Controlling Dust on Continuous Mining Operations

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Coal Mine Respirable Dust Control Summit
National Mine Health and Safety Academy
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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
Water Sprays on Continuous Miners

Function:
- Suppress/wet
- Capture
- Redirect

Application:
- High flow/low pressure
- Droplet size/velocity
- High pressure/location
Wetting/Suppression

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

✓ Flow rate most important
Spray Locations

A

Top sprays flat fan nozzles turned horizontally

B

1 ft maximum

Side sprays flat fan nozzles turned vertically

C

2.5 ft

30°

Bottom sprays

Bottom sprays (underside of boom)
Spray Capture Effectiveness on Airborne Dust

- Smaller Droplet Sizes
- High Velocity Droplets

✓ Pressure Most Important
Redirecting/Moving Air

- Pressure/location important

![Graph showing cfm induced/gpm for different spray types at 75 psi and 150 psi.](image)

- ✔️ 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
Self-Cleaning Hollow Cone Sprays

Self-Cleaning Movable Swirl Chamber Spray Design

Typical Static Swirl Chamber Spray Design
Laboratory Testing

Water Flow @ 60, 80, & 100 psi

Dust Capture Efficiency @ 80 psi

Spray Air Flow Inducement @ 80 psi

Water Droplet Sizes @ 80 psi
# Hollow Cone Spray Comparisons

<table>
<thead>
<tr>
<th>Spray Type</th>
<th>Water flow @ 60 psi (gal/min)</th>
<th>Water flow @ 80 psi (gal/min)</th>
<th>Water flow @ 100 psi (gal/min)</th>
<th>Induced Airflow @ 80 psi (ft³/min)</th>
<th>Capture Efficiency @ 80 psi (%)</th>
<th>Mean Water Droplet Size @ 80 psi (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BD-3</td>
<td>0.64</td>
<td>0.73</td>
<td>0.81</td>
<td>1180</td>
<td>9.9</td>
<td>18.8</td>
</tr>
<tr>
<td>SH-3</td>
<td>0.73</td>
<td>0.82</td>
<td>0.92</td>
<td>1350</td>
<td>8.9</td>
<td>16.0</td>
</tr>
<tr>
<td>RK-3</td>
<td>0.67</td>
<td>0.77</td>
<td>0.84</td>
<td>1190</td>
<td>7.2</td>
<td>15.0</td>
</tr>
<tr>
<td>BD-5</td>
<td>1.07</td>
<td>1.23</td>
<td>1.36</td>
<td>2070</td>
<td>7.1</td>
<td>12.5</td>
</tr>
<tr>
<td>SH-5</td>
<td>1.14</td>
<td>1.38</td>
<td>1.44</td>
<td>2080</td>
<td>7.1</td>
<td>9.6</td>
</tr>
<tr>
<td>RK-5</td>
<td>1.08</td>
<td>1.24</td>
<td>1.39</td>
<td>1580</td>
<td>5.3</td>
<td>6.6</td>
</tr>
</tbody>
</table>
# Wetting Agents

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

<table>
<thead>
<tr>
<th>Wetting Agent</th>
<th>Water Sample</th>
<th>0.05 % Solution</th>
<th>0.10% Solution</th>
<th>0.20% Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>&gt; 900 sec.</td>
<td>863 sec.</td>
<td>373 sec.</td>
<td>193 sec.</td>
</tr>
<tr>
<td>B</td>
<td>&gt; 900 sec.</td>
<td>&gt; 900 sec.</td>
<td>&gt; 900 sec.</td>
<td>1238 sec.</td>
</tr>
<tr>
<td>C</td>
<td>&gt; 900 sec.</td>
<td>&gt; 900 sec.</td>
<td>&gt; 900 sec.</td>
<td>1301 sec.</td>
</tr>
</tbody>
</table>
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

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

Courtesy of Joy Mining Machinery
Wethead Benefits

- Bit cooling - reduce frictional ignitions
- Increase bit life
- No increase in water consumption
- Potential to reduce respirable dust
## Wethead vs Standard Sprays

<table>
<thead>
<tr>
<th></th>
<th>Mine A</th>
<th>Mine B</th>
<th>Mine C</th>
<th>Mine D</th>
<th>Mine E</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ventilation</strong></td>
<td>Blowing</td>
<td>Exhausting</td>
<td>Blowing</td>
<td>Blowing</td>
<td>Exhausting</td>
</tr>
<tr>
<td><strong>Section</strong></td>
<td>Super sect.</td>
<td>Single</td>
<td>Super sect.</td>
<td>Single</td>
<td>Single</td>
</tr>
<tr>
<td><strong>Scrubber</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

*Boom Sprays Plugged Between Comparisons*
All Mines - CM Operator

Continuous Miner Operator Dust Levels

Mine:
- A
- B
- C
- D
- E

Concentration, mg/m³:
- 0.0
- 0.5
- 1.0
- 1.5
- 2.0
- 2.5
- 3.0

Exhaust
Blowing
No Scrubber

Legend:
- Stnd
- WH
All Mines - Return

Return Dust Levels

Concentration, mg/m³

A B C D E

Blowing Blowing Blowing Exhaust

No Scrubber

Mine

Stnd WH
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
Flooded-bed Scrubbers
Capture and Remove Airborne Dust
Scrubber Filter Study

Filters Tested

- 30-layer
- 20-layer
- 10-layer
- Bottle brush
- 15-layer
- Bondina
10 vs 30 Layer Filters
Respirable Dust Collection Efficiencies

<table>
<thead>
<tr>
<th>Filter type</th>
<th>Collection efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20-L</td>
<td>90</td>
</tr>
<tr>
<td>15-L</td>
<td>80</td>
</tr>
<tr>
<td>Brush</td>
<td>90</td>
</tr>
<tr>
<td>10-L</td>
<td>60</td>
</tr>
<tr>
<td>Synthetic</td>
<td>100</td>
</tr>
<tr>
<td>30-L</td>
<td>100</td>
</tr>
</tbody>
</table>
Air Quantity Measured With Each Filter Panel

Airflow (cfm)

Filter type

20-L 15-L Brush 10-L Synthetic 30-L
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

Correct location
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

Off-Curtain side miner position

Curtain side miner position

Scrubber exhaust

Remote operator location

A

B

Intake air
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

Test Factors: Spray Pressure (80psi – 160 psi)
Blocking Sprays (Off – On)
Scrubber Flow (Max. – Reduced 20%)
Slab Cut Dust Results – Off Curtain Side

- Hollow-RRC
- Flat-RRC
- Hollow-Oper
- Flat-Oper

Dust Conc., mg/m³

No Blocking Sprays
Blocking Sprays

Spray Pressure-Scrubber Airflow

160psi-Low, 80psi-Low, 160psi-Max, 80psi-Max, 160psi-Low, 80psi-Low, 160psi-Max, 80psi-Max
Slab Cut Dust Results – Curtain Side

- Hollow-LRC
- Flat-LRC
- Hollow-Return
- Flat-Return

**Dust Conc., mg/m³**

- No Blocking Sprays
- Blocking Sprays

**Spray Pressure-Scrubber Airflow**

1.60 psi-Low
2.80 psi-Low
3.160 psi-Max
4.80 psi-Max
Slab Cut SF$_6$ Gas Results

Spray Pressure-Scrubber Airflow vs. SF$_6$ Gas Conc., ppm

- Hollow-OCS
- Flat-OCS
- Hollow-CS
- Flat-CS

Blocking Sprays vs. No Blocking Sprays
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

Consistent position with respect to CM.
Present during cutting and loading activities
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

- 0 to 9%: 65%
- 10 to 19%: 22%
- 20 to 35%: 13%
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

<table>
<thead>
<tr>
<th></th>
<th>Mine A</th>
<th>Mine B</th>
<th>Mine C</th>
<th>Mine D</th>
<th>Mine E</th>
<th>Mine F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miner Operator</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>-</td>
<td>None</td>
</tr>
<tr>
<td>Miner Generated</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>Lower</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Bolter Operator</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Bolter Generated</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

All daily average dust concentrations measured at the bolter and miner operator positions were less than 2.0 mg/m³
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**

<table>
<thead>
<tr>
<th>Mine</th>
<th>Continuous miner cuts</th>
<th>Roof bolter cuts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Scrubber off</td>
<td>Scrubber on</td>
</tr>
<tr>
<td>A</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>B</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>C</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>
Dust level results for 20-foot cuts with & without scrubber

<table>
<thead>
<tr>
<th>Mine</th>
<th>SC - off</th>
<th>SC - on</th>
<th>Oper - off</th>
<th>Oper - on</th>
<th>Ret - off</th>
<th>Ret - on</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mine A</td>
<td>14%</td>
<td>86%</td>
<td>91%</td>
<td>86%</td>
<td>86%</td>
<td>40%</td>
</tr>
<tr>
<td>Mine B</td>
<td>82%</td>
<td>86%</td>
<td>86%</td>
<td>86%</td>
<td>86%</td>
<td>14%</td>
</tr>
<tr>
<td>Mine C</td>
<td>40%</td>
<td>14%</td>
<td>40%</td>
<td>14%</td>
<td>40%</td>
<td>14%</td>
</tr>
</tbody>
</table>
Conclusions

- Continuous miner and shuttle car operators’ dust concentrations
  - respirable dust exposures $\leq 0.55$ 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

## Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of mines</td>
<td>10</td>
</tr>
<tr>
<td>Mining height (inches), mean ± SD</td>
<td>64.1 ± 16.7</td>
</tr>
<tr>
<td>Ventilation rate (cfm), mean ± SD</td>
<td>8338 ± 2870</td>
</tr>
<tr>
<td>No. of cuts sampled</td>
<td>167</td>
</tr>
<tr>
<td>No. of headings sampled</td>
<td>109</td>
</tr>
<tr>
<td>No. of crosscuts sampled</td>
<td>61</td>
</tr>
</tbody>
</table>

- 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

![Graph showing dust concentrations over time with a breakthrough event marked.]
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

- Slender profile
- Small carbide
- High wear rate
- High dust levels

- Intermediate profile
- Large carbide
- Low wear rate
- Low dust levels

- Fat profile
- Irregular transition
- Shank rubs
- High dust levels
Improved Cutting Methods
Roof Bolter Dust Control
Outline

Roof Bolter Dust Controls
- Dry collection vacuum system
- Dust collector maintenance and cleaning
- Dust collector bags and pre-dump
- Collector exhaust water box
- Stand-alone dry scrubber
- Canopy air curtain
Roof bolter dry dust collector

(approximately 60 cfm at 12” Hg vacuum at drill head)

**COLLECTION SIDE**
- Drill Bit
- Drill Steel
- Drill Base
- Collector Hose
- Pre-Cleaner
- Canister Filter
- Cyclone
- Dust Collector Box

**DISCHARGE SIDE**
- Vacuum Pump
- Muffler
Operator overexposures

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

- Ensure that required vacuum is achieved
- Eliminate leaks in vacuum system
  - hoses and clamps
  - collector door gasket integrity
  - door not bent
  - door latches intact, 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?
Discharge side 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

Key
- Bag
- Bagless

PRESSURE, in wg

TEST NUMBER

0 5 10 15 20 25 30
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
Collector 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
• reduces cleaning time for collector box
Pre-cleaner dust evaluation

• concerned with pre-cleaner dust potentially exposing bolter operators

• 46 bulk samples of pre-cleaner and collector dust were collected from mines in MSHA Districts 4, 5, 6, and 7

• samples analyzed for quartz content and particle size distribution

• airborne respirable dust measurements taken in 3 sections of 2 mines to quantify respirable dust contribution from pre-cleaner dust discharge
Bulk Sample Results - Size

- collector box dust significantly smaller (38% < 10 µm) than pre-cleaner discharge dust (18% < 10 µm)
Bulk Dust Results - Quartz

- Quartz content (weight %) not significantly different between pre-cleaner discharge dust (27%) and collector box dust (26%)
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 dust 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

- not a substitute for poorly maintained collector box
- minimal potential for benefits/impact on operator exposure when dust collector box is properly maintained (minimal dust in exhaust)

Water box introduces additional maintenance requirements
- periodic replenishment of water reservoir
- periodic removal of material accumulations in box

<table>
<thead>
<tr>
<th>Feed Material</th>
<th>Dust Collection Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Muffler</td>
</tr>
<tr>
<td>Coal</td>
<td>5%</td>
</tr>
<tr>
<td>Limestone</td>
<td>7%</td>
</tr>
</tbody>
</table>
Stand-alone dry scrubber

(provide clean split of air for the roof bolter operators)
Dry scrubber (DS) prototype
(NIOSH Contract 200-2010-36164 with J. H. Fletcher & Co.)

- 4 ft wide x 4 ft high x 15.7 ft long
- 30 hp. vane axial fan (480 V) with variable frequency drive (VFD) speed controller
- dual 28-in. O.D. cylindrical air filters
  - disposable filters, paper media – 99% at 2 micron
  - washable filters, polyester media – 99% at 5 micron
- crawler tram hydraulically controlled via remote transceiver
Self-adjusting (VFD) fan speed controller

Operator Input → IQAN PLC → VFD Controller → Axial Fan

Pressure Transducer → DS Filters

Pitot Tube
DS laboratory testing

- DS airflow quantity
- DS respirable dust reduction efficiency
- Filter Δ pressure vs. dust loading
- DS noise levels
# Target vs. measured DS airflows
*(straight exhaust configuration)*

<table>
<thead>
<tr>
<th>Airflow Instrument, Quantity</th>
<th>Testing Period</th>
<th>DS Target 3,000 ft³/min</th>
<th>DS Target 9,000 ft³/min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot Wire (Vane Anemometer), ft³/min</td>
<td>Initial DS</td>
<td>2,220 (2,350)</td>
<td>9,150 (9,170)</td>
</tr>
<tr>
<td>Pitot Tube (Vane Anemometer), ft³/min</td>
<td>Initial DS</td>
<td>2,130 (2,450)</td>
<td>8,560 (9,280)</td>
</tr>
<tr>
<td>Hot Wire (Vane Anemometer), ft³/min</td>
<td>†Modified DS</td>
<td>3,000 (3,060)</td>
<td>9,190 (8,850)</td>
</tr>
<tr>
<td>Pitot Tube (Vane Anemometer), ft³/min</td>
<td>†Modified DS</td>
<td>2,830 (3,000)</td>
<td>8,530 (8,870)</td>
</tr>
</tbody>
</table>

†Fletcher made velocity transducer and VFD fan controller modifications
Disposable filter results

- Dust concentrations generated $17.8 \pm 3.3 \text{ mg/m}^3$
Washable filter results

- Pre-washed dust concentrations generated 17.4 ± 3.7 mg/m³
- Post-washed dust concentrations generated 19.1 ± 3.9 mg/m³
Filter washing dust generation

- Personal average = 1.2 mg/m³
- 10-ft Downstream average = 8.3 mg/m³
Filter Δpressure vs. dust loading

- Disposable Filters, 3,000 ft³/min
- Disposable Filters, 9,000 ft³/min
- Pre-washed Filters, 3,000 ft³/min
- Pre-washed Filters, 9,000 ft³/min
- Post-washed Filters, 3,000 ft³/min
- Post-washed Filters, 9,000 ft³/min

Filter ΔP, in. w.g. vs. Filter Dust Loading, kg

- 0.0 ft³/min
- 2.0 ft³/min
- 4.0 ft³/min
- 6.0 ft³/min
- 8.0 ft³/min
- 10.0 ft³/min
- 12.0 ft³/min

Filter Dust Loading, kg

- 0.0 kg
- 0.5 kg
- 1.0 kg
- 1.5 kg
- 2.0 kg
- 2.5 kg
- 3.0 kg
DS noise levels

- Inlet with loaded filters
- Inlet with clean filters
- Outlet with loaded filters
- Outlet with clean filters

A-weighted LEQ (dB) vs. Measured Airflow (CFM)

Key points:
- Inlet with loaded filters: 78.0 dB at 2000 CFM, 83.3 dB at 6000 CFM, 90.1 dB at 12000 CFM
- Inlet with clean filters: 65.0 dB at 2000 CFM, 87.5 dB at 6000 CFM
- Outlet with loaded filters: 90.1 dB at 2000 CFM, 83.3 dB at 6000 CFM, 78.0 dB at 12000 CFM
- Outlet with clean filters: 65.0 dB at 2000 CFM, 87.5 dB at 6000 CFM
Underground dust studies

- Right side MMU at a 9 entry supersection and at a 12 entry supersection
- Blowing face ventilation with 90° DS exhaust discharge
- Attempted to match DS airflow quantity to return entry face quantity
- Two CMDPSUs & one PDR instantaneous dust monitor at each sampling location
- Calibrated PDRs to determine dust concentrations when mining
Dust sampling strategy
Airflow quantity ranges tested

- Last open cross-cut airflow - 11,270 to 27,720 ft³/min
- Face airflow without DS operating - 1,660 to 4,890 ft³/min
- DS airflow quantity - 2,720 to 4,900 ft³/min
- Face airflow with DS operating - 2,300 to 8,220 ft³/min
- Face airflow increase from DS - 1.4 to 1.7 times
# Underground sampling results

<table>
<thead>
<tr>
<th>Bolter Location</th>
<th>Mine Test Section</th>
<th>Roof Bolter Dust Conc. B mg/m³ (cuts)</th>
<th>Crosscut Dust Conc. Upstream DS C mg/m³ (cuts)</th>
<th>Face Dust Conc. Downstream DS D mg/m³ (cuts)</th>
<th>‡DS Face Dust Reduction Efficiency %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upstream CM</td>
<td>1</td>
<td>0.59 (6)</td>
<td>2.77 (6)</td>
<td>1.32 (6)</td>
<td>52.9</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.17 (9)</td>
<td>2.43 (5)</td>
<td>0.91 (5)</td>
<td>59.9</td>
</tr>
<tr>
<td>Downstream CM &amp; Upstream DS</td>
<td>1</td>
<td>1.80 (6)</td>
<td>1.85 (7)</td>
<td>0.99 (7)</td>
<td>46.3</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1.60 (4)</td>
<td>1.35 (3)</td>
<td>0.66 (3)</td>
<td>50.7</td>
</tr>
<tr>
<td>Downstream CM &amp; Downstream DS</td>
<td>1</td>
<td>NA (0)</td>
<td>NA (0)</td>
<td>NA (0)</td>
<td>NA (0)</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1.10 (4)</td>
<td>1.69 (4)</td>
<td>1.06 (4)</td>
<td>36.8</td>
</tr>
<tr>
<td>Average of All Cuts</td>
<td>1</td>
<td>1.26 (12)</td>
<td>2.24 (13)</td>
<td>1.13 (13)</td>
<td>49.1</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.71 (17)</td>
<td>1.90 (12)</td>
<td>0.88 (12)</td>
<td>50.5</td>
</tr>
</tbody>
</table>

NA – Not available
‡Determined as the time-weighted average of the DS face dust reduction efficiencies for the individual cuts.

- DS dust collection efficiencies of 93.2% at MMU 1 and 99.2% at MMU 2
- Higher dust reduction efficiency expected by using DS as auxiliary fan
DS disposable filter life

- MMU 1 DS operated for 461 min. @ 2.24 mg/m³
- MMU 2 DS operated an additional 509 min. @ 1.90 mg/m³
- Filter Δ pressure reached 3.9 in. w.g. for 4510 ft³/min of DS airflow @ 35 Hz fan motor frequency with ~ 16.2 hr. run time
- Filter life can be estimated from laboratory testing with formula shown below:

\[
\text{Filter Dust Loading Time (hr.)} = \frac{2.27 \text{ (kg)} \times 1,000,000 \left( \frac{\text{mg}}{\text{kg}} \right)}{\text{Dust Concentration} \left( \frac{\text{mg}}{\text{m}^3} \right) \times \text{Airflow Quantity} \left( \frac{\text{m}^3}{s} \right) \times 3600 \left( \frac{s}{\text{hr}} \right)}
\]

- Operating DS at 4000 ft³/min and 2 mg/m³ dust concentration ≈ 167 hr.
Canopy air curtain

Reduces dust exposures when bolting 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 showed 95% reduction under canopy at 60 fpm mean entry air velocity.
  - Sampling 100% of time under canopy air curtain
- Field study of 3 bolter places shows reductions of 53, 35, and 89%.
  - Bolter operator under canopy only about 50% of the sampling time
- Fletcher is refining the canopy air curtain for their equipment
Controlling worker exposure

• Minimize quantity of dust generated
• Apply dust controls close to source
• Utilize a multitude of controls
• Worker involvement – CPDM data

✓ Maintenance is critical
Questions?

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