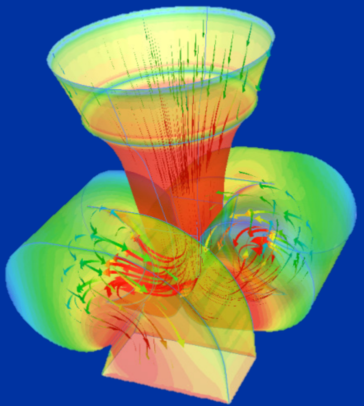
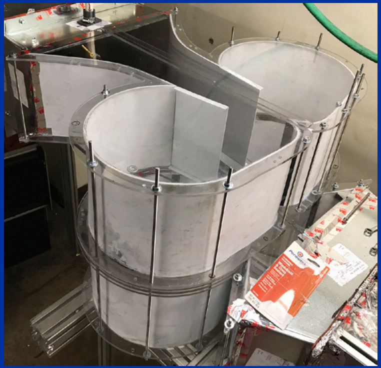
College of Engineering
Department of Mining Engineering

Maintenance Free Dust Filters for Underground Mines





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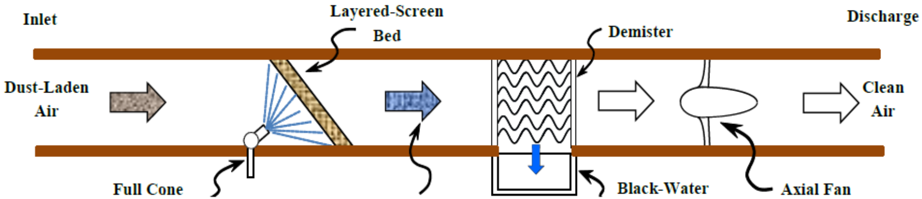
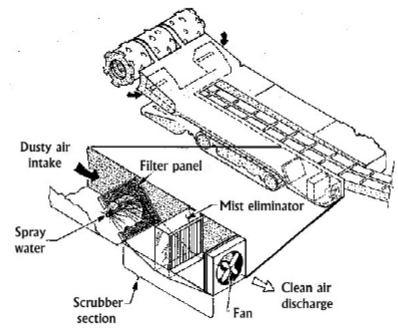
Outline

- Mining scrubber systems
- Computer (CFD) modeling of Vortecone
- Lab testing for cleaning efficiency on a reduced scale prototype
- Self-cleaning impingement filter – Modeling and experiments
- Analysis of the conventional fibrous type screen filter
- Vortecone, impingement, and conventional filters compared

Target: Flooded Bed Scrubbers

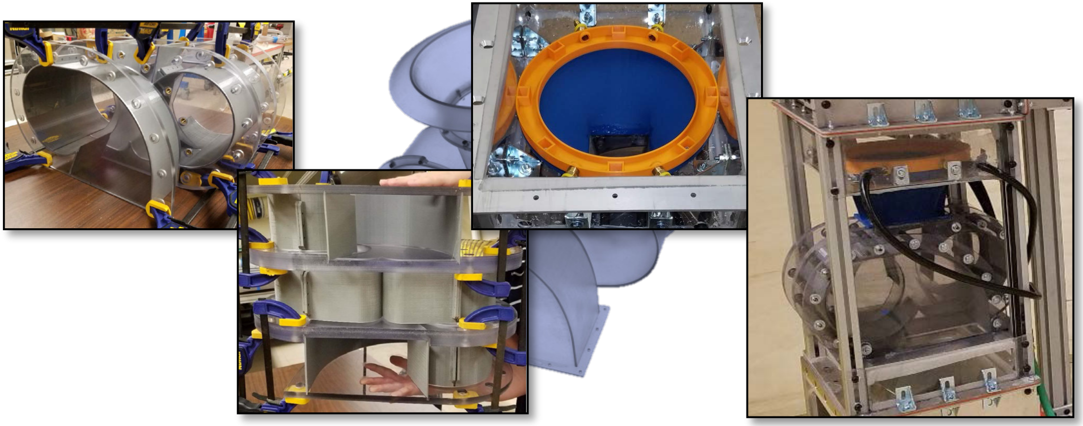




- Inlet, duct work : Captures and directs air
- Fibrous screen : Captures particles from the airstream
- Water spray : Assists capture, prevents dust accumulation
- Demister : Removes excess moisture
- 60-90 % dust reduction [outdated numbers, update coming]
  - Maintenance intensive, screen clogging

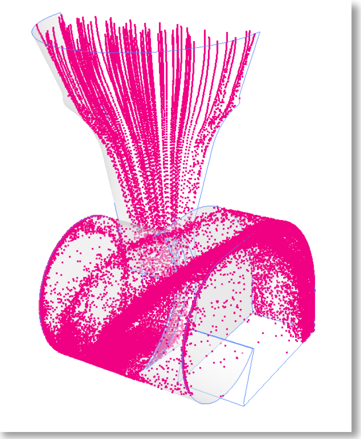
The Vortecone Filter

- Automobile painting generates over-sprays [1-300 μm]
- Very High Cleaning efficiency, no maintenance



The Vortecone Mechanism

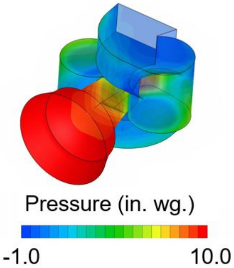
- Fluids accelerated into the vortex chamber
- Particles cast out of swirling airstream differentially based on mass
- Dirty air and water enter air and dirty water leave

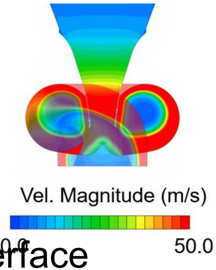


Rapidly Swirling Water Film

- Flow sensitive to geometry
- No internal data acquisition system

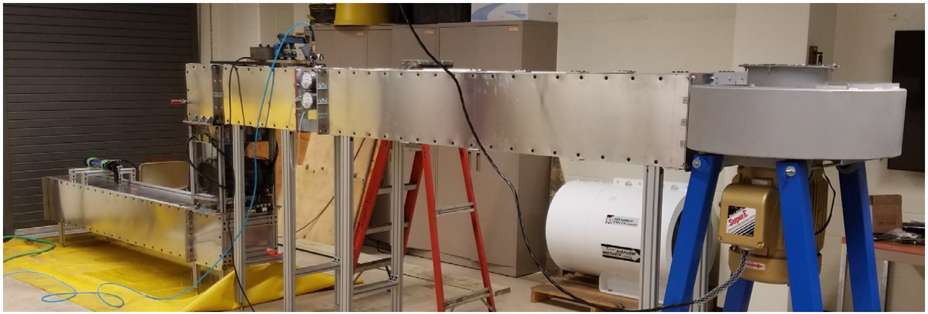
CFD Modeling



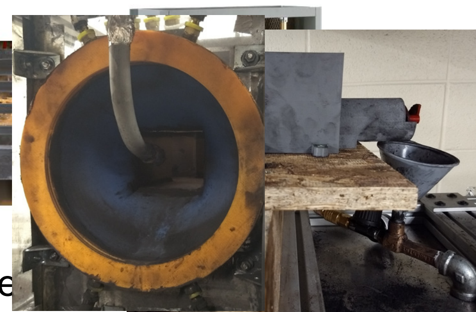


- Steady State Models:
  - Shows flow parameters when averaged over a long duration
- Transient State Models and the VOF
  - Volume of fraction (VOF) approach to mimic the air-water interface
- Dust Particle Transportation and Tracking
  - Cleaning efficiency with particle size
  - User defined functions to model particle trapped by water film and not on impermeable Vortecone surface; good agreement with experiments

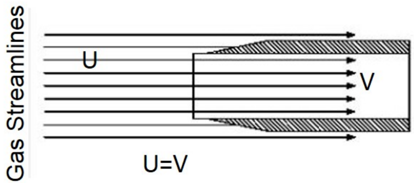
Laboratory Testing



- VFD, Centrifugal fan, Vane and rail equipped duct [12” X 18”]
- Pressure [P_T and P_S] measurement
- Full-cone water spray with controlle
- 3D printed Arduino controlled dust feeder
- TSI OPS 3330 – Used 9 particle size channe

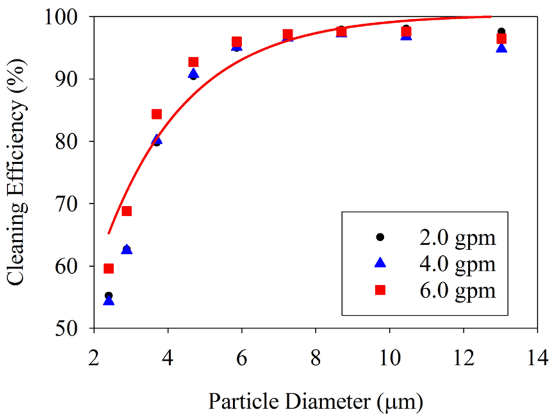


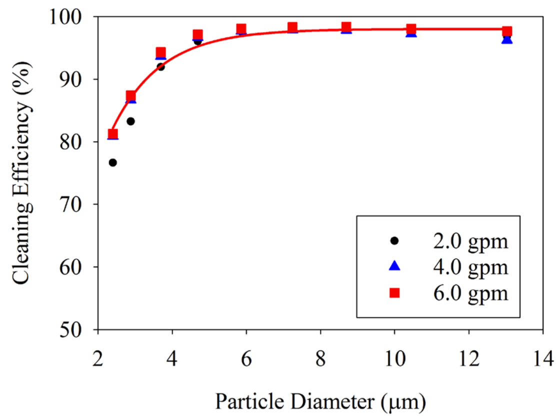
Iso-kinetic Sampling of Airflow [Fixed OPS Flow= 1.0 l/min]



- Optical properties - Complex refractive index
- Experimental errors are eliminated by randomly running tests

Cleaning Efficiency





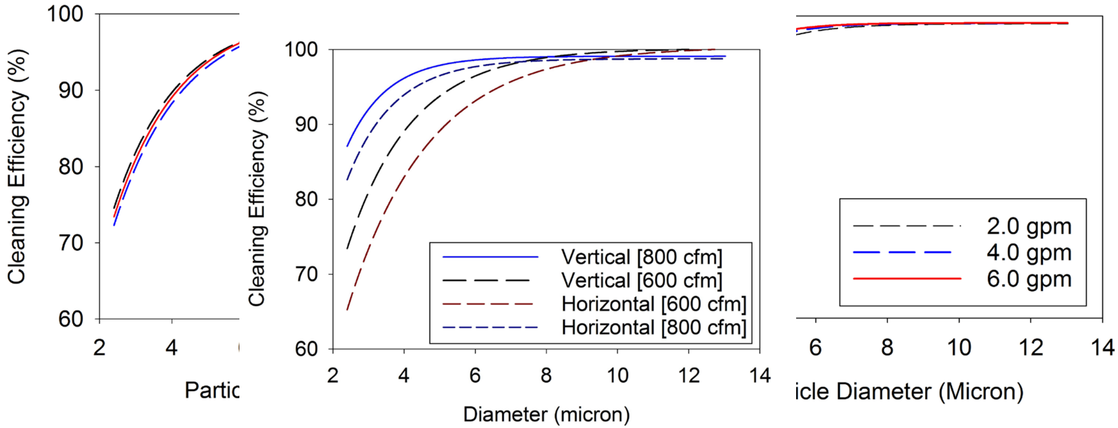
- Cleaning efficiency, $\eta = a\left(1 - e^{-bd}\right)$ [Used for all filters]
  - [a and b: Constants for a known set of flows, d: particle diameter]
  - Area under curve indicates particle capture

Initial Hypothesis

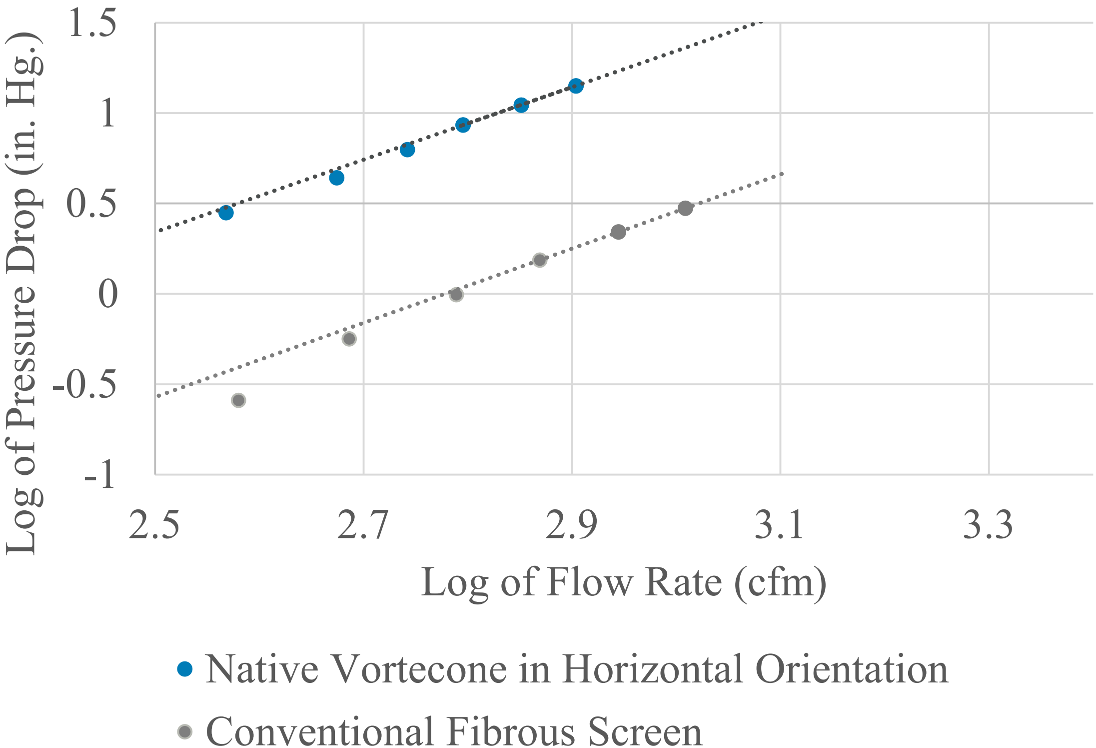
- Vortecone cleaning and maintenance free operation make it an attractive alternative to conventional screens

Lab Testing: Vertically Upright Orientation

- Efficiency improves with an increase in flow and particle size
- Higher efficiency in the vertically upright orientation

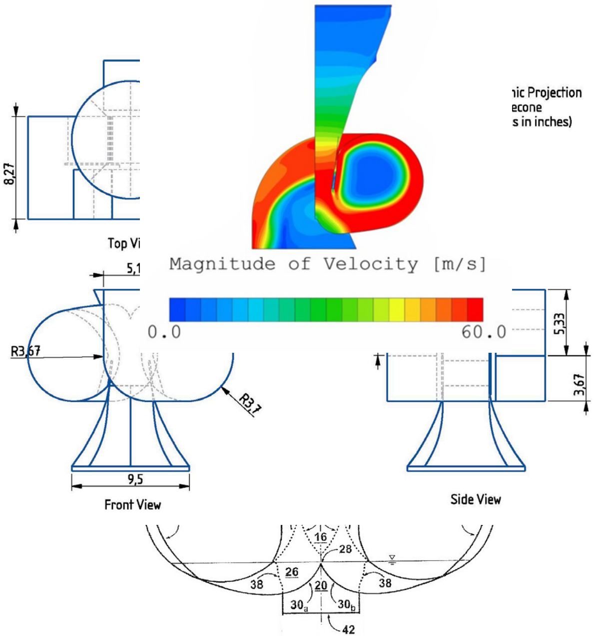


The Problem: High Capture at a Price



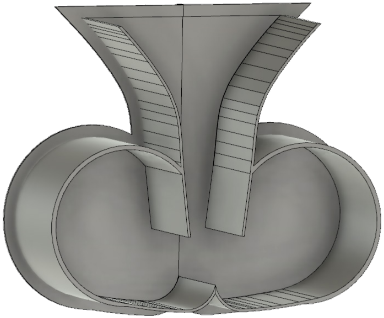
Parametric Studies of the Vortecone

- Rapid acceleration requires power
- Investigation of a few parameters
  - Guide flaps [23_a]
  - Radius of the vortex chamber [32]
  - Sharp curve at the bottom [30_a]
- Vortecone redrawn
  - CFD models for system curve
  - 48 % less resistance (pressure drop and power needed)



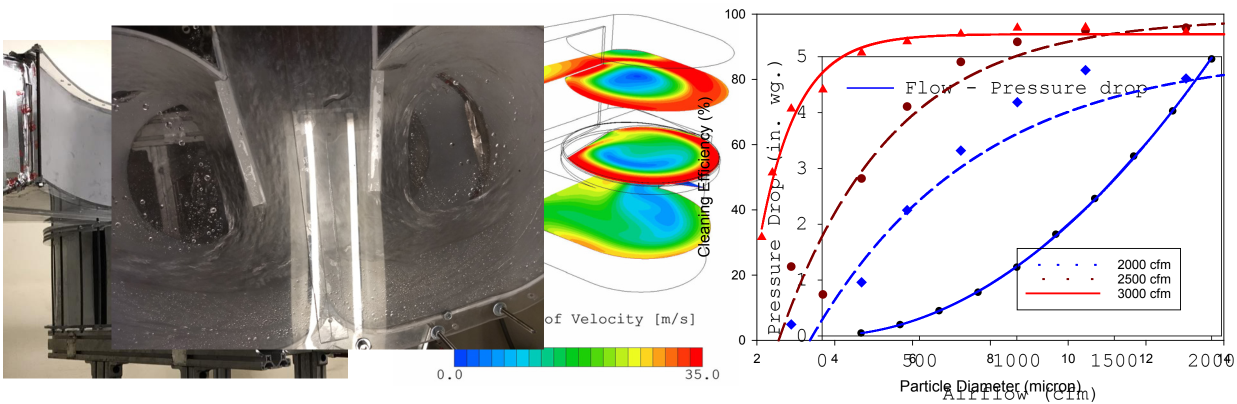
The Redesign

- Parametric study to determine the features that dictate flow and pressure drop
  - Length and width of guide flaps
  - Radii of lobes
  - The sharp curve at the lower end of the Vortecone



Horticone

- Design for horizontal implementation, Vortecone with one outlet
- Wider inlet guide to slow down airflow to just the minimum speed, lowers the power requirements significantly



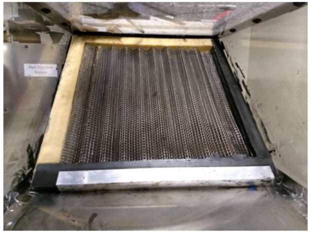
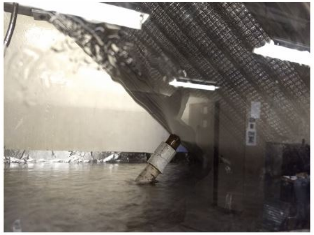
Works Better

- Vortecone provides a very high capture rate, leading to great efficiency
- Hortecone is a step change improvement, especially for working in underground environments

- Both require a redesign of the flooded bed scrubber

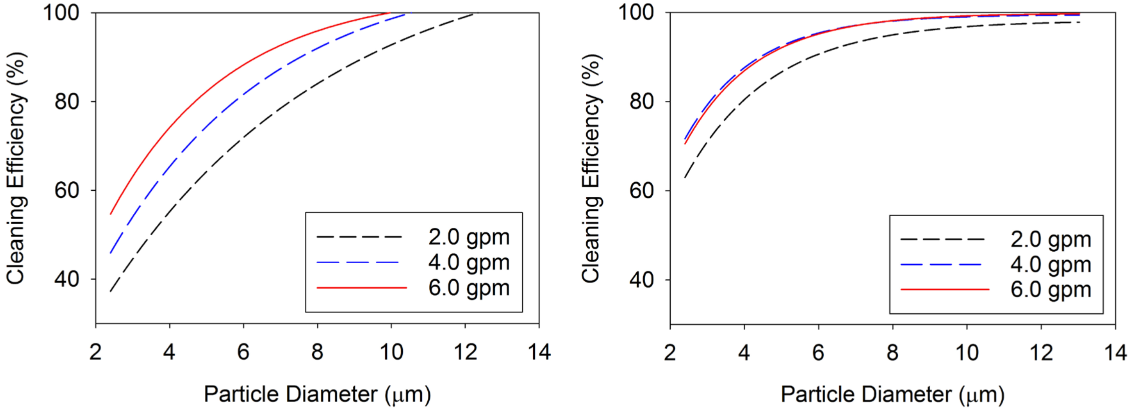
The Conventional Fibrous Screen: Lab Set-up

- Water flooded screen recommended by the USBM
  - Usually 10-30 layered screen used in the industry
  - Used a 20 layered screen for lab testing

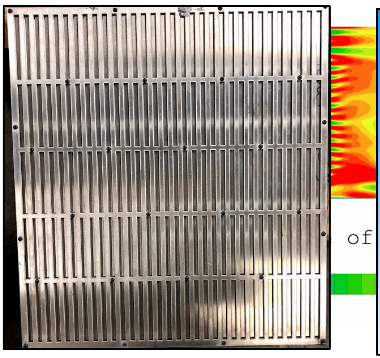

Conventional Screen Laboratory Results

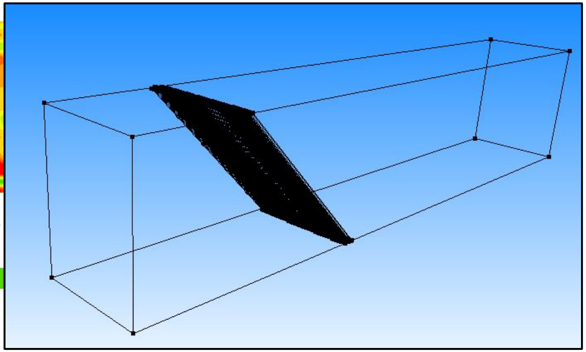
- Cleaning efficiency improved with increase in dust size and airflow
- Water flow affecting efficiency at the lower airflow



Designing the Impingement Type Filter*

- Three thin aluminum sheets with wide, long rectangular slits
- Designed screen separation to force acceleration





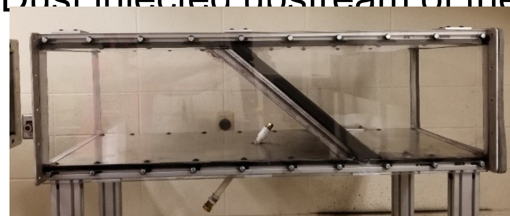
* US Patent and Trademark Office, Application # 62/74,6711

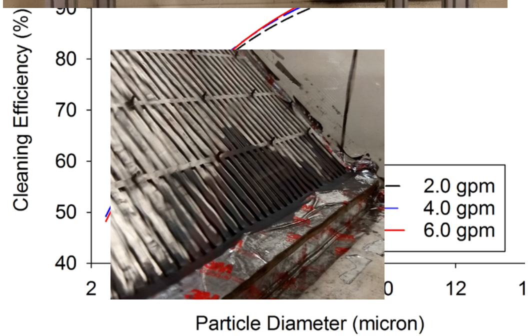
Particle Tracking for Impaction

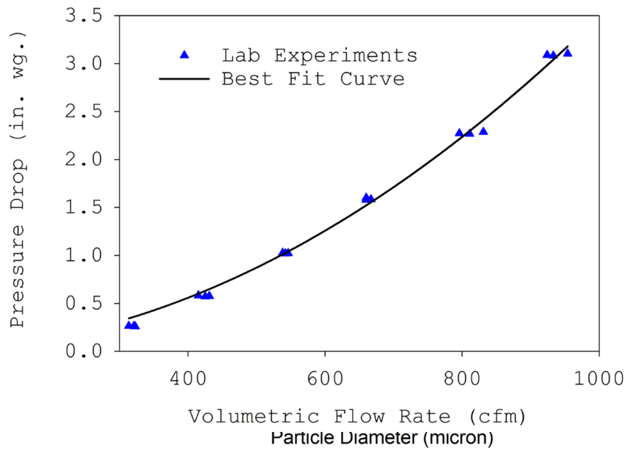
- Released ‘mass-particles’ with a wide range of diameter at the inlet;
- Particles hitting the screen assumed to be trapped

Lab Testing of the Impingement Screen

- Modified the test set-up for impingement screen testing
- Dust injected upstream of the screen, sampled iso-kinetically
- ncrease in airflow

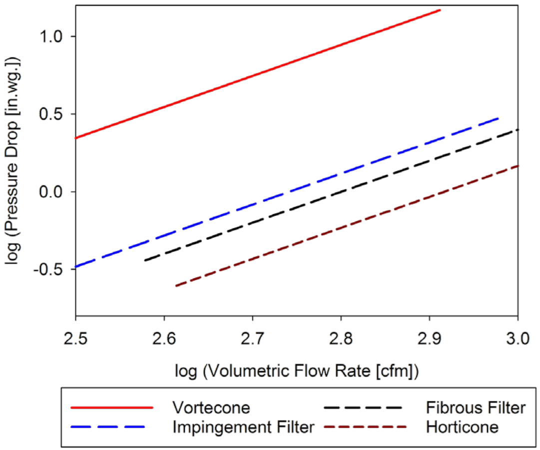






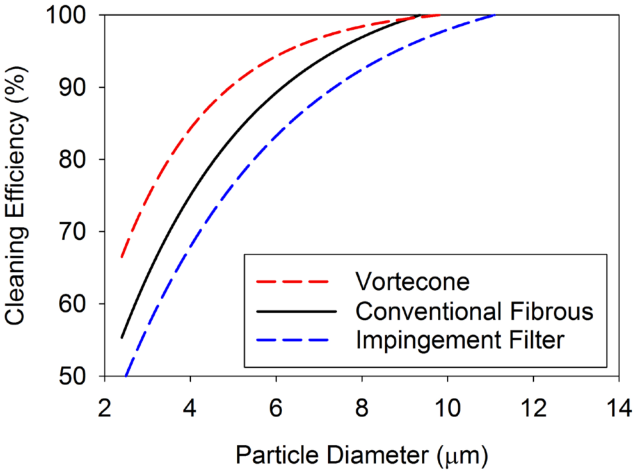
Filters Performance Compared

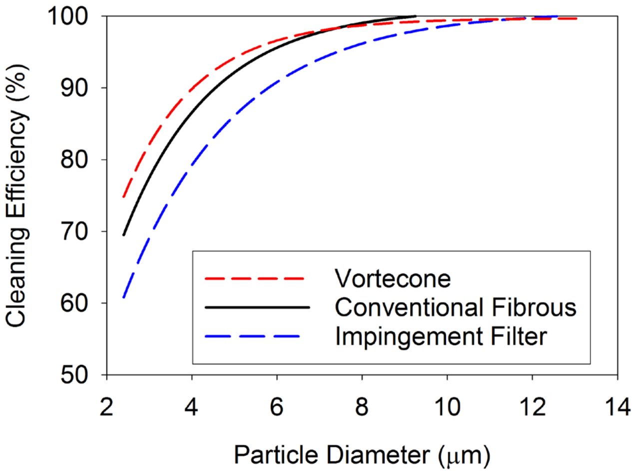
- Used the same set-up for the PQ and cleaning efficiency curves
  - $P = RQ^2 \Rightarrow \log P = \log R + 2 . \log Q$ [straight line]
  - Vortecone shows highest resistance (pressure-drop) to flow



Screen	Resistance ($kN.s^2/m^8$)	Compared to Vortecone
Vortecone	22.99	100.0
Impingement	3.43	14.9
Conventional	3.13	13.7
Horticone	1.73	7.52

Cleaning Efficiency Comparison [6.0 gpm]





- Consistent air and water flows

Filter Performance Factor [FPF]

- FPF= $\frac{1}{P}\boxed{\int_{dS}^{dL} a\left(1-e^{-bd}\right).dd}$, P is the pressure drop at known flow

Area under the cleaning efficiency curve (Integral)

Table. FPF calculations at 600 and 800 cfm

Cut-off sizes	Vortecone	Impingement Screen	Conventional Screen
Integral	988	915	961
P (in.wg.)	7.99	1.24	1.02
FPF	123	738	942

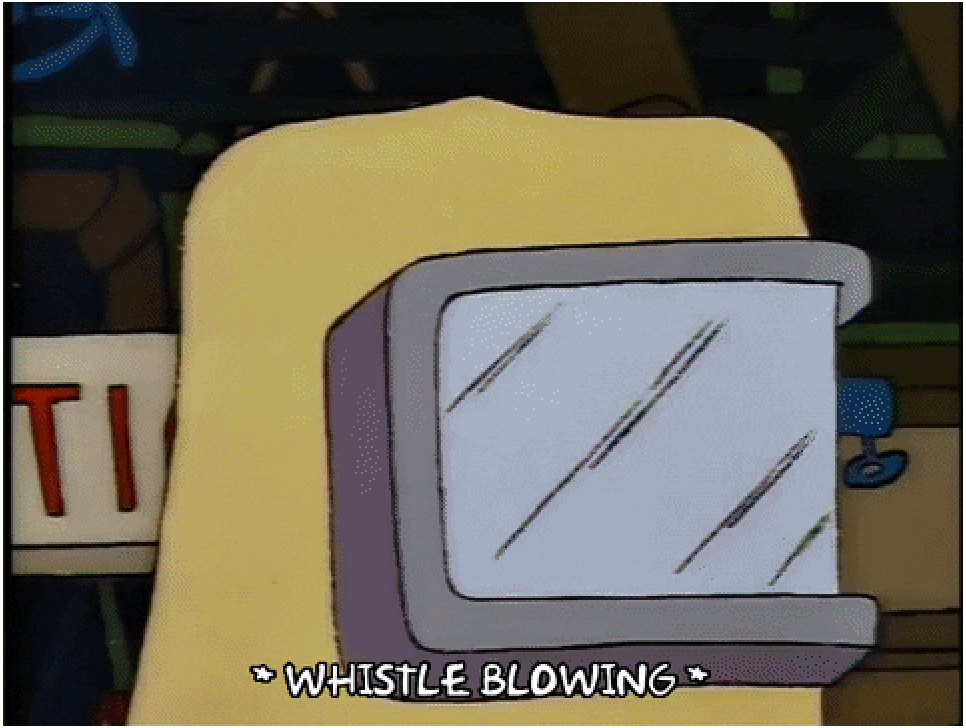
Cut-off sizes	Vortecone	Impingement Screen	Conventional Screen
Integral	1,029	967	1,004
P (in.wg.)	14.18	2.21	1.82
FPF	73	437	552

A filter with a high FPF is desirable.

Conclusions

- Combination of computer simulation and physical model in rapid prototyping results in filters with competitive performance
- Long term, Vortecones or the Horticone make great filters where water is present or can be recycled
- Short term, impingement screen replacements for conventional screens provide comparable cleaning results, at comparable pressure drops, and added benefit of maintenance free operation

- Follow on project just started taking the impingement screen technology, improving it and deploying it underground


* WHISTLE BLOWING *