EXPERIMENTAL TEST RESULTS OF A SHEARER-MOUNTED FLOODED-BED DUST SCRUBBER

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Joe Sottile
University of Kentucky
SPONSOR AND TEAM

• Sponsor: Alpha Foundation for the Improvement of Mine Safety and Health
• PI: Thomas Novak
• Co-PIs: Chad Wedding, Joe Sottile
• UK Staff – Ed Thompson
• Graduate Students
  • Sampurna Arya, Ph.D. student
  • Ashish Kumar, Ph.D. student
  • Adam Levy, M.S. student
  • Brad Coleman, Ph.D. student
  • Kayla Mayfield, Ph.D. student
SPONSOR AND TEAM

• NIOSH Personnel
  • Jim Rider
  • Jay Colinet
  • Others

• Consultants
  • John Campbell
  • Dan Moynihan

• Joy Global
  • Joe Defibaugh
  • Others

• Alliance Coal
  • Numerous
BACKGROUND

• Dust is a consequence of many (virtually all) mining processes
• Coal Mining
  • Heath Issues – CWP
  • Safety Issues – Float Dust
• Longwall Mining
  • Accounts for apx. 60% of underground production
  • High production
  • High dust generation
BACKGROUND

• Longwall dust mitigation measures
  • Dilution with ventilation air
  • Wetting and capture by water sprays
  • Confinement and isolation by water sprays
Dust Control Using Flooded-Bed Dust scrubbers

- Application of flooded-bed dust scrubbers to continuous miners patented by John Campbell in 1983
- Capture dust and clean dust-laden air close to the source of generation
Problems with Applying Dust Scrubbers to Longwall Systems

- Nature of the mining process
  - Large machine – limited available space
  - Visibility
  - Much higher airflow rates compared with continuous mining
  - Potential for overloading/damaging scrubber with rock/coal
Prior Attempts at Using Scrubbers on Longwalls

- Ventilated drum
- 3500 cfm airflow
- 50% capture with face airflow of 28,000 cfm
- Maintenance issues
Prior Attempts at Using Scrubbers on Longwalls

- Ventilated cowl
- 50% reduction in dust
- Reliability and maintenance issues
Prior Attempts at Using Scrubbers on Longwalls

- Scrubber added to headgate ranging arm
  - Demonstrated dust reductions of 14% to 56%
  - Prone to damage
PROJECT OBJECTIVE

• Design and build a full-scale mock-up of a shearer with an integrated flooded-bed dust scrubber
• Evaluate performance of scrubber
• Limit efforts to dust generated near headgate drum
RESEARCH APPROACH (BRIEFLY)

- Information Gathering
- Developing Computer-Generated Design
- Scale modeling and CFD Verification
FABRICATION OF FULL-SCALE MOCKUP

- Frame - Constructed with 80/20 T-slotted framing system
- Covering – high-density polyethylene sheets
- Scrubber – Scrubber and demister designed for continuous miner but with 50-hp fan driven by VFD
- Controls – Programmable Automation Controller (PAC)
- Rotating headgate drum with watersprays
FRAME AND COVERING
HEADGATE CUTTING DRUM
SC RUBBER SYSTEM
CONTROLS
COMPLETED MOCKUP
TESTING – NIOSH PRL LONGWALL GALLERY

Location: CDC NIOSH Pittsburgh Research Laboratory
- 125 ft-long longwall gallery
- Adjustable ceiling/shield height
- Air velocity up to 700 fpm
- Ability to inject respirable dust (Keystone Mineral Black 325BA)
INSTALLATION AT PRL LONG WALL GALLERY
DUST INJECTION

- Dust injected at three locations near headgate drum
DUST MEASUREMENT LOCATIONS

16 dust monitoring locations
• 12 along face
• 4 in return airway
DUST MEASUREMENT

• Combination of ThermoFisher Scientific PDM 3600 and PDM 3700
• Experiments conducted with NIOSH equipment by NIOSH personnel
EXPERIMENTAL PROCEDURE

• Full Factorial Design
  • Three factors
  • Two levels
  • Five replications
  • Total number of tests: \((5)(2^3) = 40\)
# EXPERIMENTAL FACTORS AND LEVELS

<table>
<thead>
<tr>
<th>Factor</th>
<th>Low Level</th>
<th>High Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scrubber inlet extension</td>
<td>Removed</td>
<td>Included</td>
</tr>
<tr>
<td>Scrubber capacity</td>
<td>6300 cfm (2.97 m$^3$/s)</td>
<td>13,700 cfm (6.47 m$^3$/s)</td>
</tr>
<tr>
<td>Face air velocity</td>
<td>500 fpm (2.54 m/s)</td>
<td>700 fpm (3.56 m/s)</td>
</tr>
<tr>
<td></td>
<td>40,800 cfm (19.3 m$^3$/s)</td>
<td>57,200 cfm (27.0 m$^3$/s)</td>
</tr>
</tbody>
</table>
OPERATING CONDITIONS

<table>
<thead>
<tr>
<th>Step</th>
<th>Operating Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Dust only</td>
</tr>
<tr>
<td>2</td>
<td>Dust + scrubber fan</td>
</tr>
<tr>
<td>3</td>
<td>Dust + scrubber fan + scrubber sprays</td>
</tr>
<tr>
<td>4</td>
<td>Dust + scrubber fan + scrubber sprays + splitter arm sprays</td>
</tr>
<tr>
<td>5</td>
<td>Dust only</td>
</tr>
</tbody>
</table>
DETERMINING DUST REDUCTION

Dust Reduction = \( \left( 1.00 - \frac{C_S}{(C_{01} + C_{02})(0.5)} \right) \times 100\% \)

\( C_S = \) dust concentration measured with the scrubber fan and sprays ON and splitter arm sprays OFF
\( C_{01} = \) dust-only concentration at beginning of test
\( C_{02} = \) dust-only concentration at end of test
LOCATIONS STUDIED

- Return airway with shearer clearer sprays OFF
- Walkway with shearer clearer sprays OFF
- Face area with shearer clearer sprays OFF
- Area above shearer body with shearer clearer sprays OFF
- Return airway with shearer clearer sprays ON
- Walkway with shearer clearer sprays ON
**ANALYSIS-EXAMPLE**

Summary of results for return airway-Splitter arm sprays OFF

<table>
<thead>
<tr>
<th>Treatment Combinations</th>
<th>Design Factors</th>
<th>Reduction in Dust Concentration (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>(1)</td>
<td>-1</td>
<td>-1</td>
</tr>
<tr>
<td>a</td>
<td>1</td>
<td>-1</td>
</tr>
<tr>
<td>b</td>
<td>-1</td>
<td>1</td>
</tr>
<tr>
<td>c</td>
<td>-1</td>
<td>-1</td>
</tr>
<tr>
<td>ab</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>ac</td>
<td>1</td>
<td>-1</td>
</tr>
<tr>
<td>bc</td>
<td>-1</td>
<td>1</td>
</tr>
<tr>
<td>abc</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

A = scrubber inlet extension, B = scrubber capacity, C = face air velocity
Regression model parameter estimates for return airway-splitter arm sprays OFF

<table>
<thead>
<tr>
<th>Term</th>
<th>Estimate</th>
<th>Std Error</th>
<th>t-ratio</th>
<th>Critical Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>37.4054</td>
<td>0.5643</td>
<td>66.28</td>
<td>2.739</td>
<td>&lt; 0.0001*</td>
</tr>
<tr>
<td>A</td>
<td>3.0667</td>
<td>0.5643</td>
<td>5.43</td>
<td>2.739</td>
<td>&lt; 0.0001*</td>
</tr>
<tr>
<td>B</td>
<td>12.4549</td>
<td>0.5643</td>
<td>22.07</td>
<td>2.739</td>
<td>&lt; 0.0001*</td>
</tr>
<tr>
<td>C</td>
<td>3.4374</td>
<td>0.5643</td>
<td>6.09</td>
<td>2.739</td>
<td>&lt; 0.0001*</td>
</tr>
<tr>
<td>AB</td>
<td>0.4824</td>
<td>0.5643</td>
<td>0.85</td>
<td>2.739</td>
<td>0.3990</td>
</tr>
<tr>
<td>AC</td>
<td>1.1807</td>
<td>0.5643</td>
<td>2.09</td>
<td>2.739</td>
<td>0.0444</td>
</tr>
<tr>
<td>BC</td>
<td>0.0074</td>
<td>0.5643</td>
<td>0.01</td>
<td>2.739</td>
<td>0.9896</td>
</tr>
<tr>
<td>ABC</td>
<td>-1.0495</td>
<td>0.5643</td>
<td>-1.86</td>
<td>2.739</td>
<td>0.0721</td>
</tr>
</tbody>
</table>

A = scrubber inlet extension, B = scrubber capacity, C = face air velocity

\[ \hat{y} = 37.405 + 3.067a + 12.455b + 3.437c \]
### SUMMARY OF RESULTS

**Summary of scrubber performance with splitter arm sprays OFF**

<table>
<thead>
<tr>
<th>General Location</th>
<th>Dust Monitoring Stations</th>
<th>Treatments for best performance</th>
<th>Maximum Predicted Dust Reduction</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return</td>
<td>13-16</td>
<td>Inlet extension included</td>
<td>56.4%</td>
<td>Scrubber capacity is largest effect</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100% scrubber capacity</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Face air velocity 700 fpm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walkway</td>
<td>1, 2, 3, 8</td>
<td>Inlet extension included</td>
<td>74.2%</td>
<td>Scrubber capacity is largest effect</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100% scrubber capacity</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Face air velocity 700 fpm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Face Area</td>
<td>7, 12</td>
<td>Inlet extension included</td>
<td>65.1%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>100% scrubber capacity</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Face air velocity 700 fpm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shearer Body above</td>
<td>4-6</td>
<td>Inlet extension included</td>
<td>60.6%</td>
<td></td>
</tr>
<tr>
<td>scrubber module</td>
<td></td>
<td>100% scrubber capacity</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Face air velocity 700 fpm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shearer Body above</td>
<td>9-11</td>
<td>Inlet extension included</td>
<td>80.6%</td>
<td>No face-air-velocity main effect</td>
</tr>
<tr>
<td>tailgate module</td>
<td></td>
<td>100% scrubber capacity</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
SUMMARY OF RESULTS

Summary of scrubber performance with shearer clearer sprays ON

<table>
<thead>
<tr>
<th>General Location</th>
<th>Dust Monitoring Stations</th>
<th>Treatments for best performance</th>
<th>Maximum Predicted Dust Reduction</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return</td>
<td>13-16</td>
<td>Inlet extension included 100% scrubber capacity Face air velocity 700 fpm</td>
<td>62.5%</td>
<td>Scrubber capacity is largest effect No face-air-velocity main effect</td>
</tr>
<tr>
<td>Walkway</td>
<td>1, 2, 3, 8</td>
<td>Inlet extension removed 100% scrubber capacity Face air velocity 500 fpm</td>
<td>97.4%</td>
<td>- Correlation coefficient of 0.60 - Intercept of 91.5% - Dust reduction ranges from 85.5% to 97.4% - These results indicate that the splitter arm sprays prevent a significant portion of dust from entering the walkway regardless of the treatments</td>
</tr>
</tbody>
</table>
CONCLUSION

• Shearer-integrated scrubber has potential to capture and clean airborne respirable dust (up to 56% without shearer clearer sprays, up to 62% with shearer clearer sprays as measured in return airway at PRL longwall gallery)

• Shearer-integrated scrubber has potential to reduce airborne respirable dust along walkway (up to 85% without shearer clearer sprays)

• Tests were conducted under controlled laboratory conditions

• Future considerations
  • Overloading of scrubber
  • Clogging/damage due to coarse particles entering scrubber inlet
  • Damage to ductwork
  • Noise
QUESTIONS