OFFICE OF MINE SAFETY AND HEALTH RESEARCH

Controlling Dust on Continuous Mining Operations

John Organiscak

NIOSH

Pittsburgh

CDC Workplace Safety and Health

National Institute for Occupational Safety and Health NIOSH

MSHA Dust Samples
2009 to 2012

Occupation	Coal Dust > 2 mg/m³	Coal Dust > 1.5 mg/m³	Quartz Dust > 100 µg/m³
CM Operator	3.7%	8.8%	9.7%
Roof Bolter	1.1%	3.7%	10.6%
Shuttle Car	1.3%	3.7%	0.0%

Objective

To describe and illustrate proven methods and engineering controls to minimize respirable dust concentrations on continuous mining operations

Outline

Continuous Miner Dust Controls

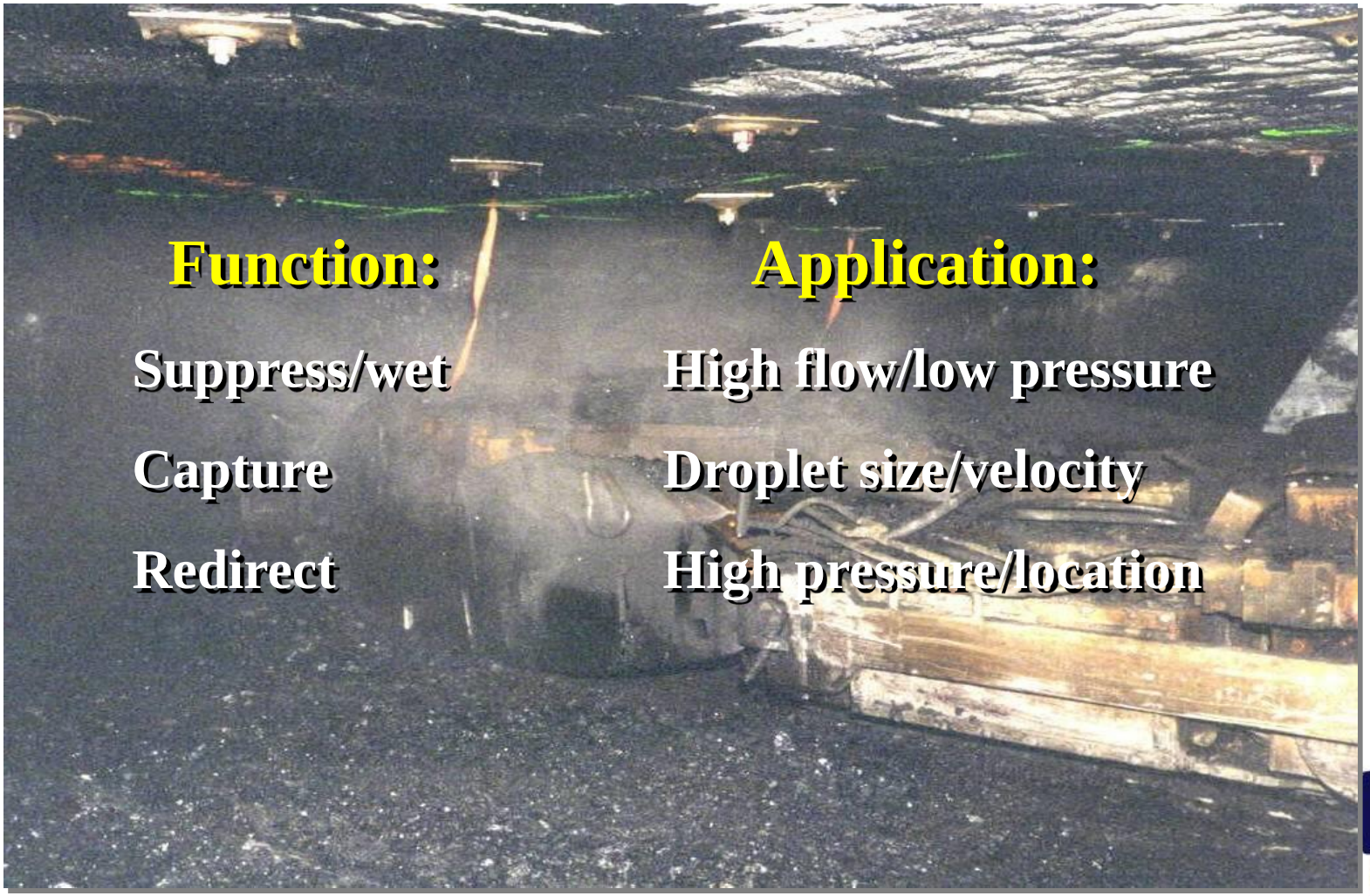
- Water Sprays
- Wetting Agents
- Wethead Drum
- Scrubbers
- Face Airflow Practices (Ventilation)
- Spray and Scrubber Optimization for Exhaust Face Ventilation Systems
- Underground Studies of Continuous Miner Scrubber Effectiveness
- Mining Crosscuts
- Bit Design and Cutting Considerations

Outline (continued)

Roof Bolter Dust Controls

- Drill Dust Collection System
- Dust Collector Maintenance and Cleaning
- Dust Collector Bags and Pre-dump
- Collector Exhaust Water Box
- Canopy Air Curtain (Needs Refinement)
- Stand Alone Scrubber (Needs Field Testing)

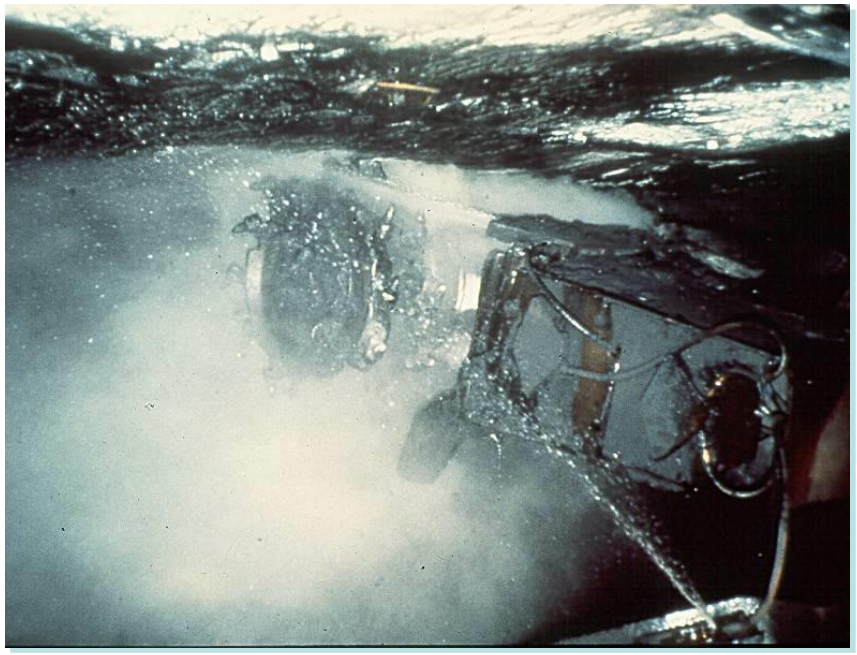
Water Sprays on Continuous Miners

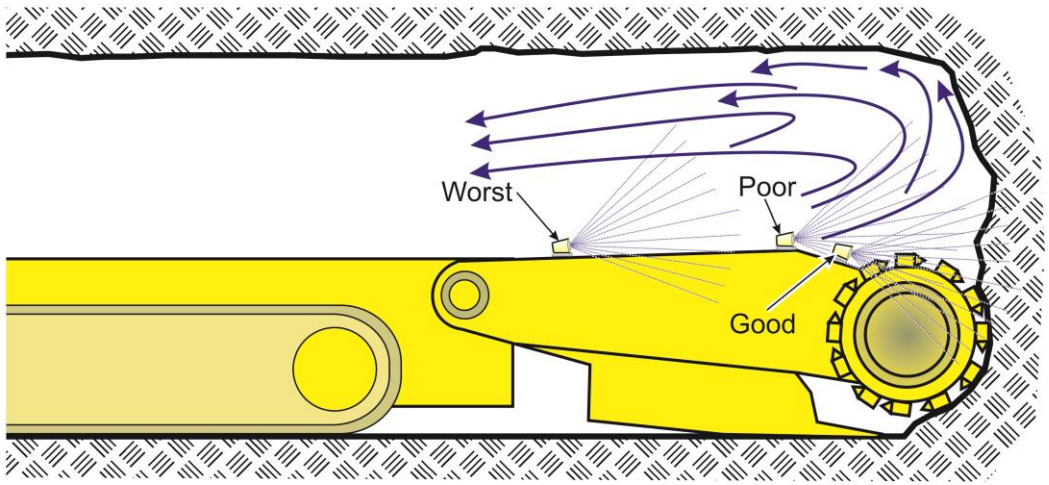


Wetting/Suppression

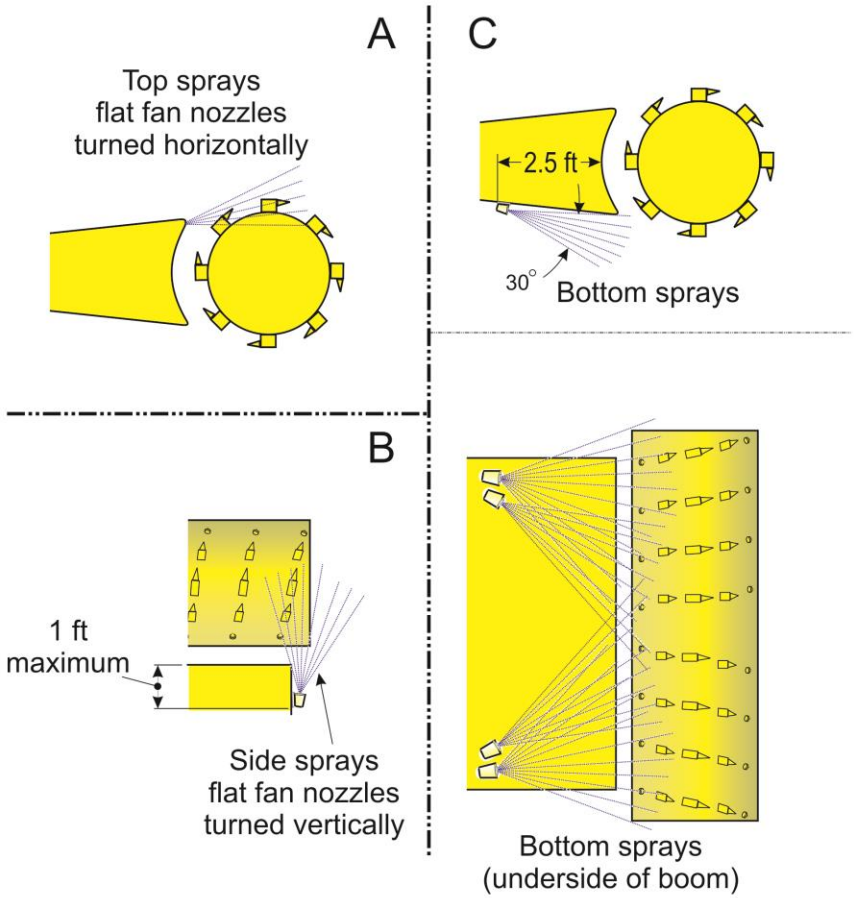
- Sprays close to cutting head
- Surfactants (wetting agents)

✓ **Flow rate most important**



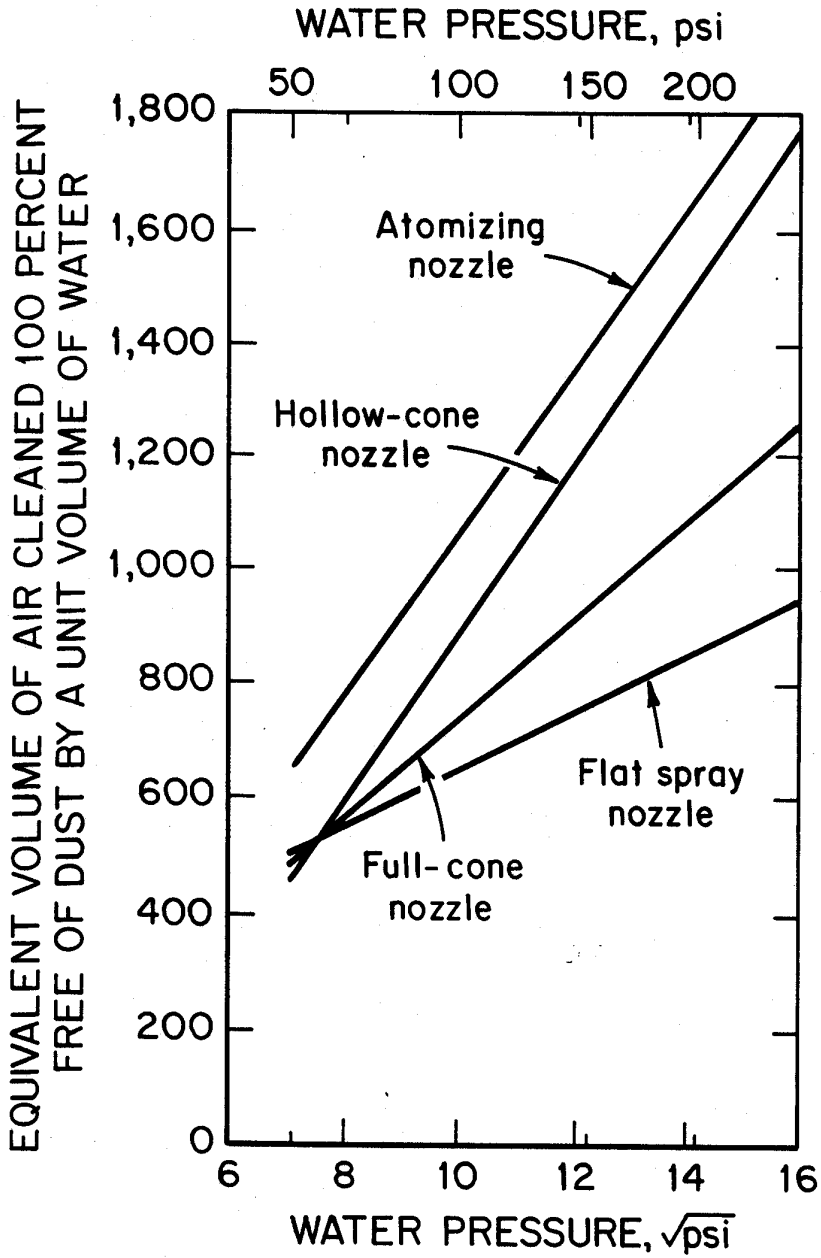


Spray Locations

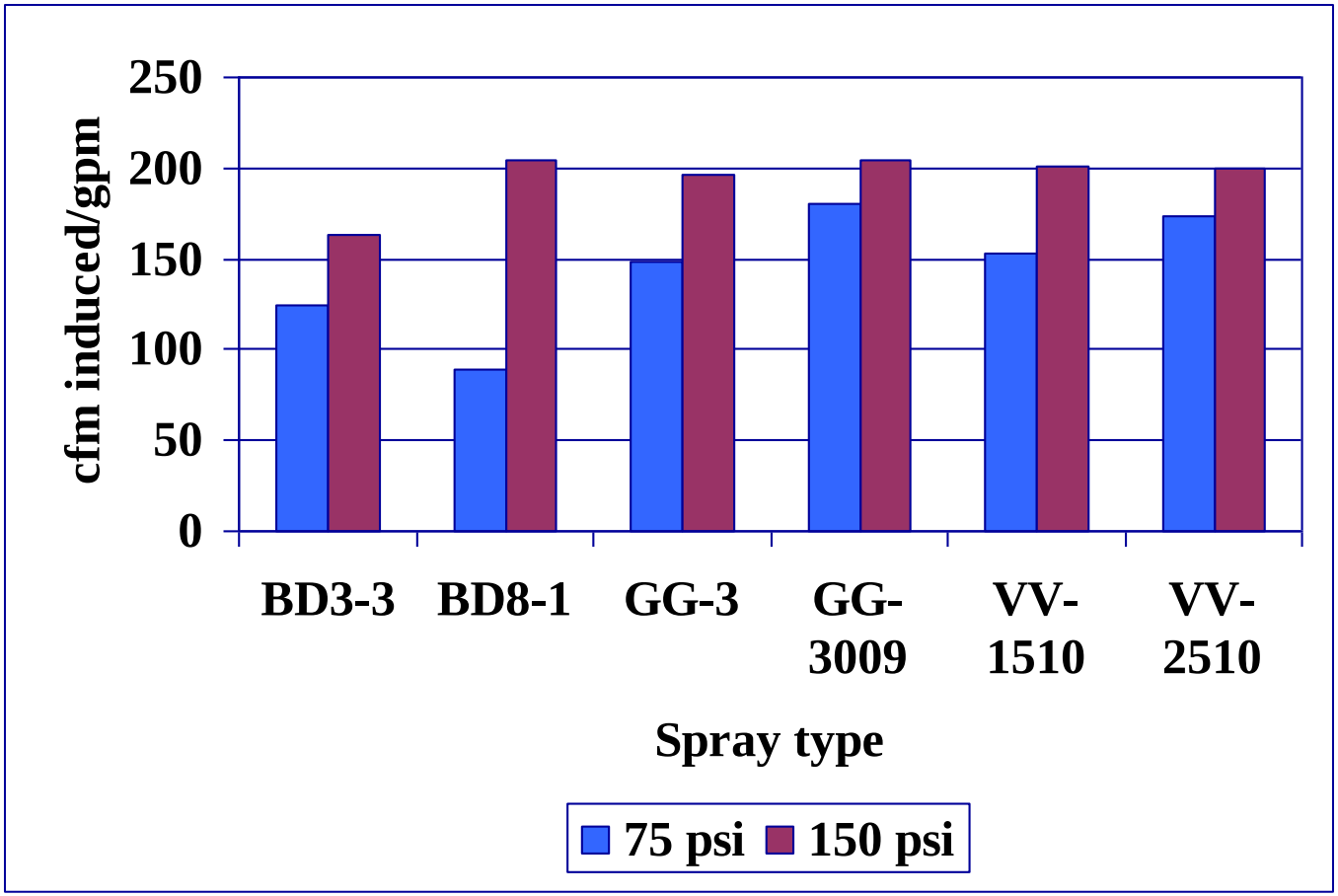


Spray Capture Effectiveness on Airborne Dust

- Smaller Droplet Sizes
- High Velocity Droplets
- ✓ **Pressure Most Important**



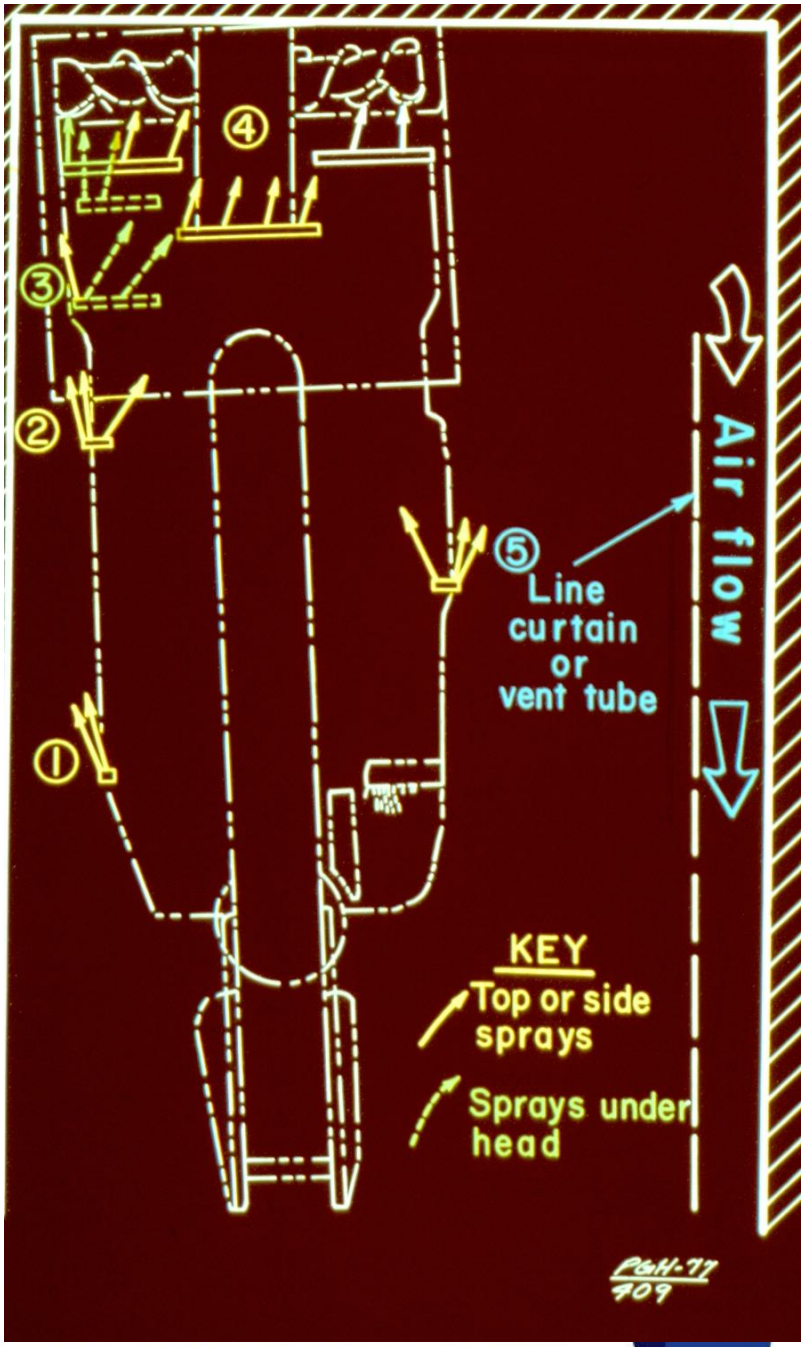
Redirecting/Moving Air



✓ Pressure/location important

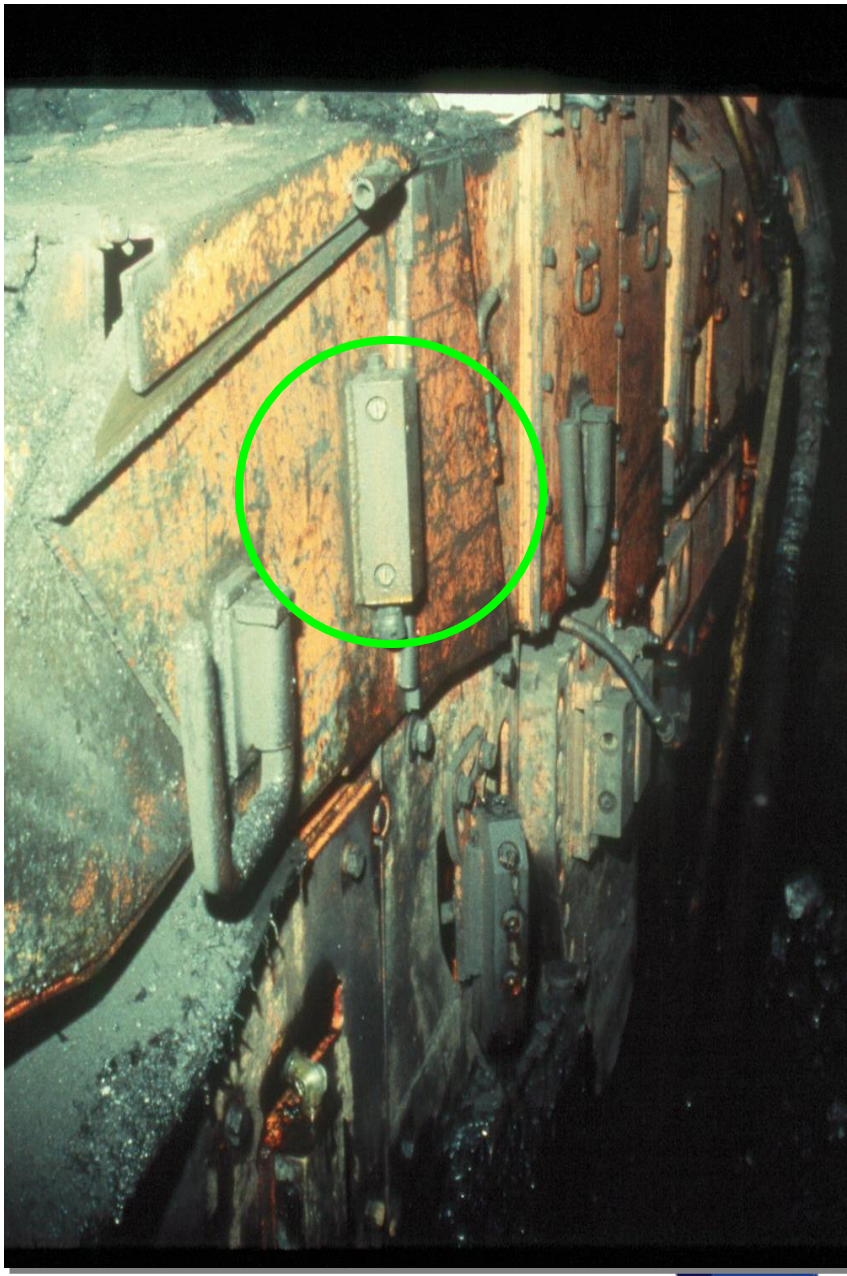
Spray Fan System
(without scrubber)

- Exhausting Ventilation
- Primarily for Methane Control
- Reduced Dust Control Effectiveness



Blocking Sprays
(with scrubbers)

- Contains dust beneath boom
- Lower dust levels at operator and around machine



Spray Water Filtration

Reduces Plugging

Wetting Agents

Study	Year	Wetting Agent Testing	Result / Conclusion
USBM/BCR	1980	Anionic, Cationic & Nonionic, 0.1 to 1.0 %	Different coal wettability 27% reduction at auger section
Penn State	1991	Anionic, Cationic & Nonionic, 1.0%	Lab study showed smaller droplet size had more impact
Penn State	1992	Anionic, Cationic & Nonionic, < 1.0%	Cationic more net + charge, slightly better than others
Penn State	1993	Cationic on Anthracite, hvA, & Subbituminous	No rank effect, but optimum agent concentration effect
Rolla	1993	Contact < & sink test screening on bituminous	Sink test a good prescreening tool for potential dust reduction
USBM	1996	0.02 to 0.08% anionic agent & polymer mixtures	40% reduction on 1st LW study Inconclusive on 2nd LW study

Do Currently Used Wetting Agents Work?

- Pulverized Keystone Mineral Black 325BA or -325 mesh (-44um) Pocahontas No. 3 coal dust (Difficult to Wet)

- Three Wetting Agents Used by Mining Companies
  A. Homogenous blend of colloids, sequestrants, and nonionic surfactants
  B. Anionic surfactants and polymers
  C. Anionic surfactant

- Dust Sink Tests at 0.05%,0.10%, and 0.20%

- Airborne spray dust capture testing with BD3 hollow cone nozzle at 80 psig and 160 psig

- Measured Surface Tension, PH, Conductivity, TDS or Salinity

Coal Dust Sink Tests

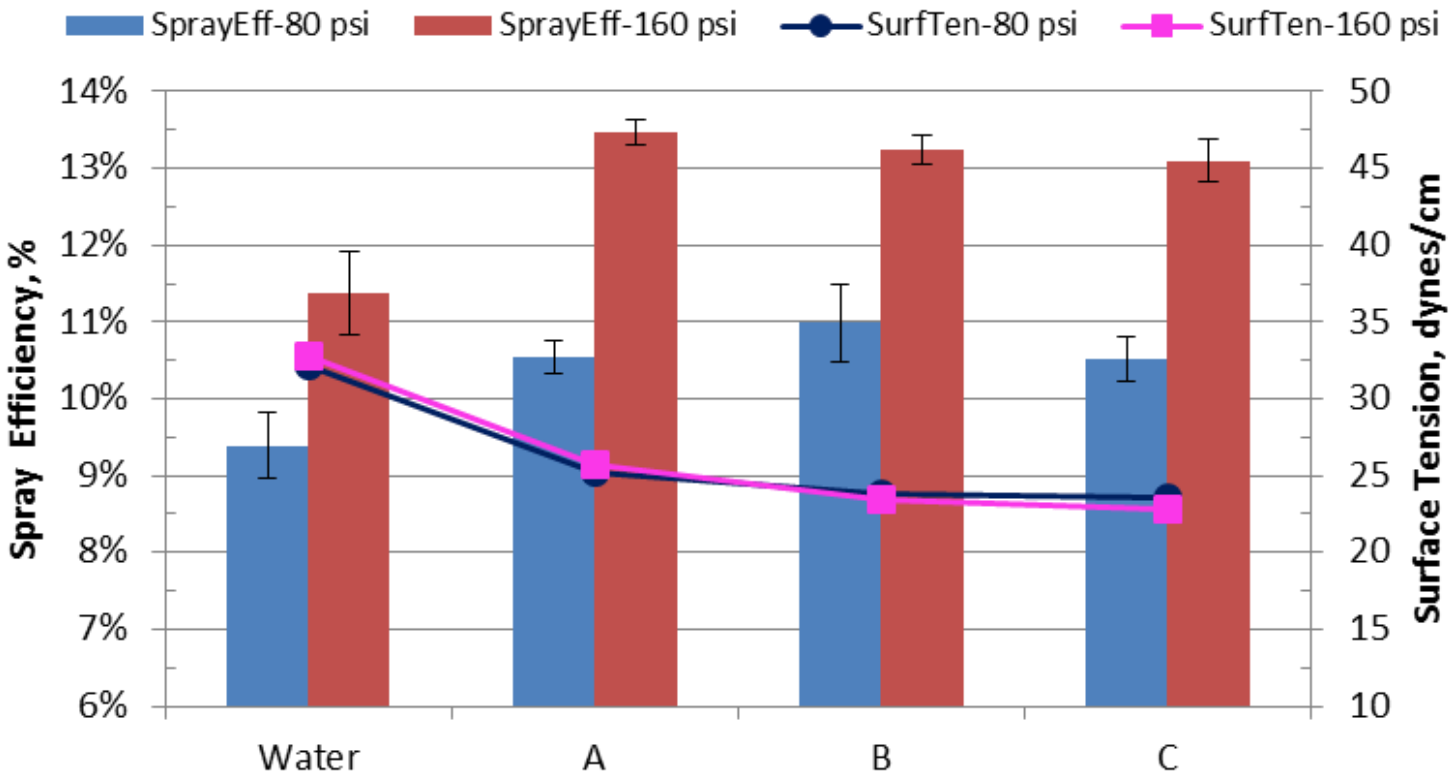
at 0.05%, 0.10% and 0.20% concentrations

Sink Test Wetting Results

average of 3 tests

Wetting Agent	Water Sample	0.05 % Solution	0.10% Solution	0.20% Solution
A	> 900 sec.	863 sec.	373 sec.	193 sec.
B	> 900 sec.	> 900 sec.	> 900 sec.	1238 sec.
C	> 900 sec.	> 900 sec.	> 900 sec.	1301 sec.

Airborne Dust Capture Tests
at 0.20% Solution



✓ Suppression effects most likely coal seam site specific

Wethead Spray Technology

Locates water sprays directly behind each bit on the cutter head at point of attack

Courtesy of Joy Mining Machinery

- 62 to 73 sprays on head
- 25-30 gpm at 100psi
- Solid or hollow cone sprays

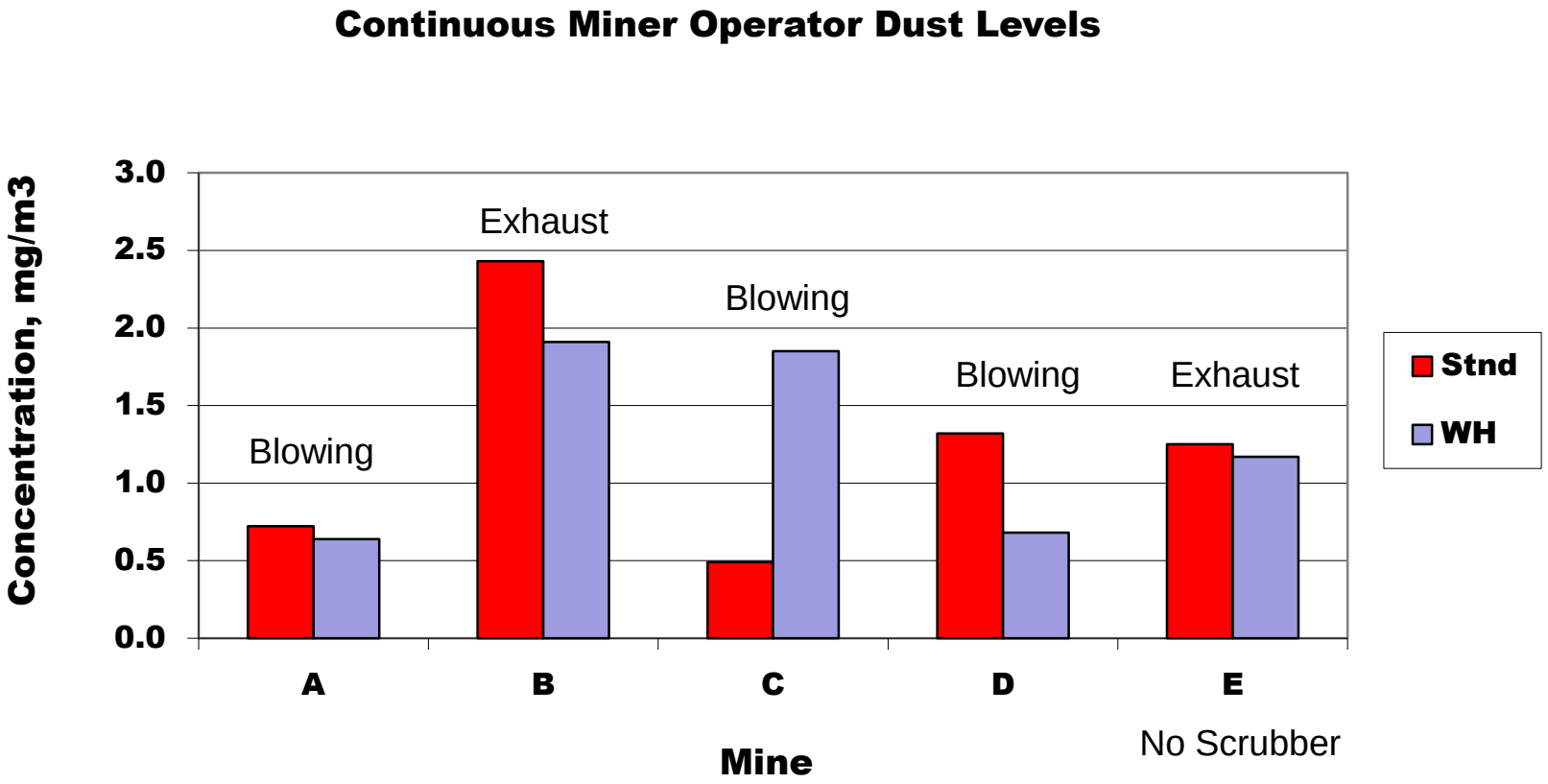
Wethead Benefits

- Bit cooling - reduce frictional ignitions
- Increase bit life
- No increase in water consumption
- Potential to reduce respirable dust

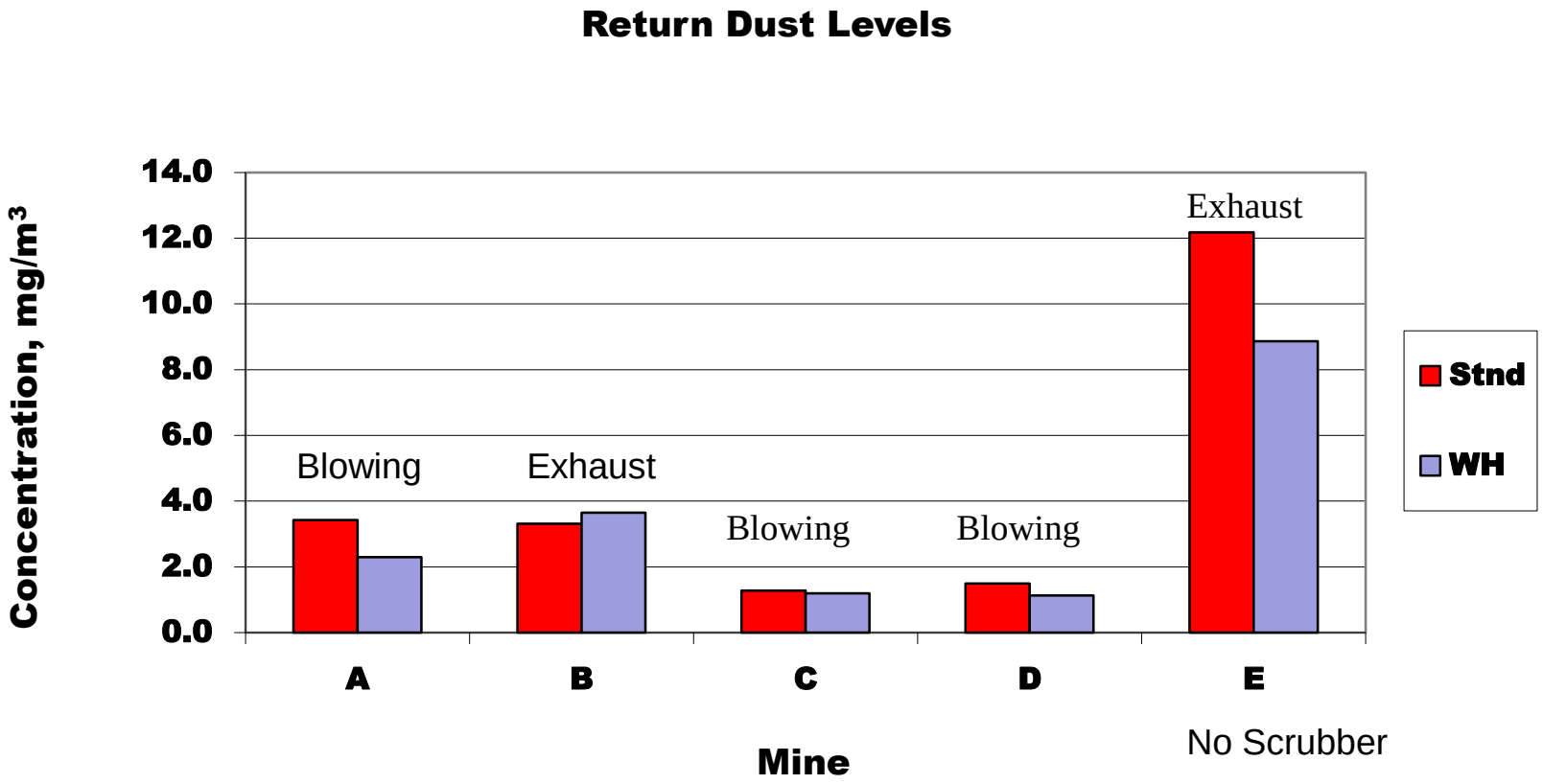
Wethead vs Standard Sprays

	Mine A	Mine B	Mine C	Mine D	Mine E
Ventilation	Blowing	Exhausting	Blowing	Blowing	Exhausting
Section	Super sect.	Single	Super sect.	Single	Single
Scrubber	Yes	Yes	Yes	Yes	No

All Mines - CM Operator



All Mines - Return



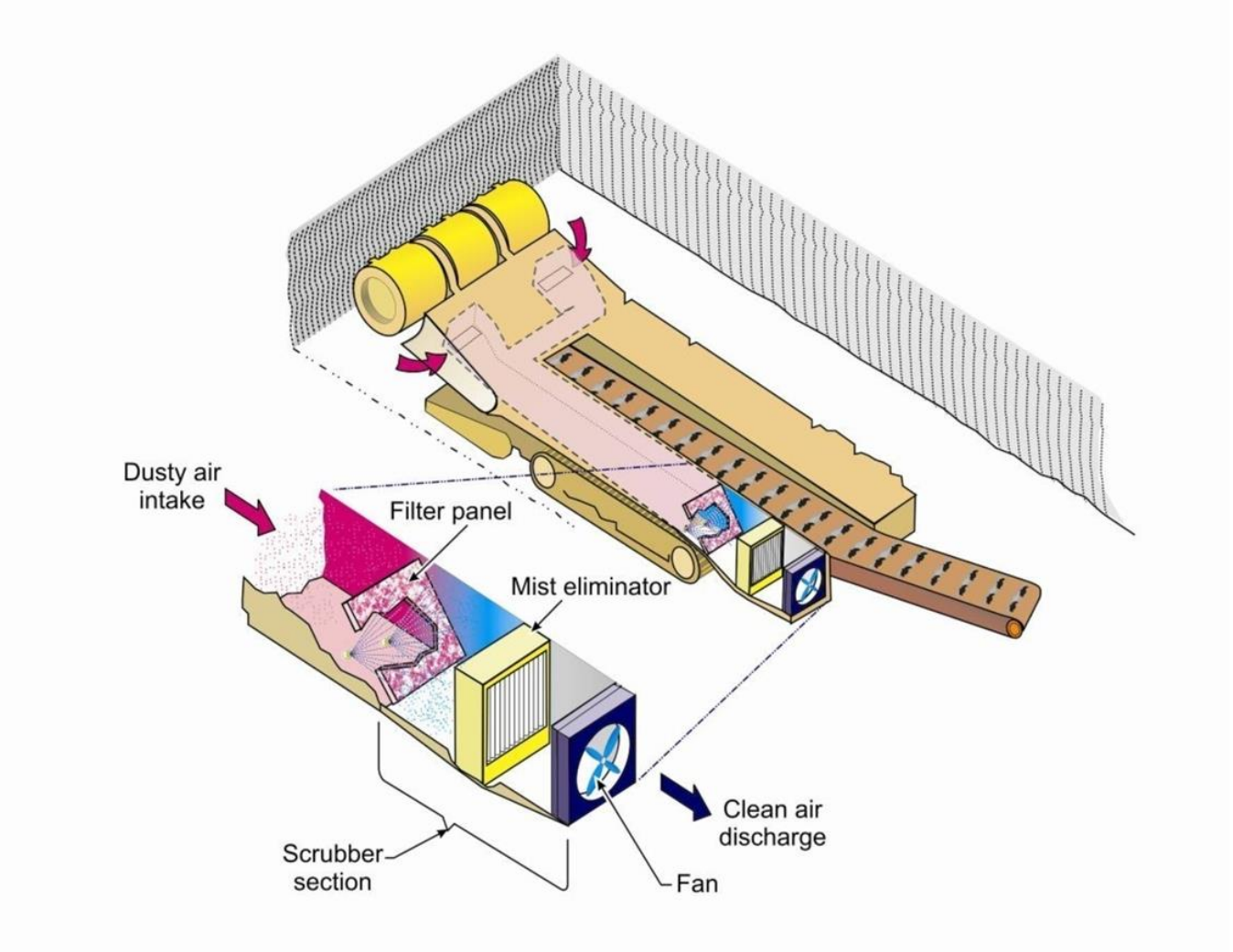
Conclusions & Observations

- Dust reduction in return with exhausting ventilation without scrubber
- Moderate to small reductions at the CM operator
- Quartz dust reduction variable
- Increased visibility
- Operator acceptance

➢ **Would an increase in water flow rate at lower spray pressures notably increase dust control?**

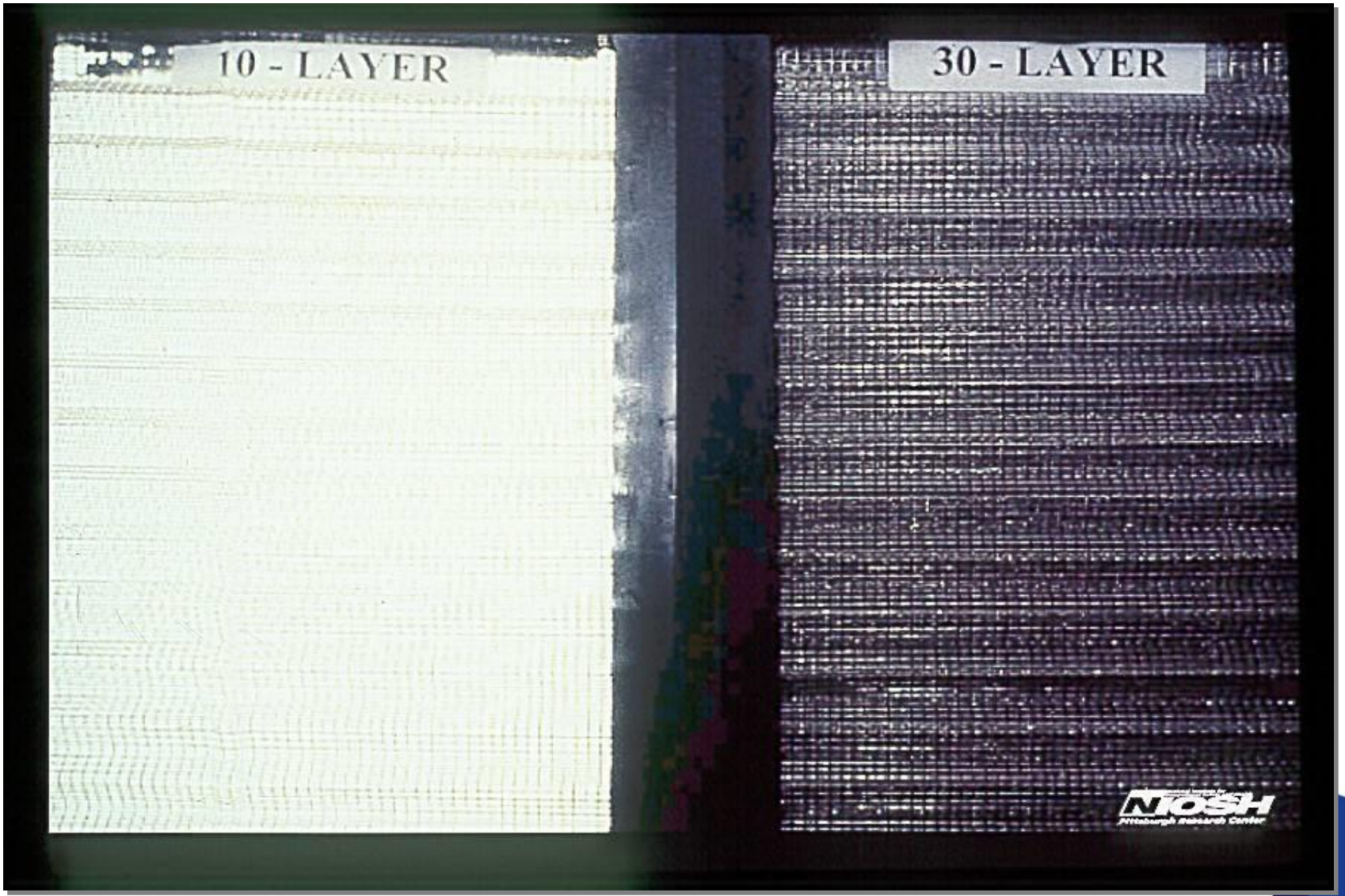
Flooded-bed Scrubbers

Capture and Remove Airborne Dust

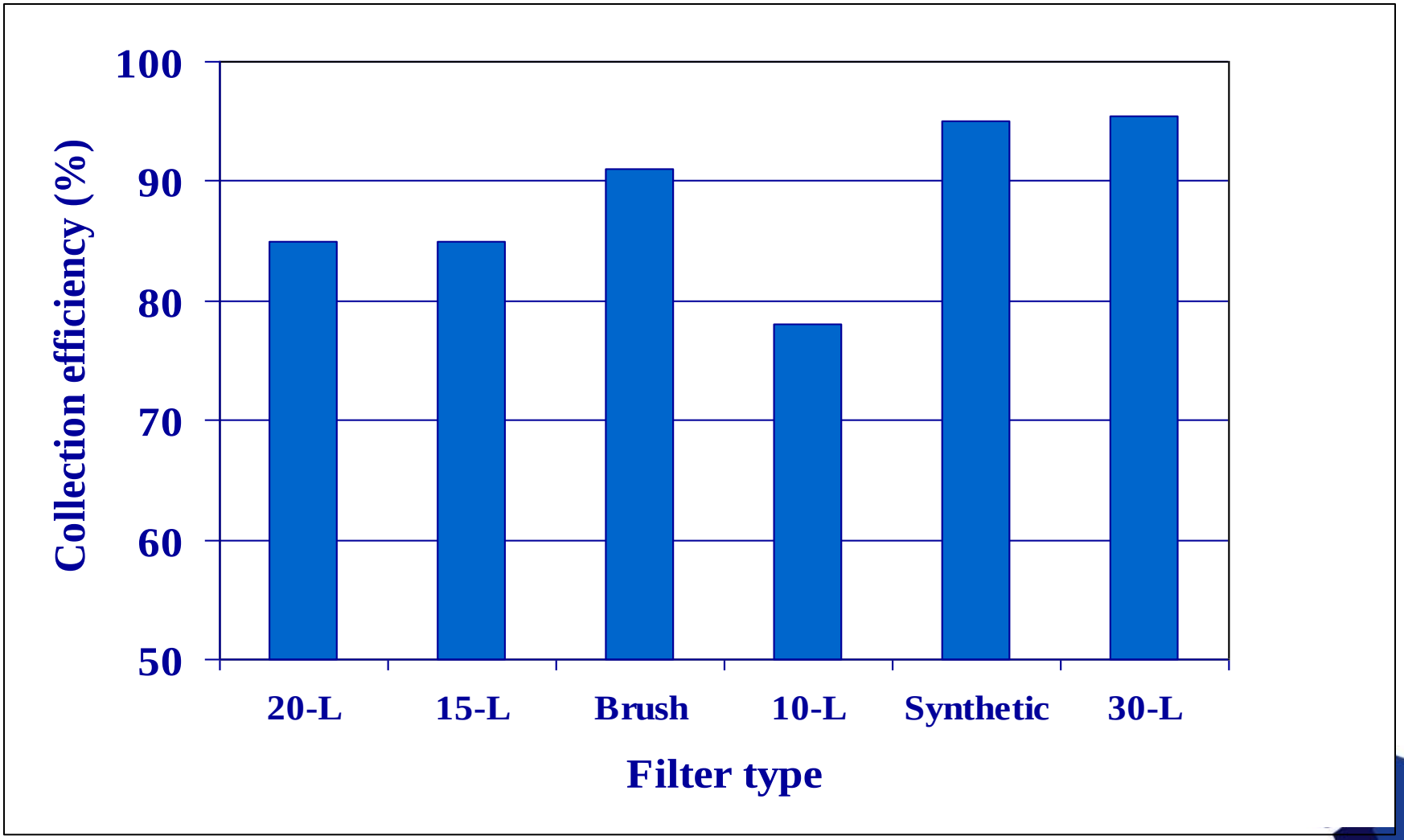


Scrubber Filter Study

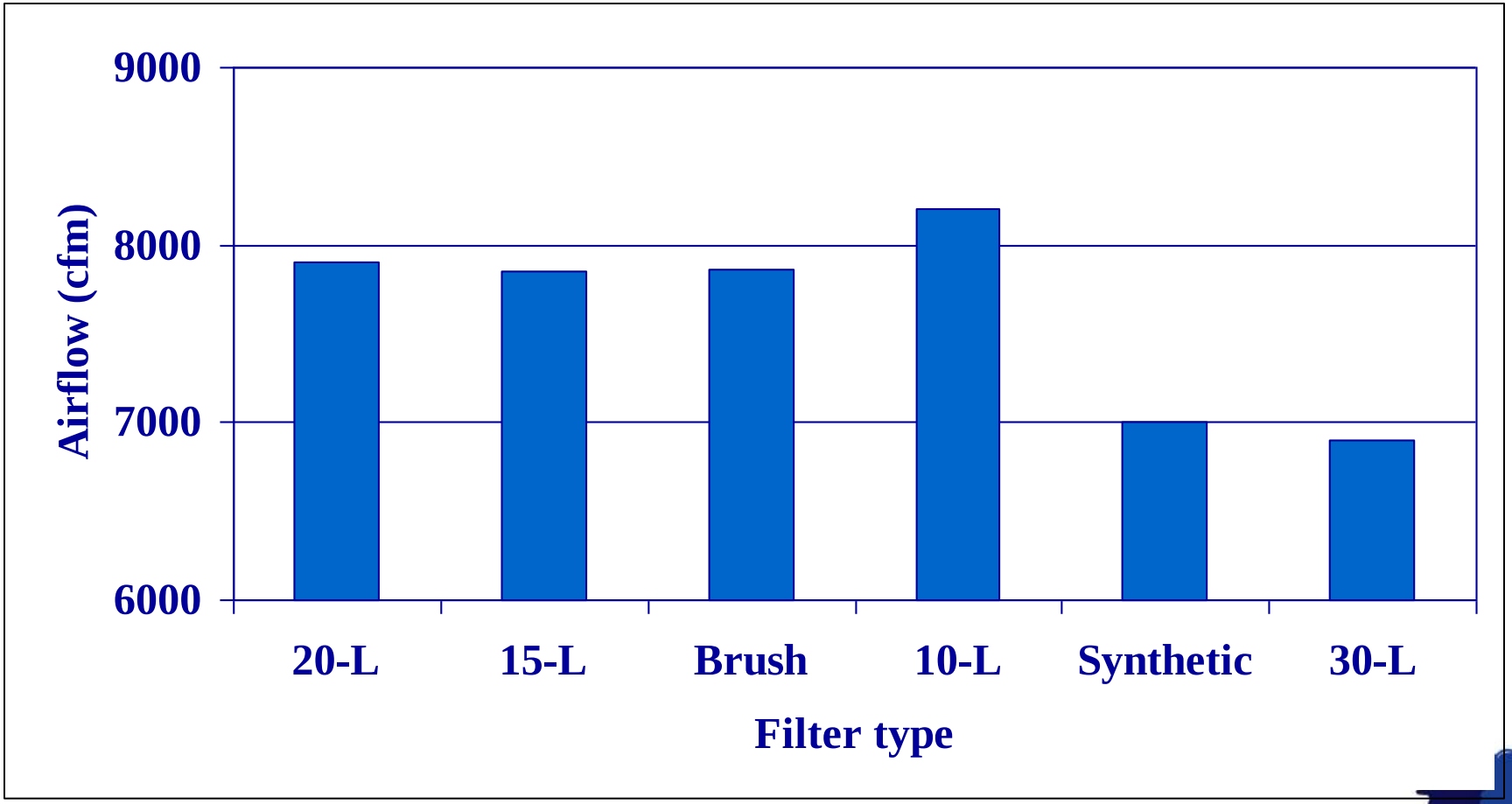
10 vs 30 Layer Filters



Respirable Dust Collection Efficiencies



Air Quantity Measured With Each Filter Panel



Scrubber Efficiency

- Scrubbers can lose 1/3 of airflow after one cut
- Check air velocity with pitot tube
- Most common loss of efficiency due to filter panel clogging

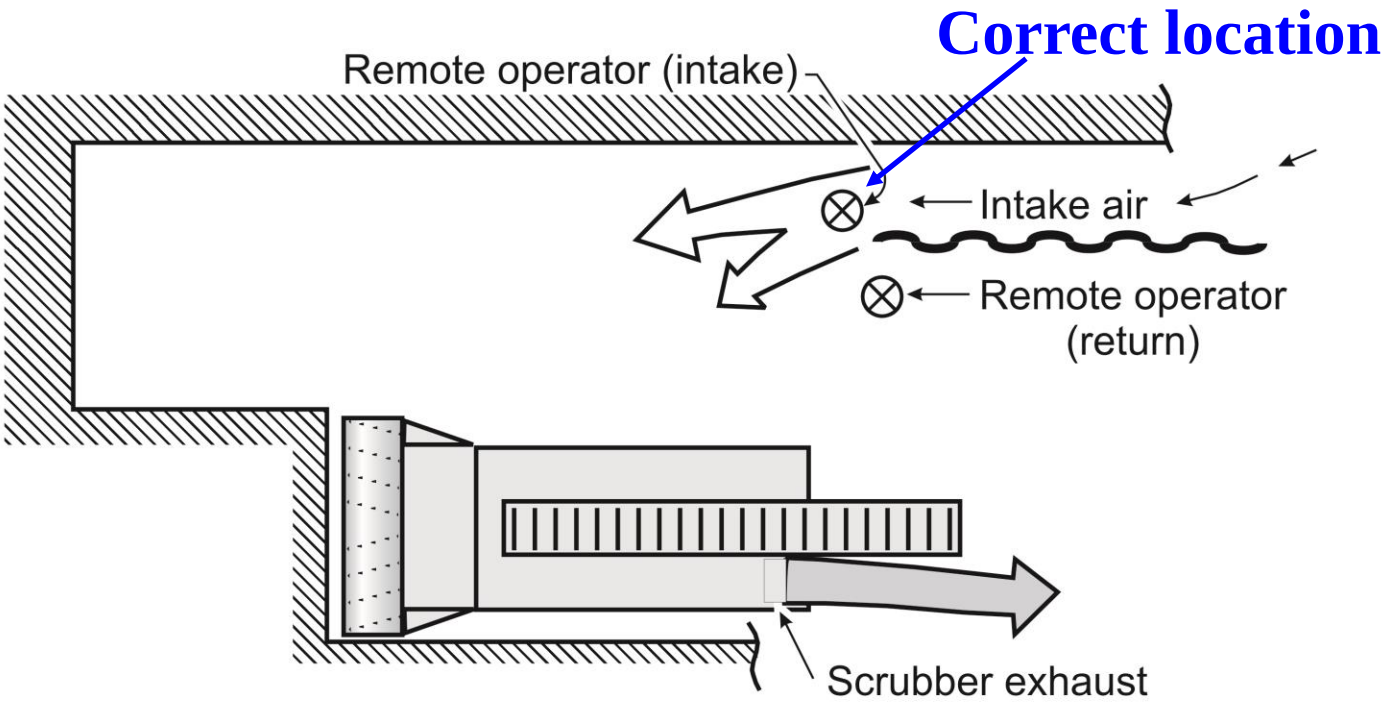
Clean and Maintain Scrubber Filter and Demister

- Filter spray(s) should completely wet the panel (full cone sprays)
- Clean filter panel each cut and ductwork twice per shift
- Replace filter each shift, back flush and allow to dry, then shake out remaining dust

Clean the Demister and Sump Weekly at a Minimum

Face Airflow Practices

Blowing Ventilation



Blowing Ventilation

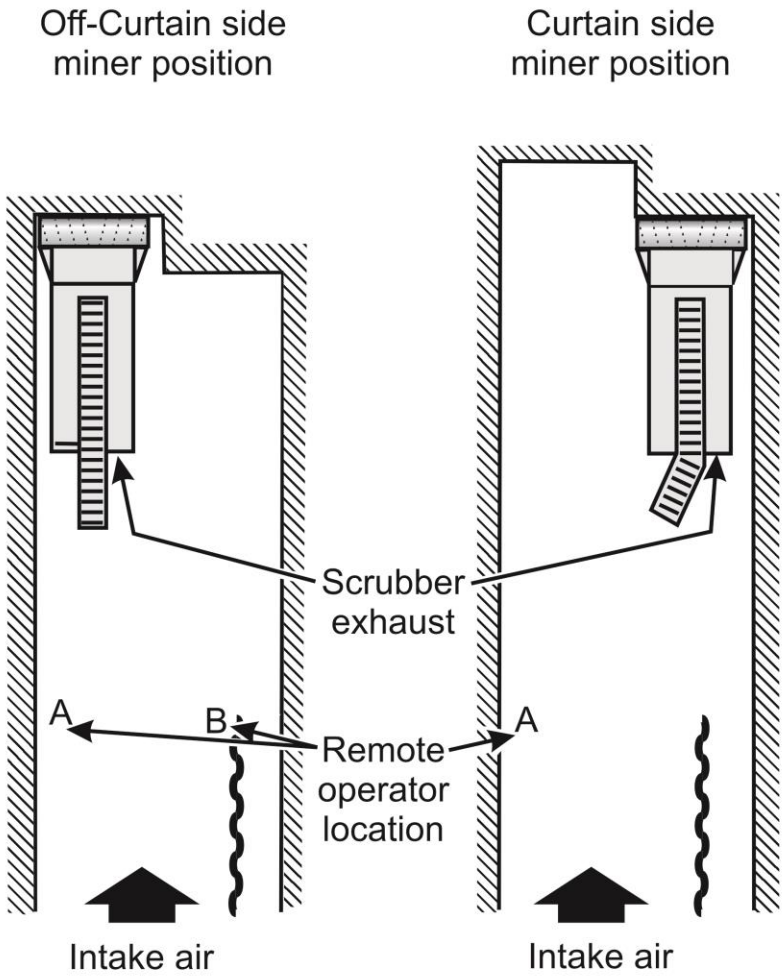
- Advantages
  - Greater penetration to face > 800 fpm
  - Effectively sweeps dust and methane from the face
  - Easier to maintain than exhaust
- Disadvantages
  - Restricts operator movement
  - Shuttle car operators must work in return air
  - Incorrect air balance may cause recirculation or overpowering

Blowing Ventilation

Recommendations

- Airflow at end of curtain should match or be no more than 1000 cfm > scrubber airflow
- Measure airflow into place with scrubber off
- Shuttle car operator on curtain side of entry
- Scrubber discharge on off curtain side

Face Airflow Practices
Exhausting Ventilation



Exhausting Ventilation

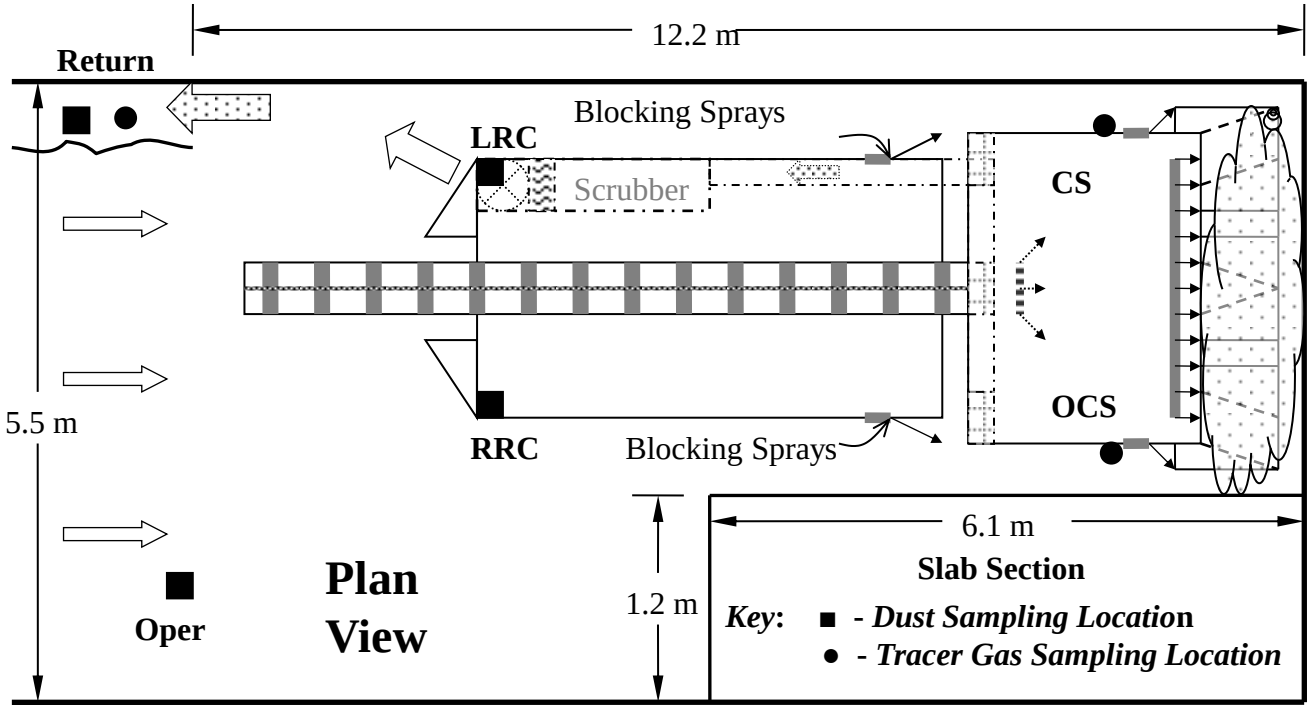
- Advantages
  - Operator has greater range of movement
  - Shuttle car operator remains in fresh air
  - Minimal effects on scrubber inlet capture effectiveness
- Disadvantages
  - Curtain is difficult to maintain
  - Less effective sweep of dust and methane from the face than blowing

Exhausting Ventilation
Recommendations

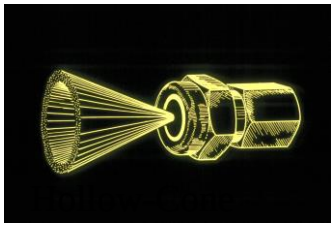
- Operator/helpers remain on intake side of entry
- Line curtain secured firmly to roof and floor
- Mean entry air velocity – 60 fpm minimum
- Curtain setback beyond scrubber discharge
- Shuttle car operator on off curtain side of entry
- Exhaust curtain airflow should exceed scrubber airflow.

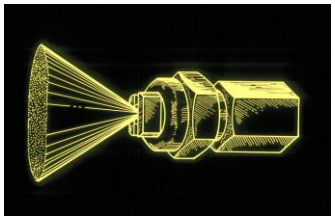
Spray and Scrubber Optimization For Exhaust Face Ventilation Systems

Continuous Miner Gallery Laboratory Experiments



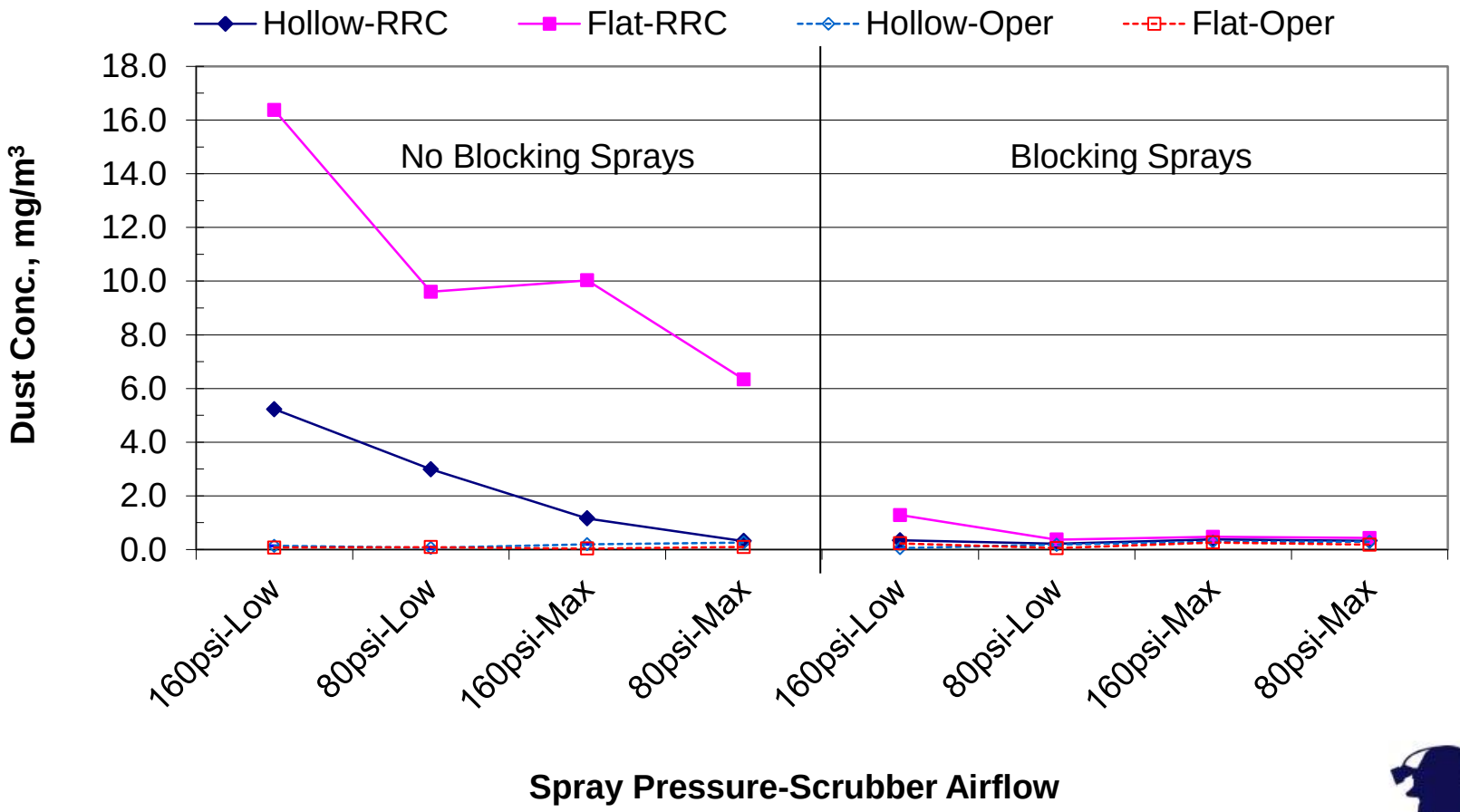
2 Spray Types



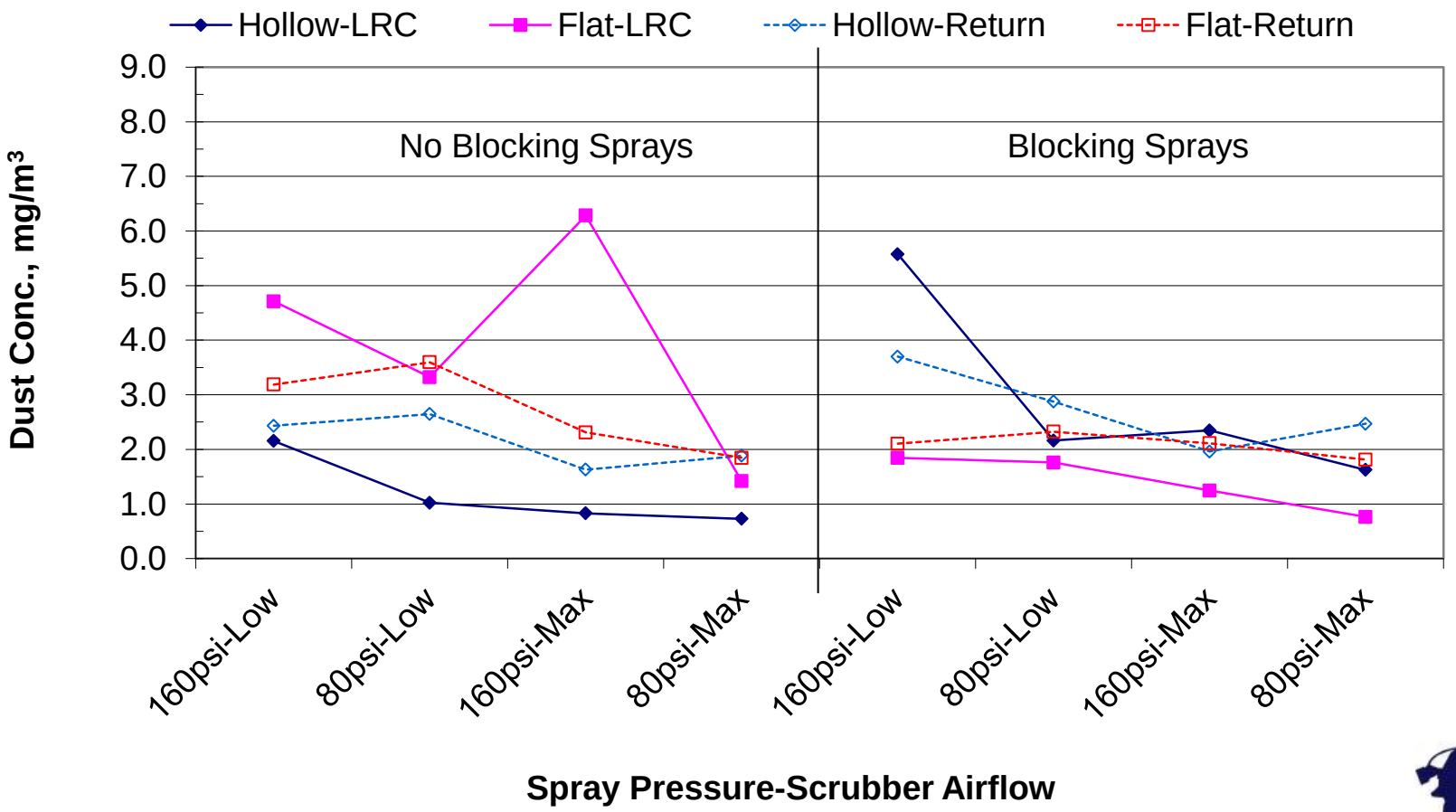


Test Factors: Spray Pressure (80psi – 160 psi)
Blocking Sprays (Off – On)
Scrubber Flow (Max. – Reduced 20%)

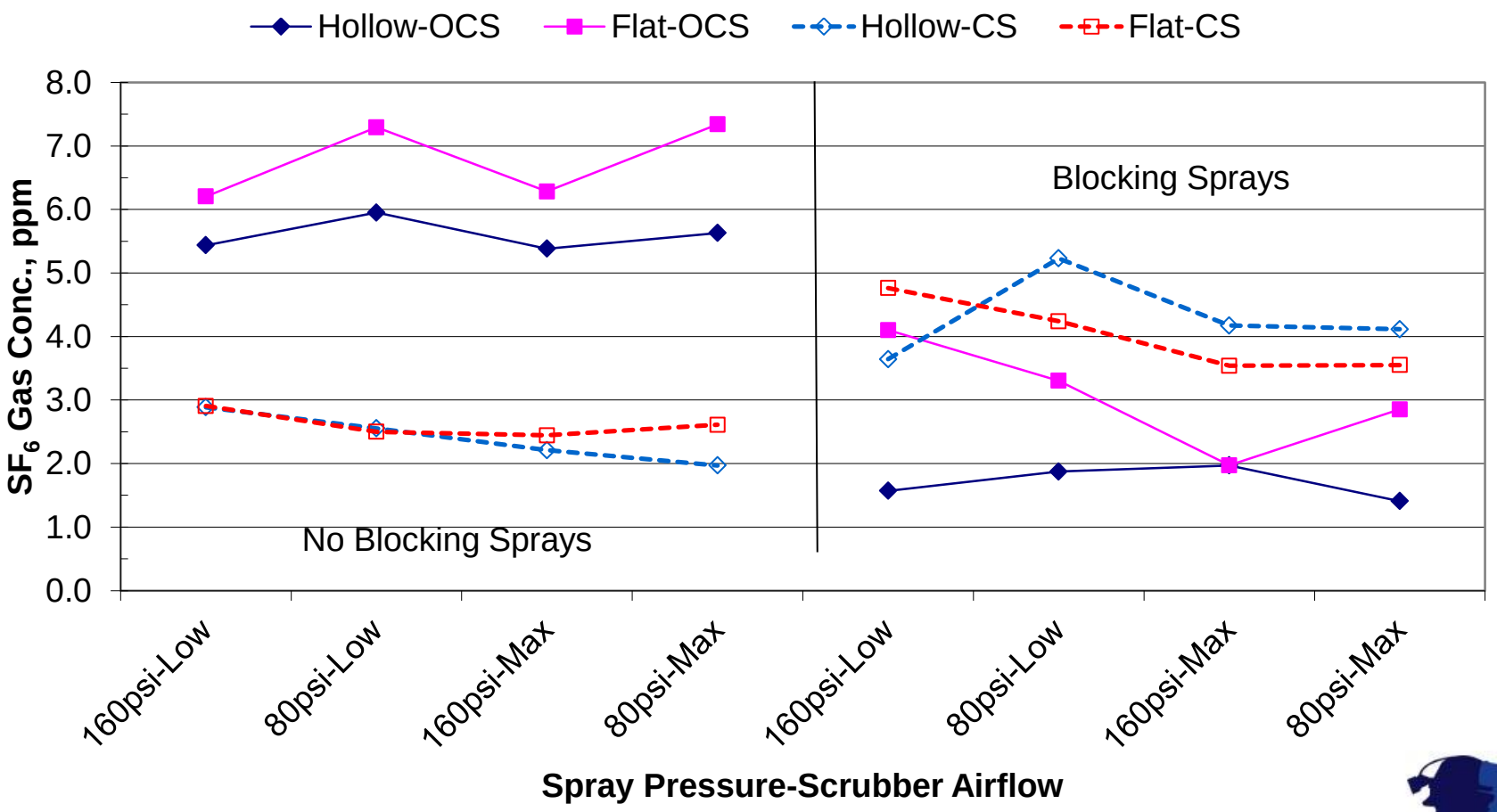
Slab Cut Dust Results – Off Curtain Side



Slab Cut Dust Results – Curtain Side



Slab Cut SF_6 Gas Results



Spray system optimization
Results – Optimal Dust & Gas Results

- Operator Position – Off curtain location
- Spray Type – Hollow Cone
- Spray Pressure – 80 psi
- Blocking Sprays – Yes
- Scrubber airflow – Maximum

Underground Studies of Continuous Miner Scrubber Effectiveness

- **MSHA approves use of deep cuts (roof, methane, dust control)**
  - Mines must demonstrate effective control in standard cuts before MSHA considers approval of deep cut
  - Flooded-bed scrubber is a key component in deep cut dust control

- **Industry – Are deep cuts dustier than standard cuts?**
  - Blowing and exhausting ventilation systems evaluated

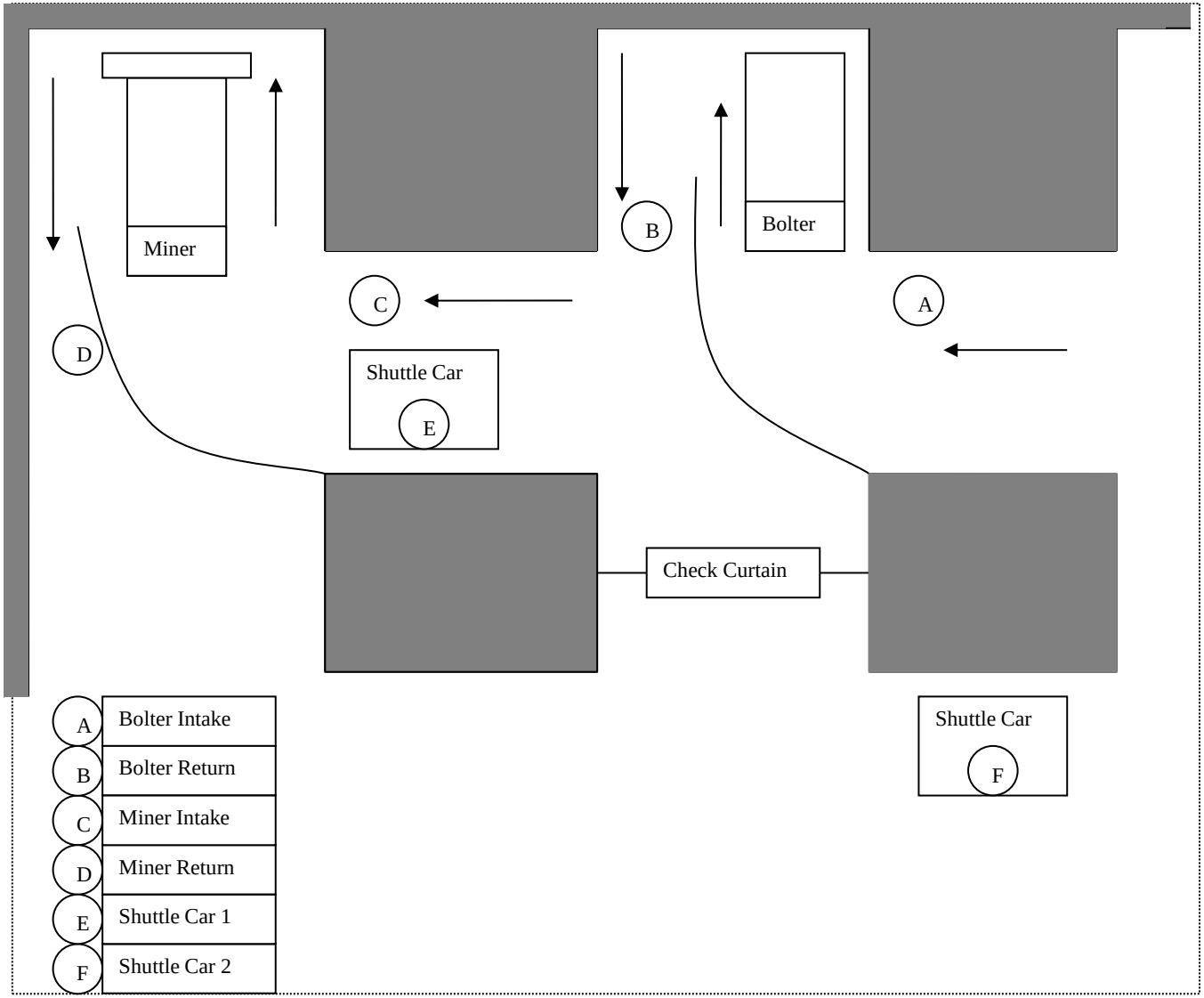
- **MSHA – How do dust levels compare in 20-foot cuts with and without a scrubber operating?**
  - NIOSH conducted evaluation of scrubber use in 20-foot cuts with exhaust ventilation and an extended curtain setback

Face Dust Levels at Deep-Cut CM Sections

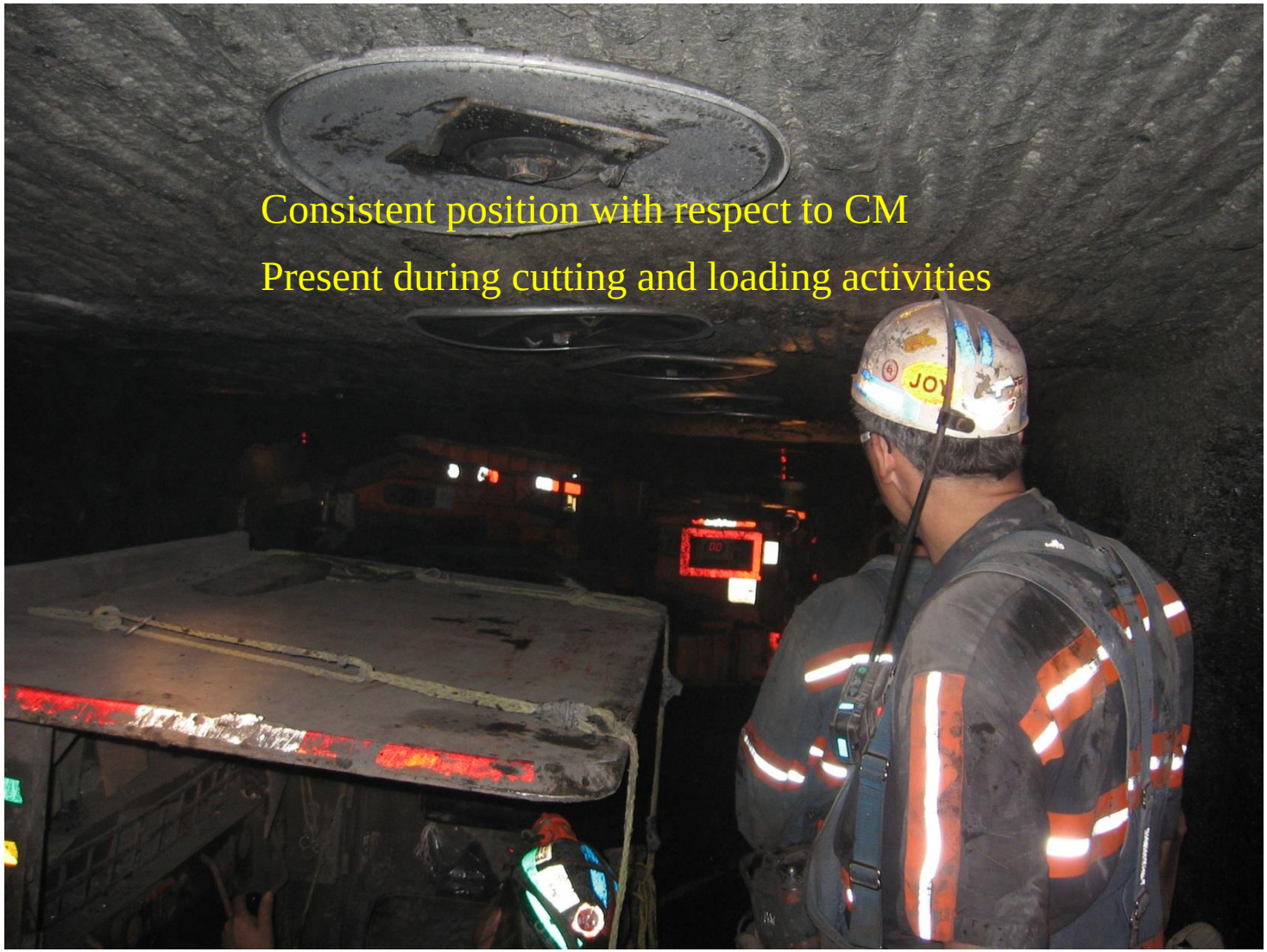
- 6 underground dust surveys: KY,WV,IL,VA,UT
  - 3 – Blowing face ventilation
  - 2 – Exhausting face ventilation
  - 1- Blowing/Exhausting face ventilation

✓ No blocking sprays used at any of these operations

Plan view of area dust sampling

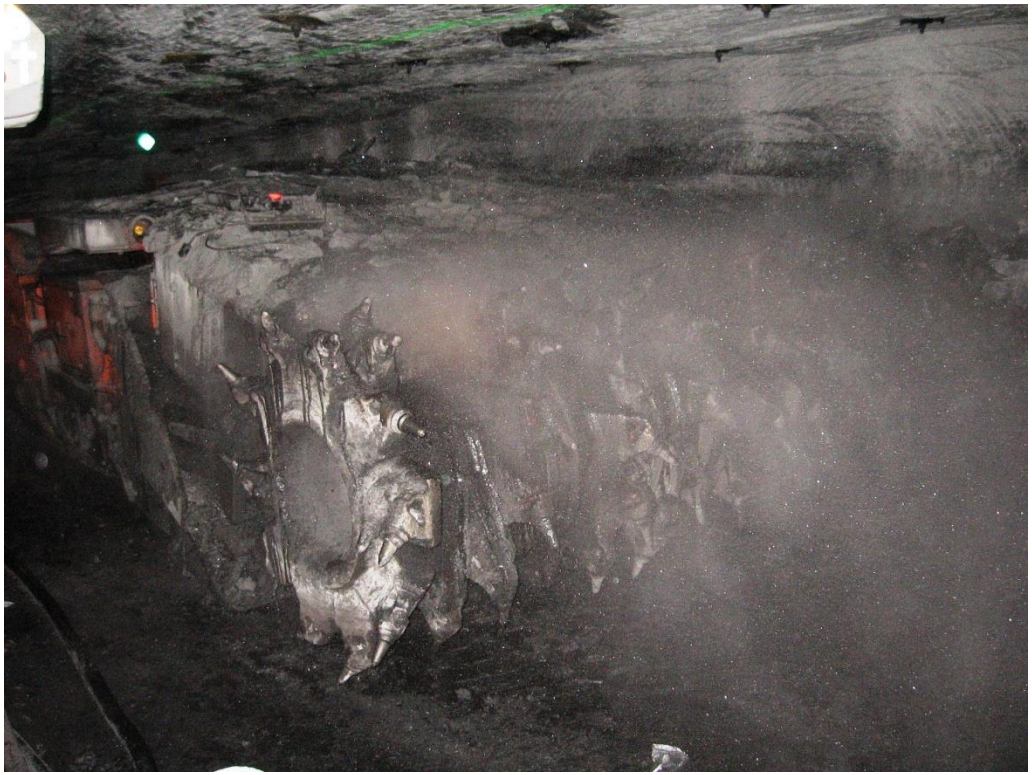


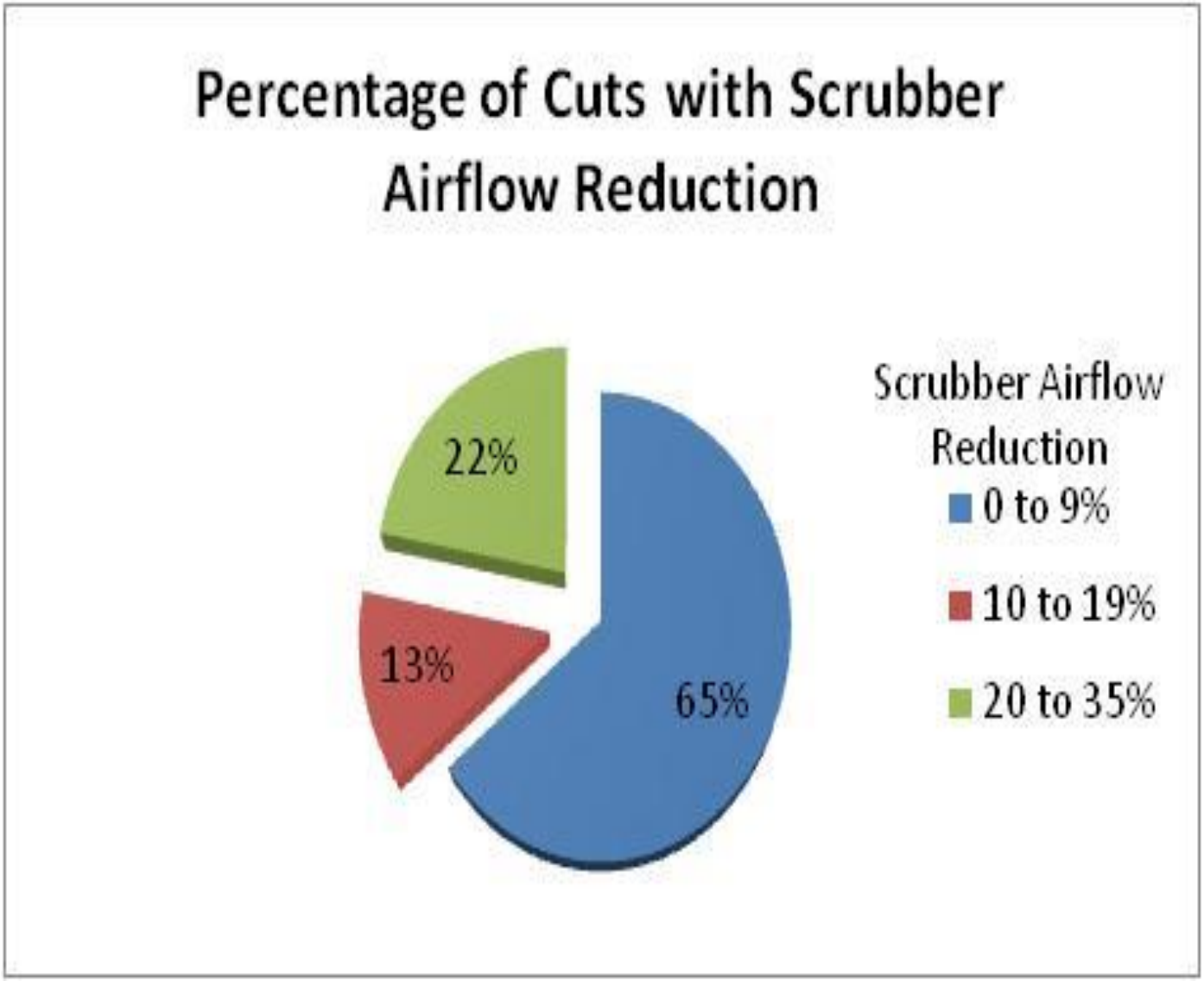
Shuttle car sampling



Continuous miner

- Scrubber airflow
  - Beginning of cut
  - 20 ft into cut
  - 40 ft into cut
- Curtain airflow
- Curtain setback




Percentage of Cuts with Scrubber Airflow Reduction
22%
13%
65%
Scrubber Airflow Reduction
0 to 9%
10 to 19%
20 to 35%

Exhaust curtain - shuttle car results

- Average regular cut dust level at face= 0.20 mg/m^3
- Average deep cut dust level at face= 0.35 mg/m^3
- Not statistically significant
- 10 of 14 cuts experienced no significant change in dust levels during cut
- 4 experienced 0.2 to 0.4 mg/m^3 higher dust during the deep cut due to use of on-curtain side cab*
- Mines with larger scrubbers had lower dust*

* Also confirmed by laboratory studies

Blowing curtain - shuttle car results

- Average regular cut dust level at face = 1.96 mg/m^3
- Average deep cut dust level at face = 2.32 mg/m^3
- Not Statistically Significant
- 13 of 18 cuts experienced no significant change in dust levels during cut
- 1 experienced higher dust during the deep cut possibly due to improper curtain to scrubber airflow ratio (curtain airflow almost twice scrubber airflow)
- 1 experienced higher dust during deep cut due to change in shuttle car route
- 2 experienced higher dust for unknown reasons
- 1 experienced lower dust due to operator positioning

Other Dust Results

Statistically Significant (85% CI) Changes in Dust Levels at Other Positions from Regular to Deep Cut Depth

	Mine A	Mine B	Mine C	Mine D	Mine E	Mine F
Miner Operator	None	None	None	None	-	None
Miner Generated	None	None	None	Lower	None	None
Bolter Operator	None	None	None	None	None	None
Bolter Generated	None	None	None	None	None	None

All daily average dust concentrations measured at the bolter and miner operator positions were less than 2.0 mg/m^3

Conclusions and Observations

- Use of extended-cut practices did not hinder dust control efforts on the bolter and miner faces at the surveyed mines

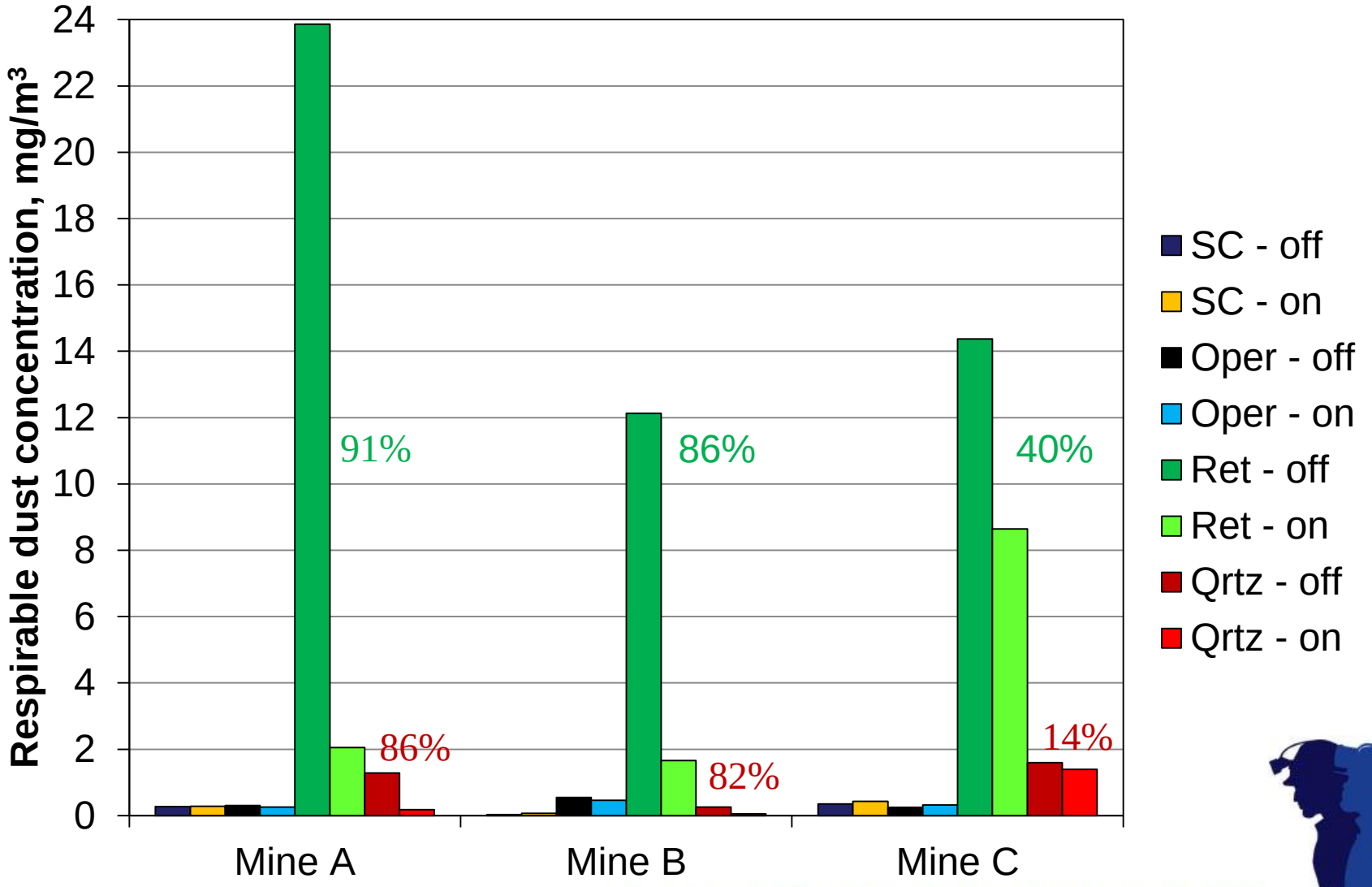
- All mines had good curtain and scrubber airflows
- 30 to 50 ft curtain setback distances
- Operator located at mouth of curtain on blowing faces and parallel to or outby curtain mouth on exhausting faces
- For exhaust faces, use off-curtain side shuttle car cabs
- For blowing faces, curtain-to-scrubber airflow ratio of 1.0 before activation of scrubber
- 20-mesh scrubber screens require back-flushing each cut
- Industry could further benefit from use of blocking sprays
- Ventilate and advance curtain on bolting faces

Continuous Mining Dust Levels With and Without a Scrubber

Sampling summary

Mine	Continuous miner cuts		Roof bolter cuts			
	Scrubber off	Scrubber on	Total	Upwind of miner or miner off	Downwind of miner	
					Scrubber off	Scrubber on
A	7	7	13	12	0	1
B	7	7	14	9	2	3
C	4	4	7	4	2	1

Dust level results for 20-foot cuts with & without scrubber



Conclusions

- Continuous miner and shuttle car operators' dust concentrations
  - respirable dust exposures ≤ 0.55 mg/m^3 for both test conditions
  - *no statistically significant differences with/without scrubber*
- Miner return dust concentrations
  - 91%, 86% & 40% reductions at Mines A, B & C with scrubber on
  - *statistically significant differences at Mines A and B*
- Roof bolter intake dust concentrations downwind of the miner
  - 85% and 34% reductions at Mines B and C with the scrubber on
  - no statistical analysis completed

Conclusions (continued)

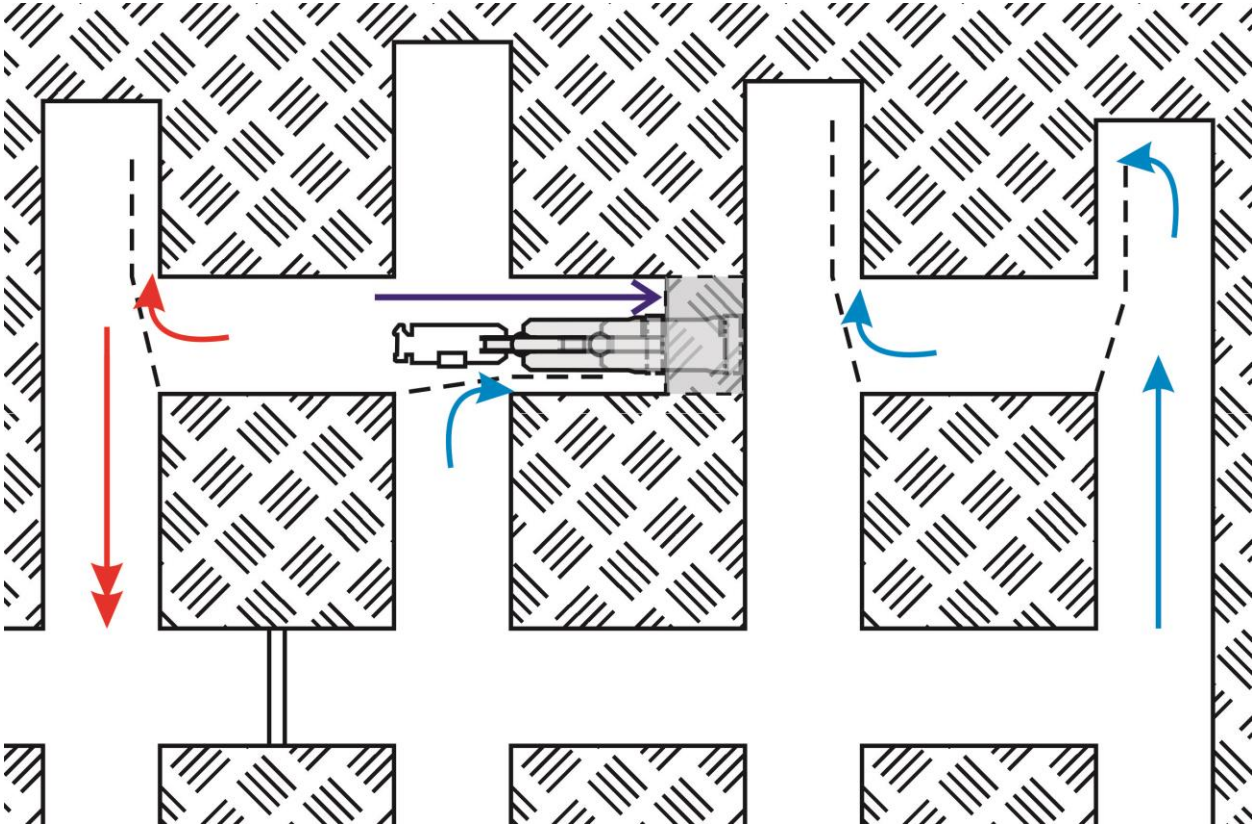
- Quartz dust concentrations in the miner return
  - 86%, 82%,& 14% reductions at Mines A, B,& C with scrubber on
  - *statistically significant differences at Mines A and B*
- Scrubber air quantities
  - 2,000 cfm (29%) and 1,500 cfm (35%) reductions at Mines B and C after completing one cut
  - *scrubber filters should be cleaned after each cut to ensure proper airflow*

Crosscut Dust Study

Characteristic	Value
No. of mines	10
Mining height (inches), mean ± SD	64.1 ± 16.7
Ventilation rate (cfm), mean ± SD	8338 ± 2870
No. of cuts sampled	167
No. of headings sampled	109
No. of crosscuts sampled	61

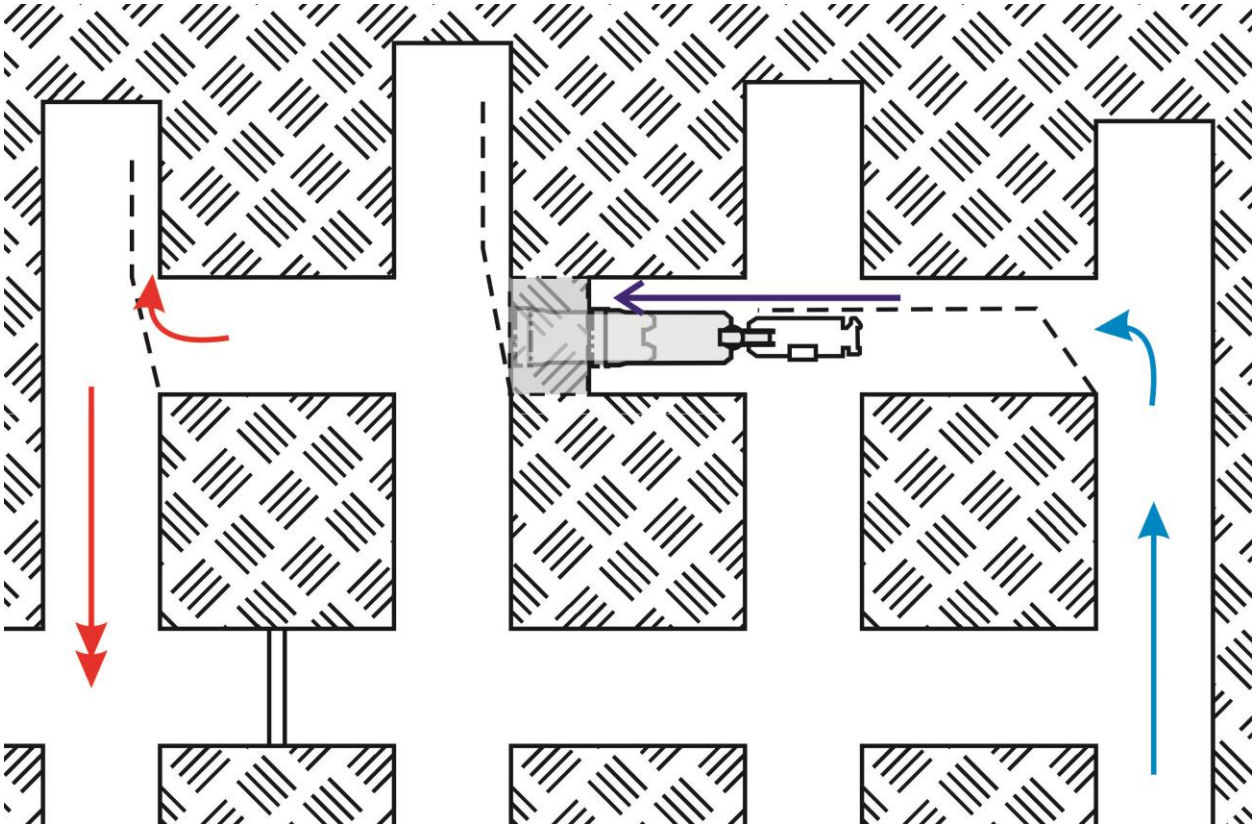
- Mines selected from prior OMSHR field studies from 2007 to present
- Fully mechanized, ventilated by curtain, used on-board flooded bed scrubbers

CM Dust Levels



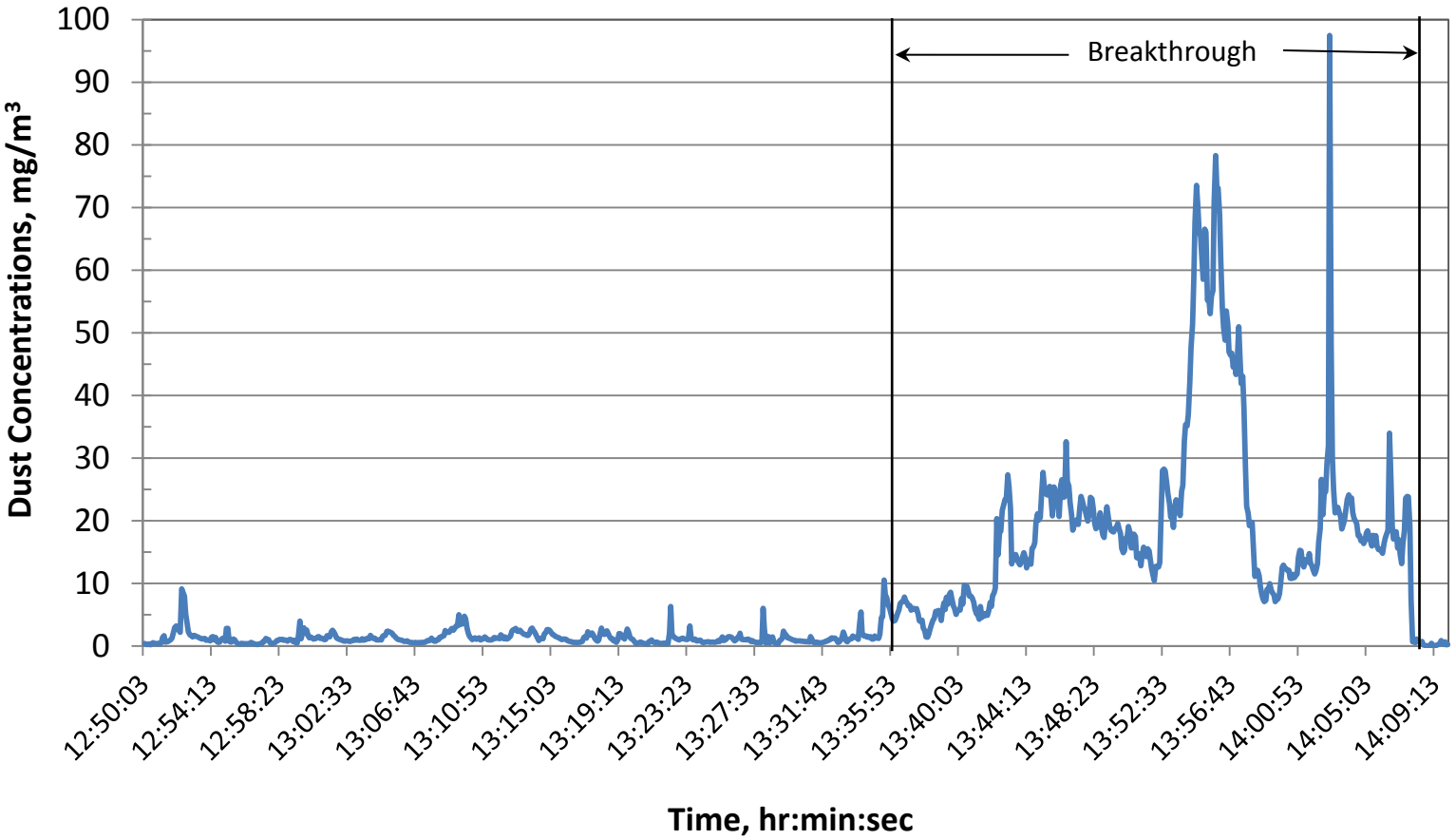
- No significant difference in dust levels between headings and crosscuts
- **Blowing** ventilation **lower** than exhausting face vent
- Turning **crosscuts into ventilation** found to be **higher**

SC Dust Levels

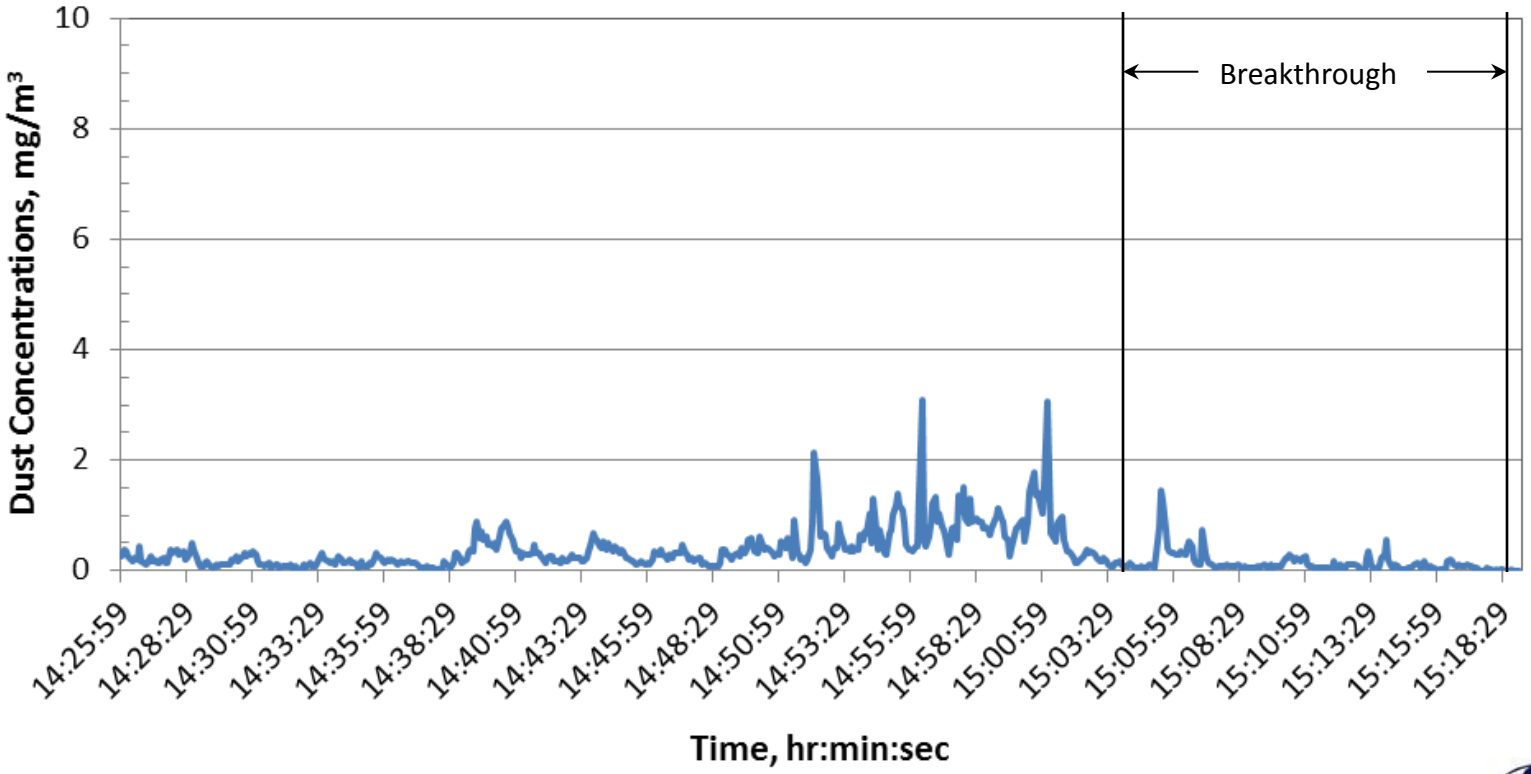


- **Crosscuts** found to be **lower** than headings
- **Blowing** face ventilation found to be **higher** than exhausting
- Turning **crosscuts into ventilation** found to be **higher**

CM Oper. Dust Levels for X-cut Breakthrough into Ventilation



CM Oper. Dust Levels for X-cut Breakthrough with Ventilation



Crosscut Mining Recommendations

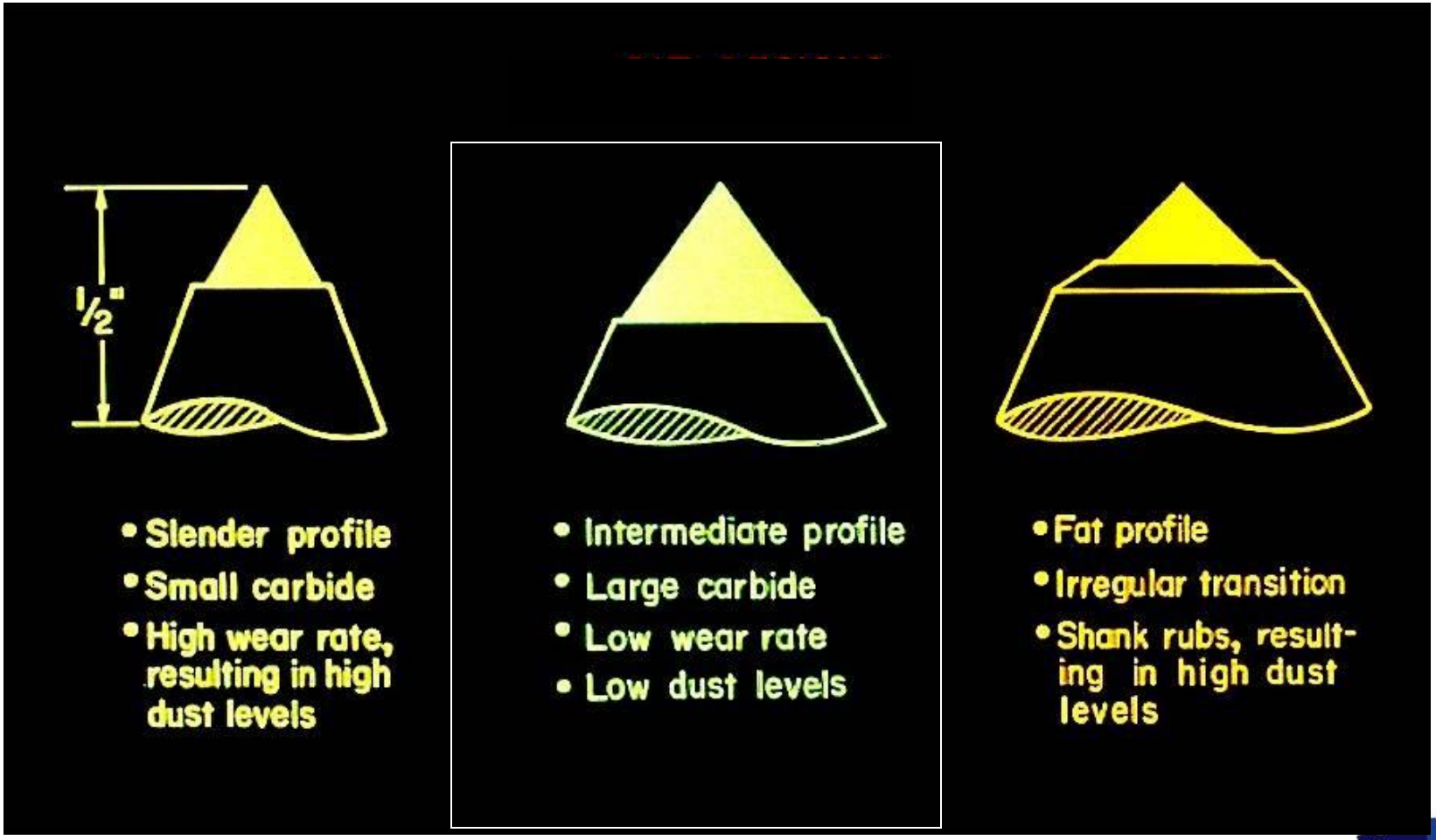
- Mine crosscuts with the direction of section ventilation

- When mining crosscuts against the direction of section ventilation
  - minimize the breakthrough time by squaring up the face a few feet before breakthrough
  - block/seal the projected breakthrough rib area with ventilation curtain to restrict the opposing airflow pattern during breakthrough

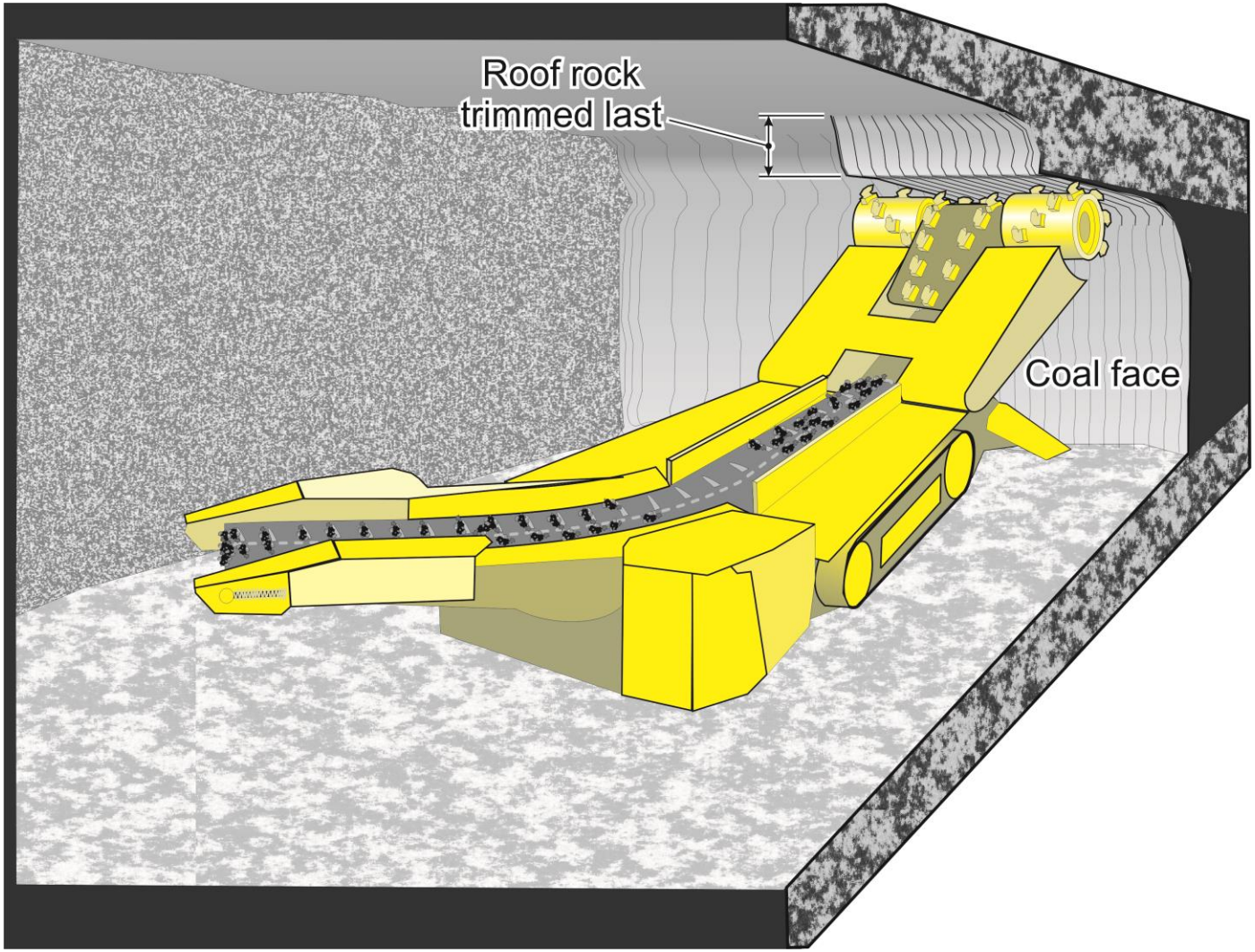
Other Considerations

- Bit Design
- Cutting Roof Rock

Bit Designs

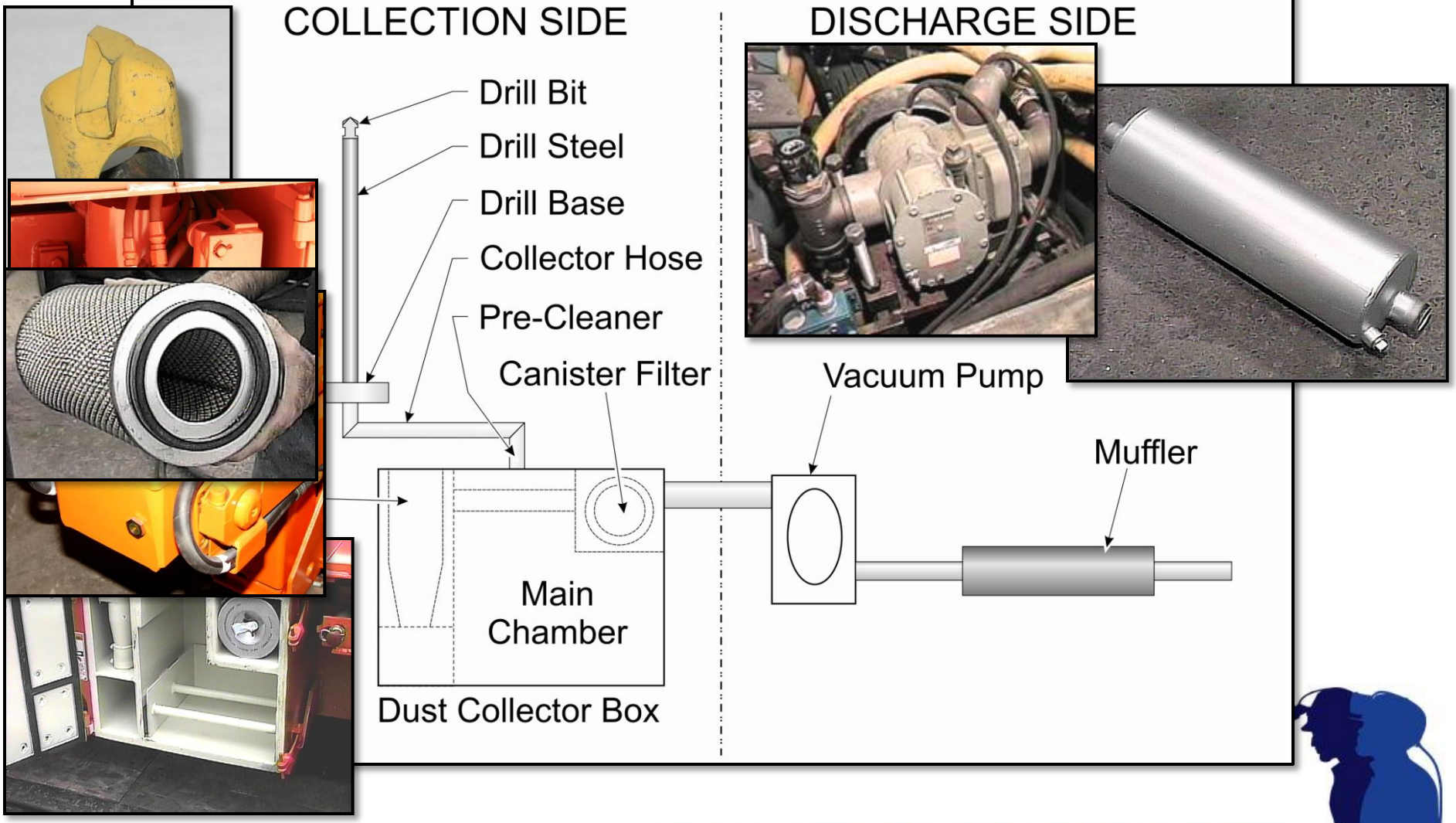

1/2"
• Slender profile
• Small carbide
• High wear rate, resulting in high dust levels
• Intermediate profile
• Large carbide
• Low wear rate
• Low dust levels
• Fat profile
• Irregular transition
• Shank rubs, resulting in high dust levels

Improved Cutting Methods



Roof Bolter Dust Control

Roof Bolter Dust Collector



Operator Over Exposures

- Poor maintenance of vacuum dust collector
- Improper cleaning of collector compartment
- Removing and replacing canister filter
- Contamination of the downstream collector components

Maintenance

- Eliminate leaks in vacuum system
- Check door gasket integrity
- Hoses and clamps
- Door latches intact
- Door not bent, seating tight

Improper Cleaning of Dust Box

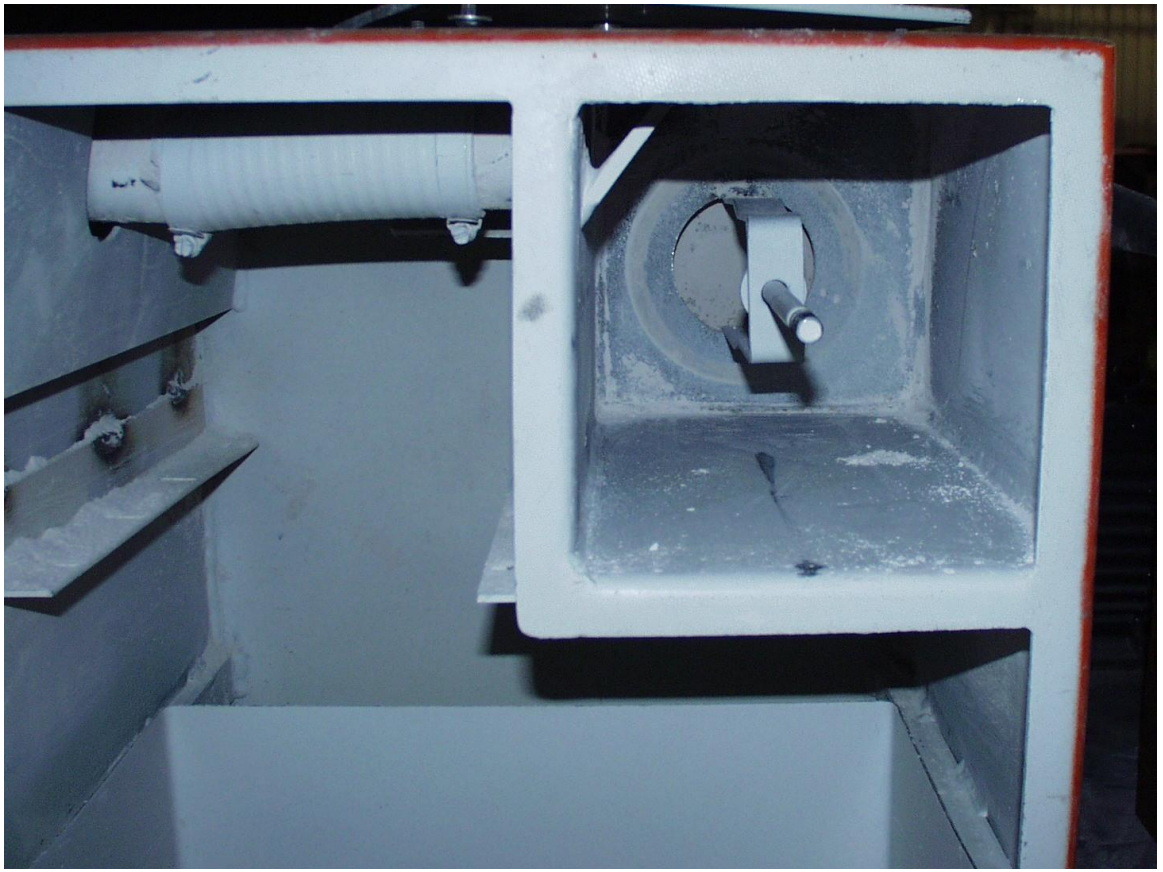
- Insufficient air
- Downwind of ventilation
- Too close to source
- Clothes contamination

Filter Removal and Replacement

Cleaning the Filter?

OFFICE OF MINE SAFETY AND HEALTH RESEARCH

Discharge Contamination



Disposable Collector Bag

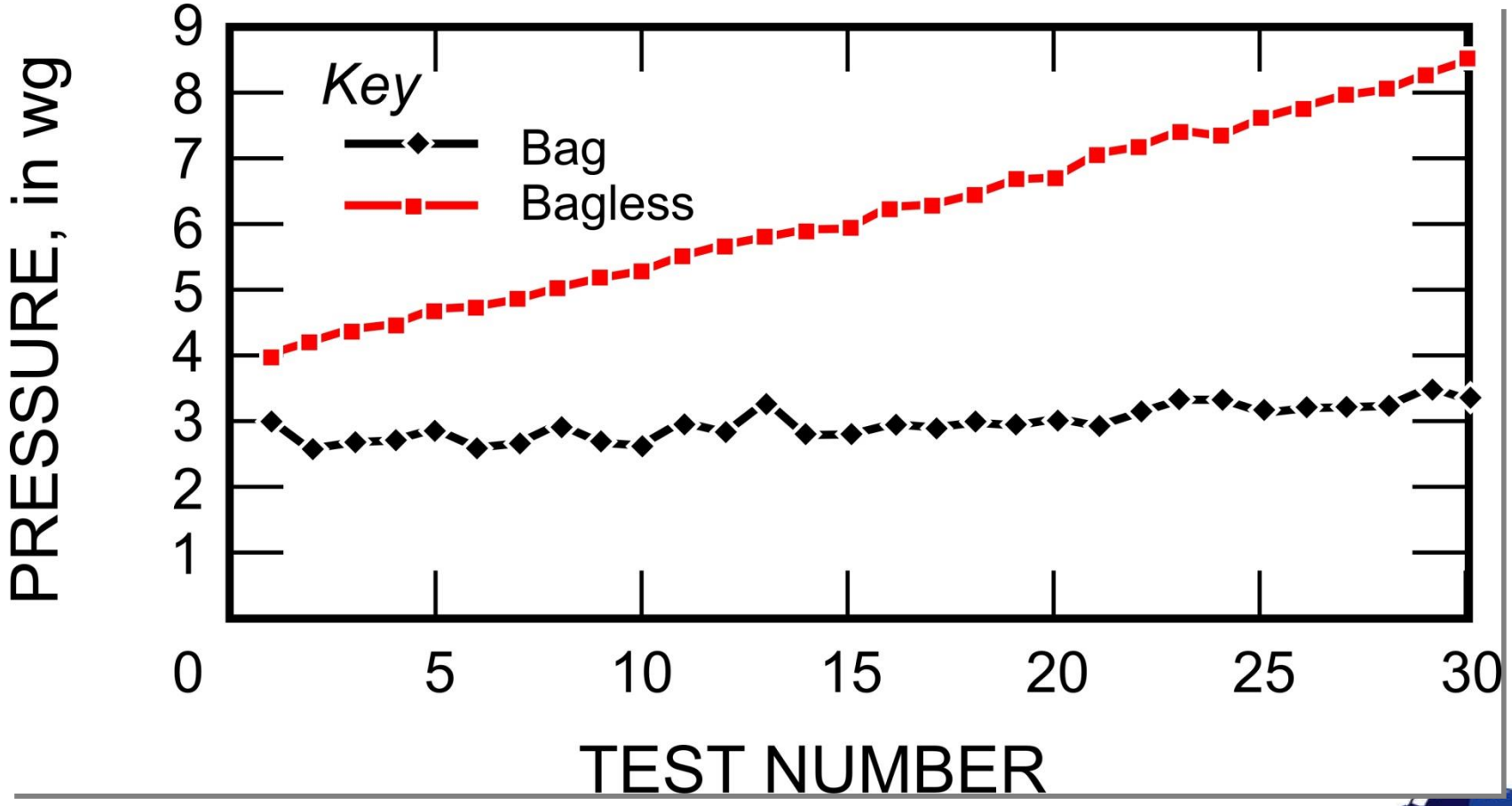
- Distributed by JH Fletcher for bolters
- Can be retrofitted to most Fletcher dust collectors
- Recommended to be used with pre-cleaner

Collector Box Tests

Without Bag

With Bag

Pressure Drop Across Filter



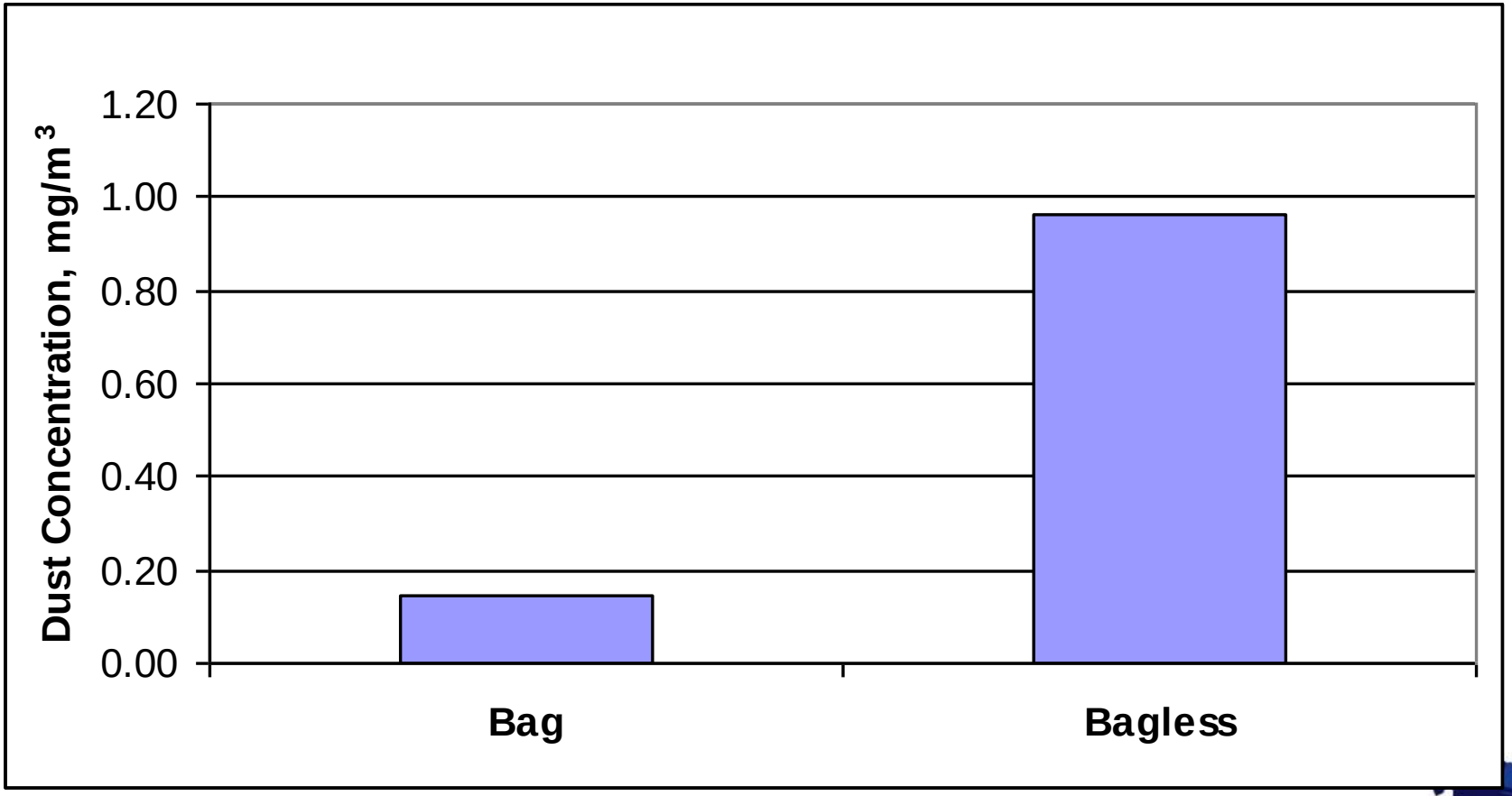
Lab Results Summary

- 99.6% of feed dust contained in collector bag
- Dust concentration in exhaust: 2 times higher without bag
- Particle count of fine dust (< 2 microns) 3 times greater without bag
- Canister filter loading greatly reduced with bag in place

Bolter Bag Field Study

- Dual boom Fletcher bolter
- Upwind of miner
- Exhausting ventilation
- Bag vs bagless

Gravimetric Sample Results
Collector Emissions



✓ Collector box cleaning time reduced from 4 minutes to 30 seconds

Collector Bag Benefits

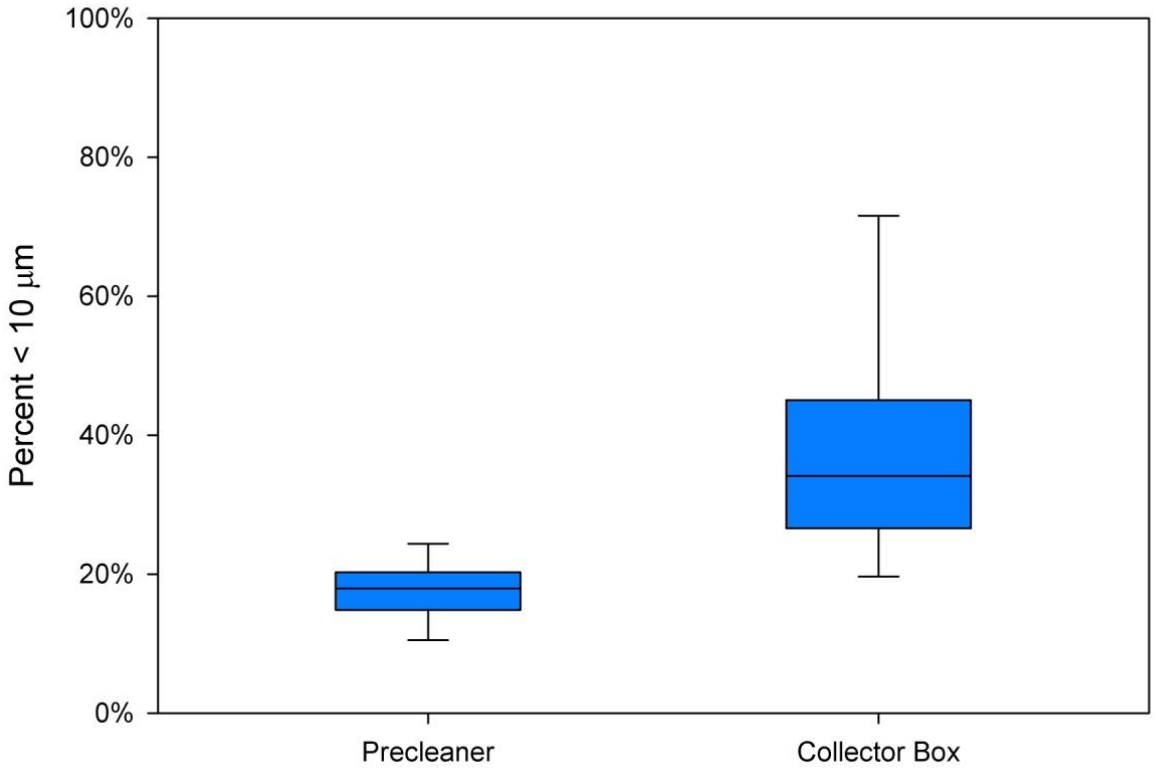
- Keeps dust contained during removal from box
- Keeps dust out of entry traffic preventing further entrainment
- Prolongs filter usage – reduces replacement frequency
- Reduces dust on outby collector components
- Reduces dust emissions from collector exhaust

Pre-cleaner Dust Evaluation

- Roof bolter dust collector samples collected by NIOSH & MSHA from UG coal mines in Districts 4, 5, 6, and 7.
- Bulk dust samples analyzed for quartz content and particle size distribution.
- Airborne respirable dust samples collected by NIOSH to identify any respirable dust contribution from pre-cleaner dust dump events.

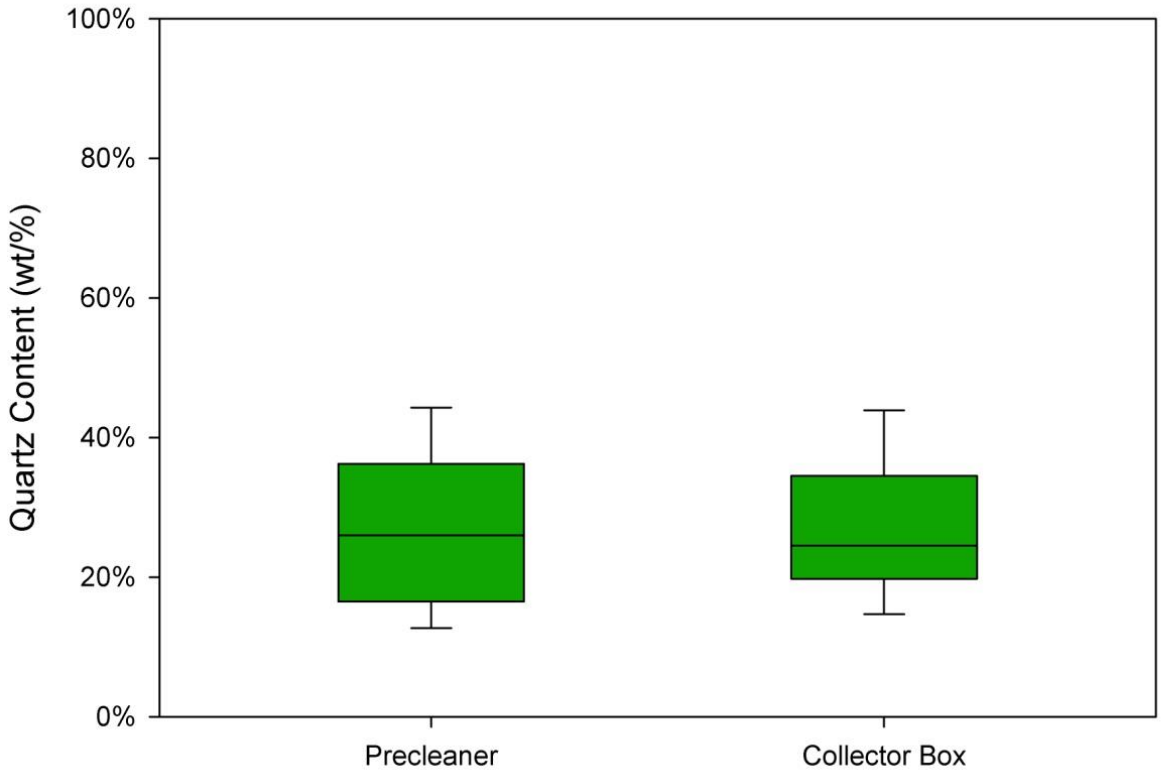
Bulk Sample Results - Size

- Collector box dust significantly smaller than pre-cleaner discharge dust.



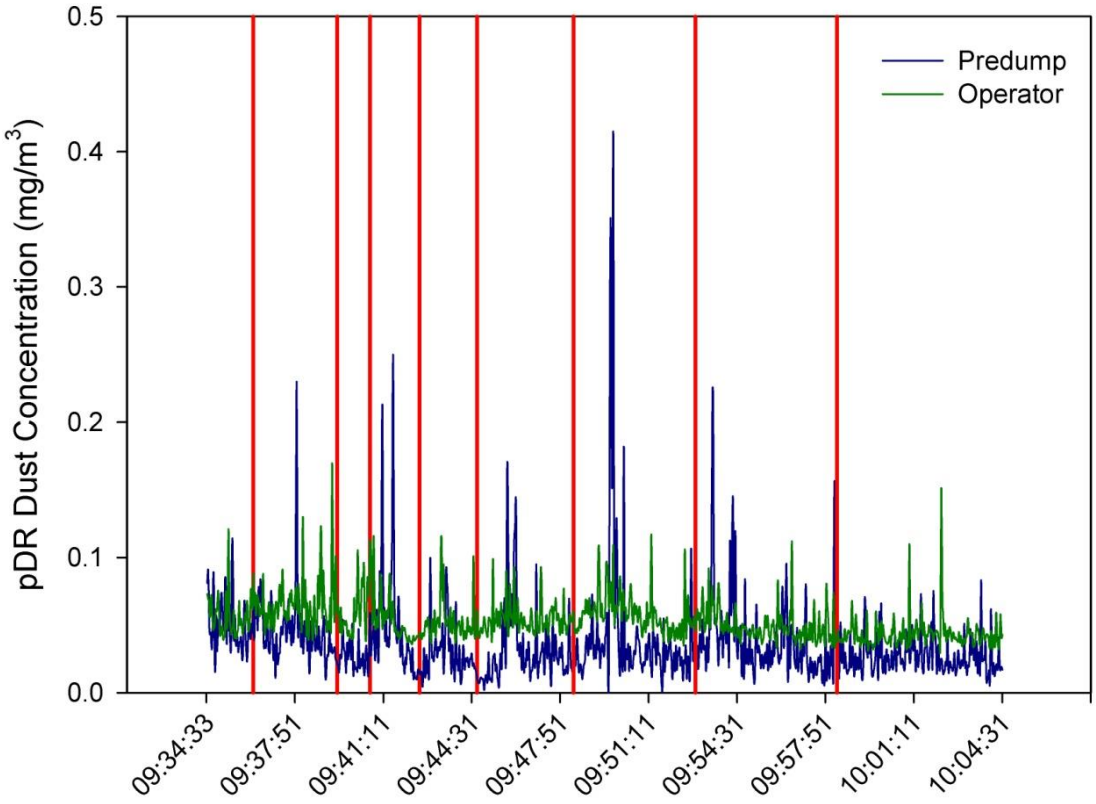
Bulk Dust Results - Quartz

- Quartz content (weight %) not significantly different between pre-cleaner discharge dust and collector box dust.



pDR Data Analysis

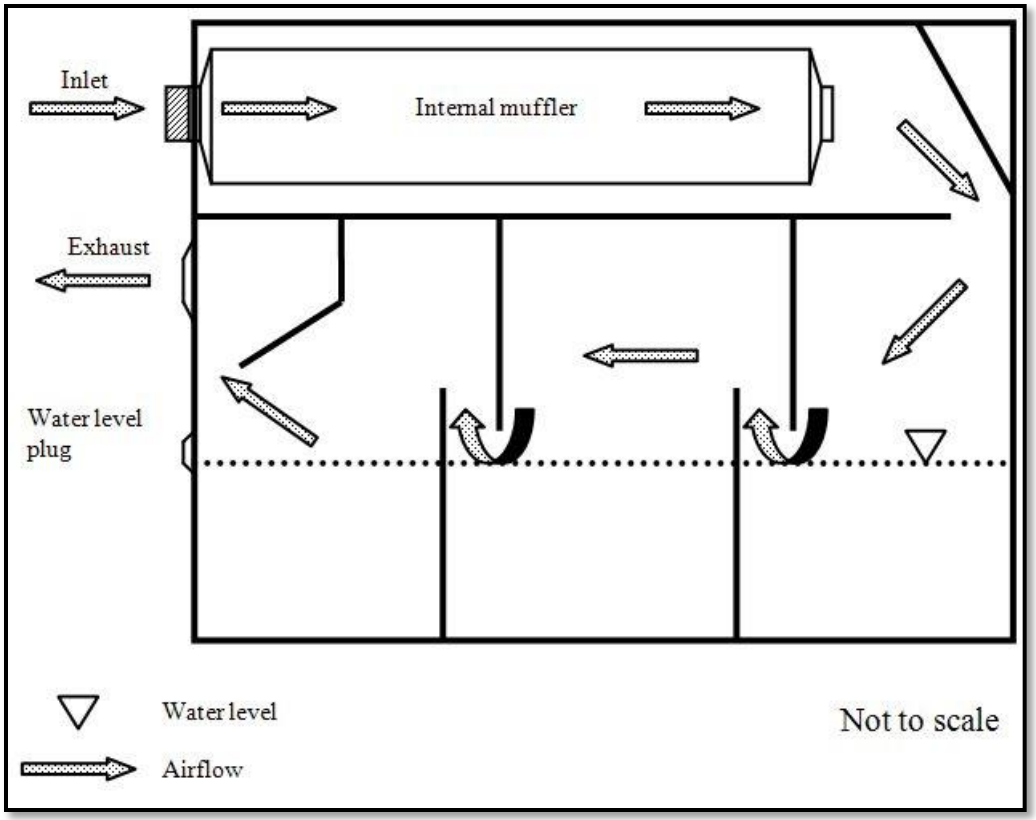
- Pre-cleaner dust dump events did not result in measurable increases of airborne respirable dust.



Conclusion

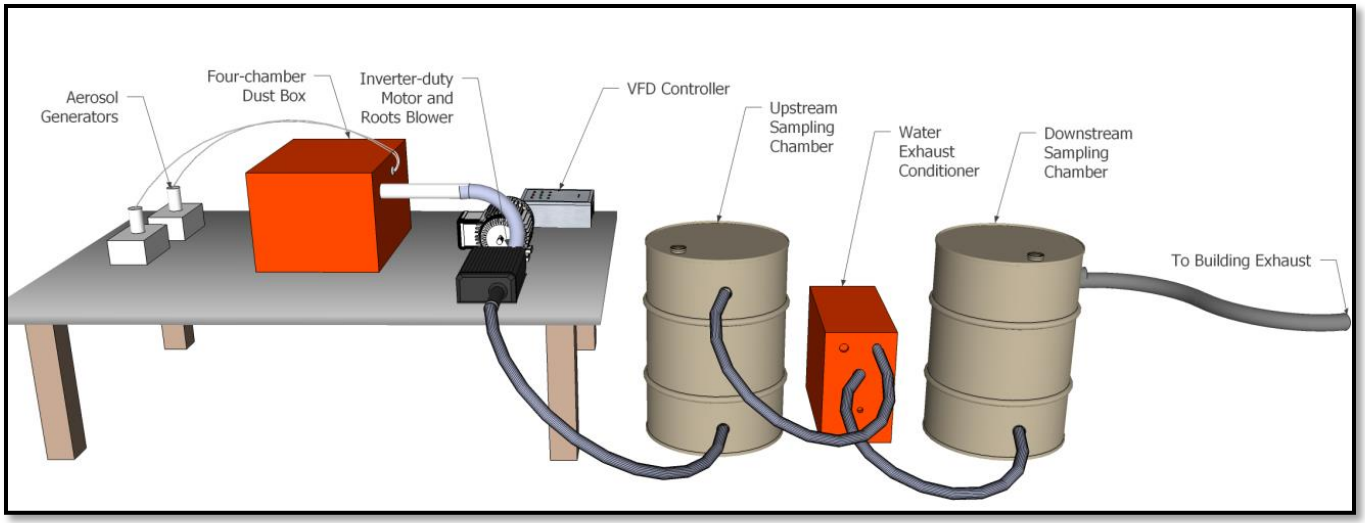
- No detectable contribution to airborne respirable dust from roof bolter pre-cleaner discharge events was observed in limited field sampling.
- Pre-cleaner dump dust is a potential hazard due to the amount of respirable size and quartz content. Miners should be trained to avoid disturbing dust piles.

Water Exhaust Conditioner



Laboratory Tests

- Add water box to existing dust collector simulator in lab
- Test two dust types: limestone and coal
- Sample upstream and downstream of device

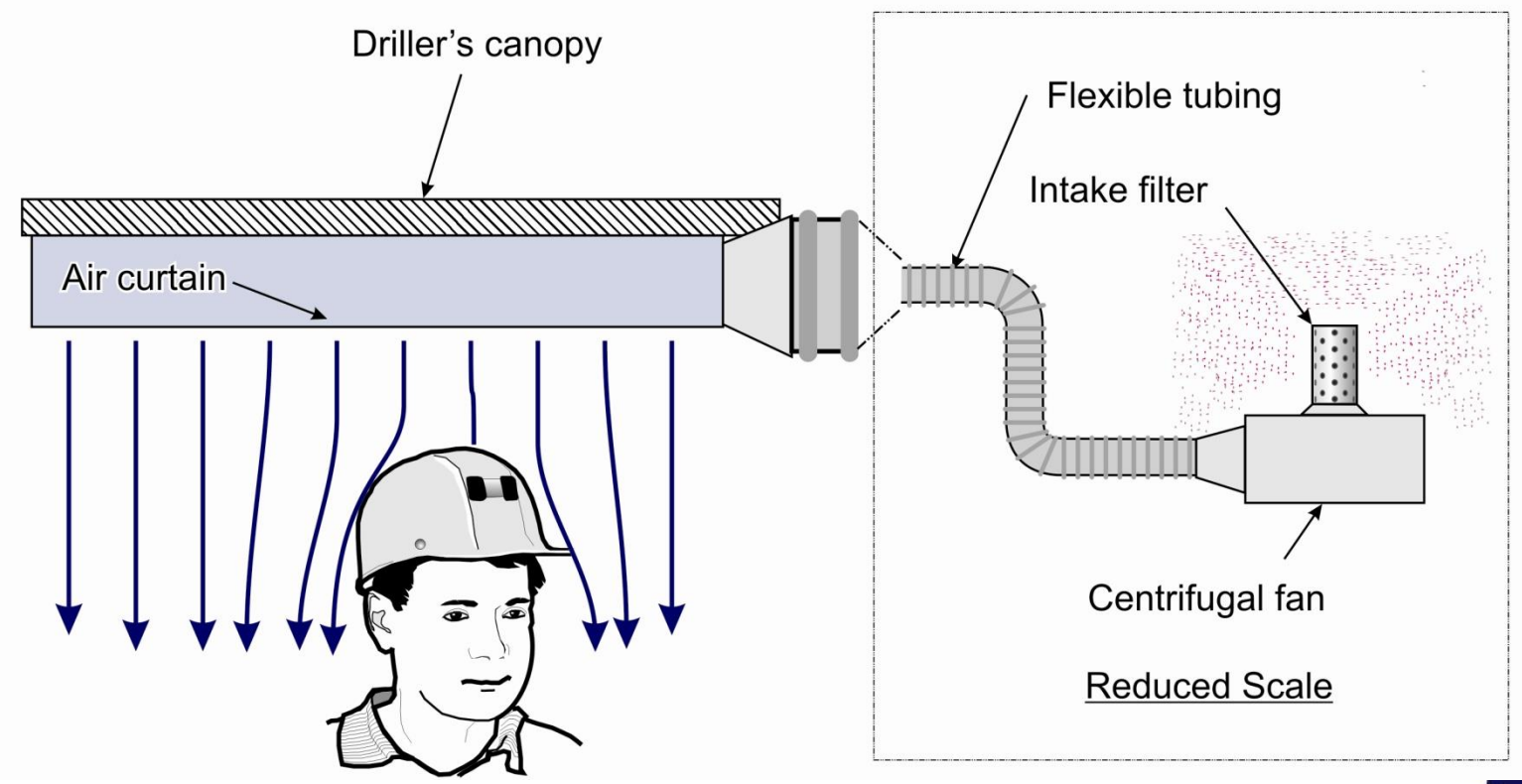


Exhaust conditioner Results

- Exhaust conditioner improves respirable dust collection efficiency by 41%
- Minimal potential for benefits/impact on operator exposure when dust collector box is properly maintained
- Not a substitute for poorly maintained collector box

Canopy Air Curtain

Limits exposures downwind of continuous miner



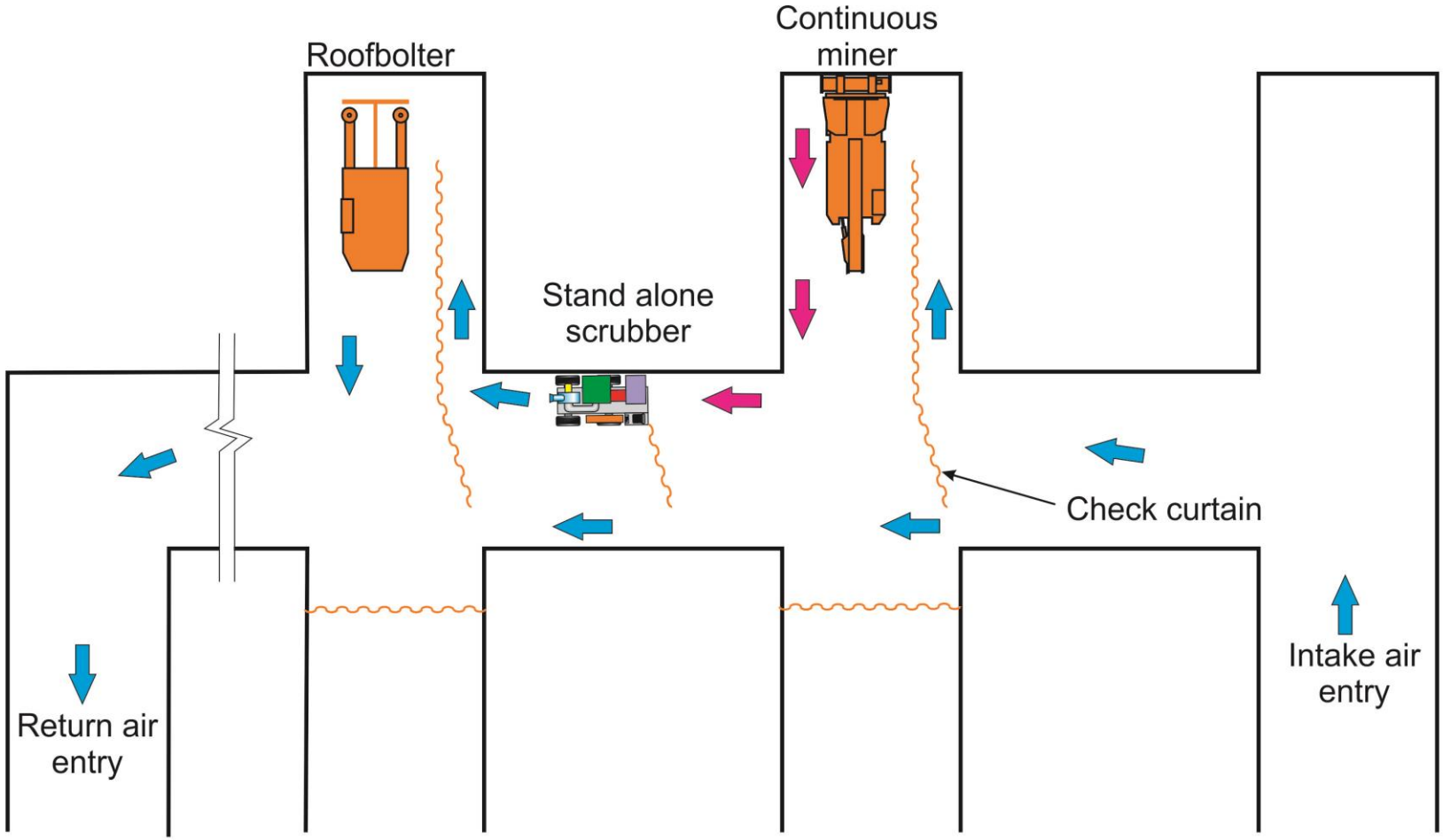
Canopy Air Curtain Testing

- Lab testing of various designs to provide maximum protection for bolter operators
- Field test the best design to determine dust reduction during normal bolting operations

Canopy Air Curtain Results

- Lab study show 95% reduction under canopy at 60 fpm mean entry air velocity.
  - **Sampling 100% of time under CAC**
- Field study of 3 bolter places shows reductions of 53, 35, and 89%
  - **CAC operator under canopy only about 50% of the sampling time**

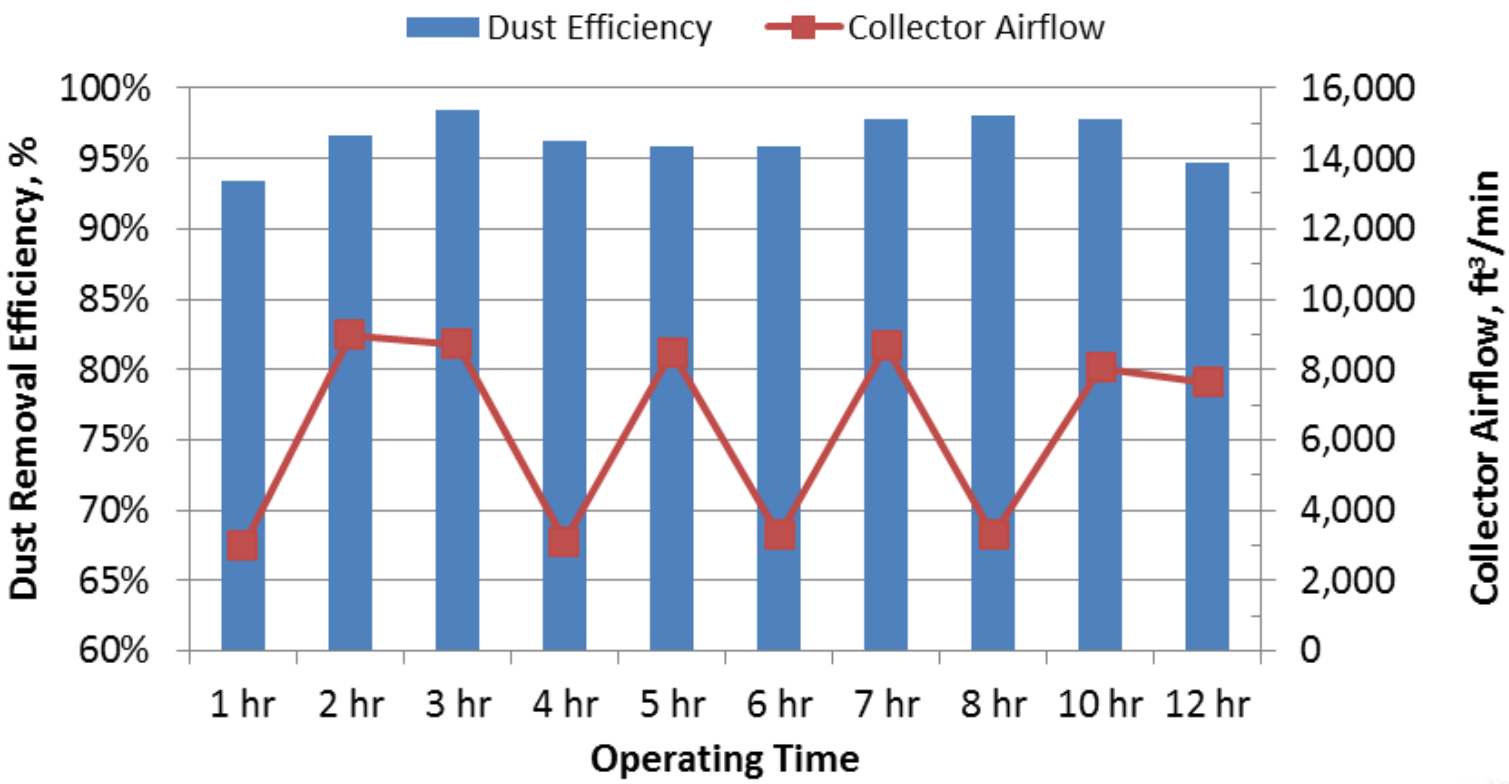
Stand Alone Scrubber
Clean a Split of Air for the Roof Bolter



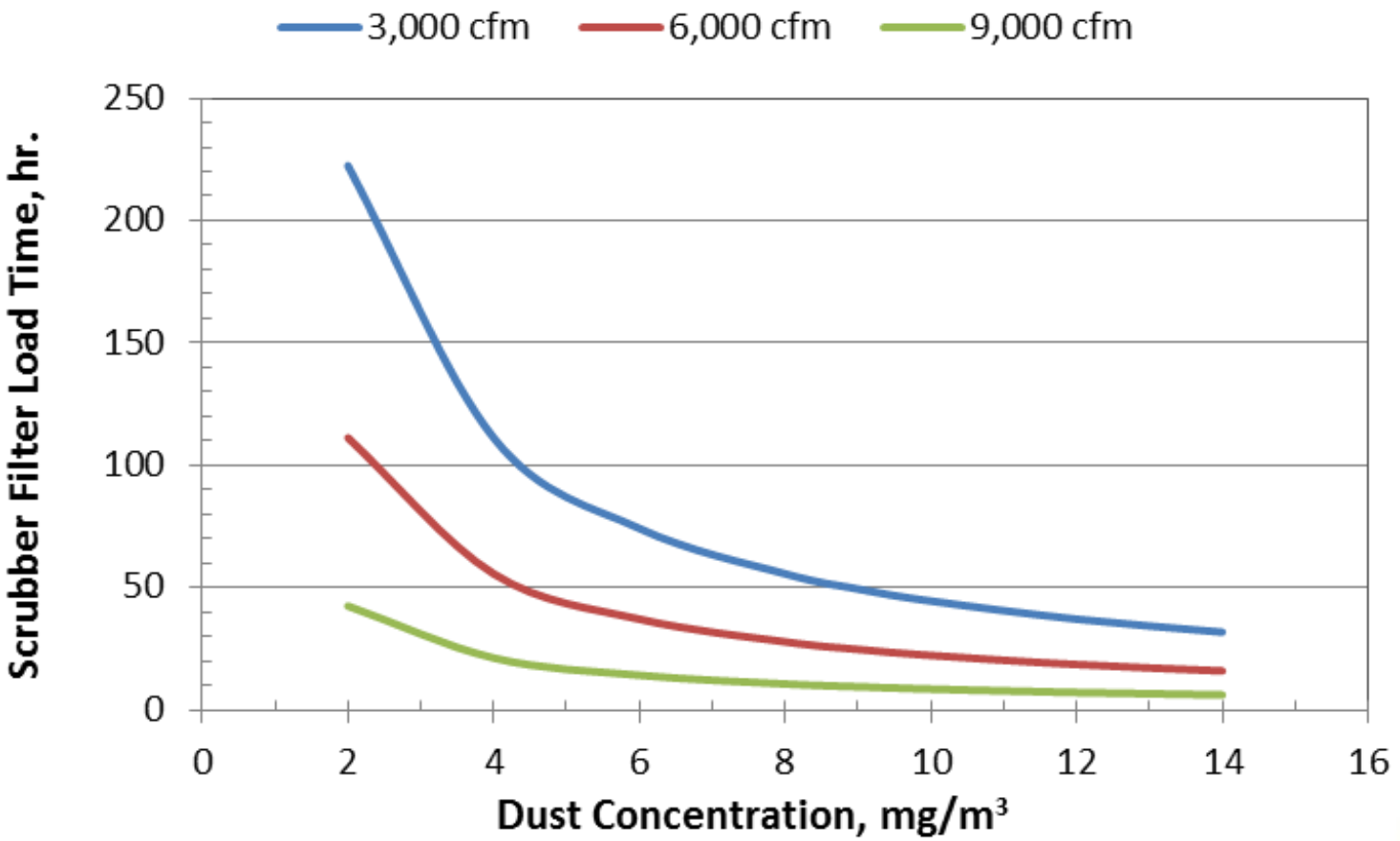
Fletcher Dry Scrubber (DS)

- 4 feet wide x 4 feet high x 15.7 feet long
- 30 hp. vane axial electric fan (480 V) with variable frequency drive (VFD) speed controller
- Scrubber airflow quantity selected via remote transceiver
- Dual 28 inch O.D. cylindrical disposable air filters rated at 99% efficiency for 2 µm particles
- Crawler tram hydraulically controlled via remote transceiver

DS Laboratory Test Results



DS Filter Life Projections



Controlling Worker Exposure

- Minimize Quantity of Dust Generated
- Apply Controls Close to Source
- Utilize a Multitude of Controls
- Worker Involvement
- ✓ **Maintenance is Critical**

Questions?

John Organiscak, 412-386-6675 or jorganiscak@cdc.gov

Timothy Beck, 412–386–4776 or tbeck@cdc.gov

Jay Colinet, 412-386-6825 or jcolinet@cdc.gov

J. Drew Potts, 412-386-4487 or jpotts1@cdc.gov