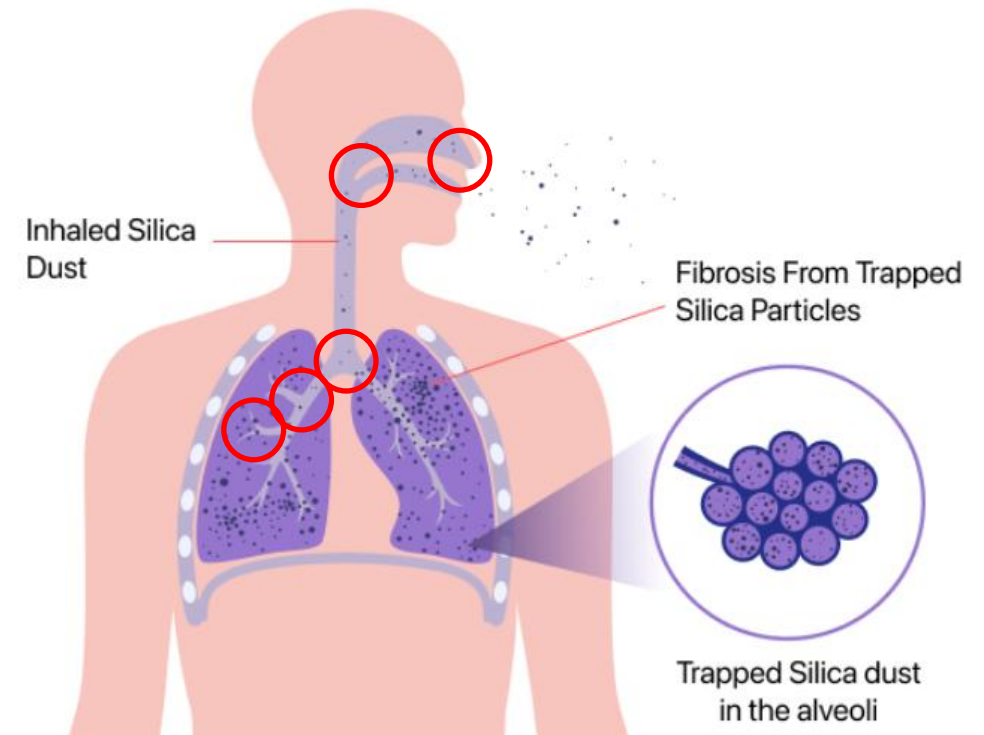
Collection Efficiency and Cut-point

- Collection efficiency refers to the percentage of airborne particles of a particular aerodynamic diameter that are captured for analysis
- Smaller particles are collected at a higher efficiency, and larger particles are collected at a lower efficiency
- The ISO 7708:1995 Respirable curve has a collection efficiency of 50% at 4 μm
 - This is referred to as the “Cut-point”
- Each cyclone or impactor has a specific flow rate that must be used to achieve a 50% cut-point at 4 μm

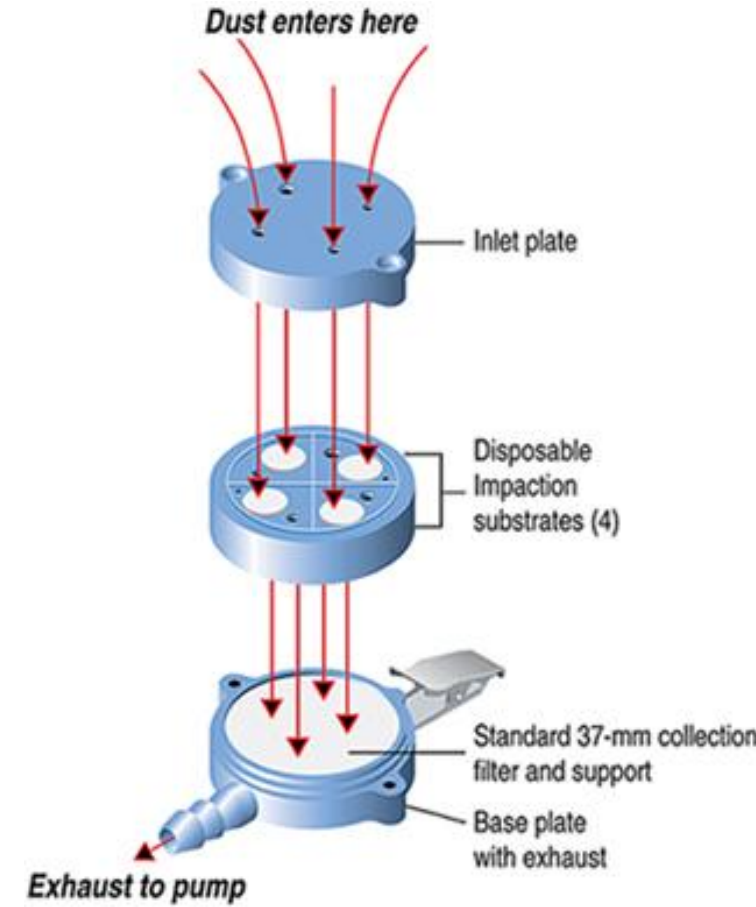
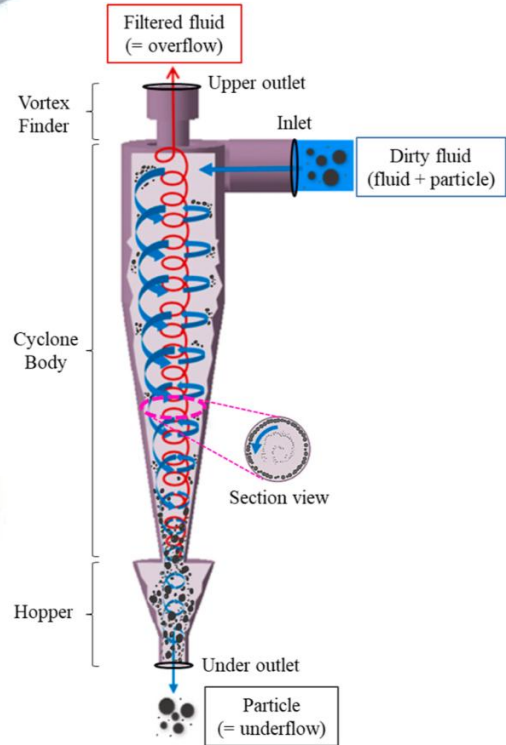


Collection Efficiency and Our Bodies

- The ISO 7708:1995 curve closely follows what our body naturally does to prevent larger particles from entering our lungs
- Our body has several natural impaction or deposition sites:
 - Nose/Mouth
 - Back of throat
 - Bottom of Trachea
 - Bronchi and Bronchioles
- We are our own 'Oiled Impactor'

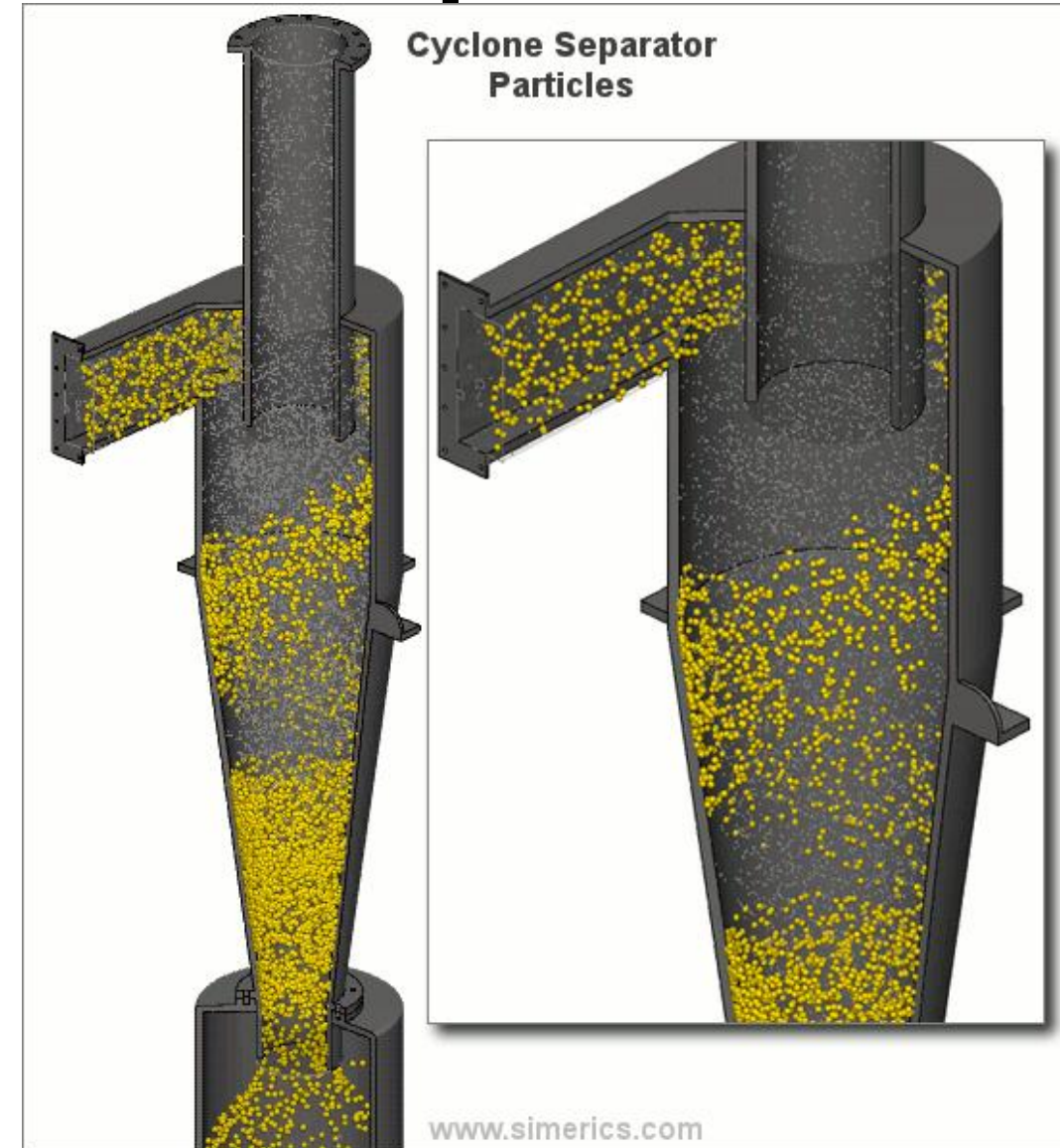


Size selective samplers



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 at the bottom.
- **Clean(er) 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.

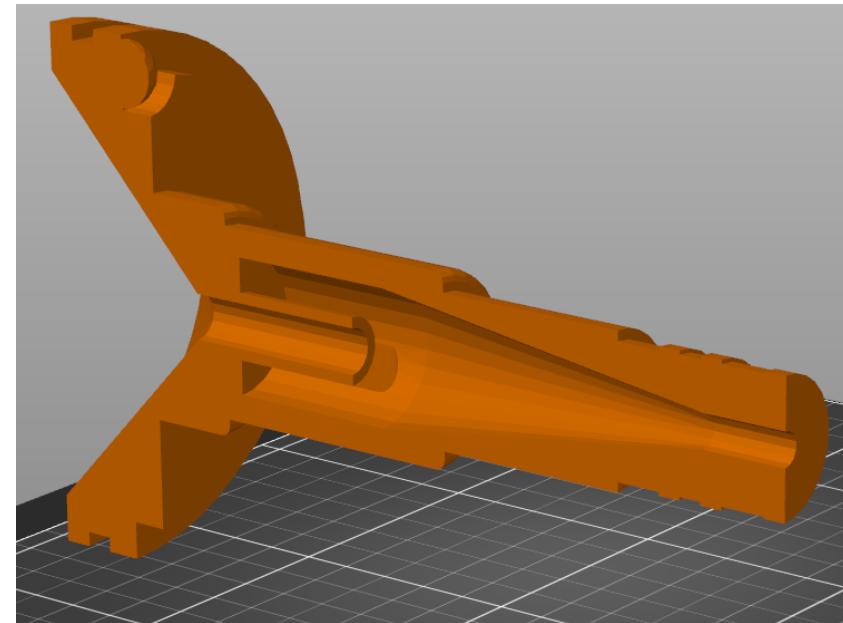
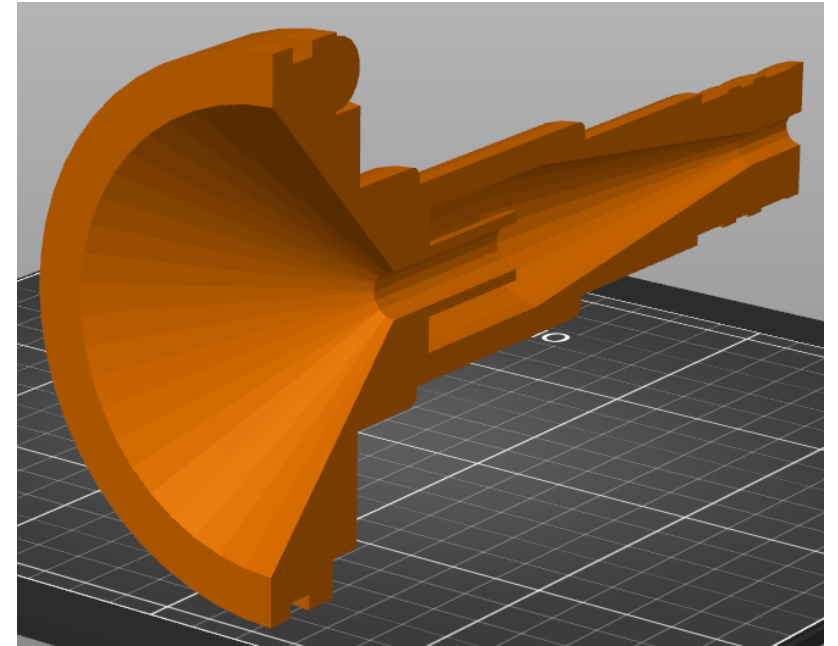
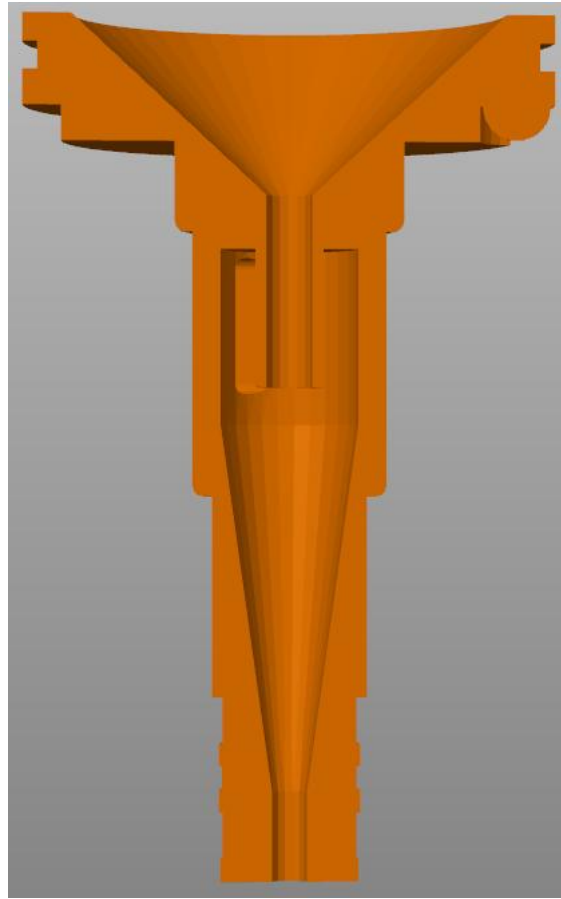
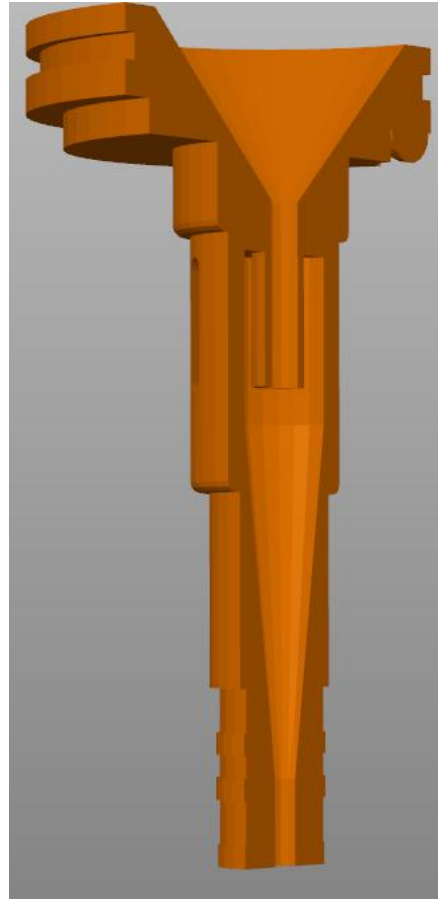
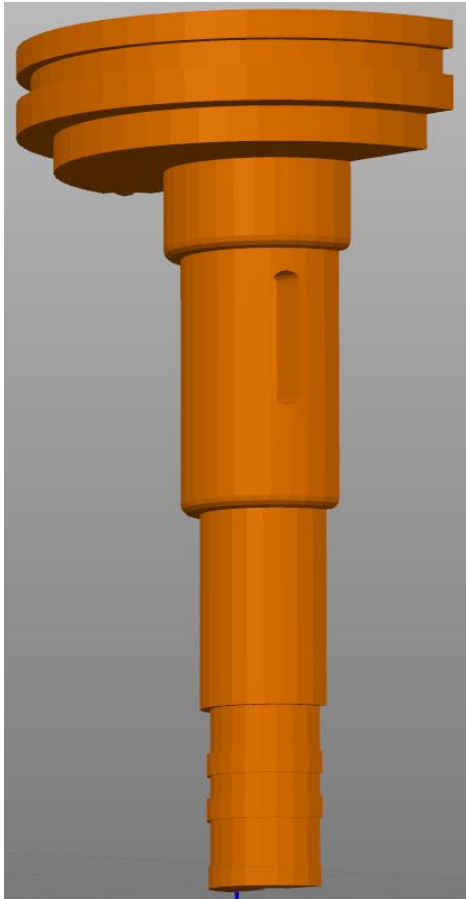


Factors Influencing Cyclone Collection Efficiency

- Particle Size Distribution
 - Cyclones are not very efficient at collecting small particles
- Design Parameters
 - Diameter, length, etc.
- Inlet Flow Rate and Velocity
 - Too high can cause turbulence and/or re-entrainment of particles
 - Too low will have insufficient centrifugal force to separate particles effectively
- Operating Conditions
 - Temperature and Humidity
 - High/low concentration of dust in the air
- Maintenance and Wear
 - **Cyclone walls can be loaded with dust** if not cleaned, changing the internal geometry and flow
 - Blockages of the inlet affecting flow



What's Inside?



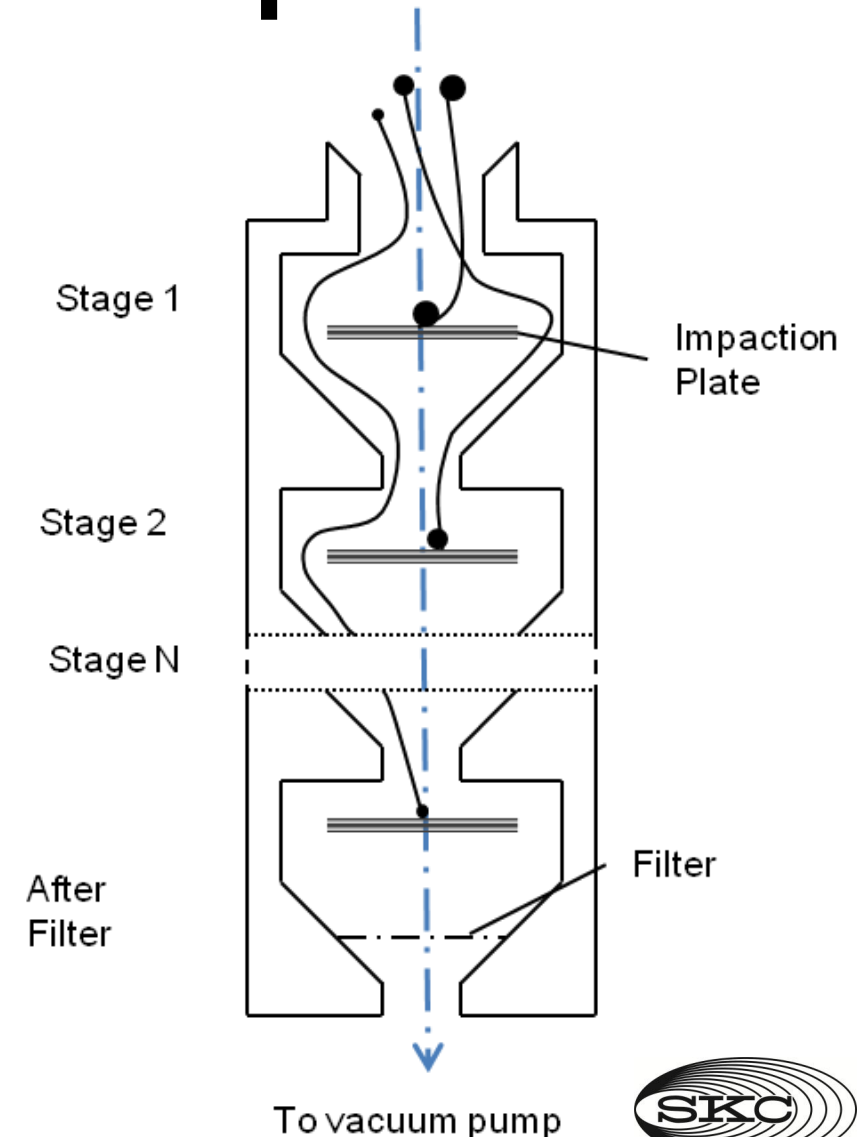
Consider Impactors as an Alternative

Impactors can achieve accurate sampling while overcoming some of the challenges of using traditional cyclones



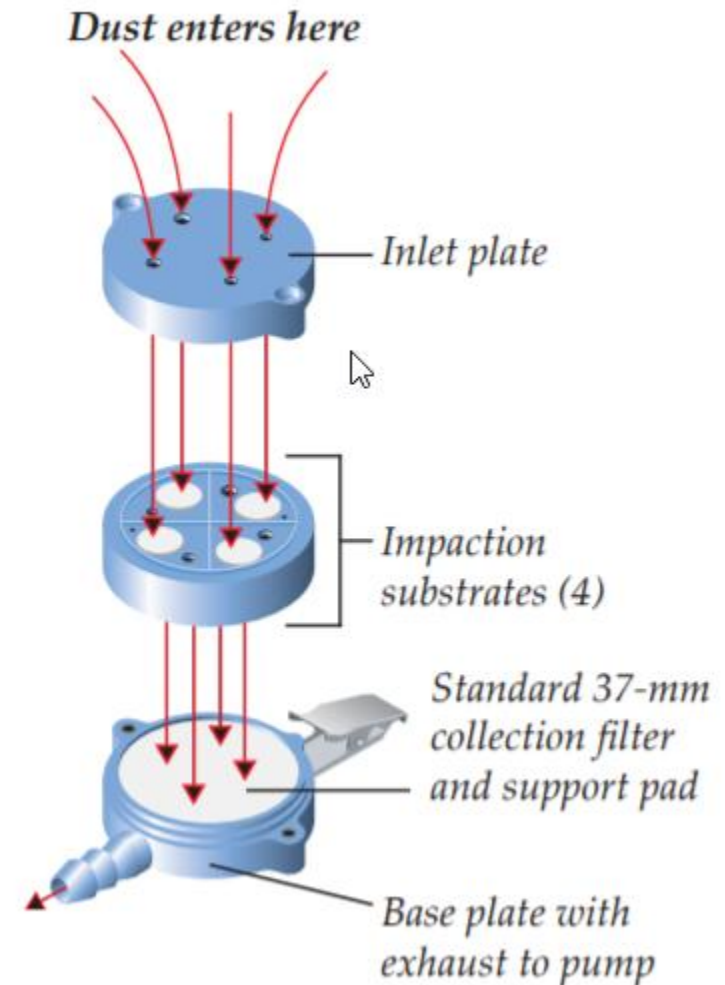
Basic Principles of Impactor Operation

- **Air Intake:** Air is drawn into the impactor through an inlet.
- **Velocity Increase:** As the air passes through one or more nozzles, it accelerates, increasing the air velocity.
- **Impaction Plate:** The accelerated air stream directs particles towards an impaction plate positioned in the path of the flow. Larger particles, due to their greater inertia, cannot follow the air stream and impact on the plate, where they are collected.
- **Smaller Particles:** Smaller particles, with less inertia, remain in the air stream and are carried to subsequent stages of the impactor or exit the device, depending on the design.



Principle of Operation

- Unlike cyclones that use centrifugal force, impactors use particle inertia and an impaction substrate to remove larger particles. We'll use the PPI as an example impactor throughout this webinar
- Impactors retain larger particles on an oiled collection plate. The PPI contains four internal, pre-oiled impaction plates.
- Many impactors are built in multiple stages. The PPI's four impactor "stages" are arranged in parallel rather than stacked.
- The PPI's impactor plate assembly is sonically welded in place, ensuring consistency and ruggedness for field use.



Disposable Impactors



2 L/min



Full-shift sampling



4 L/min



Task-based sampling or low-dust environments

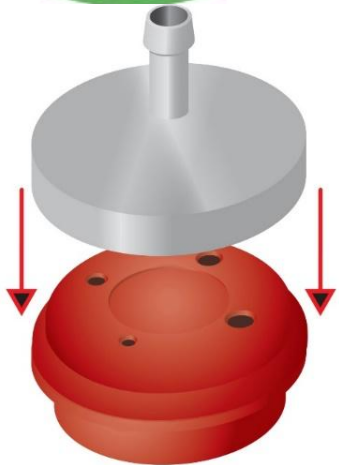


8 L/min



Advantages Over Traditional Cyclone

- Impactors often have a calibration adapter to attach to a flowmeter (previously known as a “calibrator”)
- No tipping hazard. You can invert the sampler without causing large particles to land on the filter, invalidating the sample.
- No cleaning necessary after the sampling
- Much smaller and easier to wear



Full Regulatory Compliance

- Approved for use in both the **OSHA** and **MSHA** Final Silica Rule

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28331

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

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, 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.

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16439

Incorporating the ISO/CEN convention in the definition of respirable crystalline silica will permit employers to use any sampling device that conforms to the ISO/CEN convention. There are a variety of these

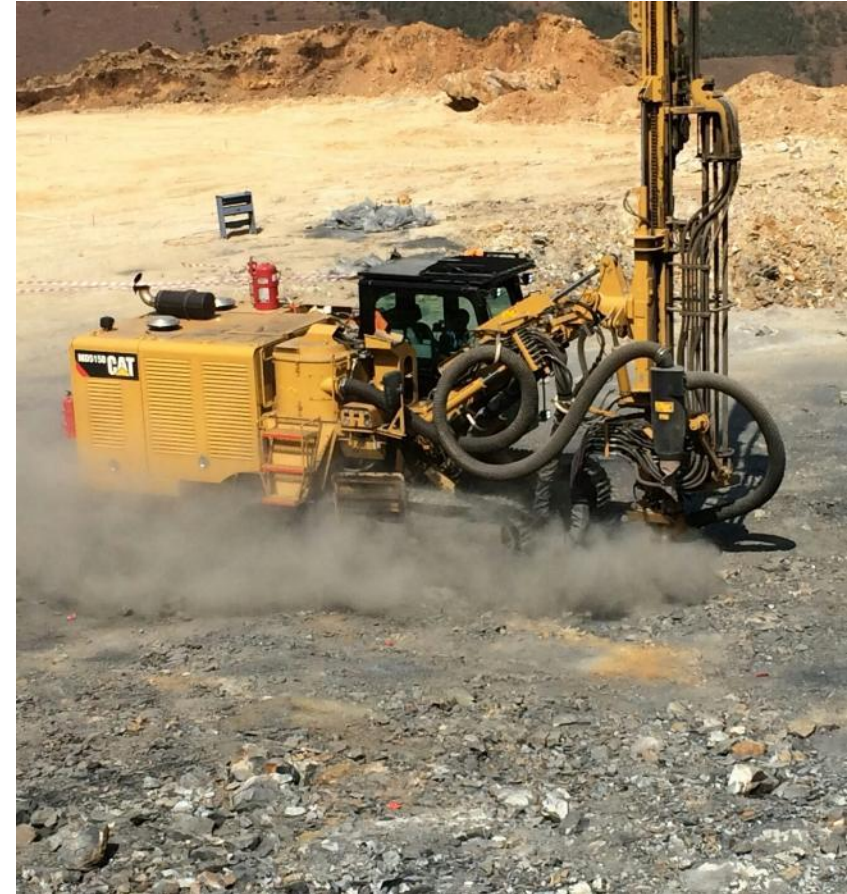
cyclone samplers on the market, such as the Dorr-Oliver, Higgins-Dewell (HD), GK2.69, SIMPEDS, and SKC aluminum. In the PEA, OSHA reviewed several studies demonstrating that these samplers collect respirable particles with efficiencies that closely match the ISO/CEN convention (Document ID 1720, pp. 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.



What do I Need to Sample for Silica?

- Constant flow pump
- Flow rate verification device
- Size-selective sampler
 - Tygon[®] tubing
 - Cassette holder if using a cyclone
- Pre-weighed 5- μ m PVC filter
 - Paired with 37-mm Cassette or Impactor
- Note pad and pens
- Camera/phone, if allowed





AirChek
TOUCH Pump



Representative
Sampling PPI for
Flow Rate Verification



Calibration
Adapter



chek-mate
Flowmeter



3 Feet Tygon Tubing
for Sampling and
Flow Verification



1 Foot Tygon
Tubing for Flow
Verification

Proper Placement



Improper Placement



Don'ts of Silica Sampling

- **In General:**
 - **Not doing a pre/post-flow rate verification:** Without both checks, you can't confirm sampling accuracy, and results may be invalid.
 - **Not taking notes in the field:** Missing task descriptions, environmental conditions, and anomalies makes interpreting results difficult.
 - **Not sampling in the breathing zone:** Samples not captured in the breathing zone do not accurately depict personal exposure.
 - **Not using an accredited lab for analysis:** Labs without proper accreditation may not follow recognized quality standards, putting your data reliability at risk.



Don'ts of Silica Sampling

- **Cyclones:**

- **Inverting the cyclone:** Large particles in the grit pot have the ability to migrate to the collection media, invalidating the sample.
- **Cyclone inlet not facing the correct way:** Inlet needs to be properly oriented, or it may be blocked by the user
- **Not cleaning after each use:** Dust can collect and accumulate on the walls of the cyclone, effectively reducing the diameter of the cyclone. This can lead to a reduced cut-point.
- **Incorrect flow rate:** Each cyclone has a specific flow rate. Increasing or decreasing the flow directly impacts the size of particles collected.
- **Operating without a grit pot:** Air will enter both from the top and bottom of the cyclone, disrupting the airflow and voiding the sample.
- **Not using multiple cassettes when sampling high dust tasks:** This can lead to filter overloading and additional costs for analysis. No more than 2 mg of dust on the filter per NIOSH 7500.



Don'ts of Silica Sampling

- **Impactors:**
 - **Incorrect flow rate:** Each Impactor has a specific flow rate. Increasing or decreasing the flow directly impacts the size of particles collected.
 - **Not using multiple Impactors when sampling high dust tasks:** The oiled substrates can handle between 6-7 mg of dust before becoming overloaded and 'spilling' onto the filter.
 - This can lead to filter overloading and additional costs for analysis. No more than 2 mg of dust on the filter per NIOSH 7500



Overloading Issues with Cyclones and Impactors

- **What is Overloading?**
 - Excessive dust mass collected on filter (>2 mg for NIOSH methods)
 - Leads to inaccurate results or invalid samples
- **High Dust Environments = High Risk**
 - Mines, construction, foundries, and other dusty workplaces
 - Impactor plates can exceed capacity (6-7 mg)
 - Dust can build up on the inside of cyclones and reduce cut point
 - Inlets can become clogged with large particles

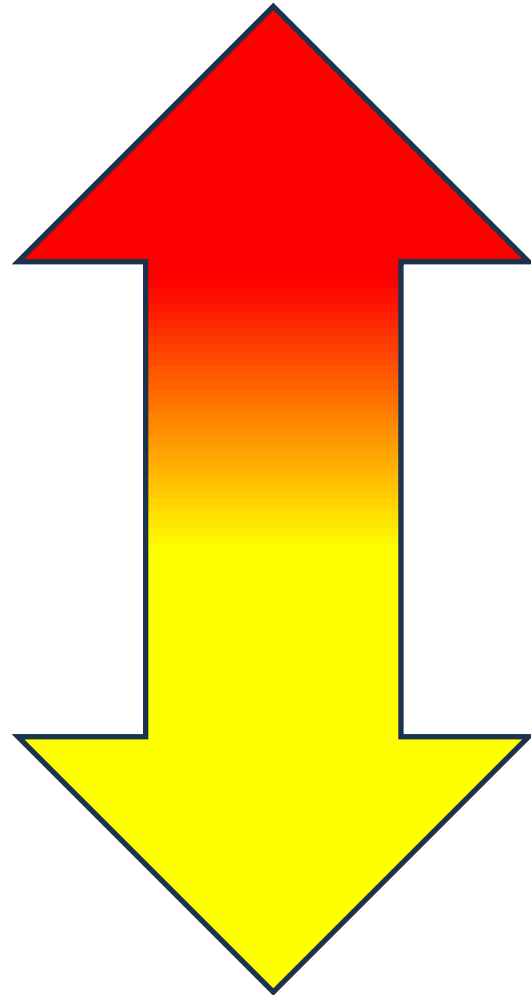


Overloading cont'd

- **Consequences of Overloading**
 - Potential voided sample results or increased costs for analysis
 - Time cost for resampling
 - Missed opportunity to identify real exposures
- **Best Practices to Prevent Overloading**
 - Proactively change cassettes/impactors during long or dusty shifts
 - Use real-time dust monitors to predict overload potential
 - Consider shorter sampling durations when appropriate
- **Takeaway for IHs**
 - Anticipate high dust conditions in advance
 - Plan for cassette/impactor changes mid-shift
 - Learn from mistakes and previous sampling loads



Flow Rates and Their Impact on Cut-point

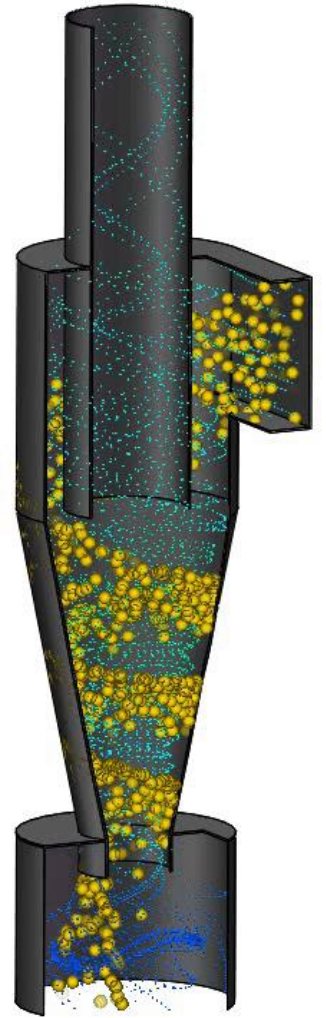
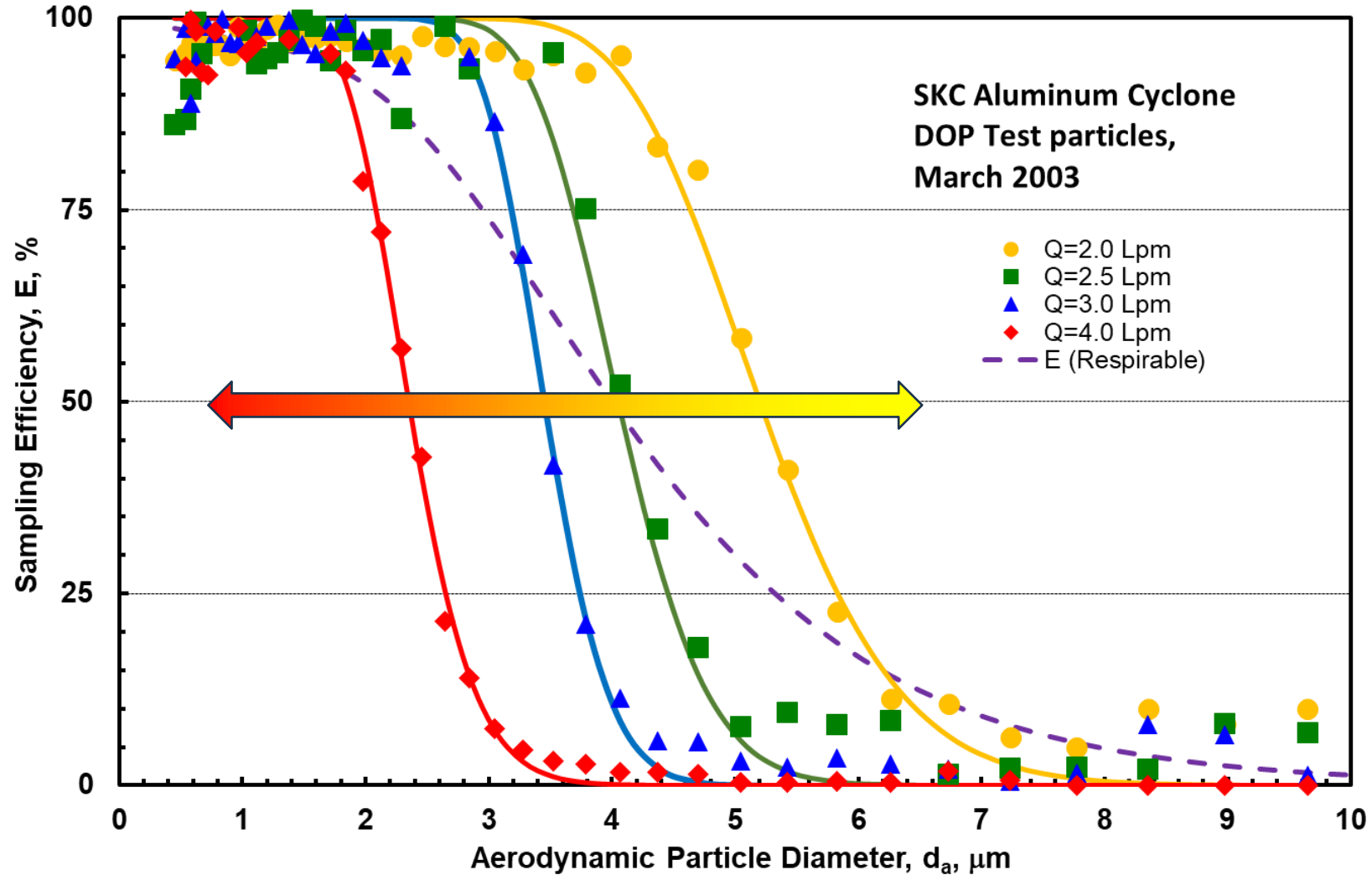


- Flow rate is inversely related to the cut point
 - Higher flow rate results in a lower cut point
 - Lower flow rate results in a higher cut point

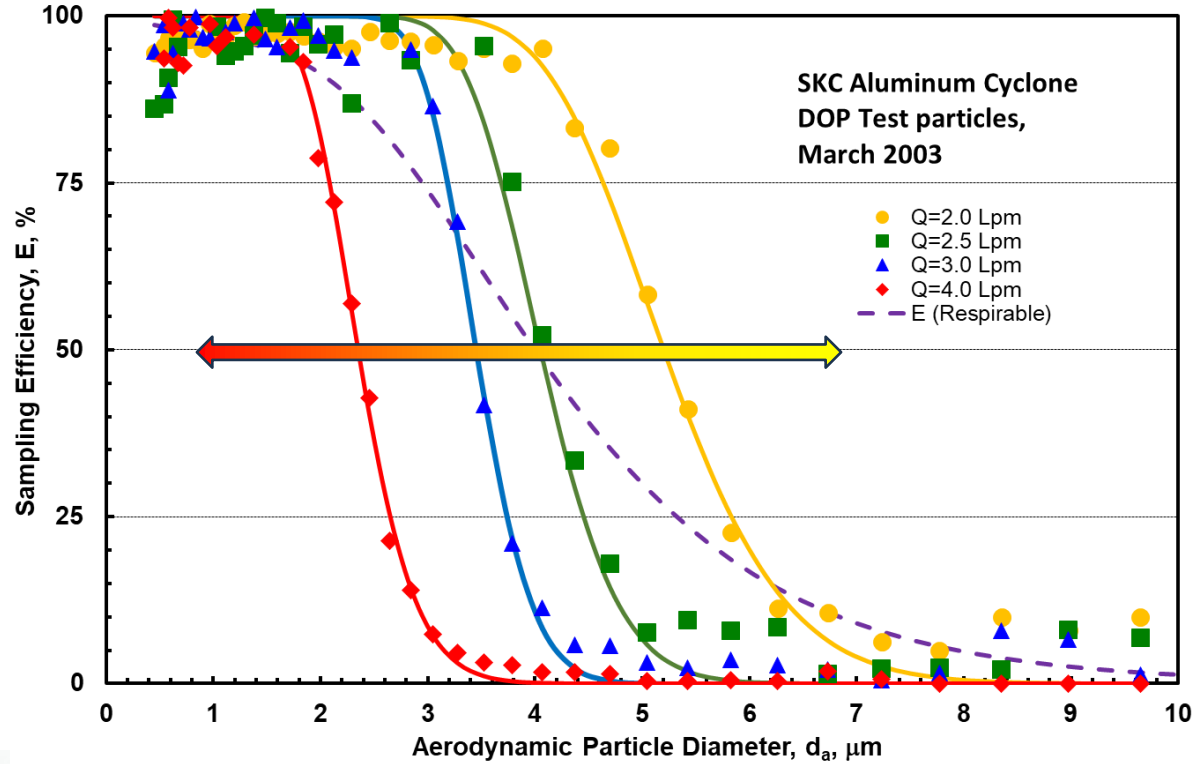
SKC Aluminum Cyclone



SKC Aluminum Cyclone



Practical Representation



What Happens After a Sample is Taken?

- Post-flow rate verification is performed
- Start/Stop times are noted and used to calculate volume
 - (total minutes x flow rate = volume)
 - 600 minutes x 2 L/min = 1200 L (1.2m³)
- Lab Chain of Custody (COC) is filled out and shipped with samples to the lab



How are Samples Analyzed?

- Samples are received by the lab



How are Samples Analyzed?

- Pre-weighed filter is removed from impactor or 37-mm cassette and weighed
 - This is why using a pre-weighed filter is a necessity
 - Analytical error between Disposable Impactor and 37-mm cassette is the same
 - Both are analyzed exactly the same



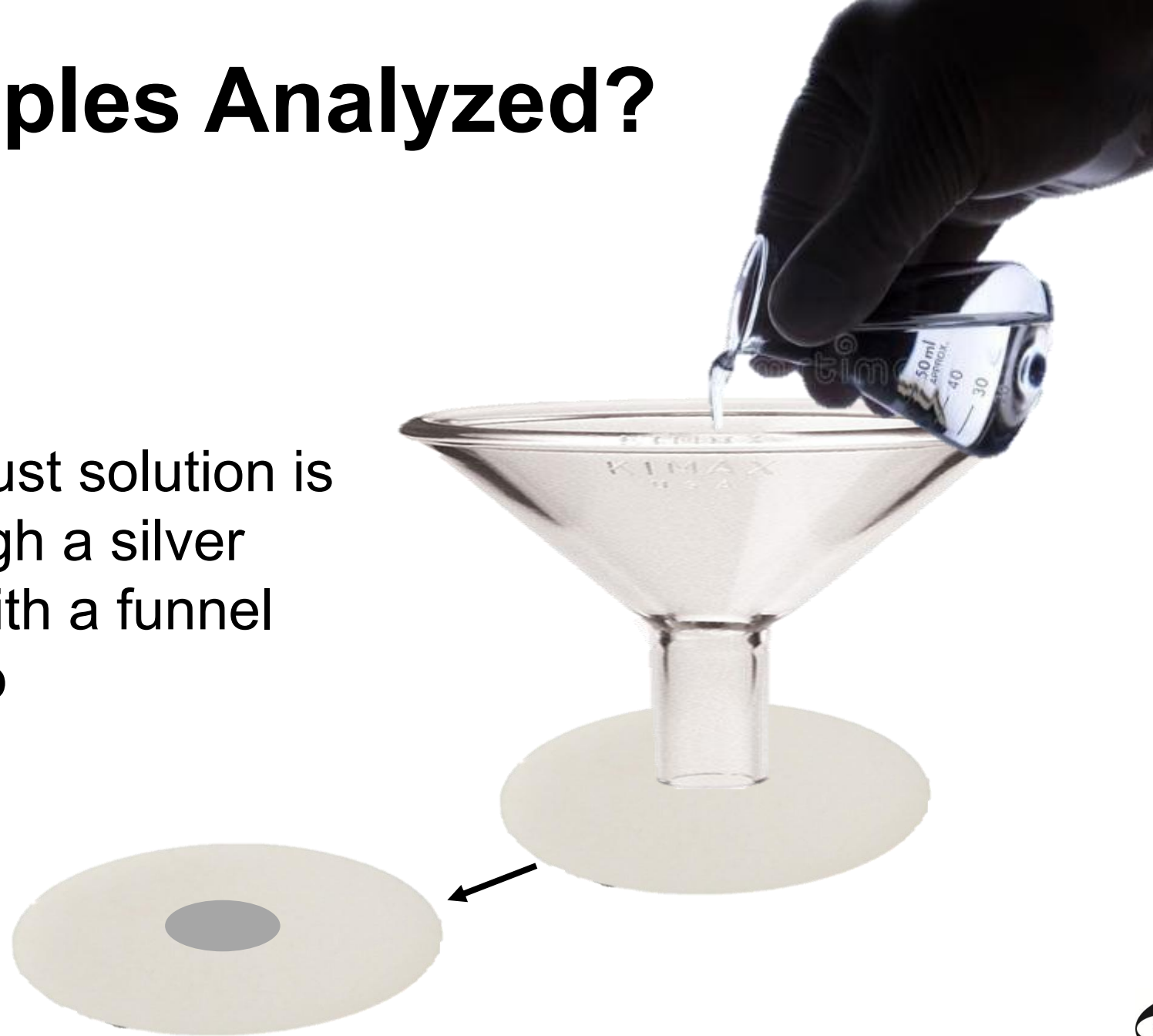
How are Samples Analyzed?

- After weighing, filter is then digested in tetrahydrofuran



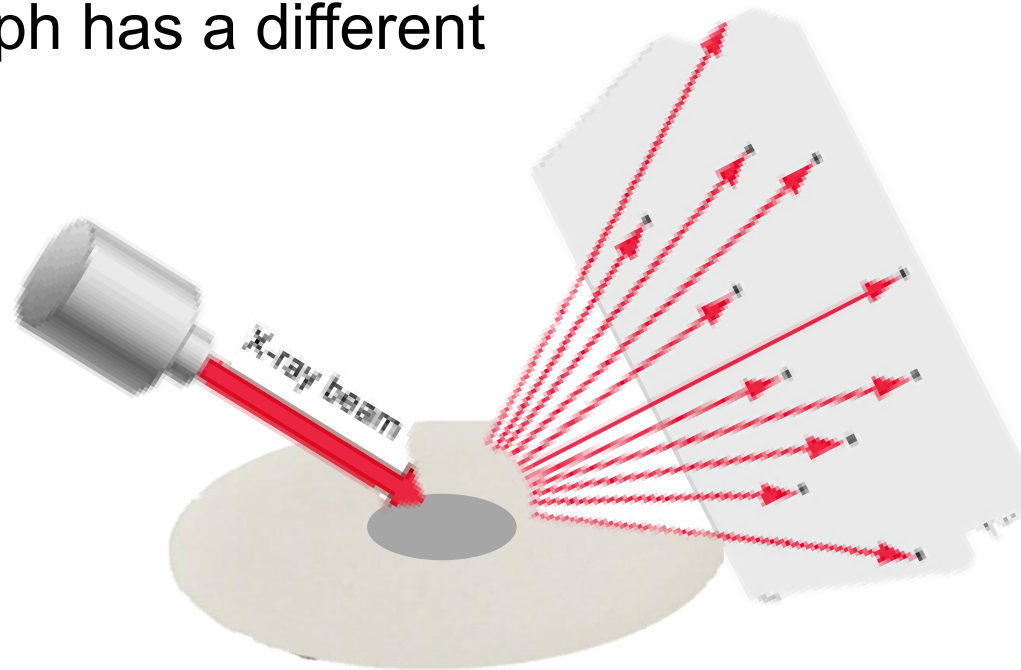
How are Samples Analyzed?

- Tetrahydrofuran/dust solution is then filtered through a silver membrane filter with a funnel and vacuum pump



How are Samples Analyzed?

- Silver membrane filter is then placed into the XRD Analyzer to determine silica content
 - Each polymorph has a different 'signature'



How Much Does Analysis Cost?

- NIOSH 0600 by Microbalance
 - Respirable Dust - \$24

- NIOSH 7500 Silica by XRD*
 - Quartz - \$75
 - Quartz + Cristobalite - \$85
 - Quartz + Cristobalite + Tridymite - \$95

- Media Costs
 - ~\$5 Pre-weighed 37-mm Cassette
 - \$90 for each Cyclone
 - ~\$29 Pre-weighed Disposable PPI



- *Samples having particulate weights that exceed the method-specified maximum filter loading will be subject to surcharges for additional sample preparation and analysis fees. Filters with particulate weights exceeding 2 mg will be assessed an additional \$25 (up to 2x additional sample splits at \$25 each).

- Filters with particulate weights exceeding 7 mg will be processed as a billable bulk sample at the applicable bulk prices.
 - Quartz - \$160
 - Quartz + Cristobalite - \$175
 - Quartz + Cristobalite + Tridymite - \$190



Prices provided by ALS in SLC, UT

Additional Costs to Consider

- Resampling due to invalid samples
 - Consider the additional time required for you, the supervisor, as well as the person being sampled
- Follow-up sampling based on initial results
 - Frequency will be determined by initial results
- Implementing Controls
 - Elimination
 - Substitution
 - Engineering
 - Administrative
 - PPE



Additional Costs to Consider

- Regulatory penalties for non-compliance
- Labor costs per sample:
 - MSHA estimates that M/NM mines with 21-500 employees have a labor cost of \$380 per sample
 - This does not include the cost of production loss from supervisors and miners during sampling



Impactor vs Cyclone: Practical Considerations

PPI (Parallel Particle Impactor)

- Meets ISO/CEN Criteria; referenced in latest OSHA and MSHA Silica Rules
- Quicker deployment and easier end-of-shift routine
- Fewer voids and re-samples due to tipping
- No equipment maintenance (no spare parts, no repairs)
- Compatible with existing lab methods and pumps
- Higher worker acceptance (smaller, less intrusive)
- Easier overall deployment (convenience)

Traditional Cyclone

- Lower cost per unit (often disposable cassettes with cyclone bodies)
- Widely used and referenced in older regulatory methods (historical precedent)
- Durable and well-established in the field
- Increased voids/re-samples due to tipping
- Compatible with existing lab methods and pumps
- Operators already familiar with setup and calibration



Actual picture of an IH after a full-shift sample



Questions?





THANK YOU!

Here's how to contact me for more information!

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