Next Generation Filters for Mining Machines and Environments

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Acknowledgments

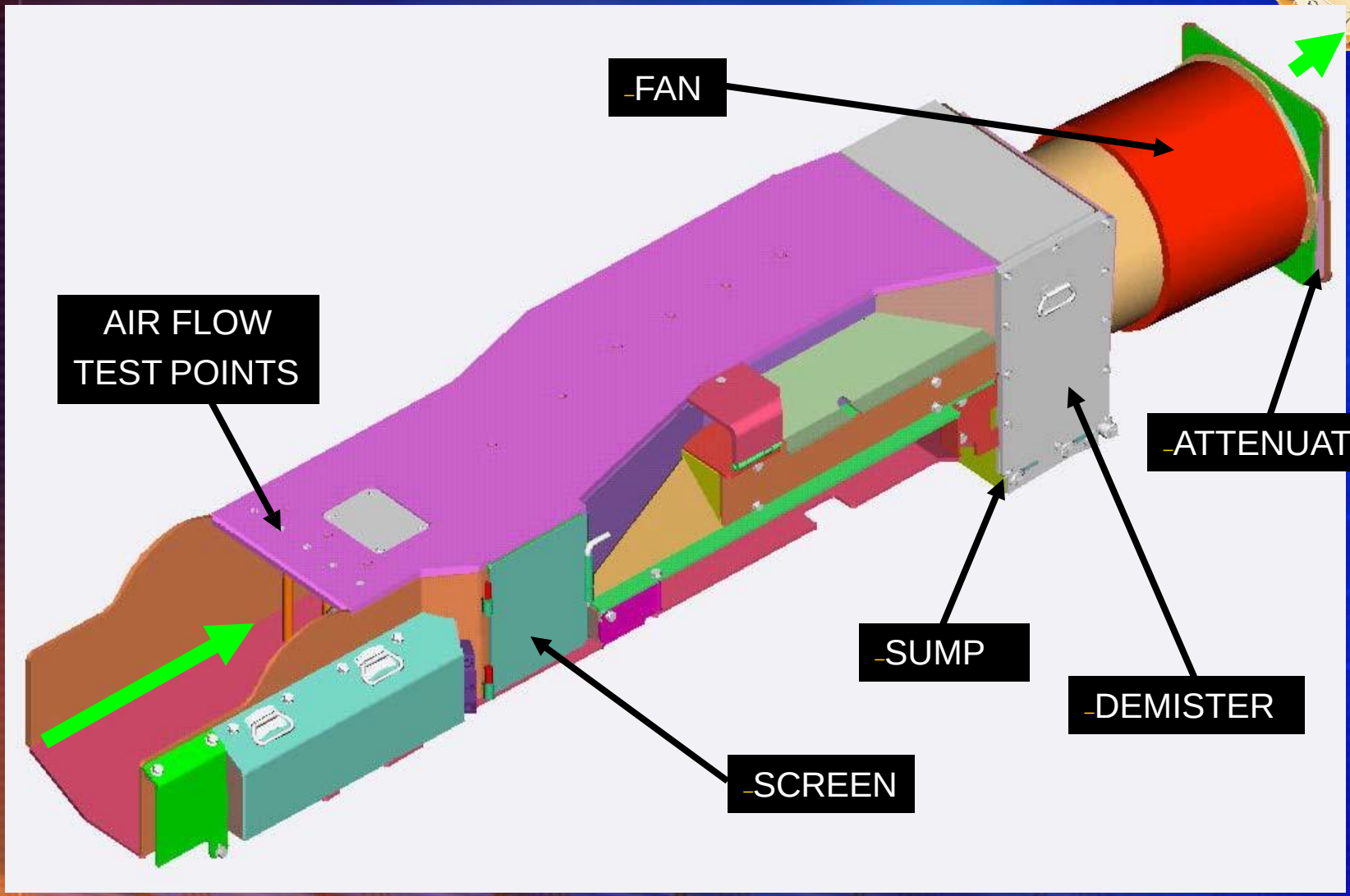
- Much of this work has been developed under CDC/NIOSH Grants:
  - Contract number 200-2014-59922: “Coal Mine Dust mitigation through novel scrubber development and numerical modeling” - background
  - Contract number 75D30119C06228: “Maintenance Free Filters for Continuous Miner Scrubber Systems” – development and testing
  - New Contract starting September 1, 2022
- The views and data in this presentation are those of the presenter and in no way represent the views or opinions of the CDC/NIOSH or any of its employees

- Technology in this presentation is covered by the following patents:
  - Kumar, A.R., Schafrik, S., Wedding, W.C., Velasquez, O., Filter Assembly and Scrubber Section for A Continuous Miner. US Patent No. 11,207,627 B2. 12/28/2021.
  - Schafrik, S., Kumar, A.R., Taylor, A., An Efficient Non-Clogging Inertial Vortex Type Particle Scrubber. US Patent App. 17/,084,073, 2020. (expected to be granted in June 2022)

Introduction

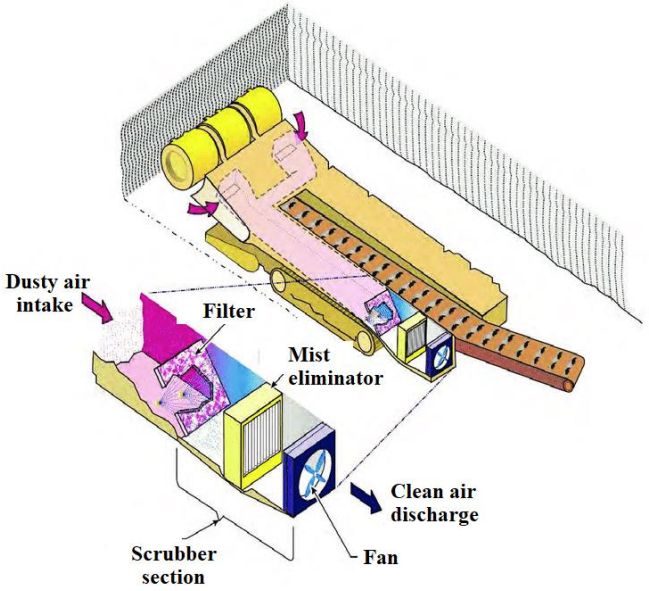
- Several projects at UKY involve scrubbers
- In our work, we identified the need for a maintenance-free screen

Flooded Bed Dust Collector

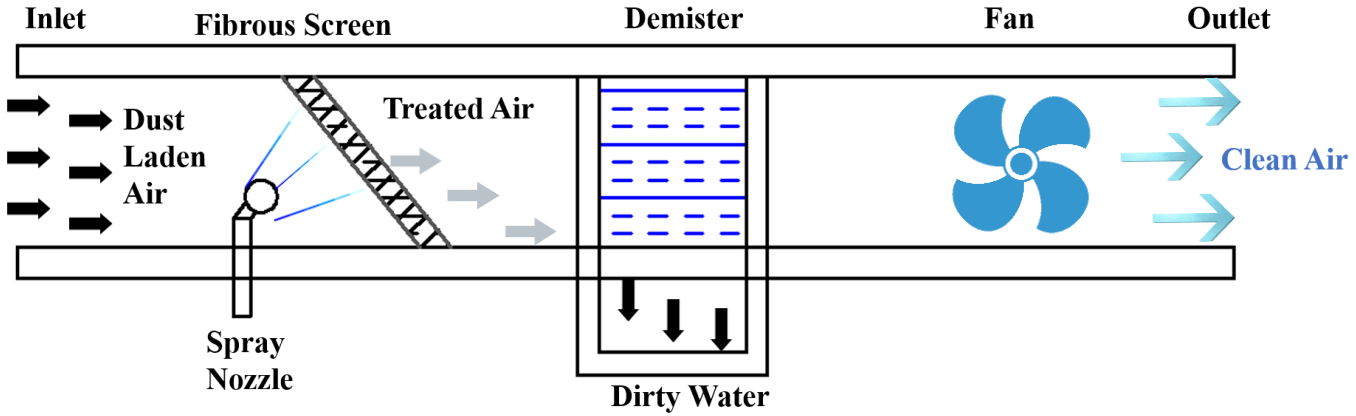


Continuous Miner Scrubbing System

- 60-90 % dust reduction
- Two screen system, an impingement screen, and a demister



Scrubber assembly (NIOSH)



Working Principle of Scrubber Assembly

Screens

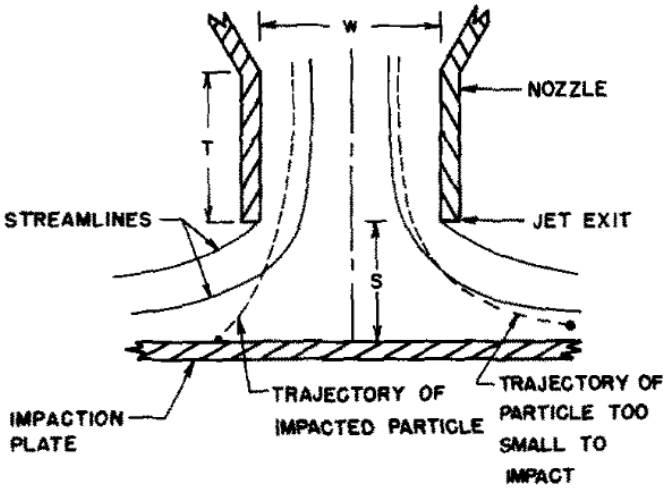
- Screen slows velocity of dust allowing the spray water and dust to mix
- Screens only “filter” large particles
- Screen set at angle to increase turbulence and increase overall screen surface area
- Woven steel mesh (.0035” wire)
- Pleated
- Layers (folded “sock” of mesh)
  - 10 layer (course)
  - 20 layer (standard)
  - 30 layer (fine)
- Polyurethane bound

Maintenance

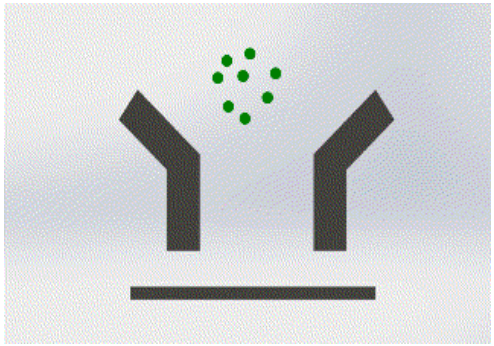
- 2 X per shift
  - Tap out contaminants on screen
  - Flush screen
- Daily
  - Flush inlets and ductwork w/ screen in place and screen cover open
- Weekly
  - Backflush slurry pump
  - Open sump drains
  - Flush demister
  - Flush sump
  - Dry screen and tap out contaminants

Fundamental of Impactor Design

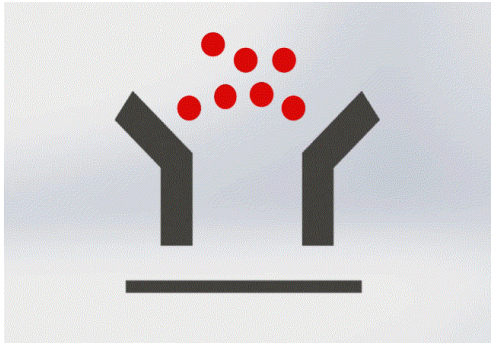
- Factor affecting the design of impactor
  - Spacing
  - Density and velocity of aerosols
  - Width of opening



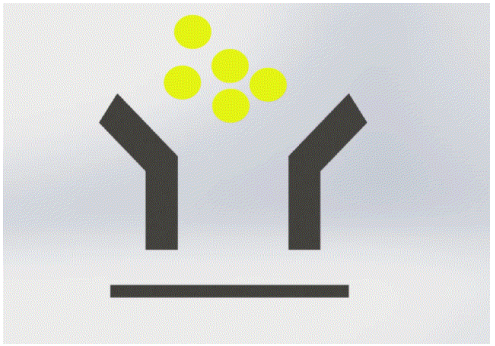
Streamlines and Particle Trajectories of Typical Impactor (Marple 1966)



2 micron



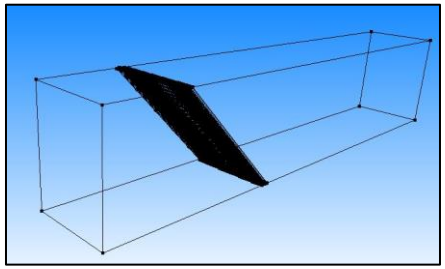
5 micron

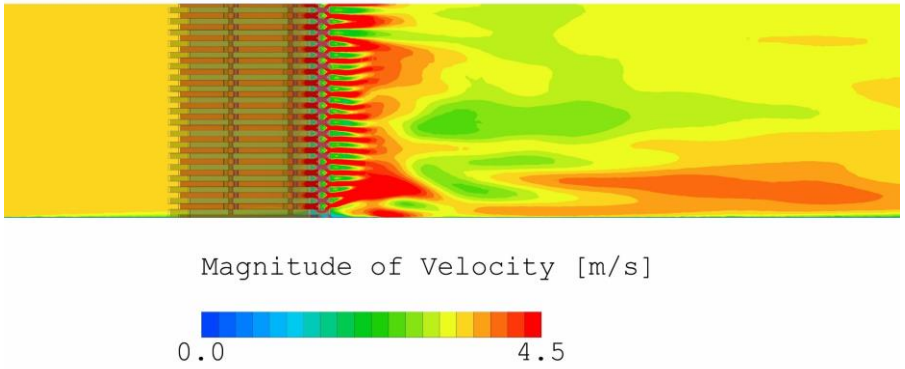


8 micron

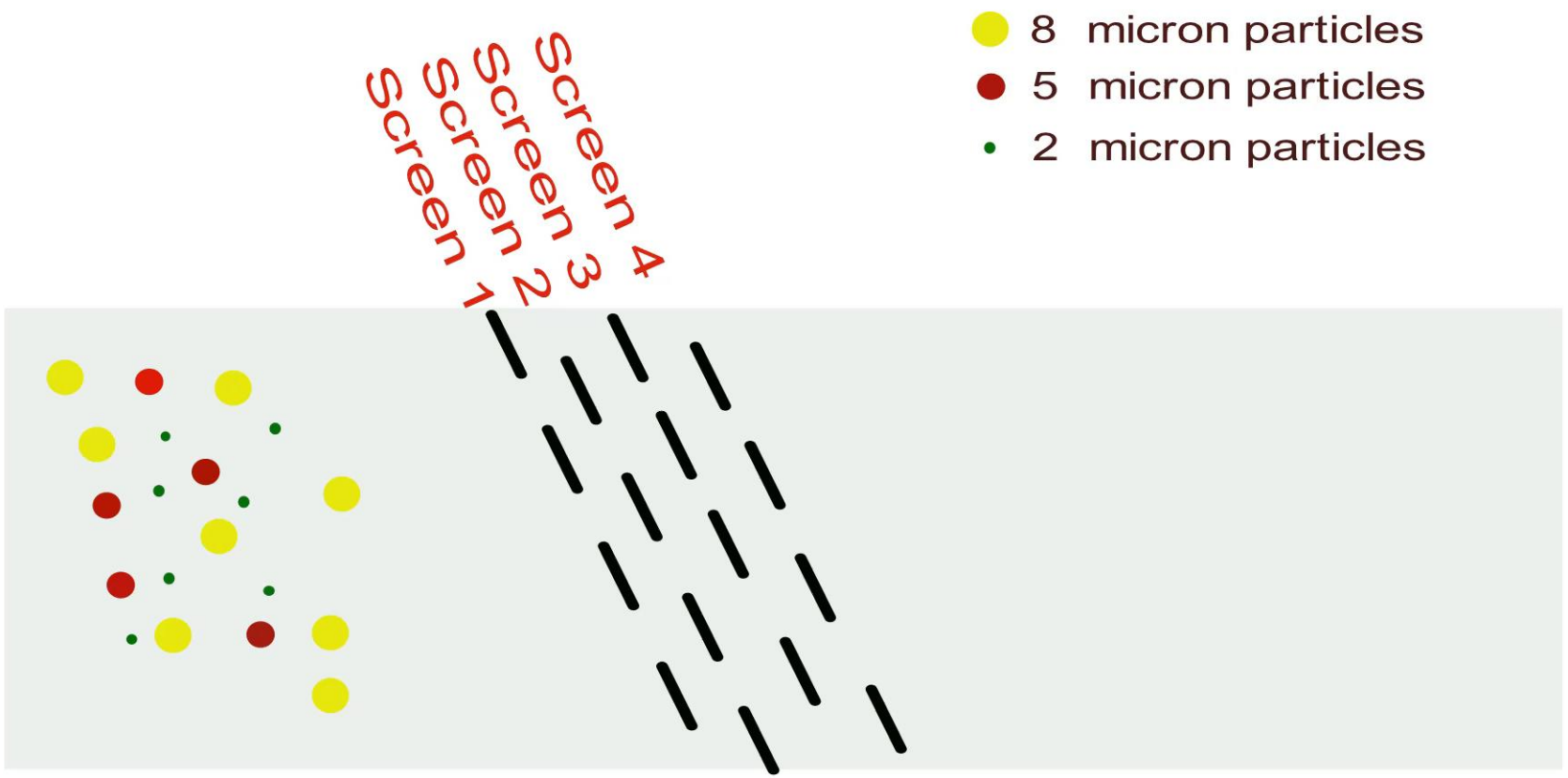
Designing the Impingement Type Filter

- Thin aluminum sheets with rectangular slits





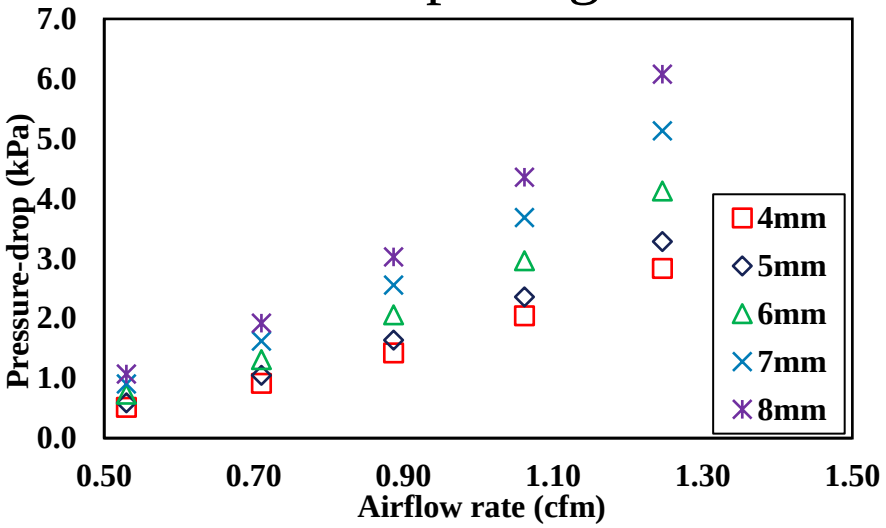
Four-Stage Impingement Screen



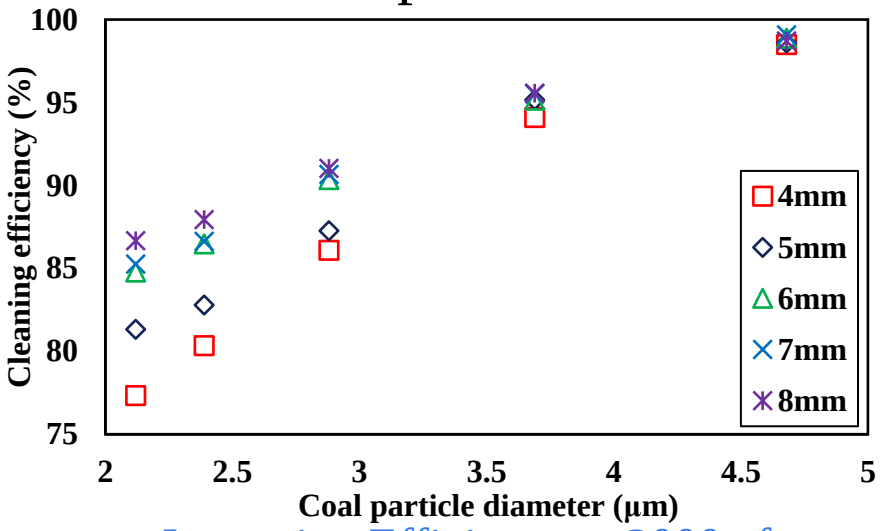
Particle Trajectory

Impingement Screen Design Considerations

- Allowing no airflow will maximize capture and a non-existent screen will maximize airflow
- CFD was used to determine the optimum operating point for the size of the openings
- Many different geometries were tried in CFD
  - Flat plates are the most efficient for airflow
  - Round openings are the most efficient for capture



System-curve



Impaction Efficiency at 2000 cfm

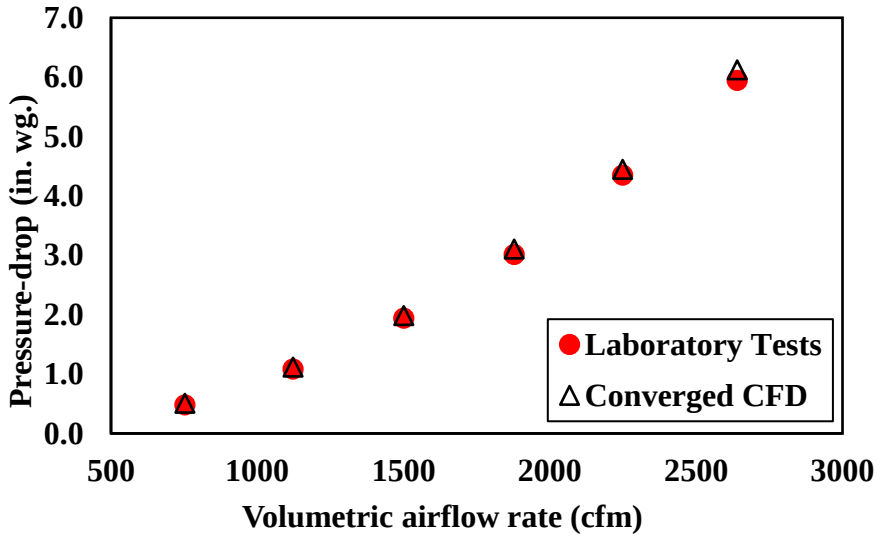
CFD Validation

- Validation
  - Airflow : 2000 cfm
  - Dust : Coal
  - Condition : Dry run for CFD
  - Steady-state : Mean error (3%)
  - Transient state : Mean error (5%)

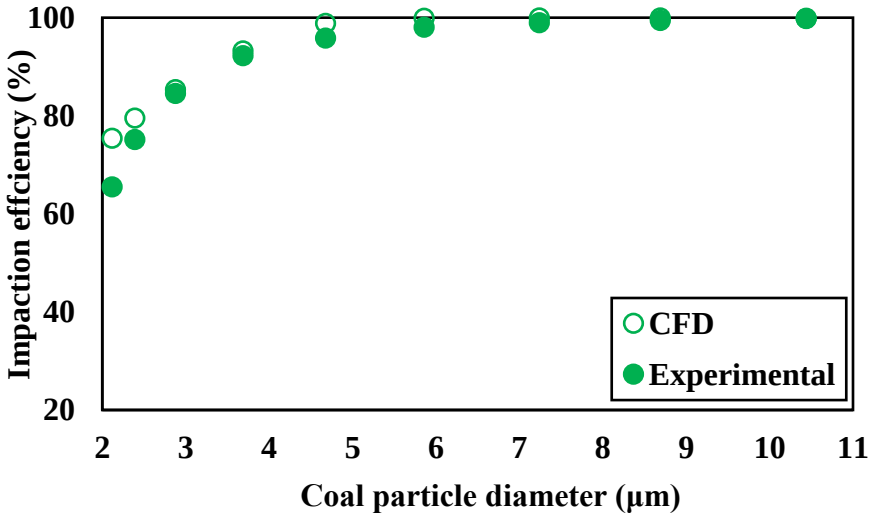
International Journal of Coal Science & Technology Springer

RESEARCH

CFD and Laboratory Studies of Dust Cleaning Efficacy of an Efficient Four Stage Non-Clogging Impingement Filter for Flooded-Bed Dust Scrubbers



System-curve



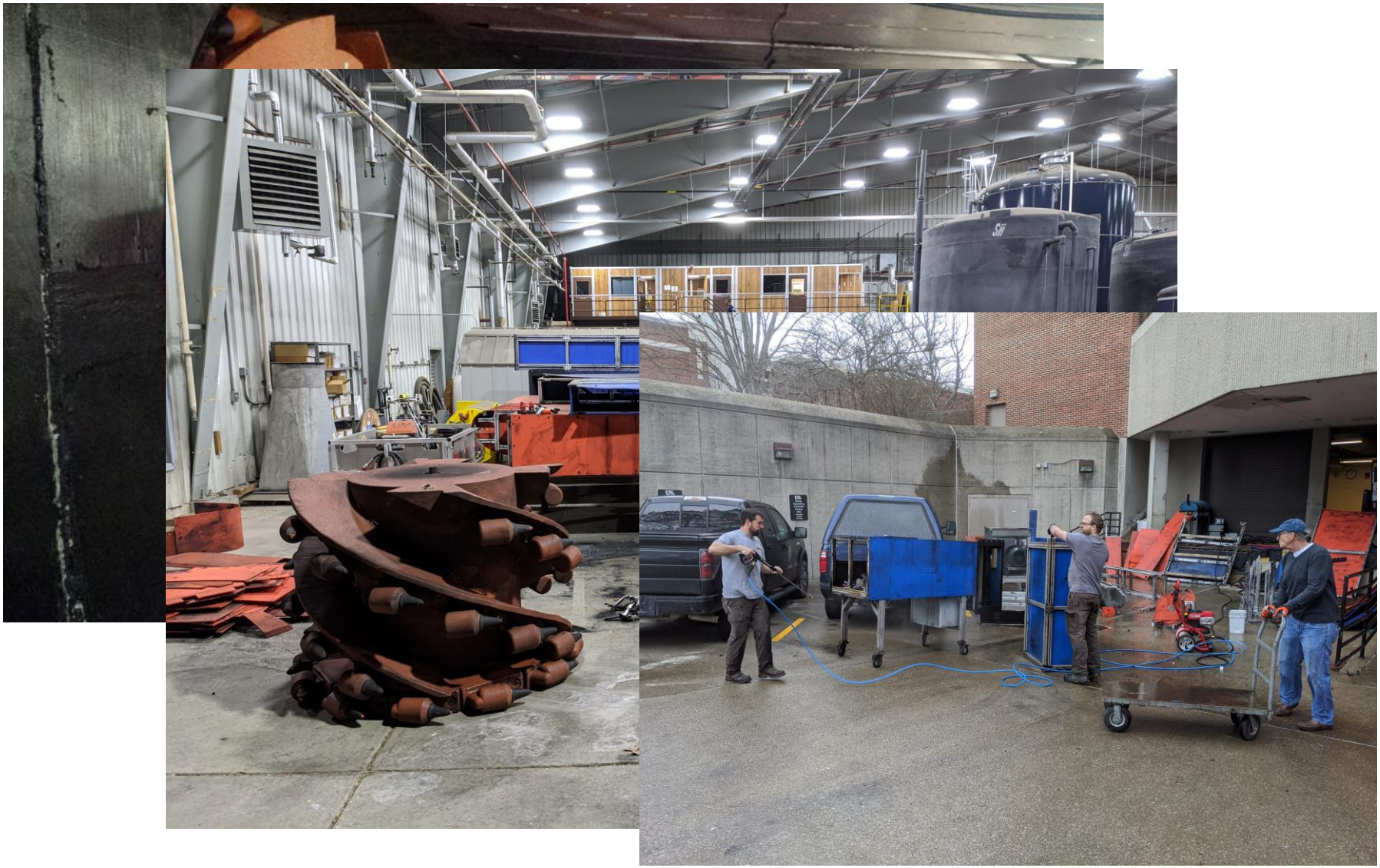
Coal

University of Kentucky

Screen Generations

- Generation 1, Design 1 – Shorter slits, round corners
- Generation 1, Design 2 – Longer slits, round corners
- Generation 2 – Maximize capture and airflow, long slits, round corners, larger opening
- Generation 3 – Mimic Airflow of Existing Screen, *Generation 2 with different spacing*
- Generation 3.5 – Small change (1/32!) in opening geometry

Not All Research Tools Last Forever



Dust Gallery Testing Procedure

- Duster on for 5 minutes
- Scrubber on for 15 minutes for the desired airflow
- Minute to minute differential mass deposition (Δm)
- Normalizing the value of Δm
- Scrubber screen approaching 0% Δm faster is better

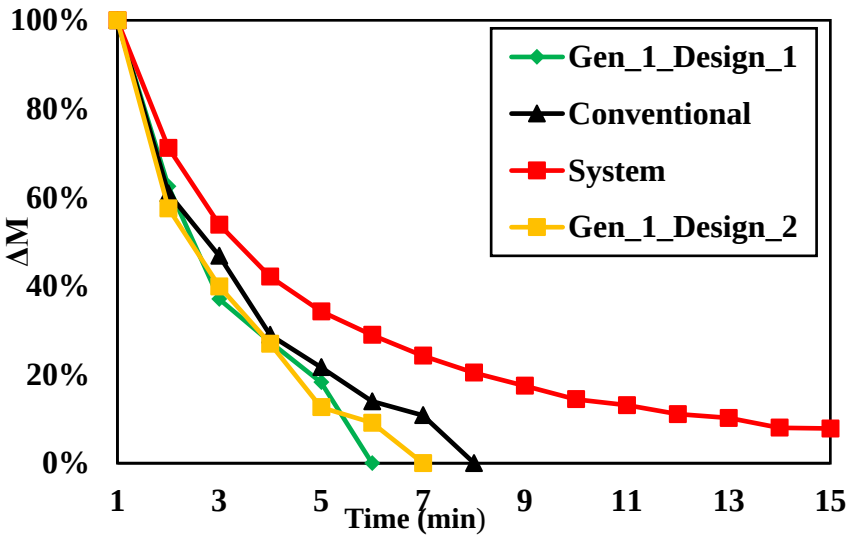
Dust Gallery after 5 Minute of Dusting

Dust Gallery after 15 Minute of Scrubber Operation

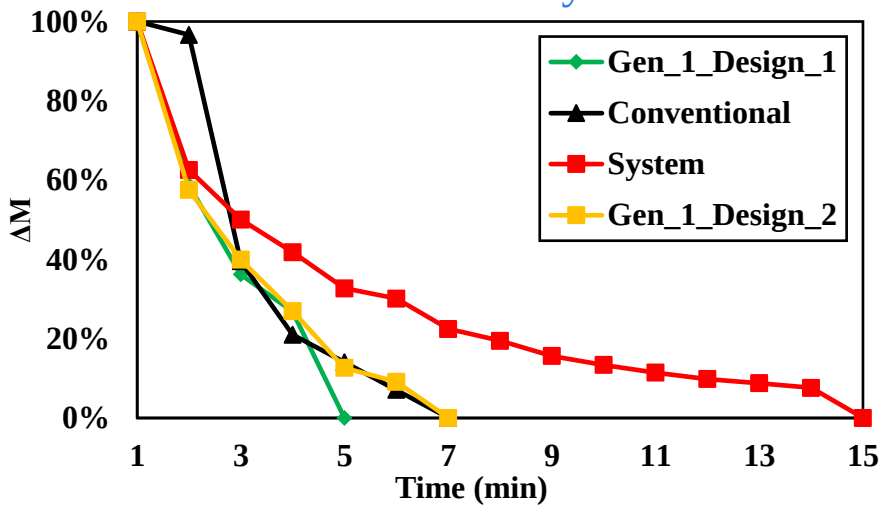
First-Generation Dust Gallery Testing

- Scrubber operated for 15 minutes
- Design 1 performed best
- System is the base case, where there is no screen

System



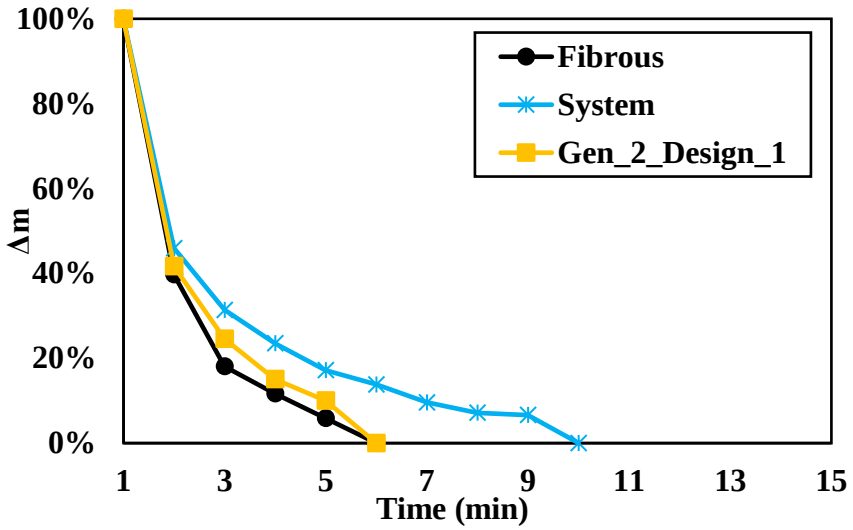
5000 cfm



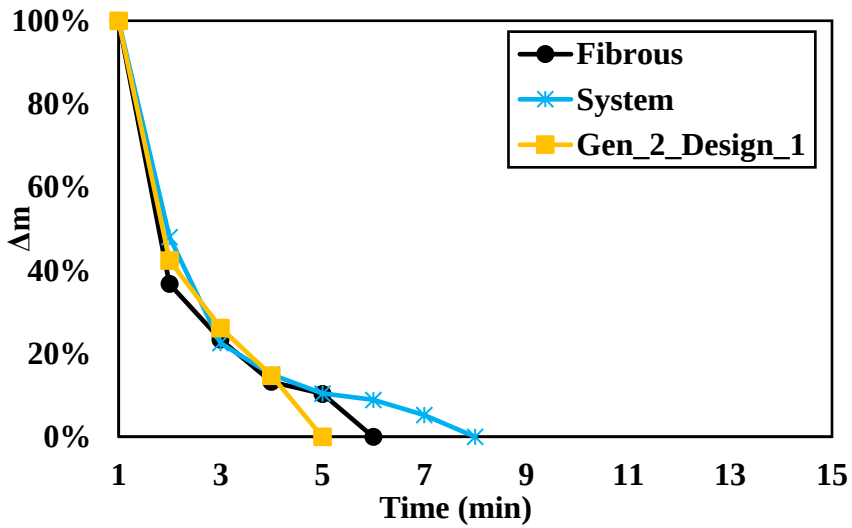
6000 cfm

Second-Generation Dust Gallery Testing

- Same procedure as first-generation testing
- Tested at 7000, 8000 cfm airflows



7000 cfm



8000 cfm

Extreme Conditions Testing

- Highwall miners use the scrubber to clear the air for the cameras
- No water spray on the screen
- Difficult mining conditions
- Screen went over 1,200 feet of advance before clogging

Screens in Miners

Generation 1 Design 1 was put in a miner on an off shift and the airflow was tested

Existing Screen

1.3	1.4	1.8	2.1	1.2
1.2	1.6	1.5	1.5	0.9
1.2	1.8	1.6	1.6	1.4

Generation 1 Design 1

0.5	0.5	0.5	0.5	0.5
0.5	0.5	0.5	0.5	0.5
0.5	0.5	0.5	0.5	0.5

Generation 3 (Design 1) Testing

- Testing is taking place between UKY and Komatsu PDTC
- Screen is installed in their scrubber test assembly
- Screen is loaded with approximately 2 gallons of size #4 and below coal dust
- Airflow testing before loading and after 10 minutes of the system running

Screen	Preload Flow	Post-load Flow
Standard	7317	5538
New Design	6801	5873

Ongoing Work

- Generation 3.5 is being tested right now
  - In initial testing existing screen is at 6472 CFM, and Generation 3.5 is at 6404 CFM
- Additional work will be done with two mine partners to verify that the Generation 3.5 screens will perform
  - Off-shift, single shift, and multiple shift testing
  - Verify airflow and run dust on the area near the scrubber discharge

Future Scrubber Technology - Vortecone

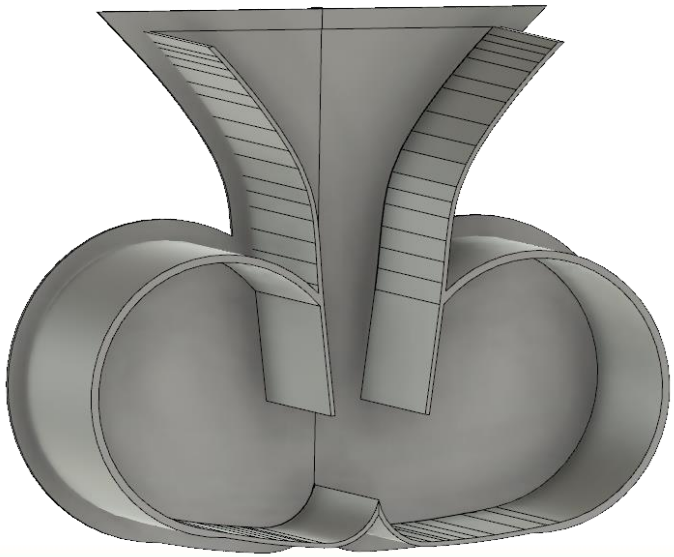
- Separates particles by forcing them to undergo high-speed rapid swirls in vortex chambers
- Automotive industry
  - >99% capture on over-spray paint particles
- 30% more efficient than a cyclone

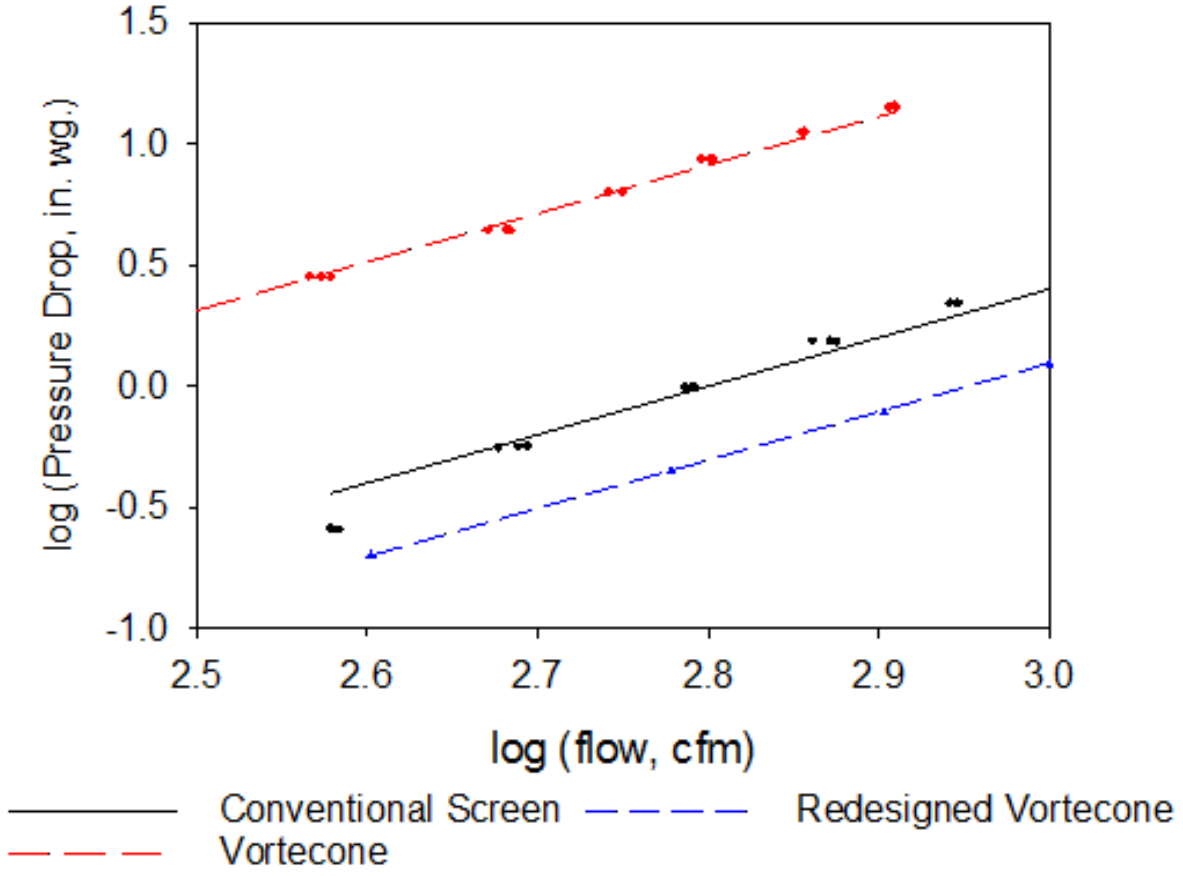
Purpose for Researching Vortecone

- Improve the health and safety of miners
- Increase the efficiency of equipment and operations
  - Increase production
- Redesign the Vortecone
  - Lower the resistance of the system
  - Fit onto a continuous miner
  - Improve/maintain particle capture abilities

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

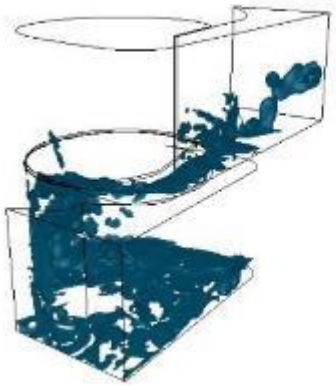



1.5
1.0
0.5
0.0
-0.5
-1.0
log (Pressure Drop, in. wg.)
2.5
2.6
2.7
2.8
2.9
3.0
log (flow, cfm)
Conventional Screen
Redesigned Vortecone
Vortecone

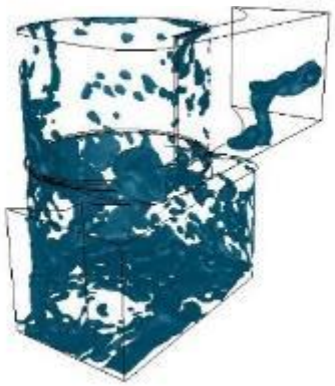
CFD Modeling: Transient States

Water films

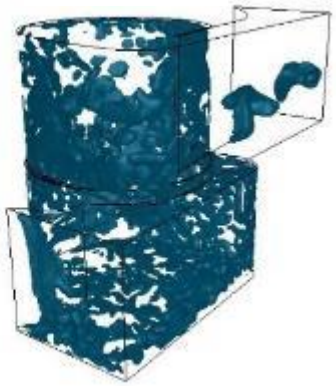
800 cfm



1400 cfm

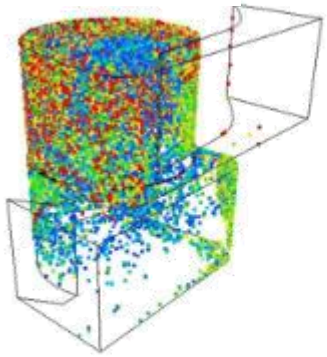


2000 cfm

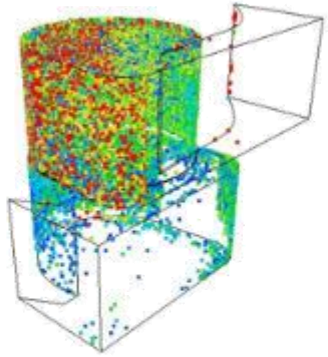


Particles and air

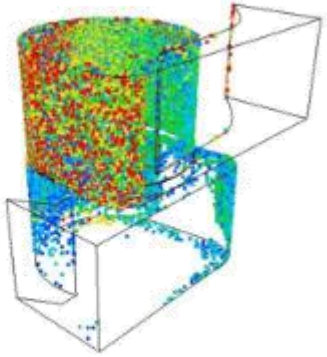
800 cfm



1400 cfm



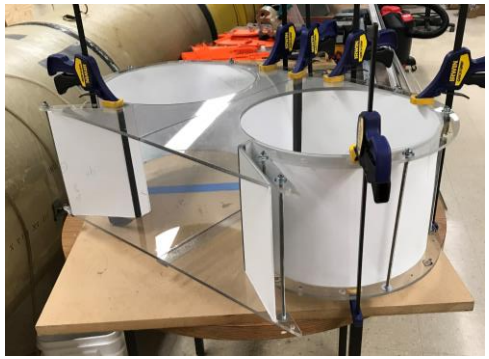
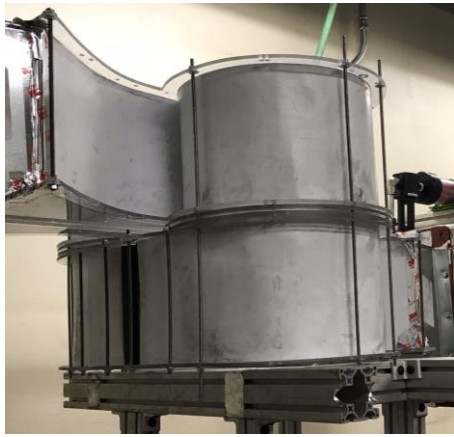
2000 cfm



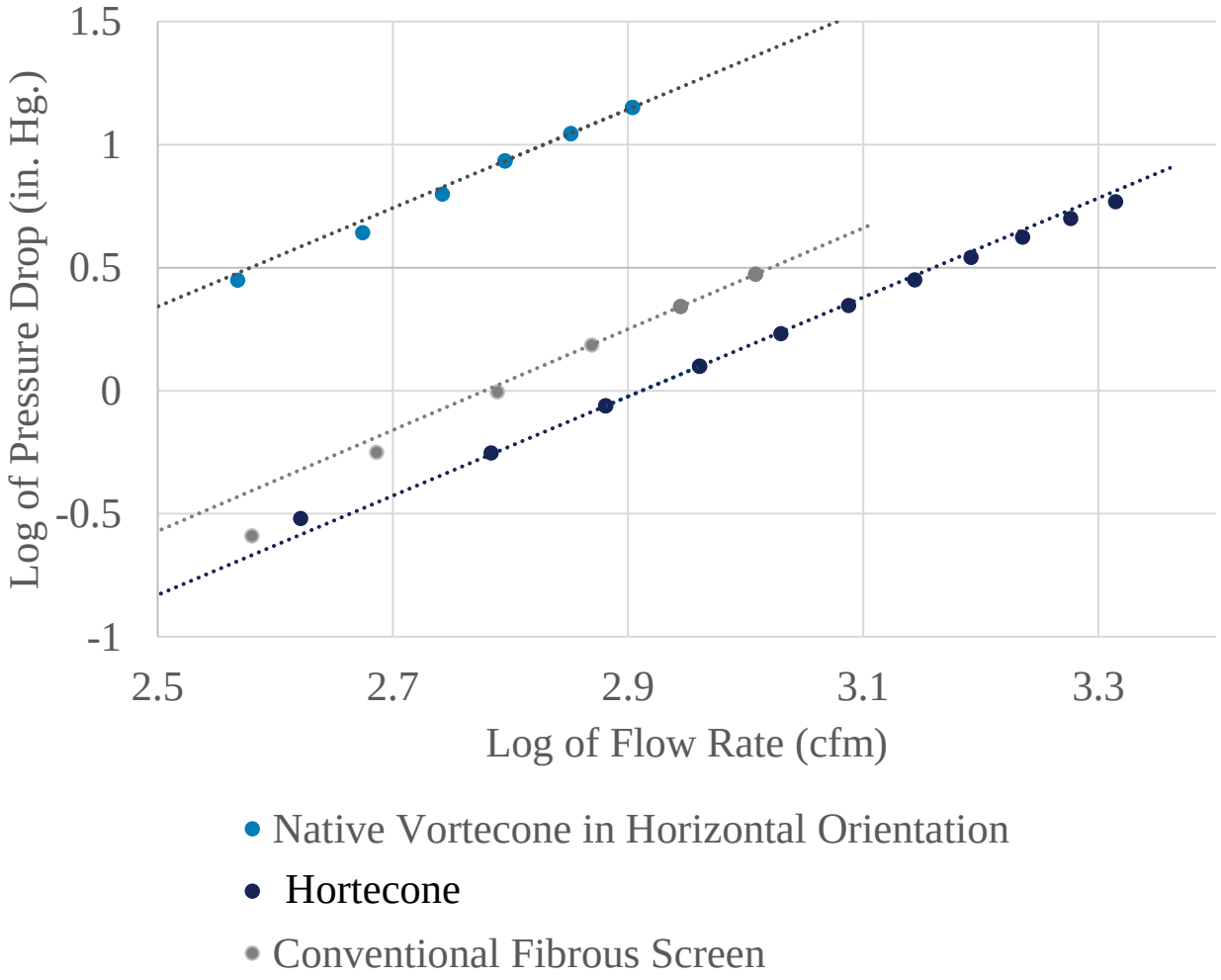
Construction of Hortecone

- 1/8” polystyrene for curved sides
- 1/4” polycarbonate for flat surfaces



Experimental Results: Pressure Drop



Conclusions

- The new style impingement screen is being developed as a drop-in replacement for the current screens with the current motors – bonus is no-maintenance
- With a change to the fans in the existing scrubber design, already developed screens with significantly higher capture efficiency could be used in future scrubbers
- The Hortecone could be used as a stand-alone filter
  - Investigating in agricultural applications

See you in Denver!

- SME Annual Meeting
- Feb 26-March 1 in Denver

- Technical program with more industry-specific content than ever
- Sessions on Accessing Capital, Alternative Energy on mine sites, Automation, Dust, Ethics, Industry Projects, Mental Health First-Aid, RCS