All the Small Things

The Nuanced Details of Industrial Hygiene We Don’t Typically Think About

Dusty Ott, CIH
SKC Inc.

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What We'll Cover: 9 Small Things

1. Mass Units
2. Gas Units
3. Particle Size
4. Size Selective
5. Cyclone/Impactors
6. Sorbent Tubes
7. Detection limits
8. Exposure Limits
9. Noise

Units of Measurement - Mass

g gram



A single paperclip

1.0 gram

mg milligram

About 15-20 grains of salt

.001 gram



Units of Measurement - Mass

µg microgram

A single eyelash is 50-100 µg

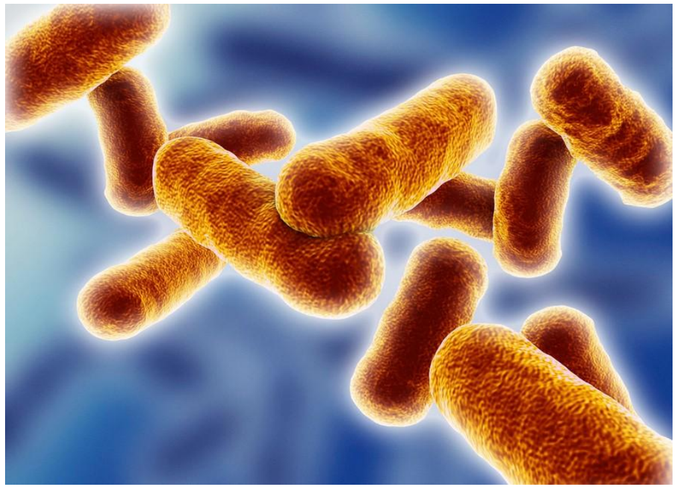
.000001 gram



ng nanogram

Single bacteria

.000000001 gram



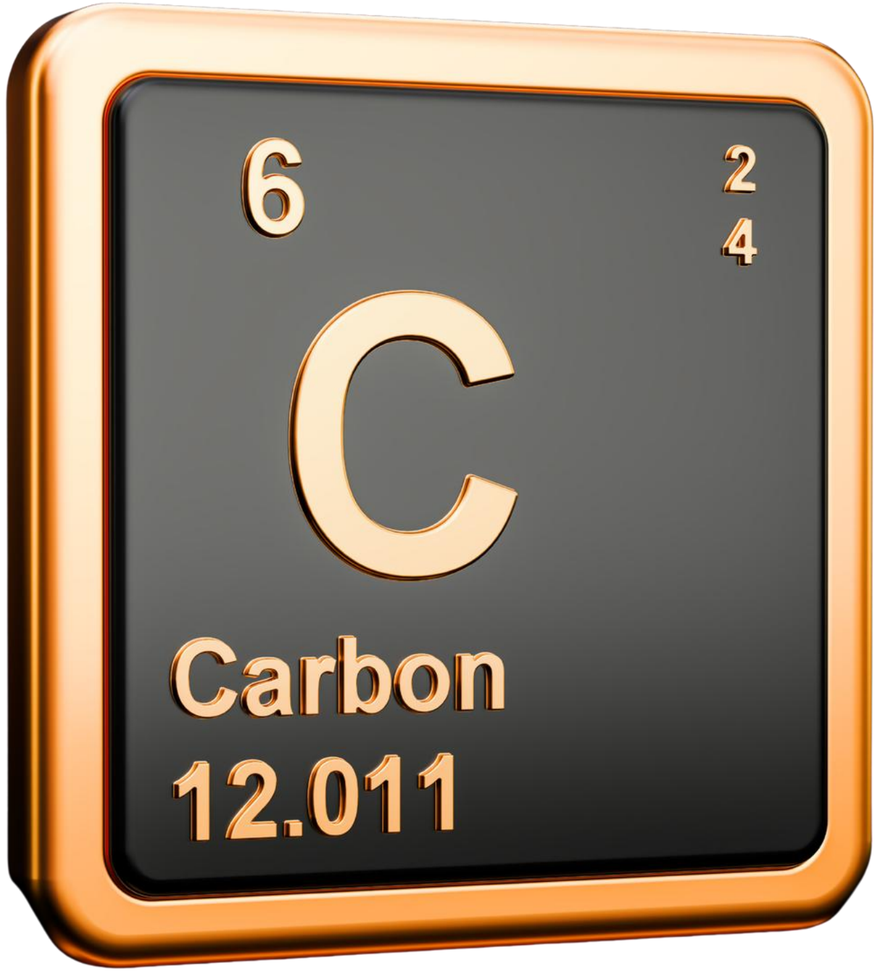
pg picogram

Single DNA molecule

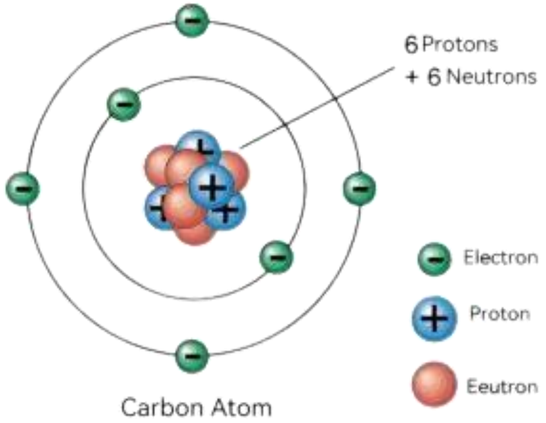
.000000000001 gram



Units of Measurement - Mass



A carbon-12 atom
weighs 19.9 attograms



ag attogram

- 1 quintillionth of a gram
- 1 single proton weighs 1.67 attograms

- .000000000000001 gram

Examples where these measurements are found

g - Not normally used

mg - PNOS - 5 mg/m³

µg - Silica 50 µg/m³

ng - Beryllium 200 ng/m³

pg - environmental levels

ag - particle physics





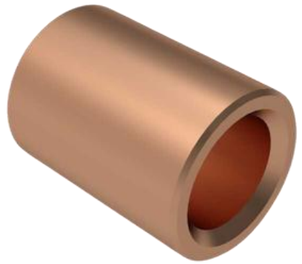
Beryllium in the Superdome

If just 1 gram of beryllium were released and evenly distributed throughout the Superdome, the resulting concentration would be approximately 0.33 µg/m³.

1.7 times OSHA's 8-hour exposure limit of 0.2 µg/m³



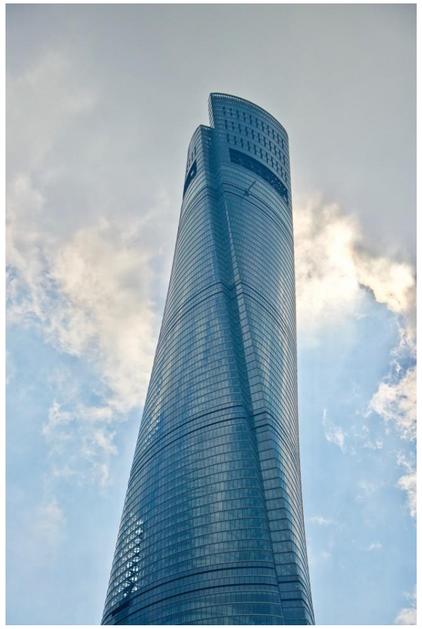




If 1 ng was the equivalent of 1 pound:



µg - Small Car



mg - Large Building



g - Entire Mountain



The Concept of Dilution

PPM vs PPB vs PPT vs PPQ

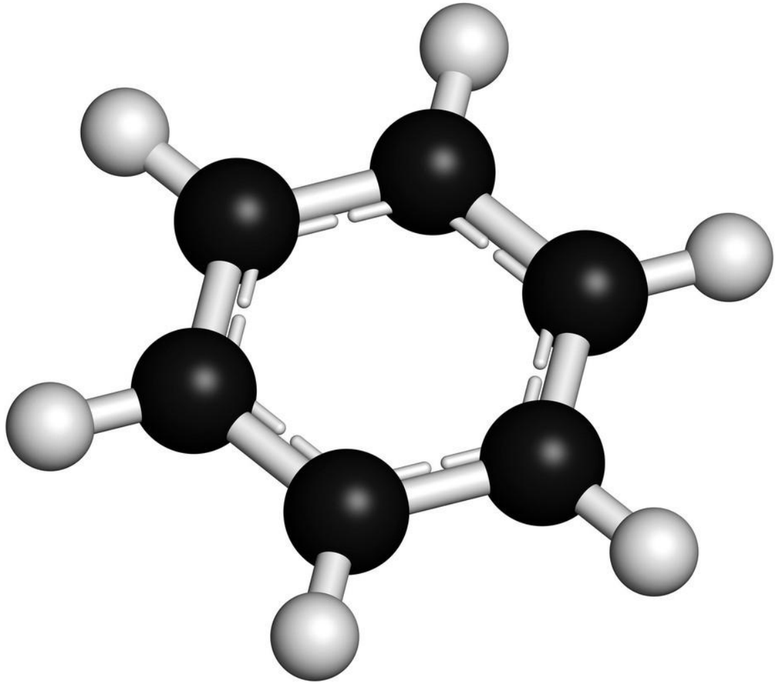


1 PPM

1 in 1,000,000
1 drop in 13 gallons







IH Example

Carbon Monoxide: OSHA PEL of 50 PPM
Benzene: OSHA PEL of 1 PPM

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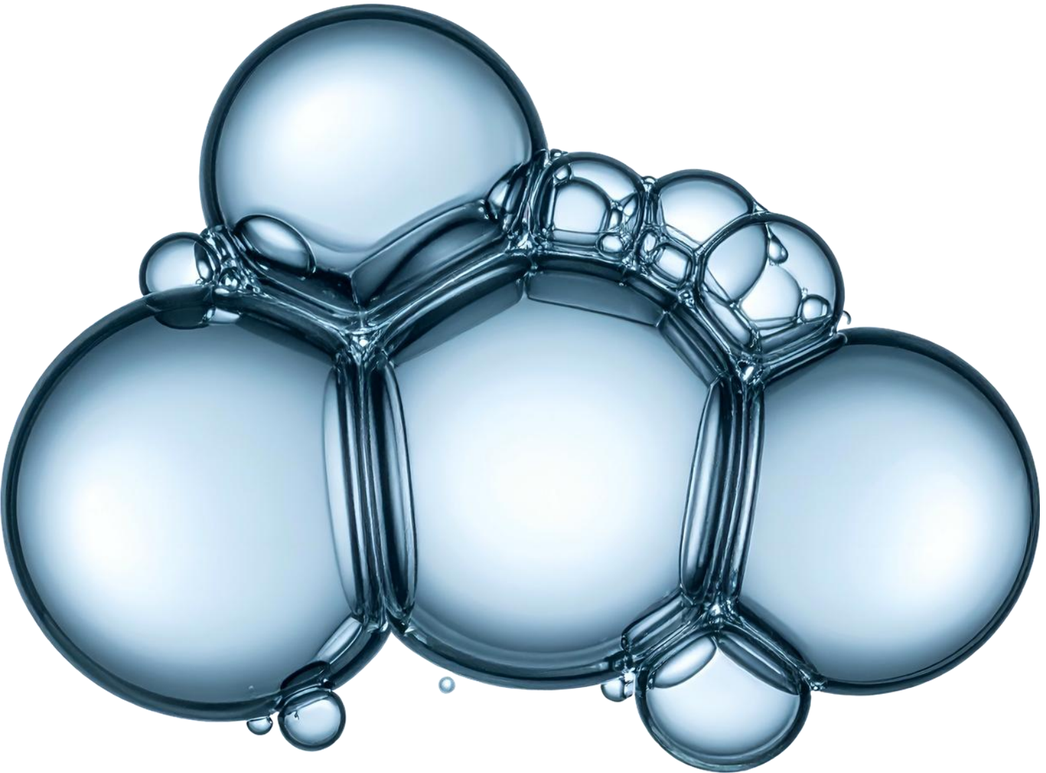
1 PPB

1 in 1,000,000,000
1 drop in 13,000 gallons



Semi with 2 tanker trailers





IH Example

Ozone: OSHA PEL of 100 PPB
MDA (methylenedianiline): OSHA PEL of 10 PPB

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1 PPT

1 in 1,000,000,000,000

1 drop in 13 million gallons



20 Olympic Sized Pools
-25m x 50m @ 2m deep



IH Example

PFOS/PFOA: EPA drinking water limit of 4 PPT

Dioxin: EPA Drinking water limit of 30 PPT

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1 PPQ

1 in 1,000,000,000,000,000

1 drop in 13 billion gallons

20,000 Olympic-sized pools

10 square miles of pools at 6.6 feet deep



IH Example

Nothing yet…

Switching Gears





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 ↘



SOURCES Cleanspace, Daniel Lowerbey, EPA, Financial Times, News Medical, Science Direct, SOMP, Susan Sakolowski, Petroclean, U.S. Dept. of Energy
COLLABORATORS RESEARCH + WRITING Carmen Jung, Inaa Ghosh | DESIGN + ART DIRECTION Hanson Scheir

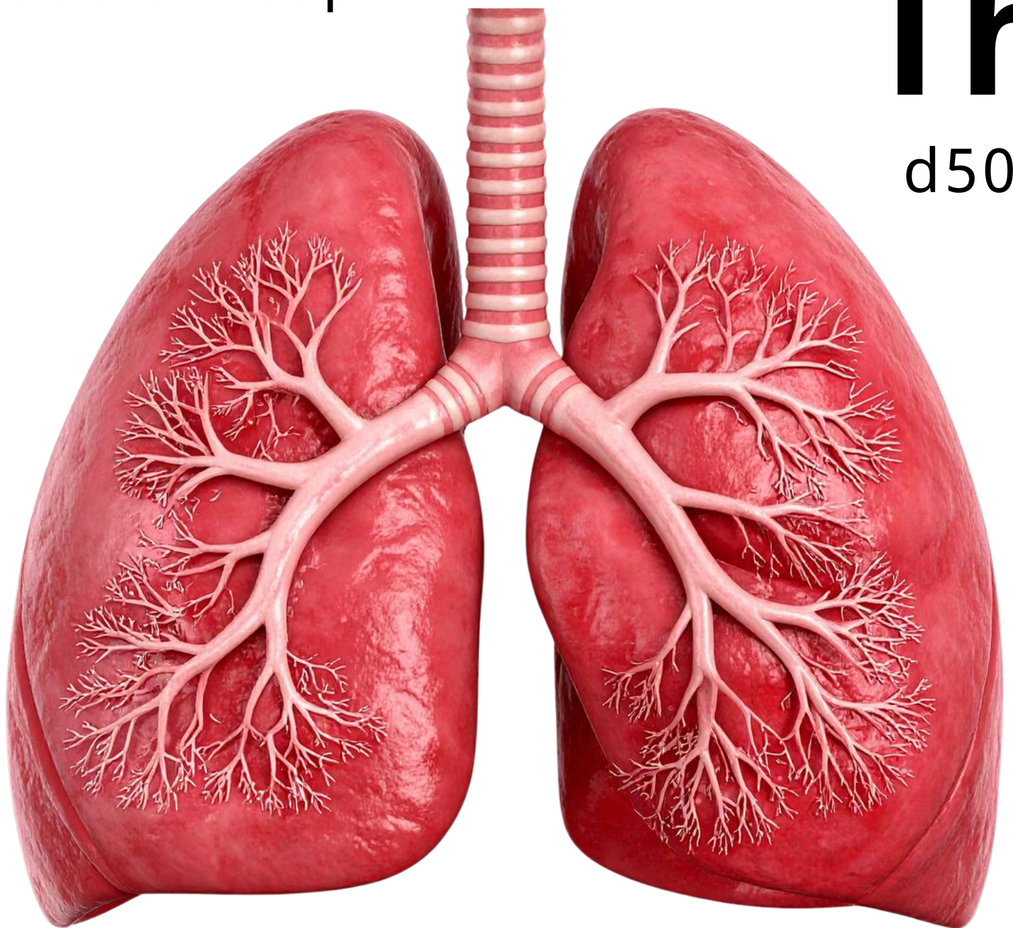
VISUAL CAPITALIST /visualcapitalist @visualcap visualcapitalist.com

[Zooming In: Visualizing the Relative Size of Particles]

Three Fractions: Where particles deposit in the lungs

Inhalable

d50 of 100µm



Thoracic

d50 of 10µm

Respirable

d50 of 4µm



What does d50 mean?

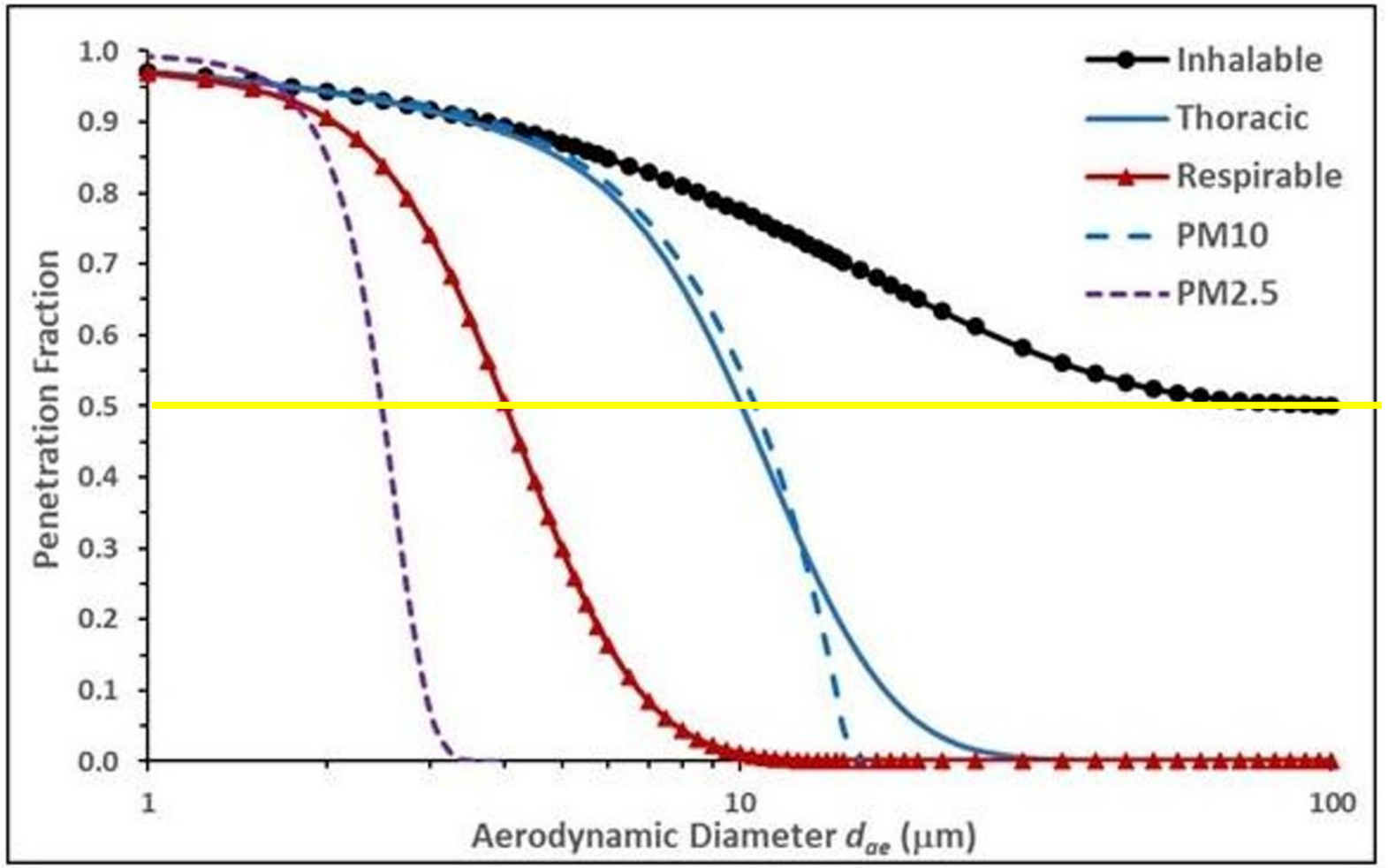
Inhalable
d50 of 100µm

Thoracic
d50 of 10µm

Respirable
d50 of 4µm

PM2.5, PM10

d50 represents the 50% collection efficiency of each sampling convention



CDC/NIOSH: Quantification of Airborne Dusts From Powders

Three Fractions: Where particles deposit in the lungs

Inhalable

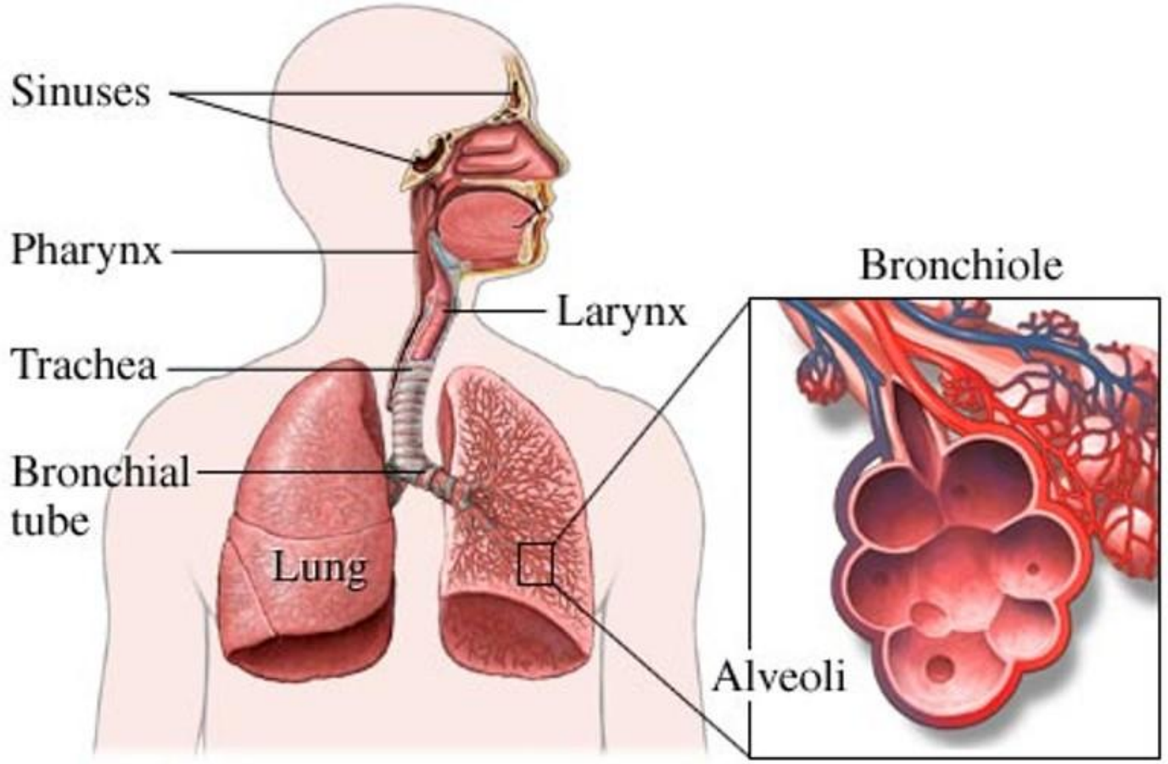
Deposits in:

Nose

Mouth

Throat

Upper respiratory tract



Normal Lung Function » Pediatric Pulmonary Division » College of Medicine » University of Florida

Examples:

Wood dust

Grain dust

Pollen

Large dust particles

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Three Fractions: Where particles deposit in the lungs

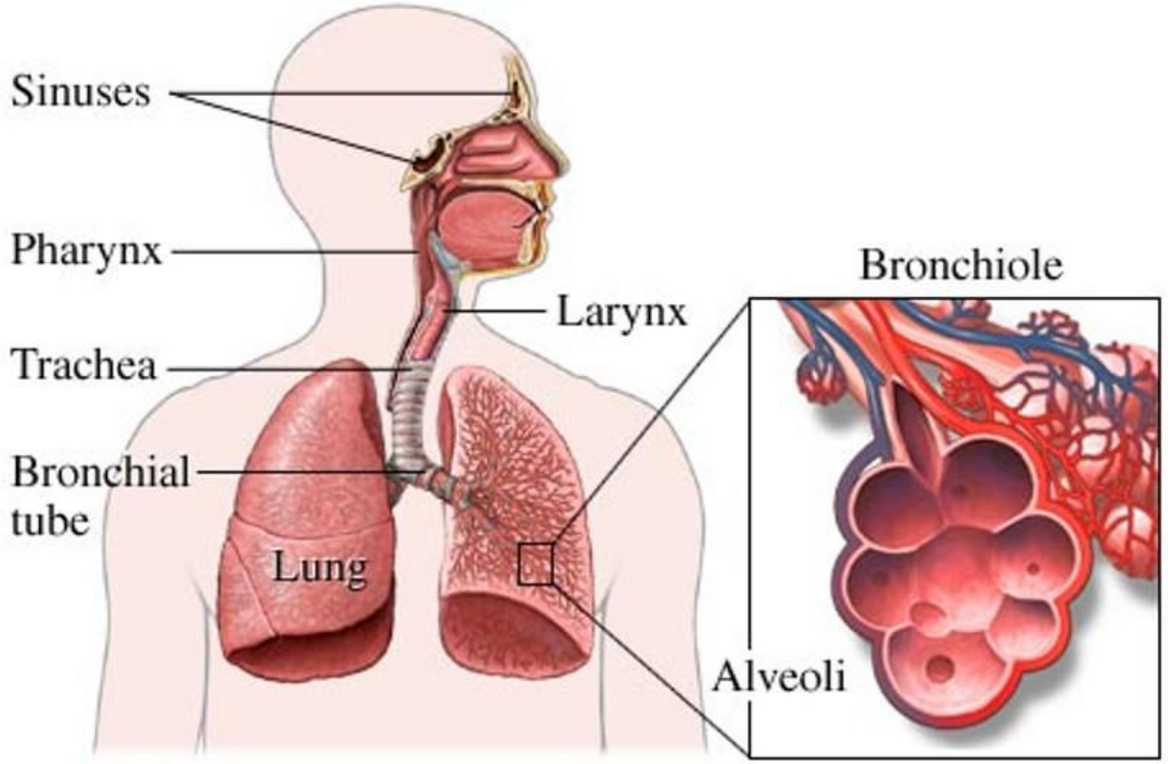
Thoracic

Deposits in:

Trachea
Bronchi
Bronchioles

Examples:

Metal fumes
Sulfuric acid mist



Normal Lung Function » Pediatric Pulmonary Division » College of Medicine » University of Florida

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Three Fractions: Where particles deposit in the lungs

Respirable

Deposits in:

Bronchioles

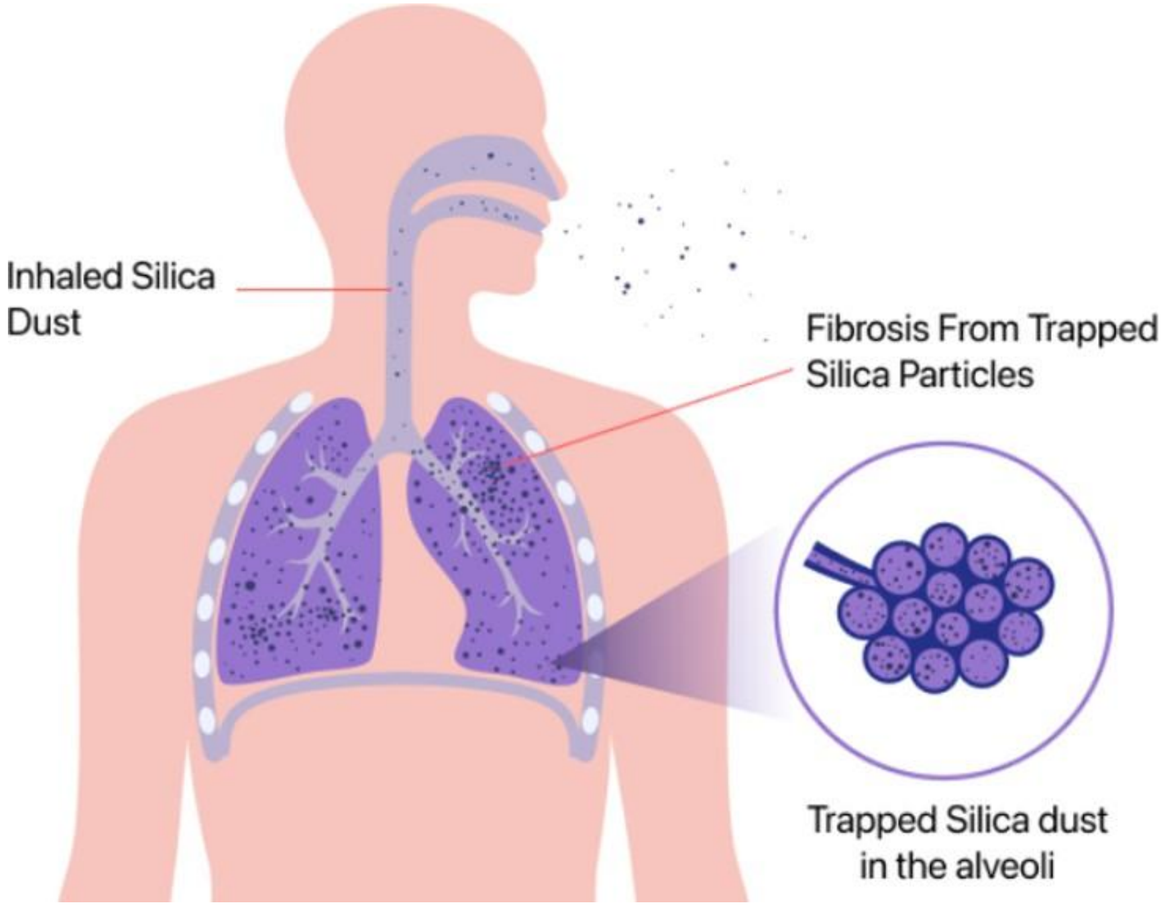
Alveoli

Examples:

Silica

DPM

Metal Fumes



Silicosis: Symptoms, Life Expectancy, Occupational Risks

What about Total Dust?

“Total” doesn’t mean “everything”

d50 of ~ 30 µm

Deposits in upper respiratory tract



Confusing naming convention

Settling Velocity in Calm Air

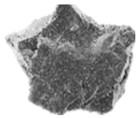
Particle Diameter (µm)	Settling Velocity	Time to Fall 1 Meter
1	0.003 cm/s	~9.3 hours
2	0.012 cm/s	~2.3 hours
4	0.049 cm/s	~34 minutes
10	0.30 cm/s	~5.6 minutes
20	1.21 cm/s	~1.4 minutes
30	2.72 cm/s	~37 seconds
50	7.56 cm/s	~13 seconds
100	30.3 cm/s	~3.3 seconds



Respirable Sized Particle vs. PVC Filter Thickness



37-mm filter ~152-µm thick



4-µm particle



If a 4-µm particle was the size of a softball, how large would a 37-mm filter be?

2700 feet in diameter and 11 feet thick



Burj Khalifa

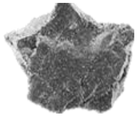
Respirable Sized Particle vs. PVC Filter Thickness



37-mm filter ~152-µm thick
with 8-µm pore size



How does a filter with an **8-µm** pore size capture a **4-µm** or smaller particle?

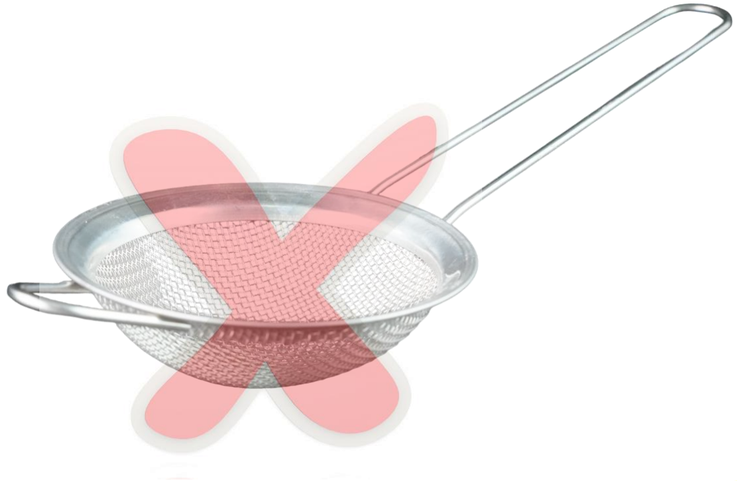


4-µm particle

Respirable Sized Particle vs. PVC Filter Thickness

A PVC filter with an 8-µm pore size does not act like a kitchen sieve. Instead, it is a dense, three-dimensional network of fibers that captures particles through **interception, impaction**, and **diffusion** as air flows through it.

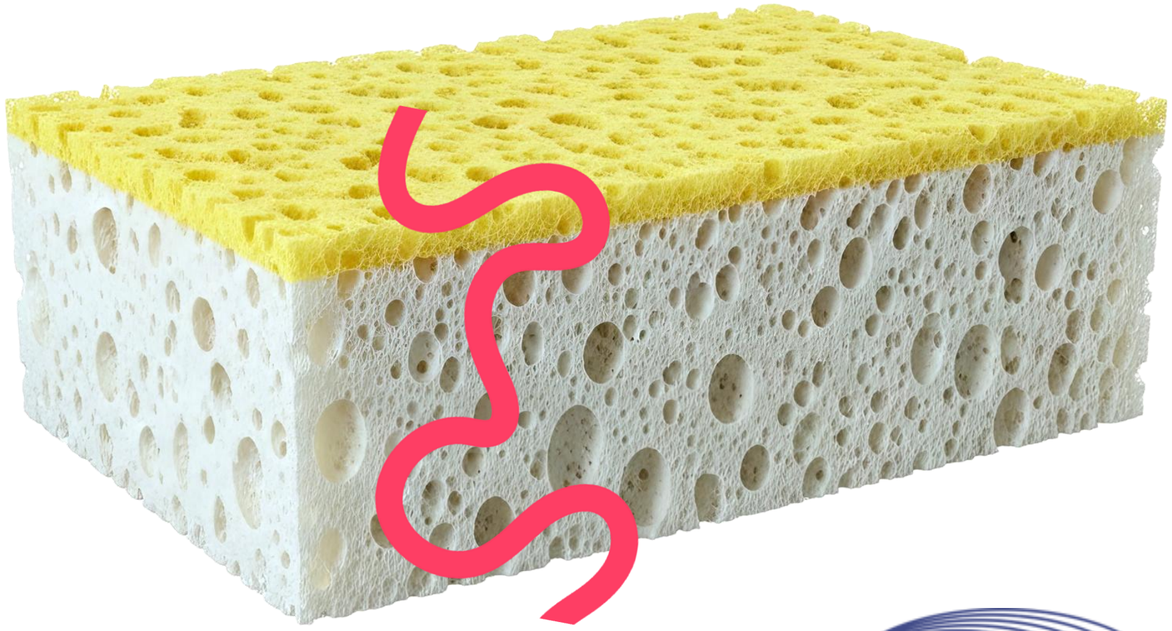
There is no direct path.



4-µm particle the size of a softball (~4 in)

Pore size of 8 inches

11 feet thick



Size-selective Sampling - How does it work?

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.



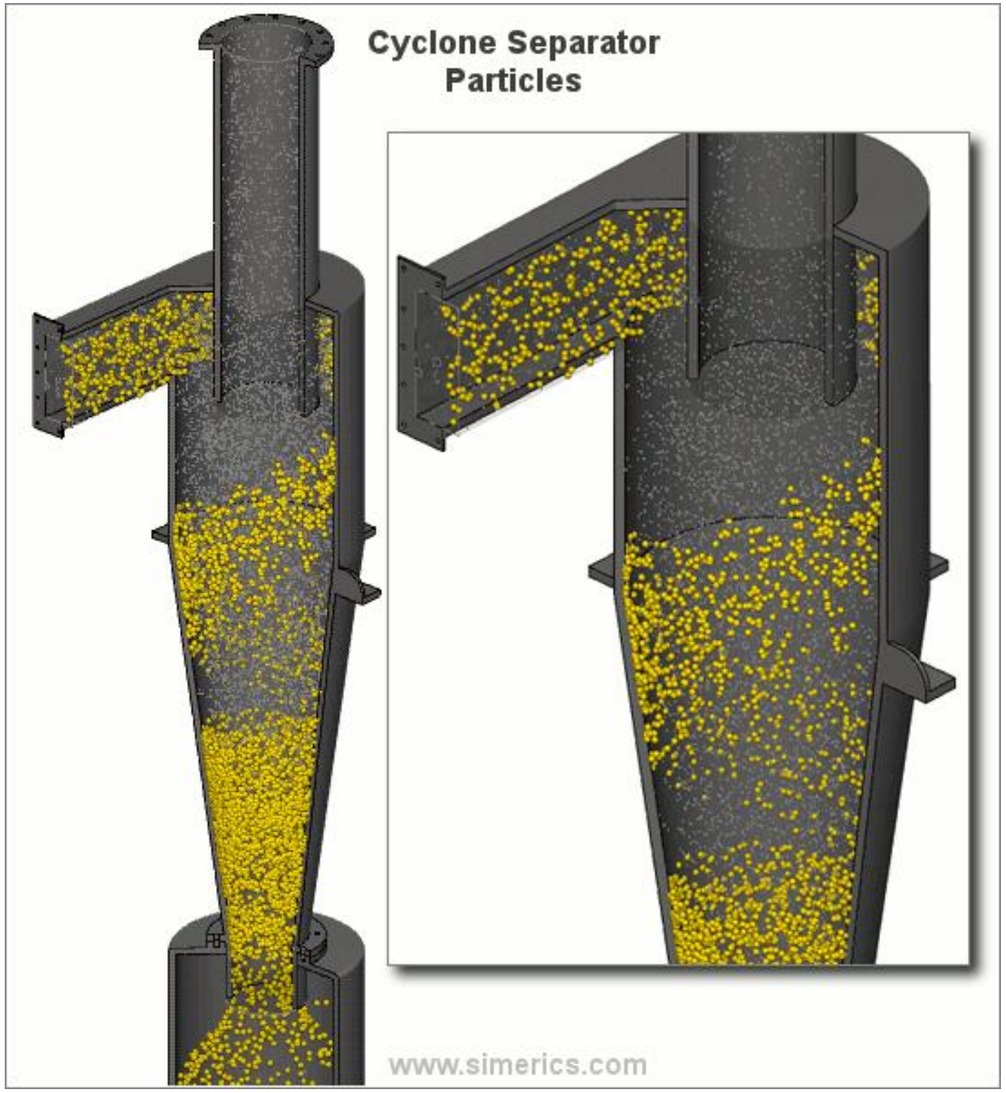






Size-selective Sampling – What Makes a Cyclone?

A cyclone separates particles using centrifugal force. As the air stream spins inside the cyclone, larger particles have enough inertia to move outward and are removed, while smaller respirable particles remain in the air stream and are collected on the filter.

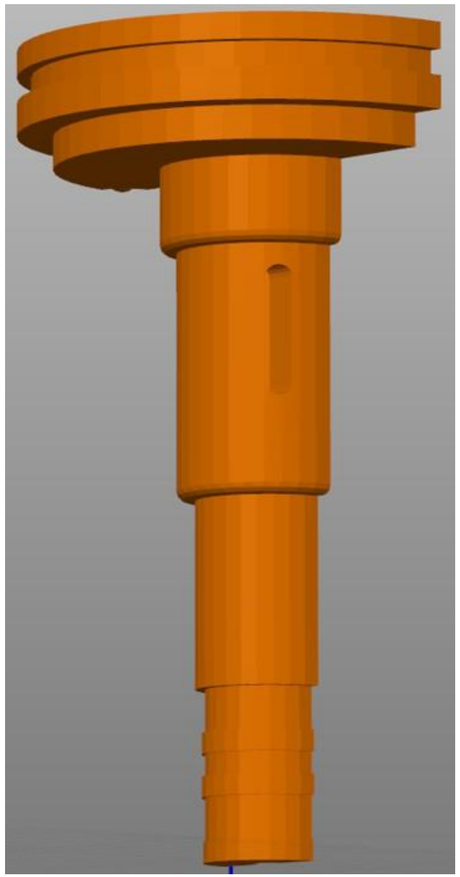


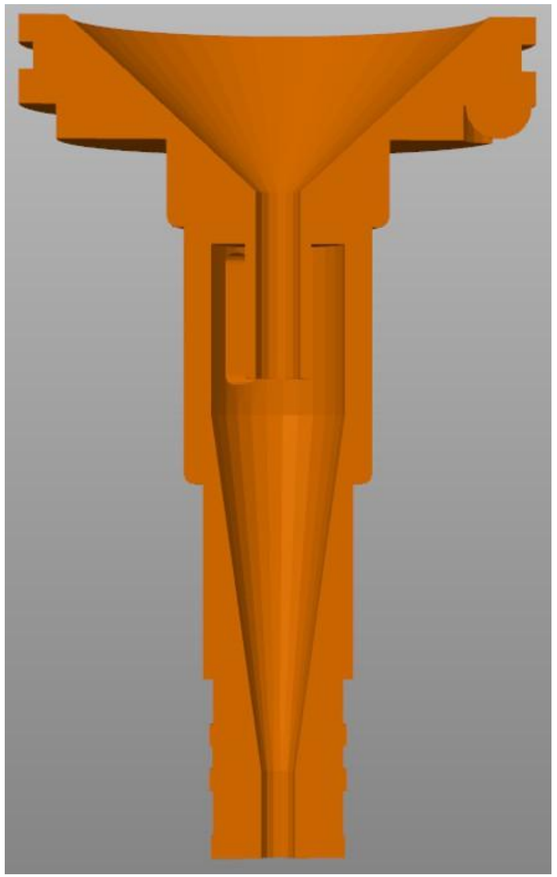


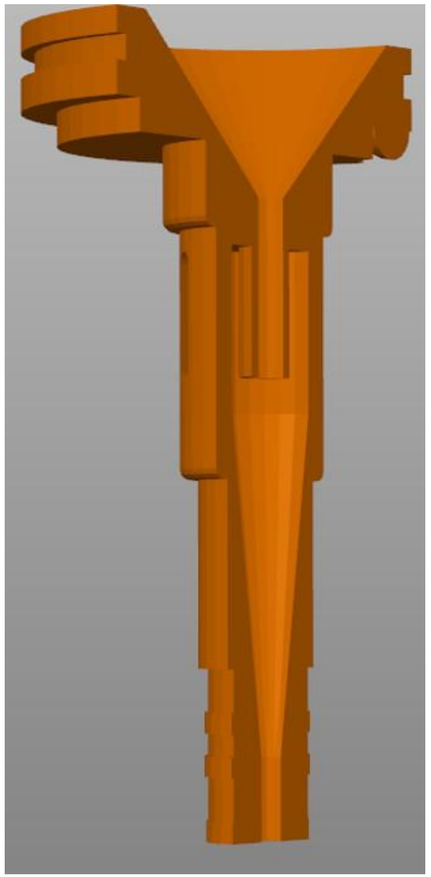
Key parts:

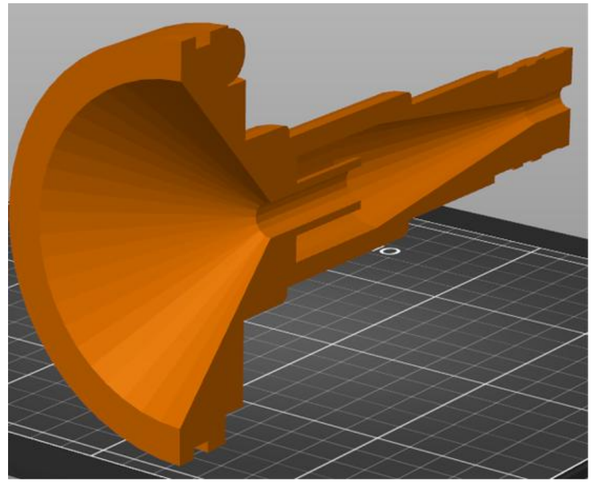
Vortex Generator
Ascending Vortex
Outlet
Descending Vortex
Grit pot

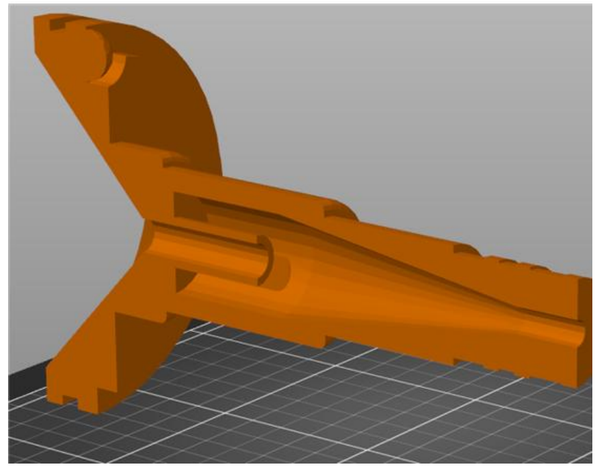
Size-selective Sampling - Cyclones - What's Inside?







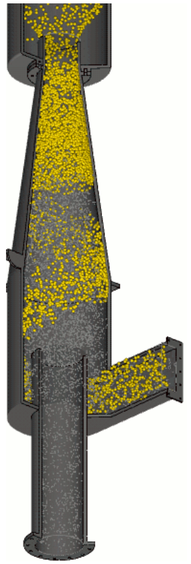


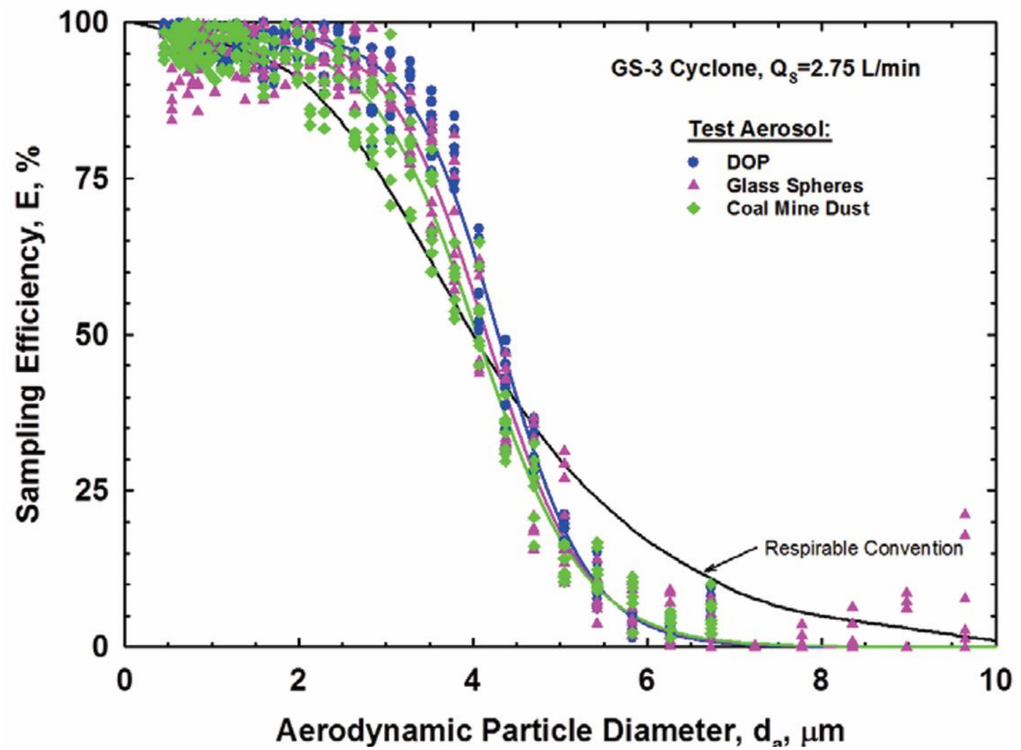


Cyclone Pros - Cons

Cons

- Orientation matters
- Particle loading can impact performance
- Requires cleaning after each use
- Size, weight, and worker burden
- Flow rate will alter cut point
- Over-samples smaller particles, and under-samples larger particles



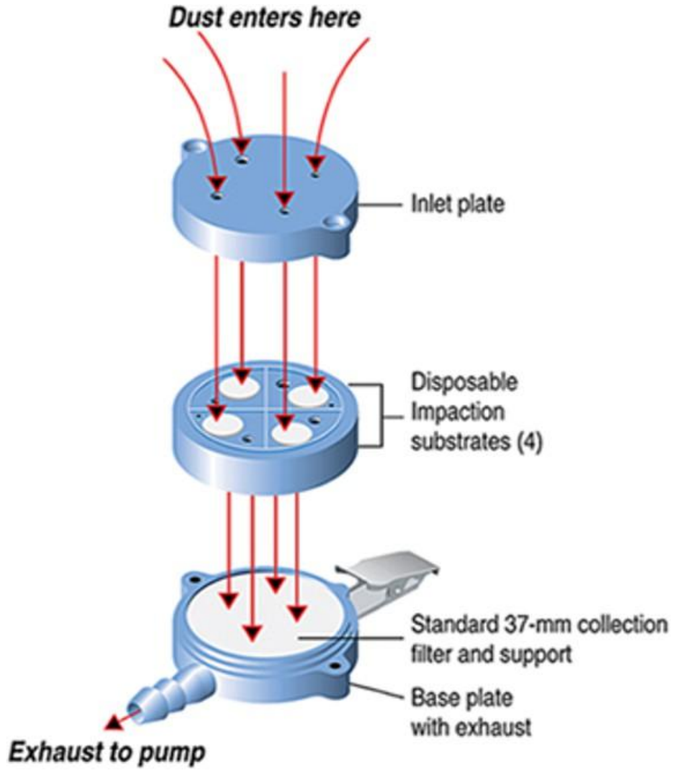


Pros

- 37mm cassettes are inexpensive
- Cyclone can last for years
- Widely used and accepted

Size-selective Sampling – Disposable Impactors

An impactor separates particles by inertial impaction. As the airstream passes through the parallel inlets, larger particles are unable to follow the changing direction of the airflow and impact onto oiled substrates. Smaller, respirable particles follow the airstream and pass through to the filters where they are collected for analysis.





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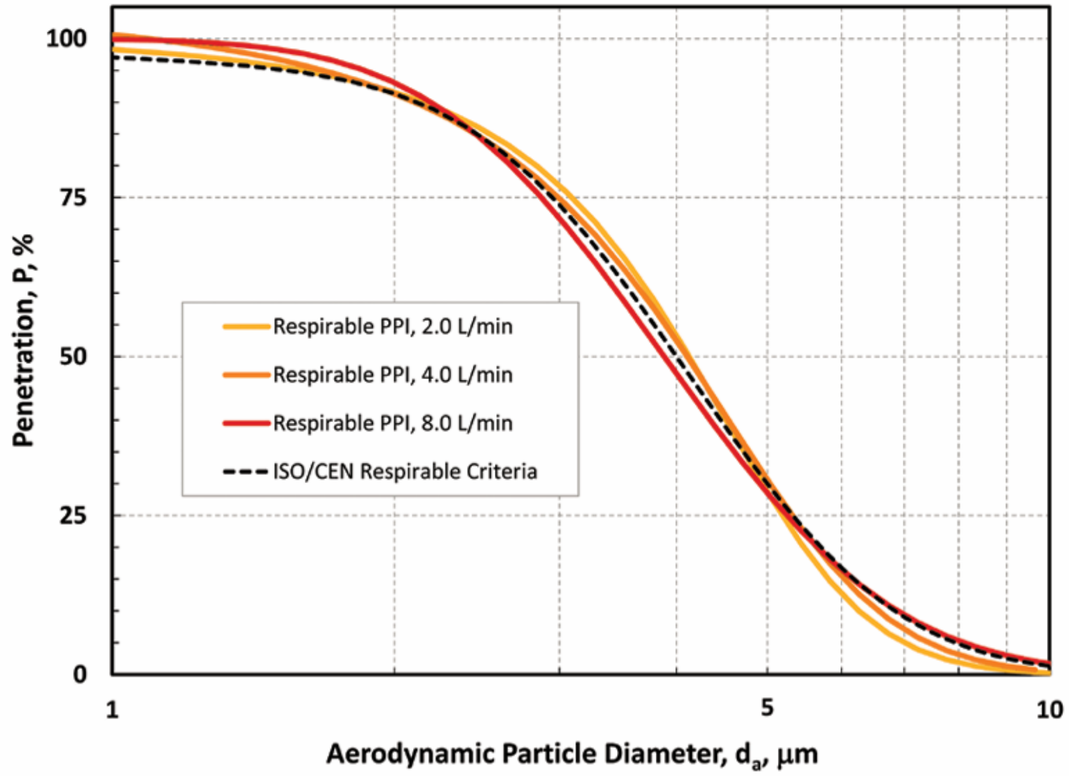
Impactor Pros - Cons

Cons

- Not as widely used as cyclones
- More expensive than a 37mm cassette
- Particle loading can impact performance
- Flow rate will alter cut point

Pros

- Disposable – no cleaning required
- Small size and low weight
- No orientation bias
- Multiple flow rate options from 2 - 8 LPM
- Follows ISO 7708-1995 Respirable convention by design



Comparison of PPI Samplers' performance with the ISO 7708/CEN respirable convention

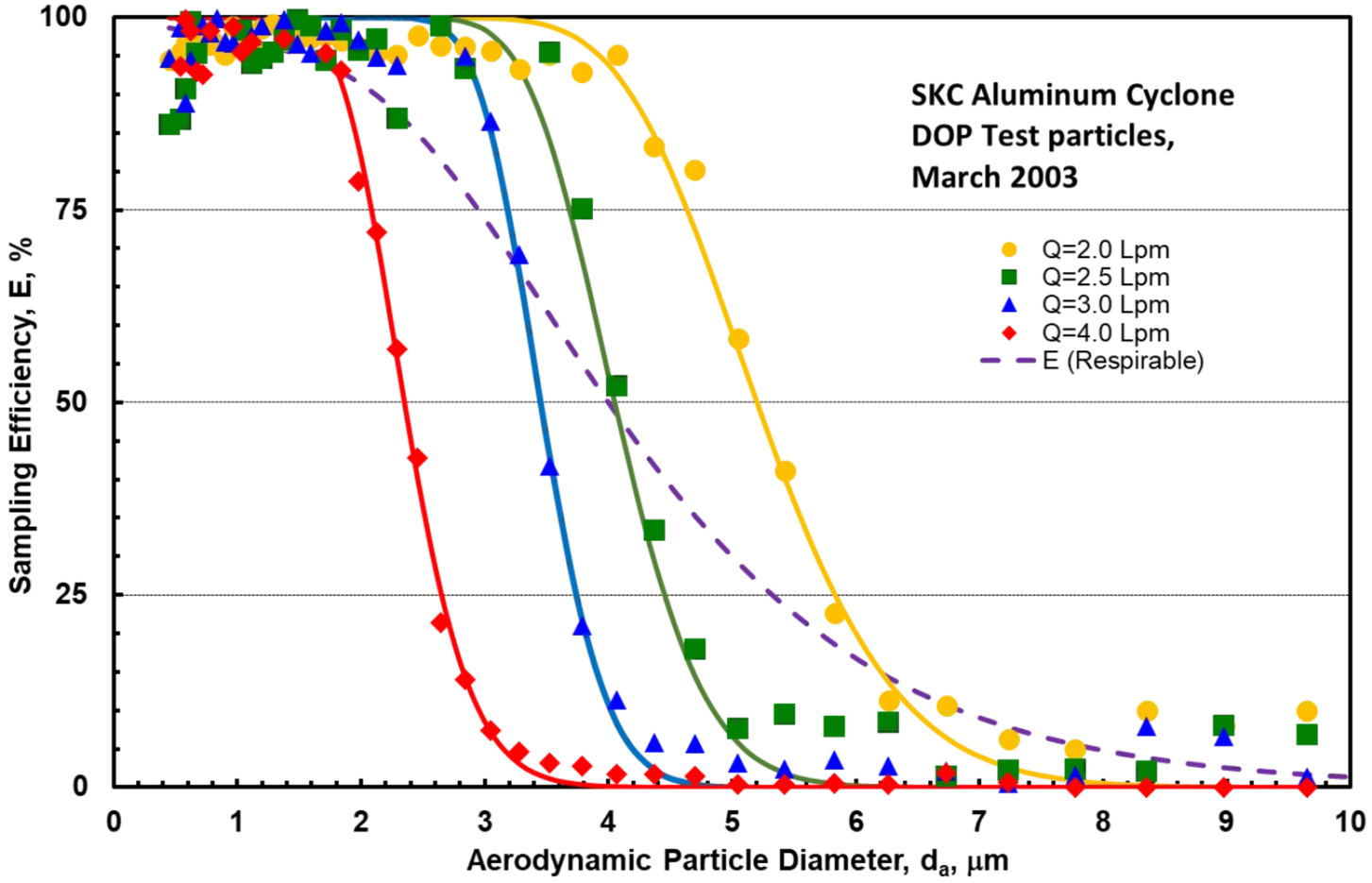


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Flow Rate's Impact on Size Selective Sampling

Flow rate is inversely related to the cut point

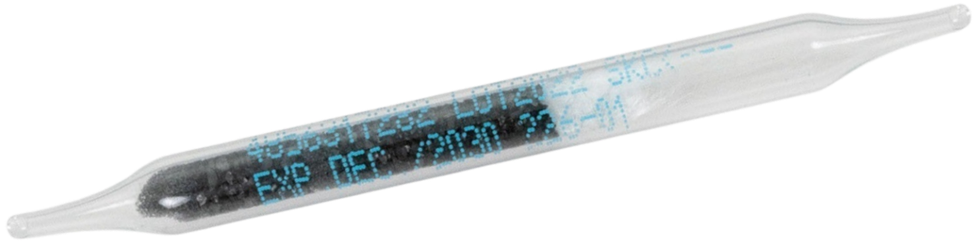
- Higher flow rate results in a lower cut point
- Lower flow rate results in a higher cut point



Moving on to vapors...



Sorbent Tubes



Each gram contains 1000-1,500 m² of surface area.



These 226-01 tubes each contain 150 mg of sorbent. Two sections with 100/50 mg, respectively.



These 226-09 tubes each contain 600 mg of sorbent. Two sections with 400/200 mg, respectively.

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Sorbent Tubes

VOC molecules are carried through the glass tube and encounter the enormous internal surface area of the activated carbon. They are attracted to and temporarily held on the carbon surface primarily through Van der Waals forces.





Activated charcoal is highly porous

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Sorbent Tubes

Each gram contains 1000-1,500 m² of surface area.



This single 226-01 sorbent tube has the same surface area as an entire tennis court.



Sorbent Tubes

Each gram contains 1000-1,500 m² of surface area.



This single 226-09 sorbent tube has the same surface area as 3-4 tennis courts



Sorbent Tubes

Lower Reported Concentrations

Our example:

10 µg reporting limit

100 mL/min for 226-01 tube

200 mL/min for 226-09 tube

600 minute run time

Sample Volume	Calculation	Concentration
60 L (100mL/min)	10 µg ÷ 0.060 m^3	167 µg/m^3
90 L (150mL/min)	10 µg ÷ 0.09 m^3	111 µg/m^3
120 L (200mL/min)	10 µg ÷ 0.120 m^3	83 µg/m^3

As volume increases, the reported concentration decreases.

Particulate Samples

Lower Reported Concentrations

Our example:

5 µg reporting limit

1.7 L/min to 8 L/min

600 minute run time

Flow rate	Air volume	Reporting concentration
1.7 L/min	1,020 L = 1.02 m^3	4.90 µg/m^3
2.0 L/min	1,200 L = 1.20 m^3	4.17 µg/m^3
2.5 L/min	1,500 L = 1.50 m^3	3.33 µg/m^3
4.0 L/min	2,400 L = 2.40 m^3	2.08 µg/m^3
8.0 L/min	4,800 L = 4.80 m^3	1.04 µg/m^3

As volume increases, the reported concentration decreases.

Noise - Sound Intensity

Sound Intensity

Measured in Watts/m²

$$I = \frac{(\Delta p)^2}{2\rho v_w}$$

3 dB increase = 2x intense

Intensity is how much energy is transmitted.



What doubling looks like...

dB												
85	0											
88	2	0										
91	4	2	0									
94	8	4	2	0								
97	16	8	4	2	0							
100	32	16	8	4	2	0						
103	64	32	16	8	4	2	0					
106	128	64	32	16	8	4	2	0				
109	256	128	64	32	16	8	4	2	0			
112	512	256	128	64	32	16	8	4	2	0		
115	1024	512	256	128	64	32	16	8	4	2	0	
118	2048	1024	512	256	128	64	32	16	8	4	2	0

Noise - Threshold

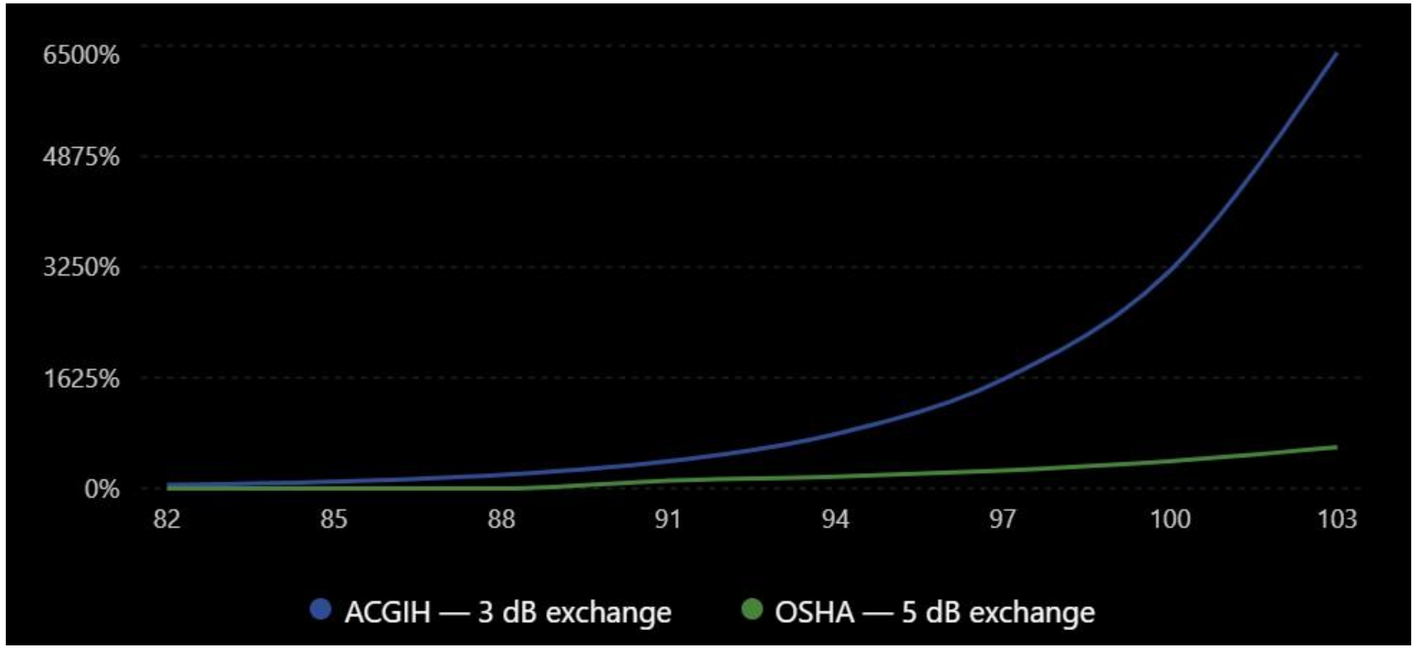
80 dB Threshold

The perfect example of how it works.



Noise - 5dB vs 3 dB Criterion

Sound Level	ACGIH Dose	OSHA Dose
82 dBA	5O%	**0%**
85 dBA	100%	**0%**
88 dBA	200%	**0%**
91 dBA	400%	**114.90%**
94 dBA	800%	**174.10%**
97 dBA	1,600%	**264.20%**
100 dBA	3,200%	**400%**
103 dBA	6,400%	**606.30%**
106 dBA	12,800%	**919.50%**
109 dBA	25,600%	**1,393.20%**
112 dBA	51,200%	**2,111.20%**



ACGIH® dose doubles every 3 dB, while OSHA dose doubles every 5 dB. ACGIH also begins accumulating dose at 85 dBA, compared with OSHA's 90 dBA threshold.

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Noise - Upper Limit

Provides a ‘Ceiling Limit” for noise levels.

Is not a ‘threshold’ where any noise above is not included.
A common misunderstanding is that any noise over the upper limit is not included in the calculations.

Useful to provide other metrics like ULT and CUL.
This is the number of times noise levels over the upper limit last for 30 seconds or more.

Device Setup

MSHA - PEL		**User Custom**	
Response	Slow	Response	Slow
Threshold	90	Threshold	90
Upper Limit	117	Upper Limit	100
Exchange Rate	5	Exchange Rate	5
Criterion Level	90	Criterion Level	90
RMS Weighting	A	RMS Weighting	A

MSHA - PEL		**User Custom**	
TWA	79.3 dBA	TWA	79.3 dBA
Dose	22.7%	Dose	22.7%
Lavg	110.6 dbA	Lavg	110.6 dbA
Lmax	123.4 dbA	Lmax	123.4 dbA
Lmin	71.7 dBA	Lmin	71.7 dBA
Peak	136.9 dB	Peak	136.9 dB
Exposure	6.8 Pa²-h	Exposure	6.8 Pa²-h
ULT	00:00:21	ULT	00:05:22
SEL	137.9 dBA	SEL	137.9 dBA
pTWA(8)	110.6 dBA	pTWA(8)	110.6 dBA
pDose(8)	1734.4%	pDose(8)	1734.4%
CUL	28	CUL	28

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Noise - Dual Hearing Protection

Noise reduction from earplugs and earmuffs is **not additive**.

33dB + 29dB $\neq$ 62dB

Earmuffs over earplugs provide a **maximum of 5 dB additional attenuation** to the higher-rated device.

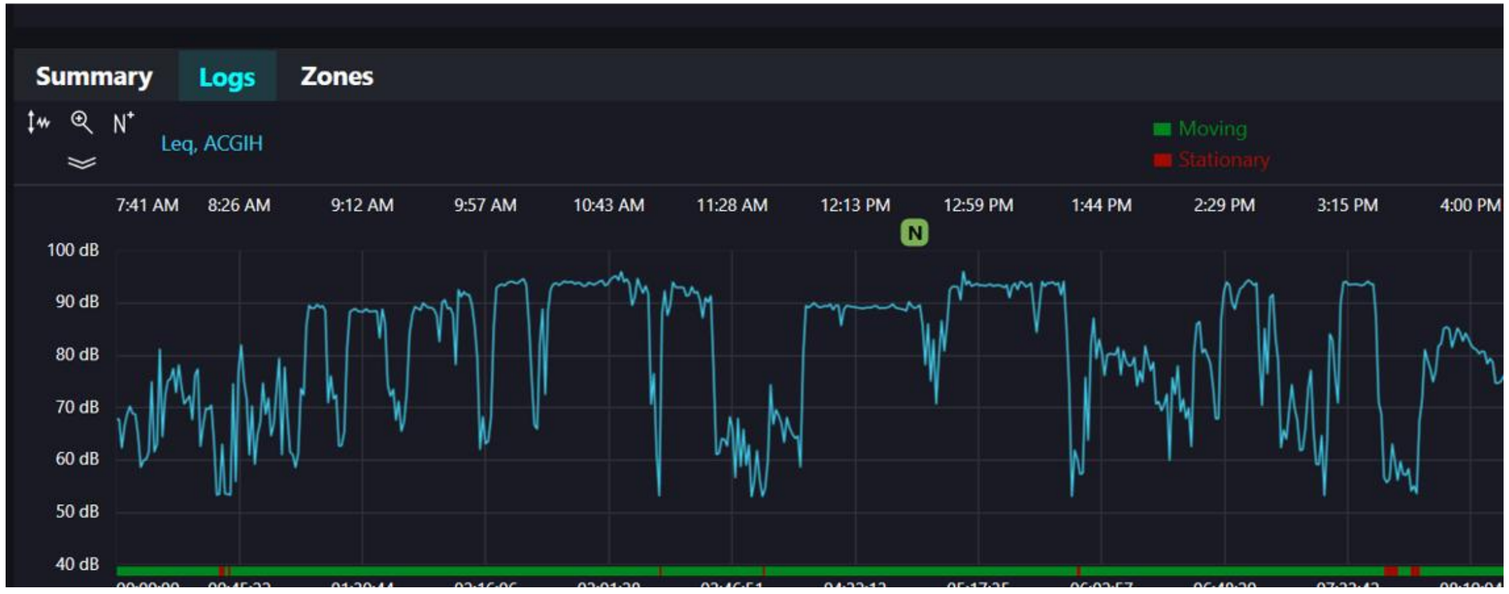


Noise - What should I graph?

Too much information is confusing and does not tell a good story.

Using ACGIH® Leq makes for a clean and easily readable graph that represents actual noise exposure throughout the shift.





THANK YOU!

Here is how to contact ME for more information!

- **E: dott@skcinc.com**
- **P: 724.678.1096**

www.skcinc.com | **Follow us on social media! |**

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